DAIRY PRODUCTION SYSTEMS RELEVANT TO THE TROPICAL REGIONS OF AUSTRALIA

1. REVIEW OF THE LITERATURE

*F. G. SWAIN

INTRODUCTION

Farm systems in any environment require a large, evenly distributed and reliable supply of feed which is efficiently utilized by the animal. The system which evolves in a particular environment will depend upon the interaction of the climate, the supply of technical information on the soil—plant—animal complex, and the management skills and economic and social status of the producer.

To have an understanding of dairy farm systems in the tropics it is necessary to first consider the individual components of the system. This has been done in the other reviews in this issue. In summary, an understanding is necessary of the climate, the yield and distribution of the feed supply, management procedures for plants and animals and the animal itself. The task now remains to examine what published information we have available when these various components are combined in a dairy farm system for tropical areas. This review will be confined, wherever possible, to dairy farm system evaluation studies where biological and/or economic data on the whole system are presented.

Almost all the published studies on dairy farm systems for the tropics have been conducted by Australian research workers. This contention is supported by Holder (1967) and Mears (1970). Accordingly the emphasis in this review is on Australian scientific literature relating to the tropics; brief reference is also made to studies of dairy farm systems in some of the temperate areas of the world where research has been underway for a much longer period. Important principles have been developed in these temperate areas, some of which may have application in the tropics.

DAIRY FARM SYSTEMS IN TEMPERATE ENVIRONMENTS

Mott (1960) and McMeekan and Walshe (1963) provided guidelines for increasing the utilization of pastures and the intensification of dairy farm systems in the temperate areas. Many workers, particularly in New Zealand, have built on these guidelines and the findings and principles from their work appear also to be relevant to dairy farm systems in the tropics. Some of these principles can be summarised as follows:

1. Percentage utilization of grazed pastures, even under the intensive high rainfall conditions of New Zealand, is still relatively low (in the range 20-50 per cent), (Brougham 1966, Campbell 1966, 1967, 1969).
2. Stocking rate is the most effective technique available to the system manager to increase the efficiency of production (McMeekan 1956, 1960).
3. Milk production per acre from pasture can be greatly influenced by regulation of grazing pressure (defined as the number of animals per unit of available forage) (Gordon *et al.* 1966).

*Department of Agronomy, University of New England, Armidale, N.S.W. Present address: Riverina C.A.E., Box 588 P.O., Wagga Wagga, N.S.W.

4. Where overgrazing of pastures and undernutrition of stock occurs, relatively small reductions in stocking rate may substantially relieve grazing pressure (Campbell 1966).
5. Stocking rate and production can be increased by a redistribution of available feed supply and by making the most of a limited amount of feed after calving (Graham and Candler 1965, Hutton and Parker 1965, Campbell and Clayton 1966, Hutton 1966a).
6. Efficient utilization of temperate pastures by dairy cattle can be achieved by concentrating on the period of highest individual animal efficiency, matching animal requirements to pasture growth and making increased use of grain supplement to fill gaps in the system (Hutton 1963, 1966b, c, Hutton and Parker 1966).
7. Substantial increases in dairy production in temperate areas may result from the use of alternative fodder crops in preference to grazed pastures; because of the physiological advantages of the fodder crops for dry matter production over time, when compared with production from pasture type plants (Mitchell 1960, 1966).

Two questions relating to the work on dairy farm systems in the temperate areas are:

1. Do these same principles apply to dairy farm systems in the tropics or will they have to be modified?
2. Is it possible to develop and maintain efficient, high producing dairy farm systems in the tropics?

These questions will serve as a basis for the rest of the review.

DAIRY FARM SYSTEMS IN *TROPICAL ENVIRONMENTS

The purpose of this section of the review is to classify dairy farm systems in the tropics into various types based on source of feed supply, indicating what published information is available on each type of system and what additional information is required.

Systems based on tropical and temperate legume—grass pastures and forage crops
Studies in northern New South Wales

Over the period 1957 to 1970 a series of papers have been published on feed-year farm system research undertaken at and from Wollongbar Agricultural Research Station in northern N.S.W. An integrated approach has been adopted involving agronomists, animal nutritionists and farm management specialists. The objective has been to replace the existing unproductive grass dominant pastures with a combination of tropical and temperate legumes, grasses and forage crops designed to provide a continuity of high quality feed throughout the year. Because of the integrated nature of the research programme, the Wollongbar papers have been reviewed as one group.

