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PREFACE

In keeping with one of the basic objectives of *Advances in Agronomy*, this volume covers a variety of subjects of concern to crop and soil scientists. Likewise, the sixteen North American and Australian authors who contributed these papers have a breadth of backgrounds and interests. They have covered topics vital to both public and scientific concerns.

The continuing world-wide attention to tropical agriculture is recognized in this volume. An analysis is made in one chapter of the potential, and the problems, of ratoon cropping—a practice of considerable importance with tropical crops such as bananas, sugar cane, and pineapples. An extensive review of research to improve and utilize tropical pastures relates to the potential for forage production in the tropics. The problems involved in the production and utilization of a number of important tropical forage species are also emphasized. While one is impressed with the research contributions, the opportunities and problems ahead present challenges which dwarf these accomplishments of the past.

Two other chapters relate to the animal industry as well as crop production. One is a review of the research on birdsfoot trefoil (*Lotus corniculatus* L.), an important pasture and forage legume of especial value in the North Central and Northeastern states. The second deals with grass tetany, a ruminant animal malady associated with forages low in magnesium and often relatively high in nitrogen and potassium. Factors affecting the animal disorders, probable reasons for them, and therapeutic techniques are reviewed.

A review of recent research findings on frost and chilling damage to plants includes evidence as to the mechanism of damage, and information on methods of preventing or reducing this damage. In another chapter the relationship of geometric configuration of roots to nutrient uptake is examined. Research is reviewed which identifies the conditions under which nutrient transfer in the soil and root system configuration limit nutrient uptake.

Growing public concern for environmental quality has forced a realistic consideration of the part tne soil might play as a sink for various kinds of wastes. Included are pesticides and other exotic chemicals, sewage, and similar wastes. One chapter is addressed to a review of the reaction of soils (clays) with organic compounds. The increasing specificity of our knowledge is impressive but the need for greater understanding of these reactions in soil is even more obvious.

The soil environment for plant roots and other living organisms is considered in two chapters. A critical review of the platinum electrode method for measuring soil aeration casts some doubt on the interpretation of earlier findings, especially those wherein so-called critical values of oxygen flux for root and plant growth were established. The microflora of grasslands and grassland soils is discussed in one chapter. These contributions will be especially helpful as background for those concerned with ecosystems and how man is modifying them.

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TROPICAL PASTURES

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I. Introduction

Improvement of tropical grasslands was neglected for many years because most of the areas involved are in developing countries with pressing sociological and economic problems. Also, it had been concluded (Whyte *et al.*, 1953) that it would be very difficult to introduce a legume into tropical grasslands and establish legume-based pastures as productive as those in temperate areas. It was left to grassland scientists in several countries, including Hawaii (Takahashi, 1956), Jamaica (Motta, 1956) the Congo (Germain and Scaut, 1960), and Australia (J. G. Davies, 1960), to pioneer research on legume-based pastures for the tropics. This work was intensified and expanded mainly at experiment stations in northeastern Australia and Hawaii. At some of the centers significant progress has been made in solving the problems of tropical legume–grass pastures. The staff of the C.S.I.R.O. Cunningham Laboratory in Brisbane summarized their findings (C.A.B. Bull. 47, 1964) for the benefit of pasture workers in other tropical areas. More recently, in 1966, W. Davies and Skidmore edited a book, "Tropical Pastures," which presents the modern approach to tropical pastures.

Now that reliable tropical legumes and grasses are available as well as knowledge of their fertilization, management, and productivity, considerable interest has been stimulated in the tropics in the use of improved tropical pastures for animal production. A rapid expansion in the areas planted with tropical pasture species can be envisaged with a concomitant increase in production of beef and milk so that the "protein drought" in many countries will gradually disappear. The development of pasture ecosystems for the wide range of environments throughout the tropics will present many new problems. This will require increasing research activity in many countries on pasture and animal production and a swing away from the preoccupation with veterinary and animal health problems.

II. Climate and Potential for Improved Pastures in the Tropics

The tropics and its agricultural development are discussed by Phillips (1961) and Webster and Wilson (1966). Wet equatorial climates with constant heat, rainfall, and humidity occur mainly within 5° to 10°N and S of the equator over a large area of South America and in West Africa, Malaysia, Indonesia, the Philippines, New Guinea, and various Pacific Islands. Annual rainfall is usually 80–120 inches, but a higher maximum is obtained in a number of places. The crops grown include rubber, oil palm, banana, coffee, coconut, cocoa, and rice, and experiments and some commercial plantings have shown that productive pastures can be established in the wet tropics.

