Spray Irrigation On Grasslands

P. F. NOBLE,
Research Officer, Rukuhia Soil Research Station, Hamilton.

THIS paper is essentially a summary of much that has already been said and written concerning spray irrigation on pasture, particularly from a dairying viewpoint. In addition certain economic espects will be discussed, and the problems which are still present both in the practical and experimental sides will be enumerated.

Irrigation of dairy lands has been suggested at various occasions during the last 25 years, but except for isolated cases of wild flooding nothing further was done. However, the dry summers in early post-war years raised the question of the value of high rainfall if it were not evenly distributed during the full production season, and as very little dairying land in the North Island lent itself to flood irrigation, the use of spray equipment was the logical line of investigation if irrigation were to be the answer to the problem. Apart from the fact that topography made the use of sprays and pipelines necessary, this method of irrigation has several advantages over the other methods viz., economy of water use, evenness of distribution, elimination of salting and puddling hazards, low initial costs. More work is required in its day to day operation and sources of water are not always to hand, but taking it by and large, it is a most satisfactory system.

Overseas work had been large confined to crops and lucerne with very little work done on permanent pastures, so when the work was started at Rukuhia in the summer of 1946-47 there was no real guide available.

Initially plots were treated with applications at the rate of ½in. and 1in. as near as possible at 10 day intervals, but after one season the ½in. applications were discarded as being impractical and from then on plots have received applications of 1in., 1½in. or 2in.

Equipment presented a problem as no commercial plant was available in New Zealand and in the first two seasons very primitive spray lines were in use. Subsequently they were replaced by more up-to-date and portable equipment which is still in use. Since then several different varieties of equipment of two main types have become available, and spray irrigation is now much less onerous.

The pastures in the experimental area were sown down in autumn 1946 on an area that had been under vegetable cultivation for some years. Irrigation was commenced in December 1946. That season was ideal for experimental work with a sustained dry spell. The control plots became very dry and as the pasture opened up, penny-royal and flat weeds become firmly established. The plots receiving ½in. applications of water showed reasonable growth, but were very inferior to those receiving 1in. of water. As a result, in the following season, the control plots were eliminated, production figures from nearby experimental plots providing records for comparison. Treatments were then made at 1in., 1½in. and later at 2in.

It has been found that 1½in. of water applied at 10 day intervals at a rate not exceeding 1in. in 3 hours, is a satisfactory mode of irrigation.

Two inch applications under sheep management on Hamilton clay gave no apparent increase over 1½in. and unless otherwise stated, production figures from experimental plots are those receiving 1½in. water applications. Figures relating to production for the four years, 1948-1952 are tabulated below:—

TABLE I.

	1948-49	1949-50	*1950-51	1951-52
Irrigated Production (lb. D.M./acre)	14900	14215	11560	11830
Unirrigated	12360	12930	8030	9700
% Increase with Irrigation	20%	10%	45%	22%

* 1in. applications

The mean of percentage increase in production is 25% which was also roughly the figure obtained in the first two years exploratory work (2). Thus we can safely say that over six years spray irrigation of pastures has meant an increase of 25% in D.M. production. From records maintained at the Station for the years 1946-49 inclusive there is ample evidence that sheep grazing hours as a measure of production indicate the same trends between treatments as does the mower but actual gains are greater. Normally mowing shows greater returns than grazing (5) so it is quite likely that sheep management with resultant close grazing and subsequent close cutting is not giving a true indication of absolute production under irrigation.

The percentage increases in Table 1 became somewhat different if we consider the figures from the seasonal aspect:—

TABLE II.

