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INCREASING FODDER PRODUCTION FOR THE GRAZING ANIMAL

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SUMMARY

The factors discussed in this review include irrigation, grazing management and the genetic improvement of pasture plant material. It is concluded that the use of these techniques may increase dry matter production, although by varying amounts. However, the gains to be expected are qualitatively different and, so, different animal management techniques may need to be used to assess the value of the pasture production gains from these sources in terms of increased animal output.

THE POTENTIAL SCOPE of this review is so great that many omissions have consciously been made. Chief among these is the use of fertilizers. This has been dealt with by other contributors to this symposium and by Karlovsky (1966).

With what has been included, the purpose has rather been to compile a brief for the devil's advocate than to suggest that the answers are clear cut. This more positive task will be undertaken in the two succeeding papers.

The subject is dealt with under the following headings:

(1) The supply of factors necessary for plant growth. Fertilizers being excluded, irrigation alone is considered.

(2) The effects of the grazing animal on plant growth. Some aspects of treading and defoliation are here considered.

(3) The supply of plant material with a higher genetic potential for production, through breeding, selection and plant introduction.

FACTORS NECESSARY FOR PLANT GROWTH

IRRIGATION

The replacement of absent or deficient minerals essential for plant growth is practised on a majority of New Zealand farms in some fashion or other. The replenishment of necessary water for plant growth is the exception rather than the rule. Yet the pasture production benefits from irrigation can be impressive, although of course highly variable from one environment to another. Elliott (1966) has reported that at Rukuhia Soil Research Station the 16-year average increase in pasture dry matter (D.M.) production from irrigation has been 31%; this on pastures already producing 11,400 lb D.M./ac/annum. The effect in parts of the South Island can be much more spectacular (G. G. Cossens, pers. comm.). This worker reports a 2½-fold increase in pasture production on the Linnburn soil, 4-fold on the Molyneux, and almost 7-fold in lucerne on a Ranfurly soil which had the water-table at 7 ft.

Irrigation, then, is unquestionably effective as a means of increasing pasture production even in humid parts of the North Island. Why is it not more widely undertaken?

Irrigation, as a technique, does not fit well into the pattern of New Zealand farming because of its high labour requirement. The work on automated irrigation at Winchmore could contribute a partial solution where the border-dyke system is employed.

Irrigation water drawn from bores may be contaminated, as with iron, for example (Coup and Campbell, 1964), the ingestion of which by the animal may depress its production, although gross pasture production has been increased. This can certainly apply throughout the Waikato basin where ground-waters containing up to 177 ppm Fe have been recorded (M. R. Coup, pers. comm.).

Irrigation necessarily increases pasture production in the summer. With existing stock management methods this may be a less critical time to have additional fodder available. Thus, Campbell (1966a) reported that there was no significant correlation between the whole-lactation production of dairy cows and available pasture D.M. in the months from October to March inclusive, although the amount of D.M. available in early lactation (August and September) was correlated with whole-lactation fat yield.

Unless management practices, not now employed, are instituted, so that the extra fodder grown by irrigation in summer is utilized, either by feeding directly to stock at a critical stage of production or by conserving it to feed at a more critical time, irrigation could be unprofitable in many seasons. This indeed has been the finding of economic studies of irrigation in both islands of New Zealand (Miller, 1957; Stewart, 1963).

GRAZING ANIMAL EFFECTS

TREADING

Evidence as to the degree of pasture damage caused by treading is contradictory, but the experimental conditions and techniques employed to induce treading damage have also been divergent (Edmond, 1958a, b, 1962, 1963, 1964; Scott, 1963; Campbell, 1966b).

Pragmatically it would seem that soil type, soil wetness, pasture cover and severity of treading could all affect the degree of pasture damage. There is scope for unified research, on a range of soil types whose physical properties are thoroughly evaluated, in an effort to relate degree of pasture damage to soil physical properties. Other soils likely to be susceptible to treading damage might then be identified on the basis of physical criteria and management modified to avoid pasture damage on them.

DEFOLIATION

The agronomist and grassland manager have welcomed the invasion of their province by the plant physiologist, seeing in the outcome of his discipline the means of explaining and benefically controlling effects of defoliation upon the growth and regrowth of the grazed pasture.

