BIBLIOGRAPHIC DATA SHEET

PN-AAJ-072

THE LEGUME/RHIZOBIUM SYMBIOSIS IN TROPICAL AGRICULTURE: A BIBLIOGRAPHIC UPDATE

PERSONAL AUTHORS - BOSE, JOHN

CORPORATE AUTHORS - HAWAII UNIV. DEPT. OF AGRONOMY AND SOIL SCIENCE

1980, 169P.

ARC NUMBER - 016.631847.B743
CONTRACT NUMBER - AID/DSAN-G-0100
PROJECT NUMBERS - 9310129
SUBJECT CLASS - AF0014000000

DESCRIPTORS - LEGUMINOUS PLANTS, TROPICAL AGRICULTURE, NITROGEN FIXATION, BIBLIOGRAPHIES, RHIZOBIUM, SYMBIOSIS

D16 631847
B743

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THE LEGUME/*RHIZOBIUM* SYMBIOSIS IN TROPICAL AGRICULTURE: A Bibliographic Update

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

UNIVERSITY OF HAWAII
COLLEGE OF TROPICAL AGRICULTURE & HUMAN RESOURCES
Department of Agronomy and Soil Science
NitFAL PROJECT

THE LEGUME/*RHIZOBIUM* SYMBIOSIS IN TROPICAL AGRICULTURE:

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June, 1980

UNIVERSITY OF HAWAII COLLEGE OF TROPICAL AGRICULTURE AND HUMAN RESOURCES

DEPARTMENT OF AGRONOMY AND SOIL SCIENCE NifTAL PROJECT

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ABSTRACT: A subject arranged, annotated list of 697 documents in the University of Hawaii NifTAL Project collection. This bibliography updates a similar listing published in 1978, with some changes in subject designations to reflect new areas of emphasis in research. All authors and key words from titles and annotations have been indexed, with a cross-reference guide to indicate the subject assignment of each citation.

PREFACE

The listings in this bibliography have originated from several sources, including: computer search of magnetic tapes from the National Agricultural Library (CAIN), to October, 1978; *Current Contents* listings; Automated Science Citation Alert (ASCA) service, based on the computerized listings in *Current Contents*; and from staff requests, reference lists accompanying published papers, and the much appreciated receipt of reprint copies from authors.

Unless otherwise indicated by a language abbreviation following the title, all articles are in the English language. Most of the articles in other languages have English summaries or abstracts accompanying the original.

The institutional affiliations of first authors as listed with their individual publications are provided for identification only, and are not intended to be either current or complete addresses.

Responsibility for collecting, writing and editing all material in this publication rests solely with the bibliographer. Suggestions for corrections and additions will be gratefully received. Even as this edition is being prepared for printing, the list of new documents to be annotated for future supplements is growing rapidly. Authors can be best assured of inclusion in subsequent issues by the regular mailing of reprints to the address below. All documents in the NifTAL collection are available on a limited basis to approved NifTAL clients in countries eligible for USAID support. Additional information about NifTAL services and cooperative research programs will be sent on request.

The support of the United States Agency for International Development in compiling and producing this bibliography is gratefully acknowledged. For excellent service and determined searches beyond the call of duty, a special thanks is extended to the reprographics service of the University of Hawaii Library. To these, and to the NifTAL staff, sincere appreciation is expressed. But this is a secondary work, and any measure of success is only a reflection of the excellent material produced by the twelve hundred or more scientists listed in the index.

John Bose, II, Bibliographer University of Hawaii NifTAL Project
Paia, Maui, Hawaii 96779, USA

01.* BIBLIOGRAPHIES, GENERAL REVIEWS, RESEARCH SURVEYS

0101 2225 The *Rhizobium*-legume symbiosis and the problems of infection, efficiency and host specificity. (Fre)
Blondeau, R. (U Sci Tech Lille, Villeneuve-d'Ascq., France).
Annee Biol (ser 4) 16:481-516, 1977.
A general review of recent advances, with emphasis on research toward solving the problems referred to in the title. Includes 157 references to literature published through May, 1976.

0102 3321 Annotated bibliography of Australian work on *Rhizobium* published during 1973-1977.
Brockwell, J. (CSIRO, Canberra, A.C.T., Australia), M. Zorin and P.M. Atkinson.
CSIRO (Australia) Div Plant Indus tech pa 34, 1978, 78 p.
Continuation of an earlier bibliography which covered the period 1948-1972. The present compilation, like its predecessor, includes citations and brief summaries of work published by Australians or by visitors working in Australia. There are 255 entries and an address list of first authors.

0103 2139 Abstracts on field beans (*Phaseolus vulgaris* L.), Volume II.
CIAT Bean Information Center.
Bean Info Ctr, Cali, Colombia ser HE-32, Feb, 1978, 330 p.
A compilation of the citations and abstracts distributed through the CIAT card service. The entries are arranged under 12 subject areas, some of which have one to seven subtopics. An index to first authors and key words is also provided. Of the 880 references with abstracts or summaries, 12 deal with nitrogen fixation, nodulation or *Rhizobium*.

3071 Abstracts on field beans (*Phaseolus vulgaris* L.), Volume III.
CIAT Bean Information Center.
Bean Info Ctr, Cali, Colombia ser 08EB-3, Dec, 1978, 272 p.
A continuation of 0103 above, with added subtopics to reflect work in new areas of research. The 612 references include 25 or more articles dealing to some degree with the *Phaseolus vulgaris-Rhizobium* symbiosis.

0105 2785 VIII Reunion Latinoamericana sobre *Rhizobium*, Cali, Colombia, 1976. (Spa)
Graham, P.H. (CIAT, Cali, Colombia) and J. Halliday (eds.).
CIAT Servicos de Informacion, Cali, Colombia, 1976, 188 p.
Includes thirty resumes of work and eight invited papers dealing with

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* The first two digits preceding each entry designate the subject, and the final digits of the upper number enumerate the individual entries under that subject. The NiFTAL document number is on the second line. Entries within subject groups are arranged alphabetically by author, then chronologically by date of publication.

inoculant production, symbiotic specificity, environmental and nutritional factors, nodulation problems, the energetics of nitrogen fixation, and a review of the infection process.

0106 An annotated bibliography of Egyptian work in biological nitrogen
3113 fixation published during the period 1946-1972.
Hamdi, Y.A. (Agr Res Ctr, Giza, Egypt).
IBP Sec PP - Nitrogen Fixation Biblio Rept, 1973, 127 p.
An effort was made to include all BNF work conducted in Egypt and work done elsewhere by Egyptians. There are sections on root-nodule bacteria, *Azotobacter*, and blue-green algae. Most of the annotations are either detailed summaries or verbatim copies of the original abstracts.

0107 Agricultural development indicators, a statistical handbook.
2698 International Agricultural Development Service
IADS, New York, NY, USA, 1978, 56 p.
Twenty-six indicators of the food status, demographics, political situation, economy, agricultural production, food consumption and agricultural inputs (land and other resources) were tabulated for 140 nations and geopolitical entities. Each two facing pages list indicators for from four to ten countries within a region. Continental and area maps show regional divisions and country locations.

0108 Select bibliography on symbiotic nitrogen fixation.
2223 Mohan Rao, N. (U Agr Sci, Bangalore, India).
U Agr Sci, Bangalore U Libr Biblio Ser No 29, 1976, 139 p.
An alphabetically arranged listing of articles published from 1966 to 1975, with a subject index and list of source journals. Coded lists indicate the availability of abstracts or full articles in Indian libraries.

0109 Soil Microbiology Department [report].
2556 Nutman, P.S. (Rothamsted Exp Stn, Harpenden, Herts., England).
In Rothamsted rept 1974, pt 1, p. 245-256.
Nine areas of work involving legume nodulation are described, along with other activities of the soil microbiology department. The publications section lists 28 articles and papers produced by the department.

0110 Nitrogen fixation.
2769 Sadana, J.C. (Natl Chem Lab, Poona, India) and B.M. Khan.
J Sci Ind Res 36(10):510-533, 1977.
A review of nitrogen fixation (industrial and natural) with emphasis on biological fixation and the biochemical actions of nitrogenase. Properties of nitrogenase components for 8 microorganisms, including *Rhizobium japonicum* and *R. lupini* were tabulated, with references and a model for nitrogenase action. Possibilities for genetic manipulation and some present and potential applications of biological processes were summarized. The reference list has 390 citations, but without article titles.

0111 Advancement of understanding of the process of biological nitrogen
2771 fixation.
Serova, F.Ya. (Inst Hist Sci, Moscow, USSR) and V.K. Shil'nikova.
Biol Bul Acad Sci USSR 2(5):636-643, 1975 (tr 1976)
This brief history relates 19 significant events leading from the discovery of nitrogen by Reserford in 1772 to the experimental inoculation of legumes by Prazhmovskii in 1891. References to the original seminal papers document most of the events.

0112 IX Reunion Latinoamericana sobre *Rhizobium*, Cocoyoc, Morelos, Mexico,
3334 23 al 26 de Octubre, 1978.
Valdes, M. (Relar Presidente)
Comite Org de la IX Relar, 1978, 63 p.
Resumes of 60 papers under the headings: cultivation and selection of strains; physiological, biochemical and ecological aspects of the bacteria and the symbiosis; genetics of *Rhizobium*; cultural practices; and production and handling of inoculants.

02. CARBON AND CARBON COMPOUNDS

0201 Structural studies of the extracellular polysaccharides of *Rhizobium*
2462 *japonicum* strains 71A, CC708, and CB1795.
Dudman, W.F. (CSIRO, Canberra City, A.C.T., Australia).
Carbohyd Res 66:9-23, 1978.
Investigation of the structures of acidic polysaccharide revealed apparently identical rhamno-4-*O*-methyl-glucuronans from all strains.

0202 α-ketoglutarate dehydrogenase mutant of *Rhizobium meliloti*.
2482 Duncan, M.J. (Harvard Med Schl, Boston, MA, USA) and D.G. Fraenkel.
J Bact 137(1):415-419, 1979.
The mutant was unable to grow on L-arabinose, acetate or pyruvate and grew only slowly on other carbon sources. Revertants had regained kgd activity. Metabolic pathway differences between *R. meliloti* and *R. japonicum* may be explained by studying such mutants.

0203 The opportunity for and significance of alteration of ribulose
2643 1,5-Biphosphate carboxylase activities in crop production.
Hardy, R.W.F. (Du Pont & Co., Wilmington, DE, USA), U.D. Havelka and B. Quebedeaux.
In Siegleman, H. and G. Hind, eds., Photosynthetic carbon assimilation. NY, Plenum, 1978, p. 165-178.
The discoveries leading to the proposal that the dual oxygenase-carboxylase activity of RuBP carboxylase is the major primary reaction leading to photorespiration provided a basis for developing photosynthetically efficient legumes and cereals. CO_2 enrichment produced as high a yield in nodulating soybeans as did CO_2 enrichment plus nitrogen fertilizer.

0204 Structural studies of the *Rhizobium trifolii* extracellular
3059 polysaccharide.
Jansson, P.E. (U Stockholm, Sweden), B. Lindberg and H. Ljunggren.
Carbohyd Res75:207-220, 1979.
Studies employing several methods led to a proposed structure composed of heptasaccharide repeating units, some of which were incomplete.

0205 Carbon dioxide fixation by lupin root nodules. II. Studies with
2692 ^{14}C labeled glucose, the pathway of glucose catabolism, and the effects of some treatments that inhibit nitrogen fixation.
Laing, W.A. (DSIR Div Plant Physiol, Palmerston N, N.Z.), J.T. Christeller and W.D. Sutton.
Plant Physiol 63(3):450-454, 1979.
Detached lupin nodules incorporated labeled glucose into amino acids in less than 3 minutes. The observed selective incorporation of glucoses into either organic or amino (predominantly aspartic) acids is consistent with the provision of carbon skeletons for amino acid synthesis by the phosphoenolpyruvate carboxylase reaction. Inhibition of N_2 fixation generally paralelled inhibition of nodule CO_2 fixation.

0206 Some effects of increased atmospheric carbon dioxide on white clover
2203 *(Trifolium repens)* and pea *(Pisum sativum)*.
Masterson, C.L. (Agr Inst, Wexford, Ireland) and M.T. Sherwood.
Plant Soil 49(2):427-432, 1978.
Carbon dioxide enrichment increased DM yield and N percentage in clover, but tended to decrease the % N in pea.

0207 Dynamics of polysaccharide excretion by nodule bacteria. (Rus)
2649 Nalbandian, A.D. (Inst Microbiol, Abovyan, ARSSR), G.S. Babayan and N.M. Sayadyan.
Isves Akad Nauk SSSR Ser Biol 979(2):310-312, 1979.
Characteristics of the growth of cultures in a glucose medium indicated that the polysaccharides were not utilized as a carbon source.

0208 Carbohydrate metabolism in *Rhizobium trifolii* : Identification and
2885 symbiotic properties of mutants.
Ronson, C.W. (U Warwick, Coventry, Warwickshire, England) and S.B. Primrose.
J Gen Micro 112:77-88, 1979.
Mutants lacking enzymes of certain metabolic and catabolic pathways remained effective, suggesting that neither glucose, fructose nor sucrose are used directly by bacteroids to provide ATP and reductant for nitrogen fixation. The major energy source may be tricarboxylic acid cycle intermediates from the nodule cytosol.

0209 Effect of glucose on polyol metabolism by *Rhizobium trifolii*.
3057 Ronson, C.W. (U Warwick, Coventry, Warwickshire, England) and S.B. Primrose.
J Bact 139(3):1075-1078, 1979.

When glucose was catabolized to at least glucose 6-phosphate, phenomena similar to catabolite repression and inhibition were observed. In bacteria able to metabolize glucose, the glucose inhibited the activity of either the ribitol transport system or ribitol dehydrogenase, thereby maintaining preferential metabolism of 'good' carbon sources

0210 Influence of straw and CO_2 on N_2-fixation and yield of field-grown
2202 soybeans.
Shivashankar, K. (U Agr Sci, Hebbal, Bangalore, India) and K. Vlassak.
Plant Soil 49(2):259-266, 1978.
Incorporation of straw, with or without CO_2 enrichment, markedly influenced N_2-fixation and yield. Nitrogenase activity was increased up to four-fold by straw at 4 t/ha alone or straw 2 t/ha + CO_2. This study confirms that straw can be considered to provide a partial substitute for expensive CO_2-enrichment for improving nitrogen fixation.

0211 Differential stimulation and inhibition of growth of *Rhizobium*
2326 *trifolii* strain T1 and other *Rhizobium* species by various carbon sources.
Skotnicki, M.L.(Aust Natl U, Canberra, A.C.T., Australia) and B.G. Rolfe.
Microbios 20:15-28, 1977.
Differentiation between the various species of fast- and slow-growing rhizobia could be made on the basis of growth responses to tricarboxylic acid (TCA) intermediates in the presence of various carbon sources. All the rhizobia showed some defects in the TCA cycle.

0212 Effect of different kinds of sugars on nodule formation in leguminous
2150 plants as examined by excised root culture technique.
Yoshida, S. (U Nagoya, Japan) and M. Yatazawa.
Soil Sci Plant Nutr 24(1):131-134, 1978.
The excised root culture technique was used to observe the effects of sugars on nodule formation. The optimum sucrose concentration for nodule formation was higher than for root growth (10 vs 5%). Either glucose or fructose in combination with sucrose had the greatest overall effect

0213 Surface carbohydrates of *Rhizobium*. β-1, 2-glucans.
3003 Zevenhuizen, L.P. (Agr U Wageningen, Netherlands) and H.J. Scholten-Koerselman.
A Van Leeuw 45(2):165-175, 1979.
Low molecular weight glucan was the principal polysaccharide component in cells grown in carbohydrate-rich medium. The glucans were present as firmly attached capsular material. A possible role in variable binding properties of rhizobia was discussed.

Additional references with information on carbon may be found under
Inoculant Materials *Rhizobium* Cultures and Culture Media
Photosynthesis and Photosynthates

03. COMPETITION (MICROBIAL)

0301 2655 A study of the competitive ability of streptomycin and spectinomycin mutants of *Rhizobium trifolii* using various marker techniques.
Jones, D.G. (U Coll Wales, Aberystwyth, Wales) and E.S.P. Bromfield.
Ann Appl Biol 88(3):448-450, 1978.

The majority of the mutants with resistance to both antibiotics were inferior to parental strains in symbiotic effectiveness and competitive ability against an ineffective strain. However, by screening large numbers of mutants, strains corresponding to the parental strains might be selected.

0302 2117 Selection of *Rhizobium japonicum* strains on their competitiveness for infection. (Fre)
Lagacherie, B. (Ctr Rech Dijon, France), R. Hugot and N. Amarger.
Ann Agron 28(4):379-389, 1977.

Competitiveness was measured by comparing the dry weight of plants inoculated with an effective strain mixed with an ineffective one. The importance of competitiveness as a criterion in strain selection was discussed.

0303 2269 Competitive advantage of bacteriocin-producing and phage-producing strains of *Rhizobium trifolii* in mixed culture.
Schwinghamer, E.A. (CSIRO, Canberra, A.C.T., Australia) and J. Brockwell.
Soil Biol Biochem 10(5):383-387, 1978.

In either broth or wet peat, bacteriocinogenic and lysogenic strains strongly suppressed growth of sensitive strains. Suggestions were offered for avoiding depletion of desired strains in mixed-strain inoculants.

0304 2815 Competition between *Rhizobium* strains in nodule formation: interaction between nodulating and non-nodulating strains.
Winarno, R. (St Agr U, Wageningen, Netherlands) and T.A. Lie.
Plant Soil 51(1):135-142, 1979.

The presence of a non-nodulating strain invariably suppressed the nodulating activity of infective strains.

Additional references with information on microbial competition may be found in relevant listings under:
Inoculation effects and requirements; Microorganisms (other than rhizobia); Specificity and promiscuity; Survival (microbial).

04. ENERGETICS

0401 2365 Energetics of biological N_2 fixation.
Burris, R.H. (U Wisconsin, Madison, WI, USA).
In Mitsui, A., *et al*, Biological solar energy conversion. NY, Academic, 1977, p. 275-289.

The potential for improving biological nitrogen fixation processes for food production and energy conservation makes research on all BNF processes an urgent need. Energy efficiencies can be improved by selecting

systems that produce minimal amounts of hydrogen and use minimal amounts of plant-supplied ATP. Present energetics are little better than the Haber industrial process, although BNF offers the advantage of utilizing sun energy rather than natural gas.

0402 Photosynthesis as a source for energy and materials.
2554 Calvin, M. (U Cal Berkeley, USA).
Amer Scientist 64(3):270-278, 1976.
The possibility of a synthetic system based on natural photosynthetic quantum-capturing of solar energy was discussed. Various biomass systems were also explored, and the need to meet N requirements pointed out.

0403 Effect of variable energy input on nitrogen fixation in instantaneous
2479 linear discharges.
Chameides, W.L. (U Florida, Gainsville, FL, USA).
Nature 277(5692):123-125, 1979.
A formula for calculating the global production of NO by lightning was derived from a model shock wave. Lightning and combustion were determined to be the likely sources of most atmospheric nitrogen oxides.

0404 Energy consumption in the U.S. Chemical fertilizer system from the
3237 ground to the ground.
Davis, C.H. (TVA, Muscle Shoals, AL USA) and G.M. Blouin.
In Lockeretz, W. (ed.) Agriculture and energy. NY, Academic, 1977, p. 315-331.
Approximately 402 x 10^{12} BTU energy was consumed to produce nitrogen fertilizer in the U.S. in 1974, plus additional processing and distribution costs. Technologies are available to use coal instead of natural gas for nitrogen production, and to reduce other energy inputs. Energy data for production of various forms of nitrogenous fertilizers are provided, with maps showing production and distribution patterns in the U.S.

0405 Loss of energy during the fixation of atmospheric nitrogen by
2429 nodulated legumes.
Evans, H.J. (Oregon St U, Corvallis, OR, USA), T. Ruiz-Argueso, N. Jennings and J. Hanus.
In Report of the public meeting on genetic engineering for nitrogen fixation. Washington, Natl Acad Sci, 1977, p. 61-76.
In laboratory experiments, about one mole of hydrogen gas was given off for each mole of nitrogen converted to ammonia. This calculates to about 25% of the 28 ATP equivalents needed for nitrogen reduction. The average energy losses by the symbiosis to H evolution is about 30%, but for some strains this may be as low as 4% when most of the hydrogen can be utilized internally. Rhizobia able to synthesize the hydrogenase complex have a considerable energy efficiency advantage over those which cannot.

0406 Energy and nitrogen fixation.
3024 Gutschick, V.P. (Los Alamos Lab, Los Alamos, NM, USA).
BioSci 29(9):571-575, 1979.

ENERGETICS, *continued*

The use of fossil fuels to increase the amount of nitrogen available to crops is, for the present, a clear gain. As these fuels become scarcer, the expanded use of legumes can contribute to the growing food needs of the world, but this alone will not solve the problem. Alternative energy sources and manufacturing processes, better management of soil N, recycling of nutrients and increased biofixation must all contribute to the maintenance of the energy and nutrient budgets.

0407 2850 Characteristics of N_2 fixation by field grown legumes that indicate that energy is the major factor limiting N_2 fixation.
Hardy, R.W.F. (du Pont Co, Wilmington, DE, USA).
In Genetic engineering for nitrogen fixation; proceedings of a conference. Basic Life Sci 9:381-399, 1977.

A review of the energetics of symbiotic nitrogen fixation with a summary of the affecting environmental and physiological factors. Six types of activity aimed at increasing biological photoproductivity and reducing fossil energy inputs to crop production were suggested: identification and assessment of limiting factors; development of screening techniques and criteria; discovery and evaluation of possible solutions to problems of limitation; and implementation of chosen solutions.

0408 2588 Possible routes to increase the conversion of solar energy to food and feed by grain legumes and cereal grains (crop production): CO_2 and N_2 fixation, foliar fertilization, and asimilate partitioning.
Hardy, R.W.F. (du Pont Co, Wilmington, DE, USA), and U.D. Havelka.
In Mitsui, A., *et al*, eds. Biological solar energy conversion. NY, Academic, 1977, p. 299-322.

The present efficiency of only about 1% in the conversion of solar energy to grain affords opportunities to raise production to meet world food demands. A higher ratio of legumes to cereals will be required. The limitation of photosynthate supply for nitrogen fixation in legumes may be lessened through CO_2 enrichment and by regulating the partitioning of assimilates.

0409 2484 Stabilizing agricultural energy needs - role of forages, rotations, and nitrogen fixation.
Heichel, G.H. (USDA SEA, St. Paul, MN, USA).
J Soil Water Cons 33(6):279-282, 1978.

A model for an energy audit was devised. The partitioning of energy into N sources can be greatly reduced through utilization of legumes, individually and in rotation. By growing 10% of the U.S. corn in rotation with alfalfa, the demand for natural gas could be reduced by 28 billion cu ft.

0410 2529 Nitrogen fixation and bioenergetics: the role of ATP in nitrogenase catalysis.
Ljones, T. (U Bergen, Norway).
FEBS Ltr 98(1):1-8, 1979.

The process of ATP hydrolysis coupled with electron transfer can be studied with pure enzyme proteins of nitrogenase in simple and well

defined media. A simple model of reductive dephosphorylation was favored over multiple roles for ATP. Unanswered questions in the biochemical system were raised, and required role definitions for a full understanding of the bioenergetics of nitrogen fixation were pointed out.

0411 2229 Respiration and energy requirement for nitrogen fixation in nodulated pea roots.
Mahon, J.D. (Prairie Reg Lab, Saskatoon, Sask., Canada).
Plant Physiol 60(6):817-821, 1977.
A simple method for determining the coefficient for respiration associated with N fixation was proposed. Under the conditions of the tests in this experiment, the energy requirement was 17 g carbohydrate consumed per g nitrogen fixed.

0412 2856 Environmental and genotypic effects on the respiration associated with symbiotic nitrogen fixation in peas.
Mahon, J.D. (Prairie Reg Lab, Saskatoon, Sask, Canada).
Plant Physiol 63(5):892-897, 1979.
Only plant genotype effects on fixation-linked respiration were significant in combinations of four pea cultivars with four *Rhizobium leguminosarum* inoculants, although both symbionts significantly influenced the total rate of acetylene reduction. The least respiration per unit of ammonia produced symbiotically in a cultivar was 4.8 moles CO_2 per M NH_3, while the greatest was 13.3 M. This compares to a theoretical minimum of 4.7 M.

0413 2214 Food production and the energy crisis.
Pimental, D. (Cornell U, Ithaca, NY, USA), L.E. Hurd, A.C. Bellotti, M.J. Forster, I.N. Oka, O.D. Sholes and R.J. Whitman.
Science 182:443-449, 1973.
Energy inputs for various corn yields were determined, and alternative production methods discussed. It was determined that green manuring offered greater energy economy than the transportation and application of livestock manure.

0414 2813 Respiratory costs of nitrogen fixation in soybean, cowpea and white clover. 1. Nitrogen fixation and the respiration of the nodulated root.
Ryle, G.J.A. (Grassland Res Inst, Hurley, Berks., England), C.E. Powell and A.J. Gordon.
J Exp Bot 30(114):135-144, 1979.
The three legumes exhibited similar respiratory losses of CO_2 from nodulated roots (6.3 - 6.8 mg C/mg N fixed). These findings are compatible with a theoretical energy component for reduction of nitrogen to ammonia plus an equal or larger component for growth and maintenance of roots and nodules.

0415 2814 Respiratory costs of nitrogen fixation in soybean, cowpea and white clover. 2. Comparisons of the cost of nitrogen fixation and the

utilization of combined nitrogen.
Ryle, G.J.A. (Grasslands Res Inst, Hurley, Berks., England), C.E. Powell and A.J. Gordon
J Exp Bot 30(114):145-153, 1979.

The source of N had little or no effect on the rate of photosynthesis or shoot respiration, but the rate of respiration of nodulated roots was as much as two-fold greater than that of plants utilizing nitrate N. The 3 legumes analyzed all respired 11-13% more of their fixed carbon each day than plants lacking nodules.

Certain entries under Hydrogen and Hydrogenase, and under Photosynthesis and Photosynthates, also relate directly to Energetics.

05. ENZYMES (OTHER THAN HYDROGENASE OR NITROGENASE ALONE)

0501 Phosphoglucose isomerase mutant of *Rhizobium meliloti*,
2478 Arias, A. (Inst Inves Biol Clemente Estable, Montevideo, Uruguay), C. Cervenansky, A. Gardiol and G. Martinez-Drets.
J Bact 137(1):409-414, 1979.

Nitrosoguanidine mutagenesis produced a rhizobial strain which failed to on mannitol and 6 other carbohydrates, but did grow on glucose, L-arabinose and others . Revertants to normal growth phenotype had regained the pg enzyme. Nitrogen fixation was reduced and delayed when the mutant strain was the inoculant.

0502 Effect of enzymatic reduction of Lb and Mb on nitrogen fixing activ-
2530 ity of the bacteroids of *Rhizobium lupini*.
Bashirova, N.F. (A.N. Bakh Biochem Inst, Moscow, USSR), S.S. Melik-Sarkisyan and V.L. Kretovich.
Sov Plant Physiol 25(4):561-565, 1978.

A positive correlation between met-Lb-reductase activity and the content of leghemoglobin in nodules was found. The nitrogen fixing activity of isolated lupine bacteroids was stimulated in the presence of either total Lb or its isolated macrocomponents (LB_1,LB_2 and myoglobin).

0503 Enzymes of nitrogen metabolism in legume nodules - comparative study.
2448 Boland, M.J. (DSIR, Palmerston N, N.Z.), A.M. Fordyce and R.M. Greenwood.
Aust J Plant Physiol 5(5):553-559, 1978.

Nodules from 12 herbaceous legumes all contained substantial quantities of glutamine synthetase. Levels of glutamate dehydrogenase and glutamate synthase varied widely. A glutamine synthetase and NADH-dependent glutamate synthase pathway was proposed as universal in legume nodule metabolism.

0504 Purification and characterization of D-amino acid aminotransferase
2569 from *Rhizobium japonicum*.
Gosling, J.P. (University Coll, Galway, Ireland) and P.F. Fotrell.
Biochim Biophys Acta 552(1):84-95, 1978.

The enzyme had a broad substrate specificity and was very active with D-α-aminobutyrate, D-aspartate, D-alinine and D-glutamate. Apparent molecular weight was 58,000 and the pH optimum was 7.8-7.9. This enzyme has a recognized role in cell wall synthesis, but its function in higher plants is uncertain.

0505 Pectolytic enzymes in *Rhizobium*.
2099 Hubbell, D.H. (U Florida, Gainesville, FL, USA), V.M. Morales and M. Umali-Garcia.
Appl Envir Micro 35(1):210-213, 1978.
Very low levels of pectolytic enzyme activity were detected in infective and noninfective strains of *Rhizobium* on sensitive pectin agar plates. The possibility that penetration of the root hair cell wall involves a highly localized activity of rhizobial hydrolytic enzyme is consistent with this finding. Among rhizobia tested, the temperate forms showed greater activity than did tropical rhizobia.

0506 Purification and properties of vitamin B_{12}-dependent ribonucleotide
2708 reductase from *Rhizobium meliloti*.
Inukai, S. (Nagoya U, Japan), K. Sato and S. Shimizu.
Agr Biol Chem 43(3):637-646, 1979.
By growing *R. meliloti* on cobalt deficient medium containing methionine, it was possible to obtain milligram quantities of pure enzyme from relatively small amounts of starting material. Studies indicated that ribonucleotide reductase of *R. meliloti* is quite different from that of *Lactobacillus leichmannii*.

0507 Hydrolytic enzyme production by *Rhizobium*.
3182 Martinez-Molina, E. (U Florida, Gainesville, FL, USA), V.M. Morales and D.H. Hubbell.
Appl Envir Micro 38(6):1186-1188, 1979.
Production of cellulase and hemicellulase was confirmed, and a possible role in the root infection process discussed.

0508 Studies on symbiotic nitrogen fixation: nitrogen-fixing and
3245 hydrogenase activities in extracts of legume root nodules.
Maruyama, Y.
In Takahashi, H. (ed.) Nitrogen fixation and nitrogen cycle. Japanese Int Biol Prog 12:35-40, 1975.
Both enzymes were found in the bacteroidal fraction of cell-free nodule extracts, while leghemoglobin was found in the supernatant fraction. A neutral pH and low pO_2 were optimal for nitrogenase activity.

0509 Initial organic products of fixation of dinitrogen by root nodules
2739 of soybean *(Glycine max)*.
Meeks, J.C. (Michigan St U, E. Lansing, MI, USA), C.P. Wolk, N. Schilling, P.W. Schaffer, Y. Avissar and W-S. Chien.
Plant Physiol 61(6):980-983, 1978.
The initial product of fixation was glutamine, then glutamate and alanine. After 15 minutes, the major isotope-labeled products were glutamate and

alanine, with glutamine comprising only a small fraction. The idea that glutamine synthase-glutamate synthase is the primary route for assimilation of fixed nitrogen in soybean nodules was supported by the results of this study.

0510 The role of 6-phosphogluconate dehydrogenase in *Rhizobium*.
2015 Mulongoy, K. (N Carolina St U, Raleigh, NC USA) and G.H. Elkan.
Can J Microbiol 23(9):1293-1298, 1977.

Enzymatic activity of an NAD-linked 6-PG dehydrogenase was similar in slow- and fast-growing rhizobia, but an NADP-dependent 6-PG dehydrogenase was detected only in the fast-growers and was more than twice as active as the NAD-linked enzyme. Evidence was presented for the absence of the pentose phosphate pathway in slow-growing rhizobia.

0511 Properties of pyruvate kinase from soybean nodule cytosol.
2722 Peterson, J.B. (Oregon St U, Corvallis, OR, USA) and H.J. Evans.
Plant Physiol 61(6):909-911, 1978.

The studies indicated that pyruvate kinase from plant cells of soybean nodules is regulated in a way that contributes to efficient nitrogen fixation by providing proper quantities of PEP for PEP carboxylase and the subsequent synthesis of aspartate and asparagine during nitrogen fixation.

0512 Phospho*enol*pyruvate carboxylase from soybean nodule cytosol. Evidence
2812 for isoenzymes and kinetics of the most active component.
Peterson, J.B. (Oregon St U, Corvallis, OR, USA) and H.J. Evans.
Biochim Biophys Acta 567(2):445-452, 1979.

Five activity bands were resolved by electrophoresis, and a small quantity of the enzyme from the most active gel band was separated by preparative electrophoresis. Experiments indicated that the major factors controlling the enzyme's activity were phospho*enol*pyruvate and HCO_3^- concentrations. This enzyme was tentatively added to the scheme proposed for control of pyruvate kinase and phospho*enol*pyruvate utilization in soybean nodule cytosol.

0513 Localization of glutamate-dehydrogenase and glutamate synthase in
2942 roots and nodules of *Lupinus* seedlings.
Ratajczak, L. (A. Mankiewicz U, Poznan, Poland), W. Ratajczak, H. Mazurowa and A. Wozny.
Biochem Physiol Pflanz 174(4):289-295, 1979.

A high NADH-dependent GDH activity in nodules was localized mainly in the mitochondral fraction. The highest activity of GDH in the roots of lupine was in the cells surrounding the nodule. Results of this study support the conclusion that ammonia assimilation in lupine is by the GS/GOGAT enzyme system.

0514 Nodule nitrate reductase as a source of reduced nitrogen in soybean.
2468 Randall, D.D. (U Missouri, Columbia, MO, USA), W.J. Russell and D.R. Johnson.
Physiol Plant 44(4):325-328, 1978.

Significant nitrate reduction in the absence of detectable nitrate reductase indicated the probability of nodule nitrate reduction, but the total pathway and quantification remain to be established.

0515 Effect of oxygen tension on nitrogenase and on glutamine synthetases
2764 I and II in *Rhizobium japonicum*.
Ranga Rao, V. (C.F. Kettering Res Lab, Yellow Springs, OH, USA), R.A. Darrow and D.L. Keister.
Biochem Biophys Res Comm 81(1):224-231, 1978.
Rhizobium japonicum cells normally have two forms of glutamine synthetase (GS I and GS II), but cells grown under low O_2 tensions contain only GS I. High adenylation was not correlated with reduced nitrogenase activity as has been previously reported, but was observed concomitant with nitrogenase production and activity.

0516 Glutamate dehydrogenase of lupin nodules - purification and
3006 properties.
Stone, S.R. (U Sydney, Australia), L. Copeland and I.R. Kennedy.
Phytochem 18(8):1273-1278, 1979.
On the basis of molecular weight determinations, a hexameric structure was proposed for GDH from the plant fraction of lupin nodules. A bidirectional, sequential mechanism for amination and deamination, with a greater potential for amination, was proposed.

0517 Differentiation of *Rhizobium japonicum*. II. Enzymatic activities in
2510 bacteroids and plant cytoplasm during the development of nodules of *Glycine max*.
Stripf, R. (U Marburg, Lahnberge, Marburg, W Germany) and D. Werner.
Z Naturforsch C 33:373-381, 1978.
Maximum nitrogenase activity was developed 19 days after infection, followed by a sharp drop in activity (var. Caloria). A higher maximum activity lasting 7 days was found in var. Mandarin. In both varieties, leghemoglobin continued to increase during the period of decreased nitrogenase activity, but declined when nitrogenase activity measured significantly again, 30 to 45 days after infection. Close relationships between enzymatic activities in the bacteroids and the plant were noted.

0518 Enzymatic differentiation in symbiosis of *Glycine max* and *Rhizobium*
2864 *japonicum* with effective and ineffective strains. (Ger)
Stripf, R. (U Marburg, Lahnberge, Marburg, W Germany) and D. Werner.
Ber Deutsch Bot Ges 91(2-3):683-692, 1979.
Nitrogen metabolism enzymes developed in a pattern similar to that of nitrogenase in the plant cytoplasm, but glutamine synthetase was 3-4 times more active in ineffective bacteroids than in effective bacteroids.

0519 Allantoin production and its utilization in relation to nodule
2733 formation in soybeans. Enzymatic studies.
Tajima, S. (Nagoya U, Japan), M. Yatazawa and Y. Yamamoto.
Soil Sci Plant Nutr 23(2):225-235, 1977.

Evidence accumulated in this study suggested that uricase in nodules is of bacteroid origin, and that purines are degraded in bacteroids. The mechanism of allantoin formation in bacteroids will be the subject of further studies.

0520 Differentiation of *Rhizobium japonicum*. I. Enzymatic comparison of
2509 nitrogenase, repressed and derepressed free living cells and of bacteroids.
Werner, D. (U Marburg, Lahnberge, Marburg, W Germany) and R. Stripf.
Z Naturforsch C 33:245-252, 1978.

Maximum nitrogenase activity of derepressed free living cells was seen at less than 2% O_2, and this was reduced by 90% with no oxygen in the gas phase. Bacteroids and nitrogenase active cells were more similar in glutamine synthetase and other enzymatic activities than were bacteroids and nitrogenase repressed cells. Activities in the latter were about 50% lower.

0521 Carbon dioxide fixation in the legume root nodule.
2736 Wheeler, C.T. (U Glasgow, Scotland).
Ann Appl Biol 88(3):481-484, 1978.

Nodules of outdoor grown *Vicia faba* were used to study the distribution of carboxylase activity in the nodules. Studies of ^{14}C incorporation into amino acids showed that both the bean nodule cytosol and bacteroid fractions possessed carboxylase activity. Confirmatory evidence of the presence of PEP carboxylase in the cytosol fraction was provided, but the nature of the enzymes in broad bean bacteroids remains to be established.

0522 Denitrification and anaerobic, nitrate-dependent acetylene reduction
2840 in cowpea *Rhizobium*. J Gen Micro 111:445-448, 1979.
Zablotowicz, R.M. (U California, Riverside, CA, USA) and D.D. Focht.

The denitrifying enzyme system, with the exception of nitrous oxide reductase, was found to be functional in cowpea bacteroids. Posession of both nitrogen fixing and denitrifying pathways in the same organism may help in the survival of the organism during anaerobic conditions associated with waterlogging. It may also be an important selection criterion for rhizobia subject to anoxic periods from irrigation or rainfall.

Articles specifically on Hydrogenase or Nitrogenase alone are entered under those subjects. A number of references under Genetic Factors also relate to Enzymes.

06. GENETIC FACTORS

0601 Nitrogen fixation and delayed leaf senescence in soybeans.
2234 Abu-Shakra, S.S. (U California, Davis, CA, USA), D.A. Phillips and R.C. Huffaker
Science 199(4332):973-975, 1978.

Several thousand plants in the F_2 generation were examined to determine whether prolonged photosynthetic activity could lead to symbiotic nitrogen fixation throughout seed development. The selected plant exhibited no

detectable hydrogen evolution from nodules and had an acetylene-dependent ethylene production rate of 1.5 μM/hr/g dry nodule. Five of 14 F_3 plants showed delayed senescence.

0602 Sequence complexities of the poly(A)-containing m-RNA in uninfected
2980 soybean root and the nodule tissue developed due to the infection by *Rhizobium*.
Auger, S. (McGill U, Montreal, Canada), D. Baulcombe and D.P.S. Verma.
Biochim Biophys Acta 563(2):496-507, 1979.
The total complexities of poly(A)+polysomal RNA structural gene populations from uninfected roots and mature nodules were compared. A very abundant component comprising 18-20% of the nodule RNA, which was shown to be leghemoglobin, was absent in uninfected root RNA. The Lb-m sequences could be present in roots, but at very low concentrations.

0603 Phenotypic reversion of nitrogenase in pleiotropic mutants of *Rhizobium*
2756 *meliloti*.
Barabas, I. (Hungarian Acad Sci, Szeged, Hungary) and T. Sik.
Can J Micro 25(3):298-301, 1979.
Nitrogenase, but not nitrate reductase, activity was restored to 2 out of 3 mutants by purines, and partially restored by amino acids.

0604 Preparation of a complementary DNA for leghemoglobin and direct
2397 demonstration that leghemoglobin is encoded by soybean genome.
Baulcombe, D. (McGill U, Montreal, Canada) and D.P.S. Verma.
Nucl Acid Res 5(11):4141-4153, 1978.
The complementary DNA hybridized with soybean DNA but not with *Rhizobium* DNA, directly demonstrating that Lb genes are of plant origin.

0605 Linkage mapping in *Rhizobium leguminosarum* by means of plasmid-
2335 mediated recombination.
Beringer, J E. (John Innes Inst, Norwich, England), S.A. Hoggan and A.W.B. Johnston
J Gen Micro 104(2):201-207, 1978.
Mapping data derived from R68.45-mediated crosses was presented. Circularity was demonstrated by co-inheritance of 7 adjacent markers.

0606 Transfer of drug resistance transposon TN5 to *Rhizobium*.
2404 Beringer, J.E. (John Innes Inst, Norwich, England), J.L. Beynon, A.V. Buchanan-Wollaston, and A.W. Johnston.
Nature 276(5688):633-634, 1978.
The experiment showed that a plasmid carrying the lysogenic phage Mu could be used to introduce a transposon into 3 *Rhizobium* species. Such mutations can theoretically be mapped, obviating the need for plant tests of each recombinant from defective symbiotic mutants.

0607 Generalized transduction in *Rhizobium leguminosarum*.
2880 Buchanan-Wollaston, V. (John Innes Inst, Norwich, England).
J Gen Micro 112:135-142, 1979.

Ultraviolet treatment reduced the virulence of phages and increased the transducing frequency. Generalized transduction previously reported in *A. leguminosarum* also occurred in *R. trifolii*, both directly and from the other bacterium.

0608 General transduction in *Rhizobium meliloti* by a thermosensitive
2957 mutant of bacteriophage DF2.
Casadesus, J. (CSIC, Estac Exp Zaidin, Granada, Spain) and J. Olivares.
J Bact 139(1):316-317, 1979.

A secondary, thermosensitive mutant was produced to simplify routine genetic analysis experiments by avoiding the need for antiserum to protect the growth of transductants.

0609 Rough and fine linkage mapping of the *Rhizobium meliloti* chromosome.
2966 Casadesus, J. (CSIC, Estac Exp Zaidin, Granada, Spain) and J. Olivares.
Mol Gen Genet 174(2):203-209, 1979.

R68.45-mediated linkage measurements were found to be indeed rough and subject to revision by cotransductional analysis.

0610 Identification and characterization of large plasmids in *Rhizobium*
3032 *meliloti* using agarose gel electrophoresis.
Casse, F. (Inst Natl Rech Agron, Versailles, France), J.S. Julliot, M. Michel, J. Denarie and C. Boucher.
J Gen Micro 113:229-242, 1979.

A method for determining large plasmids was used to survey plasmids of 25 effective strains from various geographical origins. Twenty-two of the strains carried large plasmids, with molecular weights estimated to range from 90×10^6 to 200×10^6. These large plasmids were apparently undetected by previously used methods.

0611 Presence of large plasmids and use of the P-1 factors in *Rhizobium*.
3114 Casse, F. (Inst Natl Rech Agron, Versailles, France), M. David, P. Boistard, J.S. Julliot, C. Boucher, L. Jouanin, T. Huguet and J. Denarie.
In Timmis, K.N. and A. Puhler (eds) Plasmids of medical, environmental and commerical importance. Netherlands, Elsevier, 1979, p. 327-338.

A review of the isolation, screening and characterization methodology of working with large plasmids and of their use in genetic research.

0612 Genetic specificity of nodulation.
2112 Devine, T.E. (USDA, Beltsville, MD, USA) and D.F. Weber.
Euphytica 26(3):527-535, 1977.

Certain combinations of particular *Rhizobium japonicum* strains with particular soybeans produce high rates of nitrogen fixation, but it is difficult to avoid infection by less desirable soil rhizobia. A genetic system for establishing strains through development of superior, highly specific host cultivars and bacteria was proposed.

0613 Oxidative metabolism of a pigmented mutant of *Rhizobium meliloti* and
2110 its revertants.
Dogra, R.C. (Haryana Agr U, Hissar, India) and S.R. Vyas.
J Appl Bac 44(1):117-123, 1978.
Non-infective pigmented mutants were induced by u. v. irradiation. A genetic link between pigmentation and ability to nodulate was indicated by the fact that a majority of the colorless revertants were able to nodulate the host plant. The parent strain and all the nodulating revertants oxidized several substrates at a higher rate than did the non-nodulating revertants or pigmented mutants. Certain energy-yielding metabolic pathways may be essential to the nodulating process.

0614 Genetic modification of N_2 fixing bacteria.
2437 Gordon, J.K. (U Wisconsin, Madison, WI, USA), T.J. Wacek, R.J. Maier, P.E. Bishop and W.J. Brill.
In Lockeretz, W. (ed.) Agriculture and energy. NY, Academic, 1977, p. 355-359.
Mutant strains of *Rhizobium japonicum* were able to overcome the repression effects of ammonium, one of the limitations on symbiotically fixed nitrogen. Asymbiotic N fixing bacteria are being studied to produce strains which excrete ammonium when a suitable energy source is available. By combining these symbiotic and asymbiotic characteristics in the microflora of soybean fields, greater yields without added N may become possible.

0615 P. L. [Public Law] 480 project: rhizobia potential.
2660 Guilford, M.C. (USDA Agr Res Serv).
Agr Res 26(6):11, 1977.
Brief report of a cooperative project in Lublin, Poland which complements U.S. research. Dr. Z. Lorkiewicz of the Maria Curie-Sklodowska University is genetically mapping traits involved in effectiveness and ineffectiveness of *Rhizobium meliloti*. Applications of basic genetic research may lead to generation of superior strains of rhizobia.

0616 Induction of nitrogenase activity in associations between *Rhizobium*
2084 and organs, cells and tissues of nodulating and non-nodulating soybean strains.
Hess, D. (U Hohenheim, Stuttgart-Hohenheim, W. Germany) and C. Schetter.
Z Pflanz 86(2):177-185, 1978.
Data in this experiment demonstrated that the nodulating gene is necessary only for the natural infection process but is not directly involved in the induction of nitrogenase activity itself.

