CLIMATE, PASTURE PRODUCTION AND IRRIGATION

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INTRODUCTION

THE HISTORY of agriculture is mainly a record of man's struggle to adapt his farming to the climate in which he lived, and also of his efforts to become independent of that climate. It is no accident that many of the myths and legends of early man were very much concerned with events closely related to the farming year. Early meetings of a primitive version of Federated Farmers were possibly concerned more with ensuring that the sun returned after mid-winter, with the promise of spring, than with the barter value of the grain crop.

Although the very first attempts to live with the climate were possibly mainly confined to moving about in response to seasonal changes, man discovered relatively early in the world's history that in one very important respect he could markedly change the effect of the climate. We will probably never know when irrigation was first used, but it was certainly more than 5,000 and possibly as many as 9,000 years ago. The widespread use of irrigation in the arid centres of the world changed a great deal more than the farmer's method of farming-it changed the lives of everyone and laid the basis of civilization as we know it.

The problem of the changes which occur with the altered climate which accompanies irrigation is one which is still relevant to the farmer of today, and it is proposed to describe some of the changes which take place in the pattern of pasture production under irrigated as compared with dryland conditions.

CLIMATE

There are many factors which influence the seasonal pattern of pasture production-sward composition, management, fertilizer programme and soil fertility-but for the drier areas of Canterbury two of the major influences are climatic-temperature and rainfall.

Some climatic parameters for Winchmore are given in Table 1 and Fig. 1. The mean annual air temperature is 50.9°, with a range from 40.5" in July to 60.4" in January. Summer temperatures can be high, frequently exceeding 70". The highest maxiinum screen temperature recorded was 96.6" on January 19, 1956, and on this day Ashburton had the record New Zealand screen temperature of 101" F. There are 131 ground frosts in the year, and, of these, half are less than 5°, and only 2% are greater than 15". During the winter months there is a frost on three days out of four. Rainfall is reasonabiy well distributed from month to month : the average annual total is 30.3 in., and there is a tendency for seasonal totals to increase from winter through to autumn. There are 117 days of rain per year, half of which record less than 10 points and 70% of which are less than 25 points.

The effect of this uniform rainfall (most of which is received in light falls), and high summer temperatures on the soil moisture content is shown in Fig. 1. Soil moisture levels drop steadily from August through to January and have reached as low as an average of 7% in the latter month. At Winchmore, periods have been recorded during the summer of up to 56 consecutive days when the soil moisture has been below wilting point (10%). With decreasing temperatures, and hence decreasing evapotranspiration, soil moisture levels increase steadily from February through to May.

TABLE 1: CLIMATIC AND PASTURE

	No. of *Years*	*Jun.*	*Jul.*	*Aug.*	*Sep.*	*Oct.*	*Nov.*
Rainfall (in.)	18	**1.75**	**2.64**	**2.45**	**1.50**	**2.48**	**3.11**
Mean air temperature (°F)	18	41.6	40.5	42.8	47.4	51.6	54.7
Radiation (langleys/day)	7	136	143	226	345	482	607
NON-IRRIGATED							
Soil moisture, O-4 in. (%)	10	28.5	30.1	29.8	26.6	19.2	15.8
Mean 2 in. soil temp. ("F)	10	39.2	38.1	41.7	47.5	54.1	59.6
Pasture prod. (lb/ac/day)	10	5.0	4.2	5.3	20.9	31.7	23.0
IRRIGATED							
Soil moisture, O-4 in. (%)	10	34.1	34.1	33.6	29.9	26.4	27.4
Mean 2 in. soil temp. ("F)	10	39.3	38.0	41.9	47.4	54.0	58.8
Pasture prod. (lb/ac/day)	10	5.8	4.4	6.3	23.2	35.8	37.8

