EFFICIENT USE OF SUPERPHOSPHATE IN THE PASTURE PROGRAMME

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1. INTRODUCTION

Phosphate deficiency is very marked in Australian soils, particularly in the southern half of the continent. The annual usage of superphosphate in Australia is just over two millions tons,[1] approximately 65 per cent of which is applied to pastures. Each year, therefore, landholders are spending something like £40 million on the purchase, transportation and application of this fertilizer.

The present considerations refer mainly to the use of superphosphate on pastures in the higher rainfall sheep areas, where there are very extensive areas of low fertility soils in climatic zones favourable for the growth of various introduced pasture species. In such areas, particularly during the last ten years, many landholders have used substantial quantities of superphosphate to ensure satisfactory establishment and growth of sown pasture species, the most notable of which is Subterranean Clover (*Trifolium subterraneum* L.).

Widespread success in pasture establishment has led to more intensive production and many landholders, because of higher capital and annual costs, are now conscious of the need for more precision in the use of superphosphate. Lower farm incomes and the consequent limiting of expenditure on superphosphate bring into sharper focus the problem of how best to use this fertilizer, having regard to financial limitations on the quantity that can be used on the property and, also, to the previous treatments of the various paddocks. This problem is of great importance; firstly, because superphosphate is a major cost item (and one which is likely to be reduced when incomes are low), and, secondly, because the rate of superphosphate application is an important determinant of the yield, botanical composition and seasonal growth pattern of pasture.

[1] *Quarterly Review of Agricultural Economics,* Vol. *XIII,* No. 2 (April, 1960), p. 99

2. SUPERPHOSHATE IN THE PASTURE PROGRAMME

Pasture Establishment

With very few exceptions it is standard practice in southern Australia to apply superphosphate at the time of sowing pastures. The lower the fertility of the soil the greater the dependence of the seedlings on fertilizer phosphate. On the extensive areas of soils of very low fertility, for example on the tablelands of New South Wales, there is no chance of successful establishment without the use of superphosphate.

In such areas nitrogen deficiency is very pronounced. The essential first step, therefore, is to sow clover, taking great care to ensure successful nodulation by the nitrogen-fixing bacteria. The clovers and the root nodule bacteria must, of course, be adequately supplied with phosphate and, in some cases, one or more trace elements should also be applied.

Grass-Clover Balance

After a period of vigorous growth by clover-dominant pasture the soil nitrogen content will be raised to a level satisfactory for grass growth. This change in fertility results in invasion by several species of grasses and weeds which are adapted to the improved conditions. The sequence of botanical changes is illustrated in Fig. 1.

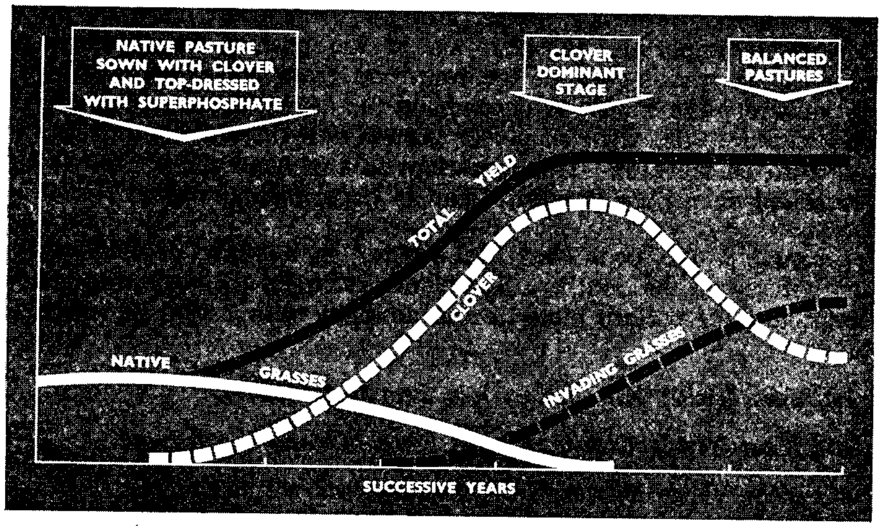


Fig. 1. Changes in Botanical Composition of Pasture Consequent upon Improvement of Soil Fertility.

