EDITOR'S NOTE.

*In March and April, 1962 Dr. Davies visited Taiwan at the invitation of the Government of the Republic of China. After an extensive fact finding tour of the island he gave a seminar on pasture development on April 2 and 3. Dr. Chang Lien-Chun, a personal friend of Dr. Davies, organised the tour and the seminar. He also recorded the proceedings of the seminar and undertook the task of translating it into Chinese. This Chinese version is available from Dr. Chang who is at present with the Chinese Agricultural Technical Group to Vietnam, 31, Cao Thang, Saigon, South Vietnam. Dr. Chang made the proceedings available to TROPICAL GRASSLANDS and the following is an abbreviated and somewhat rearranged form of these proceedings.*

# PASTURE DEVELOPMENT IN THE SUB-TROPICS, WITH SPECIAL REFERENCE TO TAIWAN.

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## ABSTRACT

*The author gave a seminar in Taiwan in 1962 on development of pastures on the island. This paper is an abbreviated form of the proceedings of the seminar. Establishment and growth of pastures are discussed with regard to climate, especially day-length, soils, plant nutrition and the use of legumes and grasses.*

*The yield and quality of tropical versus temperate pasture species and how animal production from pasture can be increased are dealt with in some detail. Advice on pasture development in the various regions of Taiwan is given.*

## ESTABLISHMENT AND GROWTH OF PASTURES

### *Climate*

In the sub-tropics special attention has to be given to the effect of day-length on pasture species. This is true for species as well as for varieties within species. Day-length affects flowering and seed setting as well as the vegetative growth of plants. Plants grown in the wrong day-length will not set seed, they will not yield their maximum, nor will they give the proper proportion of leaf and stem to provide high quality forage for the animal. In the sub-tropics there is a relatively small change of day-length throughout the year and pasture plants must be sensitive to such small changes so as to maximise the vegetative growing period, which means leaf production, without sacrificing seed production. I shall illustrate this with the example of two species of *Paspalum* grown in Queensland. Flowering of *P. dilatatum* is controlled by temperature as well as by day-length. When the temperature exceeds 70°F flowering media are laid down and when the day-length exceeds 12¾ hours flower heads will appear. Because of these conditions, *P. dilatatum* in Queensland flowers throughout the growing period. This means that the plant produces large quantities of stem and comparatively little leaf. In contrast *P. plicatulum*, a grass introduced from northern Brazil, has a short flowering period in April and May so that it has a vegetative growing period from October till April instead of the vegetative growing period from October till November for *P. dilatatum*. To illustrate the difference, we obtained an annual yield of 15000 kg/ha of dry matter from *P. dilatatum* and of 26000 kg/ha of dry matter from *P. plicatulum* under equal conditions. The increase is due to the fact that there is a continuous leaf production instead of continuous flowering during the main growing season. It also means that *P. plicatulum* is utilising the sunlight with much greater efficiency than *P. dilatatum*. The same thing is true for a number of other grasses. In Napier grass (*Pennisetum purpureum*) there is great variation between strains in time of flowering and relative leaf production. In *Setaria sphacelata* there are a number of varieties with different day-length response and con-

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sequently there is a wide range of flowering time. The same is true for Rhodes grass (*Chloris gayana*). I want to emphasise that for the tropics and sub-tropics great attention must be paid to maximising leaf production because this is the key to improving the quality of the diet of the grazing animal.

## *Soils and plant nutrition*

Pastures can be grown over a very wide range, in fact, probably over the complete range, of the great soil groups. I shall not go into details of the effects of the various physical and chemical characteristics on plant growth but I shall highlight a number of soil properties which I think are very important as far as pasture and forage crops are concerned. These are: the moisture holding capacity, the rate of infiltration, the level of nutrients in the soil and the base exchange capacity. I particularly want to stress the importance of plant nutrients and their availability in soils. Soils vary widely in their natural fertility with respect to all the nutrient elements required by plants. In Australia we have found that our soils are almost invariably deficient in phosphorus and nitrogen and commonly deficient in any one or more of the other major and trace elements.