PASTURE PRODUCTION: NON-IRRIGATED

The seasonal pattern of non-irrigated light land pasture production is shown in Fig. 2 (a). During the winter months low soil temperatures ($<42°F$) are a limiting factor and pasture growth rates are low to negligible. Although soil moisture levels are dropping by September and October, they are still adequate for pasture growth which is controlled over these two months by the temperature, and which reaches a maximum for the year in October. From this month through to February, production steadily declines as a result of falling soil moisture. During early autumn (March, April) both soil temperature and soil moisture are, on the average, satisfactory for pasture growth : soil temperatures during autumn are the same as during the spring, and soil moisture levels are slightly higher during the autumn than the spring. There is a slight surge of production in recognition of this improved environment, but the pasture is badly affected by the previous three dry months, and there is little clover present. By late autumn (May), soil temperatures have dropped and daily production is less than 10 lb/acre. Under the conditions on the experimental area where these figures were obtained, the pasture is predominantly ryegrass and subterranean clover, with some cocksfoot, goosegrass and suckling clover. The bulk of the contribution from the

PRODUCTION DATA: WINCHMORE

Dec.	Jan.	Feb.	Mar.	Apr.	May	Total	Monthly Mean	Seasonal Means/Month Wi.	Sp.	Su.	Au.
2.79	2.58	2.36	3.07	2.66	2.87	30.26	2.52	2.28	2.36	2.58	2.87
57.8	60.4	60.3	56.5	51.7	45.9	—	50.9	41.6	51.2	59.5	51.4
642	605	476	354	255	165	4,436	370	168	478	574	258
14.6	12.7	14.0	18.6	20.6	26.6	—	21.4	29.5	20.5	13.8	21.9
64.2	66.8	65.5	60.2	52.7	45.2	—	52.9	39.7	53.7	65.5	52.7
16.1	12.5	11.9	15.2	13.3	8.4	—	14.0	4.8	25.2	13.5	12.3
26.6	25.8	26.2	27.5	28.6	31.7	—	29.3	33.9	27.9	26.2	29.3
62.3	64.5	63.6	59.4	52.5	44.9	—	52.2	39.7	53.4	63.5	52.3
40.1	43.0	40.2	29.5	20.3	10.1,	—	24.7	5.5	32.3	41.1	20.0