It has long been known that infrequent harvesting gives a greater yield of D.M. per acre than more frequent harvesting. This effect has been shown by many workers (see Sullivan and Sprague, 1943).

The explanation of this effect was early thought to lie in the depletion of root reserves of carbohydrates. These reserves, it was believed, acted as a reservoir upon which the defoliated plant could draw to initiate and sustain new growth (Weinmann, 1952: May, 1960). Voisin's (1959) concept of grazing management was based substantially on this theory. Through the use of labelled radioactive $^{14}CO_2$ Marshall and Sagar (1965) have confirmed the results of other recent workers showing that the decline in root carbohydrates of perennial herbage grasses after defoliation is largely caused by lack of replacement from the leaves and not by their mobilization to initiate new leaf growth.

The alternative explanation of the observed effect lies in the importance of intercepting and using for photosynthesis all incident light falling on a given area of land in order to maximize crop production from that area. This factor was first emphasized by Watson (1947; 1952) and the definition of Leaf Area Index (L.A.I.) (the leaf area per unit area of land) was proposed by him. Crop growth rate was then seen to be the resultant of leaf area index and net assimilation rate (*i.e.*, the rate of increase of dry weight per unit of leaf area). However, Watson (1956) considered leaf area index to be the main determinant of differences in dry weight yield per unit land area.

The initial work on this concept was with cereal and root crops and the importance of crop row spacing or drill width in achieving a high L.A.I. rapidly is obvious. Extension of the concept to the grazed pasture has been the work of Brougham, Black and others (Donald and Black, 1958).

So it came about that, whereas earlier pasture management studies had concentrated on measuring regrowth yield of pastures mown to a constant height at different time intervals (Woodman and Norman, 1932), the small plot research emphasis changed 25 years later to mowing at constant time and altering the L.A.I. of the stubble by varying the height of cutting. A more rapid rate of regrowth was obtained from the least severely defoliated pastures, and, hence, the D.M. yield from them was greatest at a constant time after first harvesting, up to the point where mutual shading of the pasture leaves reduced growth rate (Brougham, 1956). Subsequent work (Brougham, 1959) on the frequency and intensity of grazing by sheep, which were employed only as itinerant defoliators, showed that long spelling or frequent, light grazing gave higher D.M. yields than frequent, severe grazing.

The problem has been to know how to apply this valuable new information on the relation between defoliation and production to the management of grazed pastures. Two conflicts are evident. The first, which has been referred to earlier (Campbell, 1964) is that lax grazing, quite apart from its depressing effect on animal product per acre through poor utilization of the pasture, permits the accumulation of senescent and dead plant leaves which are relatively or totally unresponsive, photosynthetically, to incident light energy.

The second conflict arises from the fact that in mowing trials, or trials employing animals only as itinerant grazers, it is possible—even necessary when examining a single factor—to vary one factor (*e.g.*, interval between defoliations or defoliation height) at a time. But the farmer with a fixed acreage of land and a fixed number of stock cannot do this. If he decides to lengthen his grazing interval to gain the apparent advantages of long spelling shown by Woodman *et al.*, he must start off by grazing each paddock in the rotation more severely and thus to some extent forfeit leaf area and rapid initial regrowth. He cannot readily change time interval between grazings without also changing grazing severity.

Work in progress at Ruakura (Campbell, unpub. data) suggests that, on self-contained farmlets stocked at 10 and 15 ewes/acre, higher annual yields of D.M. arise from infrequent, severe defoliation than from frequent, less severe defoliation; in other words, other things being equal, a slow rotation has grown more grass than a fast one. The decline of clovers in the pasture under the slow rotation may, however, reduce its productivity in the long term.

This result may be explained in terms of Leaf Area Duration (Watson, 1956), which is the integral of L.A.I. over the period between grazings.

Leaf area index by itself may provide a first approximation of the main determinants of D.M. yield in a grazed pasture, leaf area duration may provide a second, but, in grazed pastures where senescent and dead material is present, the effective leaf area duration, where "effective" implies photosynthetically active, is probably an even more important physiological determinant of D.M. yield, and should be the primary objective of good grazing management. Unfortunately, it is not yet known how to achieve this or what different combinations of management factors may result in an optimum value.