The geology of Taiwan is quite different from that of Australia. Most of your rocks are geologically relatively young. In Australia practically all the continent consists of geologically old rocks. I also want to point out that any evidence of nutrient deficiency in your soils on your paddy land probably will not apply to your hills and mountains. The reason for this is quite simple. Your rivers are draining different rock formations as they are coming down from the mountains into your arable land and those streams are certainly carrying a range of rock material in the form of sand, silt and clays which are bringing in the range of nutrients required, especially since most of the rocks are young and have not passed through a series of geological leaching. There is however, one similarity between your hills and mountains and our situations in Australia. In both instances the rainfall, which is usually quite heavy, is received during the hotter seasons of the year. This tends to maximise leaching of the more soluble nutrients—nitrogen, potassium, calcium, phosphorus and sulphur. Therefore you will have to examine the different soils to see whether the nutrients have been leached from the soil profile. The most important soil nutrients are nitrogen, phosphorus, potassium and calcium. However, consideration should not be limited to these four elements, the other elements in the major group such as sulphur and magnesium are also important. I also want to stress that the trace elements such as copper, zinc and molybdenum may be decisive in determining whether you can grow a legume or not. Without these trace elements it is not possible to grow legumes and grasses satisfactorily. Soils may have considerable quantities of copper, zinc and molybdenum when chemically analysed but these elements are frequently present in unavailable forms. Therefore the chemical analysis of soil will not detect whether there is a deficiency in any of these elements with regard to plant growth. This was the situation with regard to molybdenum in the original case where Dr. Anderson detected molybdenum deficiency on a laterite soil in southern Australia. That soil contained high amounts of total molybdenum and yet about 150 g of soluble molybdenum compounds per ha made a complete difference between growing large yields of subterranean clover (*Trifolium subterraneum*) and a total inability to grow the clover.

Legumes are generally higher in their content of all elements than grasses. This is true for nitrogen, phosphorus, calcium, sulphur, copper and molybdenum. The main exception is potassium. Some grasses such as *Setaria sphacelata* can have extremely high potassium contents, up to 4% of K in the leaves. It is doubtful whether this large percentage of potassium is really essential for the plant. The point I want to emphasise is that as the legumes are higher in their content of nitrogen, phosphorus, calcium, sulphur, copper and molybdenum it follows quite naturally that they have a greater requirement for these nutrients. The interesting element is nitrogen. Legumes can and will grow very satisfactorily on soil nitrogen as some farmers in Taiwan very well know. Several times I have seen farmers using urine as a fertilizer for beans. They are using nitrogen fertilizer on a plant which, in fact, is capable of fixing its own nitrogen. It would be instructive to make a detailed study of this practice because several trace elements are present in urine and it may well be that the real reason for its value for beans is not to provide nitrogen but to correct another nutrient deficiency.

Let us now consider the importance of nitrogen and phosphorus on a pasture mixture of both grasses and legumes. When soils are deficient in these two elements grasses will not grow well but legumes will thrive even on soils that contain no nitrogen at all, as long as the legume is provided with adequate amounts of other nutrients. The amount of nitrogen that can be fixed can reach the level of 400 to 500 kg/ha/yr. For instance, white clover in New Zealand has given 450 kg/ha/yr., lucerne 500, *Leucaena leucocephala* also 500 kg. In general the range of these plants under grazing will provide from 100 to 250 kg N/ha/yr. The important thing is to realise that the greater part of nitrogen fixed by the legume is retained in the above-ground parts of the plant, not in the roots. Only 5-8% of the total nitrogen fixed by a legume from the atmosphere is in the roots, whereas 92-95% is contained in the above-ground parts of the plant. This means that much of this fixed nitrogen finds its way to the animal and since the animal only retains a comparatively small proportion of the total nitrogen ingested, a large amount is returned to the soil. Usually I regard 75-85% of the nitrogen ingested by the animal being returned to the soil. This amount depends on the nitrogen balance of the animal. This, to a large extent, is true of the other elements as well. Thus, under grazing, legumes grown on soil low in nitrogen can increase the nitrogen content of the soil appreciably over a number of years. However, under a system of cropping or zero-grazing this does not apply. With a good crop of soya bean practically all the nitrogen which the plant has taken, either from the soil or from the atmosphere, is harvested in the seed. It must be realised that a legume which is cut for forage or harvested for seed does not, in fact, increase the soil's nitrogen very significantly. Similarly with regard to grasses, such as Napier, guinea and pangola you will be removing soil nitrogen by constant cutting. For these reasons you cannot estimate the nitrogen requirement of a pasture under any form of cutting—you can only estimate the yield of pasture under cutting in such a way. By so doing you will invariably get a far greater response to the application of nitrogen under a cutting regime than you will under a grazing regime.