0617 Plasmid-determined bacteriocin production by *Rhizobium leguminosarum*.
3031 Hirsch, P.R. (John Innes Inst, Norwich, England).
J Gen Micro 113:219-228, 1979.
Two types of bacteriocin, designated *Small* and *medium*, were identified from 97 isolates of *R. leguminosarum*. Three isolates appeared to carry determinants of *medium* bacteriocin production which were self-transmissible

at frequencies of 10^{-1} to 10^{-2}, suggesting the presence of bacteriocinogenic plasmids. There was also evidence of plasma determination of *small* bacteriocins.

0618 2984 Report of the public meeting on genetic engineering for nitrogen fixation held at the National Academy of Sciences, Washington, D.C., October 5-6, 1977.
Hollaender, A. (ed.)(Associated Universities, Washington, DC, USA).
Natl Sci Foundation, Washington, DC, 1978, 122 p.

The report is composed of ten papers covering biological nitrogen fixation and the present status of research, with strategies toward the goal of increasing the levels and efficiencies with which crops acquire and utilize biologically fixed nitrogen. The concluding discussion relates research proposals to cautionary imperatives in genetic research. Individual papers from this report have been entered under appropriate subjects in the present bibliography.

0619 2500 Variation in mobilization of plant nitrogen to the grain in nodulating and non-nodulating soybean genotypes.
Jeppson, R.G. (U Illinois, Urbana, IL, USA), R.R. Johnson and H.H. Hadley.
Crop Sci 18(6):1058-1062, 1978.

A higher proportion of total N content in the seed vs. the remainder of the plant would give a greater efficiency to soybeans. Genotype differences in N mobilization were recorded, but harvest N indices were not significantly affected by N fertilization. A technique for screening a large number of genotypes for N efficiency was proposed.

0620 2654 Genetic studies of *Rhizobium*.
Johnston, A.W.B. (John Innes Inst, Norwich, England) and J.E. Beringer.
Ann Appl Biol 88(3):484-487, 1978.

Because the pea is genetically the best characterized legume, most of the studies described have been done with *R. leguminosarum*, which makes possible genetic examinations of the host, the bacterium and their symbiosis. Mutants were used in 3 areas of genetic research: isolation studies to identify nodulating strains; the isolation of ineffective mutants; and the use of auxotrophy or antibiotic resistance to define a gene exchange system. Recombination studies may pave the way to the generation of recombinant strains possessing the best attributes of different parents and species.

0621 2653 Interspecific crosses between *Rhizobium leguminosarum* and *Rhizobium meliloti*: formation of haploid recombinants and of R-primes.
Johnston, A.W.B. (John Innes Inst., Norwich, England), S.M. Setchell and J.E. Beringer.
J Gen Microbiol 104(2):209-218, 1978.

The haploid recombinants carried *rif* and *str* alleles which had transferred from *R. leguminosarum* to *R. meliloti*, but rarely in the reverse direction.

Progeny were isolated which were high frequency donors of the selected alleles, and were found to harbor R-primes in which sections of the *R. meliloti* chromosome were inserted into the R68.45 used as a conjugative plasmid in the crosses. Four classes of R68.45-prime were obtained. These should be useful in genetic analysis of *Rhizobium*.

0622 2405 High frequency transfer of nodulating ability between strains and species of *Rhizobium*.
Johnston, A.W.[B.] (John Innes Inst, Norwich, England), J.L. Beynon, A.V. Buchanan-Wollaston, S.M. Setchell, P.R. Hirsch and J.E. Beringer.
Nature 276(5688):634-636, 1978.
The ability to nodulate peas was transferred via plasmids to other species of *Rhizobium* and to non-nodulating strains of *R. leguminosarum*. The transconjugants tended to have reduced nodulating ability with their original host.

0623 2396 Tryptophan genes in *Rhizobium* - their organization and their transfer to other bacterial genera.
Johnston, A.W. (John Innes Inst, Norwich, England), M.J. Bibb and J.E. Beringer.
Mol Gen Genet 165(3):323-330, 1978.
R68.45 was used to promote recombination, and a number of *trp* alleles of *R. leguminosarum* were mapped in 3 distinct chromosomal regions. Three derivatives of R68.45 were isolated, and sections of the *R. meliloti* chromosome were inserted into these. Evidence indicated that the *trp* genes are arranged similarly, if not identically, in the two *Rhizobium* species.

0624 2938 Use of RP4-prime plasmids constructed in vitro to promote a polarized transfer of the chromosome in *Escherichia coli* and *Rhizobium meliloti*.
Julliot, J.S. (INRA Ctr Natl Rech, Versailles, France) and P. Boistard.
Mol Gen Genet 173(3):289-298, 1979.
A system for the polarized transfer of chromosomes which has applicability to genetic mapping in any Gram negative bacteria was described. Studies of the genetic constitution of recombinants and their gradient transfer of various markers confirmed the polarized transfer.

0625 2475 Nodulating behavior of colchine induced polyploids of *Phaseolus aureus* Roxb.
Kabi, M.C. (B.C.K.V.V. Nod Res Lab, Mohanpur, W Bengal, India) and P.N. Bhaduri.
Cytologia 43:467-475, 1978.
Polyploidy was found to enhance root hair infection, and induced early nodulation. On tap roots, the number of nodules was tetraploids>triploids> diploids, but this order was reversed on lateral roots. There was a similar reversal between pre-flowering and flowering stages.

0626 2658 Isolation of the auxotrophic mutants of *Rhizobium japonicum* S10 using ethylmethane sulfonate.
Kalra, K.L. (Punjab Agr U, Ludhiana, India), R.P. Sethi and A.S. Khurana.
Sci Cult 43(6):271-273, 1977.

EMS was shown to be a potent agent for producing stable mutants of *R. japonicum*. The mutants were auxotrophic for amino acids, and the frequency of reversion was low.

0627 2343 Yield potential for tropical legumes from a geneticist's point of view.
Khan, T.N. ((Dept Agr, S Perth, W Australia).
In Vincent, J.M. *et al*, eds., Exploiting the legume/*Rhizobium* symbiosis in tropical agriculture. U Hawaii CTAHR Misc Pub 145, 1977, p. 21-37.

Legume yields need improvement to make them a more attractive investment compared to cereals and other crops. The 1974 FAO figures show legume yields of 559 kg/ha compared to 1818 kg/ha for cereals, which probably accounts for the relatively low acreage in legumes (74 million ha vs. 734 for cereals). Available data indicate considerable scope for improvement of legume yields in the tropics. Breeding strategies and selection criteria were discussed, with a special appeal for preservation of germplasm, particularly of today's "lesser important" species and their related wild species.

0628 2976 Genetic and biochemical analysis of mutants affected in nitrate reduction in *Rhizobium meliloti*.
Kiss, G.B. (Hungarian Acad Sci, Szeged, Hungary), E. Vincze, Z. Kalman, T. Forrai and A. Kondorosi.
J Gen Micro 113:105-118, 1979.

Twenty-five induced mutants which were unable to utilize nitrate as their sole N source were isolated from a strain of *R. meliloti*. Four mutation sites were mapped and their respective physiological effects characterized. All mutants remained infective and effective, indicating that nitrogenase and nitrate reductase do not share a common molybdenum cofactor.

0629 3065 Transfer of RP4 and R68.45 factors to *Rhizobium*.
Kowalczuk, E. (Maria Curie Sklodowska U, Lublin, Poland) and Z. Lorkiewicz.
Acta Microbiol Polonica 28(3):221-229, 1979.

The R factors were introduced by conjugation at frequencies of 10^{-5} to 10^{-6}. Plasmids from other bacterial species were maintained stably in *Rhizobium*, and could be transferred inter- and intra-specifically to other *Rhizobium* recipients.

0630 2838 Transfer of R factors to and between genetically marked sublines of *Rhizobium japonicum*.
Kuykendall, L.D. (USDA Agr Res Ctr, Beltsville, MD, USA).
Appl Envir Micro 37(5):862-866, 1979.

Antibiotic resistance factors were transferred from *Pseudomonas* strains to slow-growing rhizobia, and a transfer system was developed which may be useful in the genetic mapping of genes which determine nodulating and N-fixing abilities.

0631 2681 Gamma radiation induced and natural variability for nodulation in legumes.
Maherchandani, N. (Haryana Agr U, Hissar, India) and O.P.S. Rana.
J Nucl Agric Biol 6(3):75-77, 1977.

Ten lines superior in nodulation to the original variety of cowpea were induced and identified. Natural variability for nodulation was found in a number of chickpea genotypes, but no relation to grain yield was found. Two host genotypes out of ten studied were more responsive to effective associations with rhizobia.

0632 2978 Fingerprinting bacterial chromosomal DNA with restriction endonuclease *Eco*RI: comparison of *Rhizobium* species and identification of mutants.
Mielenz, J.R. (U California, Davis, CA, USA), L.E. Jackson, F. O'Gara and K.T. Shanmugam.
Can J Micro 25(7):803-807, 1979.

DNA cleavage patterns in agarose gels after electrophoresis were compared. Patterns from *R. japonicum*, *R. trifolii* and *R. meliloti* were clearly distinguishable. A presumptive "*Rhizobium trifolii* mutant strain" which nodulates soybeans was shown to be derivative of *R. japonicum* strain 110 and not *R. trifolii*.

0633 2113 Symbiotic variability in *Vicia faba*. 3. Genetic effects of host plant, *Rhizobium* strain and of host x strain interaction.
Mytton, L.R. (Welsh Plant Br Stn, Aberystwyth, Wales), M.H. El-Sherbeeny and D.A. Lawes.
Euphytica 26(3):785-791, 1977.

Because non-additive variations attributable to specific host genotype x *Rhizobium* genotype interactions accounted for 73.8% of phenotypic differences, the greatest improvement in symbiotic nitrogen fixation is most likely to occur through simultaneous selection of both symbionts. A proper strategy for exploiting variability will depend on more knowledge of host-strain selectivity and *Rhizobium* soil populations.

0634 2716 Some problems and potentials in breeding for improved white clover-rhizobium (*Trifolium repens-Rhizobium trifolii*) symbiosis.
Mytton, L.R. (Welsh Plant Br Stn, Aberystwyth, Wales).
Ann Appl Biol 88(3):445-448, 1978.

After a one-cycle selection for symbiotic effectiveness, experiments can be designed to apportion genetic variability according to (1) the general (or additive) effects of the plant genotype; (2) the general (or additive) effects of the *Rhizobium* genotype; and (3) specific effects of individual plant x *Rhizobium* genotype combinations (non-additive, or interaction effects). Selective breeding based on variability can then proceed. In addition, field competetiveness must be verified. Strategies for achieving these ends were described.

0635 Expression of *Escherichia coli* tryptophan operon in *Rhizobium*
2672 *leguminosarum*.
Nagahari, K. (Mitsubishi Kasei Inst Life Sci, Tokyo, Japan),
T. Koshikawa and K. Sakaguchi.
Mol Gen Genet 171(2):115-119, 1979.
Conjugative plasmid transfer converted rhizobia phenotype Trp^- to Trp^+. The resulting changes in enzyme activities were studied.

0636 Regulation of nitrogen fixation in *Rhizobium* spp Isolation of
2719 mutants of *Rhizobium trifolii* which induce nitrogenase activity.
O'Gara, F. (U California, Davis, CA, USA) and K.T. Shanmugam.
Biochim Biophys Acta 500(2):277-290, 1977.
Initial mutagenesis was induced by treating stationary phase cultures with the chemical NTG, then slow-growing mutants were selected for inability to utilize NH_4^+ as sole nitrogen source. The mutants were found to be resistant to the amino acid analog L-methionine-D L-sulfoximine, which led to development of clones capable of inducing nitrogenase activity. These were studied and characterized.

0637 Mutant strains of clover rhizobium *(Rhizobium trifolii)* that form
2720 nodules on soybean *(Glycine max)*.
O'Gara, F. (U California, Davis, CA, USA) and K.T. Shanmugam.
Proc Natl Acad Sci U S A 75(5):2343-2347, 1978.
Mutant strains [described in 0636 above] were used for the selection of additional mutants with altered host range properties. The selected mutant strains produced effective nodules on mungbean and soybean plants, but either failed to nodulate clover or formed ineffective nodules. One strain also consumed hydrogen from the gas phase. The mutant strains had a generation time almost twice that of the parent. Other alterations in characteristics were also studied.

0638 Morphology and nitrogenase activity of agar cultures and root nodules
2517 formed by D-cycloserine-resistant mutants of *Rhizobium* sp. strain
32H1. J Gen Micro 112:177-184, 1979.
Pankhurst, C.E. (DSIR, Palmerston N, NZ) and A.S. Craig.
The loss of nitrogenase activity in agar culture of one-step mutants was about 90%, but the loss of nodule activity was 25-50%. It was suggested that the mutants were unable to concentrate D-cycloserine due to a defective transport system for alanine. Second and third step mutants, which showed a further decline or complete loss of nitrogenase activity, were of only one of the three parent morphological types. It was suggested that the changes resulted from alterations in the permeability of the bacterial cell wall.

0639 Factors of multiple resistance to antibiotics in rhizobia.
2748 Pariiskaya, A.N. (Inst Micro, Acad Sci, USSR) and O.P. Gorelova.
Microbiology 45(5):747-750, 1976.
Multiple resistance is known in rhizobia, but the distribution of R factors has not been established. Of 44 collection strains checked for simultaneous

resistance to several antibiotics, 15% showed multiple resistance. It was not difficult to locate rhizobia with multiple resistance in field collected nodules. The percentage of clones of *Vigna* rhizobia carrying multiple resistance was reduced from 94% to 74% by treatment with acridine orange.

0640 Production of mutant nodule bacteria unable to reduce acetylene.
2962 Pariiskaya, A.N. (Acad Sci Inst Micr , Moscow, USSR) and T. A. Kalininskaya.
Microbiology 47(6):911-915, 1978.

Ineffective mutants were easily selected from very diverse phenotypes: resistance to various antibiotics and antimetabolites; spontaneous changes in colony morphology; auxotrophy, etc. Because disturbances in these mutants may relate to diversity of functions, they were deemed unsuitable for genetic studies of nitrogen fixation. Proven strategies for acquiring true nif mutants are needed.

0641 Symbiotic effectiveness of phage-resistant mutants of two strains of
2393 *Lotus* rhizobia.
Patel, J.J. (DSIR, Palmerston N, NZ).
Plant Soil 49(2):251-257, 1978.

The phage-resistant mutants of a fast-growing strain were as effective at nitrogen fixation as the parent strain, but most mutants of a slow-growing strain were less effective than the parent. All the mutants of *Lotus* rhizobia retained nodulating ability.

0642 Enhancing biological nitrogen fixation.
2721 Phillips, D.A. (U California, Davis, CA, USA), D.W. Rains, R.C. Valentine, R.C. Huffaker.
Cereal Foods World 23(1):26-29, 1978.

Significant advances in optimizing symbiotic N_2 fixation through genetic means may be possible by manipulating both the host legume and the microsymbiont. Naturally occurring strains of *Rhizobium* which fix N at high rates while also losing energy through hydrogen evolution might be made more efficient by introduction of an improved uptake hydrogenase. Plant characters might be altered to delay leaf senescence and prolong nitrogen fixation. Achieving these advances will require cooperative efforts by several disciplines.

0643 Strain-specific ineffective nodulation of the tropical legume
2302 *Desmodium* by *Rhizobium*.
Pinchbeck, B.R. (U Alberta, Edmonton, Alta., Canada).
Crop Sci 18(3):513-514, 1978.

The mode of inheritance of the ineffective nodulation interaction between *Desmodium uncinatum* by *Rhizobium* strain CB1789 was studied. Chi-square analysis of the segregation data of F_2 and backcross plants supported the hypothesis that a dominant gene at a single locus is responsible. Similar results have been reported with soybeans.

GENETIC FACTORS, *continued*

0644 2752 Fertility inhibition in *Rhizobium lupini* by the resistance of plasmid RP4.
Pühler, A. (U Erlangen-Nurnberg, Erlangen, W Germany) and H-J. Burkhardt.
Mol Gen Genet 162(2):163-171, 1978.
Analysis of transfer patterns indicated that the genetic information for fertility inhibition in *R. lupini* is a substantial part of the transfer unit of the RP4 plasmid. RP1 and R68 plasmids elicited the same fertility inhibition as RP4 when transferred to this bacterium.

0645 2389 Transformation of streptomycin resistance in *Rhizobium* and *Azotobacter*.
Sadasivam, S. (Tamil Nadu Agr U, Coimbatore, India) and S. Pandian.
Current Sci 47(22):863-864, 1978.
DNA from streptomycin resistant cowpea *Rhizobium* was used in genetic transformation experiments with *Azotobacter chroococcum*. The frequency of transformation was lower than had been previously reported, possibly due to progressive inactivation of the transformable DNA.

0646 2086 A *Rhizobium* mutant incabable of nodulation and normal polysaccharide secretion.
Sanders, R.E. (U Colorado, Boulder, CO, USA), R.W. Carlson and P. Albersheim.
Nature 271:241-242, 1978.
A single mutational event was apparently responsible for both reduced production of extracellular polysaccharide and the inability of the mutant to nodulate pea seedlings. This was evidenced by the isolation of revertants which produced extracellular polysaccharide and could nodulate, but nevertheless retained streptomycin and rifamicin resistance.

0647 2074 Nitrogenase activity on protoplasts isolated from root nodules of *Glycine max*.
Schetter, C. (U Hohenheim, Stuttgart-Hohenheim, W Germany) and D. Hess.
Biochem Physiol Pflanz 171(1):63-67, 1977.
As a step toward possible induction of nitrogen fixation in a non-legume, nitrogen fixing root nodule protoplasts were isolated and fused to protoplasts from soybean cell suspensions. Attempts to further culture the products failed due to overgrowth by bacteria set free from burst protoplasts.

0648 2458 Transfer of nitrogen fixation genes from a bacterium with the characteristics of both *Rhizobium* and *Agrobacterium*.
Skotnicki, M.L. (Australian Natl U, Canberra, A.C.T., Australia) and B.G. Rolfe.
J Bact 133(2):518-526, 1978.
A strain of bacterium able to nodulate clover and also form swelling galls on tomato stems in the manner of *Agrobacterium tumefaciens* was able to transfer genetic material, including a cluster of *nif* genes, to *Escherichia*

coli K-12. A possible involvement of "silent plasmids" was discussed.

0649 Characterization of plasmids isolated from *Rhizobium meliloti*.
2819 Spitzbarth, M. (U Erlangen Nurnberg, Erlangen, W Germany), A. Pühler and W. Heumann.
Arch Microbiol 121(1):1-7, 1979.
RP4 plasmid DNA was isolated by sacrosyl lysis, and was found to be able to restore N fixing capacity to an ineffective *R. meliloti* strain. The same method also permitted isolation of cryptic plasmid DNA from wild type strains.

0650 Genetic analysis of meridoploidy in *Rhizobium lupini*.
2266 Springer, R. (U Erlangen Nurnberg, Erlangen, W Germany) and W. Heumann.
Mol G Genet 165(1):57-63, 1978.
Merodiploid donor strains were crossed with haploid recipients to determine whether the two carotenoid regions of the donor had been separately or jointly transferred and recombined. Analysis led to the conclusion that in meroploid strains the two homologous regions are inserted in tandem sequence.

0651 The DNA content of *Rhizobium* (strain NZP 2257) bacteroids and
2281 bacteria.
Sutton, W.D. (DSIR, Palmerston N, NZ), R.C. Van Den Bos and T. Bisseling.
Plant Sci Lttrs 12:145-149, 1978.
Measurement by two methods showed that bacteroids from lupin nodules had a higher average DNA content than stationary phase bacteria. Bacteroid DNA content increased slightly with nodule age.

0652 On the diploid state of the meristematic cells of leguminous root
2167 nodules. (Fre)
Truchet, G. (Inst Cytol Biol, Marseille, France).
Ann Sci Nat 19(1):3-38, 1978.
Fine detail studies indicated that the augmentation of the mean nuclear volume of nodule cells occurs only in the invasion zone of the nodule where the cells synthesize DNA but do not divide. A monosomatic meristem was proposed to explain the cytophysiological properties of nodule cells.

0653 Cloning of soybean leghemoglobin structural gene sequences synthe-
2948 sized *in vitro*.
Truelsen, E. (Aarhus U, Denmark), K. Gausing, B. Jochimsen, P. Jørgensen and K.A. Marcker.
Nucl Acid Res 6(9):3061-3072, 1979.
Double-stranded Lb DNA was inserted into a plasmid, and a cloned DNA fragment of one plasmid was isolated, then characterized and mapped. The restriction cleavage map and DNA sequence agreed with the amino-acid sequence of soybean leghemoglobin.

0654 Catabolite repression-like phenomenon in *Rhizobium meliloti*.
2446 Ucker, D.S. (Mass Inst Tech, Cambridge, MA, USA) and E.R. Signer.
J Bact 136(3):1197-1200, 1978.

A pleiotropic mutant deficient in several catabolic properties was unable to nodulate effectively, suggesting a connection between regulation of nodulation and nitrogen fixation, and of catabolic physiology.

0655 Transformation as a method for increasing the activity of alfalfa
2787 rhizobia.
Zaretskaya, A.N. (All Union Sci Res Inst Agr Micro, USSR).
Microbiology 45(5):750-754, 1976 (tr 1977).

Effective strains were selected from about 100 transformants resistant to streptomycin, and tested for nitrogenase activity in tubes according to the scheme: donor, recipient, transformant strains. A wide range of activity was exhibited, from decreased to increased by up to 40% in comparison with the original strains. Passage through plants permitted selecting for even higher effectiveness. Selection by the macrosymbiont, in accordance with Natman's concept, was supported by the results.

0656 Intraspecific variability for nitrogen fixation in southernpea (*Vigna*
2471 *unguiculata* (L.) Walp.).
Zary, K.W. (Texas A & M U, College Stn, TX, USA), J.C. Miller, R.W. Weaver and L.W. Barnes.
J Amer Soc Hort 103(6):806-808, 1978.

One hundred cowpea genotypes showed significant differences in N_2 fixing efficiency when inoculated with mixed inoculant. This variability suggests good possibilities for breeding for nitrogen fixing ability.

0657 Restoration of effectiveness of *Rhizobium meliloyi* ineffective
2676 mutants by transduction of high-level streptomycin resistance.
Zelazna-Kowalska, I. (Maria Curie Sklodowska U, Lublin, Poland) and M. Kowalski
Acta Micro Pol 27(4):339-345, 1978.

Transduction of chloramphenicol and linked temperature-sensitive mutations did not change symbiotic properties of an ineffective, lysine dependent mutant, but subsequent transduction of high level streptomycin resistance restored effectiveness.

0658 Bacteriocinogeny of *Rhizobium trifolii*.
2713 Zelazna-Kowalska, I. (Maria Curie Sklodowska U, Lublin, Poland).
Acta Micro Pol 28(1):39-45, 1979.

Bacteriocinogeny in *R. trifolii* has been associated with the carrying of phage particles and with lysogeny. The bacteriocins produced by mutant strains were sensitive to proteases, inferring that bacteriocinogeny is plasmid controlled. Elimination of this plasmid character did not affect other special characteristics of the mutant strain.

0659 Effect of *strA* mutation on symbiotic nitrogen fixation by *Rhizobium*
2712 *meliloti*.

Zelazna-Kowalska, I. (Maria Curie Sklodowska U, Lublin, Poland).
Acta Micro Pol 28(1):47-52, 1979.

Low level resistance to streptomycin was associated with changes in membrane permeability and loss of effectiveness. Further mutation to high level resistance was correlated with membrane permeability to the antibiotic and the return of effectiveness.

0660 Potential for nitrogen fixation in vegetables.
2527 Zobel, R.W. (Cornell U, Ithaca, NY, USA) and D.H. Wallace.
Hortsci 13(6):679-682, 1978.

This report includes a section on macrogenetic engineering of rhizobia and their legume hosts. Breeding for greater competitiveness and persistence in rhizobia, and for improved symbiotic relationships by legumes, show promise.

0661 Effect of acriflavine and sodium dodecyl sulphate on infectiveness
3143 of *Rhizobium trifolii*.
Zurkowski, W. (Maria Curie Sklodowska U, Lublin, Poland), M. Hoffman and Z. Lorkiewicz.
Acta Micro Pol ser A, 5(22):55-60, 1973.

The loss of infectiveness induced by acriflavine or SDS, and the lack of reversion to infectiveness, suggested that this character is plasmid controlled.

0662 Bidirectional replication of the chromosome in *Rhizobium trifolii*.
2029 Zurkowski, W. (Marie Curie Sklodowska U, Lublin, Poland) and Z. Lorkiewicz.
Mol Gen Genet 156(2):215-219, 1977.

Evidence of bidirectional replication, previously known in other bacteria, was shown in thymine-dependent mutants of *R. trifolii* T37 by means of autoradiographic experiments.

0663 Effective method for isolating non-nodulating mutants of *R. trifolii*.
2677 Zurkowski, W. (M. C. Sklodowska U, Lublin, Poland) and Z. Lorkiewicz.
Genet Res 32(3):311-314, 1978.

Incubation of cultures at 37°C (9° above optimal) produced up to 75% non-nodulating mutants. Elimination of the Nod⁺ character was accomplished by loss of a large plasmid. The method was found to be effective for isolating mutants from numerous strains of *R. trifolii*.

0664 Genetic mapping of the chromosome of *Rhizobium trifolii*.
2675 Zurkowski, W. (Maria Curie Sklodowska U, Lublin, Poland) and Z. Lorkiewicz.
Acta Micro Pol 27(4):309-319, 1978.

Fifteen genetic markers were characterized for a wild strain and its auxotrophic mutants. Synchronized cultures were studied for revertants and recultured to allow phenotypic expression of the mutation. A preliminary map for *R. trifolii* was proposed on the basis of replicative mapping supplemented by genetic analysis.

07. HORMONES AND GROWTH SUBSTANCES

0701 Effect of plant growth regulators on the nitrogen fixing (acetylene
2596 reduction) activity of soybean plants.
Huang, C-Y. (Natl Taiwan U).
Taiwania 22:80-90, 1977.

Kinetin and 2,4-D suppressed acetylene reduction in intact plants and detached nodules. It was assumed that the growth regulators inhibited nodulation and promoted nodule degeneration.

0702 Realization of yield potential in soybean (*Glycine max* [L.] Merr.)
2160 and cowpea (*Vigna unguiculata* [L.] Walp.).
Summerfield, R.J. (U Reading, England), F.R. Minchin and E.H. Roberts.
Proc BCPC/BPGR Symp Opportunities for plant growth regulation, 1978, p. 125-134.

Grain legume yields have either stagnated or declined over the past 25 years, while those of many cereal grains have increased dramatically. The possibility of utilizing growth regulators to prolong photosynthetic activity and nitrogen fixation in legumes was discussed.

0703 Root hormones and plant growth.
2450 Torrey, J.G. (Cabot Fndn, Harvard U, Petersham, MA, USA).
Ann Rev Plant Physiol 27:435-459, 1976.

A review of literature on the presence and role of auxins, gibberellins, cytokinins, abscisic acid and ethylene in roots and root systems. The effects of hormones on root elongation, geotropism, lateral root initiation, secondary thickening and bud formation by roots were reviewed. Among the 247 citations, several are concerned with roots and root hormones in relation to symbiotic nitrogen fixation.

0704 Asymbiotic association of *Rhizobium* with pea epicotyls treated with
2079 a plant hormone.
Verma, D.P.S. (McGill U, Montreal, Canada), N. Hunter and A.K. Bal.
Planta 138:107-110, 1978.

Indole-3-acetic acid treatment caused swelling of the epicotyl tissue, and the application of *Rhizobium* to the cut surface of swollen tissue induced ineffective infection. No membrane structure around the bacteria was formed during this infection. Nitrogenase activity could be detected only when the [O_2] was reduced below 1%, but a possible parasitic or saprophytic association under such conditions may deny use of the fixed N to the plant.

08. HYDROGEN AND HYDROGENASE

0801 Hydrogenase in *Rhizobium japonicum* increases nitrogen fixation by
2598 nodulated soybeans.
Albrecht, S.L. (Oregon State U, Corvallis, OR, USA), R.J. Maier, F.J. Hanus, S.A. Russell, D.W. Emerich and H.J. Evans.
Science 203(4386):1255-1257, 1979.

R. japonicum strains that synthesized the hydrogenase system fixed more nitrogen, and the soybeans they nodulated produced greater yields, than

those lacking the system. This characteristic, which permits recycling of hydrogen which may otherwise be lost, should be incorporated into the gene pool of rhizobial inocula to increase efficiency of the nitrogen fixing process.

0802 The effect of source-sink manipulations on nitrogen fixation in peas.
2230 Bethlenfalvay, G.J. (U California, Davis, CA, USA), S.S. Abu-Shakra, K. Fishbeck and D.A. Phillips.
Physiol Plant 43:31-34, 1978.

Nitrogen fixation and hydrogen evolution were significantly lower in partially defoliated plants and generally higher in depodded plants. Because the ratio of H_2 evolution to acetylene reduction remained proportional despite source-sink manipulation, the relative efficiency of nitrogen fixation in the source-sink manipulation treatments was not significantly different from the controls.

0803 Variation in nitrogenase and hydrogenase activity of Alaska pea root
2857 nodules.
Bethlenfalvay, G.J. (U California, Davis, CA, USA) and D.A. Phillips.
Plant Physiol 63(5):816-820, 1979.

Two of five *Rhizobium leguminosarum* strains tested possessed hydrogenase activity. Strains with the potential to reassimilate H_2 had significantly higher rates of N_2 fixation than those not exhibiting hydrogenase activity. This activity was lower in associations grown under higher photosynthetic photon flux densities, and decreased relative to total H_2 production by nitrogenase.

0804 Hydrogen evolution and uptake by nodules of soybeans inoculated with
2370 different strains of *Rhizobium japonicum*.
Carter, K.R. (Oregon St U, Corvallis, OR, USA), N.T. Jennings, [F.] J. Hanus, H.J. Evans.
Can J Micro 24(3):307-311, 1978.

Six of 32 strains exhibiting no H_2 evolution in air were shown to take up H_2. Nodules formed by strains which evolved hydrogen had relative efficiencies of 0.41 to 0.80 compared to a range of 0.96 to 1.0 for the non-hydrogen evolving strains. Studies will determine whether these relative efficiencies affect crop yields.

0805 Hydrogen-dependent nitrogenase activity and ATP formation in
2483 *Rhizobium japonicum* bacteroids.
Emerich, D.W. (Oregon St U, Corvallis, OR, USA), T. Ruiz-Argueso, T.M. Ching and H.J. Evans.
J Bact 137(1):153-160, 1979.

Evidence from effects of H_2 addition, succinate, and iodoacetate on acetylene reduction and ATP supply led to the conclusion that the hydrogen-oxidizing system in H_2 uptake positive bacteroids benefits the N_2-fixing process by providing respiratory protection to the O_2-labile nitrogenase proteins and by generating ATP through oxidation of H_2 from the nitrogenase system. It is uncertain whether H_2 serves as a reductant for nitrogenase in *R. japonicum* bacteroids.

0806 Autotrophic growth of H_2-uptake-positive strains of *Rhizobium*
2791 *japonicum* in an atmosphere supplied with hydrogen gas.
Hanus, F.J. (Oregon St U, Corvallis, OR, USA), R.J. Maier and H.J. Evans.
Proc Natl Acad Sci USA 76(4):1788-1792, 1979.

The Hup^+ strains were capable of producing the energy for the support of CO_2 fixation and growth through hydrogen oxidation via the Knallgas reaction. Omission of either H_2 or CO_2 in the gas phase over cultures prevented the accumulation of carbon in the culture.

0807 Determination of hydrogenase in free-living cultures of *Rhizobium*
2291 *japonicum* and energy efficiency of soybean nodules.
Lim, S.T. (U California, Davis, CA, USA).
Plant Physiol 62(4):609-611, 1978.

A rapid procedure for determining hydrogenase activity of free-living rhizobial cultures by means of the tritium exchange assay. Of 10 strains tested, 3 produced hydrogenase activity while the remaining 7 showed neither hydrogenase activity nor H_2 uptake in either cultures or nodules.

0808 Regulation of hydrogen utilization in *Rhizobium japonicum* by cyclic
2868 AMP.
Lim, S.T. (U California, Davis, CA. USA) and K.T. Shanmugam.
Biochim Biophys Acta 584(3):479-492, 1979.

Cyclic AMP was found to alleviate the inhibition of hydrogen uptake by mallate, suggesting the synthesis of a protein other than hydrogenase. In *R. japonicum*, cyclic AMP was shown to play a major role in the regulation of hydrogen metabolism.

0809 *Rhizobium japonicum* mutants unable to use hydrogen.
2387 Maier, R.J. (Oregon St U, Corvallis, OR, USA), J.R. Postgate and H.J. Evans.
Nature 276(5687):494-495, 1978.

To do comparative physiological and agronomic studies of rhizobia with hydrogen uptake capabilities and mutants lacking that capability, the isolation of such mutants was undertaken. A substrate on which hydrogenase formed toxic products was devised, and the desired mutants were cultured from surviving rhizobia. Further testing of these Hup^- mutants will proceed.

0810 Regulation of hydrogenase in *Rhizobium japonicum*.
2601 Maier, R.J. (Oregon St U, Corvallis, OR, USA), F.J. Hanus and H.J. Evans.
J Bact 137(2):824-829, 1979.

Incubation under a gas phase of 86.7% N_2, 8.3% N_2, 4.2% CO_2 and 0.8% O_2 yielded rapid rates of H_2 uptake. Further increase in hydrogenase activity ceased when H_2 was removed after initiation of hydrogenase derepression. No direct effect of CO_2 on hydrogenase activity was observed.

0811 Properties of the hydrogenase system in *Rhizobium japonicum*
2687 bacteroids.
McCrae, R.E. (Oregon St U, Corvallis, OR, USA), [F.] J Hanus and H.J. Evans.
Biochem Biophys Res Com 80(2):384-390, 1978.

Exposure of bacteroids to additional hydrogen increases oxygen uptake but decreases respiratory CO_2 production, indicating a conservation of endogenous substrates. Oxy-hydrogen reaction activity was consistently demonstrated by bacteroids that evolved little or no hydrogen, but not found in those evolving hydrogen.

0812 Activity of the H_2-oxidizing hydrogenase in different N_2-fixing
3053 bacteria.
Pinkwart, M. (U Gottingen, W Germany), H. Bahl, M. Reimer, D. Wolfle and H. Berndt.
FEMS Microbiol Ltrs 6(3):177-181, 1979.

Induction and derepression of hydrogenase in batch cultures or *Rhizobium japonicum* and in cultures of certain asymbiotic nitrogen fixing bacteria was reported. Hydrogenase expression in rhizobia appeared to be more sensitive to oxygen tension than in other bacteria.

0813 Hydrogen (H_2) evolution in rhizobia.
2497 Reporter, M. (C.F. Kettering Res Lab, Yellow Springs, OH, USA).
Plant Physiol 61(5):753-756, 1978.

Nitrogenase activity was expressed in liquid suspension cultures of *Rhizobium japonicum* separated from soybean plant cells by two or three bacterial membrane filters. Evolution of H_2 was influenced by oxygen concentrations, the quality of the conditioned plant cell medium, and the presence of ammonia. The lighter of two plant substance species lead to a higher proportion of acetylene reduction and less hydrogen formation.

0814 Hydrogen production and uptake by pea nodules as affected by strains
2157 of *Rhizobium leguminosarum*.
Ruiz-Argueso, T. (Oregon St U, Corvallis, OR, USA), [F.]J. Hanus and H.J. Evans.
Arch Microbiol 116(2):113-118, 1978.

To supress nitrogenase dependent H_2 evolution, intact pea nodules were exposed to a high O_2 concentration. Under these conditions, hydrogenase activity was demonstrated even in nodules that evolved large amounts of hydrogen in air. The capacity for hydrogen uptake was located in the bacteroids and was dependent on oxygen consumption.

0815 Characteristics of the H_2 oxidizing system in soybean nodule bacter-
2965 oids. Arch Microb 121(3):199-206, 1979.
Ruiz-Argueso, T. (Oregon St U, Corvallis, OR, USA), D.W. Emerich and H.J. Evans.

About 1 mol of hydrogen is evolved for each mol of nitrogen reduced in soybean nodules. A rhizobial strain possessing high H uptake capacity was identified, and, by oxidizing the hydrogen through its hydrogenase system functioned with little or no loss due to H_2 evolution

0816 2526 Hydrogenase system in legume nodules: a mechanism of providing nitrogenase with energy and protection from oxygen damage.
Ruiz-Argueso, T. (Oregon St U, Corvallis, OR, USA), D.W. Emerich and H.J. Evans.
Biochem Biophys Res Com 86(2):259-264, 1979.
Strains with a hydrogenase system were able to function at a higher pO_2 and had a higher rate of nitrogenase activity when H_2 was increased up to saturation.

0817 2691 Hydrogen evolution from alfalfa and clover nodules and hydrogen uptake by free-living *Rhizobium*.
Ruiz-Argueso, T. (Oregon St U, Corvallis, OR, USA), R.J. Maier and H.J. Evans.
Appl Envir Micro 37(3):582-587, 1979.
The mean loss of electron flow through nitrogenase due to evolved hydrogen was 25% for 19 *R. meliloti* strains and 35% for 7 strains of *R. trifolii*. These strains all lacked sufficient hydrogenase to recycle a substantial portion of the hydrogen evolved during nitrogen fixation, the lowest rate of energy loss being 17%.

0818 2034 Hydrogen reactions of nodulated leguminous plants. 1. Effect of rhizobial strain and plant age.
Schubert, K.R. (Oregon St U, Corvallis, OR, USA), J.A. Engelke, S.A. Russell and H.J. Evans.
Plant Physiol 60:651-654, 1977.
Relative efficiency values, based on rates of H_2 evolution and of C_2H_2 evolution, were calculated for 13 strains of "cowpea" *Rhizobium*. The values ranged from 0.70 to near unity. High relative efficiencies were correlated with the ability to recycle H_2 via hydrogenase. The role of the host plant in expression of hydrogenase activity was indicated but not fully investigated.

0819 2729 Hydrogen reactions of nodulated leguminous plants. II. Effects on dry matter accumulation and nitrogen fixation.
Schubert, K.R. (Oregon St U, Corvallis, OR, USA), N.T. Jennings and H.J. Evans.
Plant Physiol 61(3):398-401, 1978.
A soybean cultivar inoculated with USDA 31 evolved H_2 in air equivalent to 30% of the energy transferred to the nitrogenase system, while the same cv inoculated with USDA 110 produced nodules with an active hydrogenase and consequently did not evolve H_2 in air. Because of other possible variables, no cause-and-effect relationship between hydrogenase and plant yield or total nitrogen fixation has yet been proven.

0820 3063 Studies on hydrogenases in legume root nodule bacteroids: effect of ATP
Suzuki, T. (U Tokyo, Japan) and Y. Maruyama.
Agr Biol Chem 43(9):1833-1839, 1979.
Two fractions of hydrogenase from nodules of soybean and lupin showed

differential reaction to ATP - one was stimulated, the other either inhibited or not affected. Hydrogenase activity was measured by tritium uptake.

Certain references listed under Energetics also relate to hydrogen and the hydrogenase system.

09. INOCULANT PRODUCTION AND DISTRIBUTION

0901 A review of development of rhizobial inoculants for soybeans in
2249 India.
Balasundaram, V.R. (IARI, New Delhi, India) and N.S. Subba Rao.
Fert News 22(10):42-46, 1977.
Reviews the work done on isolating and testing soybean rhizobia in India, and the development of an indigenous inoculant supply service.

0902 Legume inoculants for Latin America.
2322 Batthyany, C. (Lab Dispert SA, Montevideo, Uruguay).
In Vincent, J.M. *et al* Exploiting the legume/*Rhizobium* symbiosis in tropical agriculture. U Hawaii Col Trop Agr 145, 1977 p. 429-439.
The South American continent has climates from near arctic to tropical, with mountain elevations of 5,000 to 6,000 meters. As of 1976, 7 meetings of Latin American legume bacteriologists had been held, and these continue every 2 years. Four international committees and projects were described in this report, followed by a country by country and regional summary of activities.

0903 Preparation of legume seed inoculants.
2936 Date, R.A. (Cunningham Lab, St. Lucia, Brisbane, Australia) and R.J. Roughley.
In Hardy, R.W.F. and A.H. Gibson, eds., A treatise on dinitrogen fixation, sec. IV. NY, Wiley, 1977, p. 243-275.
This review includes sections on strain selection criteria and methods; culturing inoculants; preparation and packaging of inoculants; factors affecting growth and survival of rhizobia in inoculants; quality control and production standards; and 110 references to literature covering various aspects of the above.

0904 The *Rhizobium* supply service in Papua New Guinea: July 1971-June 1974.
2309 Elmes, R.P.T. (Dept Agr Stock & Fisheries, Port Moresby, PNG).
PNG Dept Agr Stock & Fisheries Res Bul 13:61-73, 1974.
During the 3 year period, 3,371 bottles of inoculant were supplied to growers in Papua New Guinea and elsewhere. In 39.9% of the cases recorded, inoculation resulted in improved plant performance, but in 37.6% of the cases, uninoculated plants were as effectively nodulated as the treated plants. Demand for pasture and ground cover inoculants increased during the period.

0905 Reliability of commercial soybean inoculants in Georgia.
2878 Giddens, J. (College Exp Stn, Athens, GA, USA).
Georgia Agric Res 20(4):11-12, 1979.

Plate counts and greenhouse nodulation tests were performed on sample inoculants from seed stores throughout the state. Peat base inoculants were generally superior to clay base or other inoculants, and those containing molybdenum or fungicide were usually inferior.

0906 Performance of commercial soybean inoculants in Alabama.
2594 Hiltbold, A.E. (Auburn U, Auburn, Ala, USA) and D.L. Thurlow.
Highlights Agr Res, Ala Agr Res Stn 25(1):12, 1978.

Of 32 products tested, inoculants from Nitragin and Rudy-Patrick produced the most nodules. Inoculants from several producers were without effect.

0907 Problems in developing an inoculant capability.
2349 Persaud, H.B. (Ctr Agr Stn, Mon Repos, Guyana).
In Vincent, J.M. *et al*, Exploiting the legume/*Rhizobium* symbiosis in tropical agriculture, U Hawaii Col Trop Agr Misc Pub 145, 1977, p. 441-446.

The basic requirements for inoculant production include a research lab and transfer room, stainless steel fermenter of 200 to 1,200 liter capacity with appropriate aeration and agitation, a steam source for sterilization, and materials for culture media. Peat or a suitable carrier material must be available. The major constraints to development of an inoculant capability are the availability of financial and technical support.

0908 The relationship between the numbers of rhizobia in broth and the
2053 quality of peat-based legume inoculants.
Roughley, R.J. (Hort Res Stn, Gosford, N.S.W., Australia) and J.A. Thompson.
J Appl Bact 44:317-319, 1978.

Broth counts above 5 x 10^8 rhizobia/ml were found to be of little value in predicting the final number in sterilized or unsterilized peat cultures.

0909 Inoculants for India.
2351 Sahni, V.P. (Bactogin Labs, Jabalpur, India).
In Vincent, J.M. *et al*, Exploiting the legume/*Rhizobium* symbiosis in tropical agriculture, U Hawaii Col Trop Agr Misc Pub 145, 1977, p. 413-427.

Inoculants have been commercially used in India since 1934, but a systematic effort to build a country-wide inoculant supply potential goes back only about 15 years. Some 23 million hectares are under pulse crops in India, and this provides an important portion of the protein nutrition for the people of India. The soil harbors both efficient and inefficient rhizobial strains for the traditional crops, which makes the establishment of new strains difficult. A number of technical, economic and demographic barriers have impeded the spread of inoculant use in India.

0910 Isolation of rhizobia of rabi pulses from three districts of U.P.
2414 Sanoria, C.L. (Banares Hindu U, Varanasi, India).
J Sci Res, Banares Hindu U 28(1):107-108, 1978.
Efficient strains of *Cicer* rhizobia were isolated from local soils, and are under production as inoculants. Additional strains from gram, pea, lentil and khesari are being isolated and screened.

0911 Quality control of inoculants.
2353 Vincent, J.M. (U Sydney, Australia).
In Vincent, J.M. *et al*, Exploiting the legume/*Rhizobium* symbiosis in tropical agriculture. U Hawaii Coll Trop Agr Misc Pub 145, 1977, p. 447-456.
The requirements for a good inoculant are 1)the proper organism for the legume; 2) a strain selected and maintained so as to be effective with the specific legume; and 3) a sufficient number of young, active rhizobia for each seed. Examples of how these ends can be achieved were presented, and a model program described.

10. INOCULATION METHODS AND MATERIALS

1001 Studies on survival of *Rhizobium leguminosarum* in 2 carriers as
2263 affected by moisture and temperature conditions.
Bajpai, P.D. (C.S. Azad U Agr Tech, Kanpur, India), B.R. Gupta and B. Ram.
Ind J Agr Res 12(1):39-43, 1978.
For storage longer than two weeks, a mixture of farmyard manure and tank silt was equal to peaty soil as a carrier for *Rhizobium*. Storage periods longer than 12 weeks require maintenance at 20°C and about 40% moisture.

1002 Influence of *Rhizobium japonicum* strains and inoculation methods on
2194 soybeans grown in rhizobia-populated soil.
Boonkerd, N. (USDA, Beltsville, MD, USA), D.F. Weber and D.F. Bezdicek.
Agron J 70(4):547-549, 1978.
This study was conducted to determine if inoculant strains could nodulate soybeans in competition with indigenous rhizobia, leading to enhancement in nitrogen fixation. Various levels of inoculant in peat and in broth were applied, but nodulation and growth were not affected. The distribution of serogroups in the nodules was affected by heavy doses of broth, but not by peat inoculation.

1003 Recent developments in legume inoculation.
2539 Brockwell, J. (CSIRO, Canberra, Australia).
Austral Seed Rev 2(2):10-13, 1972.
The history of inoculation, from soil transfer in fields and the 1896 seed inoculation patent of Nobbe and Hiltner to present methods was briefly traced. Modern techniques described include granular inoculants, soil drenching and improved methods of seed coating.