	1948-49	1949-50	1950-51	1951-52
Irrigation Period	16/12/48-12/4/49	27/12/49-18/4/50	21/12/50-27/4/51	31/12/51 24/4/52
Irrigated Production (lb. D.M./acre)	7000	4600	5200	3990
Unirrigated	3600	1850	2150	2120
Increase %	95	140	140	85

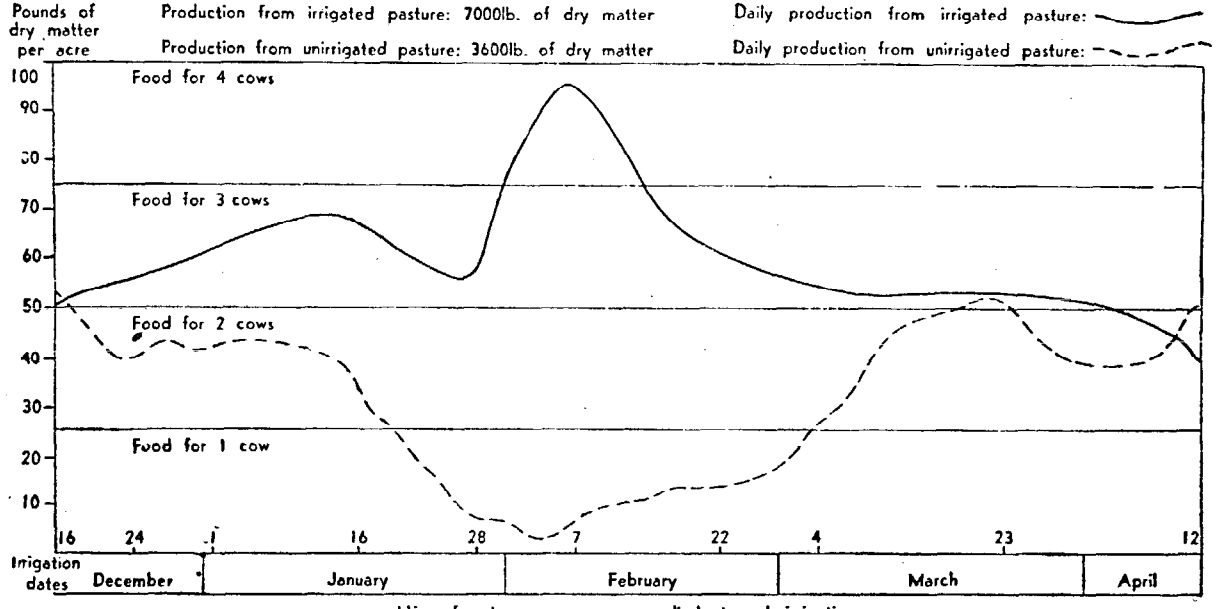
Mean increase 120%.

These figures show that over four years during a period of 3-4 months in the irrigation season D.M. production is increased by an average of 120%. However, these figures in themselves do not give the full story. References to Fig. 1 (1948-49) shows that irrigated production peaked in February, then declined steadily and ultimately fell away considerably. This general pattern of irrigation production has occurred several times.

Fig. (2) (1950-51) indicates from the parallel nature of the curves, a common dependency on rainfall and hence lack of adequate soil moisture in the irrigated area.

An important aspect of any irrigation work is the quantity and availability of soil moisture together with an appreciation of the requirements for growth with its associated evapo-transpiration. Studies on soil moistures on the experimental plots indicated that under drought conditions soil moisture in the top 4 inches can be at or near wilting point while in the next four inches there is sufficient soil moisture to maintain reasonable plant growth. However, it was apparently not available to the plant roots. Penman at Rothamstead (4) has assumed that maximum growth occurs when there is maximum transpiration which in turn occurs when the soil is at or near field capacity. This is of course dependent on atmospheric conditions favourably disposed for evaporation. Under these conditions potential transpiration losses from a grass covered surface can be deduced for various times of the year from figures obtained for evaporation from a free water surface. In summer months the potential loss from pasture on soil at or near field capacity is approximately 0.8 of the loss from a free water surface. If the losses are not of that order then maximum growth is not being obtained. Taking the moisture deficit as the amount of water expressed as inches required to restore

Effect of Irrigation on Pasture Growth in Summer—December 16, 1948, to April 4, 1949



1½in. of water per acre was applied at each irrigation

Fig 1.