The nature of the low productivity problem facing dairy farmers on the subtropical far North Coast of N.S.W., and progress in research over the first seven years (1950-1957) was outlined in a report produced by the University of Sydney, Anon (1957). This was followed by a survey of dairying in the area by Bird (1962). The first new farming system developed consisted of supplementing the existing, unfertilized grass pastures with an annual forage crop, sod-sown vetch, to provide feed in the late winter and spring. Holder, Swain and Colman (1963),

*'Tropical' in this context includes sub-tropical as well as tropical climatic regions.

using farmlets at Wollongbar Research Station, reported the results of a three year comparison of this system with the existing unimproved farm system in the area. The vetch supplement produced a significant increase in butterfat production during the period from calving to the end of vetch grazing in two of the three years of the trial. The authors recognised, however, that the vetch supplement system did not fill all the gaps in the field supply from the unimproved grass pastures. They indicated that research had commenced to find new farm systems which would provide a continuity of feed throughout the year.

During 1964 and 1965 a series of papers appeared outlining the new feed-year systems being studied and the methods being used to evaluate these systems, Swain *et al.* (1964), Bird and Swain (1964), Swain (1964), Hudson *et al.* (1965). Feed year systems based on perennial tropical legume-grass pastures, supplemented with temperate legume and cereal forage crops, were being evaluated under small farmlet conditions at Wollongbar and in commercial whole farm case studies on four soil types in the Richmond-Tweed region.

Colman, Holder and Swain (1966) reported the results of a 3 year study comparing the production from spring calved cows grazing an unimproved grass pasture farmlet with that of summer-calved cows grazing on a farmlet where 56% of the area had been improved with the tropical legume *Glycine wightii* and the temperate legumes *Trifolium subterraneum* and *Vicia sativa*. Cows on the improved pasture produced 48% more butterfat and had a better reproductive performance than cows on the unimproved pasture. The tropical legume formed a persistent and high yielding association with Kikuyu grass (*Pennisetum clandestinum*). The temperate legumes were unreliable components of the winter pasture, but when present in the system they allowed longer lactations and higher butterfat production.

A progress report on studies with farm systems was produced by Mears (1967). Encouraging increases in butterfat production per acre were obtained from the various systems and costs of improvement were much lower than returns from increased production. However, insect problems and unreliable establishment of tropical legume-grass pastures adversely affected the adoption of the system by producers. Holder (1967) provided information on the nutritive value of tropical legume and grass species and related this to milk production obtained in grazing trials at Wollongbar and from the commercial case studies in the region. Holder concluded that greater production of milk from tropical legume-grass pastures could be obtained than had previously been thought possible. It was considered doubtful, however, that production would ever match that from legume-grass pastures in the temperate areas. This latter prediction was supported by Dale and Holder (1968). The need to study systems based on tropical grass pastures, adequately fertilized and heavily stocked, was emphasised by Holder (1967).

A series of papers appeared in 1970 which summarised the findings from the feed-year systems studies undertaken during the previous twelve years in northern N.S.W. Colman (1970) summarised the results of the farmlet studies at Wollongbar from 1958 to 1969 (Table 1). These results indicated that, where legume-grass systems were used, highest production increases occurred where the existing unimproved pasture base had been replaced with a tropical legume-grass pasture and the temperate legume, vetch, had been sod-sown into a portion of this area. Further production increases were obtained where nitrogen was substituted for vetch to provide spring feed or where a tropical grass plus nitrogen system replaced both the tropical and temperate legumes. Jeffery *et al.* (1970) added support to these conclusions when they reported that mean production per hectare* for the

*Extrapolated from production per cow.

unimproved system (referred to by Colman 1970), and an improved system consisting of 100% tropical legume-grass fertilized with phosphorus and potassium, was 96 kg and 157 kg butterfat respectively for the two years 1966-67 and 1967-68.

TABLE 1

Stocking rate and butterfat production from pasture systems at Wollongbar from 1958 to 1969 (Colman 1970)

System	Stocking Rate Cows/ha	Butterfat (kg)	
		Per Cow	Per Hectare
1. Unimproved Pasture	1.03	98	92
2. Unimproved Pasture plus Vetch on 20% of area	1.03	122	125
3. 16% Glycine javanica 20% Vetch 20% Subterranean clover	1.45	100	144
4. 100% Tropical legume-grass plus vetch	1.70	94	160
5. 100% Tropical legume-grass plus 56 kg N/ha	1.79	118	212
6. Kikuyu grass plus 336 kg N/ha	3.29	100	329
7. Kikuyu grass plus 336 kg N/ha	4.94	91	448

Results from feed-year case studies on eight commercial whole farms in the Richmond-Tweed region were summarised by Swain *et al.* (1970). Detailed results on three of the eight case studies, which were on red-basaltic soils, were presented by Swain, Bird and Drane (1970). Murtagh, Drane and Colman (1970) gave details of the results of the two case studies which were on alluvial soils.