1004 Studies on seed pelleting as an aid to legume seed inoculation. 4.
2540 Examination of preinoculated seed.
Brockwell, J. (CSIRO, Canberra, A.C.T., Australia), D.F. Herridge, R.J. Roughley, J.A. Thompson and R.R. Gault.
Austral J Exp Agr Anim Husb 15:780-787, 1975.
Consistently lower numbers of rhizobia on preinoculated seed compared to seed inoculated in the laboratory indicated that some stage or stages of the preinoculation process had a lethal effect on the bacteria. Preinoculation provided on average less than one-hundredth the number of rhizobia obtained with laboratory inoculation.

1005 Application of legume seed inoculants.
2656 Brockwell, J. (CSIRO, Canberra, Australia).
In Hardy, R.W.F. and A.H. Gibson (eds.) A treatise on dinitrogen fixation, sec. IV. NY, Wiley, 1977, p. 277-309.
This chapter offers a concise historical survey and review of the present state of knowledge on the need for and methods of inoculation, the problems and techniques for establishing soil populations of rhizobia, and assessment of the results of inoculation. There are 175 references.

1006 Inoculation, acetylene reduction and yield of faba beans as affected
2418 by inoculum concentration and soil nitrate level.
Dean, J.R. (U Manitoba, Winnipeg, Canada) and K.W. Clark.
Can J Plant Sci 57(4):1055-1061, 1977.
Acetylene reduction was 37% less in high nitrate soils than the minimum rate in low nitrate soil. In dry seedbeds, higher rates of powdered inoculum were required. Granular inoculants may overcome this problem. At one high nitrate location, yields decreased with inoculation, suggesting that more abundant nodules diverted carbohydrates from developing pods.

1007 Polyacrylamide-entrapped *Rhizobium* as an inoculant for legumes.
2790 Dommergues, Y.R. (ORSTOM, CNRS, Dakar, Senegal), H.G. Diem and C. Divies.
Appl Envir Micro 37(4):779-781, 1979.
Inoculant prepared with polyacrylamide gel, either wet or dried and ground, compared well with peat-based inoculant.

1008 Effect of inoculant formulation on survival of *Rhizobium trifolii*
3069 and the establishment of oversown white clover (*Trifolium repens*).
Hale, C.N. (DSIR, Auckland, NZ), W.L.Lowther and J.M. Lloyd.
NZ J Exp Agric 7(3):311-314, 1979.
Commercially prepared inoculant compounds were effective in improving the survival of rhizobia on white clover seed by reducing the effect of seed coat toxins.

1009 Coal compared to peat as a carrier of rhizobia.
2683 Halliday, J. (CIAT, Cali, Colombia) and P.H. Graham.
Turrialba 28(4):348-349, 1978.

After six months storage, inoculum on peat had 1.2 x 10^9 rhizobia/gram survival, but only 1 of 3 coals tested met the minimum standard of 10^6 rhizobia/gram. Due to the formation of hard lumps in storage, use of the milled coal was abandoned.

1010 2100 A note on *Rhizobium* inoculation of beans (*Phaseolus vulgaris*) using the fluid drill technique.
Hardaker, J.M. (Natl Veg Res Stn, Wellesbourne, Warwick, England) and R.C. Hardwick.
Exper Agric 14(1):17-21, 1978.

A slurry of germinating seeds and inoculum, applied with a fluid drill, produced a mean of 7.0 nodules per plant after 28 days, compared to 2.14 for dry-sown inoculated seeds (peat culture with 10% sucrose solution) and 0.64 nodules per plant for the uninoculated control. Dry conditions and low inoculum counts (approximately 760 *Rhizobium*/seed) for both treatments may have affected this experiment.

1011 2591 Legume inoculation by spraying suspensions of nodule bacteria into soil beneath seed.
Holy, F.W. (CSIRO, Canberra City, A.C.T., Australia), R.J. Hutchings and M. Zorin.
J Aust Inst Agric Sci 42(4):241-244, 1976.

A sowing machine, chisel seeder, and sodseeder were modified with adjustable nozzles, tank, pump and lines to place inoculum in suspension beneath the seed at a rate greater than possible with seed inoculation. The method offers advantages in certain problem situations.

1012 2746 Survival of *Rhizobium trifolii* (strain CIAT 61) in three carriers. (Spa)
Munevar, M.F.(Cent Exp Tibaitata, Bogota, Colombia) and P.H. Graham.
Rev Inst Colomb Agropec 12(3):225-230, 1977.

Rhizobia did not survive "cachaza" (sugar cane juice froth), possibly due to high acidity. Survival for 120 days at 28°C on coal was slightly better than on peat.

1013 5095 Survival of *Rhizobium japonicum* on coal-based legume inoculants.
Paczkowski, M.W. (N Dakota St U, Fargo, ND, USA) and D.L. Berryhill.
Appl Envir Micro 38(4):612-615, 1979.

Anthracite, bituminous and subbituminous coals and lignite, with a pH range of 4.7 to 7.5, were tested as carriers for inoculants. All except an Illinois bituminous (pH 5.0) and a Texas lignite (pH 4.7) supported the growth and survival of the 3 rhizobial strains tested. The other carriers were still acceptable after 12 months storage.

1014 1585 Carriers of rhizobia and the effects of prior treatment on the survival of rhizobia.
Strijdom, B.W. (Plant Protec Res Inst, Pretoria, S Africa) and C.C. Deschodt.
In Nutman, P.S., ed., Symbiotic nitrogen fixation. Int Biol Prog

Vol 7. Cambridge U Press, England, 1975, p. 151-168.
Peat inoculants have been consistently proven superior to liquid cultures over the years. No suitable synthetic carrier has found favor, despite numerous efforts to find one. Although sterilized peat offers advantages over unsterilized, no completely satisfactory method of sterilization has yet been found.

11. INOCULATION REQUIREMENTS AND EFFECTS

1101 Yield of alfalfa (Saranac cultivar) inoculated with very efficient
2901 strain of *Rhizobium meliloti* in presence of *Rhizobium* species. (Fre)
Antoun, H. (Agr Canada Rech Stn, St Foy, Quebec, Canada), L.M. Bordeleau and R.A. LaChance.
Can J Plant Sci 59(2):521-523, 1979.
Inoculation with an effective strain of *R. meliloti* alone and with 1 or more strains of 4 other *Rhizobium* species were evaluated for plant dry matter production. The presence of *R. phaseoli* had a negative effect on yield, but *R. japonicum*, *R. trifolii* and *R. leguminosarum* had a synergistic effect on the lucerne *Rhizobium*.

1102 Inoculation of tropical pasture legumes.
2336 Date, R.A. (CSIRO, Brisbane, Australia).
In Vincent, J.M., *et al*, Exploiting the legume/*Rhizobium* symbiosis in tropical agriculture. U Hawaii Col Trop Agr misc pub 145, 1977, p. 293-311.
About 40 genera of tropical pasture legumes were grouped according to their effectiveness with either a wide range or quite specific rhizobia. Those which nodulate with a number of strains but are effective with only a few were categorized as the most troublesome. A 3-treatment experiment for determining the need to inoculate, with a grid for interpreting results, was presented, along with criteria for strain selection. Additional information on inoculation, pelleting and the evaluation of nitrogen fixation was also provided.

1103 Soybean inoculation.
1882 Frederick, L.R. (USAID, Washington, DC, USA).
In Goodman, R.M., ed., Expanding the use of soybeans. U Illinois INTSOY ser 10, 1976, p. 44-45.
Because some soybean plants do not nodulate in the field and may require variety-specific rhizobia, the selection of compatible combinations of rhizobia and soybean varieties is important. To ensure good nodulation and survival, application of at least one million microorganisms per seed was recommended.

1104 Response of cowpea [*Vigna unguiculata* (L) Walp] to *Rhizobium*-VA
2273 mycorrhiza dual inoculation.
Godse, D.B. (U Agr Sci, Bangalore, India), S.P. Wani, R.B. Patil and D.J. Bagyaraj.
Current Sci (India) 47(20):784-785, 1978.

Dual inoculation increased nodulation and produced plants with better root and shoot development. The mycorrhizal plants presumably benefited from increased P uptake.

1105 Inoculation and nitrogen fixation in the genus *Phaseolus*.
2340 Graham, P.H. (CIAT, Cali, Colombia) and J. Halliday.
In Vincent, J.M., *et al*, Exploiting the legume/*Rhizobium* symbiosis in tropical agriculture. U Hawaii Col Trop Agr misc pub 145, 1977, p. 313-334.

Only a small percentage of *P. vulgaris* seed is inoculated, and often with limited success, but significant yield increases have been obtained under certain conditions. Beans are grown in a wide range of temperature situations, and their symbiotic effectiveness is very susceptible to temperature effects. Special methodologies and studies are needed to cope with the special problems associated with nodulation and nitrogen fixation in beans.

1106 Field responses by tropical forage legumes to inoculation by
2613 *Rhizobium*.
Halliday, J. (CIAT, Cali, Colombia).
In Sanchez, P.A. and L.E. Tergas (eds.) Pasture production in field soils of the tropics.
CIAT Beef Prog, Cali, Colombia, 1979, p. 123-137.

Rhizobium strains from the CIAT collection are first assessed for host compatibility, then for N fixing ability under optimal conditions. Those with greatest potential are tested under acid stress in pot culture, and selected strains then field tested. Field responses to inoculation were achieved with a majority of the 14 forage legumes tested. Pelleting with lime was advantageous with some species. Whether the introduced rhizobia can survive for long-term benefit is under investigation.

1107 Soybean inoculation trials.
2573 Ham, G.E. (U Minnesota, St. Paul, MN, USA), W.C. Lindemann, C.K. Kvien and G.W. Randall.
Soil Ser Minn U Agr Ext Serv 103:153-154, 1978.

Neither coating of seeds with inoculant nor application of granular inoculants caused a significant increase of yield in fields where soybeans had been previously grown.

1108 Planning an international network of legume inoculation trials: the
3051 proceedings of a workshop, Kahului, Hawaii, January, 1979.
Harris, S.C. (U Hawaii NifTAL Proj, Paia, HI, USA).
U Hawaii - USAID NifTAL Proj, 1979, 241 p.

This publication records the two plenary sessions (12 papers) and the issue papers, discussions and summary of conclusions from 6 working sessions during which the need for such a network was affirmed and strategies for achieving its goals were arrived at by the 29 workshop participants . Designs for 3 levels of experiments, and procedures for implementing the network, were produced by two task groups.

1109 Inoculation of soybeans.
2342 Jardim Freire, J.R. (U Fed Rio Grande, Porto Alegre, Brasil). *In* Vincent, J.M. *et al*, Exploiting the legume/*Rhizobium* symbiosis in tropical agriculture. U Hawaii Col Trop Agr misc pub 145, 1977, p. 335-379.

Efforts to establish soil populations of selected strains of rhizobia through inoculation were studied, and the many factors limiting their success discussed. Research priorities and strategies include: the need for standardization of tests and selection procedures; additional research on the interrelationship of environmental factors and nitrogen fixation, on the composition and performance of inoculants, and on the problem of introducing new strains into old producing areas.

1110 Role of inoculation in establishing subclover on California annual
2504 grasslands.
Jones, M.B. (U California Hopland Fld Stn, Hopland, CA, USA), J.C. Burton and C.E. Vaughn.
Agron J 70:1081-1085, 1978.

Carefully selected strains applied at a high rate in peat inoculum with 40% gum arabic solution as a sticker, and with lime coating, gave good results. To evaluate competitiveness and persistence, *Rhizobium* strains should be tested at least 2 years.

1111 Symbiotic response of *Glycine max* (L.) Merrill to inoculation with
2111 different commercial inoculants of *Rhizobium japonicum* from agricultural institutions.
Kumar Rao, J.V.D.K. (U Agr Sci, Hebbal, Bangalore, India) and R.B. Patil.
Mysore J Agric Sci 11:342-344, 1977.

Inoculants from 5 commercial producers were compared on Davis soybeans. An IARI culture gave the best results.

1112 Effect of strains of *Rhizobium trifolii* on the establishment of
2280 oversown white clover *(Trifolium repens)*.
Lowther, W.L. (Invermay Agr Res Ctr, Mosgiel, NZ) and P. Johnstone.
Soil Biol Biochem 10:293-295, 1978.

Particular strains had an effect on the numbers of seedlings established, but not on the dry matter production per seedling. Whether the advantage derives from greater survival, nodulating ability, or some other factor will require further investigation.

1113 Comparative performance of different isolates from gram (*Cicer*
2557 *arietinum* L.) *Rhizobium* in pot culture and field experiment.
Medhane, M.S. (Coll Agric, Poona, India) and P.L. Patil.
Pesticides 8(3):48-49, 1974.

Gram yield was increased 24 to 62% by inoculation with various strains of rhizobia, but no particular strain was identified as superior.

1114 The effect of mixtures of *Rhizobium* strains on the dry matter pro-
2001 duction of white clover grown in agar.

Mytton, L.R. (Welsh Plant Breeding Stn, Aberystwyth, Wales) and J. de Felice.
Ann Appl Biol 87(1):83-93, 1977.
Uninoculated plants, with and without N, and plants inoculated with single and mixed strains were evaluated. Competitiveness and effectiveness were not absolutely linked but were found to be under separate genetic control. Furthermore, these characters are essentially joint properties of the specific plant-*Rhizobium* association.

1115 Response of soybeans to commercial soil-applied inoculants.
2717 Nelson, D.W. (Purdue U, Lafayette, IN, USA), M.L. Swearingin and L.S. Beckham.
Agron J 70(3):517-518, 1978.
No yield responses or increase in nodule mass per plant resulted from either soil inoculants of seed-applied inoculants. The test field had not been cropped to soybeans for more than 15 years.

1116 Inoculation of soyabeans (*Glycine max*) in Israel with *Rhizobium*
2963 *japonicum*.
Okon, Y. (Hebrew U, Jerusalem, Israel), M. Volfovitch, Y. Henis and M.J. Pinthus.
Exp Agric 15(3):267-272, 1979.
In soils lacking a natural population of soybean rhizobia, 100% nodulation was achieved by either the slurry method, granular inoculant spread with seeds, or by spraying a bacterial suspension into the furrow. Pelleting was less effective. Survival after one year was much better in heavy soil than in sandy soil.

1117 Soybean inoculation research.
2727 Rabb, J.L. (Red River Valley Exp Stn, Bossier City, LA, USA), L.D. Willis, Jr. and E.P. Dunigan.
Ann Res Rept Red River Val Exp Stn La, 1977, p. 121-123.
Peat-based, oil-based, clay-based, granular and frozen inoculants were tested for four years. None of the treatments caused significant increases in nodule number or weight, nor in the rate of nitrogen fixation.

1118 Different responses of *Rhizobium* strains of Bengal gram (*Cicer*
2753 *arietinum* L.) grain yield.
Rai, R. (Agric Res Inst, Dholi, Bihar, India), S.N. Singh, M.D.Murtuza.
Curr Sci 46(6):572-573, 1977.
Response to 8 selected strains was tested in field experiments. Yield increase over control ranged from 13.9 to 39.8%. There was no correlation between yield and number or dry weight of nodules.

1119 Interaction between chick peas (*Cicer arietinum* Linn.) genotypes and
2796 strains of *Rhizobium* sp.
Rai, R. (Rajendra Agr Res Inst, Bihar, India) and S.N. Singh.
J Agr Sci 92:437-441, 1979.
Inoculation led to a significant increase in grain yield, and significant

strain/genotype interactions were recorded. The plant genotype giving the highest yield also exhibited maximum leghemoglobin and amino acid content in the nodules.

1120 2909 Some characteristics of biological nitrogen fixation, yield, protein and oil accumulation in irrigated peanuts (*Arachis hypogaea* L.).
Ratner, E.I. (Agr Res Org Volcani Ctr, Bet Dagan, Israel), R. Lobel, H. Feldhay and A. Hartzook.
Plant Soil 51(3):373-386, 1979.

Under optimal conditions, peanuts fixed 222 kg N2/ha, or 58% of total N accumulated in the plants. Exceptionally hot and dry weather drastically reduced nitrogenase activity. Maximum nitrogenase activity was observed during podfilling, and was very low until 50-60 days after planting.

1121 0390 Note on effect of *Rhizobium japonicum* inoculation on cowpea, groundnut and green gram.
Sahu, S. (Orissa U Agr Tech, Bhubanswar, INDIA) and B. Behera.
Ind J Agron 17(4):359-360, 1972.

Grain yields increased significantly due to inoculation and application of phosphate. The soil nitrogen was increased by a magnitude of 30, 18 and 18 by cowpea, groundnut and green gram respectively. Inoculation and P increased those values by 58, 29 and 26% respectively.

1122 3144 Studies on the effect of different rhizobial strains of *Phaseolus calcaratus* Roxb. in sand culture.
Saono, S. (Natl Biol Inst, Bogor, Indonesia) and H. Karsono.
Ann Bogor 6:143-154, 1977.

Of 90 rhizobial strains tested, 75 nodulated rice bean, and 44 significantly affected whole plant growth. Inoculation had a greater effect on below ground than above ground growth. The results imply that any strain with a symbiotic capacity value ≥ 0.33 is almost certain to be effective, while an Sc value <0.33 is almost certain to indicate ineffectiveness.

1123 2147 Response of lentil to *Rhizobium* inoculation and N.
Sekhon, H.S. (Punjab Agr U, Ludhaina, India), J.N. Kaul and B.S. Dahiya.
J Agr Sci 90(2):325-327, 1978.

Inoculation with a superior strain gave the same yield as application of 25 kg N/ha, but the highest yield was from combined inoculation and 20 kg N/ha on both loamy-sand and sandy-loam soil.

1124 2199 Effects of *Rhizobium* and nitrogen fertilizer on nitrogen fixation and growth of field peas.
Sosulski, F. (U Saskatchewan, Saskatoon, Sask., Canada) and J.A. Buchan.
Can J Plant Sci 58(2):553-556, 1978.

Inoculation failed to increase yields or N content of Century field peas, but application of fertilizer at seeding (106 kg N/ha) markedly increased forage and seed yield and raised protein content.

12. LEGHEMOGLOBIN

1201 Control of leghemoglobin synthesis in snake beans.
2498 Broughton, W.J. (U Western Australia, Nedlands, WA, Australia) and M.J. Dilworth.
Biochem J 125:1075-1080, 1971.

Preparations of Lb from nodules produced by 2 strains of rhizobia with large genetic differences showed no difference under electrophoresis, isoelectric focusing or ion exchange chromatography. Comparative and individual examination of the leghemoglobin from the 2 strains supported the hypothesis that the RNA for leghemoglobin is transcribed from plant DNA.

1202 CO and O_2 complexes of soybean leghemoglobins: pH effects upon
2818 infrared and visible spectra. Comparisons of CO and O_2 complexes of myoglobin and hemoglobin.
Fuchsman, W.H. (Oberlin Coll, Oberlin, OH, USA) and C.A. Appleby.
Biochem 18:1309-1321, 1979.

These data were consistent with a model in which protonation of the distal histidine permits protein-free heme FeCo geometry in leghemoglobin-CO complexes but not in CO complexes of myoglobin or hemoglobin. Small structural differences in the region between E and F helixes of leghemoglobins a and a_1 compared to a_2 were also suggested.

1203 Separation and determination of the relative concentrations of the
3017 homogenous components of soybean leghemoglobin by isoelectric focusing.
Fuchsman, W.H. (Oberlin Coll, Oberlin, OH, USA) and C.A. Appleby.
Biochim Biophys Acta 579(2):314-324, 1979.

Separation of the components by flat bed isoelectric focusing, either with or without the aid of nicotinate, was sufficiently sensitive for analytical experiments on leghemoglobin from single nodules. Changes in the relative content of the various components were traced from early nodulation to maturity, and were attributed to changes in relative rates of biosynthesis.

1204 Isolation and *in vitro* translation of leghemoglobin mRNA from yellow
2821 lupin root nodules.
Konieczny, A. (U Agr, Inst Biochem, Poznan, Poland) and A.B. Legocki.
Acta Biochem Pol 25(4):379-390, 1978.

Messenger RNA for leghemoglobin, extracted from polysomes, was purified by chromatography and sucrose gradient centrifugation, then used to synthesize a product identical to authentic leghemoglobin.

1205 Study of the affinity of lupine leghemoglobin for ligands. Influence
2893 of pH and nature of the buffer.
Krasnobaeva, K.A. (K.A. Tamiryazev Plant Physiol Inst, Moscow, USSR) and B.P. Atanasov.
Mol Biol 12(6):952-957, 1978.

The affinity for a number of ligands was pH dependent. Leghemoglobin was shown to have a greater conformational lability than other heme proteins.

Qualitative differences between the leghemoglobin of lupine and soybean were shown.

1206 Sensitive fluorometric assay for leghemoglobin.
2533 LaRue, T.A. (Prairie Reg Lab, Saskatoon, Sask., Canada) and J.J. Child.
Analyt Biochem 92(1):11-15, 1979.
An assay based upon the action of heated oxalic acid on hemeproteins detected 200 ng of hemoglobin/ml and was sufficiently specific to permit estimation from either single nodules or extracts of whole roots. The technique showed a more consistent correlation with nitrogenase activity than is shown by standard colorimetric assays.

1207 The amino acid sequence of leghemoglobin component *a* from *Phaseolus*
2575 *vulgaris*.
Lehtovaara, P. (U Helsinki, Finland) and N. Ellfolk.
Eur J Biochem 54(2):577-584, 1975.
The bean globin had 79% identity with soybean globin and 21% identity with the human hemoglobin γ-chain. A penultimate tyrosine, not found in the soybean or invertibrate globins studied so far, is invariably found in vertebrates and was present in kidney bean leghemoglohin. The findings were consistent with the supposition of a common ancestry for plant leghemoglobins and animal globins.

1208 Oxygen capacity of leghemoglobin in leguminous plants.
2679 Livanova, G.I. (K.A. Tamiryazev Inst., Moscow, USSR), G. Ya. Zhiznevskaya and E.A. Mishurov.
Biol Bull Acad Sci URRS 1(1):57-62, 1974.
Tha magnitude of oxygen capacity changed in ontogenesis, with the maximum occurring within the budding-flowering phase. The oxygen capacity was lower by a factor of 20 in ineffective strains.

1209 Electron-paramagnetic-resonance studies of leghemoglobin from soya
2030 bean and cowpea root nodules. Identification of nitrosyl-leghemoglobin in crude leghemoglobin preparations.
Maskall, C.S. (Rothamsted Exp Stn, Harpenden, Herts., England), J.F. Gibson and P.J. Dart.
Biochem J 167(2):435-445, 1977.
The electron paramagnetic resonance (e.p.r.) spectra of the fluoride, azide, hydroxide and cyanide complexes of the leghemoglobin of soybean and cowpea nodules were very similar to those of the corresponding myoglobin derivatives. The presence, possible origin, and effects of nitrosyl-leghemoglobin were discussed.

1210 Isoelectric focusing in the study of lupin nodule leghemoglobin.
2740 Melik-Sarkisyan, S.S. (A.N. Bakh Inst, Moscow, USSR), N.F. Bashirova, L.P. Vladzievskaya, G.P. Karpilenko and V.L. Kretovich.
Biol Bull Acad Sci USSR 2(6):788-794, 1975 (Eng tr 1976).
Two major and 3 minor components of high-spin Lb, and 5 components of the

low-spin Lb derivatives cyanferri-Lb and oxy-Lb, were fractionated by isoelectric focusing. The fractions were characterized spectrally and by isoelectric point. Results obtained, and the results in the literature, suggest that legume Lb's investigated up to this study are acidic proteins, whereas the Hb and Mb of vertebrates are generally neutral.

1211 Enzymatic reduction of legoglobin.
2741 Melik-Sarkisyan, S.S. (A.N. Bakh Inst, Moscow, USSR), N.F. Bashirova, N.O. Zauralova and V.L. Kretovich.
Biochemistry (NY) 41(7, pt 2):1085-1087, 1976 (Eng tr 1977).
Oxylegoglobin is known to stimulate the nitrogen-fixing activity of isolated bacteroids. In this study, the stimulation was also observed in the presence of oxidized forms of myoglobin and legoglobin incapable of binding oxygen. It was suggested that the bacteroids secrete a reductase-type enzyme which reduces ferri-Lb. This ferri-Lb reductase would serve the role of maintaining the Lb in nodule cells in a reduced state.

1212 Biochemical evidence that leghemoglobin genes are present in the
2730 soybean but not in *Rhizobium* genome.
Sidloi-Lumbroso, R. (Jewish Gen Hosp, Montreal, Que, Canada), L. Kleiman and H. Schulman.
Nature 273(5663):558-560, 1978.
Biochemical proof of the location of the Lb genes has been lacking because it has not been possible to detect Lb in legume tissues in the absence of *Rhizobium*. Hybridization of DNA complementary to Lb with soybean but not with *Rhizobium* DNA was reported in this paper.

1213 Spin state equilibria in soybean ferric leghemoglobin and its
2899 complexes with formate and acetate.
Trewhella, J.(U Sydney, N.S.W, Australia), P.E. Wright and C.A. Appleby.
Biochem Biophys Res Com 88(2):713-721, 1979.
In the presence of fluoride or acetate, leghemoglobin is locked into a high spin ferric conformation, while the formate complex has an equilibrium mixture of high and low spin states. Both formate and acetate ligate directly to the iron.

1214 Molecular basis for proton-dependent anion binding by soybean
2897 leghemoglobin *a*.
Trewhella, J. (U Sydney, N.S.W., Australia), P.E. Wright and C.A. Appleby.
Nature 280(5717):87-88, 1979.
Nuclear magnetic resonance studies of the nicotinate complex of soybean ferric leghemoglobin *a* were the basis for a proposed role for a haem propionic acid group as a mediator of anion binding. When deprotonated, the group functions as an electrostatic 'gate' which restricts the access of anions to the haem pocket.

1215 Leghemoglobin synthesis in soybean root nodules. Characterization
2528 of the nascent and released peptides and the relative rate of synthesis of the major leghemoglobins.
Verma, D.P.S. (McGill U, Montreal, Quebec, Canada), S. Ball, C. Guerin and L. Wanamaker.
Biochem 18(3):476-483, 1979.

The major forms and components of leghemoglobin, and their relative proportions during nodule formation and maturation, were studied. It was concluded that Lb remains in the host-cell cytoplasm after translation, and does not cross the membrane envelope enclosing the bacteroids. Although the presence of Lb sequences in soybean genome has been demonstrated, expression of those genes appears to be controlled by *Rhizobium*.

1216 Determination of the blocked N-terminal of soybean leghemoglobin *b*.
2982 Whittaker, R.G. (U New S Wales, Kensington, NSW, Australia), B.A. Moss and C.A. Appleby.
Biochem Biophys Res Comm 89(2):552-558, 1979.

In a comparison of soybean leghemoglobins *a* and *b* by microscale peptide mapping, the maps generated by trypsin alone or trypsin and thermolysin indicated general homology, with the only variation detected being N-terminal peptides. Lb *b* was blocked at the N-terminal and lacked the first amino acid of the corresponding Lb *a* peptide. The evidence indicated that Lb *a* is the precursor of Lb *b*.

1217 Leghemoglobin in legume nodules.
2788 Zhiznevskaya, G. Ya. (K.A. Tamiryazev Plant Physiol Inst, Moscow, USSR).
Biol Bull Acad Sci USSR 3(3):324-334, 1976 (Eng tr 1977).

A review of current views on the structure and function of Lb, with 74 references to contemporary work. Although the tertiary structure of Lb is similar to that of the myoglobin and hemoglobin of vertebrates, there are significant differences in the amino acid sequence. Other oxygen-transporting carriers have been experimentally substituted for leghemoglobin, and the level of nitrogen fixation in the bacteroids fell only if the O_2 affinity of the particular carrier was higher or lower than that of leghemoglobin.

13. LEGUMES: AGRONOMY AND EVALUATION

1301 Experience with dry-land pasture legumes in Northern Mashonaland.
2151 Carew, G.W. (Prov Conserv Exten Office, Salisbury, Rhodesia).
Rhodesia Agr J 75(1):1-4, 1978.

Trials of from 12 to 16 species at six sites led to the recommendation that siratro and silver leaf desmodium be sown for veld improvement, and that green leaf desmodium, Cooper glycine and Archer (*Macrotyloma axillare*) be used under certain pasture conditions. Information on planting and management was included.

1302 Field problems of beans in Latin America.
2524 Centro Internacional de Agricultura Tropical (Cali, Colombia).
CIAT Ser GE-19, 1978, 136 p.

Despite their importance in the diet of Latin Americans, beans provide average yields less than one-sixth their potential. This booklet, designed for use by scientists and farmers, includes sections on plant diseases and pests, nutritional disorders, and miscellaneous production problems. Color photographs aid in the identification of particular pests and disorders, and control measures offer suggestions for their solution. Inoculation is mentioned as a control measure for N dificiency, but nodulation problems are not covered.

1303 Establishment of pasture legumes in North Hill Island hill country.
2105 I. Buried seed populations.
Charlton, J.F.L. (DSIR, Palmerston N, NZ).
NZ J Exp Agric 5:211-214, 1977.

Studies of legume seeds buried in the upper layers of soil showed a similarity between plant populations and seed distribution, with exceptions probably due to seeds deposited in animal droppings. In some areas, herbicides may be used to increase the legume content of pastures without the need to oversow.

1304 Establishment of pasture legumes in North Hill Island hill country.
2149 II. Seedling establishment and plant survival.
Charlton, J.F.L. (DSIR, Palmerston N, NZ).
NZ J Exp Agric 5:385-390, 1977.

Establishment at 4 months was 7.6% legumes from aerially sown seed, and 7.9% legumes in another test plot from hand-sown seed. Effects of sowing time, climatic conditions, site characteristics and other variables were discussed.

1305 Evaluation of legume mixtures for hay planting.
2702 Cooper, C.S. (USDA, Bozeman, MT, USA).
Agron J 71(1):81-83, 1979.

Highest yield was from a sainfoin-birdsfoot trefoil mixture. These species are non-bloating and are excellent for stockpiling of hay.

1306 Legumes in the semi-arid tropics.
2325 Dart, P.J. (ICRISAT, Hyderabad, India) and B.A. Krantz.
In Vincent, J.M. *et al*, Exploiting the legume/*Rhizobium* symbiosis in tropical agriculture. U Hawaii Col Trop Agric misc pub 145, 1977, p. 119-154.

More than 95% of the annual rainfall in the SAT occurs during a 4 to 7 month rainy season. Such areas occur in 48 countrues with a total area of 19.6 million km^2 and a population of over a half billion, mostly from India. Pulse yields could be readily doubled by good management in the SAT, but production has actually declined. Principal legume crops are chickpea, groundnut, pigeon pea and cowpeas. Cropping patterns and management practices to increase pulse yields for dietary improvement were detailed.

1307 Legumes -- past, present and future.
2293 Delwiche, C.C. (U California, Davis, CA, USA).
BioScience 28(9):565-570, 1978.
There are about 600 genera and 13,000 species of legumes, constituting the second largest family of plants. The agricultural future of legumes as contributors of nitrogen and as a protein source, particularly as related to energy supplies and expansion of agricultural lands, was discussed. A table lists origins, uses, areas of cultivation and agronomic comments for 18 economically important legumes.

1308 The flowering of annual pasture species and cultivars in Western
2106 Australia.
Devitt, A.C. (Dept Agr, S Perth, W.A., Australia), B.J. Quinlivan and C.M. Francis.
Aust J Exper Agr Anim Husb 18:75-80, 1978.
Major differences in time of flowering between species, sites and planting dates were found. Temperature was the most influencing variable.

1309 Importance of legumes and their contribution to tropical agriculture.
2085 Döbereiner, J. (EMBRAPA, RJ, Brasil) and A.B. Campelo.
In Hardy, R.W.F., ed., A treatise on dinitrogen fixation, sec IV.
NY, Wiley, 1977, p. 191-220.
The substitution of biologically fixed nitrogen for manufactured nitrogen fertilizer should be given high priority, particularly for tropical areas where land is available and N demand high. With some attention to mineral nutrition, management practices and the selection of appropriate legumes and their rhizobia, substantial increases in protein production could be achieved.

1310 Comparison of Brazilian and naturalized Australian ecotypes of
2541 *Stylosanthes humilis* in the dry tropics of Queensland.
Edye, L.A. (CSIRO Davies Lab, Townsville, Qld., Australia) and D.F. Cameron.
Aust J Exper Agr Anim Husb 15:80-87, 1975.
In trials conducted at two sites over a three year period, none of the nine Brazilian introductions were superior to cv. Gordon in dry matter and pod yield, but the Australian material gave lower *in vitro* digestibility during the dry season than did the introductions. Variations in flowering time and growth habit affected productivity of the Brazilian introductions.

1311 Comparison of some *Stylosanthes* species in the dry tropics of
2542 Queensland.
Edye, L.A. (CSIRO Davies Lab, Townsville, Qld., Australia) and D.F. Cameron.
Aust J Exper Age Anim Husb 15:655-662, 1975.
Stylosanthes hamata cv. Verano was superior in dry matter yield at all sites, but nodulation problems prevented an adequate comparison. *S. humilis* cultivars showed better perennation over the 3 year trial.

1312 Release of soybean genotype UCD-1.
2669 Edie, S.A. (U California, Davis, CA, USA), S.S. Abu-Shakra, D.A. Phillips, R.C. Huffaker and B.H. Beard.
Agron Prog Rept Agr Exp Stn, U Calif, Davis, 1979.
The genotype of this release maintained photosynthetically active leaves and apparently continued nitrogen fixation in the root nodules beyond the stage of seed maturation.

1313 The contribution of symbiotic nitrogen fixation to the nitrogen
2968 economy of natural ecosystems. I. Occurrence of herbaceous legumes in derived savanna fallow and their nodulation in pot culture.
Ezedinma, F.O.C. (U Nigeria, Nsukka, Nigeria), N.N. Agbim and S.S.C. Onyekwelu.
Plant Soil 51(4):503-513, 1978.
In a highly disturbed ecosystem, 44 species of wild herbaceous legumes belonging to 12 genera were collected from 7 locations representing different geomorphological soil formations in Anambra State of Nigeria. All 19 of the species tested in the greenhouse formed nodules. The potential value of herbaceous legumes to the nitrogen economy of savanna fallow was discussed.

1314 Some problems and potentials of field beans (*Phaseolus vulgaris* L.)
2931 in Latin America.
Graham, P.H. (CIAT, Cali, Colombia).
Field Crops Res 1:295-317, 1979.
A discussion of the major constraints to increased bean yields, with suggested strategies for overcoming them. The potential for improved nitrogen fixation was found mainly in climbing cultivars with relatively long growth cycles. Enhanced N fixation is one of the criteria in a suggested sequence for germplasm selection. 165 references.

1315 Nodule development and nitrogen fixation in cultivars of *Phaseolus*
2101 *vulgaris* L. as influenced by planting density.
Graham, P.H. (CIAT, Cali, Colombia) and J.C. Rosas.
J Agric Sci 90(1):19-29, 1978.
Climbing cultivar P 590 fixed 15.1 μM C_2H_4 at 8.5 plants/m^2, declining to 4.2 μM at a density of 41.5 plants. Acetylene reduction remained high at both densities with the prostrate cv P498. Spacing did not prolong N fixing activity in the prostrate cultivars, but P590 showed appreciable nodule development between the 39th and 69th days of growth, with continued high fixation rates.

1316 Influence of intra-row spacing and cutting regimes on the growth
2451 and yield of *Leucaena*.
Guevarra, A.B. (U Hawaii NifTAL Proj, Paia, HI, USA), A.S. Whitney and J.R. Thompson.
Agron J 70(6):1033-1037, 1978.
Three harvest frequencies, 3 population densities and two plant types

were compared. Percentage forage fraction was highest under frequent cutting and higher plant density. The recommended management practice was a density of 15 x 50 cm and a 3 month cutting frequency. Hawaiian type K341 *L. leucocephala* yielded the most forage.

1317 The influence of storage conditions on bean seed quality.
3011 Harty, R.L. (Standards Branch, Qld., Australia).
Qld Agric J 103(6):534-535, 1977.

During storage, bean seeds tend to equilibrate to a constant moisture content value at a particular temperature. Estimated maximum safe seed moisture content for open storage for 1 year was 11% at 27°C. Sealed storage should be combined with low initial seed moisture content.

1318 Yield potential for tropical pasture legumes.
2341 Jones, R.J. (CSIRO, Queensland, Australia).
In Vincent, J.M. *et al,* Exploiting the legume/*Rhizobium* symbiosis in tropical agriculture. U Hawaii Col Trop Agr misc puh 145, 1977, p. 39-65.

Pasture legumes, usually not re-sown annually and grown in association with other species, must be assessed in terms of animal production. In addition to these special considerations, they must also be related to particular environmental and soil factors. The difficulty, or impossibility, of improving production by inoculation was pointed out, along with the need for field evaluation of *Rhizobium* strains. Data on grass and legume yields for evaluating the productive efficiency of land use were provided and related to the need for appropriate management.

1319 Crops of the West African semi-arid tropics.
2983 Kassam, A.H. (ICRISAT, Hyderabad, India).
Int Crops Res Inst Semi-Arid Trop, Begumpet, Hyderabad, India, 1976, 154 p.

A review of practical information on 23 crops grown in the area, in which Part II, pages 37-50, is on legumes (cowpea, groundnut and soya bean). For each crop there is a brief introductory paragraph on the history and economic importance, then sections on ecology, cultivation, pests, and special problems associated with storage. A table lists 24 categories of agronomic information for 4 cultivars of groundnut.

1320 Selecting and breeding legumes for enhanced nitrogen fixation.
2974 Recommendations for research, and proceedings of a workshop, October 23-24, 1978.
LaRue, T.A. (ed.)(Boyce Thompson Inst., Ithaca, NY, USA).
Boyce Thompson Inst at Cornell U, 1978, 18 + 5 p.

This document contains a summary of reports on various aspects of enhancement, measurement and evaluation of symbiotic nitrogen fixation. Research recommendations call for multi-disciplinary approaches to breeding, genetic improvement, host specificity, plant physiology studies for identification of useful traits, and assay techniques to aid in maximizing symbiotic benefits.

1321 Guide for field crops in the tropics and subtropics.
1542 Litzenberger, S.C., ed. (USAID, Washington, DC, USA).
Office of Agric, USAID, Washington, DC, 1974, 321 p.
A guide designed for the non-specialist, with chapters on the following legumes: field beans, cowpeas, chickpeas, lentils, broadbeans, mungbeans, pigeon peas, field peas, groundnuts, soybeans and several "secondary" food legumes. Each section includes a brief description of the crop, its agronomic characteristics, nutritional value and uses. There is rather detailed information on the cultivation, harvesting and storage of most crops listed.

1322 Influence of slope position on nitrogen fixation and yield of dry
2809 peas.
Mahler, R.L. (N Carolina St U, Raleigh, NC, USA), D.F. Bezdicek and R.E. Witters.
Agron J 71(2):348-351, 1979.
Higher yield and greater nitrogen fixation recorded for peas growing on the bottom slope were apparently related to greater root penetration and water uptake rather than the efficiency of the particular microsymbiont.

1323 Substitution value of birdsfoot trefoil for alfalfa-grass in pasture
2701 systems.
Marten, G.C. (U Minnesota, St. Paul, MN, USA) and R.M. Jordan.
Agron J 71(1):55-59, 1979.
The substitution in one third of the pasture produced 22-24% increase in average daily gains of lambs over a 3 year period. Although the trefoil system had a lower carrying capacity, overall per hectare productivity was increased and overhead costs reduced.

1324 Le pois carre: *Psophocarpus*, une plante riche en proteines pour les
2871 tropiques. (Fre)
Mertens, C., J. Paulus and A. Schmitz.
Fond U Luxembourgeoise, ser "Documents", Arlon, Belgium, 1979, 33 p.
The winged bean is of great potential value in overcoming dietary protein deficiencies, but more research is needed so that wider use can be promoted. Unlike most food legumes, the root, fibers, grain and leaves are all edible and rich in protein.

1325 Research needs in protein resources.
2344 Milner, M. (Mass Inst Technol, Cambridge, MA, USA), N.S. Scrimshaw and D.I.C. Wang.
In Vincent, J.M. *et al*, Exploiting the legume/*Rhizobium* symbiosis in tropical agriculture. U Hawaii Col Trop Agr misc pub 145, 1977, p. 1-20.
A study of protein resources for the U.S. National Academy of Sciences identified research needs in human nutrition and the nutritional potential of foods; toxicology of foods, including legumes; innovative technology for protein utilization; genetic improvement of protein quality and productivity; and enhancement of biological nitrogen fixation. The need to consider both the host and rhizobial strain was emphasized.

1326 The role of legumes in south and southeast Asia.
2345 Moomaw, J.C. (AVRDC, Tainan, Taiwan), H. G. Park and S. Shanmugasundaram.
In Vincent, J.M. *et al*, Exploiting the legume/*Rhizobium* symbiosis in tropical agriculture. U Hawaii Col Trop Agr misc pub 145, 1977, p. 155-169.

The protein needs of people in South and Southesst Asia are inadequately met with present diets. Legume crops in India represent only 8% of the total food production. For some other countries this may be less than 2%. International centers are working to identify and improve appropriate legumes, overcome social, economic and agronomic constraints on their production, and improve human nutrition by promoting a greater proportion of legumes in diets.

1327 Tropical legumes: resources for the future.
3000 Natl Acad Sci (US) Advis Committee on Technol Innov.
NAS, Washington, DC 1979, 331 p.

The underexploited legumes described include root crops, pulses, fruits, forages, luxury timbers, fiber, gum and green manure crops, and miscellaneous ornamental legumes. More than 30 crops or species are described, with information on their economic importance and culture. A large number of contributors assisted in assembling this report.

1328 The winged bean as an agricultural crop.
3238 Newell, C.A. and T. Hymowitz.
In Ritchie, G.A., ed. New Agricultural crops. Amer Assoc Advan Sci sel symp 38, 1979, p. 21-40.

The seeds of *Psophocarpus tetragonolobus* have approximately the same quantity and quality of protein and oil as that of the soybean. The plant also produces edible tubers with 5 to 20% protein. The greatest potential for this legume is as a source of protein in high-rainfall areas to augment staple crops such as yams and cassavas. A major effort to collect germplasm of winged bean was recommended.

1329 Role of legumes in small holdings of the humid tropics of Africa.
2348 Okigbo, B.N. (IITA, Ibadan, Nigeria).
In Vincent, J.M. *et al*, Exploiting the legume/*Rhizobium* symbiosis in tropical agriculture. U Hawaii Col Trop Agr misc pub 145, 1977, p. 97-117.

The humid tropics extend about 10° north and south of the equator, have annual mean temperatures usually exceeding 25°C, experience rainfall of more than 1,200 mm with precipitation in 6 or more months exceeding evapotranspiration, and annual dry periods of 3 to 4 months. Smallholders in this region of Africa are subsistence farmers employing very low input technology. Of the 18 most important grain legumes, only 6 are able to grow readily in the humid tropics. Other legumes supply fuel, timber, drugs and other needs. Because of their nutritional value and nitrogen fixing capability, legumes will remain important in the humid tropics.

1330 Effects of pod removal upon seeds of nodulating and nonnodulating
2820 soybean lines.
Openshaw, S.J. (U Illinois, Urbana, IL, USA), H.H. Hadley and C.E. Brokoski.
Crop Sci 19(2):289-290, 1979.

Removal of all but the two most developed pods or buds at each node increased the average seed weight and protein percentage in both nodulating and non-nodulating lines. There was no evidence of increased benefit due to prolongation of nitrogen fixing activity.

1331 The role of legumes in tropical America.
2350 Pinchinat, A.M. (Central Agron Trop Inves y Enseñanza, Turrialba, Costa Rica).
In Vincent, J.M. *et al*, Exploiting the legume/*Rhizobium* symbiosis in tropical agriculture. U Hawaii Col Trop Agr misc pub 145, 1977, p. 171-182.

Many economically important legumes are native to South America, and a number of species are widely cultivated for food. Forage legumes are frequently encountered but seldom cultivated. With only a few exceptions, legume programs have been very narrow in scope, but there has been a renewed interest in legume food crops since 1970. Seminars and workshops on nutritional aspects, plant diseases, and other topics have become quite frequent.

1332 Grain legumes in the lowland tropics.
2822 Rachie, K.O. (IITA, Ibadan, Nigeria) and L.M. Roberts.
Advan Agron 26:1-132, 1974.

Primary legumes covered in this review are: peanuts, pigeon peas, cowpeas and mung beans. Secondary species for the major environments (semi-arid, subhumid, humid and very humid) are included briefly. A large volume of information has been condensed into this publication, which includes production tables, adaptive features and botanical characteristics, and inheritance of important genetic characters. More than 500 abbreviated citations (no titles to journal articles) are listed as references.

1333 Food grain legumes as a major means of combatting malnutrition in
2905 LDC's.
Sprague, H.B.
USAID Tech Ser Bull No. 5, 1971, 23 p.

Because protein malnutrition can produce such serious and irreversible effects, greater attention to the role of food legumes is essential in attacking food shortage problems. Tables show the protein status of various regional diets, the average protein values for selected food crops, and production and yield data for legumes in various countries. Research to increase yields and improve the nutritional quality of food grain legumes was urged.

1334 Winged bean investigations at the NifTAL Project: observational
2274 garden, *Rhizobium* strain testing and response across a liming gradient.
Woomer, P. (U Hawaii NifTAL Proj, Paia, HI, USA), A. [B.] Guevarra and K.[R.] Stockinger.
Hawaii Agr Exp Stn J Ser 2307, 1978, 12 p.

The 40+ lines of winged bean planted to determine the range of morphology, pod yield and nitrogen content encountered in the species produced bean yields from a low of 17 g/plant to 420 g, and pods from 10 to 31 cm. in length. No significant difference was detected between effective strains of rhizobia. An increase in pH above 4.7 and up to 5.5 produced a positive yield response.

14. LEGUME PHYSIOLOGY AND TAXONOMY

1401 The national plant germplasm system.
2555 Agricultural Research Service and National Plant Germplasm Committee.
USDA Agr Res Serv program aid no. 1188, 1977, 12 p.

A description of the organization and function of the National Plant Germplasm System, a coordinated network of institutions, agencies and research units to introduce, maintain, evaluate, catalog and distribute plant germplasm. Principal stations or laboratories and their major responsibilities and germplasm specialties are listed. The Southern Regional Plant Introduction Station, Experiment, GA 30212 has responsibility for collecting and distributing cowpea and peanut germplasm in the U.S.