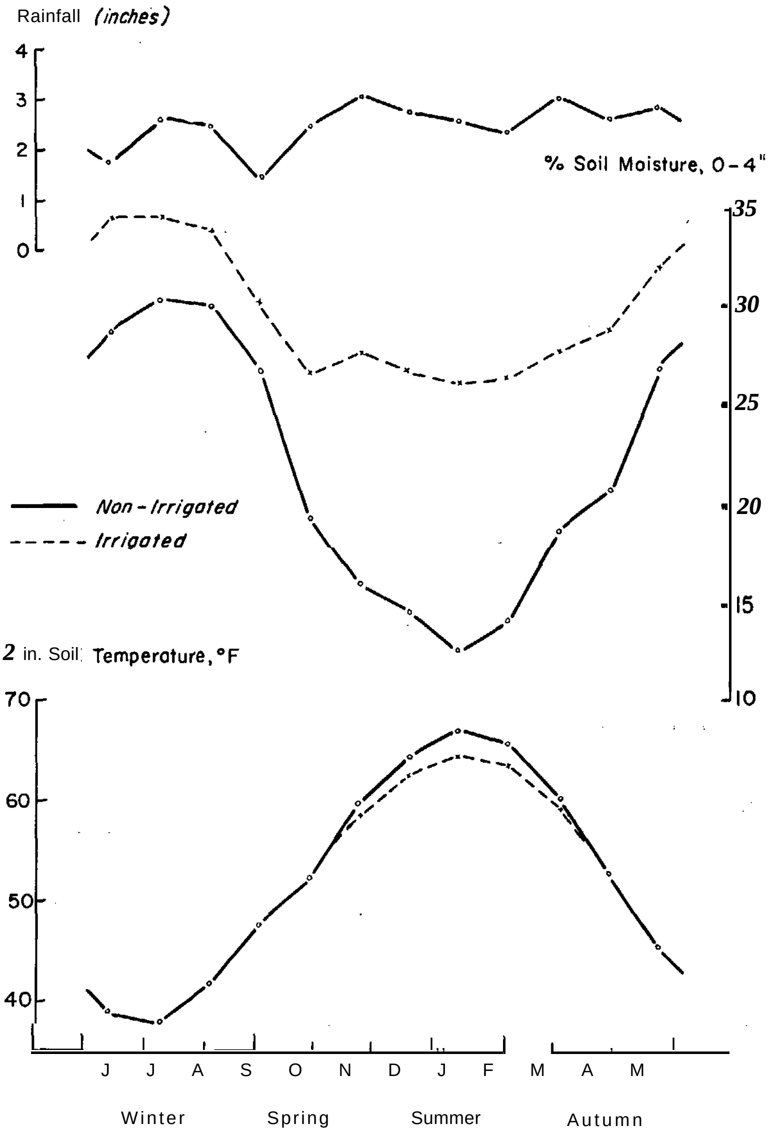

FIG. 1: *Climatological data, Winchmore.*

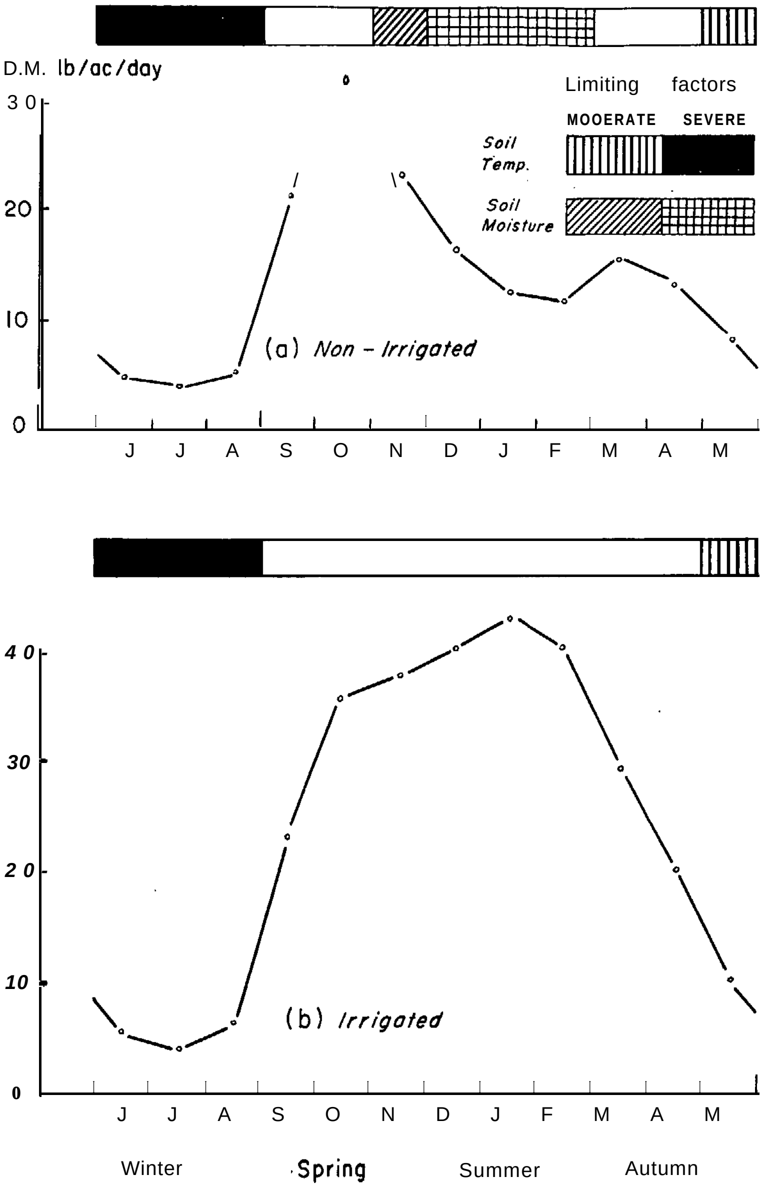

FIG. 2: *Irrigated and non-irrigated pasture production.*

subterranean clover occurs in October-November, with some additional growth in the autumn.

