
THE IMPORTANCE OF LEAF AREA AS A DETERMINANT OF YIELD IN PASTURES

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INTRODUCTION

It is seldom realized that nearly 95 per cent of the dry matter of plants is derived largely through the photosynthetic activity of their leaves, and that mineral nutrients obtained from the soil contribute directly, only to the remaining 5 per cent. Donald (1956) expressed the same idea, when after studying the effect of plant competition in pastures, he stated that if water and nutrients were in adequate supply, the ceiling yield would be determined by competition for light. Stated more simply, it means that the ultimate capacity for dry matter production depends on the degree to which plants can utilize the incoming light energy. The total amount of light energy available is the product of light intensity and light duration. The extent to which this light energy is utilized will, therefore, depend on the area of leaf displayed for light interception.

CONCEPT OF LEAF AREA INDEX

THE work of Watson (1947, 1952) was the first real advance leading to a clearer appreciation of this phenomenon. He claimed that variation in yield can be attributed mainly to changes in leaf area which can operate directly by altering the photosynthetic area and indirectly by changing the net assimilation rate. In advancing the concept of leaf area index he wrote as follows: "A comparison of the leaf area per plant of different species, is of little interest, for these must be highly dependent on the spacing of the plants, which varied in accordance with normal agricultural practice. The measure of leaf area which is relevant to the comparison of agricultural yields, that is, of the weights of different crops per unit area of land, is the leaf area per unit area of land, which it is proposed to call the leaf area index." Defined in this form, the concept of leaf area index, provides a

measure of the whole crop rather than of individual plants, an important distinction, which should be borne in mind, when undertaking studies on the physiology of field crops.

RELATIONSHIP BETWEEN LEAF AREA AND CROP YIELD

It seems reasonable to suggest at this stage, that other things being equal, the opportunity for increasing agricultural production, in general, lies in increasing the total annual photosynthesis per unit area of crop. This would depend on (1) leaf area (2) rate of photosynthesis and the length of the growing period (leaf efficiency). A measure of leaf efficiency is provided by the rate of increase of dry matter per unit area of leaf which is referred to as the net assimilation rate. Watson (1956) showed conclusively in his Rothamsted experiments on wheat, barley, sugar beet and potato, that of these factors, the main factor which influenced crop yield was leaf area. Increase in leaf area was accompanied by an increase in yield. The relationship between leaf area and dry weight yield was linear, except in the higher range, when owing to the mutual shading of the lower leaves, the net assimilation rate was depressed. Crop growth rate, therefore, increases slowly with increase of leaf area till it reaches a maximum and then falls. Thus it can be seen that leaf area has a direct bearing on dry weight yield. Cultural practices that are designed to increase agricultural yield, do so mainly by influencing leaf growth. Fertilizer applications and manurial practices also do the same.

LEAF AREA AND PASTURE GROWTH

THOUGH the importance of leaf area in crop production has been stressed for some time, only recently has it been applied to the study of pasture growth. The reasons warranting the estimation of leaf area in pasture communities, are obvious. Leaf growth, for example, directly governs the value of the sward for livestock. Further a number of species occur in close association in a sward, resulting in quite different distributions of foliage displayed for the interception of the incoming light energy. Frequent or intermittent defoliation of the sward either by the mower or by the grazing animal constantly alters the light environment in a sward.

Very few studies, however, have in fact been reported. Donald (1956), and Davidson and Philip (1956), both used the concept of leaf area index to correlate light status within the pasture and pasture growth. But perhaps the most significant contribution to an understanding of the relationship between leaf area and pasture yields was

the work by Brougham (1956) who reported the results of his investigations into the effect of intensity of defoliation on the regrowth of pasture. He reported that the height of defoliation markedly influenced the rate of regrowth. The stage at which 95 per cent of the incident light energy was intercepted and hence a maximum rate of regrowth attained, corresponded to a leaf area index of 5, and following defoliation to a height of 5 inches this was achieved approximately 4 days after cutting, whereas regrowth did not reach a maximum rate until 16 and 24 days following defoliation in pasture defoliated to 3 inches and 1 inch respectively. Beyond this point the rate of increase in leaf area and the increment in dry matter was maintained at a maximum rate. From the same experiment he calculated leaf efficiency indices for each sampling date as average daily herbage dry matter increment per area of leaf, and stated that the more intense the defoliation the lower was the initial leaf efficiency. However, a higher maximum leaf efficiency was obtained after intense defoliation.