Source: *Rural Research in CSIRO*, No. 6 (December, 1953), p. 7.

Although the replacement of native pasture by a clover dominant pasture is in itself a big advance there is still much to be achieved by introducing high-producing pasture grasses when the growth environment has been sufficiently improved. The grass-clover pasture has some important advantages when compared with the clover dominant pastures:

(i) The change to a grass pasture can result in a better winter feed supply. For example, at Canberra Willoughby[2] found that a pasture in which Wimmera Ryegrass was dominant accumulated

[2] W. M. Willoughby. "Some Factors Affecting Grass-Clover Relationships", *Australian Journal of Agricultural Research*, Vol. 5, No. 2 (1954), p. 178.

approximately 68 per cent of its growth for the season by mid-August, whereas a pasture in which Subterranean Clover was dominant produced only 40 per cent of its growth by the same date. Total yields of these particular plots were the same when measured in November.

Such an improvement in winter growth rate is important not only because the extra winter feed is so valuable but also because some decrease in production risks accompanies a shift in herbage production from spring to winter, when moisture conditions are more reliable.

(ii) Greater total yields of herbage and protein can be achieved with grassy pastures.

(iii) A vigorous grass component in a pasture gives greater botanical stability, particularly if the grass is a perennial.

-(iv) Certain livestock disorders are commonly associated with clover dominance, e.g., bloat, digestive disorders and poor breeding performance.

(v) The presence of a vigorous grass species ensures a fuller exploitation of the nitrogen-fixing capacity of legumes.

Clearly, an important consideration in the pasture development programme is the speeding-up of the transition from clover-dominance to a grassy pasture. The transition depends on the use made of superphosphate, which determines the vigor of clover growth and thereby controls the rate of soil nitrogen increase. This important role of superphosphate has been demonstrated on private properties and in experimental work.

For example, Anderson and McLachlan,[3] in a study of *Phalaris*-Sub-clover pastures on the Southern Tablelands recorded the following changes in composition of pasture plots treated annually with 2 cwt. of superphosphate:

1st Year Yield: *All species,* less than 6 cwt./acre.

2nd Year Yield: *Clover,* 55 cwt./acre—*Grass,* 8 cwt./acre.

4th Year Yield: *Clover,* 5 cwt./acre—*Grass* 42 cwt./acre.

(All yields are expressed on a dry matter basis.)

In a study of Wimmera Ryegrass and Sub-Clover at Canberra, Willoughby found that 7 cwt. of superphosphate/acre applied to a clover-dominant pasture during the years 1947-50 brought a change to grass-clover balance in this pasture, which was sown with 1 cwt. superphosphate per acre in 1942, and received no further topdressing until 1947. Other pasture plots, of the same history up to 1947 but given only 3 cwt. superphosphate/acre during the period 1947-50, were still clover dominant at the end of that period, that is, eight years after sowing.

