lated yields. Following is the precipitation for each year of the survey period averaged for twelve weather stations that represent the survey area.

**Inches Precipitation**

<table>
<thead>
<tr>
<th>Year</th>
<th>Precipitation</th>
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<td>1955</td>
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<td>14.6</td>
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<tr>
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<td>9.1</td>
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<tr>
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<tr>
<td>1950</td>
<td>15.5</td>
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<tr>
<td>1949</td>
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</table>

For the survey period, the average for the twelve stations is 11.8 inches. The long-time average for these stations is 11.0 inches. Timeliness of precipitation, temperature, wind, sunshine and other important factors that influence forage production obviously are not reflected by precipitation records. The many inaccuracies associated with estimated yield data, due to differences between people, varying standards, and so on, are acknowledged. Accuracy and statistical reliability of sampling is not implied herein. A relatively large number of recordings of estimated yield for each condition class and site, made by a variety of trained people over a widespread area and during a number of years, however, add credibility to the patterns of yield-behavior. The consistency with which certain fundamental yield-site-soil relationships have been repeated under widespread testing in eastern Oregon indicates reliability of certain principles that have been presented.

### Inoculation For Better Pasture and Forage Legumes in the Tropics

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### Need For Tropical Pasture Legumes

Attention has been called by Whyte (1953) to the lack of a suitable pasture legume which will maintain itself in association with grasses under moderate to heavy grazing conditions in the tropics. Whyte, Nilsson-Leissner and Trumble (1953) have made a rather comprehensive review of the use of legumes in the various tropical and subtropical countries. The review was based mainly on answers obtained as a result of circulating a questionnaire among the various governments. It was an attempt to fulfill the need for information on the availability of species and varieties of tropical legumes, their use in crop rotations, their effect on soil fertility and their incorporation into pasture and fodder mixtures. Whyte and Moir (1959) have stressed the need for grain legumes in the low-lying wet tropics where there are no livestock or grain crops, and the people live on starchy foods. Whyte (1962) suggests that the protein requirements of dairy and beef cattle in the tropics might best be met by concentrating on the production of high yielding fodder legumes, rather than by searching for an elusive type that would withstand heavy grazing. A number of alternatives, in use in various areas of the tropics, are suggested for providing a leguminous component to tropical grazing feeds.

During a technical meeting on “Legumes in Agriculture and Human Nutrition,” discussions on tropical pasture legumes were included. Limitations on livestock production in tropical Africa were largely attributed to the low quality of natural pastures, a situation that could be corrected by the use of a suitable tropical legume. The problem is to find one that could fill the place of the clovers and lucerne in temperature areas.

### Some Promising Tropical Pasture Legumes

Progress has been made in the humid tropics where *Pueraria phaseoloides*, *Stylosanthes gracilis* and *Phaseolus lathyroides* are grown and grazed to a considerable extent. The problem is more difficult in the dry tropics although *Stylosanthes sundaica* shows promise in northern Queensland, Australia.

Leguminous pastures are the key to increased agricultural and pastoral production on some 70 million acres of well-watered but comparatively underdeveloped subtropical country in Queensland, Australia. *Lotono- nonis bainesii* and *Dolichos lablab* show promise and attempts are being made to breed suitable varieties of lucerne. *Indigofera spicata* is also promising but is toxic to animals. It is quite possible that leguminous shrubs and trees will play an important role in tropical and subtropical pastures.

*Centrosema pubescens* was found to grow well with *Cyanodon plectostachyum* in equatorial pastures in Nigeria and to compare favorably with temperate...
zone legumes in its contribution to soil nitrogen (Moore, 1960). *Stylosanthes gracilis*, introduced into Nigeria in 1947 from Queensland (Nwosu, 1960) is a protein-rich source of livestock fodder and is high in mineral content. It can be economically produced and converted into a meal suitable for dry season feeding. The standing crop is grazed only sparingly because of its content of harsh hairs.

Hunter river lucerne, in combination with *Rhodes* grass, green panic and buffel grass (*Guyndah* strain) proved to be suitable for rotational grazing in the subtropics of Queensland, Australia (Young, Fox and Burns, 1959). All mixtures carried beef cattle at a heavy rate through a severe drought.