Appadurai (1961) in a series of experiments conducted at Wye in England between 1958—61 to study the influence of a close (1 inch above ground level) versus a lax ($2\frac{1}{2}$ to 3 inches above ground level) defoliation on the performance of a perennial rye grass/white clover sward, observed that close defoliation, particularly in the early part of the season, gave considerably higher yields of herbage dry matter than lax defoliation. This did not hold true for the later part of the season. Close cutting increased herbage yields significantly by increasing the leaf area index of the sward at a time when environmental conditions were optimum for increased leaf efficiency. The results of an experiment conducted in the spring of 1961 are shown in Table I. Close cutting significantly outyielded lax cutting in total herbage production during the experimental period. The rate of increase of leaf area under close cutting followed the same pattern as the rate of increase of total herbage. The decline in leaf area index of the mixed herbage under lax cutting was attributed to a decline in the leaf area index of the grass component, following ear emergence. This resulted in reduced total yields under lax cutting. A highly significant regression of leaf area on herbage yield was obtained under close cutting confirming the linear relationship between leaf area and herbage yield referred to earlier (Figure 1). Unfortunately, no significant regression of leaf area on herbage yield could be established under lax cutting, in this experiment, though it was confirmed in earlier investigations. It seems probable that during certain developmental phases of growth, as for example ear emergence following lax cutting under the conditions of this experiment, the relationship may not hold true.