There appears to be little that the dryland farmer can do to increase production from pasture during those periods when either temperature or soil moisture is a severe limiting factor: he can, however, by pasture management and conservation, make maximum use of the spring and autumn periods when both these climatic parameters are satisfactory.

PASTURE PRODUCTION: IRRIGATED

With an adequate level of irrigation, the effect of climate can be altered-to a very large extent in the case of soil moisture, and to a lesser extent in the case of soil temperature (Fig. 1). The average monthly soil moisture for the year is increased from 21.4% to 29.3%, and the range of soil moisture during the growing season (September-April) is reduced from 13.9% to 4.1%. At no time during the year does the monthly soil moisture fall below 25%. Soil temperatures are lower by approximately 2°F during December, January and February. The effect of these changes on the seasonal pasture production is shown in Fig. 2(b).

Although winter and late autumn soil temperatures still exert a controlling influence on production at these times, for the remainder of the year irrigated pasture production, approximately follows the rise and fall of temperature. Peak production occurs in January, when soil temperatures are highest, and this is the month with the greatest difference between irrigated and non- irrigated production. It should be noted that there is, however, no direct relationship between irrigated pasture production and soil temperature-for a given temperature, production is considerably higher in the spring than in the autumn. This point has been noted by Anslow and Green (1967) when studying the seasonal growth of several irrigated pasture grasses. They suggest that response during a period of increasing temperature may differ from that during a period of declining temperature. The effect of solar radiation is another factor-this is considerably higher during the spring than the autumn (Table 1). (It is of interest to note that the amount of dry matter produced by an irrigated pasture in the period from the vernal equinox to the summer solstice is equal to that produced from the summer solstice to the autumnal equinox.)