*Leucaena glauca*, a widely distributed leguminous tropical tree is well suited as a high protein forage for cattle (Anonymous, 1959a) (Compere, 1959) (Gantt, 1958) (Henke, 1958) (Work, 1958). It is deep rooted and quick growing and withstands drought and repeated cutting. Unfortunately, it contains an alkaloid, mimosine, which has a depilatory effect on non-ruminating animals and may cause an undesirable taste in milk if fed prior to milking. Research is under way in Australia to obtain, by introduction or by breeding, high yielding strains of *L. glauca* of low mimosine content.

Extensive studies have been made by Crowder and coworkers (Crowder, Ramirez and Chaverra, 1961) (Crowder, Vanegas, Lotero and Michelin, 1959) on grasses and legumes that occur in Colombia and on introductions obtained from other sources. As a result of these studies a number of promising species of pasture legumes, suited to different climatic zones of Colombia, have been found. For example, tropical Kudzu was very productive in the lower areas and mixes well with para or guinea grass. *Desmodium* species were found in almost all pastures and appeared to contribute a noteworthy amount of forage to the pasture mixture in the warm area (2500-6500 feet). Legumes suitable to the low-lying hot regions (0-2500 ft.) were indeed limited.

Mostert (1955) found *Psoralea obtusifolia* (*Wild Lucerne*) well nodulated and suggested it for use in association with grasses as a ley in South African pastures.

Masefield (1958) cites a number of examples where grasses grown in association with legumes show an increase in yield and protein content.

Moore (1960) believes that the inefficiency of nitrogen fixation by tropical legumes is due to lack of proper rhizobia, lack of proper nutrients, or both. Work at Ibadan, Nigeria, indicated that under suitable conditions legumes in pastures growing under equatorial conditions may contribute amounts of nitrogen to the soil similar to those added by legumes in temperature pastures.

Norriss (1959a) reports that the genus *Trifolium* contains a little-known group of species inhabiting the high mountains of tropical Africa. Some of these species constitute an important part of the pastureage of these regions and have a potential use in tropical and subtropical uplands provided effective nodulation can be obtained.

**Effective And Ineffective Rhizobia**

Bowen (1956b) studied the response to inoculation with isolates of rhizobia of a number of tropical legumes grown in wallum-heath soils of Queensland, an area where tropical legumes abound. No significant response was obtained as a result of inoculation of *Vigna sinensis*, *Phaseolus lathyroides* and *Stylosanthes gracilis*. Increased yields were obtained, however, by inoculating *Glycine max* and *G. javanica*. Yields and protein content were increased by inoculating *Phaseolus vulgaris*, *Centrosema pubescens*, *Clitorea ternatea* and *Indigofera hirsuta*.

Saubert (1958), working at the Plant Physiological Institute of the University of Pretoria, studied the nitrogen-fixing efficiency of 17 South African and exotic strains of *Rhizobium leguminosarum* on seven species or varieties of vetch (*Vicia*). The test plants consisted of a variety of *Vicia sativa* from Italy, France, Bulgaria and South Africa, *V. grandiflora* from Italy and two imported varieties of *V. villosa*. The results indicated clearly that the various strains of rhizobia differed markedly in their effect on yield and nitrogen content of the different species and varieties of vetch. A marked incompatibility was found between *V. grandiflora* and *V. sativa*. Saubert emphasizes the need for polyvalent inoculants containing tested strains of rhizobia effective for all commonly grown varietics of a given species of legume.

Eight species of *Trifolium* from equatorial mountain regions of Africa were tested by Norriss (1959a) against a range of strains of rhizobia derived from clovers of European and Mediterranean origin, in comparison with two strains of rhizobia derived from African clovers. Effective symbiosis was obtained only with an African strain derived from *T. rueppelianum*. Varying degrees of ineffective symbiosis were obtained with strains of rhizobia from clovers of European origin. These findings are of particular significance to the plant introduction officer and the taxonomist.