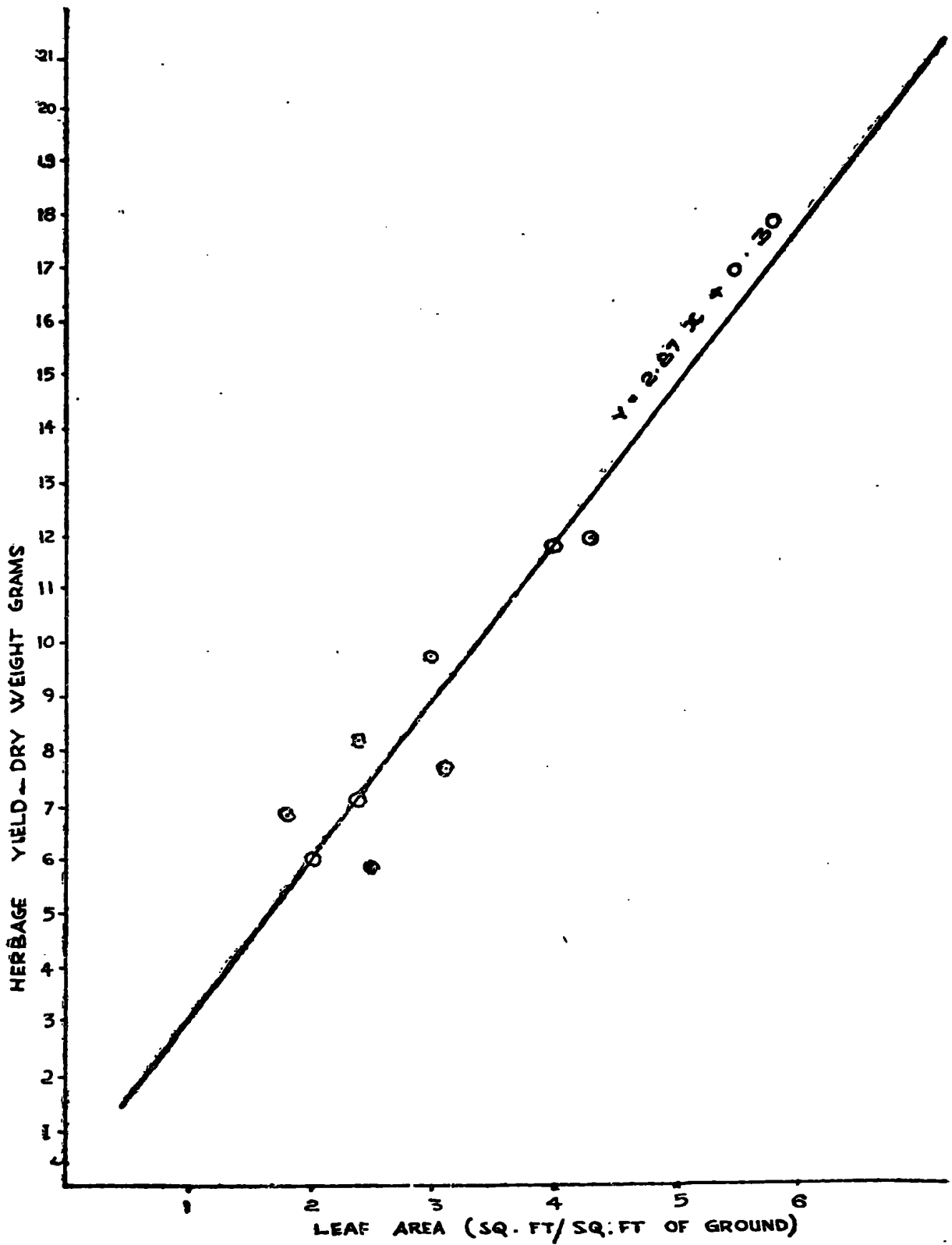


Fig. 1.—Relationship between Leaf Area and Herbage Yield under close cutting.

LEAF AREA AS A DETERMINANT OF YIELD IN PASTURES

TABLE 1

Changes in Leaf Area Index and Mean Dry Matter Yields of Mixed Herbage, Grass, and Clover estimated from $\frac{1}{2}$ sq. ft. Samples of Herbage.

	<i>Days of growth</i>								
	4	8	12	16	20	24	28	32	36
<i>Leaf area index</i>									
(1) <i>Mixed herbage</i>									
Lax cut	5.3	4.1	3.8	4.1	4.0	3.7	3.6	4.3	3.4
Close cut	1.8	2.5	2.4	2.4	3.1	3.0	4.3	5.4	5.6
(2) <i>Grass</i>									
Lax cut	4.6	3.2	2.9	2.6	3.1	2.6	2.5	2.6	1.9
Close cut	1.5	1.8	1.9	1.6	1.9	1.8	2.4	2.7	2.6
(3) <i>Clover</i>									
Lax cut	0.7	0.9	0.9	1.5	0.9	1.1	1.1	1.7	1.5
Close cut	0.3	0.7	0.5	0.8	1.2	1.2	1.9	2.7	3.0
<i>Yields—dry wt.g.</i>									
(1) <i>Mixed herbage</i>									
Lax cut	12.53	10.95	11.48	12.58	12.87	13.44	13.60	13.62	14.00
Close cut	6.80	5.75	7.04	8.14	7.56	9.69	11.91	16.17	16.93
(2) <i>Grass</i>									
Lax cut	10.77	9.11	9.25	9.14	10.81	10.70	10.75	9.58	9.63
Close cut	5.99	4.28	5.75	6.33	4.97	6.89	7.49	9.54	9.59
(3) <i>Clover</i>									
Lax cut	1.75	1.84	2.23	3.44	2.06	2.74	2.84	4.04	4.36
Close cut	0.81	1.47	1.45	1.80	2.58	2.80	4.41	6.62	7.33
<i>Each value is the mean of 3 replicates</i>									

Leaf efficiency indices $dy/dt/A$ (where dy/dt is the rate of increase of herbage yield and A is the total leaf area in sq. ft. per sq. ft. of ground) for each sampling date were obtained from values of dy/dt and A taken from smoothed curves of herbage yield and leaf area plotted against time. These smoothed curves give better estimates of yield and increment relationships than the raw data, and are devoid of the measurement errors that normally occur in such computations. Smoothed curves of herbage yield plotted against time are shown in Figure 2. Table 2 shows the leaf efficiency indices calculated for each sampling date.