### *Pasture legumes*

Because of the high cost of nitrogen fertilizer in Australia and New Zealand relative to the value of the animal product, much emphasis is placed on pasture legumes in these countries. The values for our production are not determined by the internal cost structure in Australia but they are dependent on the prices these products obtain in the world markets. I have endeavoured to impress upon our nitrogen fertilizer industry the need to reduce very drastically the cost of nitrogen. I pointed out that by so doing we could tremendously increase our production of meat, wool and cereals. Unless they achieve this within five to ten years, either by financial or other industrial devices, the market for nitrogen in Australia will remain at about its present level, because we in Queensland will be producing tropical and sub-tropical legumes instead of using nitrogen on pasture.

The two important roles of legumes in pasture are to bring in atmospheric nitrogen and to provide animals with a diet that is high in calcium, phosphorus, nitrogen and other mineral nutrients.

When we started some 10 years ago on the research and development of tropical and sub-tropical pastures there were only a few legumes of some value available, particularly Townsville stylo (*Stylosanthes humilis*), phasey bean (*Phaseolus *lathyroides*), centro (*centrosema pubescens*) and tropical kudzu (*Pueraria phaseoloides*). The first two legumes are annuals which grow every summer from seed and die off in the winter. Townsville stylo is particularly valuable because its seeds are edible and easily picked up by the animal to provide it with a protein rich diet during the non-growing period of winter. These two are sub-tropical and can survive under long dry periods. Centro and tropical kudzu are used to a small extent in a relatively small area of true tropical conditions that exists on the north-eastern coast of Queensland. In the last decade we have been searching the world for other legumes and have brought quite a number into Australia. For instance *Leucaena leucocephala, Glycine wightii, Desmodium uncinatum, D. intortum, D. sandwicense, Phaseolus atropurpureus, Lotononis bainesii* and *Vigna luteola*. We have been concentrating on these legumes together with Townsville stylo in our Division, devising techniques for their successful fertilization and of obtaining appropriate strains of *Rhizobium* for their inoculation. Of these, *G. wightii* has come into Taiwan and it looks very promising for a considerable range of your climates, but you have only one variety and there is a wide range of varieties within the species. I will illustrate the importance of getting a suitable strain of *Rhizobium* with the example of *L. bainesii*. This legume was introduced from South Africa by Mr. John Miles, our Plant Introduction Officer. When it was first tried it would only grow to about 5 to 10 cm in height and would only spread 20 to 25 cm, because the plant was not nodulated. When eventually Dr. Norris obtained the correct inoculant the plant grew to half a metre in height and spread three metres in one season. The search for the right inoculant was complicated by the fact that, as Dr. Norris discovered later, *Lotononis* is one of the most specific legumes with regard to inoculation.

I am pleased to see that the same legumes we are using in Queensland are showing promise in Taiwan. This is not merely important to us in Australia and to you in Taiwan, but to the whole tropical and sub-tropical world. There are vast areas of potential pasture country in the tropics and sub-tropics of every continent, but first class pastures in these areas have not been developed because the problem of growing tropical and sub-tropical legumes has not been solved for these areas.

### *Grasses*

When we come to consider the grasses for the sub-tropics and tropics the position is much more simple. There are many grasses available and the only problem is the supply of adequate nutrients, especially nitrogen. I will deal with particular grass species in later sections.

## PASTURE YIELD AND QUALITY

The dry matter production from pastures in the sub-tropics and tropics far exceeds that which can be achieved in the recognised pasture areas of the world—the true temperate zones. The highest yield in New Zealand, which is regarded as one of the leading pasture countries, is about 14,000 kg of dry matter per ha per year. In Puerto Rico the highest yield of dry matter of Napier grass is 58,000 kg per ha per year. In Brisbane, the best yield we have obtained is 30,000 kg of dry matter and in Europe the yields are generally between 8 and 12,000 kg. In the United States they are of a similar order. Therefore, the potential pasture production of grasses in the sub-tropics and tropics is so great that I feel we should take more advantage of it. Some of the grasses of the dry season tropics such as Pangola grass, *Paspalum*, Bermuda grass, Rhodes grass and *Setaria sphacelata* could be of value for planting in southern Taiwan from Kaohsiung down to Gengchun.