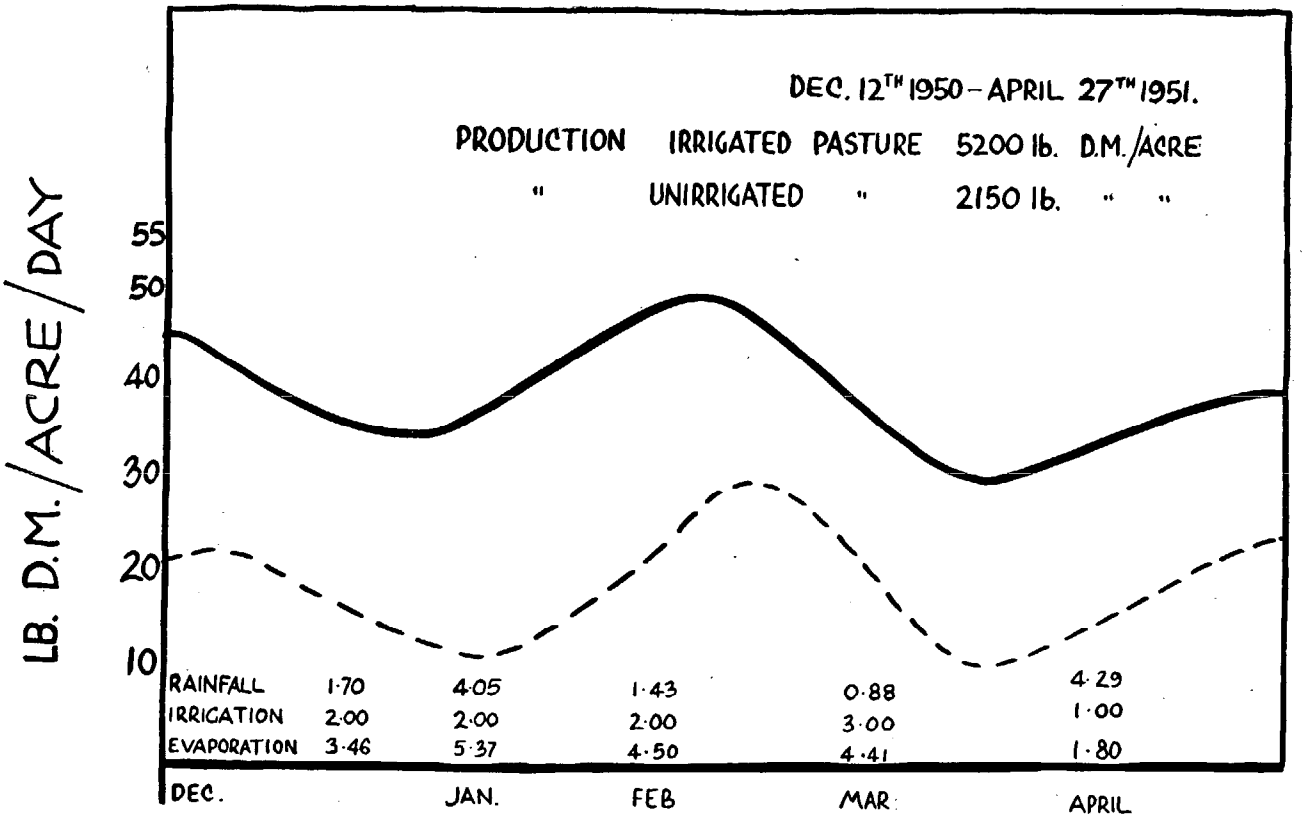

DEC. 12TH 1950 – APRIL 27TH 1951.
PRODUCTION IRRIGATED PASTURE 5200 lb. D.M./ACRE
" UNIRRIGATED " 2150 lb. " "
LB. D.M./ACRE/DAY
55
50
40
30
20
10
RAINFALL 1·70 4·05 1·43 0·88 4·29
IRRIGATION 2·00 2·00 2·00 3·00 1·00
EVAPORATION 3·46 5·37 4·50 4·41 1·80
DEC.
JAN.
FEB
MAR
APRIL

Fig II.

a certain level of soil to field capacity we can arrive at a reliable numerical expression to indicate the condition of the soil. Apart from losses in transpiration and evaporation at the surface the deficit is increased by downward movement of water beyond the root zone, and also by evaporation of water from the sprays before it is actually in contact with the soil. This latter figure can be estimated as approximately 10%.