1402 Protein-polysaccharide linkages in glycoproteins from *Phaseolus*
2132 *vulgaris*.
Brown, R.G. (Dalhousie U, Halifax, N.S., Canada) and W.C. Kimmins.
Phytochem 17:29-33, 1978.

Virus infection of leaves produced glycoproteins enriched in glucose. It has been reported previously that wounding without virus resulted in the production of glycoproteins enriched in xylose, but the authors obtained glycoproteins enriched with glucose in the absence of virus, using Sepharose in the purification process. Both hydroxyproline and serine were involved in the protein-polysaccharide linkages.

1403 Paper chromatographic survey of anthocyanins in Leguminosae. II On
3091 the flower pigments of *Mucuna sempervirens*
Ishikura N (Kumamoto U, Japan) and N Shibata
Bot Mag Tokyo 86:1-4, 1973.

Three different anthocyanins (delphinidin, petunidin and malvidin) were identified in dull-purple flowers of the legume A rapid extraction method was devised to overcome rapid fading of the pigments

1404 Paper chromatographic survey of anthocyanins in Leguminosae. III.
2172 Identification and distribution pattern of anthocyanins in twenty-two legumes.
Ishikura, N. (Kumamoto U, Japan), S. Ito and M. Shibata.

Bot Mag Tokyo 91(1021):25-30, 1978.
Malvidin and petunidin glycosides occurred in 20 of the 22 legumes studied. Distributation tables relate species and flower color to the presence of 21 identified anthocyanins. The taxonomic significance of floral pigments was discussed.

1405 Variability of some seed proteins of the species *Phaseolus vulgaris*
2139 and their relationship to phytohaemagglutinating activity.
Klozova, E. (Inst Exper Bot, Praha, Czechoslovakia) and V. Turkova.
Biologia Plant 20(2):129-34+, 1978.
Polymorphism was established in two proteins showing completely different immunochemical specificities. Various combinations of the proteins (previously classified I & II) occurred in several of 26 cultivars examined. The differentiation was accomplished by means of disc electrophoresis in acrylamide gels.

1406 Kinetics of phloem loading of valine in the shoot of a nodulated
3172 legume (*Lupinus albus* L. cv Ultra).
McNeil, D.L. (U Western Australia, Nedlands, W.A., Australia).
J Exp Bot 30(118):1003-1012, 1979.
At elevated xylem fluid concentrations, low rates of loading of D-Val into the phloem and minimal metabolism in the tissue resulted in high levels in the leaflets. Rapid metabolism of other amino acids prevented a buildup in either phloem or leaflets. L-Val supplied to the phloem in the stem was derived from a large storage pool and did not come directly from the xylem fluid.

1407 Handbook for the collection, preservation and characterization of
3049 tropical forage germplasm resources.
Mott, G.O., ed. (U Florida, Gainesville, FL, USA).
CIAT, Cali, Colombia ser 05EG-1, 1979, 95 p.
Collection of extant legume species and nodules is vital to future research needs. This handbook offers detailed instructions to ensure that the collecting of germplasm and accompanying information be sufficiently standardized to serve the required purposes. Nine appendices give standardized descriptors and definitions, country codes, recommendations of the International Board for Plant Genetic Resources, and other information for collectors.

1408 Nutrition of a developing legume fruit. Functional economy in terms
2208 of carbon, nitrogen and water.
Pate, J.S. (U Western Australia, Nedlands, W.A., Australia), P.J. Sharkey and C.A. Atkins.
Plant Physiol 59:506-510, 1977.
This study highlights the significance of the legume pod as a temporary reservoir for seed-bound solutes and as an agent for photosynthetic reutilization of respiratory products of the seeds.

1409 Modeling the transport and utilization of carbon and nitrogen in a
2810 nodulated legume.
Pate, J.S. (U Western Australia, Nedlands, W.A., Australia), D.B. Layzell and D.L. McNeil.
Plant Physiol 63(4):730-737, 1979.

The transport and partitioning of photosynthetically fixed carbon and symbiotically fixed nitrogen by white lupin were quantitatively depicted for four 10-day intervals. Xylem to phloem transfer of recently fixed N in mature stem and petioles was substandiated by the empirical models. The modeling showed 3 N sources for fruits: from leaflet translocate via phloem, from the shoot axis following xylem to phloem exchange, and from root nodules directly via xylem.

1410 Transport of organic solutes in phloem and xylem of a nodulated
2895 legume.
Pate, J.S. (U Western Australia, Nedlands, W.A., Australia), C.A. Atkins, K. Hamel, D.L. McNeil and D.B. Layzell.
Plant Physiol 63(6):1082-1088, 1979.

Sucrose was the major organic solute of phloem. Xylem sap exhibited higher relative proportions of asparagine, glutamine and aspartic acid than did phloem sap, but lower proportions of serine, valine, lysine, isoleucine and leucine. Sink regions received translocate much richer in N than would have been possible if leaves were the sole source of amino compounds.

1411 ole of lectins in plant-microorganism interactions. II. Distribu-
2463 tion of soybean lectin in tissues of *Glycine max* (L.) Merr.
Pueppke, S.G. (C.F. Kettering Res Lab, Yellow Springs, OH, USA), W.D. Bauer, K. Keegstra and A.L. Ferguson.
Plant Physiol 61:779-784, 1978.

Lectin from various tissues of soybean plants was quantified by three assay procedures: standard hemagglutination, radioimmunoassay, and isotope dilution. Most of the seed lectin was found in cotyledons, with less detected in the embryo axis and seed coat. Lectin was present in all the tissues of seedlings, but decreased with maturity until no longer detectable after 2 to 3 weeks. Lectin isolated from seeds of several soybean varieties was identical when compared by several methods. There is some evidence that SBL in tissues is either synthesized within the tissue or transported there from the cotyledons, with the latter as the more likely source. The absence of SBL in older root tissue raises questions about its role in rhizobial infection.

1412 Composition of bleeding sap in *Vigna radiata*.
2777 Sinha, S.K. (IARI, New Delhi, India), R. Khanna-Chopra, S. R. Chatterjee and Y.P. Abrol.
Physiol Plant 42(1):45-48, 1978.

The bleeding sap contained mostly basic amino acids, whereas the nodules contained both acidic and basic amino acids. The respective content patterns indicated the likelihood that the plant draws on soil N to augment symbiotically fixed N during pod filling.

1413 The evolution of pulse crops.
2932 Smartt, J.(U Southampton, England).
Econ Bot 32:185-198, 1978.

This paper suggests that evolution under domestication has been largely influenced by selection for a single character - seed size. Pulses were liberated from dependence on other species for mechanical support and from the implications of ancestral ecology when free standing plants evolved. The evidence also suggests a deep underlying genetic homology in the family, which has implications for plant breeding objectives.

1414 Effects of source-sink manipulations on seed yield of cowpea (*Vigna*
2097 *unguiculata* (L.) Walp.). I. Defoliation.
Stewart, K.A. (U Reading, Shinfield, Reading, UK), R.J. Summerfield and B.J. Ndunguru.
Trop Agric (Trinidad) 55(2):117-125, 1978.

Fifty percent leaf area removal at first flowers resulted in a 26 to 60% reduction of seed yield in determinate, nodule-dependent plants growing in pots. Both leaf area and chronological or physiological age were found to be important in assessing effects of defoliation.

1415 Inhibition studies on the interaction of *Vicia faba* lectin with
2156 carbohydrates.
Ziska, P. (State Inst Immun & Nutr, Berlin, Germany).
Acta Biol Med Germany 35:1575-1576, 1976.

The results of quantitative studies for inhibition to agglutination reaction between fava bean and yeast cells seemed to parallel the specificity of carbohydrate binding reported for concanavalin A. Further inhibition studies of the specificity of interactions of lectins with yeast cells are in progress.

1416 Domestication of pulses in the old world.
2878 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 civilized in the Neolithic. It is possible that the wild progenitors of the founder cereals and their companion pulses were collected by man long before the initiation of agriculture.

15. LIGHT FACTORS

1501 Growth and nitrogen fixation of *Phaseolus vulgaris* L. at two
2153 irradiances. I. Growth.
Antoniw, L.D. (U Dundee, Scotland) and J.I. Sprent.
Ann Bot 42(178):389-397, 1978.

Leaves and flowers developed equally at 7 or 28 W m^{-2}, but those at the lower intensity developed longer internodes, more succulant stems and

leaves, and had higher shoot:root ratios with greater leaf area. Higher final dry weight accompanying higher irradiance was attributed to an early net carbon gain. Although yields were low, the plants adapted well to limiting light conditions.

1502 2235 Growth and nitrogen fixation of *Phaseolus vulgaris* L. at two irradiances. II. Nitrogen fixation.
Antoniw, L.D. (U Dundee, Scotland) and J.I. Sprent.
Ann Bot 42(178):399-410, 1978.

Copious nodulation and high levels of acetylene reduction were seen in plants grown at either 7 or 28 W m^{-2}. The higher irradiance produced more growth, but N content as a percentage of DM was greater at the lower irradiance level. The results indicate that light affects the production of N fixing tissue rather than directly affecting nitrogenase activity.

1503 3247 Effect of light intensity on efficiency of carbon dioxide and nitrogen reduction in *Pisum sativum* L.
Bethlenfalvay, G.J. (U California, Davis, CA, USA) and D.A. Phillips.
Plant Physiol 60:868-871, 1977.

The data indicated that the relative efficiency of nitrogen fixation is not necessarily correlated with maximum plant productivity and that evaluation of a plant's capacity to reduce N_2 is directly related to concurrent CO_2 reduction. A nitrogen fixation efficiency measurement based on the N_2/CO_2 uptake ratio was proposed as an alternative to the simpler, but more limited, dry weight ratio.

1504 2373 Influence of light on pectic enzymes in root exudates of *Trifolium alexandrinum* inoculated with *Rhizobium trifolii*.
Chhonkar, P.K. (IARI, New Delhi, India).
Naturwiss Abt 133(1):50-53, 1978.

Although both pectin methyl esterase and pectin polygalacturonase production increased with increased light duration, both the enzymes were detected in the exudates of non-photosynthesizing plants. Reduced infection by rhizobia may be related to reduced enzyme exudation by roots.

1505 2581 The effect of reduced light intensity and sub-optimal potassium supply on N_2 fixation and N turnover in *Rhizobium* infected lucerne.
Feigenbaum, S. (BUntehof Agr Res Stn, Hannover, W Germany) and K. Mengel.
Physiol Plant 45(2):245-249, 1979.

Growth was depressed and protein content of tops, roots and nodules was lowered by low light intensity. Sub-optimal K had a similar, but less pronounced, effect. The responses were related to effects on overall metabolism.

1506 2438 The nodulation and nitrogen fixation of isolated roots of *Phaseolus vulgaris* L. II. The influence of light on nodulation.
Grobbelaar, N. (U Pretoria, S Africa), B. Clarke and M.C. Hough.

Plant Soil Spec Vol:203-214, 1971.
Exposure of roots to strong white light for 3 days or longer suppressed nodulation and, to a lesser extent, the production of lateral roots, but exposure immediately before inoculation stimulated subsequent nodulation.

1507 2271 Seasonal and diurnal variation of nitrogenase activity (acetylene reduction) in barrel medic (*Medicago truncatula* Gaertn.) grown in pots.
Ruegg, J.J. (U Adelaide, Glen Osmond, S.A., Australia) and A.M. Alston.
Aust J Agr Res 29(5):951-962, 1978.
Noontime rates of acetylene reduction were 10 to 60% higher than the mean daily rates. Seasonal differences followed a pattern similar to that of plant growth. Nitrogenase activity was significantly correlated with total irradiance.

1508 2967 Growth, maintenance and nitrogen fixation of nodulated plants of subterranean clover (*Trifolium subterranean* L.).
Silsbury, J.H. (U Adelaide, Glen Osmond, S.A., Australia).
Aust J Plant Physiol 6(2):165-176, 1979.
A close association between growth rate and the rate of nitrogen fixation was suggested by the coincidental decrease of CO_2 efflux to the maintenance level during a prolonged dark period when acetylene reduction decreased to near zero.

1509 2161 Effects of shading on the N_2-fixation, yield, and plant composition of field-grown soybeans.
Wahua, T.A.T. (U Ibadan, Nigeria) and D.A. Miller.
Agron J 70(3):387-392, 1978.
Total nitrogen fixing activity decreased curvilinearly under increasing shading (20 to 93%), while specific nodule activity decreased linearly. Grain yields ranged from 90% of unshaded plants at 20% shade to 2% at 93% shade. Substantial nitrogen fixation requires at least 80% ambient illumination.

16. MACRONUTRIENTS (OTHER THAN N ALONE)

1601 2321 Nutritional restraints on [forage] legume symbiosis.
Andrew, C.S. (CSIRO, St Lucia, Qld, Australia).
In Vincent, J.M. *et al*, Exploiting the legume/*Rhizobium* symbiosis in tropical agriculture. U Hawaii Col Trop Agr misc pub 145, 1977, p. 253-274.
The principal nutrients having a relatively high specific effect on legumes in mixed pastures are potassium, molybdenum, sulfur, lime and phosphorus. Copper, zinc, boron, magnesium, iron and cobalt also have importance, but the data on deficiencies of these nutrients in tropical pastures are sparse or conflicting. The diagnosis and management of plant nutrition in mixed tropical pastures must take into account the symbiotic requirements as well as the plant requirements.

MACRONUTRIENTS (OTHER THAN N ALONE), *continued*

1602 2799 Growth and mineral composition of mungbean as influenced by P and Fe fertilization.
Bassiri, A. (Pahlavi U, Shiraz, Iran), A. Kashirad and M. Kheradnam.
Agron J 71(1):139-141, 1979.
Relatively large amounts of P can interfere with the availability of Fe to plants in tropical arid to semi-arid soils. Despite varying P:Fe ratios, no Fe chlorosis was encountered in these experiments. There was no mention of the nodulation status of the plants.

1603 2356 The effects of calcium and the ionophore A23187 on nodulation, nitrogen fixation and growth of soybeans.
Blevins, D.G. (U Maryland, College Park, MD, USA), N.M. Barnett and P.J. Bottino.
Physiol Plant 41(4):235-238, 1977.
A requirement for Ca^{2+} in the infection and nodulation of soybean was confirmed. The ionophore, which increases Ca^{2+} transport across membranes, significantly affected infection and nodulation but not acetylene reduction in established nodules.

1604 2825 Effects of fertilizer salt concentration on viability of seed and *Rhizobium* used for hydroseeding.
Carr, W.W. (U British Columbia, Vancouver, BC, Canada) and T.M. Ballard.
Can J Bot 57(7):701-704, 1979.
Contact with 10-30-10 fertilizer and KCl solutions equivalent to 90 kg/m^3 water for 1 hour had the greatest effect on viability of *Trifolium repens*. Effects on rhizobia were not significant.

1605 2953 Nodule and plant development in the soybean, *Glycine max* (L.) Merr.: Growth response to nitrogen, phosphorus and sulfur.
Gates, C.T. (CSIRO, Canberra, A.C.T., Australia) and W.J. Muller.
Aust J Bot 27(3):203-215, 1979.
Extremes of combinations of the nutrients reduced nodulation to almost zero, but well balanced combinations favored nodulation from early stages through maturity. The best nodulation occurred at high levels of all 3 nutrients. Levels of sulfur above 10 ppm counteracted the limiting effect of NH_4NO_3 on nodule development.

1606 2584 Effect of lime, sulfur and molybdenum on N_2 fixation and yield of dark red kidney beans.
Janssen, K.A. (Virginia Truck & Ornam Res Stn, Painter, VA, USA) and M.L. Vitosh.
Agron J 66:736-740, 1974.
Sandy, acid soils deficient in S and Mo were treated with dolomitic lime, S and Mo. Sulfur increased nitrogen fixation nearly 60%, but the lime and Mo treatment had little effect on nodule activity. The study suggested that S and low pH may limit symbiotic nitrogen fixation in some situations.

1607 Effects of phosphorus and potassium on soybean nodules and seed yield.

2067 Jones, G.D.(Virginia Polytec Inst, Blacksburg, VA, USA), J.A. Lutz, Jr. and T.J. Smith.
Agron J 69:1003-1006, 1977.
Parameters measured included nodule number and weight; chemical composition of leaves, nodules and seed; number of pods per plant; and seed yield. Either P or K alone increased nodules per plant and per unit volume of soil. K alone increased some parameters more than P alone, but increases were largest when both P and K were applied.

1608 Field response of four tropical legumes to lime and superphosphate.
2133 Snyder, G.H.(Agr Res Ctr, Belle Glade, FL, USA), A.E. Kretschmer and J.B. Sartain.
Agron J 70(2):269-272, 1978.
Significant responses in acid soil by centro, stylo, siratro and desmodium to lime and P were observed. Desmodium required the least P for optimal DM production. Part of the effect of lime may have resulted from keeping the applied P in Ca forms rather than less available Al and Fe forms.

1609 Influence of the different supply of N, P, S, K, Mg and Ca on the
2761 formation of nodules and on the productivity of soya bean plants.
Tyankova, L.A. (Bulgarian Acad Sci, Sofia, Bulgaria), Z.P. Stoyanova and A.V. Dimitrova.
Dokl Akad Nauk Bulgaria 31(11):1447-1450, 1978.
Of the nutrients tested, S (in the proper ratio with other nutrients) had the greatest effect on Beeson var., but a lesser effect on Merit. Nodule size, which increased with S application, correlated positively with yield.

1610 Nodulation of annual medicago by strains of *R. meliloti* in a commer-
2474 cial inoculant as influenced by soil phosphorus and pH.
Wagner, G.H. (U Missouri, Columbia, MO, USA), S. Martinluk and G.M. Kassim.
Plant Soil 50(1):81-89, 1978.
Nodulation increased significantly with addition of P at 30 ppm to the soil, but a change in pH from 5.5 to 6.8 had almost no effect.

17. METHODS, TECHNIQUES, STATISTICAL PROCEDURES

1701 Enzymatic degradation of chemically modified extracellular poly-
2181 saccharides from rhizobia.
Anderson, M.A. (LaTrobe U, Bundora, Victoria, Australia) and B.A. Stone.
Carbohyd Res 61:479-492, 1978.
Much more information on the monosaccharide sequences of rhizobial polysaccharides can be made available through enzymatic degradation used in conjunction with methylation and periodate-oxidation techniques.

1702 Automatic sub-irrigation sand culture technique for comparative
2550 studies in plant nutrition.

Andrew, C.S. (CSIRO, St. Lucia, Qld., Australia).
Lab Prac 23:20-21, 1974.

The solution is transferred once each half hour from a floor-level reservoir to a trough at bench height in which pots are sub-irrigated, then returned by gravity to the reservoir. Either air pressure or a liquid pump may be used to power the transfer, which is controlled by an electric timer and solenoid valve. A single air manifold may be used to operate 32 or more units.

1703 Determination of nitrogen fixing activity in *Rhizobium japonicum*
2945 under sterile microvegetative conditions.
Bonartseva, G.A. (Acad Sci Inst Micro, Moscow, USSR), N.M. Shemakhanova and V.B. Il'yasova.
Microbiol 47(5):783-784, 1978 (Eng tr).

Preliminary infection tests and determination of N-fixing ability were accomplished in two to three weeks with soybeans grown in tubes.

1704 A simple procedure for ^{15}N determination in relatively large samples
2617 by emission spectrometry.
Burridge, J.C. (Macaulay Inst., Aberdeen, Scotland) and I.J. Hewitt.
Commun Soil Sci 9:865-872, 1978.

The technique avoids the necessity of reducing NH_3 to N_2. Further work is in progress to refine the procedure for use with smaller samples.

1705 Analysis by digestion and colorimetric assay of total nitrogen of
2314 plant tissues high in nitrate.
Cataldo, D.A. (U Wisconsin, Madison, WI, USA), L.E. Schrader and V.L. Young.
Crop Sci 14:854-856, 1974.

The method employs Folin-Wu digestion tubes and permits trouble-free analysis of total N in large numbers of plant tissue samples. Samples as small as 5 mg can be assayed with precision.

1706 A method for testing *Rhizobium* effectiveness at low pH.
2125 Cooper, J.E. (Queens U, Belfast, N Ireland).
Soil Biol Biochem 10(1):81-83, 1978.

This technique was designed to provide for accurate initial setting of pH with as little deviation as possible during the course of effectiveness testing. The liquid medium was prepared in 2 parts, with no P in part *A*. The pH of part *A* was adjusted with NaOH. Part *B* contained KH_2PO_4 & Na_2PO_4, the ratio of which sets the pH for that part. The diluted phosphate buffer provides complete pH control for the combined nutrient solutions.

1707 Rapid method for counting antibiotic resistant rhizobia in soils.
3014 Cooper, J.E. (Queens U, Belfast, N Ireland).
Soil Biol Biochem 11(4):433-435, 1979.

A method of spotting from dilution bottles onto plates suppelemnted with rifampicin was used as an alternative to the spreadplate method. This avoids certain limitations of the latter method in frequent sampling with more than one or two strains.

1708 A technique for evaluating nodulation response of soybean genotypes.
2201 Devine, T.E. (USDA, Beltsville, MD, USA) and W.W. Reisinger.
Agron J 70:510-511, 1978.
Plant growth trays suspended above a nutrient solution reservoir were used as an alternative to Leonard jars in evaluating large numbers of soybean genotypes. Each apparatus accomodated 72 plants for an 8 week growth period, with enough nutrient solution to supply the plants for 2 weeks without replenishment.

1709 Unsterilized soil-agar technique for studying *Rhizobium*-plant
2884 relationships.
Douka, C.E. (Nucl Res Ctr, Athens, Greece).
J Appl Bact 46(3):615-622, 1979.
The effects of soil biological and physio-chemical characteristics on the legume-*Rhizobium* symbiosis were examined under aseptic controlled laboratory conditions. This infection test can be used to detect very small populations of rhizobia in the soil.

1710 Determination of content of reduced and oxidized NAD and NADP in
2445 tissues of yellow lupine nodules.
Dubrovo, P.N. (K.A. Tamiryazev Plant Physiol Inst, Moscow, USSR).
Sov Plant Physiol 25(3):481-487, 1978 (Eng tr).
Pyridine nucleotide (PN) content in nodule tissue was determined by a simplified process in which quantities of reduced and oxidized NAD and NADP were measured simultaneously and without neutralization. Accuracy was verified by addition of standard solutions of PN to the alkaline and acid extracts.

1711 Modified fluorescent technique, using rhodamine, for studies of
2888 *Rhizobium japonicum*-soybean symbiosis.
Hughes, T.A. (N Carolina St U, Raleigh, NC, USA), J.G. Lecce and G.H. Elkan.
Appl Envir Micro 37(6):1243-1244, 1979.
Because soybean root hairs naturally autofluoresce in the spectral region of fluorescein dye, the fluorescent dye rhodamine was used to label capsular polysaccharides isolated from a strain of *R. japonicum*. This permitted study of ineractions with the root hairs.

1712 Propagation of winged bean (*Psophocarpus tetragonolobus* (L.) D.C.)
3010 by stem cuttings.
Lawhead, C.W. (U California, Davis, CA, USA), J.P. Bennett and M. Yamaguchi.
Trop Agric (Trinidad) 56(3):271-276, 1979.
The results indicated that winged bean clones can be porpagated readily from stem cuttings. With misting, normal plant photoperiod, and with indolebutyric acid at 0.3 to 0.8% applied to the cuttings, 92% established shoot systems within 10 weeks.

1713 A chamber designed for continuous, long-term monitoring of legume
2568 root respiration.
Minchin, F.R. (U Reading, England), M.C.P. Neves, R.J. Summerfield and A.C. Richardson.
J Exper Bot 28(103):507-514, 1977.

Diurnal and ontogenetic patterns of CO_2 production were recorded, using a chamber designed to permit continuous monitoring of root respiration by infrared gas analysis. The overall pattern of root respiration closely mirrored changes in the plant's reproductive status, and may relate to the availability of photosynthates to nodules. The chamber, which is described and illustrated in detail, can be used in glasshouses and plastic tunnels as well as in controlled environment cabinets.

1714 Microdetermination of nitrogen in plant tissues.
2511 Mitchell, H.L. (Kansas St U, Marnattan, KS, USA).
J Assoc Offic Anal Chem 55(1):1-3, 1972.

A simplified procedure which does not require distillation as in the official micro-Kjeldahl method, but which yields comparable results. The method was reported to be highly reproducible and adaptable to a wide range of N concentrations.

1715 Serology of Malaysian rhizobia.
2667 Padmanabhan, S. (U Malaya, Kuala Lumpur, Malaysia) and W.J. Broughton.
In Symposium on soil microbiology and plant nutrition, Kuala Lumpur, 1976, No. 54 [unpaged].

The serological techniques of agglutination and immunodiffusion were compared, using thermostable antigens from 30 local isolates of rhizobia. The cross-agglutination capacity of the isolates was too wide to permit establishment of discrete serogroups. In general, the two techniques were comparable in the quality of results.

1716 Rapid method to enumerate and isolate soil actinomycetes antagonistic
3015 towards rhizobia.
Panthier, J.J. (CNRS/ORSTOM Micro Lab, Dakar, Senegal), H.G. Diem and Y. Dommergues.
Soil Biol Biochem 11(4):443-445, 1979.

A selective triple-layer agar technique was used to simultaneously enumerate and isolate soil actinomycetes antagonistic to slow- or fast-growing *Rhizobium* strains. Actinomycetes were grown in a preferential medium covered by a sterile water-agar intermediate layer. After incubation of that layer, a top layer of medium for rhizobial growth was poured, and then sprayed with a suspension of the *Rhizobium* being tested. After seven days (slow-growing) and three days (fast-growing), inhibition zones were visible and counts were made.

1717 The fumigation of seeds with methyl bromide.
1125 Powell, D.F. (MAFF Plant Pathol Lab, Harpenden, Herts., England).
Ann Appl Biol 81:425-431, 1975.

Under controlled conditions, treatment with a technical or commercial

ethyl bromide is safe for 40 varieties of vegetables, cereals, fodders and grass seeds tested. Seeds at 10, 13 and 16% moisture content were treated and compared with controls in germination tests. For some seeds, including certain legumes, the highest moisture content should be avoided.

1718 Modified immunization schedule for rapid development of antibodies
2564 against whole cell *Rhizobium* antigen.
Sharma, C.R. (IARI, New Delhi, India) and A.N. Sen.
Current Sci (India) 48(4):173-174, 1979.

To avoid long immunization schedules (21 to 71 days) or daily injections over several days, an 18 day injection schedule involving 1 intramuscular and 2 ear vein injections was devised. The sera obtained were of high titre, agglutinated firmly, and were suitable for immunodiffusion tests requiring a titre of at least 3,200.

1719 Use of the acetylene method for selection of active strains of
2773 *Rhizobium meliloti* and *Rhizobium trifolii*.
Shemakhanova, N.M. (Acad Sci, Moscow, USSR), G.A. Bonartseva, and V.B. Il'yasova.
Biol Bull Acad Sci USSR 3(6):766-768, 1976 (Eng tr 1977).

The active strains of rhizobia were clearly distinguished from less active strains in plants grown in 250 ml flasks for 14 days. This offers a short, reliable method of strain selection.

1720 Bayes least significant difference: a review and comparison.
2137 Smith, C.W. (Arkansas Cotton Br Exp Stn, Marianna, AR, USA).
Agron J 70(1):123-127, 1978.

At various F values, the Bayes LSD was found to be a more powerful test than that of Fisher, Turkey or the Duncan multiple range. The author supports the suggestion that Bayes LSD be standardized by the designation BLSD in publications and communications.

1721 An integrated strategy for daylength and temperature-sensitive
2630 screening of potentially tropic-adapted soybeans.
Summerfield, R.J. (Reading U, England) and F.R. Minchin
In: Goodman, R.M., ed., Expanding the use of soybeans. U Illinois INTSOY ser no 10, 1976, p. 186-191.

Procedures for screening an entire germplasm collection of seed were devised and tested. Data for the integrated effects of daylength and temperature on time to first flower for soybean and cowpea were tabulated. Symbiotic adaptation was not a component of this stage of the strategy.

1722 Easy-to-make 'Leonard jar'.
2304 Wacek, T.J. (Rudy Patrick Inoc Lab, Princeton, IL, USA) and D. Alm.
Crop Sci 18(3):514-515, 1978.

One half gallon (1.9 liter) and one gallon (3.8 liter) size plastic containers were cut into two sections, and the top inverted and placed in the lower section to form a variation on the Leonard jar for aseptic growth of plants during the study of *Rhizobium* strains.

1723 Simultaneous measurement of nitrogen fixation estimated by acetylene-
2255 ethylene assay and nitrate absorption by soybeans.
Wych, R.D. (U California, Davis, CA, USA) and D.W. Rains.
Plant Physiol 62(3):443-448, 1978.
A gas-tight mist chamber for exposing root nodules to acetylene in the gas phase and nitrate in the liquid phase was devised.

1724 Some methods of increasing the germination of tropical legumes.
2553 Yuen, C.F. (Inst Haiwan, Kluang, Johor, Malaysia) and S.B.A. Wahab.
Kajian Veterinar 2:41-48, 1975.
Freezing, hot or boiling water immersion and H_2SO_4 caused varying degrees of increased germination in the 6 pasture legumes tested, but no treatment significantly increased germination in either *Centrosema pubescens* or *Sesbania grandiflora*.

18. MICRONUTRIENTS AND TOXIC ELEMENTS

1801 Effect of inoculation and cobalt application on growth and nitrogen
2406 fixation by sweet lupins.
Chatel, D.L. (W Australian Dept Agr, S Perth, W Australia), A.D. Robson, J.W. Gartrell and M.J. Dilworth.
Aust J Agric 29(6):1191-1202, 1978.
The nodules of inoculated plants without added Co had fewer bacteroids, suggesting that cobalt is involved in rhizobial cell division in the nodules, but apparently not in the soil.

1802 Response of cowpea genotypes to zinc in relation to photosynthesis,
2204 nodulation and dry matter distribution.
Childiyal, M.C. (IARI, New Delhi, India), O.P.S. Tomar and G.S. Sirohi.
Plant Soil 49(3):505-516, 1978.
Genotypic differences were observed in extent of depression of yield under Zn deficiency. The range of nodulation increase from zinc application in a deficient soil was 22.1 to 169.2% for the different genotypes.

1803 Cobalt and nitrogen fixation in *Lupinus angustifolius* L. II. Nodule
3019 formation and function.
Dilworth, M.J. (Murdoch U, W Australia), A.D. Robson and D.L. Chatel.
New Phytol 83(1):63-79, 1979.
Bacteroid densities in Co-deficient nodules were lower, and acetylene-reducing activity delayed, reaching only 20 to 50% of the normal activity. A cobalt influence continued even after the effect of variation due to cobalamin content had been removed.

1804 Nitrogen metabolism of soybeans. I. Effect of tungstate on nitrate
3356 utilization, nodulation, and growth.
Harper, J.E. (USDA Sci & Educ Admin, Urbana, IL, USA) and J.C. Nicholas.
Plant Physiol 62(4):662-664, 1978.

Tungstate, a known inhibitor of nitrate reductase, caused an increase in nodule mass and acetylene reduction when accompanied by NO_3^-, but caused a decrease of those parameters when accompanied by urea. The evidence suggests that NO_3^- does not directly inhibit nodulation, but has an indirect effect through subsequent metabolism.

1805 The relationship of cobalt requirement to vitamin B_{12}-dependent
2060 methionine synthesis in *Rhizobium meliloti*.
Inukai, S. (Nagoya U, Japan), K. Sato and S. Shimizu.
Agric Biol Chem 41(11):2229-2234, 1977.

Either cobalt ion or vitamin B_{12} was required as a growth factor by the *Rhizobium*. Cells grown in Co-deficient medium were elongated, with apparent loss of motility. Methionine could also restore growth, but without restoring normal morphology.

1806 Influence of mode of rhizobial incorporation and its interactions
2749 with phosphorus, magnesium and boron on the soil properties with groundnut (*Arachis hypogaea* L.).
Perumal, R. (Tamilnadu U, Coimbatore, India), C.R. Venkataramanan, K.K. Krishnamoorthy and P.P. Ramaswamy.
Food Farming Agric 9(7):209-213, 1978.

The addition of phosphorus and micronutrients to pelleting material caused a pronounced increase in the rhizobial population.

1807 Molybdenum in biological nitrogen fixation.
2016 Schrauzer, G.N. (U California San Diego, La Jolla, CA, USA).
In Molybdenum in the environment; proceedings of an international symposium, 1976, 1:243-265.

The extraordinary catalytic activities of Mo, as exemplified in nitrogenase, are attributed to the ability of that element to exist in a variety of different oxidation states and to its high affinity for a variety of reducible substrates. Model systems proposed for nitrogenase have led to a theory on the mechanism of biological nitrogen fixation which appears to be consistent with enzymological evidence.

1808 Response of *Rhizobium* culture inoculation, zinc and molybdenum
2490 application to soybean (*Glycine max* L. Merrill).
Tripathi, S.K. (Allahabad Agr Inst, India) and J.C. Edward.
Ind J Plant Physiol 21(3):248-252, 1978.

Inoculation without the addition of Mo was not effective. The addition of Zn alone had a slight benefit, but no additional benefit to that of Mo when combined with the latter.

1809 Effects of cadmium, nickel, copper and zinc on nitrogen fixation by
2283 soybeans.
Vesper, S.L. (Ohio State U, Columbus, OH, USA) and T.C. Weidensaul.
Water Air & Soil Pollution 9:413-422, 1978.

The degree of toxicity was, generally, Cd>Ni>Cu>Zn. Copper reduced nodulation, but inhibited nitrogen fixation directly only at 5 ppm or greater.

Zinc reduced nodulation, but only slightly inhibited N_2 fixation. Repression of nitrogenase synthesis by heavy metals is possibly related to ammonia accumulation. The root system was the primary sink for metal ions entering the plants. Except for Zn, accumulation in the nodules was lower than in the roots.

19. MICROORGANISMS (OTHER THAN *Rhizobium* ALONE)

1901 2245 Effects of interactions between different culture fractions of 'phosphobacteria' and *Rhizobium* on mycorrhizal infection, growth, and nodulation of *Medicago sativa*.
Azcon-G de Aguilar, C. (Exper Stn Zaidin, Granada, Spain) and J.M. Barea.
Can J Microbiol 24(5):520-524, 1978.

In low-phosphate soil, satisfactory nodulation was greatly dependent on the mycorrhizal symbiosis. Cell free supernatants from either *Rhizobium* or a *Pseudomonas* sp. phosphobacteria stimulated the growth of mycorrhizal plants, but whole cultures of phosphobacteria did not have a similar effect. Inoculation with phosphobacteria did not increase the overall pool of soluble P in the soil.

1902 2824 Endomycorrhizal fungi and *Rhizobium* as biological fertilizers for *Medicago sativa* in normal cultivation.
Azcon-G de Aguilar, C. (Exper Stn Zaidin, Granada, Spain) and J.M. Barea.
Nature 279(5711):325-327, 1979.

In field cultivation, inoculation with both rhizobia and mycorrhiza improved the growth and nutrition of alfalfa over uninoculated or singly inoculated plants. Effects of *Glomus* were related to the P status of the soil.

1903 2520 Interaction between a vesicular-arbuscular mycorrhiza and *Rhizobium* and their effects on soybean in the field.
Bagyaraj, D.J. (U Agr Sci, Bangalore, India), A. Manjunath and R.B. Patil.
New Phytol 82(1):141-145, 1979.

Plants dually inoculated with *Glomus fasciculatus* and *Rhizobium japonicum* in a P deficient soil produced more nodules with higher weight and N content than did singly inoculated plants. Dual inoculation also increased the plant dry weight and N content.

1904 2939 Effects of a vesicular-arbuscular mycorrhizal fungus on nitrate reductase and nitrogenase activities in nodulating and non-nodulating soybeans.
Carling, D.E. (U Missouri, Columbia, MO, USA), W.G. Riehle, M.F. Brown and D.R. Johnson.
Phytopathol 68(11):1590-1596, 1978.

Nodulating soybean plants also infected with *Glomus fasciculatus* had higher rates of nitrogenase and nitrate reductase activity, and showed

increases in total dry weight and nodule dry weight compared to singly inoculated or noninfected plants. However, no direct interaction between the microorganisms was detected.

1905 Effect of *Rhizobium japonicum* and *Endogone mosseae* on soybean root rot
3140 caused by *Pythium ultimum* and *Phytophthora megasperma* var. sojae.
Chou, L.G. (Ohio St U, Columbus, OH, USA) and A.F. Schmitthenner.
Plant Disease Reprt 58(3):221-225, 1974.

Soybean roots were exposed to all possible combinations of the four microorganisms. *Pythium ultimum* combined with a race of *Phytophthora megasperma* killed the most plants, but this rate was reduced by the presence of mycorrhiza or rhizobia.

1906 Effect of arbuscular mycorrhiza on plant growth. VIII. Effects of.
2375 defoliation and light on selected hosts.
Daft, M.J. (U Dundee, Scotland) and A.A. El-Giahmi.
New Phytol 80(2):365-371, 1978.

In both alfalfa and grasses, periodic harvesting reduced mycorrhizal infection by approximately 50%. Alfalfa yields were higher from nodulated and mycorrhizal plants. Shortened daylength caused more but smaller nodules and higher plant N content.

1907 Nitrogen fixation in nodulated and mycorrhizal crop plants.
2376 Daft, M.J. (U Dundee, Scotland).
Ann Appl Biol 88(3):461-462, 1978.

Many legumes commonly form tripartite associations with rhizobia and mycorrhiza. Alfalfa, beans and peanuts showed positive responses to dual infection, with greater nodular tissue, nodule numbers, and higher rates of acetylene reduction. Hosts and both endophytes need to be screened for maximum effectiveness of tripartite associations.

1908 Antifungal activity of *Rhizobium*.
3078 Drapeau, R. (Laval U, Quebec, Que., Canada), J.A. Fortin and C. Gagnon.
Can J Bot 51:681-683, 1973.

Inhibition zones were produced with 6 of 8 plant pathogens by both *Rhizobium* and cell-free extract of growth medium from *Rhizobium* cultures.

1909 The role of mycorrhiza in legume nutrition on marginal soils.
2346 Mosse, B. (Rothamsted Exp Stn, Harpenden, Herts., England).
In Vincent, J.M. *et al*, Exploiting the legume/*Rhizobium* symbiosis in tropical agriculture. U Hawaii Col Trop Agr misc pub 145 1977, p. 275-292.

The need for adequate phosphate for nodulation and nitrogen fixation is well known. In some soils, legumes inoculated with rhizobia fail to nodulate in pots of irradiated soil unless they are either inoculated with VA mycorrhiza or supplied with phosphorus. Until a way has been found to culture VA mycorrhiza, their production as inoculants will remain economically impracticable.

1910 Mycorrhizal fungi stimulate uptake of soluble and insoluble phosphate
2751 fertilizer from a phosphate-deficient soil.
Powell, C. LL. (Ruakura Agr Res Ctr, Hamilton, NZ) and J. Daniel.
New Phytol 80(2):351-358, 1978.

Nauru rock phosphate was available to mycorrhizal plants only, and non-mycorrhizal plants recovered only 0.4 to 13% of applied phosphate fertilizer, compared to 10 to 27% for mycorrhizal plants. Clover was inoculated with rhizobia, but no nodulation or nitrogen fixation studies were included.

1911 Effect of *Rhizobium*, *Azotobacter* [and] *Beijerinckia* inoculation on
2415 *Cicer arietinum* var. type-1.
Rawat, A.K. (Banares Hindu U, Varanasi, India) and C.L. Sanoria.
Curr Sci (India) 45(18):665-666, 1976.

Azotobacter strain B4 isolated from local farm soil had a synergistic effect on *Rhizobium* strain H44.

1912 Influence of seed bacterization on nodulation, yield and amino acid
2410 composition of seed protein of *Cicer arietinum*.
Rawat, A.K. (Banares Hindy U, Varanasi, India) and C.L. Sanoria.
Curr Sci (India) 46(11):373-375, 1977.

Aspartic and glutamic acids tended to decrease with combined inoculation of seeds with both *Rhizobium* and *Azotobacter* compared to inoculation with either microorganism alone. Nodules resulting from the dual inoculation were fewer but healthier.

1913 Soil microbial balances as the possible cause for synergistic effect
2409 of *Azotobacter* and *Rhizobium* on *Cicer arietinum*.
Rawat, A.K. (Banares Hindu U, Varanasi, India) and C.L. Sanoria.
Ind J Microbiol 18(2):135-137, 1978.

Seed inoculation with both microorganisms resulted in greater yields of Bengal gram than did either single-organism inoculation or combining *Rhizobium* with *Beijerinckia indica*. There were indications that larger *Azotobacter* counts were accompanied by reduced fungi counts.

1914 Effect of early mycorrhizal infection on nodulation and nitrogen
3047 fixation in *Trifolium subterraneum* L.
Smith, S.E. (Waite Agr Res Inst, Glen Osmond, S Australia), D.J. Nicholas and F.A. Smith.
Aust J Plant Physiol 6(3):305-316, 1979.

Mycorrhizal roots had a higher P concentration, but this was not accompanied by a higher % P in the nodules. Mycorrhizal plants had improved nodulation and increased nitrogenase activity. Delay in mycorrhizal infection caused delay in onset of enhanced nodulation.

1915 Distribution of bacteria in the soybean rhizosphere.
1907 Thomas, G.V. (Punjab Agr U, Ludhiana, India), A.S. Khurana and R.P. Sethi.
Ind J Ecol 3(2):167-171, 1976.

The population of *Azotobacter* spp. was reduced in the rhizosphere of soybean plants (Bragg and Punjab No. 1) compared to non-rhizosphere soil, while the total microflora population was increased by plant growth. Counts of rhizobia alone were not presented, but the possibility of their antagonistic effect on *Azotobacter* was raised.

1916 Protection of soybean from severe *Phytophthora* root rot by *Rhizobium*.
2144 Tu, J.C. (U Alberta, Edmonton, Ata., Canada).
Physiol Plant Pathol 12(2):233-240, 1978.

Application of rhizobia to potted soil immediately after planting lessened the severity of root rot in greenhouse experiments. There were indications *in vitro* of parasitism on the hyphae of *Phytophthora megasperma* by *Rhizobium japonicum*.

1917 Prevention of soybean root nodulation by tetracycline and its effect
2614 on soybean root rot caused by an alfalfa strain of *Fusarium oxysporum*.
Tu, J.C. (Agr Canada Res Stn, Harrow, Ont., Canada).
Phytopathol 68(9):1303-1306, 1978.

Tetracycline was lethal to rhizobia at relatively low levels, but not to *F. oxysporum*. Because inoculation with rhizobia reduces root rot, the disease was more severe with tetracycline than without it.

1918 Evidence of differential tolerance among some root rot fungi to
2674 rhizobial parasitism *in vitro*.
Tu, J.C. (Agr Canada Res Stn, Harrow, Ont., Canada).
Physiol Plant Pathol 14(2):171-177+, 1979.

Sporulation of 4 different fungi was reduced by 35 to 75% in colonies inoculated with rhizobia. Aseptate fungi (*Phytophthora megasperma* and *Pythium ultimum*) were generally more susceptible to rhizobial parasitism than were the septate fungi (*Ascochyta imperfecta* and *Fusarium oxysporum*.

1919 Spore formation and endophyte diversity in root nodules of *Alnus*
2492 *glutinosa* (L.) Vill.
Vandijk, C. (St U Leiden, The Netherlands).
New Phytol 81(3):601-615, 1978.

Two types of alder nodules were observed: one containing endophyte spores, and the other without spores. Cross inoculation experiments showed that the presence or absence of spores in non-legume root nodules was, presumptively, a genetic characteristic of the endophyte. The ecological consequences of the strain differences are under study.

1920 Mycorrhizal infection on growth and nitrogen fixation of *Pueraria*
2513 and *Stylosanthes* and uptake of phosphorus from 2 rock phosphates.
Waidyanatha, U.P.D.S. (Rubber Res Inst, Agalawatta, Sri Lanka), N. Yogaratnam and W.A. Ariyaratne.
New Phytol 82(1):147-152, 1979.

Either mycorrhizal infection or addition of P was required for good growth and nodulation, particularly with *Pueraria*. The treatments were more stimulatory to nitrogenase activity than to plant growth.

20. NITROGEN CYCLE

2001 Probable site of allantoin formation in nodulating soybean plants.
2275 Fujihara, S. (U Osaka, Japan) and M. Yamaguchi.
Phytochem 17:1239-1243, 1978.
Excision of nodules resulted in a marked decrease in allantoin, normally present in high concentrations in nodulated soybean plants. From evidence obtained by tracing ^{15}N assimilation, it was proposed that allantoin formation has a special role in the ammonia assimilation process of soybean nodules.

2002 Transfer of nitrogen between legumes and other crops.
1161 Henzell, E.F. (CSIRO, St. Lucia, Qld., Australia) and I. Vallis.
In Ayanaba, A. and P.J. Dart, eds., Biological nitrogen fixation in farming systems of the tropics. NY, Wiley, 1977, p. 73-88.
This chapter emphasizes the points that the initial flush of mineralization from legume residues provides most of the nitrogen transfer that removal of plant parts containing most of the N leaves very little for mineralization, and that in the humid tropics it is difficult to avoid loss of N residues from one crop before it can be used by another. Chiefly for these reasons, it was concluded that there is little economic justification for growing legumes solely for green manures.

2003 The significance of transpirationally derived nitrogen in protein
2207 synthesis in fruiting plants of pea (*Pisum sativum* L.).
Lewis, O.A.M. (Queen's U, Belfast, N Ireland) and J.S. Pate.
J Exp Bot 24:596-606, 1973.
Stems, leaves and roots became enriched with isotopic N following feeding of ^{15}N compounds to detached shoots through the transpiration stream. Evidence suggested the synthesis of new amino acids by seeds.