I want to go into the question of quality in relation to the climatic zone in which pastures grow. Unfortunately higher dry matter production in the sub-tropics and tropics is accompanied by a lower protein content as compared with those from temperate zones. The nitrogen content of tropical and sub-tropical pastures is usually of the order of 1-1½% of dry matter. Depending on the stage of growth, cool temperate pastures will give 3-3½% of nitrogen and associated with this higher nitrogen content is higher digestibility. This enables the animal, especially the dairy cow, to produce at much higher rates at comparable stocking rates. It is this aspect of research which we are concentrating on at present. We are aiming to obtain grasses which will give us a higher nitrogen content. One grass that comes near this aim is *Setaria sphacelata* from which we have obtained 3-3.25% of nitrogen, so it does not appear impossible to break this serious deadlock in pasture quality in the tropics.

The commonest natural pastures in Taiwan are those with *Miscanthus* and *Saccharum spontaneum.* I do not know of any data on the yields or the nutritive value of these species. My impression, which is based on visual examination for a very short time, is that these *Miscanthus* pastures are both low in yield and low in chemical composition. The fact that there is a large mass of material left at the end of the growing season does not necessarily mean that you are getting either a high yield of dry matter or that there is really much value in these pastures for the animal.

In Queensland the natural pastures, especially in the areas with rainfall exceeding 750 mm per annum, give poor yields and are of low nutritive value and that is why we have decided, after a great deal of investigation, that the replacement of these plants is the long term objective if we are going to improve the food supply of the animal and the carrying capacity of the country. Not only is the protein content of these pastures below the requirement of the grazing animal during the winter period, but the energy supply also falls below their requirements. The result of these two factors is that in late winter and spring (the dry season), the animals will lose weight. For these reasons animals are usually from 4 to 5 years old before they are ready for slaughtering. Another effect of low yield and low nutritive value of the pasture is that these pastures have a low carrying capacity. The low content in the soil of nitrogen, phosphate, base elements and sometimes potassium together with the relatively low rainfall and its erratic distribution are the basic factors responsible for the low animal production per unit area. The pasture plants growing under these conditions are adapted to survive the worst drought which may occur every decade on the average. That is why these plants make rapid growth for 7 to 8 weeks in spring or early summer. Because of the unreliable rainfall the farmers cannot fully utilise the amount of feed that grows in the summer. During the growing period the pastures must be under-grazed in order to allow the animals to survive the dry winter.

## PASTURE IMPROVEMENT

### *Tropical pastures*

The factors I have just mentioned are the reasons why we considered that a replacement of natural pastures is the objective we have to go for. However, we have found that it is not always necessary to replace the native pasture completely. I will illustrate our success in completely or partially replacing native pastures in Queensland. First of all I will deal with the introduction of Townsville stylo into native spear grass pastures. On a property near Gladstone, just south of the Tropic of Capricorn, natural spear grass pastures carry one beast to 3½ ha. By reducing the plant cover of the native pasture by burning or very heavy grazing, Townsville stylo seed can be broadcast on the surface, although we have found that better results are obtained by planting the seed in strips which are cultivated. Animal production can be improved this way without adding fertilizer but we have found that by adding superphosphate at 100 kg/ha and molybdenum at 250 g/ha the carrying capacity can be increased threefold over three or four years. However, it is necessary to double the stocking rate at planting in order to reduce competition from the native grasses.

Apart from the improvement of carrying capacity there is a very noticeable effect on growth of animals. Two and a half year old steers from unimproved pastures can be fattened in one year on the same pasture when improved with Townsville stylo and superphosphate. It is perfectly obvious of course that we can improve the situation even further by putting the breeding cow on these improved pastures. You will get higher reproduction rates, higher live weight per calf at birth, and the young animals will reach slaughtering weight much earlier. The main reason for the earlier maturity of the animals is that instead of losing weight in the large part of the year on unimproved pastures these animals will actually maintain their weight or only lose a little on improved pastures.

In areas of southern Queensland where Townsville stylo cannot be grown our practice is to replace the native pastures completely by introduced grasses and legumes. For this purpose several grasses such as Rhodes grass, *Paspalum plicatulum,* Buffel grass or *Setaria sphacelata* together with legumes like Siratro, *Desmodium intortum* and Hunter River lucerne can be used.