Swain *et al.* (1970) indicated that increases in butterfat production following development ranged from 20 to 129%. Per hectare butterfat production in the test year following development, 1967-68, ranged from 63 to 135 kg. It should be noted that this is lower than production from any of the improved farmlet studies reported in Table 1. The economic return was satisfactory on four farms, marginal on two and unsatisfactory on two. It was concluded that feed-year development based on tropical legume-grass pastures supplemented with temperate forage crops, would not be a general solution to the economic problems of low income dairy farmers in the region and would, therefore, have to be accompanied by a change in farm structure (i.e. size, enterprises, labour and capital inputs). It was also indicated that further agronomic research was needed in relation to (i) improving the quality of tropical pastures; (ii) the role of nitrogenous fertilizer; (iii) the establishment and persistence of tropical legumes; and (iv) reducing the need for costly forage crops for winter-spring feed.

In summary, results of research on legume-grass systems in northern N.S.W., has shown that substantial increases in butterfat production can be obtained, compared to production from the unimproved system. However, it is doubtful whether total reliance on a legume-grass system will provide a viable dairy farm system for the future because:

1) Some components of the system are inefficient, e.g. establishment and persistence of tropical legumes is unreliable and maintenance of the system calls for skilled management and relatively low stocking rates. Also, temperate legumes are unreliable and annual temperate forage crops are too costly. The feed-year components research currently underway at Wollongbar should provide more quantitative information on this point (Murtagh personal communication).
2) Commercial case studies indicate that the system is unlikely to produce sufficient net income to survive current and predicted economic pressures on the dairy industry in the tropics.

Possible alternatives and supplements to legume—grass systems will be considered in later sections of the review.

Studies in Queensland

Literature relating to systems based on tropical legume—grass pastures in Queensland is less comprehensive and quantitative than that from northern N.S.W.

Young and Rayner (1962 a, b) surveyed the existing situation for dairy farms in the Moreton district of south-east Queensland and defined a low productivity problem similar to that defined for northern N.S.W. Clark (1962) surveyed the effect of month of calving on the production of Queensland dairy cows and concluded that in all districts, except the Atherton Tablelands and Mackay, cows which calved in late winter and spring completed longer lactations than those which calved during other periods. However this finding was not related to changes in feed supply proposed as a result of research on tropical legume—grass pastures. Clark (1969) in his examination of Queensland herd production from 1953-54 to 1961-62 established an association between low production and short lactation. It was not possible to assess the relative importance of such factors as climate and management and in 1969 he stressed the need for more specific investigations.

Kyneur (1966) highlighted the low production problem on the Atherton Tablelands by indicating that the existing pastures support approximately 1 beast to 1.2-2 hectares, giving a production of only 162-265 litres of milk per hectare per year. It was reported that long term species and nutrition studies were underway. There was no indication, however, that work was underway evaluating new systems under whole farm or farmlet conditions in the north Queensland area.

The research on dairy pastures in Queensland by the C.S.I.R.O., Division of Tropical Pastures was reviewed by Roe *et al.* (1967) and Davies and Eyles (1968). Studies are underway on plant nutrition, species, and milk production potential (Hamilton 1969). It appears that to date no work has been undertaken and published by the Division of Tropical Pastures where dairy farm systems have been evaluated in biological and/or economic terms.

Luck (1968) advocated a farm system for the Wide Bay region of Queensland involving temperate species in the colder wetter areas; tropical legume—grass pastures on the drier and warmer hills; and nitrogen fertilizer for the fodder crops, supplementary grain crops and for perennial tropical grass species when gaps are evident in the legume-grass pasture. He considered that legume-based pastures should be used to provide the bulk of the cow feed. These proposals are similar in principle to those which emanated from the Wollongbar group in the 1960's, however, no quantitative data on the productivity of farm systems based on Luck's model have been published to date.

Problems of applying new knowledge of pasture production in dairying in south-east Queensland from the farmers viewpoint were outlined by Lamond (1968). He proposed four basic farming systems for the environment and gave some quantitative guidelines on likely productivity and income levels based on his experience with a commercial enterprise. The systems proposed by Lamond were (i) whole milk—produced under zero grazing conditions; (ii) whole milk produced under intensive grazing conditions where cows are supplemented with concentrates; (iii) milk for manufacturing purposes produced under intensive grazing conditions, and (iv) milk for manufacturing purposes in combination with beef production. All the systems were based on varying combinations of tropical legume-grass pastures, tropical grass pastures plus nitrogen and supplementary grain feeding. However, Lamond stressed that there was inadequate research data available on optimum levels of fertilizer, nutritive value of sown tropical species and stocking policy. He made a strong plea for more emphasis on evolving efficient pasture systems and less emphasis on differences in the productivity of individual pasture species.