For the four years detailed in Table I the excess of precipitation plus irrigation over open water evaporation for the four months December-March were respectively 6.5, 4.1, -2.9 and 3.2. These figures, although not expressing the actual moisture deficit do indicate relative levels of soil moisture and it is interesting to note that the year 1948-49 with the highest moisture level has given greatest production. During that season the moisture level in the root zone gradually declined from about 80% available moisture to about 50%. This decline was not regular, periodical troughs occurring near irrigation time. The following year the moisture content was substantially lower averaging 40% and production correspondingly decreased.

Further confirmation of this high moisture requirement was given by results from sighter plots in which the water applications were so arranged that two plots were rewatered to field capacity after the moisture level in the top 4 inches dropped to 75% available moisture, two more rewatered at 50% and two more at 25%. The difference in production between the high and low level was of the order of 150% and between the high and medium of the order of 30%.

I think there can be no doubt that a high moisture level, almost field capacity, is required for optimum growth, but whether or not this can be achieved economically is another point. We must also consider the danger too, when a high moisture level is maintained of losing a considerable amount of water in downward movement beyond the root zone. When water is not over plentiful and is costly to pump this loss must be regarded as serious. Before moving off the subject of soil moisture it is interesting to note that additional rainfall can help irrigated pastures considerably, whereas the effect on unirrigated areas in dry seasons is of very short duration.

Pasture composition and quality is of course of fundamental importance in any study on grasslands, and with irrigation as an aid to summer productions by no means the least advantage is the improvement which takes place in a pasture. For best results the logical thing is to irrigate best available pastures. If this is done strong growth of the grasses and clovers during spring and summer thickens the sward, eliminates weeds, and almost entirely prevents their re-establishment. The summer growth, although lush, is mature and does not present the hazards of the spring flush. Pastures that are not of high quality will improve under irrigation, with gradual elimination of weeds, and, with good management, will give greatly increased production. Some species, such as browntop and paspalum normally would not be economic propositions for irrigation. If good pastures are not available, the best practice is of course to plough and sow down new pasture. Preliminary work is now being carried out in the investigation of the effects or irrigation on special purpose pastures and it is quite likely that in this field greater yields will be obtained.

Up to the present year the manurial treatment of the irrigation plots has been serpentine super at 3cwt. per acre and lime initially at 1 ton/acre and subsequently at 10 cwt./acre. This high figure has been to offset possible leaching. Ammonium sulphate at 6 cwt./acre applied three times per year gave no apparent overall increases, but further consideration of the figures shows that a slight increase occurs after the autumn application, which may possibly be of some importance. Morgan (3) at Werribee has done considerable work on

manurial applications to irrigated pastures and in his particular case found that superphosphate applications were the only ones of real importance. A variety of super applications have this year been made on irrigated plots and information of immediate importance may be derived from these trials.

The temperature of the soil under lush pasture is considerably lower than in bare soil or sparse pasture—up to 13F. degrees difference has been recorded but usually 6 or 7 degrees is the difference. This lower surface temperature aids soil moisture by condensation of water moving upwards in the vapour phase and also considerably by condensation of the moisture in the air. In plots irrigated to the the stage at which growth was quite strong and then left unwatered for nearly four weeks in dry weather, moisture in the top four inches at the end of that time was still adequate for continued growth.

A study of the production pattern in Fig. I shows a marked peaking in February followed by gradual decline and ultimately a marked falling away. This pattern is not isolated and records shows that actual winter production from irrigated plots is slightly lower than from control plots. The peak is probably due to a favourable combination of soil moisture and soil temperatures, the slow decline indicating departure from the optimum in these conditions and the continued drop may be due to a more rapid lowering of grass minimum temperatures together with some nutrient effect. Irrigated pastures although having the benefit from high nitrogen level may not get the sudden boost which autumn rains give to other pastures, and hence do not approach the winter in a vigorous state. The slight increases from autumn applications of ammonium sulphate seem to indicate a minor nitrogen lack. This applies largely to sheep pastures because dairy farmers report excellent autumn saved pastures on irrigated areas. In another case of a farm irrigated to about 60% of its area, and hence of necessity constantly grazed and more nearly approaching sheep lands (from the irrigation viewpoint) this same winter decline has been experienced.