PLANT SELECTION, BREEDING AND INTRODUCTION

The application of genetic theory has been highly successful in the improvement of many crop plants. Cereal and fodder root crops have yielded and continue to yield economically important gains to the plant breeder's skill.

The outstanding success of pasture plant selection and breeding in New Zealand lies in the production of a higher yielding and more persistent strain of white clover. Comparing two pastures of perennial ryegrass containing, on the one hand, Pedigree white clover and, on the other, Uncertified white clover, Corkill (1949) found the total pasture yield was increased by 25% and the clover yield by 76% where the Pedigree clover was employed.

Pure sowings of Pedigree broad red clover have outyielded commercial strains by between 14% and 18% at Palmerston North and Lincoln (Corkill, *loc. cit.*).

With ryegrass, it seems probable that the greatest genetic gains arose from the identification and selection by Levy and Davies (1929) of regional ecotypes among the permanent pastures of Hawke's Bay and Poverty Bay, which were clearly superior to the South Island types developed under arable farming (Corkill, *loc. cit.*). Subsequent progress in yield improvement by further breeding and selection was not rapid. A comparison of Poverty Bay and Pedigree strains at Palmerston North in 1947 and 1948 (Corkill, *loc. cit.*) showed a D.M. yield improvement in the Pedigree strain ranging from -1.2% to $+3.6\%$. At the same time, the Pedigree strain appeared to have better winter and spring production than the Poverty Bay strain and this would clearly be very valuable to the grazing animal.

Interspecific crossing in the ryegrasses has yielded Manawa (short-rotation) ryegrass and more recently Ariki ryegrass. Lynch (1950) compared Perennial and Manawa ryegrass pastures at Marton for eight years and found an average difference in favour of the Manawa pasture of 4.7% in D.M. yield. The hybrid on average yielded 42% (or 500 lb per acre) more D.M. in winter than the Perennial but gave less at other seasons. The same author (Lynch, 1966) reported from widespread trials that Ariki ryegrass pastures yielded 6% more on average than Perennial ryegrass pastures. Most of the additional production came in late summer and early autumn.

In reviewing these trials, the writer is impressed, as was Lynch (1966) in his review of Ariki yield trials, at the number of comparisons in which the newly evolved strains have substantially increased their proportional representation in the sward compared with the control strain, yet total pasture yield has remained virtually the same because other species provided an amount of D.M. which was in inverse proportion to that of the strains under test.

It appears clear that factors other than the genotype of the herbage grasses may be operating to set a ceiling on whole pasture production. But it may also be that the existing herbage grasses are so genetically similar in their growth form, in height, and in the spatial distribution of their leaves that only a genetic departure from this basic plant structure, as proposed by Mitchell (1960), is going to increase whole-pasture yield substantially.

This apparently limited success in the breeding of herbage grasses for improved fodder production is not only a local problem. Comparisons of Aberystwyth and commercial strains of ryegrass in U.K. have shown, if anything, less encouraging results from an even longer period of intensive selection and plant breeding effort. Thus, Heddle, *et al.* (1950) found New Zealand ryegrass to yield 100 lb D.M. per acre per annum more than Aberystwyth S.24 which was no better than the Ayrshire commercial stock, while commercial Devon Eaver ryegrass yielded only 60 lb less D.M. per acre per annum. Heddle *et al.* (1956) compared two bred strains and four commercial lots of perennial ryegrass seed over three years and found one bred strain (New Zealand Certified) at the top of the list and the other (Aberystwyth S.23) at the bottom—below the comercial Kent strain from which some of the S.23 parents were selected (Beddows, 1953).

At Aberystwyth itself in a three-year sheep grazing trial to compare the productivity of the highest yielding Aberystwyth strain (S.24) and the most maligned commercial strain of ryegrass (Irish) in simple mixtures with white clover, Hughes (1956) showed a non-significant, 6% advantage in D.M. yield for the S.24 pasture on unmanured plots and a non-significant, 12% advantage on plots regularly topdressed with nitrogenous fertilizers.