2004 Synthetic nitrogen fertilizer and nitrogen-fixing leguminous plants:
2179 relative contribution to production and leaching. (Ital)
Massantini, F. (U Pisa, Italy) and F. Caporali.
Agrochim 21(6):468-477, 1978.
Soluble and slow-release fertilizer nitrogen were utilized by grass at 90 and 10% respectively in the first year. Leaching losses, which were concentrated in winter, accounted for 22% of the soluble and 10% of the slow-release fertilizer N. During the growth period, only legume as a pure crop showed N losses from applied fertilizers.

2005 Incorporation of ^{15}N into various nitrogenous compounds in intact
2525 soybean nodules after exposure to $^{15}N_2$ gas.
Ohyama, T. (U Tokyo, Japan) and K. Kumazawa.
Soil Sci Plant Nutr 24(4):525-533, 1978.
Ammonia appeared to be first incorporated into glutamine, then into glutamic acid and alanine. The bacteroid fraction had a high proportion of ammonia, and allantoin and asparagine were present only in the cytosol. A pathway for oxidation of ammonia to nitrate in the bacteroids was strongly suggested.

2006 Uptake, assimilation and transport of nitrogen compounds by plants.
2972 Pate, J.S. (Queen's U, Belfast, N Ireland).
Soil Biol Biochem 5:109-119, 1973.
Of the legumes included in this study, *Lupinus*, *Pisum*, *Vicia* and *Phaseolus* (in that order) were relatively active in reducing nitrate in the roots, while *Trifolium* was quite inactive in that respect.

2007 Uptake of nitrogen by pasture legumes and associated ryegrass at
2104 three sites in Otago.
Sinclair, A.G. (Invermay Agr Res Ctr, Mosgiel, NZ), I.R. McDonald and R.B. Hannagan.
N Z J Exper Agr 5:201-209, 1977.
Ryegrass benefited only marginally, if at all, from associations with several clovers at 3 locations. Performance of the different clovers at the different sites was evaluated. The highest uptake for plants studied was by lucerne in an intermediate climate.

2008 Denitrification in *Rhizobium*.
2317 Zablotowicz, R.M. (U California, Riverside, CA, USA), D.L. Eskew and D.D. Focht.
Can J Microbiol 24(6):757-760, 1978.
Three patterns of denitrification were observed in 33 strains representing 5 species of *Rhizobium*. Considerable differences in the production and metabolism of N_2O were seen among the denitrifying strains, but some strains did not reduce nitrate.

21. NITROGEN EFFECTS

2101 Interactions between symbiotic nitrogen fixation, combined N appli-
2496 cation, and photosynthesis in *Pisum sativum*.
Bethlenfalvay, G.J. (U California, Davis, CA, USA) and D.A. Phillips.
Physiol Plant 42(1):119-123, 1978.
Plants with and without supplied combined nitrogen were grown under three photosynthetic photon flux densities (PPFD), from severely limiting to near saturation. Carboxylation efficiencies and CO_2 exchange rates were highest in symbiotic plants and lowest in those supplied with ammonia. An interrelationship between PPFD and the availability of combined nitrogen was shown.

2102 Interdependence of nitrogen nutrition and photosynthesis in *Pisum*
2278a *sativum* L. 1. Effect of combined nitrogen on symbiotic nitrogen fixation and photosynthesis.
Bethlenfalvay, G.J. (U California, Davis, CA, USA), S.S. Abu-Shakra and D.A. Phillips.
Plant Physiol 62:127-130, 1978.
The idea that low levels of combined N promote symbiotic N_2 fixation was supported by this study. The carbon dioxide exchange rate was maximal in nodulated plants at 2 mM NH_4^+.

2103 Interdependence of nitrogen nutrition and photosynthesis in *Pisum*
2278b *sativum* L. II. Host plant response to nitrogen fixation by *Rhizobium* strains.
Bethlenfalvay, G.J. (U California, Davis, CA, USA), S.S. Abu-Shakra and D.A. Phillips.
Plant Physiol 62:131-133, 1978.

The data from this study revealed that photosynthetic parameters in genetically uniform plants grown under identical environmental conditions are affected by the nitrogen fixing characteristics of the rhizobial symbiont. The highest fixation rates were 6 times that of the lowest, and were associated with correspondingly higher CO_2 exchange rates.

2104 The effect of ammonium nitrate on the synthesis of nitrogenase and
2252 the concentration of leghemoglobin in pea root nodules induced by *Rhizobium leguminosarum*.
Bisseling, T. (Agric U, Wageningen, The Netherlands), R.C. van den Bos and A. van Kammen.
Biochim Biophys Acta 539(1):1-11, 1978.

The decrease of nitrogen fixation occurring after addition of NH_4NO_3 was attributed to a lowering of leghemoglobin concentration. Ammonium nitrate did not affect the synthesis of nitrogenase nor decrease the number or relative protein content of the bacteroids.

2105 Utilization of N^{15} fertilizer by nodulating and non-nodulating soy-
3083 bean isolines.
Deibert, E.J. (U Nebraska Agr Exp Stn, Lincoln, NB, USA), M. Bijeriego and R.A. Olson.
Agron J 71(5):717-723, 1979.

Fertilization of nodulating isolines had no significant influence on yield or N and oil concentration. Fertilizer applied at planting at rates above 45 kg N/ha reduced the symbiotically fixed N fraction, but delayed fertilizer application had no such effect at even much higher N rates.

2106 Nitrate-N and *Rhizobium* strain roles in alfalfa seedling nodulation
3037 and growth.
Heichel, G.H. (USDA Sci Educ Admin, St. Paul, MN, USA) and C.P. Vance.
Crop Sci 19(4):512-518, 1979.

Nodulation declined from 84% at zero N to 53% at 50 µg N/ml. There were significant differences between strains in the effects of N on nodulation. Selection of strains at ambient N levels was suggested.

2107 Influence of combined nitrogen on the symbiosis between single colony
2801 isolates of *Rhizobium* CB756 and *Macrotyloma axillare*.
Herridge, D.F. (Hort Res Stn, Narara, NSW, Australia) and R.J. Roughley.
J Appl Bact 38:75-78, 1975.

The presence of combined N caused a decrease in time to nodulation in indirect proportion to the effectiveness of the sub-strain. Whether this resulted from enhanced photosynthetic activity by the plant or stimulation of rhizobia in the rhizosphere remains uncertain.

2108 Nitrogen fertilization in establishing forage legumes.
2162 Hojjati, S.M. (Pahlavi U, Shiraz, Iran), W.C. Templeton, Jr. and T.H. Taylos.
Agron J 70(3):429-433, 1978.
Greenhouse experiments indicated the need for further research to clearly establish N requirements for establishing forage legumes.

2109 Influence of ammonium chloride on the nitrogenase activity of nodu-
2595 lated pea plants (*Pisum sativum*).
Houwaard, F. (Agric U, Wageningen, The Netherlands).
Appl Envir Micro 35(6):1061-1065, 1978.
A 20 to 40% drop in nitrogenase activity was measured when ammonium chloride at 20 mM was supplied to nodulated plants at the peak of their acetylene-reducing activity. The effect was attributed to a reduced supply of photosynthates to the bacteroids.

2110 Effect of ammonium chloride and methionine sulfoximine on the
2485 acetylene reduction of detached root nodules of peas (*Pisum sativum*).
Houwaard, F. (St Agr U, Wageningen, The Netherlands).
Appl Envir Micro 37(1):73-79, 1979.
Nitrogenase activity was significantly reduced by addition of NH_4Cl to the buffer solution in which nodules were submerged. Activity was partially restored when the nodules were replaced in a buffer solution without ammonium chloride. Simultaneous addition of ammonium chloride and methionine sulfoximine largely eliminated the inhibition.

2111 Effect of nitrogen source on nodulation, nitrogen fixation and
2657 mineral content of soybean in solution culture.
Joseph, R.A. (U Catholique du Louvain, Belgium).
Madras Agric J 64(4):211-217, 1977.
Either NH_4 or NO_3 severely suppressed nodulation and nitrogen fixation. Addition of NH_4 produced plants with greater total N content than did addition of NO_3.

2112 Effect of nitrogen, *Rhizobium* inoculation and simazine on yield and
2192 quality of Bengal gram (*Cicer arietinum* L.).
Kadam, S.S. (Marathwada Agr U, Parbhani, India), K.G. Kachhave, J.K. Chavan and D.K. Salunkhe.
Plant Soil 47:279-281, 1977.
Application of starter N at 20 kg N/ha, along with inoculation and simazine, increased yield by 68%. Simazine slightly increased the methionine content of the gram.

2113 Regulation of symbiotic nitrogen fixation in root nodules of alfalfa
2661 (*Medicago sativa*) infected with *Rhizobium meliloti*.
Kamberger, W. (U Erlangen-Nunberg, Fed. Repub. Germany).
Arch Microbiol 115(1):103-108, 1977.
Nitrite suppressed symbiotic nitrogen fixation very quickly, but ammonia and nitrate acted more slowly and only when at higher concentrations.

Glutamate and glutamine interfered with nitrogenase activity only when together with ammonium or nitrate (which can be reduced to ammonium).

2114 3239 Growth response of inoculated peas *(Pisum sativum)* to combined nitrogen.
Mahon, J.D. (Prairie Reg Lab, Saskatoon, Sask., Canada) and J.J. Child.
Can J Bot 57:1687-1693, 1979.

Low levels of ammonium nitrate greatly increased the relative growth rate during the first phase of early vegetative growth. A period of nitrogen demand stress was shown in the first three weeks, after which combined nitrogen had a lessening effect. The early stimulation of leaf area development led to greater symbiotic capacity.

2115 1959 Mineral nutrition and the legume symbiosis.
Munns, D.N. (U California, Davis, CA, USA).
In Hardy, R.W.F. and A.H. Gibson, eds., A treatise on dinitrogen fixation, section IV. N.Y., Wiley, 1977, p. 353-391.

Nutritional requirements for legumes, rhizobia in the soil, and the legume/*Rhizobium* symbiosis were outlined, and the diagnosis and correction of nutritional disorders discussed. Contradictions and gaps in our knowledge of the complicated interrelationships between mineral nutrition, toxicity, pH and interspecific competition require additional research before quantitative response predictions can be made. 183 references.

2116 3021 The nitrate stress syndrome of the nodulated field pea (*Pisum Sativum* L.): Techniques for measurement and evaluation in physiological terms.
Oghoghorie, C.G.O. (Queen's U, Belfast, N Ireland) and J.S. Pate.
Plant Soil spec vol 1971, p. 185-202.

Nodulated plants supplied with constantly maintained levels of N^{15}-labeled nitrate were studied for nitrogenase and nitrate reductase activity and for relative distribution of symbiotic N - nitrate N in plant parts. It was found that nitrogen from nodular fixation always accumulated preferentially in the soluble and insoluble matter of shoot and nodules, whereas the root derived a disproportionately large share of N from the rhizosphere nitrate.

2117 2836 Effect of soil mineral N levels and inoculation on nodulation, nitrogenase activity, and grain yield of pigeon pea.
Quilt, P. (U West Indies, St. Augustine, Trinidad & Tobago) and R.C. Dalal.
Agron J 71(3):450-452, 1979.

Incorporation of coconut fiber and bagasse reduced soil mineral N levels through immobilization and led to early nodulation and nitrogenase activity. Inoculation with exotic strains of *Rhizobium* significantly increased grain yield when soil N was not decreased so drastically as to inhibit pre-nodulation growth.

2118 Growth, nodule activity and yield of soybeans as affected by the
3129 form and application method of combined nitrogen.
Rabie, R.K. (U Tokyo, Japan), Y. Arima and K. Kumazawa.
Soil Sci Plant Nutr 25(3):417-424, 1979.

In pot experiments comparing the effects of nitrate, ammonium and urea, surface applications had the greatest effect on dry matter accumulation and the least depressive effect on nodulation. Nitrate was the most depressive form of N on the nodule dry weight, while urea, except as a spray, had a promotive effect.

2119 Effect of N fertilizer on yield, protein content and symbiotic N
3084 fixation in fababeans.
Richards, J.E. (U Manitoba, Winnipeg, Man., Canada) and R.J. Soper.
Agron J 71(5):807-811, 1979.

The N requirements were fully met from soil and symbiotic fixation. The fababeans fixed 87.1% of their total N content, and substantial amounts were fixed after pod-fill.

2120 Effect of source of nitrogen on the growth of Fiskeby soya bean: the
3043 carbon economy of the whole plants.
Ryle, G.J.A. (Grassland Res Inst, Hurley, Berks., England), C.E. Powell and A.J. Gordon.
Ann Bot 42:637-648, 1978.

Nitrate-supplied and wholly-symbiotic plants were compared. The symbiotic plants assimilated only 25-30% as much N as those given nitrate. Nodulated plants grew more slowly due to insufficient N for optimal development, and greater energy demand to assimilate fixed N in roots than to reduce supplied nitrate in leaves.

2121 Relationship between nitrate level, nitrate reductase activity and
3142 anaerobic nitrate reduction in *Pisum sativum* leaf tissue.
Skrdleta, V. (Inst Exper Bot, Praha, Czechoslovakia), A. Gaudinova and M. Nemcova.
Biol Plant(Praha) 21(4):307-310, 1979.

The ratio of *in vivo*/*in vitro* nitrate reductase activity was in good agreement, especially at lower levels of endogenous nitrate in leaf tissue.

22. NITROGEN FIXATION

2201 Nitrogen fixation in pasture. I. Introduction and general methods.
2915 Ball, R. (DSIR, Palmerston N, NZ), R.W. Brougham, J.L. Brock, J.R. Crush, J.H. Hoglund and R.A. Carran.
NZ J Exper Agric 7(1):1-5, 1979.

A brief review of the literature relevant to the role of clover in the N cycle of high fertility pastures. A table describes the climate and soils of 10 trial sites, and the use of the acetylene reduction assay, for the series of reports introduced by this paper.

2202 Biological nitrogen fixation.
2985 Brill, W.J. (U Wisconsin, Madison, WI, USA).
In Hollaender, A., ed., Genetic engineering for nitrogen fixation. Washington, Natl Acad Sci, 1977, p. 18-20.
This brief report relates biological nitrogen fixation to the world food problem, with an outline of some avenues for research aimed at deriving greater benefits from BNF.

2203 Nitrogen fixation.
3077 Brill, W.J. (U Wisconsin, Madison, WI, USA).
In Gunsales, I.C., ed., The bacteria: a treatise on structure and function, V. 7. NY, Academic, 1979, p. 85-109.
This general review covers biochemistry, regulation, genetics, bacteria-plant and bacteria-animal nitrogen fixation associations, and the evolution of N_2 fixation. 175 references.

2204 Nitrogen fixation: basic to applied.
2964 Brill, W.J. (U Wisconsin, Madison, WI, USA).
Amer Scientist 67(4):458-466, 1979.
A non-technical overview of the importance of BNF and a survey of principal areas of research to enhance its benefits.

2205 Nitrogen fixation in pasture. 3. Gisborne Plains, Manutuke.
2917 Brown, N.S. (Manutuke Res Stn, Gisborne, NZ), M.H. Gray and D.P. Sinclair.
NZ J Exper Agric 7(1):11-13, 1979.
Despite low N fixation rates, available soil N permitted relatively high pasture production levels.

2206 Overview of biological N_2 fixation.
2364 Burris, R.H. (U Wisconsin, Madison, WI, USA).
In Hollaender, A., ed., Genetic engineering for nitrogen fixation. Washington, Natl Acad Sci, 1977, p. 21-30.
A summary of the history of scientific knowledge about biological nitrogen fixation, from Boussingault's experiments in the 1860's to current concepts. The author concludes that the best strategy for increasing BNF lies with the development, selection and application of legumes with the most effective strains of rhizobia, followed by expanded use of free-living and symbiotic blue-green algae, other bacterial associations, and then genetic engineering.

2207 Advances in biological nitrogen fixation.
2279 Burris, R.H. (U Wisconsin, Madison, WI, USA).
Dev Indus Micro 19:1-13, 1978.
A review of evidence supporting the concept of electron transfer in the functioning of nitrogenase to fix nitrogen. Problems remaining to be solved: establishing the rate limiting step; the total function of MgATP in the overall system; establishing why the hydrogen evolution system

escapes the carbon monoxide block whereas all the other nitrogenase-catalyzed reductions are so blocked; and an explanation for the fact that acetylene is a noncompetetive inhibitor of nitrogen reduction whereas N_2 is a competetive inhibitor of acetylene reduction.

2208 Nitrogen fixation in pasture. X. Southland, Gore.
2925 Carran, R.A. (DSIR, Gore, NZ)
NZ J Expor Agric 7(1):39-41, 1979.
Nitrogen fixation assays of soil cores from rotationally grazed pasture showed marked similarity in seasonal pattern over 2 years, with peaks in early spring and early summer.

2209 Recent advances in chemistry of nitrogen fixation.
2388 Chatt, J. (U Sussex, England), J.R. Dilworth and R.L. Richards.
Chem Rev 78(6):589-625, 1978.
A review of developments relevant to the chemistry of nitrogen fixation, 1971-1976. The Haber process was a response to dependence on Chilean saltpeter, and a similar chemical response is needed now to meet fossil fuel dependence. Contains 299 references.

2210 Nitrogen fixation in pasture. VIII. Wairarapa Plains dryland,
2923 Masterton.
Crouchley, G. (Masterton Fld Res Area, NZ).
NZ J Exper Agric 7(1):31-33, 1979.
The rate of N fixation generally reflected soil moisture patterns. There were indications of a substantial recharge of soil N in some years.

2211 Novel aspects of nitrogen fixation.
2072 Day, J.M. (Rothamsted Exp Stn, Harpenden, Herts., England) and J.F. Witty.
Outlook Agric 9(4):180-185, 1977.
While the legume/*Rhizobium* symbiosis is the most intensively studied form of biological nitrogen fixation, the contributions of other nitrogen-fixing soil bacteria and of blue-green algae, both free-living and symbiotic, are also important. Because the algae can photosynthesize their carbohydrate requirements, fix nitrogen, and survive in an extreme range of habitats, they avoid some of the limitations encountered with the other BNF systems.

2212 Biological nitrogen fixation for food and fiber production: what are
2551 some immediately feasible possibilities?
Evans, H.J. (Oregon St U, Corvallis, OR, USA) and L.E. Barber.
Science 197:332-339, 1977.
BNF by all types of organisms contributes an estimated 175 million metric tons of N per year, about half of which comes from nodulated legumes. Nonphotosynthetic, free-living bacteria fix nitrogen at very low rates compared to symbiotic associations or photosynthetic organisms. The urgent need for improving research on nodulated legumes was reiterated (in agreement with other studies), while genetic engineering and other

efforts for spectacular innovations in biological nitrogen fixation should be pursued as long term possibilities.

2213 Investigations of possible limitations of nitrogen fixation by
2589 legumes: (1) methodology, (2) identification, and (3) assessment of significance.
Hardy, R.W.F. (du Pont & Co, Wilmington, DE, USA), J.G. Criswell and U.D. Havelka.
In Recent developments in nitrogen fixation; an international symposium, 2d, 1976, p. 451-467 (pub. 1977).

A summary of recent work at the du Pont Experiment Station on limitations of N_2 fixation. Mainly concerned with soybeans, but with some information on peanuts and peas, the limitations emphasized were: photosynthate supply, reproductive sink intensity, rhizosphere temperature and pO_2. Techniques for quantitative assessment of these factors were discussed.

2214 Biological nitrogen fixation: a key to world protein.
2833 Hardy, R.W.F. (Du Pont & Co, Wilmington, DE, USA), R.C. Burns, R.R. Hebert, R.D. Holsten and E.K. Jackson.
Plant & Soil Spec Vol 561-590, 1971.

This review focuses on the study and measurement of the biochemical processes involved in biological nitrogen fixation. It was concluded that nitrogen fertilizer will continue to be important in agricultural production, but that enhanced symbiotic nitrogen fixation in the near term, and extending the symbiotic system to other crops in the long term, are the major potential contributors to a nitrogen-hungry but environmentally conscious world.

2215 Regulation of nitrogen fixation in a grazed pasture.
2284 Hoglund, J.H. (DSIR, Palmerston N, NZ) and J.L. Brock.
NZ J Agric Res 21:73-82, 1978.

Nitrogenase activity was approximately 28% higher during years with a cool, moist summer compared to dry, warm summers. A pattern of increased legume growth when mineral N is low, and increased grass growth when, following grazing, the availability of mineral N causes a reduction in symbiotic nitrogen fixation, was suggested.

2216 Nitrogen fixation in pasture. XII. General discussion.
2927 Hoglund, J.H. (DSIR, Palmerston N, NZ), J.R. Crush, J.L. Brock, R. Ball and R.A. Carran.
NZ J Esper Agric 7(1):45-51, 1979.

The results of studies conducted at 9 representative sites indicated that annual N fixation in developed lowland pastures was around 184 kg N/ha, or less than half the value previously thought to occur. Significant positive correlations between the soil carbon/nitrogen ratio and N fixation were found.

2217 Biological N fixation in forage-livestock systems; proceedings of
2050 1975 symposium.

Hoveland, C.S. (Auburn U, AL, USA), W.E. Knight and G.C. Marten, eds. Amer Soc Agron spec pub no 28. Madison, WI, ASA, 1976, 127 p.
The first chapter, by Silver and Hardy, is entered separately in this bibliography. Other chapters deal with legume N vs fertilizer N for cool season and warm season pastures, effects of legumes on performance of grazing animals, and economic comparisons of legume and fertilizer N. The data were derived from temperate climate situations, but argue persuasively for the economic importance of pasture legumes.

2218 Symbiotic and asymbiotic N_2 fixation in a tall grass prairie.
2486 Kapustka, L.A. (U Wisconsin, Superior, WI, USA) and E.L. Rice.
Soil Biol Biochem 10(6):553-554, 1978.
The contribution of asymbiotic nitrogen fixation in a temperate prairie with a relatively low natural density of legumes was 4 to 14 times that of symbiotic nitrogen fixation.

2219 Nitrogen fixation and poly-β-hydroxybutyric acid content in bacteroids
2061 of *Rhizobium lupini* and *Rhizobium leguminosarum*.
Kretovich, W.L. (Bach Inst Biochem, Moscow, USSR), V.I. Romanov, L.A. Yushkova, V.I. Shramko and N.G. Fedulova.
Plant Soil 48(2):291-302, 1977.
A reverse correlation between the intensity of respiration and nitrogen fixation on the one hand, and the content of poly-β-hydroxybutyric acid on the other, was found when those parameters were studied either at midday or midnight. It appeared likely that ammonium-enhanced PHB breakdown is one of the regulatory mechanisms which relate polymer metabolism to nitrogen fixation.

2220 Nitrogen fixation in pasture. IV. Central North Island pumice-land,
2918 Wairakei.
O'connor, M.B. (Raukura Agr Res Ctr, Hamilton, NZ), P.N. Prime and R.C. Wilkinson.
NZ J Exper Agric 7(1):15-17, 1979.
This rotationally grazed pasture produced 7.3 t DM/ha, of which 26% was white clover. Total annual fixation was 141 and 170 kg N/ha for the two years of the study.

2221 MO study of molecular nitrogen fixation. I. model systems: $[N_2+H]^{\cdot}$,
2811 $[N_2+H]^{+}$, $[N_2+H]^{-}$.
Pelikan, P. (Slovak Tech U, Bratislava, Czechoslovakia), M. Haring, M. Ceppan, M. Breza, M. Liska and L. Turi Nagy.
J Molec Catal 5(5):349-362, 1979.
Due to the extraordinary complexity of the biocatalytic systems involved, detailed studies of reaction mechanisms of molecular nitrogen fixation are impossible. Theoretical models are, therefore, useful. The N_2 molecule is the most stable of all diatomic molecules, with an ionization potential of 15.6 eV and an electron affinity of -3.64 eV. The critical step is splitting of the first bond. This study showed that only 3 reaction coordinates (see in title above) are important with respect to N fixation,

thus reducing the number of possible arrangements in further theoretical studies leading to a modeling of the ligand sphere.

2222 Nitrogen fixation in pasture. II. Northland warm temperate, Kaikohe.
2916 Rumball, P.J. (DSIR, Kaiohe, NZ).
NZ J Exper Agric 7(1):7-9, 1979.
White clover is the dominant legume in better pasture soils, progressively replaced by *Lotus pedunculatus* or annual legumes under less favorable conditions. Soil water availability was apparently more important than temperature variation in determining the pattern and total of nitrogen fixation at this site.

2223 Nitrogen enrichment of soil and plant by *Rhizobium phaseoli* -
2911 *Phaseolus vulgaris* symbiosis.
Ruschel, A.P. (U Sao Paulo, Piracicaba, Brazil), E. Salati and P.B. Vose.
Plant Soil 51(3):425-429, 1979.
Some soil enrichment with fixed ^{15}N was detected following growth and removal of bean plants.

2224 Newer developments in biological dinitrogen fixation of possible
3190 relevance to forage production.
Silver, W.S. (U S Florida, Tampa, FL, USA) and R.W.F. Hardy.
In Hoveland, C.S. et al, eds., Biological N fixation in forage-livestock systems. Madison, WI, Amer Soc Agron spec pub 28, 1976, p. 1-34.
Grain legumes fix an average of 75 kg N_2/ha per year, while forage legumes fix about double that rate. Alfalfa achieves a high of 300 kg N_2/ha per year. This chapter is a general review of the biochemistry, physiology, genetics and economics of symbiotic nitrogen fixation, with 123 references.

2225 Dinitrogen fixation - acetylene reduction in soybeans during the
3141 reproductive growth period.
Skrdleta, V. (Inst Exp Bot, Praha, Czechoslovakia), V. Nasinec, A. Hyndrakova and M. Nemcova.
Biol Plant (Praha) 20(3):210-216, 1978.
Total and specific nitrogenase activities peaked 63 days after sowing, near the end of flowering. Photosynthetic activity and nodule weight were the most influential factors in the first exponential portion of nitrogenase activity under controlled-moisture greenhouse conditions.

2226 Nitrogen fixation in alfalfa: an overview.
3029 Vance, C.P. (U Minnesota, St. Paul, MN, USA).
In Proceedings 5th alfalfa symposium, Bloomington, MN, 1978, p. 34-41.
A brief description of the infection and nodulation processes, nitrogen fixation, effects of cultural practices on nodule function, and research needs in the alfalfa symhiosis.

2227 Nitrogen fixation, nodule development, and vegetative regrowth of
2969 alfalfa (*Medicago sativa* L.) following harvest.
Vance, C.P. (USDA Sci Educ Admin, St. Paul, MN, USA), G.H. Heichel, D.K. Barnes, J.W. Bryan and L.E. Johnson.
Plant Physiol 64(1):1-8, 1979.

Top removal caused an 88% decline in acetylene reduction capacity compared to unharvested plants. After 18 days of regrowth, acetylene reduction was comparable between the harvested and unharvested plants. Soluble protein and leghemoglobin decreased in nodules from harvested plants in an inverse relationship to increased protease activity. Nodules which had degenerated at the proximal end following harvest began to regrow and fix nitrogen when shoot growth had resumed.

2228 Symbiotic N_2 (C_2H_2) fixation by bean.
2499 Westermann, D.T. (Snake River Conserv Res Ctr, Kimberly, ID, USA) and J.J. Kolar.
Crop Sci 18:986-990, 1978.

Nitrogen fixing activity rapidly increased as plant development progressed from the three-node vegetative (V3) to early pod-filling (R3-R4), then decreased to zero at physiological maturity (R9). There was a five- to sixfold difference in accumulated seasonal activity between cultivars which was significantly related to average nodule weight and plant dry weight. The possibility of increasing both seed yield and symbiotic N_2 fixation by isolating and recombining lines with high symbiotic capabilities was suggested.

2229 Nitrogen fixation in pasture. XI. White clover populations at 9 sites
2926 in New Zealand.
Williams, W.M. (DSIR, Palmerston N, NZ) and E. Cornege.
NZ J Exper Agric 7(1):43-44, 1979.

Improved pedigrees of white clover have been available to farmers for nearly fifty years, but clovers with inferior productivity still predominate in old and even some new pastures.

2230 Nitrogen fixation and agricultural productivity.
2298 Wittwer, S.H. (Michigan Agr Exp Stn, E Lansing, MI, USA).
BioSci 28(9):555, 1978.

Four research initiatives were suggested: 1) establishment of rhizobial technology centers, 2) research in farming systems making greater use of legumes, 3) genetic engineering to improve both host and microsymbiont, and 4) improved biological nitrogen fixation associations with grasses, cereal grains and other non-legumes.

23. NITROGEN FIXATION - DETECTION AND MEASUREMENT

2301 An attempt at estimating the rate of symbiotic fixation of nitrogen
2237 in the lupine by natural isotopic tracing (^{15}N). (Fre)
Amarger, N. (Lab Microbiol du Sols, Dijon, France), A. Mariotti and F. Mariotti.
Compt Rend Hebd Acad Sci D 284(21):2179-2182, 1977.

The rate of symbiotic nitrogen fixation was accurately determined by comparing differences in the natural isotopic N fraction of atmosphere, plant, and soil nitrogen.

2302 3244 Rapports isotopiques naturels de l'azote. II. Application à la measure de la fixation symbiotique de l'azote *in situ*. (Fre)
Bardin, R. (U Lyon, France), A.M. Domenach and A. Chalamet.
Rev Ecol Biol Sol 14(3):395-402, 1977.

A formula was devised for overcoming variations in natural isotopic N in the computation of the proportion of symbiotically fixed N in plants.

2303 3071 Acetylene reduction assay on white clover genotypes and on grass/clover swards.
Connolly, V. (Oak Park Res Ctr, Carlow, Ireland) and M. O'keefe.
Ann Appl Biol 93(1):55-61, 1979.

Variation in nitrogenase activity per unit dry weight was concluded to reflect differences in seasonal growth pattern of the cultivars. The *in situ* method employed offers a means for monitoring nitrogenase activity under varying conditions without disruption of the sward.

2304 2379 Effects of long term treatment with acetylene on nitrogen fixing microorganisms.
David, K.A.V.(Westfield Coll, U London, England) and P. Fay.
Appl Environ Micro 34(6):640-646, 1977.

Evidence obtained from blue-green algae and asymbiotic nitrogen fixing bacteria indicated that long-term incubation with acetylene may lead to grossly overestimated nitrogen fixation equivalents.

2305 2870 Nitrogen isotope distribution as a presumptive indicator of nitrogen fixation.
Delwiche, C.C. (U California, Davis, CA, USA), P.J. Zinke, C.M. Johnson and R.A. Virginia.
Botan Gaz 140:S 65-S 69, 1979.

Under proper conditions and with appropriate cautions, a lower $^{15}N/^{14}N$ ratio of nitrogen-fixing organisms compared to non-fixers may provide a means of screening mixed populations for individuals fixing nitrogen.

2306 3243 Rapports isotopiques naturels de l'azote. I. Premieres résultats: sols de Dombes. (Fre)
Domenach, A.M. (U Lyon, France) and A. Chalamet.
Rev Ecol Biol Sol 14(2):279-287, 1977.

The natural ^{15}N content of soils, water and plants showed isotopic variations which may affect the ratios obtained in quantitative tests. Organisms which fractionate the nitrogen isotopes may be partly responsible for the differences.

2307 2579 Symbiotic nitrogen fixation in a sequence of pastures of increasing age measured by a ^{15}N dilution technique.
Edmeades, D.C. (U Canterbury Lincoln Coll, Canterbury, NZ) and K.M. Goh.

NZ J Agr Res 21(4):623-628, 1978.
The uptake of soil N by clover was 7-19% of the total for the pastures, reflecting the clover composition of the pastures. Older pastures had a greater efficiency of symbiotic N fixation (ratio of fixed-N to total N), but the actual rate of symbiotic N fixation declined with pasture age and gradual deterioration.

2308 2580 Use of the ^{15}N-dilution technique for field measurement of symbiotic nitrogen fixation.
Edmeades, D.C. (Ruakura Agr Res Ctr, Hamilton, NZ) and K.M. Goh.
Commun Soil Sci 10(3):513-520, 1979.
At both harvests, the ratio of ^{15}N calculated from the enriched herbage was less than that from natural herbage. Available evidence points to either fractionation during N_2-fixation, during plant uptake, or both as the likely reason for the apparent anomaly. Other studies have shown small N isotope fractionation and also the possibility of isotopic discrimination during plant uptake.

2309 2831 Measurement of nitrogenase activity of intact legume symbionts *in situ* using the acetylene reduction assay.
Fishbeck, K. (Oregon St U, Corvallis, OR, USA), H.J. Evans and L.L. Boersma.
Agron J 65:429-432, 1973.
Acetylene reduction rates for either intact nodulated plants in Perlite or nodulated root systems removed from Perlite were significantly greater than that of detached nodules from comparable cultures. Attempts to assay legumes in soil were complicated by variations in gas diffusion and nodule activity as influenced by water content.

2310 2123 Field measurements of symbiotic nitrogen fixation in an established pasture using acetylene reduction and a ^{15}N isotope method.
Goh, K.M. (Lincoln Coll, Canterbury, NZ), D.C. Edmeades and B.W. Robinson.
Soil Biol Biochem 10(1):13-20, 1978.
To obtain a reliable estimate of acetylene reduction, it was necessary to integrate day-to-day and diurnal variations. A 3 hour incubation in the acetylene reduction assay correlated best with data obtained by a ^{15}N technique. One hour of incubation led to an over-estimation of nitrogen fixation, and a 6 hour incubation to an under-estimation.

2311 1503 The acetylene reduction assay as a means of studying nitrogen fixation in white clover under sward and laboratory conditions.
Halliday, J. (U Western Australia, Nedlands, WA) and J.S. Pate.
J Brit Grassl Soc 31(1):29-35, 1976.
Effects of shading, temperature and defoliation were studied. Optimum temperature for nitrogenase activity was in the range 13-26°C, which corresponds to soil temperatures encountered during the April to September period of greatest activity in the field. Defoliation and shading both

had a drastic effect on acetylene reduction rates. The acetylene reduction assay offers a possible means of monitoring pasture management effects on nitrogen fixation.

2312 2600 Nitrogen fixation of four legumes in relation to above-ground biomass, root biomass, nodule number, and water-content of the soil.
Holter, V. (U Copenhagen, Denmark).
Oikos 31(2):230-235, 1978.
An investigation of the methodology for determining nitrogen fixation in a grassland community on reclaimed, clacy soil. Several parameters were studied in the four legumes to determine which plant characteristic was best correlated to acetylene reduction, and to ascertain the cut-off point of acetylene reduction caused by drought. Data for selecting suitable characteristics in various situations were provided.

2313 2228 Root and nodule respiration in relation to acetylene reduction in intact nodulated peas.
Mahon, J.D. (Prairie Reg Lab, Saskatoon, Sask., Canada).
Plant Physiol 60(6):812-816, 1977.
In general, a consistent linear relationship existed between total root and nodule respiration, and C_2H_2 reduction under various conditions of light and dark, defoliation and age.

2314 2211 Evaluation of a non-destructive acetylene reduction assay of nitrogen fixation for pasture legumes grown in pots.
Sinclair, A.G. (Invermay Agr Res Ctr, Mosgiel, NZ), R.B. Hannagan, P. Johnstone and A.K. Hardacre.
NZ J Exper Agric 6:65-68, 1978.
Potted plants were incubated in plastic containers for 2 hours with 200 ml acetylene, and ethylene production measured. Nitrogen fixation was also calculated by analysis of plant tissue. The respective rates were closely related within species and temperature/moisture treatments. The differences between lotus, clovers and lucerne were large, and could give a distorted view of the comparative N_2-fixing activities of different species.

2315 2141 A simple and inexpensive culture tube method for assaying acetylene reduction by facultative and anaerobic nitrogen-fixing bacteria.
Tu, C.M. (Res Inst, Agr Canada, London, Ont., Canada).
Commun Soil Sci Plant Anal 9(3):243-247, 1978.
A system employing a vial within a stoppered test tube from which atmospheric gases have been flushed by argon was devised to overcome the problem of false assessment due to oxygen sensitivity of the bacteria.

2316 2068 Clover N-fixation measurement by total-N difference and ^{15}N A-values in lysimeters.
Williams, W.A. (U California, Davis, CA, USA), M.B. Jones, and C.C. Delwiche.
Agron J 69(6):1023-1024, 1977.
In 15 comparisons (5 treatments x 3 years), the total-N difference and

^{15}N methods were strongly linear, yielding the same estimate at 338 kg N/ha fixed, but below that level the A value yielded much higher estimates than the difference method.

2317 Acetylene reduction assay can overestimate nitrogen-fixation in soil.
2678 Witty, J.F. (Rothamsted Exp Stn, Harpenden, Herts., England).
Soil Biol Biochem 11(2):209-210, 1979.
$^{14}C_2H_2$ was used to determine the source of ethylene produced in soil core assays. In a temperate pasture core, only 43% of the ethylene was derived from introduced acetylene.

24. NITROGENASE

2401 Complementary functioning of the component proteins of nitrogenase
2428 from several bacteria.
Emerich, D.W. (U Wisconsin, Madison, WI, USA) and R.H. Burris.
J Bact 134(3):936-943, 1978.
Of 56 possible heterologous crosses, 45 generated active hybrid nitrogenases. Both the Fe and the MoFe components from soybean nodules formed active complexes with complementary proteins from all the other organisms except *Clostridium pasterianum*.

2402 Preparation of nitrogenase from nodules and separation into
3097 components.
Evans, H.J., B. Koch and R. Klucas.
Meth Enzym 25:470-476, 1972.
Phenolic compounds in legume nodules react with, and denature, nitrogenase when the nodules are mascerated in air. By avoiding contact with oxygen during masceration of nodules and preparation of extracts of bacteroids, non-oxidized phenolic compounds could be removed and crude extracts with active nitrogenase could be consistently prepared. Procedures for purification and fractionation of the extracts were described.

2403 Effect of cyclic guanosine 3',5'-Monophosphate on nitrogen fixation
2956 *Rhizobium japonicum*.
Lim, S.T. (U California, Davis, CA, USA), H. Hennecke and D.B. Scott.
J Bact 139(1):256-263, 1979.
Addition of exogenous cGMP at 0.1 mM to a free-living culture of soybean rhizobia completely inhibited the expression of nitrogenase activity and markedly inhibited the expression of hydrogenase and nitrate reductase activity. The relative concentration for inhibition indicated that the action was not simply competetive inhibition of cAMP. The levels of cGMP may be under redox control such that a decrease in oxygen concentration in the medium lowers the cGMP levels, allowing the expression of enzyme systems active under N-fixing conditions.

2404 Evidence for one-electron transfer by the Fe protein of nitrogenase.
2233 Ljones, T. (U Wisconsin, Madison, WI, USA) and R.H. Burris.
Biochem Biophys Res Comm 80(1):22-25, 1978.

By using dithionite, a 2-electron donor, it was calculated that the Fe protein molecule of nitrogenase from *Clostridium pasteurianum* accepts one electron rather than two as previously suggested.

2405 Simulation of electron-paramagnetic-resonance spectrum of iron-
2447 protein of nitrogenase. A prediction of existence of a second paramagnetic centre.
Lowe, D.J. (U Sussex, Brighton, England).
Biochem J 175(3):955-957, 1978.

Unusual characteristics of the e.p.r. spectra can be explained by assuming that one of the two electrons accepted by the Fe-protein is located at a rapidly relaxing paramagnetic centre which is unobservable by e.p.r. but causes anisotropic broadening of the e.p.r. signal of the other electron.

2406 Regulation of nitrogenase biosynthesis in microorganisms.
2680 L'vov, N.P. (A.N. Bakh Inst Biochem, Moscow, USSR), N.S. Sergeev and V.L. Kretovich.
Biol Bul Acad Sci USSR 2(1):27-36, 1975 (Eng tr 1976).

A review of the influence of bound nitrogen and pO_2 in the medium on nitrogenase biosynthesis as related to the genetics of nitrogen-fixing microorganisms. A complex and flexible mechanism for the regulation of nitrogenase synthesis has evolved in nitrogen-fixing microorganisms which permits them to adapt rapidly to changing environmental conditions.

2407 Separation into components and recombination of nitrogenase from
2686 lupine bacteroids.
Martynova, E.M. (A.N. Bakh Inst, Moscow, USSR), K.B. Aseeva, Z.G. Evstigneeva and V.L. Kretovich.
Dokl Biochem Akad Nauk SSSR 228:277-279, 1976 (Eng tr).

Nitrogenase was isolated and purified under strictly anaerobic conditions using argon gas. Separation into protein components (molybdoferrodoxin and azoferrodoxin) was accomplished in a column with DEAE-cellulose. Neither of the fractions individually possessed nitrogenase activity.

2408 Structure and function of nitrogenase.
2961 Mortenson, L.E. (Purdue U, W Lafayette, IN, USA) and R.N.F. Thorneley.
Ann Rev Biochem 48:387-418, 1979.

A review of nitrogenase of 5 asymbiotic species of nitrogen-fixing bacteria. There are sections on the structure of the Fe and MoFe proteins, the effect of MgATP and MgADP on the Fe protein, and the mechanism of nitrogenase catalysis. A schematic model of reactions occurring in the reduction of N_2 and nonphysiological substrates was presented. 147 refs.

2409 Chemical evolution of a nitrogenase model. VI. The reduction of
3058 CN^-, N_3^-, N_2O, N_2 and other substrates by molybdocysteine catalysts in the presence of nucleoside phosphates.
G.N. Schrauzer (U California San Diego, La Jolla, CA, USA), G.W. Kiefer, P.A. Doemeny and H. Kisch.
J Amer Chem Soc 95(17):5582-5592, 1973.

The reactions of these nonenzymatic models, as with nitrogenase, were stimulated by ATP and other nucleoside phosphates. Other catalytic effects and rates of reduction were similar for the chemical model and the enzyme. Isotopic experiments indicated that the fixation of N_2 is molybdenum-specific.

2410 New cluster model for the FeMo-cofactor of nitrogenase.
2896 Teo, B.K. (Bell Tel Labs, Murray Hill, NJ, USA) and B.A. Averill.
Biochem Biophys Res Comm 88(4):1454-1461, 1979.
The proposed structural model consists of two Fe_4S_4 clusters bridged by an S_2Mo_2 unit. This is consistent with available chemical, spectroscopic and EXAFS data. A mechanism for nitrogen fixation based on the structural model for this cofactor of nitrogenase was suggested.

2411 Chemical evolution of a nitrogenase model. 17. Simulation of
2536 steric and of inhibitory effects at the enzymic active site with acetylenes and nitriles as the substrates, and "molybdoinsulin" catalysts.
Weathers, B.J. (U California San Diego, La Jolla, CA, USA), J.H. Grate and G.N. Schrauzer.
J Amer Chem Soc 101(4):917-924, 1979.
This study indicated that molybdate forms catalytically active complexes primarily with protein sulfhydryl groups. Reduction of acetylene with molybdoinsulin catalysts proceeded at rates similar to those observed with FeMo-co, showing that the non-heme iron compounds in FeMo-co do not participate effectively in the electron transfer from external reductant to the Mo active site, and that Fe centers are not involved in acetylene reduction.

2412 Chemical evolution of a nitrogenase model. 18. Reduction of molec-
2537 ular nitrogen with molybdoinsulin catalysts.
Weathers, B. J. (U California San Diegom La Jolla, CA, USA), J.H. Grate, N.A. Strampach and G.N. Schrauzer.
J Amer Chem Soc 101(4):925-928, 1979.
This study reaffirmed that substrate reductions of nitrogenase are typical of mononuclear Mo active site and that nonheme Fe-S or Mo-S-Fe clusters are not required for the simulation of nitrogenase reactions in artificial systems. The concept that the substrate chemistry of nitrogenase is molybdenum chemistry was supported by this work.

2413 The molybdenum-iron-sulfur cluster complex $[Mo_2Fe_6(SC_2H_5)_8]^{3-}$. A
2697 synthetic approach to the molybdenum site in nitrogenase.
Wolff, T.E. (Stanford U, Palo Alto, CA, USA), J.M. Berg, C. Warrick, K.O. Hodgson, R.H. Holm and R.B. Frankel.
J Amer Chem Soc 100(14):4630-4632, 1978.
A crystaline species consistent with a hypothetical Mo-Fe-S cluster unit implicated in the molybdenum site in nitrogenase was synthesized and characterized. Although not yet definitive, it was reported in this communication as being the closest synthetic approach available at the time.

2414 Synthetic approaches to the molybdenum site in nitrogenase.
2952 Preparation and structural properties of the molybdenum-iron-sulfur "double-cubane" cluster complexes $[Mo_2Fe_6S_8(SC_2H_5)_9]^{3-}$ and $[Mo_2Fe_6S_9(SC_2H_5)_8]^{3-}$.
Wolff, T.E. (Stanford U, Palo Alto, CA, USA), J.M. Berg, K.O. Hodgson, R.B. Frankel and R.H. Holm.
J Amer Chem Soc 101(15):4140-4150, 1979.

X-ray absorption fine structure (EXAFS) properties for the 2 clusters were studied and described, leading to the conclusion that the immediate environments of Mo in nitrogenase in these clusters are closely related and thus directly implicate Mo in the enzyme in a Mo-Fe-S cluster. By the criterion of EXAFS, the unsymetrically bridged species more closely resembles that in the enzyme.

2415 Self-assembly of molybdenum-iron-sulfur clusters as a synthetic
3034 approach to the molybdenum site in nitrogenase. Identification of the major products formed by the system $FeCl_3/MS_4^{2-}/C_2H_5SH$ (M=Mo,W).
Wolfe, T.E. (Stanford U, Palo Alto, CA, USA), J.M. Berg, P.P. Power, K.O. Hodgson, R.H. Holm and R.B. Frankel.
J Amer Chem Soc 101(18):5454-5456, 1979.

The principal Mo-containing products were documented to have been formed as "double-cubane" complexes I ($[Mo_2Fe_6S_9(SEt)_8]^{3-}$), II ($[Mo_2Fe_6S_8(SEt)_9]^{3-}$ and III ($[Mo_2Fe_7S_8(SEt)_{12}]^{3-}$. These structures, with different bridging units, were illustrated.

2416 A ^{19}F NMR method for identification of iron-sulfur cores extruded
2904 from active centers of proteins, with applications to milk xanthine and the iron-molybdenum proteins of nitrogenase.
Wong, G.B. (Stanford U, Palo Alto, CA, USA), D.M. Kurtz, Jr., R.H. Holm, L.E. Mortenson and R.G. Upchurch.
J Amer Chem Soc 101(11):3078-3090, 1979.