Interim recommendations based on the experimental results at the Station are for irrigation applications of 1½in. every 10 days applied at the rate of 1in. in three hours, an irrigated acre for every 5-6 cows, or alternatively 10-15% of the farm area to be irrigated, and the irrigated pasture to be fed in breaks grazed evenly, but not too severely. Two to three hours' grazing per day should be sufficient for dairy herds. In the light of present knowledge and costs, this arrangement appears to be satisfactory, but if the pasture is well established the rate of application could be stepped up without much fear of puddling or runoff. This increased rate would facilitate a somewhat heavier application if required, provided always that sufficient water is available.

As this experimental work was initiated with the idea of determining whether or not spray irrigation could be regarded as an economic aid to dairy production, it would be wise at this stage to study returns and how these are influenced by supplemental watering, and the cost of applying this water. It must be realised that an investigation of this nature is somewhat difficult because of the influences affecting production which are anything but static.

Two contributions in the field of economics have been made, one covering two years' irrigation during seasons with high production and well distributed rainfall, the other from a year in which very dry conditions persisted until late in the autumn. In the first case, a survey, which was only of a preliminary nature, was made. However the number of farms considered was actually only a small proportion of the total number using irrigation, and the results therefore cannot be regarded as statistically reliable. Nevertheless it does indicate certain tendencies and doubts about the efficacy or irrigation which emphasise the need for investigation to be conducted into additional aspects of irrigation.

In this particular survey figures for two years prior to irrigation were compared with those for two years under irrigation, and as a further comparison they were compared with factory figures in order to provide some reference level.

The figures used were total production for the season, production during the summer-autumn months January to May, these figures as a percentage of the total, and the January-May factory production expressed as a percentage.

By taking these seasonal figures as a percentage of the total production, increases due to general farm improvement cannot confuse the issue and variations can then be ascribed to irrigation and/or climatic conditions.

However, in all these comparisons there were only very slight gains evident during the irrigation season.

Briefly, therefore, in the years concerned, taking the value of butterfat at 3/- lb. and assuming that all the increases during the period were attributable to irrigation, then irrigation merely paid its way. This takes into account operating costs, maintenance, interest on capital and tax remission, but does not include labour, which is extremely hard to estimate and is usually eliminated. This statement of accounts taken at face value presents a rather gloomy picture for irrigation. However, there are several points which must be considered before we can get the true perspective. It has already been mentioned that the survey covered very few farms, and that the two seasons under irrigation were ones of natural high production. Actually they were record years for dairy producers. It must also be noted that the herds were all early calvers and correspondingly peaked much earlier. Nevertheless, in spite of this early peak, the four farms under survey showed a mean of just under 40% production for January-May. This gave absolute figures of 8000-14,500 lb. fat in that time. A severe drought could easily reduce these figures by 20%, a loss which could be avoided by use of the irrigation plants as installed. With herds calving later, the production likely to be saved would be increased.

Annett (1) has presented some interesting figures arising from the irrigation of his farm at Matangi in the summer and autumn of 1949-50. That summer was quite dry, and as his plant was installed quite late in the season, he was not able to irrigate prior to February. Heavy rains, amounting to 4½in., falling in the first fortnight in February no doubt reduced the moisture deficit considerably and enabled the irrigation to be beneficial almost immediately in spite of a late start in a dry season. On the basis of 20 years' records, Annett had calculated production of the order of 19000lb., taking the climate for that year into consideration. However, the figure reached was 21,000lb., giving an increase of 2,000lb. due to irrigation in three months. In support of this claim, figures were given comparing returns from the Matangi group and the irrigated farm, and also comparing the duration of lactation. On all counts the benefits from irrigation were readily apparent. In this case, in comparison with the survey above, the returns from this first abbreviated season were almost sufficient to pay for the installation.