Perhaps these results are not so surprising when Green (1964) can report that *Poa trivialis* gave 75% of the yield of S.24 ryegrass under high fertility conditions and that *Agrostis tenuis* gave 80% of the D.M. yield of S.24 ryegrass at several levels of fertility, but gave similar gross D.M. yields when grown with white clover.

It is true that some added advantage from plant breeding has accrued from an alteration in the seasonal distribution of production, at least with Manawa ryegrass, although the improved late summer production from Ariki is less valuable under current forms of animal management, and is scarcely great enought to merit any radical change in management to make fuller use of it. Improved liveweight gains in sheep have been noted on Manawa ryegrass (Rae *et al.*, 1963, 1964) but penalties of restricted adaptability and lowered persistence have had to be paid. Reports of poorer sheep performance on Ariki than on other grass species (Lynch, 1966) are not uncommon.

It would seem to be realistic in view of New Zealand and overseas experience to assert that little further progress in improved yield of the ryegrasses can be expected by further breeding and selection within the pool of genes associated with the European ecotypes. There may still be scope for selection of plant material which provides a more favourable nutrient supply to grazing livestock but it is too early yet to evaluate the practical worth of this approach.

The improvement of herbage plants through induced polyploidy was enthusiastically taken up about 35 years ago, but experience has greatly tempered the original enthusiasm. Carnahan and Hill (1961) reported that "induction of tetraploidy *per se* has rarely been significant in establishing superior grass plants." Greater success has been achieved with clovers (Levan, 1942) but problems of the low seed yield obtainable from tetraploids, even after many generations of selection for this character (Julén, 1956), may reduce the practical value of induced polyploidy if not overcome it. However, the technique may still have a valuable part to play in permitting the crossing of species or genera whose diploids have incompatible chromosome numbers.

The prognosis implied by the foregoing review may seem discouraging but it is one which echoes the historical evaluation by Myers (1960) of his own and allied work when he said, ". . . few [new forage varieties] have been so strikingly superior that their merits were quickly recognised by farmers." If this evaluation is substantially accurate, a new and purposeful approach to plant introduction seems to provide the only immediate alternative to accepting that the genetic potential of existing pasture species sets a ceiling on pastoral farming expansion which may be attained inside twenty years (Anon., 1963).

The possibility of improving pasture production through the resurrection of plant introduction is largely unknown.

Cumberland (1966) has reported that kikuyu grass pastures on basalt soils in Northland can outyield paspalum pastures by almost 30%. The strain of kikuyu used in these trials and its place in the range of ecotypes is quite uncertain and its selection was probably fortuitous. Similar findings are being made at the Grasslands Station at Kaikohe (A. F. Boyd, *pers. comm.*). Work is also being carried out with Mediterranean introductions at Grasslands Division, Palmerston North.

It is true that the history of plant introduction to Australia south of the sub-tropics has not been wholly encouraging, but this may be more due to an error of physiological objectives than to the technique of introduction. For many years, Australia, in tackling the winter growth problem, concentrated upon the importation of plant material from northern Europe, northern U.S.A. and Canada on the assumption that species adapted to low temperatures at high latidues would produce better in the milder winter environment of Australia (Vears, 1965). During this period the fortuitous introduction of subterranean clover and *Phalaris tuberosa* was more valuable than the planned introductions. A later phase depended on the importation of plant material of Mediterranean origin, in the hope of importing summer-drought-resistant qualities and winter-growth potential. More recently the theory of Vears (1963, 1965) has revolutionized the physiological basis of introduction for winter growth and hence changed the sites for plant exploration and collection.

Simply stated, Vears has noted, for example, that short daylengths primarily restrict winter growth of plants. Plants which are capable of growing in short daylengths are to be found in the tropics. But, to grow in Australian winters, plants must be capable of withstanding frost. To find frost in the tropics one must go up a mountain. Recent introductions from high altitude, tropical sites have shown great promise for autumn and winter production at the latitude of Sydney (Vears, 1965). In England (Green, 1962) a synthetic tall fescue containing high-altitude Moroccan material has out-produced New Zealand Manawa ryegrass by 65% over the six winter months.