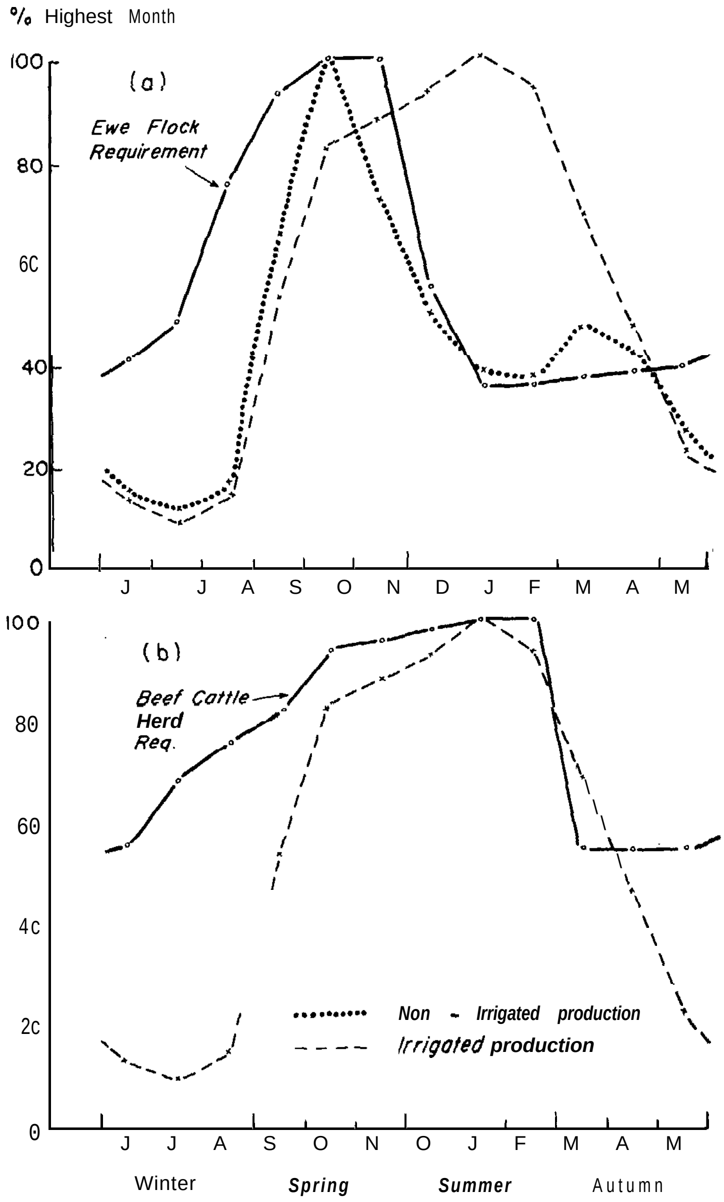

FIG. 3: *Stock requirements and pasture production.*

The irrigated sward on the area discussed is predominantly ryegrass/white clover, with some goosegrass, dogstail and weeds. The percentage contribution of the white clover reaches a peak in January-February.

STOCK FEED REQUIREMENTS

The dryland sheepfarmer has adapted his system of farming to the seasonal changes in pasture production: he lambs early to take advantage of the spring feed supply and hopes to draft the majority of his lambs before the drop in production in the summer.

The seasonal feed requirements for a standard eweflock (mid-point of lambing September 1 and weaning December 10) have been estimated by Coop (1965). If his figures for each month are expressed as a percentage of the requirement for the peak-demand months (October and November), Fig. 3(a) can be constructed. The feed requirement rises steadily from mid-winter through to late spring and falls off rapidly to the lowest demand in mid-summer. The dryland pasture production is compared with this in Fig. 3(a). (The pasture production curve is expressed each month as a percentage of the month of maximum production, October. It should be emphasized that the concern here is only with the *shapes* of these curves-particularly the time of the peaks.) It can be seen that the curve for dryland pasture production follows the same general pattern as that for feed requirement. If the pattern of irrigated production (expressed again as a percentage of the highest producing month—January) is now compared, the significance of the shift in production can be seen. The bulk of dry matter is produced during the summer, when, under a dryland management system, the feed requirement is at its lowest. The problem that faces the irrigating farmer is that of adjusting his farming system to this change in environment. It is no part of the present paper to discuss this further, and some of the possible alternatives have been listed by Stewart and Haslam (1964). Brief mention could be made. however, of two alternatives : the place of beef cattle and the possible utilization of potential summer productivity by cropping. The feed requirements of a beef cattle herd (Coop, 1965) are different from those of a ewe flock and give an indication of one wav in which the irrigated summer feed could be utilized-see Fig. 3(b).

The potential of cropping under irrigation has recently received renewed attention: one farm reported on b Whatman (1967) showed that a combination of fat lam6 production, cash cropping and small seeds under irrigation can reach a very high level of economic productivity.

It is, of course, possible with irrigation to extend the system of fat-lamb production by increasing the numbers of stock carried and allow for the later fattening of lambs. A demonstration unit managed along these lines has been operating at Winchmore for 19 years.

IRRIGATION

The main point which has been brought out so far is the shift in the period of maximum pasture production which occurs under irrigation. There are two further aspects of irrigation which should be mentioned. The first is the *reliability* of the monthly production which is obtained. This is greater under irrigated than non-irrigated conditions, particularly for the months of January and February. Over a period of ten years, January production has varied from 4 lb/ac/day to 36 lb/ac/day on non-irrigated plots, and from 33 lb/ac/day to 53 lb/ac/day under irrigation. Irrigated summer production has averaged 41 lb/ac/day over a ten-year period at Winchmore; at no time over this period has the monthly production for the three months dropped below 31 lb/ac/day. Under irrigation. therefore, the farmer can rely on a consistent level of production and plan his stock and farm operations accordingly.