Some quantitative data on dairy farm systems for Queensland was presented at a Symposium on "The Tropical Pasture Revolution" held in Brisbane in 1969. Sillar (1969) showed that there had been a tremendous upsurge in pasture sowing activity which was due mainly to direct research effort rather than "on-the-farm" experience and application. He considered, however, that there was a serious lack of production system research to provide the farmer with information on development strategies. Lemon (1969) provided a farmer's view on the various alternative farm systems. He concluded that sown tropical legume-grass pastures were the best means of raising productivity. However, he considered that knowledge on how to improve the efficiency of the farm system as a whole was urgently needed particularly because of his prediction that the farmer would have to increase production by as much as one half in the next ten years simply to maintain his present standard of living. McCarthy (1969) provided data on two representative case study dairy farms in south-east Queensland, which had undertaken new farm system development programmes, and on three surveys conducted throughout Queensland. He indicated that, while the economics of pasture improvement appeared sound, this fact had not been reflected in the rate of increase of the total area under improved pasture in Queensland. He suggested that the main reason for this was the quite inadequate communication between research and extension workers and farmers. Cook and Dolby (1970) introduced a valuable farm systems evaluation technique and provided some very useful data from their survey of the relative effects of improved pastures, crops and supplements on the annual milk production of sixty farms in the East Moreton district of south-east Queensland. Using linear programming they concluded that the material return from improved pastures (17.9 kg milk per productive hectare) is more certain than that from fodder crops even though crop return (27.9 kg milk per productive hectare) was greater. The value of the approach used is limited by the lack of retrospective data and the need to use the criterion of availability rather than utilization when assessing the significance of pasture or crops. More comprehensive conclusions could have been drawn had it been possible for the authors to relate their findings from commercial holdings to research data on farm systems obtained under more controlled conditions in similar environments.

Comparison of studies undertaken in N.S.W. and Queensland

The northern N.S.W. work has concentrated on evaluating farm systems under semi-controlled conditions and has produced a considerable amount of quantitative data. Queensland workers on the other hand have concentrated work on the separate components of the system and on assessing systems which have developed under commercial conditions. With the exception of Cook and Dolby (1970), they have produced only a limited amount of quantitative data on the whole farm system.

There is little evidence in the literature of close collaboration between research workers in the two states. Yet it is apparent that the two research programmes do complement one another very well and that a considerable amount would be gained by a joint examination of the data. For example, the data obtained from whole farmlet studies at Wollongbar could be used to assist in the formulation of more quantitative recommendations on farm systems for south-east Queensland. Likewise the approach used by Cook and Dolby (1970) on farm system evaluation could be applied to some of the data from the northern N.S.W. work.

A basic question to be considered, when reviewing the research findings from the two areas, is whether it has been shown that it is feasible to base future dairy farm systems in the tropics on legume-grass pastures.

Production from legume-grass systems is at times substantially higher than that from existing enterprises but in several situations the systems have been shown to be unreliable and unstable under intensive conditions. When the current and likely future economic and social problems of the dairy industry in the tropics are taken into account, it is apparent that production levels higher than anything obtained to date from tropical legume-grass systems will be required to produce an efficient, viable dairy industry. Consideration should therefore be given to placing more research emphasis on alternative systems and on more diverse systems which are likely to lead to large scale, intensive high production enterprises.

Systems based on tropical grass pastures fertilized with nitrogen

It is only in the last four to five years that serious consideration has been given to farm systems based on tropical grass pastures fertilized with nitrogen. Holder (1967) indicated that there was considerable scope for the use of such pastures adequately fertilized and heavily stocked, thus taking advantage of the favourable climatic conditions in the tropics and sub-tropics. Colman and Holder (1968) were the first to report on butterfat production from a Kikuyu based pasture fertilized with nitrogen and stocked at three levels. At stocking rates of 1.64, 2.47 and 3.29 cows per hectare, production per cow varied from 118 kg at the low stocking rate to 99 kg at the high stocking rate. Per hectare production varied from 183 to 327 kg B.F./ha; at the low and high stocking rates respectively. Colman (1970) collated all the data available from the Wollongbar programme on milk production from tropical pasture fertilized with nitrogen and related this to the studies on legume-grass based systems (Tables 1 and 2). It can be seen that the highest production per hectare was obtained from Kikuyu grass plus nitrogen stocked at 4.94 cows/ha (System 7). However the summarised budgets in Table 2 show that the system which combines the use of tropical legume-grass pastures and nitrogen fertilizer (System No. 5) should produce the highest net income and return to capital. This budget relates to the present structure of the dairying industry which is largely based on one man farms. Colman postulates that increased returns to capital may be obtained from grass plus nitrogen systems (Systems 6 and 7) where size of operation is increased to a three man unit so that economies of scale can be effected.