A Fourier transform ^{19}F NMR method using alternative extrusion reagent to avoid intereference by protein visible chromophores such as flavins was devised and evaluated. The method afforded a high recovery of the core. An Fe_4S_4 cluster which serves as an electron donor in the Fe protein of clostridial nitrogenase was identified.

25. NODULATION

2501 Root nodules in some members of Zygophyllaceae growing at Karachi
2684 University campus.
Athar, M. (U Karachi, Pakistan) and A. Mahmood.
Pak J Bot 4(2):209-210, 1972.

Nodules were found on the roots of *Tribulus terrestris*, *Zygophyllum simplex* and *Fagonia cretica*. The endophytes from the nodules of the first two species were assumed to be *Rhizobium* on the basis of cultural and staining characteristics.

2502 Qualitative study of the nodulating ability of legumes of Pakistan:
2603 List I.
Athar, M. (U Karachi, Pakistan) and A. Mahmood.

Pak J Bot 10(1):95-99, 1978.
Fifty-two species of the tribe Papilionaceae were either naturally nodulated or became nodulated when inoculated. Of these, five are new records according to Mrs. E.K. Allen.

2503 Root-nodule symbiosis between *Rhizobium* and *Parasponia* (Ulmaceae).
2861 Becking, J.H. (Inst Atom Sci Agr, Wageningen, The Netherlands).
Plant Soil 51(2):289-296, 1979.
Evidence that the nodulating "*Trema*" reported by Trinick in 1973 is a *Parasponia* species was confirmed by cytological and structural studies of *Parasponia* root nodules. Further evidence was obtained indicating that 3 *Trema* species bore no nodules. Bacterial isolation from *Parasponia parviflora* root nodules produced effective nodules in cowpea and siratro, and cytological studies identified the endophyte as rhizobial rather than actinomycetal.

2504 Development of the nitrogen-fixing and protein-synthesizing apparatus
2902 of bacteroids in pea root nodules.
Bisseling, T. (Agr U, Wageningen, The Netherlands), R.C. van den Bos, M.W. Weststrate, M.J. Hakkaart and A. Van Kammen.
Biochim Biophys Acta 562(3):515-526, 1979.
The apparent sequence was: leghemoglobin synthesis, then initiation of synthesis of nitrogenase component I followed by component II, with nodule development accompanied by a rapid decline in plant and bacterial protein synthesis and a corresponding decrease in bacteroid ribosomal RNA quantity and quality.

2505 Development of the nitrogen fixing apparatus in the legumes,
2360 *Centrosema pubescens* Benth., and *Vigna unguiculata* L. Walp.
Broughton, W.J. (U Malaya, Kuala Lumpur, Malaysia), C.H. Hoh, C.A. Behm and H.F. Tung.
Planta 139(2):183-192, 1978.
There was little difference in plant growth between plants supplied with nitrate and those deriving nitrogen from nodule activity. Nitrate reductase appeared to be the first measurable enzymatic activity in the nodules, followed by nitrogenase and leghemoglobin in that order.

2506 Number and diameter of nodules on *Glycine max* (L.) Merrill cultivar
3225 Santa Rosa.
Cordeiro, L. (U Sao Paulo, Brazil).
Rev Bras Biol 39(3):627-631, 1979.
Strains differing in nodule number and nodule size did not differ significantly in nodulating ability.

2507 Physiological studies on nodule formation. The characteristics and
2102 inheritance of abnormal nodulation of *Trifolium pratense* by *Rhizobium leguminosarum*.
Hepper, C.M. (Rothamsted Exp Stn, Harpenden, Herts., England).
Ann Bot 42(177):109-115, 1978.

Ineffective nodules were formed by *R. leguminosarum* on subterranean clover (100% infection rate) and red clover (5 to 7% infection rate), but not on three other clover species. Breeding of susceptible red clover plants produced a higher rate of nodulation frequency without loss of effectiveness with *Rhizobium trifolii*. These selectively bred plants are potentially useful for studying biochemical differences associated with cross-infection relationships.

2508 Nodulation of *Trifolium subterraneum* by *Rhizobium leguminosarum*.
2913 Hepper, C.M. (Rothamsted Exp Stn, Harpenden, Herts., England) and L. Lee.
Plant Soil 51(3):441-445, 1979.

Five strains of *R. leguminosarum* nodulated four clover cultivars in all but one combination. Nodule numbers and rates of formation were similar to those of an effective strain of *R. trifolii*, but the promiscuously formed nodules were ineffective. The unsuitability of using subclover for estimating *R. trifolii* populations by the plant infection method was pointed out.

2509 Ultrastructural study of the endomembrane system in infected cells
2862 of pea and soybean root nodules.
Kijne, J.W. (Biol Nitrogen Fixat Unit, Leiden, The Netherlands) and K. Planque.
Physiol Plant Pathol 14(3):339-345, 1979.

In the infection stage after rhizobial endocytosis, conspicuous ultrastructural changes in the endomembrane system of the host occur. These changes were described in relation to the development stages of nodulation.

2510 Root nodules of some tropical legumes in Singapore.
2494 Lim, G. (U Singapore) and H.L. Ng.
Plant Soil 46:317-327, 1977.

Nodulation was found in all but 2 of 55 legume species. Both of the non-nodulating legumes were of the Caesalpinoideae, and had dark colored roots. Seventeen rhizobial isolates were slow-growing, 3 very slow growing, and 14 were fast-growing. All slow-growers nodulated cowpea plants.

2511 Effect of detergent on rhizobia and nitrogen fixation.
2726 Prabha, S. (Haryana Agric U, Hissar, Haryana, India) and M.M. Mishra.
Soil Biol Biochem 9(5):373-374, 1977.

There was no *in vitro* growth of *Rhizobium trifolii* in the presence of tetrapropylene sodium alkyl benzene sulphonate (ABS), a common detergent constituent, at 50 ppm or above. At 25 ppm growth was about 50% of control. Chickpea *Rhizobium* was inhibited at 200 ppm ABS. In soil, where ABS may be degraded in 2 to 4 weeks, nodulation of berseem was enhanced when 25 and 50 ppm ABS was added at sowing, but nodulation decreased at 100 ppm or higher ABS.

2512 Initial stages of infection of alfalfa by nodule bacteria.
2775 Shil'nikova, V.K. (K.A. Tamiryazev Agr Acad, Moscow, USSR), L.A. Yarygin and A.M. Shatta.
Biol Bul Acad Sci USSR 2(2):289-295, 1975 (Eng tr 1976).
A nonrandomness of zonal distribution of twisted (curled) root hairs was statistically proven. A plant mechanism apparently prevents the development of rhizobia in the growing part of the root, but induces foci of infection activity at appropriate root hair infection points. Appearance of the first infected root hairs coincided with the first pair of true leaves.

2513 Effect of ascorbic acid on growth, yield, nodulation and nitrogen
2755 fixation in *Phaseolus aureus* Roxb.
Sinha, N.B. (Bose Inst, Calcutta, India), P.K. Nandi and P. Nandi.
Ind Agric 19(14):355-364, 1975.
Foliar spraying of AA at 25 and 100 mg/liter was stimulatory to growth and nodulation, but became inhibitory at higher concentrations.

2514 Effect of ascorbic acid on nodulation and root growth of *Phaseolus*
2175a *aureus* Roxb. in isolated root culture.
Symposium on Physiology of Microorganisms B 5401, 1978, p. 191-197.
Sinha, N.B. (Bose Inst, Calcutta, India) and P. Nandi.
Isolated root cultures in sand produced twice the number of nodules when 500 to 1000 mg/l ascorbic acid was added to the rooting medium.

2515 Effect of ascorbic acid on nodulation and root growth of *Phaseolus*
2175b *aureus* in isolated root culture.
Sinha, N.B. (Bose Inst, Calcutta, India) and P. Nandi.
J Soc Exper Agric 2(1):60-61, 1977.
Sterilized seeds were soaked in concentrations of 25 to 2500 mg ascorbic acid/liter distilled water for 2 hours. At lower concentrations, the AA stimulated lateral root formation and nodulation.

2516 Stem nodules in *Aeschynomene indica* and their capacity of nitrogen
2583 fixation.
Yatazawa, M. (Nagoya U, Japan) and S. Yoshida.
Physiol Plant 45(2):293-295, 1979.
The stem nodules reduced acetylene and contained reddish tissues. A rod-shaped bacterium from the stem nodules formed root and stem nodules on seedlings of *A. indica*.

26. NODULES

2601 N_2 fixing nodules in Ulmaceae: *Parasponia* or (and) *Trema* spp.?
3242 Akkermans, A.D.L. (U Wageningen, The Netherlands), S. Abdulkadir and M.J. Trinick.
Plant Soil 49(3):711-715, 1978.
Nodulated plants previously identified as *Trema cannabina* were probably *Parasponia parviflora* Mig. (Ulmaceae). The taxonomic distinctions were described.

2602 Indolic compounds of the bacteroid, membrane, and soluble fractions
2236 of yellow lupine nodules.
Alekseeva, I.I. (A.N. Bakh Inst Biochem, Moscow, USSR) and V.I. Shramko.
Sov Plant Physiol 24(1, pt. 2):114-118, 1977. (Eng tr)
Significant differences in indolic compounds between host plant tissues and bacteroids were recorded. The cause of higher IAA content in nodules was investigated, but remains uncertain.

2603 The diaphorase activity of a nonhemin ferroprotein from lupine
2401 nodules. (Rus)
Borodenko, L.I. (K.A. Tamiryazev Plant Physiol Inst, Moscow, USSR) and G.Y. Zhiznevskaya.
Fiziol Rast 25:455-463, 1978.
The iron content in the flavoprotein fraction was determined, and the characteristics studied by electrophoresis and gel filtration. The presence of NAD(P)H-dichlorophenolindophenol reductase activity and other characteristics made it possible to classify the protein with the soluble flavin NAD(P)H-dehydrogenases

2604 The development of root nodule xylem transfer cells in *Trifolium*
2282 *repens*.
Briarty, L.G. (U Nottingham, England).
J Exper Bot 29(110):735-747, 1978.
The development of transfer cells can be divided into the early amplification of cell surface area and a later phase in which wall synthesis has more or less stopped and the transfer function is presumably being executed. The suggested route for solutes in the xylem transfer cells is plasmodesmata-endoplasmic reticulum-plasmalemma.

2605 *Rhizobium* specific anthocyanin-like marker in lupin nodules.
2912 Caradus, J.R. (U Auckland, NZ) and W.B. Silvester.
Plant Soil 51(3):437-440, 1979.
The distinctive red pigmentation found in the nodules produced by this temperate *Rhizobium* may provide a useful marker for studying the fate of inoculum. The pigmented nodules had a lower proportion of bacteroid tissue and a lower nidtogenase activity than did normal nodules.

2606 A possible role of allantoin and the influence of nodulation on its
2334 production in soybean plants.
Fujihara, S. (U Osaka Pref, Sakai, Japan), K. Yamamoto and M. Yamaguchi.
Plant Soil 48(1):233-242, 1977.
Nodulated soybeans grown without N fertilizer had higher allantoin content in plant organs than did fertilized plants, but amino-N was comparatively lower. It appeared likely that allantoin was preferentially synthesized in nodules, and occurs especially when excess N is present.

2607 The effects of age, darkness, and nitrate on poly-β-hydroxybutyrate
2182 levels and nitrogen-fixing ability of *Rhizobium* in *Lupinus angustifolius*.
Gerson, T. (DSIR, Palmerston N, NZ), J.J. Patel and M.N. Wong.
Physiol Plant 42(4):420-424, 1978.
It was concluded that PHB functions as a reserve material in nodules for periods of restricted availability of photosynthates. Nitrate addition slightly delayed, but otherwise did not affect, PHB accumulation.

2608 Effect of rhizobial strain and host on the amino acid patterns in
2198 legume root nodules.
Greenwood, R.M. (DSIR, Palmerston N, NZ) and N.O. Bathurst.
NZ J Science 21:107-120, 1978.
Except in soybean nodules, the amino acid patterns tended to differ between strains of *Rhizobium*. It is possible that these compounds are synthesized by the bacteroids. The differences, which are pronounced in some strains, may serve to identify particular strains.

2609 Karyological and morphological observations on root nodules of some
2453 woody and herbaceous leguminous plants.
Kodama, A. (Hiroshima Agr Coll, Japan).
Bull Hiroshima Agr Coll 5(4):389-393, 1977.
A "tetraploid-apical" type of nodule was described for herbaceous legumes, and a contrasting "diploid-spherical" nodule for *Pueraria lobata*. A close relationship between nodule characteristics of meristematic tissue and other taxonomic differences was suggested.

2610 Mitosis of cells invaded by root nodule bacteria.
2390 Kodama, A. (Hiroshima Agr Coll, Japan).
Jpn J Genet 53(5):381-384, 1978.
In prophase the bacteria were found in the cytoplasm outside the chromosome mass, probably outside the nuclear membrane. The bacteria remained outside the spindle region of the invaded cell throughout subsequent mitosis. No mitosis was observed in the central part of the nodule after cells became packed with bacteroids, but the cell nucleus retained its identity.

2611 Nodule-specific plant protein (nodulin-35) from soybean.
2894 Science 205(4402):190-193, 1979.
Legocki, R.P. (McGill U, Montreal, Quebec, Canada) and D.P.S. Verma.
A polypeptide with a molecular weight of ~35,000 was found in both effective and ineffective nodules, but not in uninfected plants, bacteroids, or in free-living rhizobia. A plant rather than bacterial origin for the protein (nodulin-35) was suggested by immunoprecipitation reaction analysis.

2612 Effect of induced nodule senescence on parameters related to
2710 dinitrogen fixation, bacteroid size and nucleic acid content.
Paau, A.S. (U Houston, TX, USA) and J.R. Cowles.
J Gen Micro 111:101-107, 1979.

Nodule senescence in alfalfa and soybeans was induced by darkness and application of combined N. The alfalfa bacteroids decreased both in nucleic acid content and cell size, but those of soybean were essentially unaffected. The soybean nodules contain larger reserves of glucose which delays the effects of shutdown of photosynthesis. The mechanism of decreased nitrogenase activity and reduced bacteroid size induced by treatment with combined nitrogen remains uncertain.

2613 2767 Membranes in lupin root nodules. II. Preparation and properties of peribacteroid membranes and bacteroid envelope inner membranes from developing lupin nodules.
Robertson, J.G. (DSIR, Palmerston N, NZ), M.P. Warburton, P. Lyttleton, A.M. Fordyce and S. Bullivant.
J Cell Sci 30:151-174, 1978.

The density of the peribacteroid membranes decreased slightly during the period of development of nitrogen fixation. The ratio of lipid to protein was 6·1 for the bacteroid membranes and 2·5 for the bacteroid envelope inner membranes. Leghemoglobin was localized in the cytoplasm within the nodule and not in the bacteroid space.

2614 3241 Structure of nitrogen-fixing nodules formed by *Rhizobium* on roots of *Parasponia widersonii* Planch.
Trinick, M.J. (CSIRO, Wembley, W.A., Australia).
Can J Microbiol 25(5):565-578, 1979.

Nodules on this non-legume differed from typical legume nodules in that the rhizobia were not released from the infection thread. The walls of these threads varied greatly in thickness and were often without rigid walls. The fine structure of the bacteria did not appear to undergo changes until a late stage of senescence was reached.

2615 2306 Differentiation of nodules of *Glycine max*: ultrastructure studies of plant cells and bacteroids.
Werner, D. (Bot Inst, Lahnberge, Fed Rep Germany) and E. Mörschel.
Planta 141:169-177, 1978.

A sharp maximum of nitrogenase activity was recorded between 17 and 25 days after infection, followed by a 20-30% decline over the succeeding 15 days. The first bacteroids developed as single cells 11 days after infection. By 25 days the infected vacuoles had 3 to 5 bacteroids per section. At 35 days more than 50% of the bacteroid volume was occupied by poly-β-hydroxybutyrate. Several enzymatic interactions between the host and microsymbiont remain undetermined.

2616 3008 Anatomy and ultrastructure of root nodules of *Lupinus luteus*.
Wozny, A. (A. Mickiewicz U, Poznan, Poland) and F. Mlodzianowski.
Acta Soc Bot Pol 48(1):119-124, 1979.

The nodules from 1 month old lupine seedlings contained both transforming bacteria and typical bacteroids. Some membrane envelopes contained 2 bacteria. Vascularization was located close to the infected layer, but only at the side of attachment.

27. OXYGEN

2701 Activity of nitrogenase and glutamine synthetase in relation to
2163 availability of oxygen in continuous cultures of a strain of cowpea *Rhizobium* species supplied with excess ammonium.
Bergersen, F.J. (CSIRO, Canberra, A.C.T., Australia) and G.L. Turner.
Biochim Biophys Acta 538:406-416, 1978.

The fact that decreased oxygen supply produced a rapid decline in relative adenylation, followed by increased nitrogenase activity, supports the concept that control of nitrogenase synthesis is modulated by glutamine synthetase adenylation in "cowpea" *Rhizobium*.

2702 The occurrence and role of ubiquinone in electron transport to oxygen
2565 and nitrate in aerobically, anaerobically and symbiotically grown *Rhizobium japonicum*.
Daniel, R.M. (U Waikato, Hamilton, NZ).
J Gen Micro 110:333-337, 1979.

Ubiquinone was found at highest concentration in the bacteroids of the symbiotically grown *Rhizobium*, but was also extracted from those grown aerobically and anaerobically. It was concluded that ubiquinone functions in electron transport to oxygen but not to nitrogen.

28. PESTS AND PESTICIDES

2801 Interference of seed dressing on groundnut nodulation.
2399 Abdalla, M.H. (U Khartoum, Sudan) and S.M. Suleiman.
Mycopathol 64(3):131-136, 1978.

Dressing seeds with the fungicide Aldrex T at field dose (3 g/kg groundnut kernels) or one half that concentration both depressed and delayed nodulation. At 6 g/kg seed, the mean number of nodules was enhanced *in vitro*. Nitrate and nitrate yield of nodules was also increased by the higher dose.

2802 Sensitivity of root nodule *Rhizobium leguminosarum* to anti-fungal
2400 dressing Aldrex T.
Abdalla, M.H. (U Khartoum, Sudan) and S.M. Suleiman.
Mycopath 64(3):137-142, 1978.

An inverted growth pattern was seen in which the fungicide caused a decline of viable cells at concentrations up to 500 ppm, then an increase in viable cells from 500 to 900 ppm fungicide, with the greatest increase seen at 700 ppm Aldrex T in the medium.

2803 Effect of soil application of chloroxuron, metobromuron and
2152 fluometuron on nodulation, growth and nitrogen fixation by *Centrosema pubescens* and *Vigna cincinnata*.
Amakiri, M.A. (U Ibadan, Nigeria) and C.T.I. Odu.
Pesticide Sci 9(1):51-58, 1978.

Chloroxuron and metabromuron controlled weeds and had no injurious effects on the legumes when applied in the range of 0.5 to 2.0 mg/kg soil for the former, and 0.5 to 1.0 mg/kg soil for metobromuron. Fluometron was toxic to the legumes at the lowest concentration used (o.25 mg/kg soil). All the herbicides tested substantially decreased nodulation in the first

planting, but this effect was greatly reduced in the second planting, when the herbicide residues were approximately 25% of original dose.

2804 Studies of relationships between free-living nematodes and nodule
2140 bacteria of leguminous [plants]. (Fre)
Cayrol, J.C. (INRA, Antibes, France), C. Coudere and I. Evrad.
Rev Zool Agr Path Veg 76(3):77-89, 1977.
Two nematode species were found to carry rhizobia in their digestive tube where the hosts derive benefits from the metabolic products of the microflora.

2805 Inhibitory effects of the herbicide trifluralin on the establishment
2759 of the clover root nodule symbiosis.
De Rosa, F. (Boston U, MA, USA), D. Haber, C. Williams and L. Margulis.
Cytobios 21:37-43, 1978.
Interference with microtubule morphogenesis by trifluralin at low concentrations adversely affected nodulation.

2806 Effects of some surfactant fungicides on *Rhizobium trifolii* and its
2295 symbiotic relationship with white clover.
Fisher, D.J. (U Bristol, England), A.L. Hayes and C.A. Jones.
Ann Appl Biol 90:73-84, 1978.
Eighty apple mildew eradicants, which may be implicated in run-off to adjacent pastures, were found to supress growth and nitrogen fixation by clover. The bacteroids in root nodules where nitrogen fixation was inhibited were contracted away from the host membrane, and damage to the bacteroid membrane was apparent in electron microscope studies.

2807 Uptake of the systematic fungicide triadimefon by clover and its
2706 effect on symbiotic nitrogen fixation.
Fisher, D.J. (U Bristol, Avon, England), J.A. Packard and C.M. McKenzie.
Pest Sci 10(1):75-82, 1979.
Only soil concentrations far in excess of those likely to be encountered adversely affected plant weight or symbiotic nitrogen fixation. Because the fungicide is taken up and metabolized by clover, soil buildup to toxic levels is not likely to occur.

2808 Effect of aldrin on growth and oxidative metabolism of rhizobia.
2109 Juneja, S. (Haryana Agr Inst, Hissar, India) and R.C. Dogra.
J Appl Bact 44(1):107-115, 1978.
Rhizobia of Bengal gram and greengram showed a growth lag of about 12 hours when exposed to aldrin at 500 $\mu g\ ml^{-1}$, followed by a return to normal growth. A problem could occur in fields when insecticide is applied at a relatively high concentration, or applied directly to the seed. Studies indicated that the chemical inhibited oxidative metabolism, and that the inhibition could be partially reversed by a high concentration of glucose.

2809 Infestation of legume root nodules by a chloropidan larva.
2476 Nair, S.K. (Haryana Agr U, Hissar, India).
Plant Soil 50(2):493-495, 1978.

Heavy infestation of nodules of cowpea and crotolaria was found mainly during August and September. The affected plants were stunted and failed to bear pods. Efforts at biological control by destroying the legume host in and around the experimental field had limited success, and chemical controls are being sought.

2810 Use or fungicide-resistant rhizobia for legume inoculation.
2127 Odeyemi, O. (Cornell U, Ithaca, NY) and M. Alexander.
Soil Biol Biochem 9(4):247-251, 1977.

A simple method for culturing rhizobia which are resistant to the fungicide commonly used on their legume host was described. The bacteria retained their symbiotic effectiveness but survived fungicide treatments which were lethal to non-resistant rhizobia.

2811 Effects of the herbicides 2M-4X and 2M-4XM on photosynthetic pigments
1197 in pea plants.
Paromenskaya, L.N. (All Union Res Inst Agr Micro, Leningrad, USSR), L.D. Mikhailova and L.G. Vagiyan.
Sov Plant Physiol 22(2):348-350, 1975 (Eng tr).

Inoculated pea plants were grown in sand culture and treated with 0.2% solution of the herbicide. The relative increase of chlorophyl b in leaves as determined by spectra readings indicated significant toxic action.

2812 Effects of herbicides on nitrogen fixation of alfalfa *(Medicago*
2693 *sativa)* and red clover *(Trifolium pratense)*.
Peters, E.J. (USDA Sci Educ Admin, Columbia, MO, USA) and M.B. Zbiba.
Weed Sci 27(1):18-21, 1979.

Although some inhibition of nodulation was associated with the herbicide application at some rates, it was attributed to reduced plant growth growth caused by herbicidal injury rather than to direct effects on rhizobia.

2813 Influence of a carbamate pesticide on growth, respiration, (^{14}C)-
2908 carbon metabolism and symbiosis of a *Rhizobium* sp.
Sekar, T. (Tamil Nadu Agr U, Coimbatore, India) and A. Balasubramanian.
Plant Soil 51(3):355-361, 1979.

The growth and respiration of cowpea rhizobia were enhanced by addition of 2 ppm carbamate to the culture medium, but inhibited at the normal application level (5-10 ppm). Soil application of the insecticide reduced the nodulation of inoculated cowpea plants but increased dry matter production.

2814 Effect of herbicide, alachlor, on growth and nitrogen fixation in
2488 cyanobacteria and rhizobia.
Singh, V.P. (Banaras Hindu U, Varanasi, India), R.B. Singh, B. Dhar, R.M. Singh, B.D. Singh and J.S. Srivastava.
Ind J Exper Biol 16(12):1325-1327, 1978.

Although rhizobia tolerated 4 to 5 times higher concentrations of alachlor than did cyanobacteria, the recommended dose with soil water at field capacity would be greatly detrimental to the rhizobia as well.

2815 Effects of insecticides on acetylene reduction by alfalfa, red clover
2489 and sweetclover.
Smith, C.R. (N Dakota St U, Fargo, ND, USA), B.R. Funke and J.T. Schulz.
Soil Biol Biochem 10(6):463-466, 1978.

Loss of nitrogen fixing ability was correlated with inhibition of nodulation, and was most pronounced with oftanol, carbofuran, aldicarb and carbaryl in the soil tests. Phosmet was the least toxic insecticide tested. No significant inhibition of *Rhizobium meliloti* or *R. trifolii* in broth culture was caused by any of the insecticides at 50 ppm.

2816 Effect on rhizobia of fungicides applied to legume seed.
2631 Staphorst, J.L. (Plant Protec Inst, Pretoria, S Africa) and B.W. Strijdom.
Phytophylactica 8:47-54, 1976.

Of 13 fungicides evaluated for toxicity to 2 strains of "cowpea" rhizobia, Brassicol, Terracoat and Thiram were the least toxic. Fungicide effects were lessened when soil inoculation was used instead of seed inoculation. Sensitivity was markedly different between strains CB756 and XS30, the latter being inhibited at much lower concentrations of some fungicides.

2817 Effect of pesticides on acetylene reduction and microorganisms in
2491 sandy loam.
Tu, C.M. (Agr Canada Res Inst, London, Ont., Canada).
Soil Biol Biochem 10(6):451-456, 1978.

Acetylene reduction was repressed by chlorfenvinphos, chlorpyrifos, carbofuran, metalkamate and permethrin at a low rate of application, and by enthoprop, leptophos and chlordane at a higher rate. The soil population of rhizobia was not suppressed significantly by the pesticides and recovery to previous or higher levels was rapid. Thirty-two pesticides were studied.

2818 Effect of pesticides on acetylene reduction and growth of microorgan-
3088 isms in an organic soil.
Tu, J.C. (Agr Canada Res Inst, London, Ont., Canada).
J Envir Sci Health pt B 14(6):617-624, 1979.

Of 32 pesticides tested, none suppressed nitrogenase activity nor reduced the population of non-symbiotic nitrogen fixers for more than 7 days. Fungal populations also recovered to levels similar to or higher than those in controls within a week of pesticide application. Rhizobia were not involved in this study.

29. pH

2901 Selecting *Rhizobium* for acid, infertile soils of the tropics.
2464 Date, R.A. (CSIRO Cunningham Lab, St. Lucia, Qld., Australia) and J. Halliday.
Nature 277(5691):62-64, 1979.
Replacing mannitol with arabinose in the screening medium eliminated interference from alkali production by rhizobia and led to isolation of strains which grew better at pH 4.5 than in neutral media.

2902 Comparative effects of calcium carbonate on growth, nodulation, and
2107 chemical composition of four *Leucaena leucocephala* lines, *Macroptilium lathyroides* and *Lotononis bainesii*.
Hutton, E.M. (CSIRO, St. Lucia, Qld., Australia) and C.S. Andrew.
Aust J Exper Agric Anim Husb 18(90):81-88, 1978.
In all species additions of $CaCO_3$ up to a soil pH of 5.5 progressively increased the Ca content in plant tops. Top dry matter and total DM production were generally greatest at 1250 kg CaCO3/ha, which produced a post-harvest soil pH of 6.5.

2903 Effects of calcium, manganese, and aluminum on growth of rhizobia
2949 in acid media.
Keyser, H.H. (U California Davis, CA, USA) and D.N. Munns.
Soil Sci Soc Amer J 43(3):500-503, 1979.
In a study of 23 strains of cowpea rhizobia and 10 strains of *Rhizobium japonicum*, high Mn and low Ca slowed growth of some strains, but Mn stopped growth of none and low Ca stopped growth of only 3. Aluminum was more toxic, but its effect was partially ameliorated by Ca. All strains tolerant of Al were also tolerant of Mn and low Ca.

2904 Effectiveness of clover nodule bacteria adapted to an acid soil
2402 reaction.
Lapinskas, E.B. (Lithuanian Agr Res Inst, Vejai, LISSR).
Microbiol 47(2):285-290, 1978.
Ten of 20 strains adapted to an acid medium (pH 4.8) over a 7 year period continued to grow well after repeated transfers, but only a few exhibited an ecological advantage over unadapted strains with respect to effectiveness. After apparent adaptation to an acid medium, the strains nevertheless retained the same optimal pH values for growth as unadapted strains (pH 6.0 to 7.0).

2905 Effect of soil pH and liming on growth and nodulation of soybeans
2473 in Histosols.
Mengel, D.B. (Louisiana St U, Baton Rouge, LA, USA) and E.J. Kamprath.
Agron J 70(6):959-963, 1978.
The critical range of soil pH for shoot, root and nodule growth was 4.6 to 4.8 for most soils. Positive effects of liming were attributed to decreasing Al toxicity, increasing soluble Ca and Mg, and more favorable pH for *Rhizobium* activity.

2906 Depression of legume growth by liming.
2558 Munns, D.N. (U California, Davis, CA, USA) and R.L. Fox.
Plant Soil 45:701-705, 1976.

Twenty-two legume varieties responded differently to liming an acid soil to pH 6. In two *Stylosanthes* species, depression from liming persisted but in 8 other legumes the early depression gave way to positive growth. Seven species showed no depression. The mechanism for depression from liming remains unclear, but workers were cautioned about using short-term trials in determining liming effects.

2907 Soil acidity and related factors.
2347 Munns, D.N. (U California, Davis, CA, USA).
In Vincent, J.M. *et al*, Exploiting the legume/*Rhizobium* symbiosis in tropical agriculture. U Hawaii Coll Trop Agr misc pub 145, 1977, p. 211-236.

Soil acidity tends, with certain exceptions, to correlate with calcium deficiency, manganese toxicity and aluminum toxicity. Only certain legumes tolerate soil acidity. A few species show no response to raising pH above 4, although low pH may inhibit nodulation. Some strategies and criteria for screening legumes for acid tolerance were discussed.

2908 Influence of lime on nitrogen fixation by tropical and temperate
2559 legumes.
Munns, D.N. (U California, Davis, CA, USA), R.L. Fox and B.L. Koch.
Plant Soil 45:591-601, 1977.

Liming of an N-deficient Oxisol produced a pH range of 4.7 to 7.1 and a significant decline in available Mn. Nine tropical and seven temperate legumes were compared across the pH variable. Data were consistent with the conclusion that for most legume species growth improvement associated with liming was caused by improved N fixation. *Phaseolus vulgaris* was the apparent exception.

2909 Tolerance of soil acidity in symbiosis of mung bean with rhizobia.
2802 Munns, D.N. (U California, Davis, CA, USA), H.H. Keyser, V.W. Fogle, J.S. Hohenberg, T.L. Righetti, D.L. Lauter, M.G. Zaroug, K.L. Clarkin and K.W. Whitacre.
Agron J 71(2):256-260, 1979.

Of 40 rhizobial strains, about half were moderately to very sensitive to pH 5.0. Some strains combined high tolerance with high symbiotic effectiveness. Selecting host/*Rhizobium* combinations for tolerance to acidity requires the testing of numerous rhizobia and legume associations for performance under particular conditions.

2910 Tolerance of rhizobia to acidity, aluminum and phosphate.
2951 Keyser, H.H. (U California, Davis, CA, USA) and D.N. Munns
Soil Sci Soc Amer J 43(3):519-523, 1979.

Tolerance of cowpea rhizobia to the relative effects of low pH, high Al and low P was assessed. Low P limited attainable population density and slowed growth of some straina, low pH generally increased lag time or slowed or stopped growth, but Al was the most severe of the 3 stresses.

30. PHAGES AND PLANT VIRUSES

3001 Classification of *Agrobacterium* and *Rhizobium* phages. (Fre)
2477 Ackermann, H.W. (U Laval, Quebec, Canada).
Path Biol 26(8):507-512, 1978.
Twelve species of *Rhizobium* phages and four of *Agrobacterium* were described and classified according to morphology, serological properties and physico-chemical parameters.

3002 Properties of *Rhizobium trifolii* isolates surviving exposure to
3068 specific bacteriophage.
Barnet, Y.M. (U New South Wales, Kensington, NSW, Australia).
Can J Micro 25(9):979-986, 1979.
The properties of clones from rhizobia surviving specific bacteriophage were studied. Changes in symbiotic properties, colony morphology and somatic cross-reaction with the parent were recorded. Two temperate phages produced clones which were lysogenic, but the other four did not produce that effect.

3003 Sensitivity to phages in *Rhizobium meliloti* as a plasmid consequence.
2268 Corral, E. (U de Granada, Spain), E. Montoya and J. Olivares.
Microbios Ltrs 5(18):77-79, 1977.
Sensitivity tests led to the assumption that the biosynthesis of specific phage receptors was related to the presence of extrachromosomal DNA.

3004 Interaction between *Rhizobium japonicum* phage M-1 and its receptor.
2378 Dandekar, A.M. (U Baroda, India) and V.V. Modi.
Can J Micro 24(6):685-688, 1978.
A depolymerase enzyme component of the phage which acted on the exo-polysaccharide of the bacteria appeared to be involved in the phage-receptor interaction.

3005 Isolation and characterization of a virus (RL-1) infective on
2481 *Rhizobium leguminosarum*.
Dhar, B. (Banaras Hindu U, Varanasi, India), B.D. Singh, R.B. Singh, R.M. Singh, V.P. Singh and U.S. Srivastava.
Arch Microb 119(3):265-267, 1978.
The phage-like virus had a noncontractile tail with baseplate, hexagonal head and a burst size of approximately 100 virus particles per cell. The virus lysed 2 cultures of *R. leguminosarum*, but did not affect 58 strains of rhizobia including 10 strains from pea. This contrasts with much wider host ranges for phages of pea *Rhizobium*.

3006 Nodule infection by yellow mosaic virus in *Phaseolus vulgaris*.
2611 Orellana, R.G. (USDA Agr Res Serv, Beltsville, MD, USA) and F.F. Fan.
Appl Envir Micro 36(6):814-818, 1978.
The disease reduced the fresh weight of tops, roots and nodules, and induced premature nodule decay and nodule drop. This investigation revealed that disease can seriously affect nitrogen fixation.

3007 Tobacco ringspot virus and *Rhizobium* interactions in soybean - impairment of leghemoglobin accumulation and nitrogen fixation.
2534 Orellana, R.G. (USDA Agr Res Serv, Beltsville, MD, USA), F. Fan and C. Sloger.
Phytopathol 68(4):577-582, 1978.

Budblight disease severely delayed nodulation until early bloom, then suppressed nitrogen fixation. Impairment of the symbiotic system by TRSV contributed to the poor performance of the infected plants.

31. PHOTOSYNTHESIS AND PHOTOSYNTHATES

3101 Photosynthesis and symbiotic nitrogen fixation in *Phaseolus vulgaris* L.
2354 Bethlenfalvay, G.J. (U California, Davis, CA, USA) and D.A. Phillips.
In Genetic engineering for nitrogen fixation; proceedings of a conference. NY, Plenum, 1977, p. 401-409.

The establishment of quantitative relationships between photosynthesis and symbiotic nitrogen fixation is a necessary precursor to altering the host legume to increase nitrogen fixation. Some factors influencing the relative efficiency of the two interrelated processes were described.

3102 Effect of bentazon, a Hill reaction inhibitor, on symbiotic nitrogen-fixing capability and apparent photosynthesis.
2514 Bethlenfalvay, G.J. (U California, Davis, CA, USA), R.F. Norris and D.A. Phillips.
Plant Physiol 63(1):213-215, 1979.

Bentazon was used as an experimental tool to correlate short term changes in apparent photosynthesis with corresponding changes in N_2 fixation. Foliar treatment acted 6 hours sooner and was more severe than root treatment in inhibition of CO_2 exchange rates (CER) and nitrogen fixing capacity. A close correlation between CER and nitrogen fixing capacity supported the concept of direct dependence on photosynthate availability.

3103 Utilization of net photosynthate for nitrogen fixation and protein production in an annual legume.
2035 Herridge, D.F. (U Western Australia, Nedlands, WA) and J.S. Pate.
Plant Physiol 60(5):759-764, 1977.

In cowpea, maximum nitrogen fixation occurred 10 days prior to maximum photosynthesis. Respiration of nodules and roots utilized 24% of the C from net photosynthate over the growth cycle. The nodules consumed photosynthate equivalent to 6.8 g carbohydrate for each gram of N fixed, with the greatest efficiency during late vegetative growth. The cultivar studied (Caloona) showed a relatively poor efficiency in grain protein production (32.5 g carbohydrate/g seed protein).

3104 Partitioning of ^{14}C photosynthate and long distance translocation of amino acids in preflowering and flowering, nodulated and nonnodulated soybeans.
2971 Housley, T.L. (U Wisconsin, Madison, WI, USA), L.E. Schrader, M.

Miller and T.L. Setter.
Plant Physiol 64(1):94-98, 1979.
Partitioning of ^{14}C assimilates among neutral, basic and acidic fractions was not affected by the presence of nodules or flowers. Labeled serine was significantly higher in nonnodulated plants, and γ-aminobutyrate-alanine was significantly higher in preflowering than flowering plants. The data suggested that the amino acids formed from current photosynthate are the major ones translocated by soybeans.

3105 Partitioning and utilization of net photosynthate in a nodulated
2305 annual legume.
Pate, J.S. (U Western Australia, Nedlands, WA) and D.F. Herridge.
J Exper Bot 29(109):401-412, 1978.
Net photosynthesis in white lupin rose to a maximum in early fruiting, then fell abruptly due to shedding of leaves. The plants required an average of 9.9 g photosynthate to produce 1 g seed dry matter, and 31.0 g net photosynthate to form 1 g seed protein. *Lupinus albus* turned out to be as efficient as cowpea in seed protein production, largely due to the high protein level of its seeds (33% compared to 20% in cowpea), and to a high efficiency in translocation of nitrogen to developing fruits and seed.

32. POLYCROP SYSTEMS

3201 Intercropping - a new version of an old idea.
2411 Crookston, R.K. (U Minnesota, St. Paul, MN, USA).
Crops & Soils 28(9):7-9, 1976.
A discussion of some advantages of intercropping, the reasons it has not been widely practiced in the U.S., and a formula for determining the relative yield advantages per unit of land.

3202 Grain yields and land equivalent ratios from intercropping corn and
2699 soybeans in Minnesota.
Crookston, R.K. (U Minnesota, St. Paul, MN, USA) and D.S. Hill.
Agron J 71:41-44, 1979.
Land usage values were either unaffected or reduced by the intercropping, mainly due to reduced soybean yield. The data suggested that row patterns might be devised (e.g. soybeans in strips 3 rows wide or wider and corn in narrower strips) to increase the productivity of the land units.

3203 Nitrogen economy in forage production through grass and legume
2212 mixed cropping.
Das, P.K. (Bidhan Chandra Krishi Viswa Vidalaya, Kalyani, W Bengal, India) and B.N. Chatterjee.
Ind J Agron 22(4):240-246, 1977.
Mixed cropping with cowpea and grass during 4 seasons produced as much dry matter as can be obtained from pure grass swards, with a significant nitrogen advantage in both wet and dry seasons when 20 kg N/ha was supplied. Similar results were achieved with cowpea and maize. Rice bean produced a smaller advantage than cowpea.

3204 Studies in mixed cropping. III. Further results with maize-bean
3122 mixtures.
Fisher, N.M. (U Nairobi, Kenya).
Exper Agric 15:49-58, 1979.

During long-rain seasons over two years, a clear advantage from mixed cropping was recorded. The findings suggested that mixtures were more efficient where pure stand yields are low, but may offer little advantage where pure stand yields are already high.

3205 Intercropping of pigeonpea with other grain legumes under semi-arid
2461 rainfed conditions.
Giri, G. (IARI, New Delhi, India) and R. De.
Ind J Agr Sci 48(11):659-665, 1978.

The grain yield equivalent per land unit for pigeonpea was higher when intercropped with greengram, but lower with blackgram. Maximum production was in a 1:1 ratio at 50 cm row distance with greengram.

3206 An analysis of the role of legumes in multiple cropping systems.
2339 Gomez, A.A. (U Philippines, Los Baños) and H.G. Zandstra.
In Vincent, J.M. *et al*, Exploiting the legume/*Rhizobium* symbiosis in tropical agriculture. U Hawaii Coll Trop Agr misc pub 145, 1977, p. 82-95.

A wide gap exists between potential cropping intensity as demonstrated in experiment station trials and actual farm practices. In addition to social, economic and technological impediments to increased cropping intensity, water is also a major limiting factor. Agricultural research is finding the means to ameliorate the water limitation, but the others remain a continuing challenge. Some advantages and disadvantages of various legumes in rotation, intercropping, hedge rows and relay systems adapted to specific rainfall patterns were reviewed.

3207 Plant and nodule development and nitrogen fixation in climbing
2146 cultivars of *Phaseolus vulgaris* L.
Graham, P.H. (CIAT, Cali, Colombia) and J.C. Rosas.
J Agric Sci 90(2):311-317, 1978.

Two climbing cultivars of *P. vulgaris* were grown in monoculture and in association with 2 maize populations differing in growth characteristics. Bean cv P590 showed no interspecific competition with vigorous landrace maize until 92 days after planting, but cv P256 was depressed as early as 50 days after planting. Association with Amarillo subtropical, an improved maize, did not affect plant development in P590, but decreased P256 at the 80 and 92 day harvests. It was suggested that inhibition of nitrogen fixation would be significant only when the maize is vigorous and the bean weak in comparison.

3208 Green manure crops as a source of leaf protein.
2792 Jadhav, B. (Marathwada U, Aurangabad, Maharashtra, India), N.S. Tekale and R.N. Joshi.
Ind J Agr Sci 49(5):371-373, 1979.

Sannhemp (*Crotolaria juncea* L.) and *Sesbania sesban* L. Merr. both provided good green manure material after extraction of part of the protein by pulping.

3209 Legume contribution to the fertilizer economy in legume-cereal
2285 rotations.
Lal, R.B. (IARI, New Delhi, India) and R.K. Singh.
Ind J Agr Sci 48(7):419-424, 1978.
The fertilizer N requirement for a target wheat yield was 32 kg N/ha after a legume fodder crop, compared with 74 kg N/ha after soybean.

3210 Intercropping of corn and annual tropical legumes for silage. (Por)
2287 Martins Carneiro, A. (U Fed Minas Gerais, Brazil) and N.M. Rodriguez.
Arq Escola Vet UFMG 30(2):219-227, 1978.
In 3 experiments in which legumes (25% and 38%) were planted with corn in various field arrangements, the legumes developed poorly and made no significant contribution to the quality of the silage.

3211 Interplanting maize, sorghum and pearlmillet with short-duration
2178 grain legumes.
De, Rajat (IARI, New Delhi, India), R.S. Gupta, S.P. Singh, Mahendra Pal and S.N. Singh.
Ind J Agr Sci 48(3):132-137, 1978.
Total productivity per unit area was increased in some combinations when the cereal crops were interplanted with greengram, blackgram, soybean or groundnut.

3212 Establishing wheat after soybeans in double-cropping.
2798 Sanford, J.O. (Agr Res, Sci Educ Adm, USDA, Mississippi State, MS).
Agron J 71(1):109-112, 1979.
Overseeding wheat under a closed canopy of soybean is an acceptable method of establishing the wheat crop, and allows the wheat to be planted 1 month earlier (October vs November). Significant increases in wheat yield may be expected.

3213 Relative yield totals and yield components of intercropped sorghum
2134 and soybeans.
Wahua, T.A.T. (U Ibadan, Nigeria) and D.A. Miller.
Agron J 70(2):287-291, 1978.
The data from a 2 year field study indicate that a judicious combination of cultivars and plant density can result in proficable total yields per unit land area. Relative yield totals of 108 and 111% were achieved.

3214 Effects of intercropping on soybean N_2-fixation and plant composition
2135 on associated sorghum and soybeans.
Wahua, T.A.T. (U Ibadan, Nigeria) and D.A. Miller.
Agron J 70(2):292-295, 1978.
Soybean grown with tall sorghum had a 77% reduction in nodule number, 50% reduction in nodule weight, and 96% reduction in specific nodule activity.

The result was a 99% reduction in nitrogen fixation. With semi-dwarf sorghum, soybeans fixed 2.64 times more N than plants in monoculture, but produced 40% less dry matter. There was no evidence of an N gain by the companion plant.

3215 Intercropping: its importance and research needs. Part 1. Competition
3090 and yield advantages.
Willey, R.W. (ICRISAT, Begumpet, Hyderabad, India).
Fld Crop Abst 32(1):1-10, 1979.
This review/discussion establishes criteria and methodology for evaluating the relative advantages of intercropping systems in particular situations. The "land equivalent ratio" (LER) approach was found to be the most useful basis of evaluation.

3216 Intercropping: its importance and research needs. Part 2. Agronomy
3089 and research approaches. Fld Crop Abst 32(2):73-85, 1979.
Willey, R.W. (ICRISAT, Begumpet, Hyderabad, India).
A review and discussion of the agronomic factors which enter into the designing and evaluating of intercrop systems. The main topics covered are: total and component populations and their spatial relationships; response to nutrients and water; relative sowing times; and genotype evaluation for intercrop situations. The final section deals with experimental designs and statistical analyses for intercropping research. 133 references.

33. *Rhizobium* BACTEROIDS

3301 Nitrogen fixation by *Rhizobium* sp. 32H1. A morphological and ultra-
2762 structural comparison of asymbiotic and symbiotic nitrogen-fixing forms.
Brussel, A.A. Van (U Calgary, Alberta, Canada) and J.W. Costerton.
Can J Micro 25(3):352-361, 1979.
Morphological changes associated with induction of nitrogenase activity were more pronounced in asymbiotic cells than in bacteroids of *Rhizobium*. The differences and similarities were portrayed in a series of micrographs.