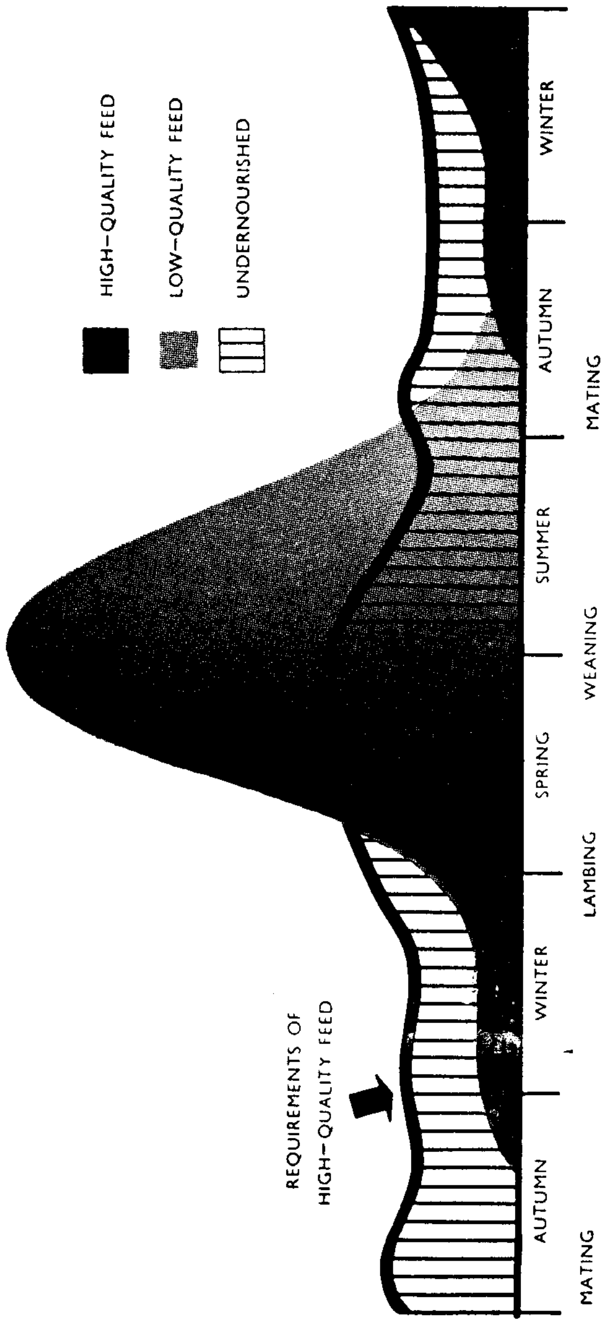
[3] A. J. Anderson and K. D. McLachlan, "Residual Effect of Phosphorus on Soil Fertility and Pasture Development on Acid Soils", *Australian Journal of Agricultural Research,* Vol. 2 (1951), pp. 377-400.

[4] W. H. Willoughby *op. cit.* p. 173.

Good Utilization of Herbage

One of the basic requirements for efficient animal production is that a high proportion of the herbage grown be actually consumed, preferably *in situ,* by the animals.

Fig. 2—The Pattern of Pasture Growth.



The curves show the average annual pattern of growth of improved pasture in southern Australia in relation to the feed requirements of breeding ewes throughout the year. More feed is required by the ewe during spring because of the demands of late pregnancy and of lactation.

Source: Rural Research in C.S.I.R.O., No. 15 (March, 1956), p. 23.

In practice it is difficult to avoid a good deal of wastage of pasture because of the great variations in growth rate throughout the year. It has been estimated[5] that as much as 80 per cent of the pasture grown is wasted,

[5] *Rural Research in CSIRO* No. 15 (March, 1956), p. 22.

in the case of sown pastures in south-eastern Australia. This is, perhaps, not surprising in view of the seasonal growth pattern depicted in Fig. 2.

Achievement of increased utilization depends very largely on lessening the effects of factors which are limiting stock numbers.[6] Stocking rates are restricted to the numbers which can be supported during the period of the annual cycle when feed availability is lowest. In the growth pattern illustrated in Fig. 2 it is the poor winter feed supply which presents difficulties when attempts are made to increase animal production. That similar limitations are imposed during winter months in a number of other districts in New South Wales is confirmed in some survey data obtained by Lloyd,[7] given in summary form in Fig. 3.

Production of more feed at a time of the year when there is already much wastage will not help the animal production programme. What is valuable is increased production at a time when there is need for more feed, to permit either increased stock numbers or more satisfactory husbandry of the existing flock or herd.

Even a little more feed in the critical winter period was found by Willoughby[8] to have a marked effect on animal production from *Phalaris*—Subterranean Clover pasture at Canberra. An increase from 50 to 750 lb. (dry matter) per acre in green feed availability in July increased liveweight gain by 2.9 lb. per sheep per week. (The actual increase was from —0.3 to + 2.6 lb.). Whereas, an increase from 1,700 to 4,870 lb. (dry matter) per acre in the amount of dry pasture available at the beginning of summer decreased liveweight loss by only 2 lb. in six weeks, or at the rate of 0.3 lb. per week.

In view of such variations in the effectiveness of increments in pasture production at different times of the year it is clearly important to consider whether or not superphosphate can be used to modify the pasture growth pattern. Reference has already been made to the fact that this fertiliser exerts a controlling influence on the rate of change from clover-dominance to grassy pastures and that such a change can effect a marked improvement in winter feed availability.