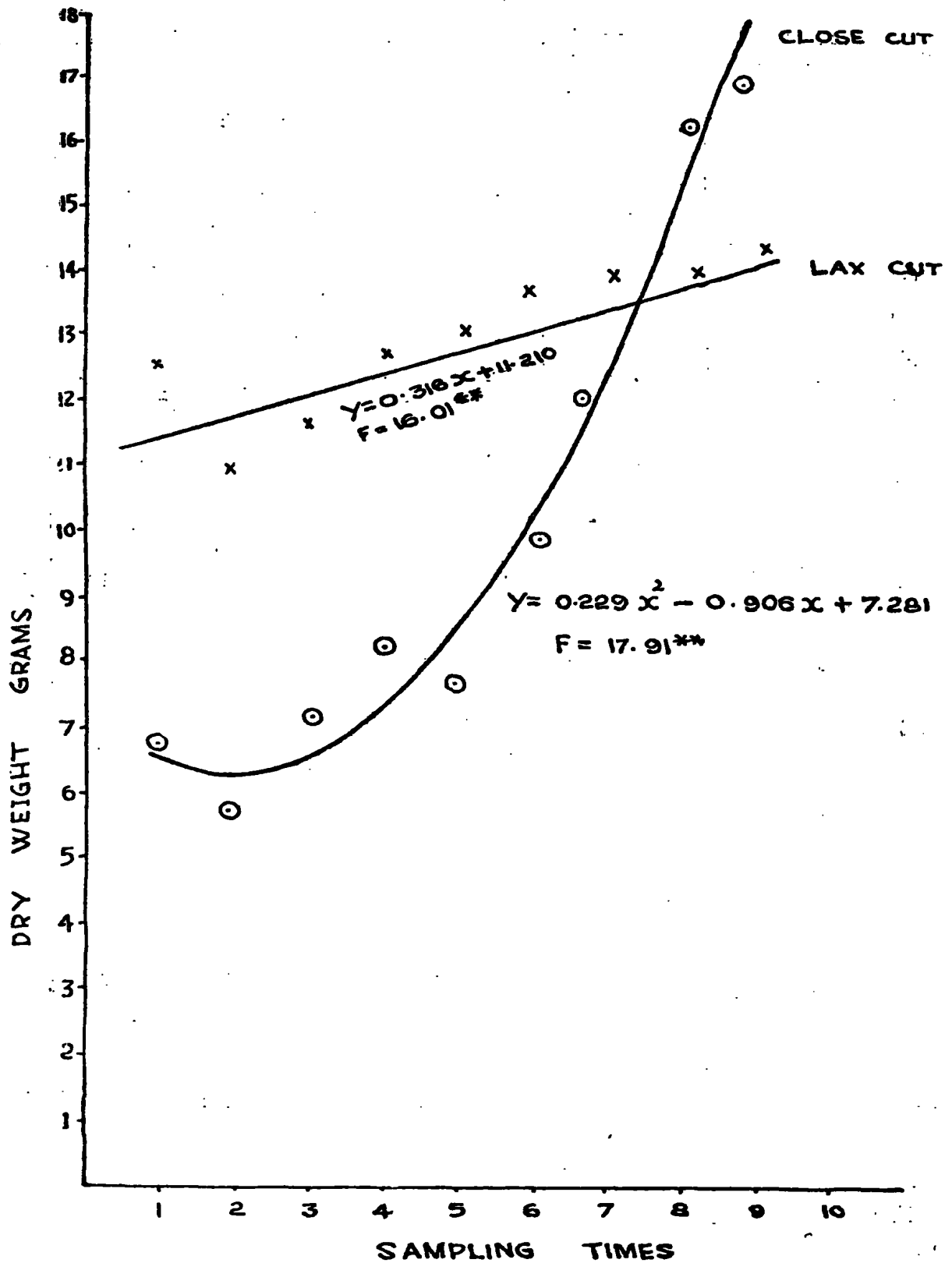


Fig. 2.—Smoothed Curves of Herbage Yield

LEAF AREA AS A DETERMINANT OF YIELD IN PASTURES

TABLE 2
Leaf Efficiency Indices

	<i>Days of growth</i>								
	4	8	12	16	20	24	28	32	36
<i>Lax cut</i> $dy/dt = 0.316$	0.069	0.071	0.073	0.075	0.078	0.080	0.083	0.086	0.089
<i>Close cut</i> $dy/dt = 0.458X$ -0.906	-0.210	0.004	0.204	0.357	0.461	0.521	0.550	0.558	0.553

Close cutting resulted in a higher maximum leaf efficiency compared to lax cutting, but the initial efficiency was lower. The higher leaf efficiency under close cutting may be attributed partly, to the fact that the foliage of close cut plants were at the proper age.

In the above studies no attempt was made to relate the leaf area index of the sward under the two cutting treatments to light interception. The work of Brougham (1957) and more recently Black (1959), however, suggests that the rate of growth of an undefoliated pasture is exponential till it attains the 'critical leaf area index', i.e., the point of complete light interception. During this phase, production falls short of that which the incoming light energy could sustain, since the leaf area is insufficient to utilize all the incoming light. Once the 'critical leaf area index' has been attained, any further increase in leaf area can no longer result in an increase in light absorption, and hence the relative growth rate falls. It is clear, therefore, that the aim of pasture management should be to attain as quickly as possible the optimum leaf area index, and maintain the pasture at this level. Such a form of management would ensure the maximum of herbage yields from a given unit of land. The concept of leaf area index, is thus of more than theoretical interest in studies of pasture production, and warrants further investigation especially under the high light intensities of the tropics.

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