TABLE 2

Budget analysis of the farm systems in Table 2 based on an 80 cow unit (Colman 1970)

System No.	80 Cow Area (ha)	Total Butterfat (kg)	Total Capital ($)	Cost/kg Butterfat ($)	Net Income ($)	% Return on Capital
1	78	7,140	38,560	0.89	493	1.3
2	78	9,752	38,560	0.80	2,703	7.0
3	55	7,956	31,280	0.90	1,441	4.6
4	47	7,229	28,680	0.95	979	3.4
5	45	9,943	27,900	0.76	3,207	11.5
6	24	7,945	21,400	0.94	1,141	5.3
7	16	7,256	18,800	0.92	1,182	6.3

Considerable potential for the use of tropical grass plus nitrogen systems in Queensland has been forecast by Lamond (1968) and Henzell (1970). Lamond presented data to support his contention that it is profitable to use nitrogen on a wide range of grasses on whole milk farms in south-east Queensland. Lamond's data are limited to one commercial farm situation and contain several assumptions on future trends. However the predicted responses certainly warrant a close

examination of the system over a wide area. Henzell (1970) postulated that during the 1970's the use of nitrogen in the tropics will occur mainly on dairy farms in coastal areas south of the tropic of Capricorn receiving an annual rainfall of more than 900-1000 mm per annum.

Clearly, whole farmlet and commercial case studies are needed to examine the feasibility of the large scale, intensive, tropical grass plus nitrogen dairy farm system for the tropics. This may well be the only type of dairy farm system which can justify its existence in tropical Australia in the future. Experience in the temperate dairying areas throughout the world supports this latter contention.

Farm systems involving supplementation with conserved fodder or grain supplements

No conclusive reports have been found in the literature on the biological and/or economic evaluation of dairy farm systems in the tropics incorporating conservation of fodder. The correspondence between Vivian and Humphreys (1969) and Bishop and Humphreys (1969) provides a basis for discussion and also a bibliography of animal production experiments testing pasture conservation systems.

Fodder conservation research in the tropics does not appear to have progressed beyond the stage of examining the technological problems associated with conserving fodder. Holder and McBarron (1964) reported on the production of Kikuyu grass silage and its palatability to dairy stock. They indicated serious losses in dry matter and digestibility. Davies (1965) considered that principles developed for production and use of conserved fodder in temperate areas will have general application in the tropics but some research will be necessary to adapt the techniques for tropical conditions. Davies and Eyles (1968) indicated that the main aims of the fodder conservation programme in the Division of Tropical Pastures are to discover whether forage from tropical pastures can be preserved efficiently as silage, and to find what effect ensiling has on feeding value. Several publications have appeared recently on this work, Catchpoole and Williams (1969) and Catchpoole (1970 a and b). However, Davies (1970) considered that the problems of silage making in the tropical regions have not yet been solved. This applies particularly to losses in digestible dry matter.

It is clear that integrated biological and economic research evaluating the role of conserved fodder in tropical farm systems is urgently needed.

Some information is available on the role of grain supplements in tropical dairy farm systems. Aronvich, Correa and Faria (1965) reported considerable increases in milk production from cows fed grain supplements while grazing on pangola grass in Brazil. However, the response was not economic. Bracks (1966) and Robson (1966) reported outstanding results from feeding home grown maize to dairy cows grazing high quality pastures and forage crops on the north coast of N.S.W. Lamond (1968) believes that even at high stocking rates and high fertilization, maximum economic efficiency of use of the present pastures in south-east Queensland will only be possible if some form of supplementation with highly digestible foodstuffs is practised. He considered that this technique will be profitable on at least some whole milk farms in the area. Jeffery *et al.* (1970) reported that cows grazing on an improved tropical legume-grass pasture at Wollongbar, which received a grain supplement, produced significantly more butterfat than those not receiving supplement, but gave only low gross cash returns. Cook and Dolby (1970) tentatively concluded from their survey of sixty farms in south-east Queensland, that significant results can only be expected from supplements when adequate feed for maintenance and some production is provided from other sources.

No clear indication is available on the role of grain supplements in tropical dairy farm systems, from the research undertaken to date. Furthermore, no published reports evaluating green-lot and dry-lot feeding systems for dairy cows in the tropics were found. In view of the current trends towards intensification and diversification in dairying, information is urgently needed on the role of these various strategies. This proposal is closely allied with the conclusions reached by Lever, Campling and Holmes (1968) in their comprehensive review on supplementary feeding.