In addition, there is evidence that even in the case of pastures which have received substantial quantities of superphosphate, there is a decline in winter production if annual applications of superphosphate are omitted. For example, it is reported[9] from a study of an old Subterranean Clover-Ryegrass pasture is a 23-inch rainfall area near Clunes in Victoria that omission of annual topdressing resulted in a decline in total pasture production in each year of the study (1956 and 1957) and that *this was largely*

[6] Stock numbers exert a much stronger influence on the level of animal production from pasture than do systems of grazing management or the merit of individual animals. (See, for example, C. P. McMeekan, "Grazing Management and Animal Production", *Proceedings of the 7th International Grassland Congress* (*New Zealand*, 1956), pp. 146-56.)

[7] A. G. Lloyd, "Fodder Conservation in the Southern Tablelands Wool Industry (1)", this *Review*, Vol. 27, No. 1 (March, 1959), pp. 5-50.

[8] W. M. Willoughby, "Limitations to Animal Production Imposed by Seasonal Fluctuations in Pasture and by Management Procedures". *Australian Journal of Agricultural Research*, Vol. 10, No. 2 (March, 1959), p. 225.

[9] "The Cost of Saving on Super", *The Commonwealth Agriculturist*, Vol. 29, No. 1 (April, 1959), pp. 3-6. (Issued by Commonwealth Fertilisers and Chemicals Ltd., Melbourne.)

