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# THE STRUCTURE OF PASTURE IN RELATION TO PRODUCTION POTENTIAL

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THE COMMENTS to be made in this paper will be concerned only with ploughable land. Data on which to base a similar analysis for steeper land inaccessible to wheeled equipment are now being assembled. It is already clear that these will lead to very different conclusions from those which arise for ploughable country.

When the curves of potential seasonal growth for a number of different pasture grasses are examined (Fig. 1) it is found that, although there are consistent, and not unimportant, differences between them, the overall picture is one of general similarity in seasonal growth response. The implications of this for pasture production are simply expressed. It indicates that the productivity of most of the New Zealand grazed pastures will be mainly determined by how well three simply stated criteria are met. The first is that there should be adequate fertility in the soil; the second that each tiller in the pasture should be firmly rooted with a vigorous root system; and the third that there should be a cover of vegetation dense enough to intercept all light. Provided these three principles are met, differences in grazing procedure become of secondary importance in governing the ceiling for production of herbage from a grazed pasture.

Whereas it can be agreed that these comments are in some respects over-simplified generalizations, there is an adequate number of field examples of their successful implementation to make it clear that they are not over-simplifications to the stage of being pointless. Anyone who feels doubtful about that conclusion should consider the position during the last thirty years concerning grazing management procedures and use of No. 1 white clover which was introduced to New Zealand by Levy. The value of white clover in a pasture is regarded now as so obvious that it is difficult to realize there could ever have been doubt on the matter. On the other hand, there is no difficulty in

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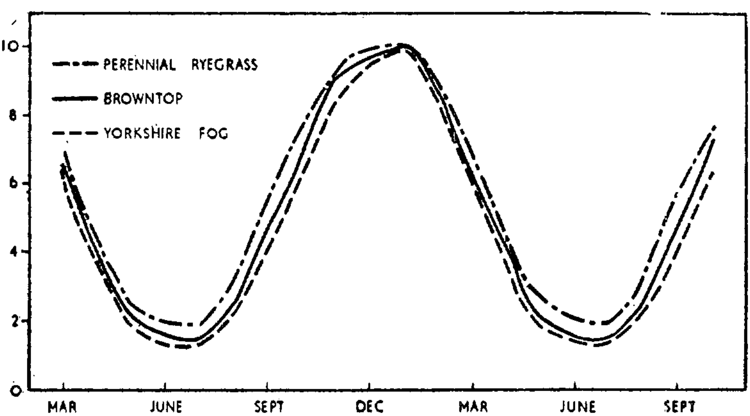



*Fig. 1: Seasonal curve of potential production of herbage (dry matter) for plants receiving no limitation of growth from soil nutrient or soil moisture conditions. For each species the highest monthly production occurs in January and is taken as equal to 10 units.*

calling to mind the range of different pasture management procedures, varying from intensive break feeding through to continuous set stocking, which have at various times been advocated or which the reader may have seen successfully practised. There is still no general decision as to which grazing procedures are best, nor any prospect of a lasting decision in favour of particular systems. This is to be expected if they are best regarded as being open to a wide range of adaptation to fit the general stock requirements and economics of each farm.

Much of the discussion and swing of fashion concerning grazing management should fall into perspective when it is realized that, provided the principles outlined above are met, modification of grazing procedure between set stocking and rotational grazing or any hybrid of these will contribute relatively little toward raising the ceiling for production of herbage from a grazed pasture. Grazing procedures are probably of more concern in governing the efficiency and convenience of feed utilization by the animal and much of the skill required for carrying out good grazing management is concerned with handling the stock so that their presence or absence at critical times does not severely restrict growth potential. A pasture may be allowed to grow too long or it may be grazed too hard or trampled too severely at critical times of the year. An extra day, or even a few hours, may often make the difference between a stock movement being beneficial and its giving a check to production which may take a month or more to overcome. Overall it is suggested that patterns of grazing procedure can be widely modified to suit the convenience of the farm and its economies.

If top farmers attempt to obtain continuing increases in production of herbage from the pasture grown in this country, they are faced with a series of dilemmas. If the pasture is left long enough to ensure efficient light utilization for considerable periods of time, there is in many parts of the country high probability of its becoming dominated by grass species which send creeping stems across the surface of the soil and through the pasture. Such creeping stems generally have frail and restricted rooting systems at the base of the individual tillers. As soon as adverse moisture and fertility conditions arise, production is liable to suffer severely. The well-established procedure for dealing with this situation is "scrubbing out" a pasture by hard grazing with either sheep or cattle. Loosely rooted tillers and creeping stems are torn out by the mouths of the grazing animals and the remainder of the tillers trampled firmly into the soil. That ensures good rooting of the tillers but in the process there are considerable periods when the pasture is bared out to a degree where efficiency of light utilization is low. The important point is that to achieve the balance a compromise is needed which is reached at the expense of overall potential production.