The other important point has been implied but not directed stated. This is the increase in *total* production which occurs with irrigation. As far as soil moisture is concerned, a non-irrigated area is just that, not irrigated. “Irrigated”, however, can mean anything from one reluctant watering applied too late to do much good, to 6 or 7 well-planned irrigations applied (within the confining limits of the roster system) at a consistent deficit or soil moisture level. Results quoted so far for irrigated production have been obtained over a period of ten seasons with an average number of 8 irrigations per season. The frequency of irrigation has been based on watering when half the available moisture has been depleted and has deliberately been kept at a high level. It is important to determine how the total production would be affected by irrigating at different soil moisture, or deficit levels.

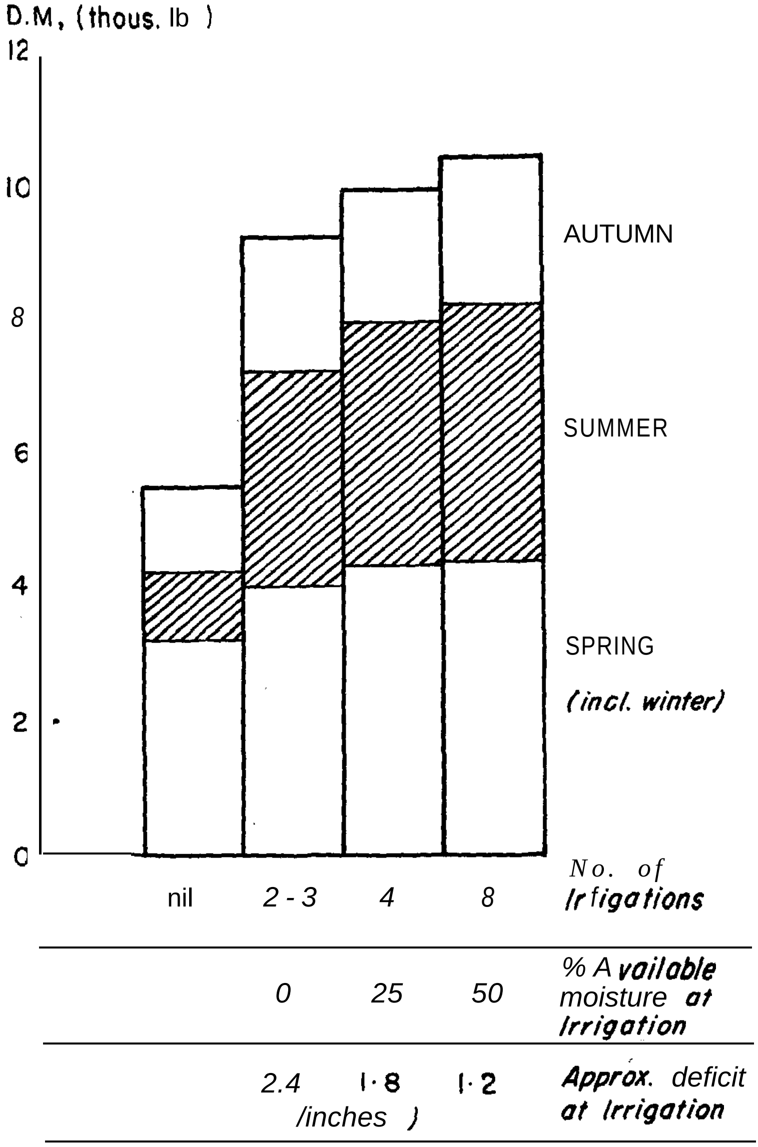

FIG. 4: *Effect of* irrigation frequency on annual pasture production.

Figure 4 summarizes the results obtained from seven years data from a frequency of irrigation experiment.

The treatments were :

(1) Non-irrigated.

(2) Irrigated when the soil moisture (0 to 4 in.) was at wilting point (nil available moisture).

(3) Irrigated when three-quarters of the available soil moisture had been depleted.