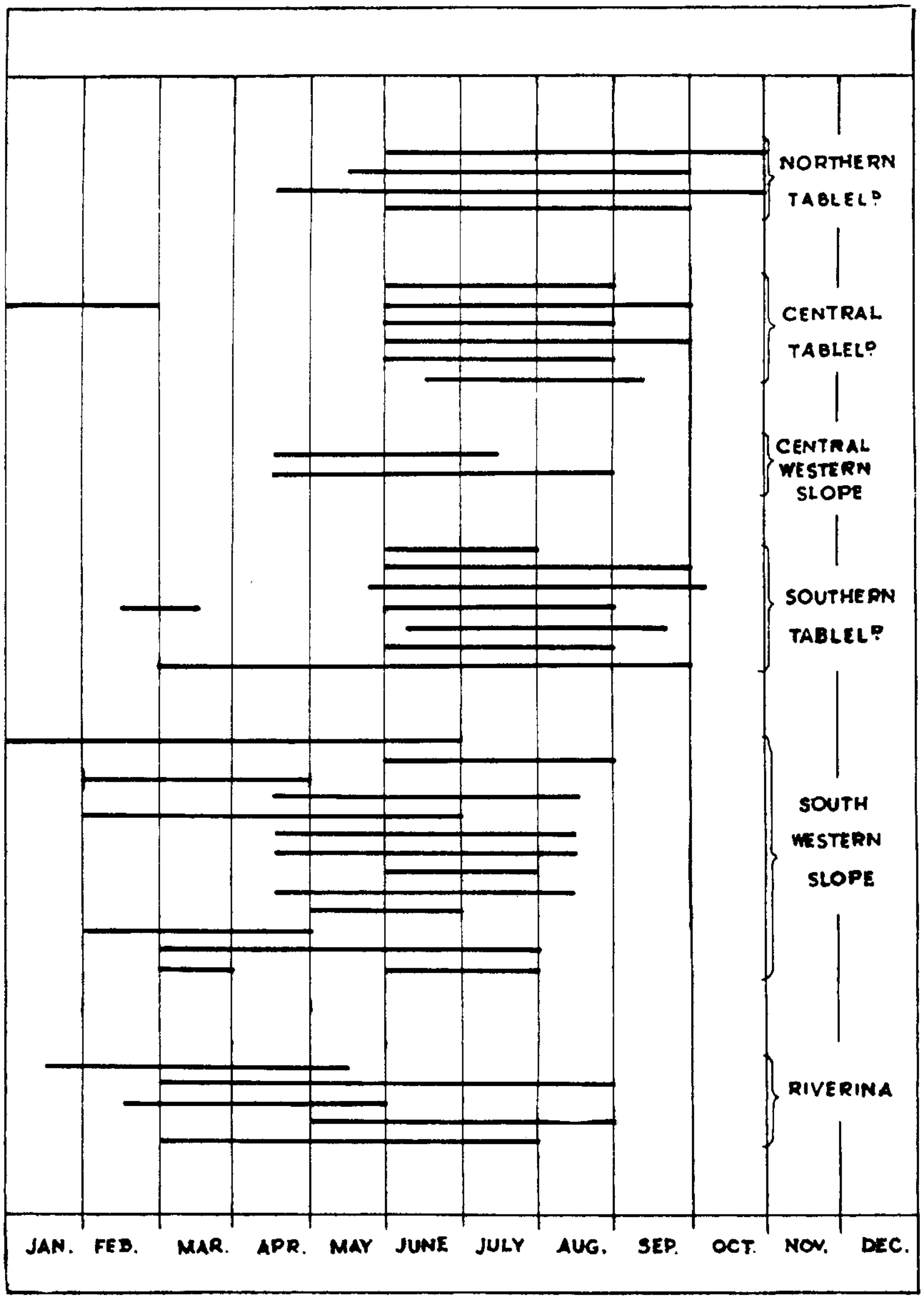


Fig. 3. Periods of Expected Feed Shortages—Estimates by 37 Graziers in Various Districts in New South Wales.

Source: A. G. Lloyd, "Fodder Conservation in the Southern Tablelands Wool Industry", this *Review*, Vol, 27, No. 1 (March, 1959), p. 25.

due to reduced production in the winter-early spring period. The particular pasture studied had previously received about 30 cwt. of superphosphate over twenty-five years.

Similarly, a report by Elliott and Karlovsky[10] in New Zealand shows that the main production penalty consequent upon discontinuance of annual topdressing is incurred during the winter-early spring period. Fig. 4, which refers to one of the soils studied, illustrates the need for annual applications. The annual treatment of 4 cwt. per acre shown in Fig. 4 has no general significance but it was found to be the annual treatment necessary to keep pasture production at about its highest point on that particular soil.

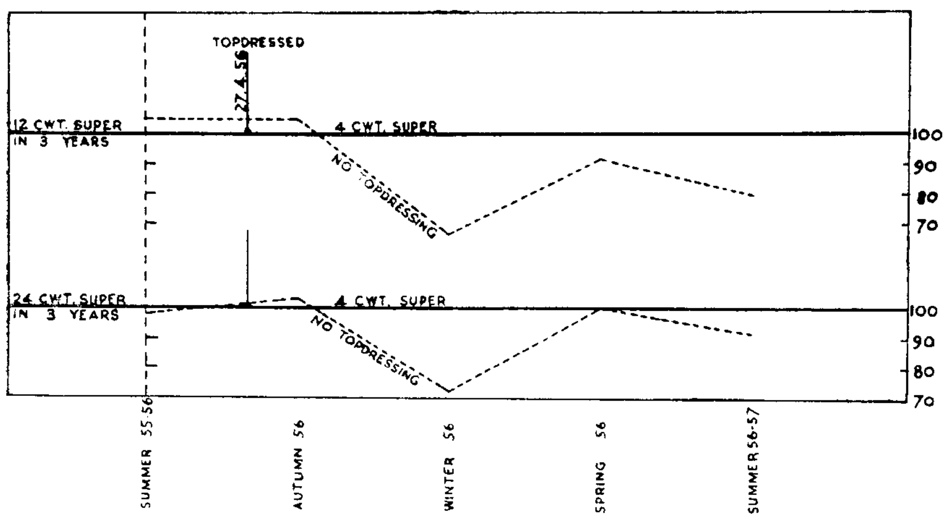


Fig. 4. The Decline in Pasture Production Following the Cessation of Topdressing on Horotiu (New Zealand) Sandy Loam.

—Topdressing continued at 4 cwt. per acre annually.

....Topdressing ceased.

Source: I. L. Elliott and J. Karlovsky, "The New Facts in Topdressing", *Proceedings of the Ruakura Farmers' Conference Week* (1957), p. 142.