A particular merit of perennial ryegrass is that its morphological form is well adapted to allow vigorous growth under reasonably intensive trampling. Its tillers tend to set their bases below the surface of the soil. This protects the meristematic regions from trampling damage and from climatic extremes. From these tillers vigorous roots grow down and, of particular importance, this grass has the potentiality for sending out short creeping stems which travel below the surface of the soil. This allows it not only to fill in gaps in the pasture but also, in effect, to go through a cycle of vegetative rejuvenation. However, as stocking rates are raised and trampling intensity rises, a point is reached, even with perennial ryegrass, where damage to the plants by trampling can become a major limitation on the growth of the plants. Restriction of growth of herbage by trampling damage at high levels of carrying capacity may place a ceiling on the total herbage productivity of the pasture which applies irrespective of potentiality for growth allowed by soil fertility and climate.

Overall, it follows that the present system of pasture production based on the utilization of the herbage by animals grazing in the field is self-limiting in terms of total production of vegetation per acre. At this stage it is appropriate to mention an additional limiting factor which promises to become of increasing importance as the general standard of productivity of the pastures is raised—that is, stock thrift. Lush herbage grown on high fertility soils is not always regarded as a desirable sole diet for livestock. Also its litter and its microclimate do provide nutritional and environmental conditions favourable for vigorous growth of micro-organisms. Readers are already aware of one fungus that is highly undesirable, *Sporidesmium*, and Thornton's earlier results indicate that there are many other fungi present which can also be detrimental to stock thrift. Although procedures may be found for controlling many of these thrift problems, prospects are that they will become an increasing expense to be charged against attempts to gain high production by grazing stock on improved pasture.

That present pasture production procedures come to a stage where they are inherently self-limiting is clearly recognized by Sears in his descriptions of the sequence of species associations which occur with the raising of fertility and in his advocacy of the use of crops for cashing in on fertility which cannot be effectively utilized by increased production of pasture herbage. The programme of research, which he has initiated to examine this situation, should be judged neither in terms of whether the average yield of crop which is obtained on farms is sufficient to justify the trouble and expense of growing a crop instead of leaving the area in grass, nor alternatively by whether the levels of production achieved on the small dairy farm at Massey College were economic in relation to the effort required to get them. The work should be considered as providing data on which to base the changes in this country's pastoral farming system which undoubtedly must occur if the industry is to move beyond the present self-limiting situation and efficiently exploit the plant production potential allowed by the climate.

It is appropriate now to turn attention to the factors governing the production potential of vegetation, of which three are outstandingly important. These are, first, the temperature adaptation of the plants, secondly, the character of their root system, and, thirdly, the structure of the vegetation cover. The importance of having plants whose vigour of growth is relatively little influenced by the range in temperature between summer and winter has long been recognized in this country. Similarly, the importance of a vigorous root system for efficient searching for minerals and water has long been emphasized. The work being done by Mouat makes it clear there should now be added to that a requirement for a root system with an appropriate cation exchange capacity. The structure of vegetation cover governs the potential for the efficiency of use of light and carbon dioxide.

Light is the source of energy for the plant's growth. It is increasingly becoming apparent that the quantity of light available each day is during much of the year an ultimate determinant of the yield which can be attained from crops. If high efficiency of plant production is to be an objective of prime importance, then light must be regarded as a valuable commodity whose supply is strictly limited. It must be ensured that the maximum practicable number of calories of light energy are transferred to calories of energy in the plants and hence are used for formation of plant tissue. The important rule for efficiency of use of light is that, once above a fairly low threshold, the lower the intensity of the radiation on to a leaf surface the higher is its efficiency of utilization for formation of plant material. It follows that, where daily supply of light is high, it should be spread as evenly as practicable over a large area of photosynthetic tissue in order that the average intensity of light per unit area of tissue remains low.

Carbon dioxide provides the major structural component of plant tissue. For every ten pounds of dry weight of vegetation grown on an acre during one day, approximately nine acre-feet of air needs to be circulated past the leaves. This is assuming a 25 per cent. extraction of $CO_2$ by the leaf, which is probably a relatively high efficiency. The importance of good air ventilation for crops from which daily growth of fifty, a hundred, or even two hundred pounds of dry matter per day per acre is expected is apparent.