Several species of tropical legumes, now recognized as most promising, failed dismally when first introduced into Queensland, Australia, because they did not nodulate (Anonymous, 1958). *Lotononis bainesii*, for example, failed to respond to 60 local or introduced strains of rhizobia,
but did beautifully when the soil was inoculated with a strain isolated from nodules of L. bainesii from South Africa, where the particular variety had originated. This rhizobia strain forms red colonies when cultured. Furthermore it appears to be the only strain that will effectively nodulate L. bainesii, a tropical pasture legume.

Leucaena glauca, a tropical tree legume of forage value, also failed initially until the proper strain of rhizobia, obtained from Indonesia and New Britain, was provided. Trifolium rupellianum and T. semipilosum introduced from the high mountains of Central Africa, failed to nodulate in the tablelands of Queensland, until inoculated with bacterial strains obtained from their original habitat.

Some Legumes Nodulate With Difficulty Or Not At All

For many years it was assumed that nodule formation was a property common to all leguminous species. Only a fraction of the known species of legumes have been examined for the presence of nodules, and a portion of those examined were found to be without nodules. In view of the evidence that receptiveness or resistance of legumes to nodulation is genetic the plant breeder may be able to produce, by breeding, a nodulating form with improved agronomic prospects from a non-nodulating form.

Mostert (1955) examined a number of legumes of South Africa for nodules and concluded that not all the leguminous species are able to symbiose with nodule bacteria. Mostert recognized, however, that a plant may be well nodulated under certain conditions and entirely lacking in nodules under others.

Masefield (1958) has pointed out some of the difficulties encountered in determining the extent of nodulation of deep-rooted tree legumes, in which nodules may come and go, or nodule-bearing roots may easily break off, or the site of nodulation may change with age.

The available information on nodulation and cross-inoculation of legumes indigenous to Queensland has been assembled by Bowen (1956). The survey shows some nodulation in all areas of the tropics, including 29 previously unlisted indigenous species and two unlisted genera.

Bonnier and Seeger (1958) made a study of the extent of nodulation of various species of legumes in tropical soils. They observed that in tropical forests, where all vegetation is returned to the soil thereby maintaining its nitrogen content in equilibrium at a high level, nodulation was rare. Furthermore, nodulation was observed in savanna soils only after disturbance of this equilibrium, such as that caused by fire. They concluded that only in cultivated soil, where the crops and their nitrogen are removed, is fresh nitrogen required in the nitrogen cycle. In such cases fixation by legumes is an important and efficient means.

Nodule-inhibiting substances have been demonstrated in the seed coat of Centrosema pubescens by Bowen (1961) and in root excretions of a non-nodulating strain of soybean by Elkan (1961).

Red Strain Of Rhizobium

A strain of nodule bacteria that is red in color was isolated in pure culture and its cultural characteristics and results of cross-inoculation test described by Norris (1958). The red strain was found in the nodules of Lotoanis, a genus containing about 120 species of herbs and small shrubs. Attempts to nodulate L. bainesii introduced into Australia met with failure until inoculated with a red strain obtained from nodules attached to the roots of L. bainesii grown in South Africa. This is reported to be the first red strain of rhizobia found as a normal field associate of a legume. Norris suggests that in the past colored strains of legume nodule bacteria have been discarded as contaminants during isolation and cautions against repetition of such mistakes, especially when dealing with unfamiliar species.

The Need For Legume Inoculation

The real significance of legumes in agriculture was first understood as a result of investigations reported by Hellriegel and Wilfarth (1888). These German scientists demonstrated that legumes grown in sterilized soil were free from root nodules and did not thrive as well as nodule-bearing plants grown in unsterilized soil. The foundation was thus laid for a considerable amount of research on symbiotic nitrogen fixation, research which has paid for itself many times over in increased yields and value of leguminous crops.

Legume inoculation is needed because not all soils contain the specific bacteria necessary to produce nodules and fix atmospheric nitrogen symbiotically.

Deficiency In Knowledge Of Tropical Legumes And Their Symbionts

Bisset (1959) studied the characteristics of 12 strains of rhizobia isolated from wild and cultivated tropical legumes growing in the Congo. Bisset shares the view advanced by Norris (1959* that tropical members of the leguminosae and strains of rhizobia associated with them are primitive.

The hypothesis is advanced by Norris (1956) that legumes originated in the tropics and that some temperate-zone species and their rhizobia have become highly specialized.