Improvement of Soil Fertility

In the short term, changes in soil fertility are important in giving a higher yield and better seasonal distribution of herbage. The long-term improvement of fertility is of great importance to individual landholders and to the nation, because it is changing the productive capacity of many millions of acres which were initially of very low fertility. Much of the land formerly capable of providing only poor grazing is becoming moderately fertile and, in due course, will be suitable for land use based on the proper integration of cropping and animal production.

[10] I. L. Elliott and J. Karlovsky, "The New Facts in Topdressing", *Proceedings of the Ruakura Farmers Conference Week* (1957), p. 142. (Published by the New Zealand Department of Agriculture.)

Superphosphate plays a key role in determining the rate of such soil improvement. A comprehensive study of trends in fertility has been made by Donald and Williams[11] in the Crookwell area on the Southern Tablelands of New South Wales. They studied the fertility of 44 paddocks which ranged from unimproved pasture to land which had been under clover as long as 25 years and had received as much as 13 cwt. of superphosphate.

They found a close relationship between the amount of superphosphate added to the various paddocks and the increments in plant nutrients in the top 4 inches of soil. The increments *per cwt. of superphosphate applied* were:

	lb. per acre
Nitrogen	85
Phosphorus	10.3
Sulphur	13.4
Exchangeable Calcium	25.5
Exchangeable Potassium	6.5
Exchangeable Magnesium	5.2

In addition to these substantial improvements in chemical fertility, the physical properties of the soil, including the soil moisture relationships, were improved by the substantial accumulation of soil organic matter. Such an upward trend in fertility is probably occurring over millions of acres in Australia where nodulated clovers are being adequately topdressed with superphosphate. Of the phosphate which accumulates in pasture soils about half is in organic form and is, therefore, of no immediate value for plant growth. Much of this, however, would become available following cultivation for cropping.

3. EVALUATION OF SUPERPHOSPHATE TREATMENTS

In view of the long term nature of pasture programmes and the continuing benefits derived from superphosphate applications it is difficult to assess their full impact on production. The assessment is further complicated by the fact that the various facets of pasture development discussed above are all strongly influenced by this fertilizer. Indeed, each application affects the whole soil-plant-animal ecosystem and the full impact, and no doubt the full value, frequently cannot be assessed by using criteria from only one element of the ecosystem.

In some situations, where immediate aims are quite specific, evaluation of the effectiveness of treatments is not difficult. When superphosphate is being used to achieve a satisfactory establishment of pasture on poor soil the obvious criteria to use are numbers and nodulation of clover seedlings successfully established. The next objective in the programme would probably be to achieve the transition from clover dominance to grass-clover balance; in such circumstances the trend in botanical composition of the sward would be the chief criterion in evaluation of treatments.

[11] C. M. Donald and C. H. Williams, "Fertility and Productivity on a Granite Soil as Influenced by Subterranean Clover and Superphosphate". *Australian Journal of Agricultural Research,* Vol. 5 (1954), pp. 64-87. See also C. H. Williams and C. M. Donald, "Changes in Organic Matter and pH in a Podzolic Soil as Influenced by Subterranean Clover and Superphosphate", *Australian Journal of Agricultural Research, Vol.* 8 (1957), pp. 179-89.

In these two cases, although it is desirable that landholders should be given accurate guidance, precision may not be of critical importance from the economic point of view, provided the agronomic aims are achieved. Any superphosphate in excess of optimum applications for attainment of the immediate aims would be a small contribution to the building up of soil phosphate, which would at that stage be well below the optimum level.

When a pasture of the desired species composition has been developed, consequent upon a period of soil improvement, the objectives in using fertilizer will change and evaluation of treatments becomes more complex. At such a stage in the pasture programme (and many landholders have now reached this stage) the emphasis must swing to increasing animal production. In view of this, the important criteria will be the yield of herbage, seasonal growth pattern and the utilization of herbage by the grazing animals. So the study comes to embrace both pasture production and animal producion. The need for careful integration of these two aspects, in research and practice, is becoming increasingly appreciated and is aptly emphasized by Wallace[12]:

> "It cannot be too strongly emphasised that in a grassland farming system feed production and feed utilisation are not separate and unrelated parts of the process of animal production, as they usually are in, for instance, the pig and poultry industries, and as they tend to be in the beef and dairy industries of some overseas countries where stock are wintered indoors and where stall feeding is commonly practised. Under our grassland system they instead form sensitively interacting phases that must be brought into delicately integrated adjustment if maximum production is to be secured. At all times we must endeavour to graze and manage our stock so as to satisfy their immediate requirements, for, unless this is done, continued high levels of production cannot be expected. But we must at the same time always carefully control our grazing management procedures to ensure that neither the amount nor the quality of future pasture production is adversely affected."