A significant contribution to the carbon dioxide requirements of a crop may come from $CO_2$ diffusing out from the soil but the writer doubts whether that could be sufficient to make a major contribution to the daily requirements of a crop when there are really high rates of growth.

Five examples can be considered to illustrate the main situations brought about by different structures of vegetation (Fig. 2). The estimates of potential annual production are for plants which are perennial and which have a temperature response curve similar to that of perennial ryegrass. Except for the overlong grass for which no firm figure is given, all estimates are based on yield data obtained by Sears and by Brougham of Grasslands Division.

In a relatively short, continuously-grazed pasture, production is limited both by inadequacy of the area of photosynthetic

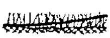
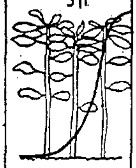
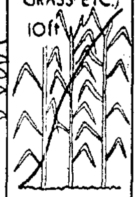
| | SHORT GRAZED PASTURE | LONGISH SPELLS BETWEEN GRAZING | EXCESSIVE SPELLS BETWEEN GRAZING | CHOU MOLLIER | MAIZE EQUIVALENT (JOHNSTON GRASS ETC.) |
|---|---|---|---|---|---|
| GROWTH FORM AND LIGHT INTERCEPTION CURVE | HEIGHT 2–3 in.  | HEIGHT 9–15 in.  | HEIGHT 9–15 in.  | 5 ft  | 10 ft  |
| MAXIMUM LEAF AREA INDEX | 4–5 | 10 | 12 | 6 | 16 |
| PEAK SUMMER DAILY AIR REQUIREMENT | 185 acre/ft. | 340 acre/ft. | 230 acre/ft. | 440 acre/ft. | 685 acre/ft. |
| VENTILATION | EXCELLENT | FAIR – GOOD | POOR | GOOD | EXCELLENT |
| POTENTIAL ANNUAL PRODUCTION PALMERSTON NORTH (lbs/DM/acre) | 12,000 | 22,000 | 15,000 | 26,000 | 42,000 |

*Fig. 2: Influence of structure of vegetation on production potential. Growth form, leaf area index, and volume of air required to provide sufficient carbon dioxide for growth during peak period, together with an estimate of potential annual production for Palmerston North are shown.*

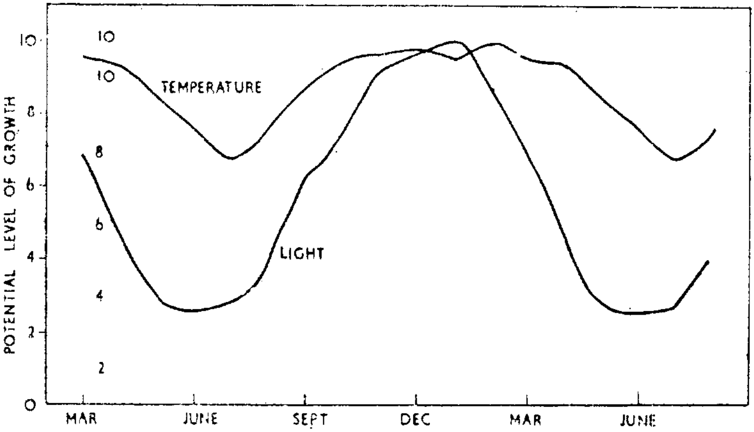
tissue and by its restriction to a very thin layer over the surface of the soil. In consequence, general experience is that the maximum production for such a pasture is of the order of 12,000 lb of dry matter per acre per year. If the pasture is allowed to grow longer, say, up to 6 in. or 12 in., the total area of leaf surface available for photosynthesis increases substantially and there is probably no major reduction in efficiency of air ventilation. As a result, production potential of the vegetation is approximately doubled. If, however, the pasture is allowed to grow much longer than that, the leaves are not rigid enough to maintain themselves erect or nearly so. They bend over, and form a horizontal thatch across the top of the pasture. As this thatch intercepts most of the light, that received by a large proportion of the vegetation is inadequate. At the same time, air exchange with the surrounding atmosphere is strongly restricted. Overall there is a considerable limitation of growth. It follows that continuing increases in production potential cannot be achieved from existing pasture species by attempting to grow them to even greater heights.

If, as an alternative, plants with a growth form such as choumoellier are sown, the production potential remains relatively high but it is not significantly above that of the moderately long pasture. Although the ventilation around the leaves is excellent, the horizontal placement of those leaves results in a poor light interception curve. The greater part of the light is intercepted by the upper leaves, which cannot make efficient use of that quantity of light, and the lower leaves receive very little.