Norris (1959*) cautions the tropical bacteriologist about accepting without question what he has learned about symbiotic
nitrogen-fixing bacteria based on temperate-zone experiences. He particularly stressed the need for an open mind regarding the following:

(a) Root hair infection. Perhaps this takes place only in a minority of cases. Peanut root hairs, for example, are few and play no part in infection since nodules are initiated by wound infection at the point of emergence of lateral roots.

(b) Cultural characteristics. Classical strains of rhizobia are white, cream or translucent, while red strains have been isolated from Lotononis bainesii (Norris, 1958) and a rusty brown one from Mimosa pudica.

(c) Cross-inoculation groups. Strain specific groups like the clovers represent a condition of degenerate specialization while freely cross-inoculating species such as those found in the cowpea group are primitive.

(d) Claims that tropical legumes fail to nodulate. Such claims should be treated with reserve until more information is available.

(e) Claims that tropical legumes fail to fix nitrogen. This may be due to the presence of nitrates.

(f) Inoculation of tropical legumes. There is just as great a need in the tropics as elsewhere for careful bacterial strain testing and selection of highly effective types.

(g) Calcium nutrition of rhizobia. Norris (1959) claims that he has shown that magnesium rather than calcium, is needed.

Our deficiency of knowledge about host plant/rhizobia relationships of tropical forms has been emphasized also by Corby (1959) who points out that little has been done to isolate agriculturally useful strains. Furthermore, imported inocula and conventional methods of using them often appear to be unsatisfactory in the tropics. For this reason a bacteriological laboratory has been established at Grasslands Agricultural Research Station at Marandellas, Southern Rhodesia, to isolate and prepare locally effective inocula and techniques for applying them. This is proposed as a first step toward improving local cultures of legumes.

Effect Of Temperature On Survival Of Rhizobium

Following field observations of poor nodulation of legumes sown on hot days, Bowen and Kennedy (1959) studied the effects of high temperature on legume bacteria. Eighty-seven strains of legume bacteria on nutrient agar showed maximum temperatures for growth of 31-38.4°C for clover, 32-32.7°C for pea, 36.5-42.5°C for medic and 30-42°C for tropical legumes strains of rhizobia. Studies of the decline of viable population on sterile wallum-heath sand at 40°C indicated the rapid death of pea and clover strains and the death of tropical legume strains within 10 hours. There was an initial drop in numbers of lucerne organisms followed by a lesser death rate. Survival of legume bacteria on seed sown at 40°C in moist soil varied with strain of organism, initial concentration of inoculum, and time of subjection to high temperature.

Studies on pre-inoculated alfalfa and clover seed stored at 5°C and 25°C for three weeks showed that temperature was a very important factor in the survival of rhizobia (Erdman-1960). Viability of the microorganisms decreased with increase in temperature over the range of 5°C to 25°C.

Some Reasons Why Legumes Do Not Respond To Inoculation

Some cases have been reported where results of legume inoculations are negative or questionable. There may be a number of causes for failure to obtain increases in yields by inoculation. Some of the more important of these are as follows:

(1) The soil may already contain an abundant supply of efficient nitrogen-fixing symbiotic bacteria of the proper strain for the legume under cultivation. This condition rarely prevails, especially if the legume has not been grown recently with success on that particular field.

(2) The inoculant may be inefficient, non-viable, contaminated with antagonistic organisms or unsuited for the particular species or strain of legume being cultivated.

(3) Environmental conditions in the soil may be unfavorable (pH, moisture, temperature, aeration, antagonistic microflora).

(4) Direct contact with fertilizers, seed disinfectants or toxic chemicals.

(5) Lack of certain major (Ca,P) or minor elements (Mo).

(6) Presence in the soil of specific bacteriophage.

For these reasons, considerable vigilance is required in order to assure the farmer that he is getting the proper strains of nitrogen-fixing bacteria for his legumes and that they are delivered to him in a viable condition. He must then be taught how and when to apply the inoculant.