However, the idea of preventing losses, although quite sound economically, is somewhat negative, and if droughts occur infrequently an irrigation plant could perhaps be regarded as an over costly insurance policy. It is therefore necessary, in order to obtain a true appreciation of irrigation, to evaluate the many indirect advantages which result from the correct application of irrigation on grasslands and the sound management of the resultant pastures.

One of the indirect advantages of irrigation which comes to mind readily in the saving of ensilage. This fodder can be eliminated entirely or kept to supplement winter feeding. The expense and

tedium of growing crops for summer feed can also be avoided if irrigation is available on a farm. It is difficult to assess the actual monetary values of such economies on a farm, and as labour has been discounted up to the present in costing of irrigation, this item could not be included in arriving at any estimated saving.

Other items, such as the long term improvement of pastures, particularly if the water supply on the farm enabled the rotation of areas for irrigation, and the availability of water for sowing and manuring at convenient times come in on the credit side of irrigation. If autumn-saved pastures on irrigated areas are as good as reported, they, too, would come in to this category.

An advantage which is more definite and more easily evaluated is in the case of a farm which by virtue of its location and topography customarily dries up considerably in a mild dry spell. Carrying capacity is virtually limited by this summer minimum, and the use of irrigation under these circumstances would enable a farmer to carry more stock. Apart from this, some farmers have already found that they can run more calves.

So much for the pasture itself. Other problems which remain to be solved and probably the most pressing are concerned with the grazing animal and its metabolism.

What is the nutrient value of irrigated pasture, and what is the optimum amount for a milking cow?

What are the relative amounts of this intake going into increased body weight and butterfat production?

Is irrigation beneficial in fat stock farming?

Another important question is whether or not there is any carry-over effect, i.e., does grazing irrigated pastures in summer and autumn give the cow a good start after calving, and what is the effect on the calf?

And of course the most important problem of all—can irrigated pastures help to give an actual increase in production per cow?

If the Animal Research Stations can give answers to these problems, particularly in regard to requirements, it would help the agronomist to determine, for example, if a smaller area of special purpose grasses irrigated to a high level of soil moisture would be the right approach to the spray irrigation of grasslands.

ACKNOWLEDGMENTS:

I wish to express thanks to Mr. J. Millar, Agricultural Economist, Hamilton, for permission to use unpublished data from his preliminary survey on irrigation economics.

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Discussion

Mr. WATERS: What is the winter production from irrigated pastures?

Mr. NOBLE: The winter production from pastures that were irrigated in the summer appears to depend on management. With sheep pastures and constantly grazed dairy pastures there appears to be a slight decline but with properly managed dairy pastures, autumn-saved pasture for winter use appears to be excellent.

Mr. KNOWLES: When should irrigated pasture be fed?

Mr. NOBLE: The practice is to feed irrigated pasture for 2 hours after the morning milking and for an hour in the afternoon.

Mr. CANDY: The benefit from irrigation depends greatly on the soil type. I doubt if the response on my farm would justify the capitalisation of about £40 per acre.

Mr. NOBLE: £30 per acre would probably be nearer the figure.

Dr. McMEEKAN: I feel that the 2 tables presented do not tell the full story. If 10 per cent. of the farm is irrigated there is a 12 per cent. increase in feed supply over the whole farm. It would be difficult to show the farmer from these figures, the value of the practice.

Mr. NOBLE: The point about the 12 per cent. increase is that it is available in the form of lush feed when it is most needed.

Mr. SMALLFIELD: One difficulty is that we lack the type of pasture that would respond to irrigation. At Winchmore, the ryegrass in December fails to respond. Irrigation is used there to provide winter feed. We should be able to find a pasture to exploit irrigation.

Mr. A. A. JOHNSTONE: One field irrigated for 2 months grew flatweeds on the high points. Is there any transference of fertility due to irrigation? Would it not be better to irrigate crops rather than pasture?

Mr. NOBLE: In my experience on rolling or flat country there has been no transference of fertility due to the topography. The irrigation of fodder crops is certainly a possibility but at this stage it would be difficult to say whether it would be advantageous.

Mr. A. G. WOOD: Were there any town milk supply farms in your survey?

Mr. NOBLE: No.