If, however, a crop has a growth form similar to that of maize or any other tall-stemmed plant with either relatively small or linear leaves, both the efficiency of light utilization and the efficiency of air circulation within the vegetation are high. In consequence, the ceiling potential for this form of growth—quite apart from any particular species—rises to over 40,000 lb per acre per year.

If this analysis of the manner in which the structure of vegetation governs the efficiency of utilization to New Zealand's climatic potential in terms of total quantity of plant product grown is reasonably soundly based, a number of conclusions follow:

(1) The type of vegetation which will give high efficiency of utilization of New Zealand's climate is one in which the dominant species possesses relatively erect stems on which moderately small or linear leaves are distributed over a wide zone of height, preferably several feet. Whether this species is graminaceous, another monocotyledon, or a member of some dicotyledonous family, is probably of secondary importance. It is more important that the species should be a perennial with a vigorous root system and possibly a certain amount of rhizomatous development and that it should have the ability to recover rapidly at all seasons of the year from cutting. It should also be noted that a vegetation cover of this structure will almost certainly lead to more efficient use of the rainfall and will have better temperature relations and probably make more efficient use of the fertility in the soil. It has often been emphasized that this country's pastures live on a skin of fertility on the soil. It also holds that they form a narrow face for radiation exchange between the atmosphere on the one hand and the vegetation cover on the soil on the other hand. This leads to rapid fluctuations in temperature, both up and down, and also to rapid fluctuations in moisture content of the surface layers of soil, particularly to rapid drying out. In consequence, any short period with-




Lowest winter potential : July
Temp. × Light : 67 × 27 = 18

Peak summer potential : January
Temp. × Light : 95 × 100 = 95

*Fig. 3: An estimate of relative influence of seasonal variations of temperature and quantity of light per day on production potential for perennial ryegrass during various seasons of the year at Palmerston North.*

out rain is promptly reflected in reduction in pasture growth, even although good supplies of moisture may still be present at greater depths in the soil.

(2) To achieve higher production of fodder from the land it will be necessary to remove the grazing animal from it and to bring the feed to the livestock rather than, as occurs now, take the stock to the feed. With mechanization and streamlining, cut-and-carry procedures for provision of herbage to livestock kept in central yards are now becoming very efficient and relatively cheap. In addition, if feed grown in the paddocks is carried to stock or fed to them from silos, the regulation of the quality and nutritional standards of the feed being received by the animals becomes much more practicable. It will immediately come to mind that if stock are removed from the paddocks they will no longer receive the automatic return of nutrients which occurs from the grazing animal. Although the quantities of nutrients returned to pastures from animals are large, the procedure is wasteful. Not only is distribution across a paddock irregular but also losses from leaching and evaporation are high and timing of application for best return frequently poor. Consequently in circumstances where total herbage production is high, real costs of collecting nutrients at a central point and transporting them to the field may be lower than would appear at first sight.

(3) If there is a vegetation cover on the land which makes efficient use of light at all times of the year, the difference between the peak production in the summer and the nadir of production in the winter becomes large (Fig. 3). Maximum growth during the winter is important, where the aim is to go as near as possible to growing each day feed that the livestock require for that day. In these circumstances it can be economic to operate systems which give major restriction of growth potential during the summer but which allow efficient growth during the winter. However, where the emphasis is on total production per year, it is important to emphasize productivity during the period when most growth can occur—that is, during the late spring, summer and early autumn. With an efficient vegetation cover, a 25 per cent. increase in productivity in the winter will produce only one-sixth of the herbage which can be obtained from a 25 per cent. increase during the summer. There is a further important practical point, namely, increased scope for standing transfer of production from periods of rapid growth for use in periods of slow growth. This practice is, of course, being attempted with pasture and it is the basis of forage cropping to provide for winter and summer shortage. The higher the weight of dry matter which can be built up in a paddock at any one time, and the longer the period for which the vegetation will continue growing and remain of good nutritional quality, the more flexible and the more efficient does such a procedure become. Notwithstanding this, any trends toward increasing the difference between summer and winter production do also place more emphasis on having efficient procedures for preservation of crop materials for use at later periods.

(4) If tall growing vegetation is used, white clover or pasture legumes with similar growth habit cease to be a satisfactory source of nitrogen for crop growth. Alternatives are the use of twining legumes for growth among the crop, alternation of leguminous and non-leguminous crops, and almost certainly greater use of purchased nitrogenous fertilizer. The energy required for the symbiotic fixation of nitrogen in root nodules comes from carbohydrate and other materials provided by the host plants. These materials could alternatively be used for increased growth and production of herbage. It is not inconceivable that a stage may be reached where it is found cheaper to use the energy available from Lake Te Anau to fix the nitrogen required by plants than to use a legume to provide the energy required.