3302 Viability of *Rhizobium trifolii* bacteroids isolated from clover root
2063 nodules.
Gresshoff, P.M. (Australian Natl U, Canberra City, A.C.T.), M.L. Skotnicki, J.F. Eadie and B.G. Rolfe.
Plant Sci Ltrs 10:299-304, 1977
Rhizobia in the differentiated bacteroid stage had a colony forming efficiency of 90%. The results indicated that bacteroid generation time is about 24 hours for this fast-growing strain, and that division ceases after 9 days.

3303 Viability of *Rhizobium* bacteroids isolated from soybean nodule
2259 protoplasts.
Gresshoff, P.M. (Australian Natl U, Canberra City, A.C.T.) and B.G. Rolfe.

Planta 142(3):329-333, 1978.
Bacteria-free isolates of soybean nodule bacteroids showed complete viability on mannitol supplemented plates. The redifferentiated bacteroid clones had the same genetic characteristics as the original inoculum strain. A probable evolutionary strategy of utilizing plant material to revert to bacterial rods in senescing nodules and amplify the number of rhizobia released into the soil was described.

3304 Involvement of the cytoplasmic membrane in nitrogen fixation by
2210 *Rhizobium leguminosarum* bacteroids.
Laane, C. (Agric U, Wageningen, The Netherlands), H. Haaker and C. Veeger.
Eur J Biochem 87:147-153, 1978.
Addition of bovine serum albumin to the incuhation mixture greatly enhanced acetylene reduction rates, even after a 7 hour storage period. Similarities between *R. leguminosarum* and *Azotobacter vinelandii* in the control of nitrogenase activity were shown.

3305 Efficiency of oxidative phosphorylation in membrane vesicles of
2960 *Azotobacter vinelandii* and of *Rhizobium leguminosarum* bacteroids.
Laane, C. (Agr U, Wageningen, The Netherlands), H. Haaker and C. Veeger.
Eur J Biochem 97(2):369-377, 1979.
A technique was devised to maintain different rates of respiration at non-saturating O_2 concentrations and to study the effects of O_2 on the P/O ratio in membrane vesicles. The membrane energization connected with H_2 oxidation was also studied.

3306 Involvement of the membrane potential in nitrogen fixation by
2947 bacteroids of *Rhizobium leguminosarum*.
Laane, C. (Agr U Wageningen, The Netherlands), W. Krone, W.N. Konings, H. Haaker and C. Veeger.
FEBS Ltr 103(2):328-332, 1979.
This study showed that the energized state and integrity of the cytoplasmic membrane of bacteroids controls the supply of reducing equivalents of nitrogenase.

3307 A possible mechanism for establishment of nitrogen fixation in
2261 bacteroids of fast-growing, acid-producing *Rhizobium*.
Paau, A.S. (U Houston, TX, USA).
J Theor Biol 74(1):139-142, 1978.
The author proposes that the apparently diffused nucleoid structure observed in mature bacteroids of effective, fast-growing rhizobia is in reality an extended or unfolded chromosomal apparatus. The relationship of this apparatus to the establishment of nitrogenase activity was discussed.

3308 Development of bacteroids in alfalfa (*Medicago sativa*) nodules.
2290 Paau, A.S. (U Houston, TX, USA), J.R. Cowles and D. Raveed.

Plant Physiol 62(4):526-530, 1978.
Bacteroids in the nodule tips were small, had low nucleic acid content, contained distinct central nucleoids, and were relatively inactive in reducing acetylene. Those in the middle regions of the nodule were much larger, had high nucleic acid content, and were without central nucleoids. These bacteroids were very active in acetylene reduction. The bacteroids in the basal nodule region were also large and without central nucleoids, but had relatively low nucleic acid content and low acetylene-reducing activity. A hypothetical scheme of bacteroid transformation was presented.

3309 DNA content of free-living rhizobia and bacteroids of various
2604 *Rhizobium*-legume associations.
Paau, A.S. (U Houston, TX, USA), J. Oro and J.R. Cowles.
Plant Physiol 63(2):402-405, 1979.
Bacteroids in effective associations all had similar or higher DNA content than the corresponding free-living forms. Two of four ineffective rhizobia contained lower DNA in the bacteroid form. The maintenance of at least one genome equivalent of DNA in bacteroids seems essential for effectiveness.

3310 Flow-fluorometric analysis of bacteroids fractionated from alfalfa
2866 and soybean nodules by buoyant density sedimentation.
Paau, A.S. (U Houston, TX, USA), J. Oro and J.R. Cowles.
Plant Sci Ltrs 15(1):63-68, 1979.
The larger sized bacteroids of *Rhizobium meliloti*, which sedimented at the lowest density, contained significantly more DNA and protein than did free-living rhizobia. Natural or induced senescence was accompanied by a decrease in bacteroid nucleic acid content.

3311 Polypeptide synthesis by *Rhizobium* bacteroids and bacteria.
2940 Shaw, B.D. (DSIR, Palmerston N, NZ) and W.D. Sutton.
Biochim Biophys Acta 563(1):216-226, 1979.
Bacteroids incubated aerobically at high osmolarity incorporated [^{35}S]-methionine into a characteristic set of polypeptides which produced label patterns differing from those produced by broth-cultured *Rhizobium* bacteria. The bacteroid polypeptides showed a transitional pattern at the time when nitrogenase activity appeared. The findings were consistent with the hypothesis that the characteristic pattern results from the intracellular environment without direct transfer of genetic information from the plant.

3312 Organic acid metabolism by isolated *Rhizobium japonicum* bacteroids.
2197 Stovall, I. (U Illinois, Urbana, IL, USA) and M. Cole.
Plant Physiol 61:787-790, 1978.
Bacteroids isolated from soybean nodules oxidized ^{14}C-labeled succinate, pyruvate, and acetate in a manner consistent with the operation of the tricarboxylic acid cycle and a partial glyoxylate cycle. Substrate carbon was incorporated into cell wall and membrane, nucleic acids, and protein components of the bacteroids.

3313 Preparation and fractionation of *Rhizobium* bacteroids by zone
2037 sedimentation.
Sutton, W.D. (DSIR, Palmerston N, NZ) and P. Mahoney.
Plant Physiol 60(5):800-902, 1977.
Bacteroids from lupin nodules were separated into slowly and rapidly sedimenting fractions by means of sucrose gradient centrifugation (20-ml gradients of 12% to 30% w/v sucrose). Purity of bacteroids was established by electron microscopy and enzyme assays. A hypothesis that younger, moderately colony-forming bacteroids sediment more slowly than older, less colony-forming bacteroids was tested. Evidence indicated that mature nodules contain both bacteroid forms.

3314 Viability of *Rhizobium* bacteroids.
2734 Tsien, H.C. (U Minnesota, Minneapolis, MN, USA), P.S. Cain and E.L. Schmidt.
Appl Envir Micro 34(6):854-856, 1977.
Contrary to the prevailing view, bacteroids of *R. japonicum* and *R. phaseoli* averaged 90% viability as determined by fluorescent antibody enumeration. Viability was not affected by nodule age.

3315 Alterations in the membranes of bacteroidal cells in soybean root
2943 nodules as revealed by freeze fracturing.
Tu, J.C. (Agr Canada Res Stn, Harrow, Ont., Canada).
Physiol Plant Pathol 15(1):35-41, 1979.
In the early stages of nodulation, the bacteroidal plasma membrane contained a significantly higher density of intramembraneous particles (IMP's) than did non-bacteroidal cells, and this increased further as nodulation progressed to the intermediate stage. Small areas devoid of IMP's were observed, becoming larger, more numerous, and frequently bounded by an area of high IMP density. These observations were interpreted to show that the plasma membrane of bacteroidal cells and the membrane envelope become highly active during nodulation.

3316 Analysis of DNA content, nitrogenase acitvity and *in vivo* protein
2386 synthesis of *Rhizobium*.
Van den Bos, R.C. (State Agr U, Wageningen, The Netherlands), T. Bisseling and A. Vankammen.
J Gen Micro 109:131-139, 1978.
The microorganisms were separated into stages of development, from bacteria to mature bacteroids. The DNA content and presence of nitrogenase components increased with development. Protein synthesis decreased rapidly with increasing bacteroid size. Cell growth and replication of DNA without cell division resulted in morphological changes in the bacteroids. The ratio of nitrogenase components I and II was not constant.

34. *Rhizobium* CHARACTERISTICS AND PHYSIOLOGY

3401 Grouping of rhizobial strains — a method based on symbiotic
2248 characteristics.
Balasundaram, V.R. (IARI, New Delhi, India) and A. Sen.
Zentralb Bakter ... Hyg II Nat Abt 132(7):616-622, 1977.
Seven symbiotic characteristics (nodulation, shoot dry weight, nodule number, nodule dry weight, leghemoglobin content, nodule N content, and shoot N content) were employed to group 20 strains of *Rhizobium japonicum*. Of 8 groups, one group with 2 strains stood distinctly apart for exceptional characteristics.

3402 Thymidine incorporation into *Rhizobium meliloti*.
2887 Behki, R.M. (Agr Canada Chem & Biol Res Inst, Ottawa, Ont., Canada) and S.M. Lesley.
Can J Micro 25(6):675-679, 1979.
Low concentrations of deoxyadenosine or other nucleosides enhanced the catabolism of thymidine, but at high concentrations the nucleosides inhibited thymidine incorporation. The nucleosides may be used to enhance the incorporation of radioactively labeled carbon in plasmid DNA.

3403 Carotenoids of rhizobia. III. 2',3'-*trans*-Dihydroxy-2-nor-β,β-
2757 carotene-3,4-dione, a novel carotenoid from a mutant of *Rhizobium lupini*.
Beyer, P. (Lehrstuhl Zellbiol, Inst Biol 2, Freiburg, Fed Rep Germany), H. Kleinig, W. Meister and G. Englert.
Zeit Naturfor C - Biosci 34(3-4):179-180, 1979.
An additional violet pigment was extracted from a mutant strain which appeared deeper red than the parent strain on agar plates. The structure and possible derivation of the pigment were investigated.

3404 *Rhizobium* species.
3095 Burton, J.C. (Nitragin Co., Milwaukee, WI, USA).
In Microbial technology, 2d ed. NY, Academic, 1979, p. 29-58.
A survey of the taxonomy of the genus *Rhizobium* and applied rhizobiology. A table lists 44 published references to effectiveness groupings of leguminous species within cross-inoculation groups as an aid to overcoming some of the limitations of the present taxonomy. Development of more effective strains for important food legumes was seen as the greatest challenge faced by rhizobiologists.

3405 Rhizobial hemoglobin & δ-aminolevulinic acid synthetase activity in
1974 *Rhizobium japonicum*.
Desai, A. (M.S. Univ Baroda, India), S. Patel and V.V. Modi.
Ind J Exp Biol 15(7):528-530, 1977.
A pigment called 'rhizobial hemoglobin' was synthesized by strain 211D growing on succinate as the carbon source. The first enzyme of heme biosynthesis, δALA, was studied under different cultural conditions and at different rhizobial culture growth periods.

3406 Examination of *Rhizobium leguminosarum* for the production of
2892 extracellular and periplasmic proteins.
Glenn, A.R. (Murdoch U, W.A., Australia) and M.J. Dilworth.
J Gen Micro 112:405-409, 1979.

The strains studied did not release extracellular proteins, but did synthesize periplasmic proteins, 14 of which were released by lysozyme/EDTA treatment. Four of the periplasmic proteins, including alkaline phosphatase, were repressed by phosphate. Only 3 enzyme activities were identified.

3407 Bacteriocin-like substances produced by *Rhizobium japonicum* and other
2469 slow-growing rhizobia.
Gross, D.C. (U Nebraska, Lincoln, NB, USA) and A.K. Vidaver.
Appl Envir Micro 36(6):936-943, 1978.

Inhibitory zones extending 2 to 8 mm from colony margins were seen in 58 of 66 *R. japonicum* test strains. Diverse strains of *R. japonicum* were differentiated into 3 groups on the basis of bacteriocin production. Competitive superiority did not appear to be related to *in vitro* bacteriocin production.

3408 Extracellular polysaccharides of *Rhizobium*: identification of
2180 monosaccharides from strain CB756.
Kennedy, L.D. (DSIR, Palmerston N, NZ).
Carbohyd Res 61:217-221, 1978.

Slow-growing rhizobia synthesized unusual sugars, 10 of which were studied and described from cultures of cowpea *Rhizobium*. One of the sugars, 6-*O*-methyl-D-galactose, had previously been incorrectly identified as fucose. Possible correlations between polysaccharide composition and nitrogen-fixing ability are under investigation.

3409 Nitrogenase activity of *Rhizobium* sp. strains in pure culture in
3060 relation to extracellular polysaccharide composition and antigenic affinity.
Kennedy, L.D. (DSIR, Palmerston N, NZ) and C.E. Pankhurst.
Microbios 23:167-173, 1978.

Five strains capable of developing nitrogenase activity in pure culture were distinguishable either serologically or by polysaccharide composition. While two strains were possibly identical with respect to somatic antigens, no general relationships were established other than the common ability to express nitrogenase in pure culture.

3410 Carotenoids of rhizobia. 11. Effect of nicotine on carotenoid
2272 pattern of *Rhizobium lupini*.
Kleinig, H. (U Freiburg, Fed Rep Germany), W. Meister and G. Englert.
Arch Microbiol 119(1):71-74, 1978.

Inhibition of the cyclization reaction in carotenoid biosynthesis resulted in the formation of monocyclic carotenoids, as consistent with the idea of "half molecule substrate". Spectroscopic studies led to identification of 3 carotenoids, with a further compound tentatively identified.

3411 Resistance of *Rhizobium* specific for *Lotononis bainesii* to ultraviolet
2519 irradiation.
Law, I.J. (Plant Protec Inst, Pretoria, S Africa).
Soil Biol Biochem 11(1):87-88, 1979.
The strains of *Rhizobium* infecting *Lotonis bainesii* are unique in possessing an intracellular red pigmentation. When compared to other rhizobia, the pigmented strains showed a higher resistance to u.v. Unpigmented offspring of these were equally resistant as their pigmented parents, and retained nodulation effectiveness

3412 *Rhizobium* strains isolated from wild and cultivated legumes:
2935 suppression of nodulation by a non-nodulating *Rhizobium* strain.
Lie, T.A. (Agr U, Wageningen, The Netherlands), R. Winarno and P.C.J.M. Timmermans.
In Loutit, M.W. and J.A.R. Miles, eds., Microbial ecology. Berlin, Springer-Verlag, 1978, p. 398-401.
Studies have shown that the *Rhizobium* strains present in the "center of origin" of leguminous plants differ from those isolated from cultivated plants in other areas. This study indicated that the competitive ability of a rhizobial strain may be unrelated to nodulating ability. By inducing changes in the roots, the non-nodulating strains may prevent nodulation by effective strains.

3413 Study of the exopolysaccharide of nitrogen-fixing nodule microorgan-
2666 isms *Rhizobium lupini*.
Linevich, L.I. (A. N. Bakh Inst Biochem, Moscow, USSR), S. Kh. Lobzhanidze and B.N. Stepanenko.
Dokl Biochem Akad Nauk SSSR 226:69-71, 1976. (Eng tr)
Two fractions were obtained from purified polysaccharide by gas chormatography, and their components analyzed by paper and gas-liquid chromatography. Components identified in fraction 1 were uronic acid, glucose, galactose, mannose, xylose and arabinose. In the second fraction, only glucose was identified.

3414 Fatty acid composition of *Rhizobium* spp.
2566 MacKenzie, S.L. (Prairie Reg Lab, Saskatoon, Sask., Canada), M.S. Lapp and J.J. Child.
Can J Micro 25(1):68-74, 1979.
Although taxonomic analysis of the 15 major fatty acid components showed that the rhizobia constitute a uniform group, two clusters (soybean-cowpea isolates and pea-bean isolates) were evident. Biochemical and physiological relationships of rhizobia differed from the conventional plant-affinity groupings in this and in previous studies cited by the authors.

3415 Chemical composition of the lipopolysaccharides of a strain of
2052 *Rhizobium lupini*.
Pfeister, H. (Inst Mikrobiol & Chem, Erlangen-Nurnberg, Germany) and G. Lodderstaedt.
Ber Deutsch Bot Ges 99:507-512, 1977.
Rhamnose was the most prominant component (37% w/w) and seemed to form the O-specific side chains. Four other sugar components were identified.

3416 Lipopolysaccharide of free-living and bacteroid forms of *Rhizobium*
2521 *leguminosarum*.
Planque, K. (St U Leiden, The Netherlands), J.J. van Nierop, A. Burgers and S.G. Wilkinson.
J Gen Micro 110:151-159, 1979.

Two molecular species were observed on electrophoresis, and three compounds were isolated by gel diffusion. No major chemical differences between the bacteria and bacteroid lipopolysaccharides were noted, but a full comparison was hampered by the gross loss of LPS during isolation and purification from bacteroids.

3417 Contribution to the study of rhizobia of native legumes from the
2303 region of Mamako (Mali). (Fre)
Sanogho, S.T. (Ctr Pedag Superi, Bamako, Mali), A. Sasson and J. Renaut.
Rev Ecol Biol 15(1):21-38, 1978.

The several strains of *Rhizobium* isolated from 13 species of legumes were found by cross-inoculation tests to be of the cowpea group. There was a large variation in nitrogen fixing efficiency.

3418 Biosynthesis of plant growth substances by some *Rhizobium japonicum*
2455 strains of various efficiency. (Slov)
Saric, Z. (Fac Agr Novi Sad, Yugoslavia), T. Hazem and V. Milic.
Arhiv Poljoprivredne Nauke 31(115):29-41, 1978.

Over a period of several years following inoculation at initial planting, 32 strains of *R. japonicum* were isolated from soybean nodules of different size and root location. Several strains of differing effectiveness and apparent positive effect on the growth and development of wheat were tested for synthesis of plant growth substances. The efficiency of nitrogen fixation correlated positively to identified stimulators, and negatively to inhibitors.

3419 Synthesis of exopolysaccharide by *Rhizobium* sp. & its serological
1930 study.
Singh, A. (Punjab Agr U, Ludhiana, India), S. Vadhera and R. Singh.
Ind J Exper Biol 15(5):404-406, 1977.

The exopolysaccharides of *R. japonicum* were serologically studied. A weak antigenic character was shown, possibly due to binding to proteins as suggested by the presence of amino acids despite purification efforts.

3420 Polarity in the exponential phase *Rhizobium japonicum* cell.
2014 Tsien, H.C. (U Minnesota, Minneapolis, MN, USA) and E.L. Schmidt.
Can J Micro 23(9):1274-1284, 1977.

By means of thin sections, freeze etching, fluorescent antibody technique, and ruthenium red staining, highly distinctive aspects of the exponential phase of *R. japonicum* cells were disclosed. Reserve polymer near one end and cytoplasmic localization near the other established polarity. The "immunofluorescent polar tip" feature was seen clearly as an extracellular

polar body on the tip of the cell with the polymer reserve. The role of the polar bodies in cell to cell attachment was confirmed by electron microscopy.

3421 Ammonia assimilation in *Rhizobium japonicum* colonial derivatives
2158 differing in nitrogen fixing efficiency.
Upchurch, R.G. (N Carolina St U, Raleigh, NC, USA) and G.H. Elkan.
J Gen Micro 104:219-225, 1978.

Specific ammonia assimilatory enzyme activities were 10 to 100-fold lower for all derivatives in N-fixing microaerophyllic and bacteroid cultures compared to aerobic cultures. The findings are consistent with the idea that rhizobia can simultaneously depress nitrogenase biosynthesis and repress ammonia assimilatory enzyme biosynthesis.

3422 Differences between strains of *Rhizobium* in sensitivity to canavanine.
2062 Weaks, T.E. (Marshall U, Huntington, WV, USA).
Plant Soil 48(2):387-395, 1977.

Some strains of *Rhizobium* were inhibited in growth by canavanine regardless of whether they nodulate canavanine-synthesizing or noncanavanine-synthesizing legumes. Under certain conditions, some rhizobia can utilize canavanine in synthetic processes.

35. *Rhizobium* COLLECTING AND COLLECTIONS

3501 A MIRCEN's network to safeguard invisible assets of nature.
3246 DaSilva, E. (UNESCO, Paris, France).
Envir Cons 6(3):213-214, 1979.

The reservoir of genetic resources of microorganisms is being tapped for a wide range of useful purposes, and the preservation of valuable strains and mutants of economic importance plays an important role in the process. The genesis of the World Network of Culture Collections and the 6 regional Microbiological Resource Centres (MIRCEN) is briefly described, with a list of names and addresses for the centres.

3502 Collection of strains of *Rhizobium*.
3050 Date, R.A. (CSIRO Cunningham Lab, St. Lucia, Qld., Australia) and J. Halliday.
In Mott, G.O., ed., Handbook for the collection, preservation and characterization of tropical forage germplasm resources. CIAT, Cali, Colombia, 1979, p. 20-27.

This chapter is aimed at the plant collector who does not have microbiological training but who is collecting nodules along with legume germplasm. It includes a list of materials and equipment, and information on recovery and sampling techniques, required documantation, and advantages of utilizing a centralized laboratory-germplasm collection for isolation and storage of *Rhizobium* strains.

3503 Rothamsted collection of *Rhizobium*. Catalogue of strains, third
2505 edition.

Dye, M. (Rothamsted Exp Stn, Harpenden, Herts., England).
Rothamsted Experiment Station, 1979, 45 p.
Introductory sections to the catalogue include an explanation of rhizobial classification, a brief history of the collection, and information about how it is maintained and how to request and use the cultures. A single recommended strain is listed for each of 19 legume species followed by other strains in the working collection, with references, by RCR numbers. Each entry also includes original host plant, location and date of collection, name of collector and isolator, and comments. Of the total of 536 strains in the Rothamsted collection, some 125 are listed in this catalogue, with a host plant index and 10 pages of references.

3504 CIAT *Rhizobium* collection; strains for forage legumes (2nd edition).
3106 Halliday, J. (CIAT, Cali, Colombia).
Centro Internacional de Agricultura Tropical, Cali, Colombia (no date), (unpaged).
A computer generated listing of strains for forage legumes in the CIAT collection. Part I is an alphabetical listing by host with source and country of the strain, and, when available, the rainfall, temperature and soil pH of the collection site. Strain characteristics include growth time on YMA plates and whether acid- or alkali-producing on YMA with bromthymol blue. Part II is a numerical list of the strains, with performance information from tube culture (stage I) and Leonard jar (stage II) tests. Effectiveness is based on a dry-matter comparison between symbiotic and nitrogen-fed plants.

3505 USDA - Beltsville *Rhizobium* culture collection catalogue.
3323 Keyser, H.H. (Cell Cult & N Fix Lab, Beltsville, MD, USA) and D.F. Weber.
US Dept Agric Sci Educ Admin, Agr Res, Beltsville, MD, PPHI Rept No. 16, 1979, 33 p.
The *Rhizobium* germplasm maintained by the Cell Culture and Nitrogen Fixation Laboratory of the Plant Physiology Institute at Beltsville is listed in this catalogue. One or more recommended strains are listed for 32 legume species, followed by a complete listing of all strains in the collection grouped by host plant. The introductory section describes the history, function and services of the collection.

3506 Catalogue of selected strains from the NifTAL *Rhizobium* collection, revised September, 1978.
2906 Reyes, V.G. (U Hawaii NifTAL Proj, Paia, HI, USA), P. Somasegaran and D.N. Munns.
University of Hawaii NifTAL Project, 1978, 8 p.+.
A listing of those strains which, on the basis of preliminary testing, have been recommended for further testing. The listed strains are available to research workers and inoculum producers. In addition to strains collected by NifTAL staff, 32 other laboratories and institutions have contributed to the collection. One or more recommended strains, plus other

effective strains, are listed for each of the "target" legumes in the NifTAL research mandate (12 grain legumes, 11 pasture legumes, and 8 underexploited tropical legumes). A numerical listing of all strains then gives institutional source, country of origin, effectiveness on particular legumes, growth characteristics, and comments on special uses.

36. *Rhizobium* COUNTS AND POPULATIONS

3601 Immunofluorescence method for counting of *Rhizobium japonicum*;
2515 statistical analysis of the results. (Fre)
Cleyetmarel, J.C. (U Lyon, Villeurbanne, France) and D. Chessel.
Ann Phytopath 10(2):219-231, 1978.
Statistical analysis of the soil rhizobia on a filter as detected by immunofluorescence produced a poissonian distribution pattern.

3602 An ecological study of rhizobia in the root region of legumes by
2547 fluorescent-antibody techniques.
Dadarwal, K.R. (IARI, New Delhi, India) and A.N. Sen.
Sci Cult (India) 39:542-544, 1973.
Distribution and persistence of rhizobia in the rhizosphere of inoculated *Phaseolus aureus* was studied. Slides buried at varying distances and depths from the inoculation site showed the horizontal migration to be more pronounced than was vertical migration.

3603 Enumeration of rhizobia from a plant-infection dilution assay using
2169 test plants grown in vermiculite.
Grassia, A. (CSIRO, Canberra, A.C.T, Australia) and J. Brockwell.
Soil Biol Biochem 10(2):101-104, 1978.
This method for estimating numbers of rhizobia in a mixed population can be used in situations where agar is not suitable. Infection of test plants followed a probability distribution from which population estimates were derived.

3604 Development of nodule bacteria in soil.
2403 Koleshko, O.I. (Lenin State U, Minsk, BESSR).
Microbiol 47(2):290-292, 1978. (Eng tr)
Soil population intensity is determined by the availability of nutritive substances. The development of a population is characterized by periods of adaptation, then active growth, and finally a stabilization of numbers and diversity in the population.

3605 Rhizobia as soil and rhizosphere inhabitants.
1943 Parker, C.A. (U Western Australia, Nedlands, W.A.), M.J. Trinick and D.L. Chatel.
In Hardy, R.W.F. and A.H. Gibson, eds., A treatise on dinitrogen fixation, sec IV. NY, Wiley, 1977, p. 311-352.
This chapter considers the behavior of introduced rhizobia, with particular attention to interactions with other soil bacteria. Practical sections deal with methods of examining soil and rhizosphere populations; identification

techniques; colonization of soil and rhizosphere by rhizobia; competition, amensalism and predation; soil nutrients utilized by rhizobia; and factors affecting survival of srhzobia in soil. The need to consider saprophytic as well as symbiotic competence in rhizobia was discussed. 200 references.

3606 Population densities of *Rhizobium japonicum* strain 123 estimated
2872 directly in soil and rhizospheres.
Reyes, V.G. (U Minnesota, St. Paul, MN, USA) and E.L. Schmidt.
Appl Envir Micro 37(5):854-858, 1979.
The population dynamics were studied in both pots and field from pre-planting through taproot disintegration. Fluorescent antibody techniques were used, and counting efficiencies were estimated to be about 30%. Most density values were no higher in the soybean rhizosphere than in wheat rhizosphere, and no evidence of specific stimulation by the legumes was encountered.

3607 Influence of soybean inoculation and nitrogen levels on populations
2891 and serogroups of *Rhizobium japonicum* in Ontario.
Semu, E. (U Guelph, Ontario, Canada), D.J. Hume and C.T. Corke.
Can J Micro 25(6):739-745, 1979.
Inoculation did not increase the population of the introduced strain at sites where soybeans had previously been grown, but did at a site where soybeans had not been grown. Additions of fertilizer N had only slight effects on the distribution of serogroups in the nodules.

3608 Adsorption of rhizobia to peat.
3119 Weaver, R.W. (Texas A & M U, College Stn, TX, USA).
Soil Biol Biochem 11(5):545-546, 1979.
Basic assumptions of enumeration methods for counting viable rhizobia in inoculum may be invalidated by the particle size of the carrier. Complete desorption in liquid is necessary to ensure random distribution in the sample, and relatively gentle shaking of peat in a diluent proved inadequate for this purpose.

37. *Rhizobium* CULTURES AND CULTURE MEDIA

3701 Production of a callus culture and a suspension of isolated kidney
2242 bean root cells and their influence on the growth of nodule bacteria during joint culturing.
Arutyunyan, R.Sh.(Acad Sci Armenian SSR, Abovyan, ASSR), N.L. Kaladzhyan, M.D. Stepanyan, N.A. Karapetyan and M.Kh. Chailakhyan.
Dokl Bot Sci Akad Nauk SSSR 229/231:88-91, 1976 (Eng tr 1977).
A modified Gamborg medium was selected on the basis of good growth by a series of reinoculations of isolated bean root tissues. During joint culture of root cells and nodule bacteria, rhizobial growth was strongly promoted by substances synthesized and excreted by bean root cells.

3702 Stepwise selection of efficient rhizobial cultures through cultural
2247 characteristics.

Balasundaram, V.R. (IARI, New Delhi, India) and A. Sen.
Zentralb Bakter ... Hyg II, Nat Abt 132(7):623-627, 1977.
Cultural characteristics were related to symbiotic properties, and a tentative system for screening strains by ability to grow on modified culture outlined.

3703 Nitrogen fixation (acetylene reduction) by free-living *Rhizobium*
2703 *meliloti*.
Bedmar, E.J. (Estac Exptl Zaidin, Granada, Spain) and J. Olivares.
Curr Microbiol 2(1):11-13, 1979.
Acetylene reduction of the same order as reported for other rhizobia was obtained from bacteria grown in a defined liquid medium under ambient atmosphere in sealed tubes. Ammonium sulfate had a depressing effect on nitrogenase activity of the same order as found in other bacteria.

3704 Expression of rhizobial nitrogenase: influence of plant cell-
2307 conditioned medium.
Bednarski, M.A. (C.F. Kettering Res Lab, Yellow Springs, OH, USA) and M. Reporter.
Appl Envir Micro 36(1):115-120, 1978.
The medium was prepared by culturing suspension cultures of soybean cells separated from rhizobia by 2 dialysis bags, one within the other. Conditioned medium from the plant cell side of the 2 membranes was used to elicit and influence nitrogenase activity in rhizobia. Preliminary determination of the presence of two sizes of compounds which aid in nitrogenase expression was reported.

3705 Nitrogenase activity of *Rhizobium meliloti* and *Rhizobium vigna* in
2944 in root tissue culture of legumes and nonlegumes.
Bonartseva, G.A. and N.M. Shemakan. [No affil given.]
Microbiol 47(5):686-689, 1978 (Eng tr).
Although legume root tissue cultures have the greatest effect on the nitrogenase activity of rhizobia, tobacco, glasswort and carrot root tissue also had a significant effect.

3706 Multicarbon-substrate growth of *Rhizobium trifolii*.
2914 Hollander, J.A. de (Vrije U, Amsterdam, The Netherlands) and A.H. Southamer.
FEMS Micro Ltrs 6(1):57-59, 1979.
Analysis revealed that simultaneous consumption of carbon substrates (glycerol supplemented with glucose, arabinose of sodium succinate, or mannitol supplemented with glucose, arabinose or sodium succinate) had occurred, and catabolic repression had not. A possible relationship of this phenomenon to the need for low oxygen tension for nitrogenase activity to occur was suggested.

3707 Growth requirements of *Rhizobium leguminosarum*, strain PRE.
2043 Egeraat, A.W.S.M. van (Agr U, Wageningen, The Netherlands).
Plant Soil 47(3):699-702, 1977.

This strain was unable to utilize sulfate as the S source, requiring sulfhydral compounds for growth. In contrast to other strains of this species, PRE displayed a sharp drop in growth when $FeCl_3$ was omitted from the synthetic medium. Thymine almost completely inhibited growth.

3708 Acetylene reduction activity in free-living cultures of rhizobia.
2155 Kaneshiro, T. (Agr Res Serv, USDA, Peoria IL, USA), C.D. Crowell and R.F. Hanrahan, Jr.
Int J System Bact 28(1):27-31, 1978.

A majority of *Rhizobium japonicum* and unclassified *Rhizobium* spp. isolates were capable of growth and acetylene reduction on a Casimino Acids-minimal medium. *R. meliloti* and *R. trifolii* grew on the Casimino Acids medium, but did not reduce acetylene. *R. leguminosarum* and *R. phaseolii* appeared unable to grow without supplemental nutrition. The taxonomic significance of growth and/or nitrogen fixation in the particular medium was discussed.

3709 Nitrogen fixation by *Rhizobium* in pure cultures.
2108 Lorkiewicz, Z. (Marie Curie Sklodowska U, Lublin, Poland), R. Russa and T. Drbanik.
Acta Microbiol Pol 27:5-9, 1978.

Asymbiotic nitrogenase activity was measured in two strains of *R. trifolii* and one of *R. meliloti* isolated from soils of Poland.

3710 Fixation of molecular nitrogen by pure cultures of nodule bacteria.
2743 Mishustin, E.N. (Inst Micro, Acad Sci USSR, Moscow) and E.P. Gromyko.
Biol Bull Acad Sci USSR 3(5):525-534, 1976. (Eng tr 1977)

An investigation of the conditions permitting nitrogen fixation in pure cultures was undertaken. The ratio of sugar consumed to N fixed was experimentally established at 1 g sugar to 1.1-1.7 mg N. A medium containing succinate was found best for establishing nitrogenase activity.

3711 Some effects of mannitol on the glucose metabolism of two derivatives
2795 of a strain of *Rhizobium japonicum* differing in mannitol dehydrogenase.
Mulongoy, K. (N Carolina St U, Raleigh, NC, USA) and G.H. Elkan.
Curr Microbiol 1(6):335-340, 1978.

Supplementing a glucose medium with mannitol stimulated not only mannitol dehydrogenase synthesis but also nicotinamide adenine dinucleotide (NAD)-linked 6-phosphogluconate (6-PG) dehydrogenase. Addition of the polyol to cell suspensions metabolizing glucose caused an immediate 40-50% drop of ATP level, which one strain derivative type could offset and the other could not.

3712 Nitrogenase activity of *Rhizobium meliloti* strains cultured with
2774 sweet clover tissue.
Shemakhanova, N.M. (Acad Sci USSR, Moscow) and G.A. Bonartseva.
Biol Bull Acad Sci USSR 1(1):119-121, 1977. (Eng tr)

Fourteen of 17 strains showed nitrogenase activity, but there were no infection threads nor bacteroids within plant cells observed although many bacteroids were seen on cells and on the surface of the medium.

3713 Effect of yeast extract concentration on viability and cell distortion
2028 in *Rhizobium* spp.
Skinner, F.A. (Rothamsted Exp Stn. Harpenden, Herts., England), R.J. Roughley and M.R. Chandler.
J Appl Bact 43(2):287-297, 1977.
Viability and rapidity of growth were favored by a liquid medium with a low concentration of yeast extract (0.1%). Concentrations >0.35% depressed viability and, in some strains, produced distorted cells.

3714 Nitrogenase activity in pure cultures of spectinomycin-resistant
2607 fast- and slow-growing *Rhizobium*.
Skotnicki, M.L. (C.F. Kettering Res Lab, Yellow Springs, OH, USA), B.G. Rolfe and M. Reporter.
Biochem Biophys Res Comm 86(4):968-975, 1979.
Spectinomycin resistant mutants of both fast-and slow-growing rhizobia could reduce acetylene. Bacteria in an acetylene-reducing culture were about twice the size of those in non-fixing cultures.

3715 *In vitro* nitrogenase activity of *Rhizobium japonicum* affected by
2650 conditioned medium from cultured plant cells.
Storey, R. (C.F. Kettering Res Lab, Yellow Springs, OH, USA), K. Rainey, L. Pope and M. Reporter.
Plant Sci Ltrs 14(3):253-258, 1979.
A nitrogenase initiating substance from soybean root cells was partially purified. Strains of rhizobia from cowpea nad soybean were differentially affected by the substance.

3716 Nondividing, bacteroid-like *Rhizobium trifolii*: *in vitro* induction
3181 via nutrient enrichment.
Urban, J.E. (Kansas St U, Manhattan, KS, USA).
Appl Envir Micro 38(6):1173-1178, 1979.
When exponentially growing cells in either mannitol-salts or glycerol-salts medium were supplemented with a mixture of glucose, Casamino acids, succinate and yeast extract, division ceased within less than the time required for doubling. Large, pleomorphic nondividing cells with bacteroid characteristics were formed. Swelling occurred in regions of most recent cell envelope synthesis, a phenomenon which may relate to lectin receptor synthesis.

3717 Organic acids and prolonged nitrogenase activity by non-growing,
3007 free-living *Rhizobium japonicum*.
Wilcockson, J. (U Marburg, Fed Repub Germany) and D. Werner.
Arch Microbiol 122(2):153-159, 1979.
Growth and nitrogen fixation were affected by including both organic acids and a pentose sugar in the culture medium. These findings suggested that the bacteroid form may be a response to organic acids in the nodule environment rather than a prerequisite to bacteroidal function.

3718 Isolation and metabolism of *Vigna unguiculata* root nodule protoplasts.
2860 Wooi, K.C. (U Malaya, Kuala Lumpur, Malaysia) and W.J. Broughton.
Planta 145(5):487-495, 1979.
Freshly isolated protoplasts containing bacteroids began to reduce acetylene after a lag period of 24 to 48 hours. Acetylene reduction, but not respiration, was inhibited by both asparagine and glutamine, offering a system for studying the mechanisms controlling N fixation.

3719 Fixation of molecular nitrogen by nodule bacteria of lupine in
2786 association with cells of tobacco and wheat.
Yurkova, G.N. (Acad Sci Ukranian SSR, Kiev, UkrSSR), M.M. Nichik, B.A. Levenko and E.P. Starchenkov.
Dokl Bot Sci Acad Nauk SSSR 229/231:115-117, 1976 (Eng tr 1977).
Nonlegume cells and their metabolites removed repression of the *nif*-operon, permitting nitrogenase expression and acetylene reduction.

38. *Rhizobium* DETECTION AND IDENTIFICATION

3801 Colorimetric enzyme-linked immunosorbent assay for the identification
2695 of strains of *Rhizobium* in culture and in the nodules of lentils.
Berger, J.A. (U Hawaii, Honolulu, HI, USA), S.N. May, L.R. Berger and B.B. Bohlool.
Appl Envir Micro 37(3):642-646, 1979.
The indirect ELISA test proved dependable, requires no microscope, uses only small amounts of antisera, and can be employed in field studies. The technique is fully described, with modifications and verifying data.

3802 Competetive ability and symbiotic effectiveness of doubly labeled
2704 antibiotic resistant mutants of *Rhizobium trifolii*.
Bromfield, E.S. (U Wales, Aberystwyth, Wales) and D.G. Jones.
Ann Appl Biol 91(2):211-219, 1979.
Mutants resistant to both streptomycin and spectinomycin were inferior to the wild-type parent strain in competing with effective strains for nodulation. The mutants were also less symbiotically effective. Measurement of mean shoot dry weight was suggested as a reasonably reliable evaluation of effective antibiotic resistant mutants for their competetive ability against ineffective strains.

3803 Multiple antibiotic resistance in *Rhizobium japonicum*.
2839 Cole, M.A. (U Illinois, Urbana, IL, USA) and G.H. Elkan.
Appl Envir Micro 37(5):867-870, 1979.
Of the 48 strains of *Rhizobium* from several sources, the majority were resistant to 6 antibiotics. Only novobiocin and tetracycline had relatively low rates of resistance. 25% of the strains were resistant to five of the eight antibiotics, and an additional 46% were resistant to combinations of 4, 3, 2 or 1 antibiotic.

3804 Serological studies with strains of *Rhizobium* isolated from some
2546 pulse crops of india.

Dadarwal, K.R. (IARI, New Delhi, India) and A.N. Sen.
Ind J Microbiol 13:7-12, 1973.

The five strains of *Rhizobium* from four legume species formed two distinct serotypes, based on cross-agglutination, band formation in agar diffusion, and electrophoretic behavior. *Cicer* rhizobia appeared to be related to *R. leguminosarum*, and *R. phaseoli* to *R. japonicum*.

3805 1961 Serological methods and their application to dinitrogen-fixing organisms.
Dudman, W.F. (CSIRO, Canberra, A.C.T., Australia).
In Hardy, R.W.F. and A.H. Gibson, eds., A treatise on dinitrogen fixation, IV. NY, Wiley, 1977, p. 487-508.

The most specific methods for identifying rhizobia and other nitrogen-fixing microorganisms in ecological and field investigations are serological. This chapter is a brief introduction to the concepts and techniques involved. Immunoglobins of the classes M and G from animal serum are the basic reagent, produced in response to injections of antigens (rhizobia) into the animal. The procedures for agglutination, precipitation, immunodiffusion, immunoelectrophoresis and immunofluorescence are outlined, and their application to work with *Rhizobia* explained.

3806 2793 Strain identification in *Rhizobium* using intrinsic antibiotic resistance.
Josey, D.P. (John Innes Inst, Norwich, Norflok, England), J.L. Beynon, A.W.B. Johnston and J.F. Beringer.
J Appl Bact 46(2):343-350, 1979.

The pattern of resistance to one or two low levels of 8 antibiotics by 26 strains of *R. leguminosarum* proved a stable property whereby the individual strains isolated from pea nodules could be recognized. All but 2 strains had unique resistance patterns.

3807 2561 *Rhizobium* strain identification in *Arachis hypogaea* nodules by enzyme-linked immunosorbent assay (ELISA).
Krishinevsky, B. (Agr Res Org Volcani Ctr, Bet Dagan, Israel) and M. Bar-Joseph.
Can J Micro 24(12):1537-1545, 1978.

In identifying strains from pure culture and single nodules, ELISA was more sensitive than agglutination or immunodiffusion tests by an order of 4 to 6 magnitudes. Strains identified by ELISA in nodules from mixed inoculants showed that one strain in each pair formed most of the nodules.

3808 2200 Detection of soluble *Rhizobium japonicum* antigens in soil by immunodiffusion.
Kremer, R.J. (U Missouri, Columbia, MO, USA) and G.H. Wagner.
Soil Biol Biochem 10:247-255, 1978.

At least one set of bands permitted detection of strains from soil cores if the population was greater than 0.1×10^9 cells/g soil. Band formation was enhanced and the appearance sharpened by addition of certain chemical solutions to the soil microcores in the agar wells.

3809 Genetically marked *Rhizobium* identifiable as inoculum strain in
2472 nodules of soybean plants grown in fields populated with *Rhizobium japonicum*.
Kuykendall, L.D. (USDA Inst Plant Physiol, Beltsville, MD, USA) and D.F. Weber.
Appl Envir Micro 36(6):915-919, 1978.
Resistance markers for azide, rifampin and streptomycin were used to trace introduced strains in nodules. The symbiotic incompatibility of Peking soybeans and strain 110 of *R. japonicum* was confirmed. Serological cross-checking confirmed the reliability of genetic markers.

3810 Enzyme polymorphism as an aid to identification of *Rhizobium* strains.
2124 Mytton, L.R. (Welsh Plant Br Stn, Aberystwyth, Wales), N.J. McAdam and P. Portlock.
Soil Biol Biochem 10(1):79-80, 1978.
Electrophoretic separation of isozyme variants was applied to 19 pure isolates of *R. leguminosarum*. While some problems remain to be solved, the method has already proved a useful complement to other identification techniques.

39. *Rhizobium* EFFECTIVENESS, INFECTIVENESS, EFFICIENCY

3901 The effectiveness of the symbiosis of *Rhizobium leguminosarum* on pea
2055 and broad bean.
Berg, E.H.R. van den (Lab Microbiol, Wageningen, The Netherlands).
Plant Soil 48(3):629-639, 1977.
In pea nodules, spherical bacteroids of strain PF2 and branched, rod-shaped bacteroids of PRE showed similar nitrogenase activity, but the former were almost ineffective on broad bean. A difference in amino acid content in effective nodules of the two strains may relate to the morphological difference.

3902 Clover rhizobia in soils: assessment of effectiveness using the plant
2994 infection count method.
Bonish, P.M. (Soil & Field Res Org, Hamilton, NZ).
NZ J Agric Res 22(1):89-93, 1979.
Although visual assessment indicated effective nodulation from high dilutions of inoculant, in two cases all or most of the nodules were formed by only partially effective rhisobia. It was concluded that, in some cases, soil N can mask infection by ineffective rhizobia. This limits the usefulness of the plant infection count method for assessing effectiveness.

3903 Associations of some uncommon leguminous plants with various rhizobia.
2323 Burton, J.C. (Nitragin Co., Milwaukee, WI, USA).
In Vincent, J.M. *et al*, Exploiting the legume/*Rhizobium* symbiosis in tropical agriculture. U Hawaii Coll Trop Agr misc pub 145, 1977, p. 381-384.
Because legumes are frequently collected without regard for their nodules,

rhizobiologists face the challenge of finding effective bacteria for each leguminous species. A study was conducted to determine the cross-inoculation patterns of 30 species of "uncommon" legumes representing 13 genera. Nodulation was produced in all but 2 species. Of the 67 combinations producing nodules, less than 40% were effective in nitrogen fixation. A table shows results of the study.

3904 Affinities between various *Stylosanthes* species as shown by rhizobial,
2294 soil pH and geographic relationships.
Date, R.A. (CSIRO, St. Lucia, Qld., Australia), R.L. Burt and W.T. Williams.
Agro-Ecosys 5(1):57-67, 1978.

Accessions from alkaline soil environments formed effective nitrogen-fixing associations only with rhizobia isolated from similar conditions. Those from wetter, more acidic environments formed effective associations with a greater range of rhizobia. The importance of considering the environmental backgrounds of both symbionts was explained, with a suggestion for the recording of relevant information by collectors.

3905 *Rhizobium* screening of *Stylosanthes* species for effectiveness in
2563 nitrogen fixation.
Date, R.A. (CSIRO, St Lucia, Qld., Australia) and D.O. Norris.
Aust J Agr Res 30(1):85-104, 1979.

Of 336 accessions, 224 were effective with a wide-spectrum strain (CB756). Sixty-two effective and 72 ineffective accessions were then evaluated against a spectrum of 22 strains of *Rhizobium* selected on the basis of host and geographic origin. Effectiveness responses were analyzed by a minimum spanning tree and MULTBET program to examine interrelationships between the *Stylosanthes* accessions and *Rhizobium* strains.

3906 Effectiveness of inoculation of alfalfa as related to plant variety
2443 and strain of *Rhizobium meliloti*.
Dorosinskii, L.M. (All Union Agr Micro Res Inst, Leningrad, USSR) and L.M. Alfanas'eva.
Microbiol 47(1):126-129, 1978 (Eng tr).

