DESIGNING CROPPING TIMETABLES FOR IRRIGATION FARMING

D. B. Bishop
Kimihia Research Centre
Wrightson N.M.A. Ltd
P.O. Box 939
Christchurch

ABSTRACT

Irrigation of arable land has stimulated both the expansion and intensification of grain and seed crop production. This paper reviews current knowledge on the water requirements of the more common crops grown in Canterbury. An attempt is made at defining the most critical stages of growth where irrigation may contribute most to yield. Either water supply or irrigation plant are often limited, and priorities in water allocation are suggested. The results of preliminary trial work investigating the role of irrigation in the development of cereal high yield systems is presented.

INTRODUCTION

In Canterbury, irrigation has had two main effects. Firstly, on light soils in areas of low summer rainfall, irrigation has often made cropping possible for the first time. In other situations it has resulted in a shift from winter sown crops to spring sown crops, allowing better utilisation of land for winter feeding of livestock. The second major effect of irrigation has been in traditional cropping regions where satisfactory yields are possible in most years without irrigation. As well as increasing yields of existing crops, irrigation has allowed for the production of more specialist high return crops such as vegetables. As an insurance policy, irrigation has made cropping a much more reliable practice. In this paper I am concerned with irrigation in traditional cropping areas, although some reference will be made to arid areas.

The majority of techniques developed as aids to irrigation planning, are concerned with soil water deficits. Far less work has been done on plant water deficits. Kramer (1963) stated that measurements of soil water content or soil water potential were not sufficient to determine the effects of water supply on plant processes and yields. He indicated that more direct relationships were likely to exist between plant water status and the growth and yield of plants. In a later publication Kramer (1969) further stated that plant growth is controlled directly by plant water stress and only indirectly by soil and atmospheric water stress. Therefore, I think we must look at the plant itself as a prime indicator of when to irrigate, rather than just the moisture status of the soil.

A water shortage at any growth stage is likely to decrease vegetative growth. However, this need not result in a decrease in yield, and irrigation to promote vegetative growth could even decrease yield, either directly or indirectly, by increasing lodging and disease. Therefore, for efficient utilisation of water, equipment, and manpower one must fully understand the crop concerned and the likely response to irrigation at the various stages of growth.

CRITICAL GROWTH STAGES

In the introduction to a comprehensive review of crop responses to irrigation Salter & Goode (1967) stressed the importance of understanding the effects irrigation will have at various growth stages. They suggested three main effects. Firstly, the beneficial effect from irrigation at certain critical growth periods. Secondly, the beneficial effect from not irrigating at other growth periods. Finally a nil response situation where no greater response is obtained from irrigating at one time or another. On reading Salter & Goode's review and other relevant literature, the first of these alternatives emerges repeatedly, regardless of crop, as the most important factor effecting yield. That is, the general concept that crops are more responsive to irrigation at certain critical growth stages. Understanding when these critical growth stages occur is the first requirement in designing cropping timetables for irrigation farming. We must know the critical periods where irrigation will contribute most to yields or conversely the periods where moisture stress is likely to be most devastating.

Cereals

In Salter & Goode's review it was generally found that with winter wheat the most important time to irrigate was during late "shooting" stage up to the time of ear emergence. Early irrigation will aid tillering, but this usually takes place when soil moisture is adequate. Irrigation after flowering was likely to increase the Thousand Grain Weight (T.G.W.) and thus contribute further to yield. Here at Lincoln, Scott *et al.* (1973) found that winter wheat responded most to irrigation at ear emergence and suggested that this was probably due to greater tiller survival. Similar responses have been recorded with spring wheat although a greater response can be expected from irrigating at the tillering stage. German work, reviewed by Salter & Goode, compared the effect of irrigation at six stages of growth and found that early irrigation accelerated vegetative growth

Proceedings Agronomy Society of New Zealand 9; 1979

only and that highest yields were obtained when irrigation was applied at ear emergence.

Russian research reviewed by Salter & Goode (1967) found a very marked moisture sensitive period immediately preceded the emergence of the ear, and that irrgiation applied at a later stage was too late to influence yield if moisture had been lacking at the early ear emergence stage. During this period drought conditions had their maximum effect in decreasing yield and irrigation had the greatest effect in increasing yield. Similar results have been obtained from a large number of trials with other cereals, including oats, maize and rice.