(5) Operation of a system in which stock are removed from the land can produce considerable operational flexibility for the

farmer. The land is not tied down for use as a grazing area for stock but serves primarily as a growing area for plants. Whether the plants which are found most profitable produce feed for livestock, food for humans—be that fruit, carbohydrate or vegetables—or industrial raw material, is of secondary concern. Provided individual farming units are maintained relatively large, and possibly a trend initiated toward increase in size of operational units, there can be not only high technological efficiency but also the capital is being invested in machinery and operational equipment which give considerable flexibility in the running of the enterprise. Assembling of machinery to handle crops and the development of experience in growing crops, make a farmer much better adapted to change the balance of his enterprise to suit trends in relative profitability. An additional point is that enterprises of this form, which are being found very efficient in other countries, do allow good scope for the direct and indirect utilization of technologically trained men. That is in itself an important feature.

(6) At first sight it may appear that a major drawback to such changes is the need for a considerable increase in farm capitalization to implement them. However, that is not necessarily so. At present there is a continuing trend for increased capitalization of the land by its division into units of smaller area, with a consequent requirement for duplication of fencing and of farm buildings. That ties up capital in a form which may impede implementation of technological progress and certainly restricts large changes. Application of developments such as those suggested above calls more for a redirection of capital rather than for an increase of capitalization per acre.

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Summing up, it appears that for ploughable land, the potential for further large increases in herbage production from the best farms is limited, or will soon be limited. It is limited both by the growth structure of the species in the present pastures and by trampling damage from the stock grazing the pastures. Trampling damage becomes of increasing importance as pasture productivity and hence stocking rates are increased. However, it is doubtful whether removal of stock and bringing the feed to the stock will lead to a major increase in profit per acre if the species present in intensively grazed pasture are encouraged to remain dominant. Their growth form is adapted to survival under trampling rather than to really high per acre production of herbage. The main conclusion suggested is that to achieve major increases in the production of herbage from ploughable land the industry should consider the possibility of removing the stock from the paddocks and also to the use of plant species with a form of growth considerably different from those present in the pastures now.

If such changes are fully implemented, they could also lead to considerable changes in the economic form of the producing units and diversification of the type of crops grown. Determining the potentiality of such changes and developing plants to allow their implementation would call for a considerable co-ordinated research effort. If this country's primary industries wish to live up to their position as big and efficient industries and to maintain it in the years ahead, this and similar challenges should be welcomed.

## DISCUSSION

DR P. D. SEARS: I am in full accord with the concepts put forward by Dr Mitchell. Where the climate allows it, systems of utilization of plants and land have been in use for a long time in intensively farmed regions. As the need for more intensive utilization of land develops in New Zealand, such trends are the logical ones to follow here. Even with combinations of existing plants, high annual yields of dry matter per acre could be obtained. A combination of maize and Italian ryegrass should be capable of producing 30,000 lb of dry matter per year.

G. GEDDES: In addition to expressing agreement with the theme presented I should like to make two points. In comparisons between crops, height can be a deceptive index of total dry weight of herbage per acre. For instance, subterranean clover may form a far denser mass of vegetation per unit volume of space occupied than either white clover or maize. Further, as long as dairy stock have to be kept in milk throughout the year, out-of-season growth is particularly valuable financially. Sod seeding of oats was found to give very good results for filling the February to mid-May gap which occurs near Sydney, provided it receives adequate nitrogen fertilizer.

Q.: *As New Zealand is competing very well with the rest of the world in primary production, mainly owing to the excellent economics of having the animal harvest the feed, is there great merit in considering alternative systems?*

A.: The present position is not static and may change in the decades ahead. Our livestock grazing system is not efficient in terms of high production of plant product for our land. Accordingly it is suggested there is a need for experimental work to examine the potentialities of alternative systems in case overseas competitive relationships, or unsuspected efficiencies in alternative farming systems, make changes worth while on the ploughable land. Field grazing of livestock will almost certainly remain the basis of farming on the steeper land. That land has greater area than our ploughable land and there are capabilities of very great development of stock numbers on it.

Q.: *Are plants known which are suitable for livestock and for implementing the suggestions put forward?*

A.: None are known which properly fit our climate. There is a research job to be done in finding suitable genetic material, synthesizing it, and then carrying out field evaluations.