You can make use of our experience in improving your native pastures. I must warn you however, that merely putting a legume into your *Miscanthus* pastures is not necessarily going to be successful. You must see to it that the nutrient and the *Rhizobium* situation for that legume is satisfactory. Then you must find out the management system which will provide the ecological balance of the pasture. This relationship between the grazing animal and its pasture is extremely important. If you overlook these factors the natural grasses will eliminate the introduced species. The present species on the hillsides of Taiwan are adapted perfectly well to the existing situation. Therefore, you must change this environment for better fertility and grazing control so that the native grass does not eliminate the introduced species. An alternative of course is to feed urea and molasses during the winter period. This gives you a somewhat better nitrogen intake, it covers the energy and in addition phosphate, calcium and, quite often, copper as these are incorporated. This has the effect of preventing at least some, if not all, of the winter loss. The only trouble with this technique is that it does not in fact improve the carrying capacity of the pasture. Supplementary feeding with urea and molasses does not keep the animal in a positive nitrogen or energy balance.

The C.S.I.R.O. Division of Tropical Pastures has concentrated primarily on improving animal production. Animals require the same diet every day of the year but no pasture will, in fact, under our extensive grazing system, provide the ideal food supply for the grazing animal for the twelve months of the year. This leads us to the consideration of three factors. First, there is supplementary feeding of concentrates from other sources than the pasture, second, the grazing of supplementary pastures or crops during the winter season and third, the conservation of existing pasture for use during the non-growing season.

Under Queensland conditions the cost of concentrates, especially protein concentrates, is far too high to enable us to use these in the beef or the sheep industry. They are used only to a limited extent in the dairy industry. We are aiming to develop pulse crops to enable us to produce more and cheaper concentrates for winter feeding. For the time being therefore we are concentrating primarily on raising the yield and the quality of the pasture so that we can not only maintain the animals for a longer period, but also so that we can make silage or hay of sufficiently high quality to maintain the animal in full production in the winter period. There is no point in doing this from low quality and low yielding pasture.

This leads me to comment on the hay made in Taiwan from pangola grass. It looks to me to have around 1% nitrogen or less. Pangola is a very vigorous and very useful grass but it does not carry a satisfactory level of nitrogen. That is why you have found it necessary to use urea and molasses together with pangola hay in order to maintain the growth of young animals. This low nitrogen content is aggravated by the fact that you people are making hay from pangola at too late a stage of growth. As you leave the pangola grass to increase in yield you must realise that the protein content drops, especially when the grass comes into the flowering stage. Therefore you are not getting the optimum concentration of nutrients. The same applies to the digestibility of the material. By leaving it too long the digestibility may drop from 65% to 40%. The next problem is that with declining percentage digestibility the intake of dry matter by the animal is lowered, because it takes longer to digest in the rumen. All these factors mean that production from the pasture is lowered as you leave the pasture longer to mature before you cut it for hay. The point I wanted to emphasise is that unless you have both high yield and high quality, fodder conservation from pasture is not an economic proposition.

Another reason for low production from pasture is over-grazing. I have gained the impression that you are trying to carry too many stock too early on new pastures. The effect of overstocking is quite simple. If one is to get the maximum yield from any plant, and certainly from pasture, one must maintain a leaf coverage which is near the optimum leaf area index. For most pastures the optimum leaf area index is about 4.5. In other words you can have 4 to 4½ leaves, one on top of the other and you will intercept the whole of the radiation and therefore use all of it for production. If one does not maintain the leaf area index at its optimum, maximum production is impossible. Over-grazing means that you have one leaf intercepting the radiation, therefore you are only getting a fraction of the potential growth. This of course, assumes that fertility and moisture are not limiting. It is therefore necessary at all times to maintain a body of leafage which completely intercepts the incident radiation. A dense pasture, although it may be short, will always intercept more radiation than a tall open pasture. This is one of the reasons why I do not judge your *Miscanthus* pastures highly—they are very open and they allow a lot of light to get through without being intercepted.

One of the problems facing animal production from tropical and sub-tropical pastures is that we are still only achieving 50% efficiency of utilisation—in other words our carrying capacity is only using half of the actual pasture growth. It should be possible to increase this efficiency by conserving some of the excess growth in summer. Apart from hay making procedures we are also studying silage making from tropical pastures. Under the high temperatures which prevail during the growing period, the making of silage is not nearly well enough understood. In silage making the loss of digestible dry matter can be anything from 25 to 50% during our warm growing period. In contrast, in cool temperate regions silage making has been improved to the point that it is usual to limit the loss of digestible matter to about 15%. Our problem with silage making has not yet been solved. It is probably a matter of consolidation of the material and maintaining low temperatures. Also, the practical aspects of whether we should put it into bunkers or into plastic sheets which are supported by concrete reinforcing wire, need to be studied.