In summary, with cereals there is overwhelming evidence to suggest moisture sensitive stages of growth. The actual stage of growth differs a little from crop to crop and between varieties, but in general the most sensitive stage is at the "booting" stage prior to ear emergence. Now, what is actually happening during this period? With each crop studied this period coincides with the development of the reproductive organs and the change from vegetative to generative growth. The main effect is to influence the number of grains formed in the ear. Boyer & McPherson (1975) found that the brief period between vegetative growth and grain development was important because it was here that the greatest potential for disruption of floral development, anthesis, fertilization and number of seeds set, occurred. At no other stage was the plant so vulnerable. Furthermore, this period often coincides with the period of maximum evapotranspiration. Also it has been found that when the reproductive organs are being formed and when flowering takes place, root growth is greatly reduced and may cease altogether. This can effect the amount of water and nutrient uptake.

Peas

As with cereals, considerable work has been done on the requirements of peas including excellent practical guides to irrigation response in New Zealand by Anderson and White (1974) and Stoker (1973, 1977). Salter (1962) found that irrigating peas prior to flowering increased vine but did not increase yield. He further reported in 1963 that irrigation before flowering increased vine weight by 50% with no increase in yield of peas whereas applying water at the start of flowering increased yield by 20% by increasing the weight of peas per pod and number of pods per plant. Maurer *et al.* (1967) using lysimeters, subjected peas to severe water stress prior to flowering and found that this did not decrease yield if ample moisture was made available at flowering. Salter and Drew (1965) found that at the flat pod stage of growth, peas again appeared insensitive to soil moisture conditions but they responded to irrigation when the pods were swelling. They also found that a decline in root activity coincided with flowering and subsequent pod filling. Trials in New Zealand have given substantial responses to irrigation. Anderson and White (1974) achieved yield increases of 56% from irrigation to vining peas and Stoker (1977) achieved yields of between 25% and 188% of seed peas. In both cases irrigation at flowering had the most effect; the greater the effect when moisture stress occurred at this stage. Similar results have been found with other grain legumes.

IRRIGATION BASED ON CRITICAL GROWTH STAGES

The results presented above are from only a few of the many trials that have shown quite clearly that there is a critical period where cereal and legume grain crops appear particularly sensitive to water deficit. There also seems little doubt that this critical period coincides with the change from vegetative to generative growth. Azzi (1956) found that if water was plentiful during this critical period a good yield was possible even if conditions were dry throughout the rest of the growth period. Furthermore when the plant's requirements have been satisfied through this critical period, the plant is in a better position to make use of additonal irrigation in the post flowering period.

The reasons for this sensitive period seem to be related to a slowing down or even cessation of root growth causing a decrease in water uptake, (Bierhuizen 1956). Evapotranspiration losses during this period are often high, thus increasing water demand. A further consideration is that of nutrient deficiency associated with the decrease in water uptake.

There seems little doubt in my mind that critical growth stages, should be used as the primary guide to irrigation scheduling. Soil moisture depletion and plant stress need to be considered, as soil moisture cannot be depleted to the level where irreversible wilting takes place. Likewise consideration must be given to the evapotranspiration rate of the crop and the prevailing humidity and wind conditions. Irrigation during periods of excessive heat, drought or low humidity should be undertaken regardless of stage of growth. This is irrigation acting as an insurance policy. The prime indicator however should be the stage of growth of the plant.

Scientists are always striving to measure causes and effects in terms of absolute quantitative values. This is certainly the case with irrigation research, where a variety of means have been developed to measure soil and plant moisture. Even the simplest of systems, such as the measurement of available soil moisture based on gravimetric analysis, although readily accepted by the scientist, tend not to be actively practiced by the irrigation farmer. As an agronomist involved with the practical side of irrigation, I'm going to stick my neck out and be a little unscientific. To me, the best guide a farmer has is his crop, being able to recognise the critical stages where irrigation will most contribute to yield and is that the crop is being irrigated when the response will be greatest. Surely this is efficiency, even if it isn't based on any fixed measurement of soil moisture or water stress.