Species valuable for New Zealand conditions are unlikely to be found in the catalogues of overseas seedsmen, nor will they be found inside a phytotron, but they may be found in the high Andes, on the slopes of Kilimanjaro or the Atlas mountains by botanists who know New Zealand's varied environment and requirements. Quarantine and evaluation procedures will be necessary to process introduced plant material but above all perhaps perseverance will be required in the face of many failures to find a few plants which will allow progress beyond 1980.

ALTERNATIVE FODDER CROPS

These may be considered as a specialized extension of the theme of plant introduction. The reasons for considering them are firmly rooted in the physiological advantages for D.M. production which they are believed to have over pasture-type plants (Mitchell, 1960; 1966).

Crops such as maize, sorghum, soybean and crossbred "Sudax" are among those proposed. They have several features in common which fundamentally affect their use by livestock. They are annuals; they are not normally grazable; they have a highly seasonal pattern of production, and their high potential yields of D.M. may only be achieved when their digestibility has fallen to quite a low level.

A little is known about the D.M. production capabilities under research conditions of some of these crops in the New Zealand environment, but almost nothing is known about their actual yields of digestible nutrients when grown on a farm scale, with all the natural hazards thrown in. Still less is known about the utilization of these crops and particularly how the final cost of animal products from them compares with costs of conventional production from pasture.

Recent local arguments on this theme have been extensive and not always fruitful. We have not all learned the truth of the maxim laid before us by our distinguished Past-president, Professor Flux (1962) when he said, "The key to clear advice . . . is usually an adequate supply of reliable data relevant to the problem." We simply do not have enough reliable data on these alternative crops to reach a correct decision as to their place in New Zealand farming. However, there are lessons to be learned from these disagreements.

DISCUSSION

There are, clearly, techniques available or which can be further developed for increasing fodder production. In this paper they have been classified according to source—nutritional, physiological or genetic. It may now be more instructive to reclassify them according to effect. Some will have the effect of improving fodder production by increasing it out of season, for example, through breeding. Some will increase production at all seasons, for example, skilful grazing management; yet others, irrigation and the new fodder crops, may enhance production by increasing the seasonal maldistribution of fodder supply which is found in the normal pasture.

Agronomists are sometimes concerned to discover from the animal nutritionist which effect they should strive for. But this is probably of less importance than how successful they are in producing a sizable effect. This is so because of the flexibility at the disposal of the nutritionist, arising both from the nutritional adaptability of the stock he feeds and from the range of management techniques upon which he can call.

Small improvements in fodder yield or small changes in the distribution of its supply will call for only small divergences from existing animal management techniques, if these are already highly efficient. But large changes, and especially changes in the distribution of fodder supply may call for a completely new approach to the management of farm livestock.

Paradoxically, the arguments referred to in the previous section on new fodder crops have arisen from the haphazard introduction of a new technique for managing livestock long before the agronomic foundation essential to support the technique had been laid. Those who have felt compelled to declare themselves for or against the new technique have been forced to rely on many assumptions to fortify untenable, dogmatic entrenchments on both sides of the front line.

The logical process is the other way round. Having found that fodder production may be increased by a specified amount, at a specified season, by a particular technique, the search should then be instituted for means of utilizing this extra fodder in the most efficient and economic manner. Putting the cart before the horse always was an inefficient way of making progress.

At all events, the animal nutritionist must be made aware of the qualitative differences—the differences in outcome of the techniques outlined above, so that he does not try to evaluate their animal production potential under a uniform animal management regime.