(4) Irrigated when one-half of the available soil moisture had been depleted.

The yield from the non-irrigated area (5,520 lb/acre) was just over half that of the heaviest irrigated treatment (10,380 lb/acre). By halving the number of irrigations (from 8 to 4) production dropped only about 4% for the year, and about the same for the critical summer period. Irrigating at wilting point (2 to 3 irrigations per year) gave a yield of 89% of the S-irrigation treatment, falling to 82% over the summer.

Whether or not an area was irrigated, therefore, was far more important than the actual level of irrigation applied. On the basis of the results shown in Fig. 4, about four irrigations per growing season would appear optimum, but it must be remembered that these results were obtained by irrigating on an accurately ‘determined soil moisture basis, which was not affected by the normal roster operating on the larger irrigation schemes. Work at Winchmore has shown, however, that it is possible to combine satisfactorily the roster with soil moisture conditions : a high level of pasture production could be maintained under this system with an average of approximately six irrigations during the growing season.

SUMMARY

Production from non-irrigated pasture in mid-Canterbury is severely limited during the summer months by a shortage of moisture in the soil. This restricts the bulk of the growth to the spring months-September, October and November-during which 45% of the year's production occurs. Production during the summer and autumn months is extremely variable: over a IO-year period, for example, February production ranged from no measurable production to 30 lb/ac/day.

On a well-irrigated pasture, the bulk of the growth is spread from October through to February, following approximately the seasonal rise and fall of temperature. Total production for the year is increased by 80 to 90%, and the reliability of the monthly production during the growing season is greatly increased.

If irrigation is to be other than a drought insurance for a dryland farming system, then the change in the seasonal distribution of pasture growth has to be recognized and taken into account. This is commented on by Stewart and Haslam (1964) who, when examining a group of high performance irrigated farms, concluded that one factor that they all had in common was that "they have adjusted their pattern of output from conventional dry land farming methods to suit the change in their environment conferred by irrigation".

In conclusion: one of the more important aspects of irrigation is that agriculture can, to a large extent, be freed from the limitations of climate, thereby making possible a greatly increased range of choice between a number of different farming alternatives.

ACKNOWLEDGEMENTS

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DISCUSSION

Disappointment was expressed by Brougham that the best growth rate was only 40 lb D.M./acre/day under irrigation over the normally dry period. This was very low when related to results from other districts where daily growth rates at this time are often 2 to 2½ times greater. In the Manawatu, for instance, a daily growth rate of under 100 lb/acre would be disappointing. With adequate water, much sunlight, satisfactory temperatures, and species such as ryegrass and white clover, there must surely be some other limiting factor. With only 2 to 4 irrigations, 90% of the yield of fully irrigated pasture had been obtained, which was a big improvement on no irrigation. In reply, Rickard said that there were several points to consider. The differences in production with numbers of irrigations were somewhat disappointing, but it was very difficult to pinpoint any particular cause such as soil or lack of nutrients. It could well be that the method of measurement used, the usual Department of Agriculture R.G.R. cutting technique, differs from other systems. It could therefore be difficult to compare the Winchmore results with, say, those in the Manawatu. When compared with trials elsewhere, measured with the same technique, the levels were largely what one would have expected.

When asked what difference in production there would be under dry-land conditions between ordinary pasture and lucerne pasture, Rickard stated that he had not done any work with lucerne and so had no figures available. Here Lobb commented that comparisons would be difficult as they would again depend on techniques—lucerne figures mainly related to crops cut for hay. However, he thought a figure of 6,000 to 8,000 lb D.M. per acre would be reasonable. He also commented that he thought the figures quoted by Brougham for the Manawatu suggested that 8 yearling cattle per acre should be carried at the peak period. Brougham replied that the figure would be very close to fact where dairyfarmers were carrying 1½ cows per acre. With large areas shut for silage and hay, the cows would often be grazing on only 50% of the farm. This would be the equivalent of 8 yearling cattle beasts per acre.