Between the low latitude zones of wet equatorial climate and the Tropics of Cancer and Capricorn (23½°N and S) there are extensive areas with annual rainfalls of 20–80 inches and with a tropical monsoon climate in which there is an alternation of wet and dry seasons. These areas occur in South America, West and Central Africa, India, and in countries of Southeast Asia including Burma, Thailand, Laos, Cambodia, and Vietnam, and also in northern Australia. Four climatic zones can be distinguished in these monsoonal areas as follows: annual rainfall of 40–80 inches in two rainy seasons with short dry seasons; annual rainfall of 25–50 inches in two short rainy seasons with pronounced dry seasons;

annual rainfall of 30–50 inches in one fairly long rainy season with a long dry season; and annual rainfall of 20–40 inches with one short rainy season and a long dry season. Rainfall reliability decreases at the lower rainfalls. In the wetter parts, perennial tropical crops are grown as in the wet tropics. Where dry seasons are well defined, annual crops like rice, cotton, and maize are important, and in the driest areas sorghum, bulrush millet, and peanuts are grown. The tropical monsoonal areas have considerable potential for improved pastures and cattle production, as shown by some of the results obtained in different regions (vide Norman and Arndt, 1959; Shaw, 1961; Stobbs, 1969a).

The moist tropical climate extends from the Tropics of Cancer and Capricorn to about latitudes 35°N and S, respectively, to give zones with a humid subtropical climate (McIntyre, 1966; C. L. White *et al.*, 1968). These encompass southeastern United States, the middle Orient, a zone including southern Brazil, southern Paraguay, northern Argentina, and Uruguay, and areas along the eastern coasts of South Africa and Australia. These humid subtropical transition zones have a rather variable rainfall (Griffiths, 1959), which is predominantly in summer but with a winter increment. Usually referred to simply as the subtropics, they are important agriculturally and grow the hardier tropical crops and, as shown in Australia (J. G. Davies and Eyles, 1965), have considerable potential for the development of cattle pastures based on tropical legumes and grasses. The subtropics of eastern Australia is described by Coaldrake (1964) as the region where plants may be subjected to water stress or surplus any month of the year and where water, rather than energy, is more likely to limit plant production. Coaldrake also commented on the drastic reduction of herbage quality caused by a relatively small number of rather mild winter frosts in these areas. Their sudden onset allows no hardening of plants, and in any case most tropical pasture plants originated in frost-free areas and their above-ground portions, though usually not the roots, are killed by frost. Most of the recent cultivars that are having an impact on tropical pasture development in Australia and elsewhere were selected and developed at research centers in Australia's subtropics (J. G. Davies and Eyles, 1968). Thus, in Australia, the subtropics and Tropics form a continuum in which the factors governing pasture production vary in degree rather than in principle.

As outlined, the tropical zones where there is distinct potential for increased cattle production on improved pastures include the wet equatorial, the tropical monsoonal, and the humid subtropical covering approximately 27% of the world's area. Of the moist tropics, 33% is wet tropics, 49% monsoonal, and 18% subtropics. The arid tropical zone, with its deserts, the dry subtropical with xerophytic scrub, herbs, and grasses; and the semiarid tropical of grassland steppes are zones where the vegetation can be improved with range management techniques and not usually with the use of sown species. As pointed out by Hutton (1968a), 60% of the world's cattle are in the moist tropics, where 10% is cropped, 20% is pasture, 35% is forest, and a third is wasteland. Forest areas and wasteland are often in hilly areas and attempts to crop them result in soil erosion. With the use of the new tropical pasture species and fertilizer, idle uplands and unimproved native pastures can be improved markedly with significant effects on beef and milk production.

III. Role of Plant Introduction

The vital role of plant introduction in the development of pastures has been recognized for many years in the United States and Australia, both of which are deficient in promising native pasture species in their temperate and also tropical areas. Although the tropics of Latin America and Africa are rich in indigenous legumes and grasses with potential value for improved pastures, Kenya is the only country in these continents where a study has been made of the important species of native grasslands (Edwards and Bogdan, 1951).

The U.S.D.A. plant introduction services, which commenced in 1898 (vide Yearbook of Agriculture, 1962) and which are now vested in the New Crops Research Branch, have not been particularly concerned with introducing tropical pasture plants. However, pangolagrass *(Digitaria decumbens)*, which was introduced as vegetative material from South Africa in 1935 by the then U.S.D.A. Division of Plant Exploration and Introduction, has made a major impact on tropical pasture improvement (Oakes, 1960). Interest in Digitaria was stimulated and led to the collection by Oakes (1965) of an extensive range of species and ecotypes within the genus. The breeding of coastal bermudagrass (Burton, 1954), which has significantly increased pasture production in the southeastern United States, was achieved through the use of two tall-growing South African introductions of *Cynodon dactylon.* U.S.D.A. plant introduction work has also assembled species in the genus Paspalum, such as *P. notatum,* and *P. dilatatum* and obtained species for the Hawaiian Experiment Station in the legume genus Desmodium.