CROPPING TIMETABLES

Based on the above somewhat unscientific statement, can we design a cropping programme whereby the whole area sown in one crop can be irrigated at its critical stage? Furthermore can we timetable other crops on the same farm so that their critical stages do not clash with each other and with other farm operations? An all embracing recipe or "blueprint" is not feasible nor is it in any way advocated here. However, I do think a degree of programming is possible, providing it is flexible enough to allow modification. There appear to be three practical possibilities.

1. Altering the Sowing Date

The progamming of vining pea drilling dates based on a heat unit or "growth degree day" system is an accepted aid in production planning. Depending on the prevailing soil and climatic conditions, changes to the sowing date will result in predictable changes in flowering and harvest dates. Therefore it is relatively simple to timetable pea crops so that they will not all flower at the same time and thus enable irrigation to be applied at this critical stage. Other crops, unfortunately, are not so predictable, and often quite drastic changes in sowing date are needed to achieve even a same difference in maturity. There is little point in sowing very early or very late to spread maturity if ultimate yield is going to be adversley affected by sowing date. Sowing at the correct time for a given location to ensure the maximum time for establishment and root growth is more important.

2. Choice of Crops.

It is unlikely that the ear emergence stages of winter wheat and of spring barley will coincide. Similarly differences can be expected between autumn sown oats and spring wheat. These difference can be used when programming for irrigation requirements. The area to be sown of each crop should be such that it is within the capacity of the irrigation plant to cover the whole of one crop when required, before the critical stage of another crop is reached. When a new crop is to be grown on the farm a prime considration must be whether it will fit in with overall irrigation needs.

3. Choice of Varieties.

Varietal improvement through plant breeding has dramatically increased potential yields of many crops. Today the farmer has many varieties to choose from. He should know their characteristics so that he can judge how best they might suit his particular farm. Of prime importance are maturity differences. This is probably most profound with peas where differences in flowering date of up to eight days are possible (e.g. Patea and Puget). Although the differences are less with cereals useful differences do occur and should be utilised. For example there is a maturity difference of at least four days between Zephyr and Ark Royal barley cultivars.

How these three factors can be utilised in designing a cropping timetable to suit a given irrigation system is best illustrated with an example. Presented in Table 1 is part of the production plan used in the 1978/79 season at Kimihia Research Centre, Lincoln.

Table 1 relates to one season only and both time of sowing and time of critical periods will alter from season to season. However once a planned sowing pattern has been established, the different crops and varieties should remain in the same basic order. With winter wheat, the date of ear emergence will remain fairly constant despite quite large differences in sowing date. For example at Kimihia, Aotea was sown on 24 March 1977 and ear emergence commenced on 18 November. Last year Aotea was sown on 30 May and ear emergence commenced on 22 November. Peas are a good crop for irrigation farming because they can be programmed quite accurately, both by altering the sowing date and by using different varieties. Unavoidable clashes may still occur but careful planning based on past crop records and experience should keep overlaps to a minimum and thus increase efficiency.

TABLE 1: Cropping Timetable

Crop	Variety	Sowing Date	Ear Emergence	50% Flower
Winter Wheat	Aotea	30.5.78	22.11.78	
Vining Peas	Patea	7.10.78		3.12.78
	Greenfeast	7.10.78		8.12.78
Field Peas	Maro	15.10.78		12.12.78
Spring Wheat	Karamu	16.10.78	18.12.78	
Spring Barley	Zephyr	6.10.78	24.12.78	
	Ark Royal	6.10.78	27.12.78	

HIGH YIELD SYSTEMS.

There has been a dramatic increase in the research effort being exerted in the field of plant breeding over the past 10 years. This has primarily been stimulated by the development of Plant Breeders Rights legislation. Such legislation is now in force in New Zealand, and due to the protection this offers, a number of new cultivars are now available to the New Zeland farmer. The main impact so far has been with barley and by choosing a newly introduced cultivar suitable for his location, the farmer can expect a yield increase in order of 10% just by changing the cultivar, regardless of other inputs.