### *Temperate pastures*

At high elevation in much of your mountain lands, that is from 500 metres upwards, the temperature regime is such that in effect you have a cool temperate climate; but this is still a sub-tropical climate with respect to day-length, just as in parts of Kenya and Tanzania. Therefore when you are considering pasture grasses and legumes to be grown in these regions you have to select from within the cool, temperate species. However, you cannot rely on species from the well known temperate pasture zones of the world because of differences in day-length. You will have to get your plants from places like Kenya and Tanzania, as plants from the temperate zones are unlikely to flower and grow properly. The legumes which appear to me as being of potential value on your higher country of say up to 2000 metres are white clover and red clover, but the existing varieties are not exactly suited to your day-length regime. There are two possible sources of white clover for you. One is Louisiana clover from the Mississippi region of the United States, and the other is the naturalized white clover we find around Brisbane. These two clover types have the same day-length requirements and both set seed very freely. Although the plants themselves are short lived—they may only live for a year or two—the re-establishment from seed is very vigorous. Louisiana clover is not as high yielding as Ladino on an individual plant basis but you should realise that when considering a pasture the size of the plant is not always the determinant—it is the number of plants and the density of plants that has to be considered.

Further consideration should also be given to lucerne (*Medicago sativa*). I should like to point out that most of the strains of lucerne that have been tested here have come from the wrong latitudes. The problem you face is that low latitude lucerne varieties are susceptible to frost. The places to send for them are India, Pakistan, especially in Baluchistan and also in Turkestan, the original home of lucerne, and you might try the Argentinean strain Saladino, which is a very good one. This could be a very valuable plant at elevations from 500 to 2500 metres. It is also true that most of the cultivars are of cool season grasses from too high a latitude. Italian rye grass grows excellently in Lishan, Chien Ching, but it does not flower properly. There is a very simple answer to that problem. All you need do is to cross the Italian rye grass with *Lolium multiflorum* and you will get early flowering strains of Italian which will give you high quality, the heavy yield of Italian and the early flowering of *multiflorum*. This is grown in New South Wales and Victoria at latitudes of 30° to 33° S, whereas most Italian rye grass comes from latitudes 45° to 55° N. The same is true for perennial rye grass, Cocksfoot, tall fescue, meadow fescue and meadow foxtail. All of those show considerable promise as a grass for mountain regions. This is not surprising. *Phalaris tuberosa,* and especially the line that came from Victoria, which is almost certainly the strain bred by Professor Trumble in Adelaide, is growing extremely well at Chien Ching and it is obviously well adapted to that region with an elevation of 1500 to 1700 metres. This grass is worth trying because it is not very severely damaged by frost or snow. The other plant that should be looked at is, surprisingly enough, *Paspalum dilatatum,* especially at medium elevations and below 1500 metres. *P. dilatatum* at those elevations will not experience temperatures of 70°F for considerable parts of the summer and will therefore not flower throughout the growing season. In Australia *P. dilatatum* is at its best south of Sydney at a latitude of about 32° S, because the temperature in summer is low enough to get a long vegetative growing period. I suggest that you can get exactly the same effect with elevation in Taiwan. *P. dilatatum* is obviously perfectly attuned to flowering at your day-length. Another grass I want to discuss is *Setaria sphacelata.* Although it is a warm sub-tropical grass, the fact is that in Africa *S. sphacelata* occurs at sea level in Portuguese East Africa as well as up to 3000 m elevation on Mt. Kilimanjaro. There is a wide range of cultivars growing up to these elevations, many of which are frost resistant and will stand snow. Recently we have brought these into Australia for use in areas where frosts are a problem.