To take total annual yield of herbage as the sole criterion in evaluation of pasture treatments would be valid only if livestock needs were equally well (or equally poorly) met at all times of the year. In endeavours to improve the agronomic and economic efficiency of superphosphate usage it is essential to pay special attention to the effect of fertilizer on growth during periods which are limiting animal production. The law of diminishing returns has been shown to apply to the relationship between feed availability and animal production[13]; increments in herbage production are very effective in increasing animal production if achieved at a time of feed shortage, less effective if obtained during a time of relatively good feed availability, and ineffective if occurring at a period when a surplus already exists.

There is little likelihood of any appreciable livestock data being obtained on the precise value of superphosphate treatments, as desirable as that may be, so information obtained from the pasture itself should include some measure of the magnitude of changes in feed availability at times of special importance in the husbandry programme (e.g., the feed supply for ewes in late pregnancy prior to early spring lambing, or for weaners).

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[12] L. R. Wallace, "Animal Production from Grassland—Present Problems and Future Needs". *The Australian Journal of Science,* Vol. 21, No. 6a (Feb. 1959), p. 167.

[13] W. M. Willoughby, *op. cit.,* p. 257.

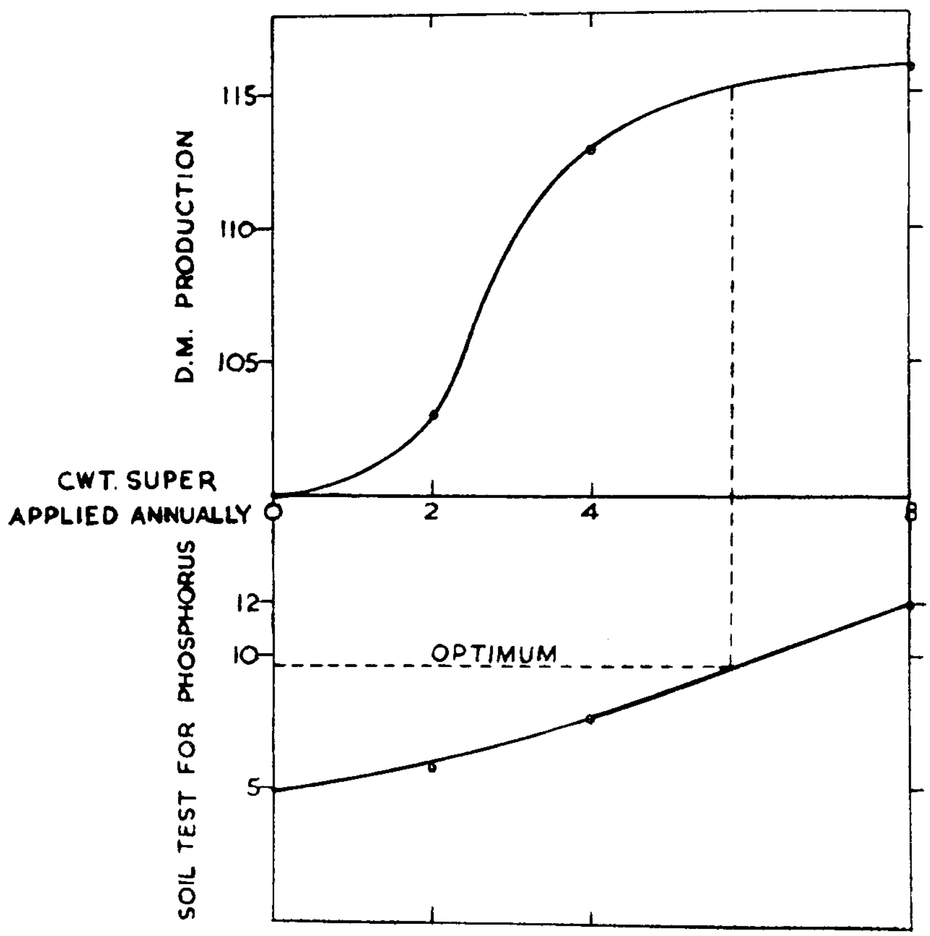

Fig. 5. Optimum Economic Soil Test for Phosphorus on Hamilton (New Zealand) Clay Loam.