Diversified dairy farm systems in the tropics

At this stage there is a lack of published research data on strategies for diversification of dairy farm systems in the tropics and on possible alternatives to dairying. Current economic pressures on dairying indicate the urgent need for this type of information.

Lamond (1968) referred to the lack of useful husbandry and economic data on a diversified enterprise involving milk for manufacturing purposes and beef. He proposed a model for consideration involving a herd of 140 cows of which 60 rear two calves each. This system would necessitate considerable reconstruction of the industry because it would require more land, capital and probably more labour. Colman (1970) speculated on the possibility of an intensive one man dairy system based on grass plus nitrogen on part of the farm supplemented with some form of beef production with a low labour requirement on the remaining area. Harrison (1970) reported the results of using improved pasture for a calf enterprise as an adjunct or alternative to dairying or vealer production in the sub-tropics. He concluded it would be a profitable enterprise for a limited number of farms in the area. Gilmour and Reilly (1970) produced evidence that softwood forest plantations should be considered as one of the alternative land uses for degraded dairy land in the Atherton Tableland. Lovett, Matheson and James (1971) have presented results of a preliminary investigation of the pattern of agriculture in northern N.S.W. The sample of dairy farms was small, but the consistency of the response patterns encountered throughout suggested that the data may be taken as useful indicators of farming trends in the area.

Work on dairy-beef enterprises as a supplement or alternative to dairying is proceeding in New Zealand (Wallace, personal communication) and Wollongbar, N.S.W. (Kaiser, personal communication). Published results from this work are urgently required. In addition, information on systems involving dairy and/or beef production plus cash cropping should be sought for dairying areas in the tropics.

SUMMING UP

A limited amount of literature is available on the evaluation, in biological and economic terms, of dairy farm systems for the tropics. That which is available refers almost entirely to Australian work and relates, in the main, to systems based on improved tropical legume-grass pastures supplemented in some way with temperate pastures and forage crops. These legume-grass systems have frequently produced substantial increases in butterfat production when compared with systems based on unimproved summer growing grass dominant pastures and in most cases the increases have been economically sound. However, the highest butterfat production figures reported were, 160 kg butterfat per hectare under research station conditions (Colman 1970) and 135 kg butterfat per hectare under commercial conditions (Swain *et al.* 1970). Whilst the figures quoted by Queensland research workers cannot be directly compared with the published information from northern N.S.W., it appears that they are generally of the same order. These butterfat production levels achieved in the tropics compare unfavourably with the range in levels

normally obtained in temperate dairying areas in Australia and in New Zealand (approximately 200 to 500 kg butterfat per hectare). It is thus doubtful whether a viable dairying industry can be maintained in the tropics if it has to rely on legume-grass pastures. There are several factors which support this proposal:

1) The legume-grass systems evolved to date are unreliable and unstable because of difficulties at establishment and in subsequent management under grazing. This applies particularly to perennial tropical and temperate legumes under high stocking rates.

2) Principles developed in the temperate dairying areas have application, with modification, to the tropics. These principles appear to be most relevant to the more stable and higher producing farm systems based on grass plus nitrogen.

3) Research to solve the problems with legume-grass systems in the tropics, and to modify principles evolved in temperate areas, cannot be justified in terms of priorities, because feasible higher production levels have already been reached with alternative dairy farm systems.

4) Systems based on legume-grass pastures will not be sufficiently productive and will not be amenable to the management practices necessary to solve the socio-economic problems facing the dairy industry in the tropics in the future.

There is unsufficient information available on farm systems based on tropical grass plus nitrogen fertilizer to draw firm conclusions on their role in the future. This is particularly so in the case of systems of this type which are supplemented in some way with conserved fodder or a grain supplement. Likewise, there is even less information on diversified enterprises incorporating dairy farming as one of the components of the system. However, it would appear that there is considerably more potential for these types of systems than those based on legume-grass pastures. For example, Colman (1970) refers to figures of 329-448 kg butterfat per hectare from grass plus nitrogen systems. Answers are required to many questions relating to management of the system, scale of operation, capital and labour availability and future market prospects before more definite decisions can be made on the role of grass plus nitrogen based systems in tropical dairying areas. However it is apparent that research on this type of system should have first priority for the future.

It is therefore concluded that there is an urgent need to increase the amount of research work undertaken on the evaluation, in biological and economic terms, of dairy farm systems for the tropics.

Decisions are needed on: The specific types of systems which should be investigated, and how these systems should be studied.

Young and Rayner (1962b) indicated that there is a need for an understanding of the present resource use and production processes and an appreciation of potential and possible alternative use of resources. Morley and Spedding (1968) stated that "unless experiments are planned with actual systems in mind they may well turn out to be irrelevant. This is a serious and usually quite unnecessary risk which should be understood before being taken".