Another point I want to make concerning the temperate legumes lucerne, white clover and red clover is that these are the classic pasture legumes and they have been studied most with respect to pH and calcium requirements, especially with regard to nodulation. Indeed, there has been so much work done on these three species that a complete misconception has arisen in the world about the requirements of legumes in general for growth in respect to calcium and pH. The point is that these three legumes originated in soils of high calcium and phosphorus status but they are, in fact, rather exceptional in their high demand for calcium and phosphorus. Also they are somewhat exceptional in that they require a pH of 5.5 or higher for satisfactory growth of the plant and of the *Rhizobium.* From the practical point of view you have to see to it that calcium and phosphorus as well as pH are satisfactory for the growth of these three legumes, as most of your mountain soils in Taiwan are acid. However, as Dr. Anderson in Australia has shown with subterranean clover, provided the calcium status is satisfactory these legumes will, in fact, grow at a pH lower than 5.5. When this was found, a very cheap and simple method for establishing these legumes was developed. It is now called 'lime pelleting" of the seed by which inoculated legume seed is covered with fine calcium carbonate. This is very effective in providing calcium for the initiation of nodulation. Once infection has taken place the significant pH is that of the nodule and not that of the soil. The *Rhizobium* multiplies within the nodule and that always has a pH of about 6.6. In other words, you do not need to use 2,000 kg/ha of calcium carbonate—you can achieve the same results without changing the pH of the whole soil mass.

## USE OF AVAILABLE INFORMATION

I will now make some comment on what I think is the best way to use the available information that you have. This is not an easy job for a person who has come here for one month and only sees the conditions during that very short period of the year. I would first of all concentrate on increasing the number of pasture species. At the present time your own pasture workers concentrate on pangola grass for very simple and good reasons. It grows well, it is easy to establish from cuttings and therefore it has been the easiest plant to develop, but pangola grass does not show any variability because it is completely sterile. Therefore you cannot adapt it to grow better in the winter or longer in the summer. The second point I want to make is that you should do everything you can to exploit the legumes that are already here. The ones that I personally would concentrate on, in addition of course to centro, are *Glycine wightii, Desmodium intortum* and *Phaseolus* species. These are all grazing legumes. Centro is very closely self fertile; in fact it is a cleistogamous species and therefore does not have any variability; it is somewhat like pangola in terms of adaptability. Such plants are either adapted to a situation or they are not, so that their use will be limited to a specific situation. No variability means limited adaptability. The other species I mentioned are showing a considerable amount of variability between cultivars. For example, there is a large number of cultivars of *Glycine wightii.* The same is true of *Desmodium intortum* of which a wide range is available. In the case of *Phaseolus atropurpureus* cv. Siratro, Dr. Hutton has breeding lines with a very considerable range of agronomic characteristics. *Lotononis bainesii* is not showing much variability, but there are over 100 other species in this genus. Mr. Bryan of our laboratory came to the conclusion that there may be about 20 species of *Lotononis* that we should introduce into Australia in order to test this genus more fully. Of the grasses, I suggest that you try more critically the *Setaria sphacelata* complex. It has a much larger range of adaptability and is of higher nutritive value than pangola. Its main weakness is that it can be grazed out, unless the pasture is managed properly. The second plant I think you should try more critically is Rhodes grass. There are some excellent cultivars of Rhodes grass now available from Africa, completely different in palatability and in day-length requirement from the Rhodes grasses which have been tested here, some of which are the very stemmy types like Katambora. You do not, in fact, have the more leafy strains of Rhodes grass. There is also a very wide range of variation in *Panicum maximum.*

Where zero-grazing is practised, Napier grass gives very high yields, especially with irrigation and nitrogen, but it is usually of low chemical composition and especially low in protein. We have tried several cultivars of Napier grass under grazing but they all tend to disappear. I would suggest that in addition to Napier you should test out *Setaria* and Coloniao, *Setaria* because it will give you higher quality material and will probably give you very close to the same yield, and Coloniao because, under irrigation, it certainly out-yields Napier grass quite easily. You should realise that by cutting and zero-grazing, as it is done on your dairy farms, the return of nutrients after they have passed through the animal will be vital. If you do not return these nutrients, the production of these plants will fall away disastrously in a relatively short time. I saw one dairy, I think it was at Changhua, where most of the nutrients are returned to the Napier grass and that was easily the best Napier grass that I saw in Taiwan. The field not only received the nutrients from the Napier but also from the concentrates that were fed to the animals. The result was obvious in the cattle—they were the best of any dairy cattle that I saw, because they were thoughtfully fed. The one thing that I would do on this farm is to use *Setaria* in addition, because I would expect to get better winter feed for the animals. Although this way you might lose some yield in summer, you would get somewhat better quality of forage and you would have extra feed in winter, which is very desirable for a dairy farm because the requirements are much the same throughout the year.