Source: I. L. Elliott and J. Karlovsky, "The New Facts in Topdressing", *Proceedings of the Ruakura Farmers' Conference Week* (1957), p. 136.

Either total yield for the year or yield for a particular season could be used in the approach adopted by Elliott and Karlovsky[14] in their studies of some New Zealand soils. For selected soils they determined, among other things: (1) the optimum soil-test phosphorus levels, (2) the amounts of superphosphate needed to raise the soil-test phosphorus to optimum levels, and (3) annual superphosphate requirements for maintaining optimum test levels and intensive pasture production. Their findings for one soil are shown graphically in Fig. 5, which illustrates the concept of an optimum level of soil phosphate and the relationship between herbage production, fertilizer treatment and soil prosphate. The optimum point has been fixed in the graph by taking the phosphate level beyond which the average annual dry matter responses obtained from 1 cwt. superphosphate fell below 100 lb. per acre.

[14] I. L. Elliott and J. Karlovsky, *op. cit.*, p. 136.

As might be expected, the shape of the curves varied from soil to soil. The optimum values, however, were found to be somewhere in the vicinity of 10 for each of the three soils described in the report. Data for the three soils is summarized in Table 1.

TABLE 1

*Phosphate Data for Some New Zealand Soils**

Soil	Soil-Phosphorus Test Values		Superphosphate Requirements	
	Initial	Optimum	To Raise Test Values to Optimum†	For Maintenance
Hamilton Clay	3	10-12	20 cwt. per acre	2 cwt. per acre annually.
Ohaupo Silt	3	8-10	30 cwt. per acre	3 cwt. per acre annually.
Horotiu Sandy Loam ..	3	9-12	40 cwt. per acre	4 cwt. per acre annually.

* Derived from I. L. Elliott and J. Karlovsky, "The New Facts in Topdressing", *Proceedings of the Ruakura Farmers' Conference Week* (1957).

† In the trials these amounts of superphosphate were applied in equal annual applications over five years.

Availibility of this type of information for major soil types in a given area would form a sound basis for a soil testing and field advisory service and thereby permit a logical and accurate approach to superphosphate usage. Such an approach would give good protection against two practices which would be particularly unsound ; namely, the adoption of annual applications which would permit only slow progress toward the optimum soil phosphorus value, and, secondly, the adoption of maintenance treatments before the optimum had been reached. In regard to the latter it should be noted that it would be a mistake not to fully exploit that portion of the graph giving the most favourable input/output relationships and, further, that it would be almost as costly to maintain soil phosphorus at a sub-optimum level as it would be to maintain it at the optimum.

4. CONCLUSION

In studies which aim to give a more complete understanding of the effects and value of superphosphate applications it is essential to have carefully defined objectives and, as far as possible, use criteria in evaluation which will give information useful to persons engaged in economic and animal aspects of studies of pasture production and utilization.

The most important studies of superphosphate usage would seem to be those aimed at increasing the efficiency of animal production from pastures already moderately well developed. Such studies must be of a long-term nature and should be based on close co-operation between research workers in agronomy, animal production and economics.

However, without the information which would result from such long-term studies it is sometimes possible for a competent person to give useful, but limited, advice on how best to use a given quantity of superphosphate on a property. In such circumstances there must be careful consideration of such factors as the fertilizer history and botanical composition of the various paddocks, particular problems of livestock management, and the topography and aspect of different portions of the property. Obviously, the person formulating such advice would have to spend some time getting to know the property and this would severely limit the amount of advisory work conducted on this basis. Furthermore, even if such empirical decisions were well made, no account would be taken of the production consequences of an unwise decision by the landholder in determining (on the basis of the present financial circumstances) the total quantity of superphosphate to be used in the particular year.