Considerable rethinking is necessary on the methods which should be used when evaluating farm systems. Yabsley and Ware (1970) and Swain (1971) have reviewed these methods recently and have provided some guidelines for the future.

Rapid changes are occurring in the structure of the dairy industry in the tropics and research on farm systems is in immediate danger of falling behind these changes and becoming obsolete. A reappraisal of research needs and priorities must be undertaken now.

REFERENCES

ANON. (1957)—University of Sydney, School of Agriculture, Report No. 2.

ARONOVICH, S., CORREA, A. N. S., and FARIA, E. V. (1965)—Proc. 9th Int. Grassld. Congr., Brazil, 919.

BIRD, J. G. (1962)—*Rev. Mktg Agric. Econ.* **30**: 13-70.

BIRD, J. G., and SWAIN, F. G. (1964)—*Rev. Mktg Agric. Econ.* **32**: 81-87.

BISHOP, A. H., and HUMPHREYS, L. R. (1969)—*J. Aust. Inst. Agric. Sci.* **35**: 197-198.

BRACKS, J. M. (1966)—*Dairy Topics* **10**: 3-9.

BROUGHAM, R. W. (1966)—*N.Z. Agric. Sci.* **2**: 19-22.

CAMPBELL, A. G. (1966)—*J. Agric. Sci., Camb.* **67**: 199-221.

CAMPBELL, A. G. (1967)—Proc. N.Z. Soc. Anim. Prod. **27**: 126-138.

CAMPBELL, A. G. (1969)—*N.Z. J. Agric. Res.* **12**: 67-74.

CAMPBELL, A. G., and CLAYTON, D. G. (1966)—Proc. Ruakura Farmers' Conf. Week, 181.

CATCHPOOL, V. R., and WILLIAMS, W. T. (1969)—*J. Br. Grassld Soc.* **24**: 317-324.

CATCHPOOL, V. R. (1970a)—Proc. 11th Int. Grassld Congr. Surfers Paradise, Australia 891.

CATCHPOOL, V. R. (1970b)—*Aust. J. Exp. Agric. Anim. Husb.* **10**: 568-576.

CLARK, C. H. (1962)—*Qd J. Agric. Sci.* **19**: 267-277.

CLARK, C. H. (1969)—*Aust. J. Exp. Agric. Anim. Husb.* **9**: 135-139.

COLMAN, R. L. (1970)—*J. Aust. Inst. Agric. Sci.* **36**: 224-232.

COLMAN, R. L., HOLDER, J. M., and SWAIN, F. G. (1966)—Proc. 10th Int. Grassld Congr. Helsinki, 499.

COLMAN, R. L., and HOLDER, J. M. (1968)—Proc. Aust. Soc. Anim. Prod. 7: 129-132.

COOK, B. G., and DOLBY, G. R. (1970)—*Trop. Grasslds* **4**: 189-194.

DALE, A. B., and HOLDER, J. M. (1968)—Proc. Aust. Soc. Anim. Prod. 7: 86.

DAVIES, G. M. (1965)—Proc. 9th Int. Grassld Congr. Brazil, 649.

DAVIES, J. G. (1970)—*Trop. Grasslds* **4**: 7-16.

DAVIES, J. G., and EYLES, A. G. (1968)—*J. Aust. Inst. Agric. Sci.* **34**: 130-145.

GILMOUR, D. A., and REILLY, J. J. (1970). *J. Aust. Inst. Agric. Sci.* **36**: 259-272.

GORDON, C. H., DERBYSHIRE, J. C., ALEXANDER, C. W., and MCCLOUD, D. E. (1966)—Proc. 10th Int. Grassld Congr. Helsinki, 470.

GRAHAM, J., and CANDLER, W. (1965)—Report, Dept. Agric. Econs. and Farm Manag. Massey University. N.Z.

HAMILTON, R. I. (1969)—*Trop. Grasslds* **3**: 88-90.

HARRISON, R. E. (1970)—*Trop. Grasslds* **4**: 121-127.

HENZELL, E. F. (1970)—*J. Aust. Inst. Agric. Sci.* **36**: 206-213.

HOLDER, J. M. (1967)—*Trop. Grasslds* **1**: 135-141.

HOLDER, J. M., and MCBARRON, E. J. (1964). Proc. Aust. Soc. Anim. Prod. **5**: 332.

HOLDER, J. M., SWAIN, F. G., and COLMAN, R. L. (1963). *Aust. J. Exp. Agric. Anim. Husb.* **3**: 153-160.