Active strains of rhizobia were effective on a broad range of alfalfa cultivars, but certain strain/cultivar interactions indicated that the host variety played a significant role in the symbiosis.

3907 Selection for acetylene reduction rates in 'Mesilla' alfalfa.
2253 Duhigg, P. (New Mexico St U, Las Cruces, NM, USA), B. Melton and A. Baltensperger.
Crop Sci 18(5):813-816, 1978.

The results indicated that plant selection under appropriate environmental conditions can lead to significant improvement in nitrogen fixation. Plant genotype effectiveness was evaluated with a single commercial inoculant.

3908 Symbiotic variation in field beans (*Vicia faba*).
2929 Lawes, D.A. (Welsh Plant Br Stn, Aberystwyth, Wales), L.R. Mytton, M.H. El-Sherbeeny and F.K. Sorwli.

Ann Appl Biol 88(3):466-468, 1978.
Evidence for very specific plant variety X rhizobial strain interactions resulted in a series of cautionary requirements in evaluating either the individual symbionts or their association.

3909 Development of an ineffective pea root nodule: morphogenesis, fine
2044 structure, and cytokinin biosynthesis.
Newcomb, W. (U Guelph, Ont., Canada), K. Syono and J.G. Torrey.
Can J Bot 55(14):1891-1907, 1977.
The failure of ineffective nodules to develop nitrogenase activity was ascribed to the absence of membrane formation around the bacteria.

3910 Symbiotic properties of antibiotic-resistant and auxotrophic mutants
2993 of *Rhizobium leguminosarum*.
Pain, A.N. (John Innes Inst., Norwich, Norfolk, England).
J Appl Bact 47(1):53-64, 1979.
Auxotrophic mutants with adenine requirement were non-infective and therefore symbiotically defective. Only a minority of rifampicin-resistant mutants were ineffective.

40. *Rhizobium* INHIBITION AND STIMULATION

4001 Effects of soil antagonists on symbiosis.
2324 Chowdhury, M.S. (U Dar es Salaam, Morogoro, Tanzania).
In Vincent, J.M., *et al*, Exploiting the legume/*Rhizobium* symbiosis in tropical agriculture. U Hawaii Coll Trop Agr misc pub 145, 1977, p. 385-411.
Antagonism by other microorganisms can have an important effect on the colonization and survival of rhizobia in the soil, either from competition, toxin production, predation or parasitism. The presence of antagonists is well documented, but knowledge of the interactions between rhizobia and their soil antagonists, both intra- and inter-specific, is limited.

4002 Inhibitory effect of seed diffusates of some legumes on rhizobia and
2545 other bacteria.
Dadarwal, K.R. (IARI, New Delhi, India) and A.N. Sen.
Ind J Agr Sci 43(1):82-87, 1973.
Great variation in inhibitory effects of seed diffusates between species and varieties of plants was noted. Bacteria producing large quantities of gum were less susceptible, and survival of rhizobia was enhanced by soaking seeds prior to inoculation.

4003 Growth response of *Rhizobium japonicum* to different rhizosphere
2633 extracts *in vitro*.
Kabi, M.C. (Nodule Res Lab, Mohanpur, India).
J Soc Exp Agric (India) 1(2):55-57, 1976.
The rhizospheres of different non-legume crops had varying effects on survival of rhizobia associated with legumes used in mixed or rotational cropping. Sunflower, hibiscus, wheat, mustard and linseed plants did not inhibit rhizobial growth, while paddy and sesamum were inhibitory.

4004 2512 Colonization by rhizobia of the seed and roots of legumes in relation to exudation of phenolics.
Kandasamy, D. (Annamalia U, Annamalainagar, India) and N.N. Prasad.
Soil Biol Biochem 11(1):73-75, 1979.
Phenolic diffusates inhibitory to rhizobia were found with germinating seeds of greengram, black gram and sun hemp *(Crotolaria juncea)*. Those of the latter were most inhibitory.

4005 2770 Observations on the inhibition of nodulation of *Arachis hypogaea* (Willd.) by *Parthenium hysterophorus* (Linn.).
Sarma, K.K.V. (Stavahana Coll, Vijayawada, India) and P. Appa Rao.
Compar Physiol Ecol 2(4):238-239, 1977.
Extracts from 100 g shoot material of the forbe were inhibitory to nodule number and size at 1% and 5% concentrations.

4006 2493 Differentiation of *Rhizobium japonicum*. III. Inhibition of nitrogenase derepression by chloramphenicol and rifampicin concentrations, not inhibiting growth.
Werner, D. (U Marburg, Fed Repub Germany).
Zeit Natur pt C Biosci 33:859-862, 1978.
The effect of chloramphenicol and rifampicin on nitrogenase development under certain cultural conditions indicated a *de novo* protein synthesis of both enzyme components.

41. ROOTS, ROOT EXUDATES AND INFECTION BY *Rhizobium*

4101 3022 Some observations on infection of *Arachis hypogaea* L. by *Rhizobium*.
Chandler, M.R. (Rothamsted Exp Stn, Harpenden, Herts., England).
J Exp Bot 29(110):749-755, 1978.
Infection of peanut differs from that of clover in that no infection threads are formed. Entry is at the junction of the root hair and the epidermal or cortical cells. The rhizobia multiply within the cortical cells, and the invaded cells divide repeatedly to form the nodule tissue. Bacteroids form when the plant cells cease to divide. Fourteen micrographs record the process in sharp detail.

4102 2758 Bacterial polysaccharide which binds *Rhizobium trifolii* to clover root hairs.
Dazzo, F.B. (U Wisconsin, Madison, WI, USA) and W.J. Brill.
J Bact 137(3):1362-1373, 1979.
A multivalent clover root lectin, trifoliin, which binds polysaccharides from the capsular material of *R. trifolii*, also had common antigens despite differences in the carbohydrate composition between the plant and the *Rhizobium*. It was proposed that the trifoliin provides a molecular interfacial structure which specifically cross-links similar antigenic determinants of the root hair cell wall and heteropolysaccharides of the bacterial capsule or cell envelope.

4103 Chemotaxis of *Rhizobium* sp. towards root exudate of *Cicer arietinum* L.
2615 Gitte, R.R. (U Agr Sci, Bangalore, India), P.V. Rai and R.B. Patil.
Plant Soil 50(3):553-566, 1978.
Fractionation of the exudate into anion, cation and neutral fractions produced a ratio of 1:7:2 respectively. Of the fractions alone, the cationic was most attractive, but less than the crude exudate. Of the individual components, histidine (cationic) and glucose (neutral) were most attractive.

4104 Effects of ethylene on root extension and nodulation of pea (*Pisum*
2910 *sativum* L.) and white clover (*Trifolium repens* L.).
Goodglass, G. (Edinburgh Sch Agr, Scotland) and K.A. Smith.
Plant Soil 51(3):387-395, 1979.
Ethylene at levels known to occur in aerobic soil inhibited extension of pea roots. Perfusion of 10 ppm ethylene into the soil near the roots of pea and clover resulted in reduced shoot dry weight, nodulation, and nitrogenase activity. Reduction of absolute nitrogenase activity through acetylene reduction activity was posed as a problem possibly meriting further investigation.

4105 Possible role of phytohaemagglutinin in *Phaseolus vulgaris* L.
2576 Hamblin, J. (U Cambridge, England) and S.P. Kent.
Nature New Biol 245(140):28-30, 1973.
Phytohemagglutinin was found to be capable of binding rhizobia to bean root hairs at suitable infection sites. The initial source for the PHA is probably the cotyledon of germinating seeds, but mature bean plants are also capable of synthesizing the product.

4106 A contribution to the histology of root nodules of *Sesbania sesban* L.
2685 Mahmood, A. (U Karachi, Pakistan) and S. Jamal.
Pak J Bot 9(1):39-46, 1977.
Root hairs were the principal route of entry, and the nodules were found to be of cortical origin. Four nodule regions were defined.

4107 The orientation of certain root-nodule bacteria at interfaces,
2408 including legume root-hair surfaces.
Marshall, K.C. (U Tasmania, Australia), R.H. Cruickshank and H.V.A. Bushby
J Gen Micro 91:198-200, 1975.
A perpendicular orientation of bacteria on the root hair surface was observed. Some of these bacteria also form rosettes in culture, and orient at right angles to an oil-water interface. The possibility of a bridging polymer at the bacterial pole was suggested.

4108 Root nitrogen content and transformation in selected grain legumes.
2090 Nnadi, L.A. (Inst Agr Res, Samaru, Nigeria) and V. Balasubramanian.
Trop Agr 55:23-32, 1978.
The extremes of N content in the legume roots examined were 1.25% for pigeon pea and 3.93% for Bambara groundnut. Two cowpea cultivars differed

widely in root N content (1.52 and 2.53%), and the nitrogen mineralized differently. The results indicated that Bambara groundnut and cowpea cv NEP-593 might be useful in improving the N status of soil even when the tops are not returned to the soil.

4109 Inhibition of soybean cell growth by the adsorption of *Rhizobium*
2970 *japonicum*.
Ozawa, T. (U Osaka, Sakai, Osaka, Japan) and M. Yamaguchi.
Plant Physiol 64(1):65-68, 1979.
The sodium cholate-soluble fraction of *Rhizobium* cell envelopes had a growth-inhibiting effect on soybean cells in suspension culture. It was suggested that rhizobial cell surface components cause a similar inhibition of soybean cell growth after adsorption during the infection process.

4110 Cytokinins and morphological aspects of French bean roots in the
2114 presence of *Rhizobium*.
Puppo, A. (Lab de Biol Veg, Nice, France) and J. Rigaud.
Physiol Planta 42(2):202-206, 1978.
Substantial quantities of exogenous cytokinins were detected in the liquid plant culture medium during the 9 days between inoculation and nodulation. The growth substances were probably responsible for morphological alterations and inhibition of growth of the root system. The evidence pointed to cytokinin production as a direct consequence of symbiosis.

4111 Infection threads in root hairs of soybean (*Glycine max*) plants
2454 inoculated with *Rhizobium japonicum*.
Ranga Rao, V. (C.F. Kettering Res Lab, Yellow Springs, OH, USA) and D.L. Keister.
Protoplasma 97:311-316, 1978.
Concentrations of rhizobia were observed in the rhizoplane after 5 days, when some root hair curling was also seen. Infection threads and nodule primorda appeared after 10 days. More than one infection thread per root hair was commonly seen, two being the usual number. Leonard jars offered the most convenient method for observing the infection process.

4112 Structure of infection threads in legume nodules.
2784 Yakoleva, Z.M. (Central Siberian Bot Garden, Novosibirsk, USSR).
N. Ya. Gordienko and G.G. Maistrenko.
Biol Bul Acad Sci USSR 2(5):732-737, 1975 (Eng tr 1976).
The infection thread was of cell wall origin with an intracellular part derived from an intercellular part. The material of the developing infection thread was of host wall origin. A suggested pathway for legume infection, in which the process is initiated by the penetration of bacteria into the walls of plant cells, was diagrammed.

42. SOIL FACTORS

4201 Fitting plants nutritionally to soils. I. Soybeans.
2368 Brown, J.C. (ARS/USDA, Beltsville, MD, USA) and W.E. Jones.
Agron J 69:399-404, 1977.

Rather than follow the traditional method of changing the soil to fit the plant, this study considers changing the plant to fit the soil. Ten soybean varieties were tested for response to nutrient stresses and toxicities, yielding data for matching particular varieties to soil conditions.

4202 Studies of *Rhizobium meliloti* isolated from salt-affected soils.
2423 Douka, C.E. (Nuc Res Ctr, Demokritos, APA, Greece), C.G. Apostolakis and V.D. Skarloy.
Ann Appl Biol 88(3):457-460, 1978.

By incorporating soil samples with agar in slopes, conditions resembling those in the field were simulated in tubes. Effective nodulation occurred in a soil with electrical conductivity of 34.2 mmho/cm, indicating that rhizobia can survive and perform under extremely adverse conditions.

4203 Scanning electron microscopy of *Rhizobium* spp. adhering to fine silt
2432 particles.
Fehrmann, R.C. (Texas A & M U, College Stn., TX, USA) and R.W. Weaver.
J Soil Sci Soc Amer 42(2):279-281, 1978.

This study established visual evidence of adherence of rhizobia to soil particles by polysaccharides produced by the bacteria. Rosettes of *Rhizobium japonicum* were seen on soil particles and aggregates.

4204 Some major fertility problems of tropical soils.
2337 Fox, R.L. (U Hawaii, Honolulu, HI, USA) and B.T. Kang.
In Vincent, J.M., *et al*, eds., Exploiting the legume/*Rhizobium* symbiosis in tropical agriculture. U Hawaii Coll Trop Agr misc pub 145, 1977, p. 183-210.

A review of the macro- and micronutrient status of tropical soils as they relate to actual and potential agricultural productivity. Special fertility problems involved in expanding agricultural development, continuous cultivation, and microvariability associated with biological activity (e.g. termite mounds) were discussed. The authors argue for a direct approach to fertility problems, for example applying phosphorus rather than indirect manipulations of phosphorus availability by chemical or biological means.

4205 Soybean growth and composition as influenced by soil amendments of
2136 sewage sludge and heavy metals: field studies.
Ham, G.E. (ARS, USDA, St. Paul, MN, USA) and R.H. Dowdy.
Agron J 70:326-330, 1978.

Tilling anaerobically digested, air dried sludge with heightened concentrations of heavy metals into the top 20 cm of soil did not significantly influence soybean seed yield. Increased Zn, Cd and Cu concentration was greatest in leaves, but large increases in sludge-bourne metals were not found in seed. The sludge served as a P source without adversely affecting yield.

4206 Influence of phenolic compounds on the growth and polysaccharide
2597 production of *Rhizobium leguminosarum*.
Jayachandran, S. (Tamil Nadu U, Coimbatore, India) and A. Balasubramanian.
Curr Sci (India) 46(5):142-144, 1977.
The polysaccharides produced by free-living rhizobia are important in soil aggregation and stabilization. The presence of phenols had qualitative and quantitative effects on soil polysaccharides from rhizobia.

4207 Acid tolerance of rhizobia in culture and in symbiosis with cowpea.
3046 Keyser, H.H. (U California, Davis, CA, USA), D.N. Munns and J.S. Hohenberg.
Soil Sci Soc Amer J 43(4):719-722, 1979.
The 21 strains tested showed a large variation in symbiotic tolerance of soil acidity. Some strains combined tolerance with high effectiveness. Simple, rapid growth tests which, with modifications, may be applied to screening other groups of rhizobia were described.

4208 The soil chemical environment in relation to symbiotic nitrogen
2882 fixation.
Loneragan, J.F. (U Western Australia, Nedlands, W.A., Australia).
In Use of isotopes for study of fertilizer utilization by legume crops. Vienna, FAO/Int Atomic Energy Agency tech rept 149, 1972, p. 17-54.
A review of the principles involved in the relations between soil properties and symbiotic systems. Problems encountered, and specific treatments for their alleviation, are discussed for the major phases affecting symbiotic nitrogen fixation (survival and growth of nodule bacteria; nodule formation; nodule function; and growth of the host legume). 132 references.

4209 Effects of soil acidity and liming on mineralization of soil nitrogen.
2270 Nyborg, M. (Res Stn, Agr Canada, Beaverlodge, Alta., Canada) and P.B. Hoyt.
Can J Soil Sci 58(3):331-338, 1978.
Laboratory and field experiments with forty soils of pH 4.0 to 5.6 indicated that soil acidity does not restrict mineralization of organic N, and that increased mineralization from lime applications is generally only temporary. Nitrification, which was best in older cultivated soils, decreased with decreasing pH, and the positive effects of liming did not diminish with time.

4210 Effect of lime on nodulation, growth, and nutrient content of
2733 *Trifolium subterraneum* on the Far North Coast of New South Wales.
Philpotts, H. (Agr Res Ctr, Wollongbar, N.S.W., Australia).
J Aust Inst Agric Sci 42(4):238-241, 1976.
Lime did not affect nodulation, but on some soils did increase clover yield.

4211 Acetylene reduction (dinitrogen fixation) and nitrification in soil
3086 as affected by the structural aggregate size.
Skrdleta, V. (Czechoslovak Acad Sci, Prague, Czech.), A. Hyndrakova and M. Nemkova.
Fol Microbiol 24(5):403-407, 1979.
Aggregates larger than 2 to 4 mm diameter exhibited considerably higher nitrogenase activity than those with a diameter less than 2 mm, but smaller aggregates exhibited more intensive nitrification.

4212 An overview of the soils of the arable tropics.
2352 Uehara, G. (U Hawaii, Honolulu, HI, USA).
In Vincent, J.M., *et al*, eds. Exploiting the legume/*Rhizobium* symbiosis in tropical agriculture. U Hawaii Coll Trop Agr misc pub 145, 1977, p. 67-80.
World population projections indicate a need to produce half again as much food by the year 2000. Of the world's 3.19 billion hectares of potentially arable lands, about half occurs in the tropics. Technology from temperate soils has not transferred well to weathered tropical soils. A combination of liming, phosphorus application, and selecting for acid tolerance is probably the best approach to pH and associated toxicity problems. Silicate amendments may reduce leaching losses.

43. SPECIFICITY AND PROMISCUITY

4301 Ultrastructure of *Rhizobium japonicum* in relation to its attachment
2246 to root hairs.
Bal, A.K. (Memorial U Newfoundland, St. Johns, Canada), S. Shantharam and S. Ratnam.
J Bact 133(3):1393-1400, 1978.
An effective strain with poor lectin-binding properties formed distinctive morphological types of which only the capsular form was found to bind soybean lectin and attach to the root hair surface. The capsular form accounted for less than 1% of the bacterial population.

4302 *Rhizobium* recognition.
2087 Beringer, J.E. (John Innes Inst, Norwich, England).
Nature 271:206-207, 1978.
The notion of lectin involvement in specificity was discussed in relation to the isolation of a mutant by Sanders, *et al*, which did not synthesize exopolysaccharide and could not nodulate its normal host. The role of capsular lipopolysaccharides and exopolysaccharides in determining the host range in *Rhizobium* species remains to be clarified.

4303 Role of lectins in plant-microorganism interactions. 1. Binding
2027 of soybean lectin to rhizobia.
Bhuvaneswari, T.V. (C.F. Kettering Res Lab, Yellow Springs, OH, USA), S.G. Pueppke and W.D. Bauer.
Plant Physiol 60(4):486-491, 1977.
Purified soybean lectin (SBL) was found to bind 15 of 22 *Rhizobium*

japonicum strains. SBL did not bind to the other 7 strains, nor to any of 9 other strains which do not nodulate soybeans. An inhibitor to SBL binding was found to be present in culture filtrates.

4304 Role of lectins in plant-microorganism interactions. III. Influence
2277 of rhizosphere/rhizoplane culture conditions on the soybean lectin-binding properties of rhizobia.
Bhuvaneswari, T.V. (C.F. Kettering Res Lab, Yellow Springs OH, USA) and W.D. Bauer.
Plant Physiol 62:71-74, 1978.

All of 11 soybean rhizobia and 2 of 6 cowpea rhizobia developed receptors to soybean lectin when cultured in root exudates or in association with roots of soybean seedlings. Six of the 11 strains did not develop specific SBL receptors when cultured in artificial media. Additional experimentation will be required to establish the role of lectin binding in specificity.

4305 A review: control of specificity in legume-*Rhizobium* associations.
2385 Broughton, W.J. (U Malaya, Kuala Lumpur, Malaysia).
J Appl Bact 45(2):165-194, 1978.

Evidence indicates that both the bacteria and the plant contribute to specificity of the symbiosis. The author defined four, and possibly a fifth, levels of specificity control: factors influencing rhizobial multiplication and growth in the rhizosphere; rhizobial binding to root hairs; initiation of root hair curling; root hair penetration; and, tentatively, abortion of infection threads. The current status of research related to each factor was reviewed, with 231 references to the literature.

4306 Trifoliin: a *Rhizobium* recognition protein from white clover.
2417 Dazzo, F.B. (U Wisconsin, Madison, WI, USA), W.E. Yanke and W.J. Brill.
Biochim Biophys Acta 539(3):276-286, 1978.

Trifoliin from clover seeds, at very low concentrations, specifically agglutinated *Rhizobium trifolii*. The highest concentrations of the recognition protein on a clover root were present at *R. trifolii* binding sites. A proposed role as a host coded determinant in the recognition of *Rhizobium* cells was described.

4307 Regulation by fixed nitrogen of host-symbiont recognition in the
2776 *Rhizobium*-clover symbiosis.
Dazzo, F.B. (U Wisconsin, Madison, WI, USA) and W.J. Brill.
Plant Physiol 62:18-21, 1978.

Infection and nodulation of white clover seedlings was completely inhibited by either NO_3^- (KNO_3 at 16 mM) or NH_4^+ (as NH_4^+ acetate at 1.0 mM). Rhizobial binding to root hairs, and detectable levels of trifoliin on the root hair surface, had parallel declining slopes as the concentration of nitrogen compound increased in the rooting medium.

4308 Transient appearance of lectin receptors on *Rhizobium trifolii*.
2705 Dazzo, F.B. (Michigan St U, E Lansing, MI, USA), M.R Urbano and W.J. Brill.

Curr Microbiol 2(1):15-20, 1979.
Trifoliin receptors appeared only as cells left the lag phase and as they entered the stationary phase of growth in broth, and could not be detected at other times. These lectin receptors appeared concurrently with development of the fibrillar polyanionic capsule. The stage of cultural growth from which inocula are prepared may affect nodulation rates. Implications of the transient receptor phenomenon on selectivity of root attachment by rhizobia were discussed.

4309 Promiscuous root nodulation of winged beans on an Oxisol in Puerto
2254 Rico.
Harding, J. (U California, Davis, CA, USA), M.A. Lugo-Lopez and R. Perez-Escolar.
Trop Agr (Trinidad) 55(4):315-324, 1978.
Promiscuous nodulation of winged bean was greater than of cowpea, hyacinth bean, pigeon pea or soybean, all grown in soil where legumes had not been previously cultivated.

4310 An Ouchterlony double diffusion study of the interaction between
2807 legume lectins and the rhizobial cell surface antigens.
Kamberger, W. (U Erlangen Nurnberg, Erlangen, Fed Rep Germany).
Arch Microb 121(1):83-90, 1979.
Soybean lectin precipitated only with the exopolysaccharides of *Rhizobium japonicum*, but lectins from pea and lentil precipitated EPS from all the fast-growing strains of *Rhizobium*. Concanavalin A showed no correlation between binding and symbiotic specificity. Wheat germ lectin did not precipitate with any rhizobial EPS, and the lipopolysaccharide of a non-nodulating soil bacterium did not precipitate with any of the six legume lectins examined.

4311 Determinants of symbiotic specificity in the *Rhizobium* pea - lentil
2671 association. (Abstr.)
Kamberger, W. (U Erlangen Nurnberg, Erlangen, Fed Rep Germany) and H.B. Nordhoff.
Hoppe-Seyler Zeit Phys Chem 360(3):295, 1979.
Lectins of both pea and lentil precipitated with exopolysaccharides of both nodulating and non-nodulating strains of *R. leguminosarum*, but with lipopolysaccharides of only the nodulating strains.

4312 Role of lectins and lipopolysaccharides in the recognition process
2835 of specific legume-*Rhizobium* symbiosis.
Kato, G. (U Tokyo, Japan), Y. Maruyama and M. Nakamura.
Agr Biol Chem 43(5):1085-1092, 1979.
Lipopolysaccharides of rhizobia were shown to react specifically with the lectins of host plants, supporting the view that LPS is the lectin binding entity in the recognition process.

4313 Symbiotic specialisation in pea plants: the requirements of specific
2665 *Rhizobium* strains for peas from Afghanistan.
Lie, T.A. (Agr U, Wageningen, The Netherlands).
Ann Appl Biol 88(3):462-465, 1978.

Indigenous *Rhizobium* strains from locations in Afghanistan where primitive peas grow naturally could infect pea plants resistant to the rhizobia that infect cultivated pea genotypes from temperate regions. The need to conserve native rhizobia germplasm was emphasized.

4314 Involvement of *Rhizobium japonicum* O antigen in soybean nodulation.
2682 Maier, R.J. (U Wisconsin, Madison, WI, USA) and W.J. Brill.
J Bact 133(3):1295-1299, 1978.

A surface antigen associated with the O antigen portion of the lipopolysaccharide was lacking in non-nodulating mutant strains. Data from chromatographic studies indicated that certain silver nitrate staining components of the O antigen were required to establish nodulation of soybean roots.

44. SURVIVAL OF *Rhizobium*

4401 Survival of *Rhizobium japonicum* serogroups in some Iraqi soils.
3240 Al-Rashidi, R.K. (U Baghdad, Abu-Ghraib, Iraq) and S.M. Damirgi.
Iraqi J Agr Sci 12:85-94, 1977.

The results showed that soil properties affected the survival of serogroups in sterilized and unsterilized soils. Plate counts and most probable numbers were two to three times higher in some soils than in others. The rates of survival were studied in relation to actinomycete populations, salinity, and nutrient status of the soils.

4402 Some factors affecting the survival of root-nodule bacteria on
2286 desiccation.
Bushby, H.V.A. (U Tasmania, Australia) and K.C. Marshall.
Soil Biol Biochem 9:143-147, 1977.

Survival of slow-growing strains was about twice that of fast growers when desiccated in sandy soil. Of various additives tested, only sugars and polyvinylpyrrolidone (PVP) protected rhizobia of both groups, but substantial increases in survival of fast-growing species resulted from amendment of the soil with montmorillonite.

4403 Desiccation-induced damage to the cell envelope of root-nodule
3023 bacteria.
Bushby, H.V.A. (U Tasmania, Australia) and K.C. Marshall.
Soil Biol Biochem 9:149-152, 1977.

Evidence of leakage suggested that changes in membrane permeability resulting from desiccation may be the cause of the high death rate of certain rhizobia. Repair of induced lysozyme sensitivity in *Rhizobium leguminosarum*, but not in the other species investigated. Evidence suggested that the lipopolysaccharide layers of surviving cells remained relatively unaltered by desiccation.

4404 Persistence of *Rhizobium japonicum* on the soybean seed coat under
2098 controlled temperature and humidity.
Davidson, F. (Research Seeds, Inc, St Joseph, MO, USA) and H.W. Reuszer.
Appl Envir Micro 35(1):94-96, 1978.
Survival on surface-sterilized seeds with 12 different coating materials and under a range of temperature and humidity conditions was determined by viable counts. At 15° C, survival on seeds after 3 weeks storage was from 2.1% to 19.3%. Mineral oil held a good number of rhizobia on the seed with a relatively high percentage surviving, but the survival rate in all treatments was quite low after storage at 30° C.

4405 Effect of prior treatment of peat with ethylene oxide or methyl
2209 bromide on survival of rhizobia in inoculants.
Deschodt, C.C. (Plant Protec Inst, Pretoria, S Africa) and B.W. Strijdom.
Phytophylactica 6:229-234, 1974.
Autoclave sterilization of peat was superior to chemical treatment for survival of rhizobia. Contaminants became abundant in the ethylene oxide treated peat after 30 days, and appreciable numbers of contaminants also survived the methyl bromide treatment.

4406 Survival of indigenous *Rhizobium meliloti* in sandy loam soils. (Spa)
3016 Sagardoy, M.A. (U Nacl Sur, Bahi Blanca, Argentina).
Agrochim 23(1):59-65, 1979.
Of the rhizobia surviving for 2 years in 15 sandy loam soils, 70% that nodulated alfalfa were effective strains. Incubation at 28° C produced a significant increase in the revived population of indigenous rhizobia.

4407 Effect of reinoculation and nitrogen fertilization on nodulation
2780 and nitrogen fixation of soybeans.
Tien, T.M. (U Florida, Gainesville, FL, USA) and K. Hinson.
Proc Soil Crop Sci Soc Fla 36:191-194, 1976.
Survival of rhizobia for four years after first inoculation without soybean crops during the period was proved by lack of significant response to reinoculation.

45. SYMBIOSIS

4501 Soluble protein and isozymes in inoculated and uninoculated *Phaseolus*
1929 *aureus* roots during development.
Agarwal, A.K. (IARI, New Delhi, India) and S.L. Mehta.
Ind J Exp Biol 15(5):391-392, 1977.
The patterns of glutamate dehydrogenase (GDH), malate dehydrogenase (MDH) and peroxidase were studied in developing roots of inoculated and uninoculated plants to determine the extent of symbiotic interaction. Quantitative and qualitative differences were seen in the peroxidase isoenzyme patterns in infected and uninfected roots, while MDH and GDH patterns remained similar. There were indications of freshly synthesized peroxidase isoenzymes resulting from host-*Rhizobium* interactions in the nodules.

4502 Primary metabolites of *Phaseolus vulgaris* nodules.
2177 Antoniw, L.D. (U Dundee, Scotland) and J.I. Sprent.
Phytochem 17(4):675-678, 1978.

The data suggest that several carbohydrates and amino compounds are donated by the host to the bacteroids, and that the quantity of donated material is influenced by irradiance level. The findings are consistent with the hypothesis that ammonia is the primary product of nitrogen fixation, initially assimilated to glutamine and glutamate in host cells.

4503 The *Rhizobium*-legume symbiosis.
2789 Beringer, J.E. (John Innes Inst., Norwich, England), N. Brewin, A.W.B. Johnston, H.M. Schulman and D.A. Hopwood.
Proc Roy Soc Ser B Biol Sci 204:219-225, 1979.

A consideration of the symbiosis as a part of the rhizobial life cycle. The infection process and related specificity, leghemoglobin, nitrogenase and nitrogen assimilation, and the role of genetic analysis in furthering our understanding of the symbiosis were reviewed. 83 references.

4504 Rhizobia and increased soybean production.
2567 Burton, J.C. (Nitragin Co, Milwaukee, WI, USA).
In Proceedings of the fifth soybean seed research conference, Chicago, 1975, p. 41-51.

A discussion of symbiotic nitrogen fixation in soybean, limitations in the symbionts, and possible ways of increasing the efficiency of the symbiosis. Suggested research objectives include: finding rhizobia with high efficiency, competetiveness, adaptability to a range of conditions, and good nodulating ability even in the presence of available nitrogen. Inoculation methods also need further improvement, and plant breeders need to know how to coordinate the symbiotic system under prevailing conditions.

4506 Host symbiont interactions. III. Purification and partial characterization of *Rhizobium* lipopolysaccharides.
2467 Carlson, R.W. (U Colorado, Boulder, CO, USA), R.E. Sanders, C. Napoli and P. Albersheim.
Plant Physiol 62(6):912-917, 1978.

No obvious correlation between nodulation groups of rhizobia and the chemical composition or immunochemistry of their lipopolysaccharide was found. Inter-specific differences were as great as intra-specific differences. Phage lysis patterns showed a similar lack of correlation. The establishment of a role for lipopolysaccharides in specificity will require additional structural studies.

4507 Nutritional restraints for tropical grain legume symbiosis.
2338 Franco, A.A. (EMBRAPA, Rio de Janeiro, Brazil).
In Vincent, J.M., *et al.*, eds., Exploiting the legume/*Rhizobium* symbiosis in tropical agriculture. U Hawaii Col Trop Agr misc pub 145, 1977, p. 237-252.

Plants relying on symbiotically fixed nitrogen may be more demanding for proper nutrition than plants supplied with combined N. The symbiotic

efficiency may also be sensitive to soil pH and the toxic effects of aluminum and molybdenum. Phosphorus deficiency has been found to be the major limiting nutrient in the tropics. Applying fritted trace elements directly to the soil or by pelleting the seeds has shown promising results, particularly with respect to molybdenum.

4508 The influence of the environment and managerial practices on the
1960 legume-*Rhizobium* symbiosis.
Gibson, A.H. (CSIRO, Canberra, A.C.T., Australia).
In Hardy, R.W.F. and A.H. Gibson, eds., A treatise on dinitrogen fixation, IV. NY, Wiley, 1977, p. 393-540.

Effects of the physical and biological environments on the initiation and functioning of the symbiosis were reviewed. Tables relate ranges of light effects and temperatures on some 25 associations to the relevant literature for each case. Methods of planting, inoculation, pest control and other agronomic practices affecting the symbiosis were also reviewed. There are 288 citations in the reference list.

4509 Certain environmental factors affecting rhizobia and symbiotic
2586 systems.
Hamdi, Y.A. (Agr Res Ctr, Giza, Egypt).
Zent Bak Parasit Infek Hyg II, Nat Abt 132(4):350-360, 1977.

A review of the effects of biological antagonists, pesticides, seed diffusates and environmental factors on the establishment of the legume/*Rhizobium* symbiosis.

4510 Plant genotype X *Rhizobium* strain interactions in cowpea (*Vigna*
2115 *unguiculata* (L.) Walp).
Minchin, F.R. (U Reading, England), R.J. Summerfield and A.R.J. Eaglesham.
Trop Agric (Trinidad) 55(2):107-115, 1978.

Four *Rhizobium* strains of differing effectiveness were used in combination with four semi-erect cowpea cultivars with differing growth habits. The importance of considering both symbionts when selecting either was demonstrated by the results.

4511 Induction of polygalacturonase in legume roots as a consequence of
2582 extrachromosomal DNA carried by *Rhizobium meliloti*.
Palomares, A. (Estac Exp Zaidin, Granada, Spain), E. Montoya and J. Olivares.
Microbios 21(83):33-39, 1978.

The ability to induce polygalacturonase production in legume roots, a phenomenon which has been related to nodule formation, was irreversibly lost after treatment of the rhizobia with acridine orange. It was concluded that the enzyme producing character may be plasmid controlled, and may account for the loss of nodulating ability as a function of time in laboratory cultures.

4512 2890 Quality and rate of extracellular polysaccharides produced by *Rhizobium meliloti* and their inducing effect on polygalacturonase production in legume roots as derived from the presence of extrachromosomal DNA.
Palomares, A. (Estac Exptl Zaidin, Granada, Spain), E. Montoya and J. Olivares.
Microbios 22(87):7-13, 1978.
The results were consistent with the production of polygalacturonase by roots being induced by rhizobial exopolysaccharides.

4513 2398 Comparative aspects of root and root nodule secondary metabolism in alfalfa.
Vance, C.P. (U Minnesota, St. Paul, MN, USA).
Phytochem 17(11):1889-1891, 1978.
The distribution and relative activity of phenolics, IAA oxidase and leghemoglobin in nodules, roots and bacteroids suggested an interrelationship which regulates indole levels in the nodule.

4514 2265 Cooperative action of plant and *Rhizobium* to dissolve host cell wall during development of root nodule symbiosis.
Verma, D.P.S. (McGill U, Montreal, Quebec, Canada), V. Zogbi and A.K. Bal.
Plant Sci Ltrs 13(2):137-142, 1978.
Two cell wall hydrolyzing enzymes (cellulase, in the host cell cytoplasm, and pectinase, in the bacteroids) are probably involved in the dissolution of the host cell wall during the infection process.

4515 1671 Exploiting the legume/*Rhizobium* symbiosis in tropical agriculture.
Vincent, J.M. (U Sydney, Australia), A.S. Whitney and J. Bose, eds.
U Hawaii Coll Trop Agr misc pub 145, 1977, 469 p.
The proceedings of a 1976 workshop sponsored by the USAID NifTAL Project at Kahului, Maui, Hawaii. The twenty-three papers have been entered under appropriate subjects in this bibliography, and cover a wide range of topics on yield potentials, soil factors, multiple cropping systems, the role of legumes in various regional and local farming systems, inoculation practices with specific legumes, and measures to provide inoculants and control their quality as a means of promoting legume food and forage crops.

46. TEMPERATURE EFFECTS

4601 2206 Effect of root temperature on dry matter distribution, carbohydrate accumulation and acetylene reduction activity in alfalfa and birdsfoot trefoil.
Barta, A.L. (Ohio Agr Res & Dev Ctr, Wooster, OH, USA).
Crop Sci 18(4):637-640, 1978.
Plants were grown at 16° and 30° C root temperatures. The higher temperature resulted in significantly lower total nonstructural carbohydrate accumulation in trefoil roots, which may explain why that legume fails to persist under some warmer conditions. Rates of acetylene reduction were significantly reduced at high root temperature only in alfalfa.

4602 Effects of incubation temperature and oxygen tension on nitrogenase
2832 activity of legume root nodules.
Dart, P.J. (Rothamsted Exp Stn, Harpenden, Herts., England) and J.M. Day.
Plant Soil spec vol:167-184, 1971.

Some nodules showed activity from 2 to 40° C, with maximum activity for most legumes between 20 and 30° C. *Medicago sativa* and *Vigna unguiculata* had maximum activity at 35 and 40° C, respectively. In closed vials, nodule respiration reduced the pO^2 which led to decreased nitrogenase activity, but by maintaining the oxygen tension at 20% the activity continued for 6 hours.

4603 Effect of high soil temperatures on nodulation of cowpea, *Vigna*
2381 *unguiculata*.
Day, J.M. (Rothamsted Exp Stn, Harpenden, Herts., England), R. J. Roughley, A.R.J. Eaglesham, M. Dye and S.P. White.
Ann Appl Biol 88(3):476-481, 1978.

Growth was best at 30 and 36° C. At 40°C two strains failed to nodulate, and the three other strains tested formed no nodules at 42°. Nodulation was most affected the first 3 days after sowing, and was unaffected when 10-15 day old seedlings were exposed to the same conditions.

4604 Low temperature effects on soybean (*Glycine max* [L.] Merr. cv. Wells)
2292 free amino acid pools during germination.
Duke, S.H. (U Wisconsin, Madison, WI, USA), L.E. Schrader, M.G. Miller and R.L. Niece.
Plant Physiol 62(4):642-647, 1978.

Differences in the relative proportions and distribution of glutamate, aspartate and peptides in seed tissues after germination at 10°C and 23°C were determined. The activities of glutamine synthetase and asparagine synthetase were considerably lower in the lower temperature situation.

4605 Response of soybeans to high temperature during germination.
3012 Emerson, B.N. (U Illinois, Urbana, IL, USA) and H.C. Minor.
Crop Sci 19:553-556, 1979.

Absolute response of genotypes to temperature was dependent on previous history of the seed. Length of storage and whether harvested at maturity or delay-harvested were important factors. Four genotypes were classified as having above average tolerance to 36°C temperature, and four as having below average tolerance, but all genotypes showed significant reduction in germination at 38°C.

4606 Influence of temperature on growth and nitrogen fixation in cultivars
3081 of *Phaseolus vulgaris* L. inoculated with *rhizobium*.
Graham, P.H. (CIAT, Cali, Colombia).
J Agr Sci Camb 93:365-370, 1979.

Maximum fixation occurred in the 15-25°C range, but the peak in fixation was progressively delayed as the lower end of the range was approached. This delay led to N deficiency symptoms at the 28 day harvest. The results suggested a need for starter nitrogen in cooler bean-producing regions.

4607 2873 Effect of temperature on N_2 fixation (C_2H_2 reduction) by nodules of legume and *Actinomycete*-nodulated woody species.
Hensley, D.L. (Purdue U, W Lafayette, IN, USA) and P.L. Carpenter.
Bot Gaz 140 (supp):S58-S64, 1979.

Temperature response data for *Actinomycete* induced nodules of *Elaeagnus umbellata* were compared to similar response data for rhizobial nodules. Nodules were incubated at temperatures from 2 to 44°C. *Actinomycete* nitrogenase activity showed a surge between 8 and 11°, reached maximum activity at 34-36°, then rapidly declined at higher temperatures. Activity ceased at 43°C. The optimum range for woody legumes was about 20-30°C. There was rapid recovery from near-freezing teperatures, but high temperature effects were irreversible.

4608 3004 Influence of temperature on root hair infection of *Trifolium parviflorum* and *T. glomeratum* by root nodule bacteria. I. Effects of constant root temperature on infection and related aspects of plant development.
Kumarasinghe, R.M.K. (Rothamsted Exp Stn, Harpenden, Herts., England) and P.S. Nutman.
J Exp Bot 30(116):503-515, 1979.

Infection and nodulation were reduced at temperatures below 18°C and above 30°C. Primary infections seemed less temperature susceptible than did secondary infections, and nodule numbers were relatively more sensitive than infection to temperature extremes.

4609 3005 Influence of temperature on root hair infection of *Trifolium parviflorum* and *T. glomeratum* by root nodule bacteria. II. Effects of changes in root temperature.
Kumarasinghe, R.M.K. (Rothamsted Exp Stn, Harpenden, Herts., England) and P.S. Nutman.
J Exp Bot 30(116):517-528, 1979.

Transfer of seedlings grown at low (6 or 12°C) or high (36°C) root temperatures to 24°C caused a "switching on" of root hair infection. Reaction to various temperature transfer patterns suggested the build-up of an infection promoting substance within the root tissue at favorable temperatures.

4610 2709 Effect of temperature, solar radiation and moisture on the reduction of acetylene by excised root nodules of *Alnus glutinosa*.
McNeil, R.E. (Purdue U, W Lafayette, IN, USA) and P.L. Carpenter.
New Phytol 82(2):459-465, 1979.

The nodules appeared to fix nitrogen at high rates only when ample soil moisture was available. Under favorable moisture conditions, a positive response to solar radiation and temperature was also seen.

4611 2456 Effects of air temperature on seed growth and maturation in cowpea (*Vigna unguiculata*).
Roberts, E.H. (U Reading, England), R.J. Summerfield, F.R. Minchin, K.A. Stewart and B.J. Ndunguru.
Ann Appl Biol 90:437-446, 1978.

Four day-night temperature regimes were investigated, with mean values of 22.8 to 28.3°C. The mean dry weight of individual seeds contained in the first fruit were twice as much for the coolest as for the warmest regime, with intermediate values for intermediate temperature regimes. The overall effect on the duration of seed growth was a shortening by 25% in the warmest regime.

4612 Effect of root temperature on floral morphology in cowpea (*Vigna*
2138 *unguiculata* [L.] Walp.) cv K 2809.
Stewart, K.A. (U Reading, England) and R.J. Summerfield.
Plant Soil 49:443-448, 1978.

A large diurnal variation in temperature resulted in floral construction which restricted self polination, drastically reducing seed yield. Male sterility in cowpea is an inherited, recessive out-crossing mechanism identified in field populations, and is associated with similar floral abnormalities. The need to evaluate the environmental and genetic influences of this character was pointed out.

4613 Growth, reproductive development and yield of effectively nodulated
2310 cowpea plants in contrasting aerial environments.
Summerfield, R.J. (U Reading, England), F.R. Minchin, K.A. Stewart and B.J. Ndunguru.
Ann Appl Biol 90(2):277-291, 1978.

Factorial combinations of daylength (11 hr 40 min or 13 hr 20 min), day temperatures (27 or 33°C) and night temperature (19 or 24°C) to simulate humid tropical environments were used in growth cabinets with symbiotic and inorganic N supplied cowpea plants. The comparisons indicated that effectively nodulated plants are as adaptable to the aerial environment as are plants depending on inorganic nitrogen, with equally good or better seed yields. Warm night temperatures generally led to production of more branches.

47. WATER FACTORS

4701 The effect of different water regimes on growth and nodule development
2435 of greenhouse grown *Vicia faba*.
Gallacher, A.E. (U Dundee, Scotland) and J.I. Sprent.
J Exper Bot 29(109):413-423, 1978.

Plants on excess water regime grew better, fixed more nitrogen than those on drought stress. Unlike soybean, broadbean nodules did not produce ethanol when incubated under water. The nodules showed rapid response to fluctuations in water supply.

4702 Effects of short-term waterlogging on growth and yield of cowpea
2116 (*Vigna unguiculata*).
Minchin, F.R. (U Reading, England), R.J. Summerfield, A.R.J. Eaglesham and K.A. Stewart.
J Agr Sci (Camb) 90:355-366, 1978.

Waterlogging before flowering reduced vegetative growth by about 50% in

both symbiotic and non-symbiotic plants. The data support the conclusion that rapid recovery of the nodule system was, at least in the short term, detrimental to recovery of the host plant. The identification of symbiotic combinations more tolerant of waterlogging should be pursued.

4703 Growth and specific nodule activity of soybean during application and
3097 recovery of a leaf moisture stress.
Patterson, R.P. (N Carolina St U, Raleigh, NC, USA), C.D. Raper and H.D. Gross.
Plant Physiol 64(4):551-556, 1979.
Vegetative and reproductive growth, nodule energy charge, and specific nodule activity were all depressed by leaf moisture stress. The nodule energy charge recovered rapidly after rewatering, but nitrogenase activity required 4 to 5 days to recover.

4704 Effects of water stress on nitrogen fixation in root nodules.
2834 Sprent, J.I. (U Dundee, Scotland).
Plant Soil spec vol:225-228, 1971.
In addition to affecting the formation and longevity of nodules, water stress was also shown to affect nitrogen fixation rates in nodules, lichens and blue-green algae. Moderate water stress reversibly slows down acetylene reduction and respiration in nodules, but severe stress led to irreversible cessation of nitrogen fixation. Observations indicated an interaction between host cytoplasm, bacteroids and uninfected neighboring cells.

4705 Factors affecting nodulation and nitrogen fixation by *Vicia faba*.
2732 Sprent, J.I. (U Dundee, Scotland).
Ann Appl Biol 88(3):473-476, 1978.
Broadbean has a potential yield apparently greater than that of soybean, possibly due to lower oil content. A high water requirement makes this legume susceptible to water stress, but recovery from either drought or waterlogging was good. By timing the sowing of broadbeans, it may be possible to avoid the coincidence of water stress and periods of greatest susceptibility.

CROSS REFERENCE GUIDE

(1980 Bibliography)

This page may be detached for use as a cross-reference between citation numbers and articles on particular topics by authors, and to relate index term citations to subject designations.

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An attempt has been made to list all authors for each citation in the bibliography. There are undoubtedly some cases of synonymy due to variant usage by authors or their publishers. Entry of names is in accordance with Anglo-American cataloging rules which, in some cases, may differ from preferred usage by the author. Through correspondence with the bibliographer, corrections can be made in future compilations.

As an aid to locating particular articles by an author, a contents list with subject designation numbers has been designed for removal to afford portability. This device will also serve as a cross-reference between general and specific topics for users of the subject index.

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