Selecting Effective Strains Of Rhizobia

In seeking better strains of rhizobia, isolations should be made from pink nodules obtained from the roots of vigorous dark green plants. Pinkness in the nodule is due to the presence of leghemoglobin which is necessary for efficient symbiotic nitrogen fixation (Virtanen, Erkama and Linkola, 1947).

Chromatography has been suggested as an aid in selecting effective strains of rhizobia (Wieringa and Bakhuis, 1957). The method is based on the collection of bleeding sap of plantlets grown under aseptic conditions and determining its content by the use of chromatography of certain amino acids. The sap of
uninoculated or ineffectively nodulated legumes was found to contain only aspartic acid and possibly threonine while acid and possibly nodulated plants contained aspartic acid, asparagine, glutamine, hydroxyproline and threonine. Sometimes one or two additional unknown substances were found in the sap of effectively nodulated plantlets.

A continued search for better inoculants for the various legumes of agricultural value is necessary. This requires the cooperation of bacteriologists, agronomists and taxonomic botanists.

The maintenance in pure culture and testing of collections of rhizobia is also a vital part of any widespread effort directed towards an effective inoculation program.

**AID/USDA Legume Inoculation Project**

Highly effective strains of legume bacteria are available for about fifty species of legumes as a result of a joint AID/USDA project on legume inoculation. Most of these legumes are tropical or subtropical species and the cultures of N-fixing bacteria were isolated from the nodules of legumes from various countries. Strain evaluations are made under greenhouse conditions. Promising strains are then tested under soil and climatic conditions found in the countries where they will be used. About one third of the cultures tested in the field have resulted in increased yields of the inoculated legumes.

**Summary**

A review of the current literature on tropical pasture legumes and their associated root nodule bacteria points out the need for further efforts directed toward the search for compatible grass-legume mixtures that will grow under the different conditions encountered in the tropics. Alternatively, high yielding fodder legumes should be sought to meet the need for protein of livestock in the tropics.

More efficient nitrogen-fixing strains of rhizobia with which to inoculate specific tropical pastures and fodder legumes are needed. Instances of crop failures due to the lack of proper strains of rhizobia in the soil are cited. Inoculation with efficient strains of rhizobia provides an economical form of insurance against such failures.

Both yield and nutritive value of pasture and fodder legumes can often be increased by inoculation.

Nodules may be formed by ineffective or parasitic strains of rhizobia resulting in little or no atmospheric nitrogen fixation.

There is evidence of a deficiency in our knowledge of host plant/rhizobia relationships of tropical legumes. Knowledge gained from legume inoculation in temperate climates is not necessarily applicable under tropical conditions.

**LITERATURE CITED**


**AID**—Agency for International Development, the U.S. Government bilateral agency which has superseded the International Cooperation Administration.


**BOWEN, G. D. 1961. The toxicity of legume seed diffusates towards...**
Grazing Problems in Turkey

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Permanent pastures and meadows occupy about 75 million acres in Turkey. This acreage exceeds that used for all cultivated crops, about 62 million acres, of a total land area of 192 million acres. Considerable grazing is also obtained from stubble fields after grain harvest or from weedy fallow, and from about 5 million acres of forested land. The total forested land in the country is about 26 million acres.

Approximately 80 percent of the people live in villages and are engaged in agricultural pursuits. Their principal activities are the production of grain and other cultivated crops and the raising of livestock. Animal products include meat, cheese, and milk as important food items for their regular diet; wool and mohair for clothing and carpets; and leather for a multitude of uses. About 20 percent of the people live in cities engaged in industry, business, and government administration.

Grazing Methods

Herding of livestock prevails throughout the country. Fences are not used to confine animals to grazing areas. Under the village system livestock are privately owned but the animals graze together on community pastures (Figure 1). The cultivated area is in private ownership but the grazing is done on public land and fees are not required for the grazing rights.

Trend in Livestock Numbers

Livestock numbers have increased considerably during the past 10 years. Goats have increased by 35 percent and make it especially difficult to manage the rangeland. Further complications occur from the mixed classes grazing the common range (Figure 2). Water buffalo, cattle, camel, sheep, donkeys, and horses in addition to the goats rely almost entirely for their livelihood upon grazing the grass and browsing the brush. Cultivation has increased to now occupy 20 percent more land during the past 10 years. This