As a result of the work on indigenous grasses in Kenya (Edwards and Bogdan, 1951) the tropical world has obtained valuable ecotypes of a number of grasses including Rhodes *(Chloris gayana),* buffel *(Cenchrus ciliaris),* star *(Cynodon dactylon),* molasses *(Melinis minutiflora),* guinea

(Panicum maximum), kikuyu *(Pennisetum clandestinum)*, and Setaria *(Setaria sphacelata)*. The indigenous legumes were also studied in Kenya, and valuable ecotypes of *Glycine wightii* (formerly *G. javanica*) (Bogdan, 1966a) and species of Dolichos and Vigna have been made available to pasture scientists in other countries. Kenya workers have studied both native and introduced pasture plants at the Grassland Research Station, Kitale, since 1951. The cultivated varieties of herbage plants resulting from this work were described by Bogdan (1965).

The Kenyan example could well be emulated in the countries of Central and South America, where there is a wealth of indigenous legumes waiting to be collected, classified, and assessed. Latin America is the source of a few important grasses, notably in the genus Paspalum, but does not possess as valuable a grass flora as Africa. Although Africa has an extensive range of native legumes, it has not as yet contributed as many promising pasture legumes as Latin America. There is an awakening interest in many tropical countries in introduction of tropical legumes and grasses that have shown promise elsewhere. Most of them still show a reluctance to investigate their own rich native flora for promising pasture plants.

As pointed out by Hutton (1970), Australia is singularly deficient in indigenous legumes and grasses that can be used as the basis for improved pastures and increased animal production. As a result, there has been a continuing interest in Australia in pasture plant introduction, which commenced on a random basis about the 1880's, and became organized in 1930 with the establishment of the Plant Introduction Section of the C.S.I.R. Division of Plant Industry (McTaggart, 1942). Up to the present, 50,000 introductions have been brought into Australia and 61% of these are pasture and forage species. Much of the current pasture development in the Australian Tropics is based on the chance annual introduction Townsville stylo *(Stylosanthes humilis)* which was recognized at Townsville around 1900 and known formerly as Townsville lucerne. Introduction of tropical pasture species has been a major aim of C.S.I.R.O. plant introduction work since its inception, and a large number of legume and grass accessions from tropical countries have been evaluated over the years. The selection of grasses adapted to northern Australia has been relatively easy, whereas obtaining adapted legumes has proved difficult, particularly for the subtropics, where rainfall is variable and frosts can occur.

Since the turn of the century, the Australian wet tropics of about 4 million acres of northeastern coastal country between Mossman and Mackay has had adapted introductions of tropical grasses such as guinea, molasses, and para (*Brachiaria mutica*). Schofield (1941) eventually obtained successful legumes for this area including stylo (*Stylosanthes guyanensis*), centro (*Centrosema pubescens*), puero (*Pueraria phaseoloides*), and calopo (*Calopogonium mucunoides*).

Much of the plant introduction work for northern Australia over the last thirty years has aimed at obtaining legumes and grasses for pasture development in the extensive tropical monsoonal and humid subtropical areas between latitudes 30°S and 11°S and comprising about 260 million acres (J. G. Davies and Eyles, 1965). Miles (1949) made distinct progress with this problem by evaluating an extensive range of introduced legumes and grasses in central coastal Queensland from 1936 to 1946. He showed that the low mineral and protein status of the native pastures could be raised by perennial legumes in a number of genera including Arachis, Centrosema, Desmodium, Glycine, Indigofera, and Stylosanthes. The most promising grass introductions included ecotypes of *Chloris gayana, Cenchrus ciliaris, Digitaria* sp., *Panicum maximum, Paspalum notatum, Setaria sphacelata,* and *Urochloa* sp. Miles' results (1949) stimulated the first work in overseas plant exploration by Australia. Hartley (1949) joined a U.S.D.A. expedition to subtropical South America and collected mainly ecotypes of species in the genera Arachis, Desmodium, Stylosanthes, and Paspalum. From these introductions the cultivars Oxley Fine-stem stylo and Hartley plicatulum (*Paspalum plicatulum*) (Bryan and Shaw, 1964) have been selected.

Another ten important overseas collections of pasture plants have been made by Australians in tropical monsoonal and humid subtropical areas during the period 1952–1968 (Hutton, 1970). A range of material was collected, particularly in the legume genera Centrosema, Desmodium, Glycine, Phaseolus, and Stylosanthes, and the grass genera Cenchrus, Panicum, Paspalum, Setaria, and Urochloa. Only the introductions from J. F. Miles' visits to South Africa and east and west Africa in 1952 have been fully evaluated. These have yielded Miles Lotononis (*L. bainesii*) (Bryan, 1961), Rongai *Dolichos lablab* (Wilson and Murtagh, 1962), and Samford Rhodes grass. R. J. Jones' collections (1964) of *Setaria sphacelata* from East Africa have already produced the frost-tolerant cultivar Narok setaria, and it is anticipated that further promising lines will come from these. The systematic exploration in 1965 of legumes and a few of the grasses by Williams (1966) in the main states of Brazil, and in Bolivia, Paraguay, and northern Argentina, has substantiated that these areas are rich in indigenous species potentially valuable as tropical and subtropical pasture plants. Williams found annual types of stylo similar to Townsville stylo in a number of regions.