HUDSON, W. J. C., SWAIN, F. G., HOLDER, J. M., COLMAN, R. L., and BIRD, J. G. (1965). Proc. 9th Int. Grassld Congr., Brazil, 923.

HUTTON, J. B. (1963)—Proc. Ruakura Farmers' Conf. Week, 194.

HUTTON, J. B. (1966a)—Proc. Ruakura Farmers' Conf. Week.

HUTTON, J. B. (1966b)—Dairy fmg A. : 113-126.

HUTTON, J. B. (1966c). *N.Z. Agric. Sci.* **1**: 18.

HUTTON, J. B., and PARKER, O. F. (1965)—Proc. Ruakura Farmers' Conf. Week.

HUTTON, J. B., and PARKER, O. F. (1966)—Proc. N.Z. Soc. Anim. Prod. **26**: 71-85.

JEFFERY, H. J., COLMAN, R. L., DALE, A. B., and HOLDER, J. M. (1970). Proc. Aust. Soc. Anim. Prod. **8**: 476-481.

KYNEUR, G. W. (1966)—*Qd J. Agric. Anim. Sci.* **23**: 1.

LAMOND, D. R. (1968)—*Trop. Grasslds* **2**: 129-134.

LEMON, C. A. (1969)—*Trop. Grasslds* **3**: 157-159.

LEVER, J. D., CAMPLING, R. C., and HOLMES, W. (1968)—*Dairy Sci. Abs.* **30**: 355-361.
LOVETT, J. V., MATHESON, E. M., and JAMES, P. G. (1971)—*J. Aust. Inst. Agric. Sci.* **37**: 15-24.
LUCK, P. E. (1968)—*Trop. Grasslds* **2**: 190-195.
MCCARTHY, W. O. (1969)—*Trop. Grasslds* **3**: 162-164.
MCMEEKAN, C. P. (1956)—Proc. 7th Int. Grassld Congr. New Zealand, 146.
MCMEEKAN, C. P. (1960)—Proc. 8th Int. Grassld Congr. Reading, 21.
MCMEEKAN, C. P., and WALSHE, M. J. (1963)—*J. Agric. Sci. Camb.* **61**: 147.
MEARS, P. T. (1967)—*Trop. Grasslds* **1**: 98-104.
MEARS, P. T. (1970)—*Trop. Grasslds* **4**: 139-152.
MITCHELL, K. J. (1960)—Proc. N.Z. Anim. Prod. Soc. 82-92.
MITCHELL, K. J. (1966)—*N.Z. Agric. Sci.* **1**: 23.
MORLEY, F. H. W., and SPEDDING, C. R. W. (1968)—*Herb. Abstr.* **38**: 279-287.
MOTT, G. O. (1960)—Proc. 8th Int. Grassld Congr. Reading, 606.
MURTAGH, G. J. M., DRANE, F. H., and COLMAN, R. L. (1970)—Proc. 18th Int. Dairy. Congr. Sydney, 566.
ROBSON, J. K. (1966)—*Agric. Gaz. N.S.W.* 77: 679-682.
ROE, R., HAMILTON, R. I., JONES, R. M., and REES, M. C. (1967)—Ann. Rep. Div. Trop. Past. C.S.I.R.O. : 35-41.
SILLAR, D. I. (1969)—*Trop. Grasslds* 3: 154-157.
SWAIN, F. G. (1964)—Proc. Aust. Inst. Agric. Sci. Symposium, Sydney, 28.
SWAIN, F. G. (1971)—In "Intensive Pasture Production in Australia". (Eds Lazenby and Swain). Angus and Robertson Ltd.
SWAIN, F. G., BIRD, J. G., and DRANE, F. H. (1970). N.S.W., Dept. Agric. Misc. Bull. No. 11.
SWAIN, F. G., HOLDER, J. M., COLMAN, R. L., and BIRD, J. G. (1964)—Proc. Trop. Grassld Soc. Aust., Lismore : 35.
SWAIN, F. G., MEARS, P. T., DRANE, F. H., MURTAGH, G. J., COLMAN, R. L., BIRD, J. G., and YABSLEY, G. (1970)—Proc. 11th Int. Grassld Congr., Surfers Paradise, Australia : 925.
YABSLEY, C. M., and WARE, B. H. (1970)—Proc. Refresher Course Dairy Cattle Nutrition. Werribee, 271.
YOUNG, J. G., and RAYNER, I. H. (1962a)—*Qd J. Agric. Sci.* **19**: 493-525.
YOUNG, J. G., and RAYNER, I. H. (1962b). *Qd J. Agric. Sci.* **19**: 549-553.
VIVIAN, G. F., and HUMPHREYS, L. R. (1969)—*J. Aust. Inst. Agric. Sci.* **35**: 50-51.