REFERENCES

Anon., 1963: *Proc. N.Z. Inst. Agric. Sci., 9:* 1.
Beddows, A. R., 1953: *Welsh Pl. Breed. Stn Bull. Series H, No. 17*: 81 pp.
Brougham, R. W., 1956: *Aust. J. agric. Res., 7*: 377
——— 1959: *N.Z. J. agric. Res.,* 2: 1232.
Campbell, A. G., 1964: *Proc. N.Z. Soc. Anim. Prod., 24:* 17.
——— 1966a: *J. agric. Sci., Camb., 67*: 217.
——— 1966b: *N.Z. J. agric. Res., 9*: 1009.
Carnahan, H. L.; Hill, H. D., 1961: *Bot. Rev., 27*: 1.
Corkill, L., 1949: *Emp. J. exp. Agric., 17*: 157.
Coup, M. R.; Campbell, A. G., 1964: *N.Z. J. agric. Res., 7*: 624.
Cumberland, G. L. B., 1966: *Res. Rep. No. 9, Res. Div. N.Z. Dep. Agric.* Cyclo., 9 pp.
Donald, C. M.; Black, J. N., 1958: *Herb. Abstr., 28*: 1.
Edmond, D. B., 1958a: *N.Z. J. agric. Res., 1*: 319.
——— 1958b: *ibid., 1*: 652.
——— 1962: *ibid., 5*: 389.
——— 1963: *ibid., 6*: 265.
——— 1964: *ibid., 7*: 1.
Elliott, I. L., 1966: *N.Z. agric. Sci., 1* (8): 15.
Flux, D. S., 1962: *Proc. N.Z. Soc. Anim. Prod., 22*: 5.
Green, J. O., 1962: *Exps. Prog. Grassld. Res. Inst., 15:* 12.
——— 1964: *ibid., 17*: 14.
Heddle, R. G.; Dawson, J. L.; Gregor, J. W., 1950: *Scot. Agric., 29*: 189.
Heddle, R. G.; Herriott, J. B. D.; Hunter, R. F.; Erskine, D. S. C., 1956: *Tech. Bull. No. 16,* Edinburgh School of Agric. 35 pp.
Hughes, R., 1956: *Welsh Pl. Breed. Stn. Bull. Series H, No. 18:* 78 pp.
Julén, G., 1956: *Proc. 7th int. Grassld. Congr.*: 471.
Karlovsky, J., 1966: *Proc. Ruakura Fmrs' Conf. Week*: 115.
Levan, A., 1942: *Hereditas, 28*: 245.
Levy, E. B.; Davies, W., 1929: *N.Z. J. Agric., 39*: 1.
Lynch, P. B., 1950: *N.Z. J. Agric., 81*: 545.
——— 1966: *ibid., 113*: 55.
Marshall, C.; Sagar, G. R., 1965: *Ann. Bot., 29* n.s.: 365.
May, L. H., 1960: *Herb. Abstr., 30*: 239.

Miller, J. H., 1957: *Proc. N.Z. Grassld. Ass., 19:* 37.
Mitchell, K. J., 1960: *Proc. N.Z. Soc. Anim. Prod., 20*: 82.
——— 1966: *N.Z. agric. Sci., 1* (8): 23.
Myers, W .M., 1960: *Proc. 8th int. Grassld. Congr.:* 7.
Rae, A. L.; Brougham, R. W.; Barton, R. A., 1964: *N.Z. J. agric. Res.,* 7: 491.
Rae, A. L.; Brougham, R. W.; Glenday, A. C.; Butler, G. W., 1963: *J. agric. Sci., Camb., 61*: 187.
Scott, R. S., 1963: *Proc. N.Z. Grassld. Ass., 25:* 119.
Stewart, J. D., 1963: *Lincoln College* (*N.Z.*), *Publ. No. 1,* 22 pp.
Sullivan, J. T.; Sprague, V. G., 1943: *Pl. Physiol., 18*: 656.
Vears, C .K., 1963: *Aust. Grassld. Conf., 3:* 1/28.
——— 1965: *Pl. Introduction Rev., 1 (3)*: 62A. C.S.I.R.O. Div. Pl. Industry.
Voisin, A., 1959: *Grass Productivity*. Crosby Lockwood, London. 353 pp.
Watson, D. J., 1947: *Ann. Bot., 11*: 41.
——— 1952: *Adv. Agron., 4*: 101.
——— 1956: *Proc. 3rd Easter School Agric. Sci.,* Nottingham Univ., p. 187.
Weinmann, H., 1952: *Proc. 6th int. Grassld. Congr., 1:* 655.
Woodman, H. E.; Norman, D. B., 1932: *J. agric. Sci., Camb., 22*: 852.