Even higher yields are possible due to the higher genetic yield potential associated with many of the new barley cultivars. At Kimihia Research Centre we have been active in introducing new high yielding barleys for the last three years. Although many factors are considered in evaluating a new cultivar, yield relative to control has been of prime importance. However, I think we are failing if we are satisfied in achieving yield increases of 10% for example, when the potential is there for a 20% increase. With this in mind a preliminary trial was undertaken in 1978/79 season aimed at developing "high yield systems", similar to the English blueprint concept. The timely use of irrigation is an important part of such a system.

TABLE 2: Comparison of Traditional and High Yield Growing Techniques With Cultivars "Hassan" and "Zephyr".

Treatment	Traditional	High Yield
Seed Treatment	Dithane M45	Baytan
Seed rate	125Kg/Ha	225Kg/Ha
Fertilizer at sowing	18 - 18 - 0	108 - 18 - 0
Topdressing	–	30 - 12 - 10
Irrigation	–	50mm at ear emergence
Weed Control	Bandamine/ Brominal	Bandamine/ Brominal
Disease Control	–	Bayleton
Aphid Control	–	Nexion

TABLE 3: Comparison of yields and returns.

Cultivar	Treatment	Yield tonnes/ Ha	Additonal Costs	Gross margin per Ha.
Zephyr	traditional	3.8	–	$330.00
Hassan	traditional	4.4	$8.13	$374.67
Zephyr	high yield	4.7	$184.00	$224.08
Hassan	high yield	5.5	$202.17	$276.43

Two blocks measuring 0.15 hectares of the standard cultivar Zephyr were compared with blocks of the new introduction 'Hassan". One block of each cultivar was managed in the traditional manner for the Lincoln area. The other blocks of each cultivar were subjected to our high yield programme. A summary of treatments is given in Table 2. The yields shown in Table 3 are from unreplicated blocks and should be considered with caution. They are produced here to demonstrate a trend rather than absolute yield.

On the basis of returns per hectare, the high yield systems failed, despite substantial increase in yield. The trial has been of a preliminary nature and further work is planned to investigate which treatments contributed most to yield and contributed most to profit. Particular attention will be given to the response to irrigation compared to other inputs, and also the response to irrigation when associated with fertiliser top dressing.

CONCLUSIONS

This paper has tried to look at the question of cropping timetables for irrigation from a practical viewpoint. Adequate research has taken place, both overseas and in New Zealand, concerning crop responses to irrigation. Critical stages occur where irrigation is most effective. A cropping timetable which allows irrigation to take place at these critical stages, will be the most efficient, and could result in a decrease in the total number of irrigations normally applied.

Finally, the plan breeder is providing new cultivars with very high yield potentials. The farmer and the agronomist have a responsibility in developing husbandry systems whereby this potential can be profitably reached

REFERENCES.

Anderson, J.A.D., White, J.G.H. 1974. Yield of green peas II. Effect of water and plant density. *N.Z. Journal of Experimental Agriculture 2:* 165-71.

Azzi, G. 1956. "Agricultural Ecology" Constable & Co. Ltd London.

Bierhuizen, J.F. 1976. Irrigation and water use efficiency. "Water and Plant life". Eds Lange O.L., Knappen L., Schulze E. D., Springer–Berlag pp. 421-430.

Boyer, J.S., McPherson, H.G. 1975. Physiology of water deficits in cereal crops. *Advances in Agronomy 27:* 1-23.

Kramer, P.J. 1963. Water stress and plant growth. *Agronomy Journal 55:* 31-35.

Kramer, P. J. 1969. "Plant and soil water relationships: A modern synthesis" McGraw – Hill Book Co. New York.

Maurer, A. R., Ormrod, D.P., Fletcher, H.F. 1968. Response of peas to environment IV. Effect of five soil water regimes on growth and development of peas. *Canadian Journal of Plant Science, 48:* 129-137.

Salter, P.J. 1962. Some responses of peas to irrgiation at different growth stages. *Journal of Horticulture Science 37:* 41-9

Salter, P.J. 1963. The effect of wet or dry soil conditions at different growth stages on the components of yield of a pea crop. *Journal of Horticultural Science 38:* 321-324.

Salter, P.J., Drew, D. H. 1965. Root growth as a factor in the response of *Pisum sativum* to irrigation. *Nature 206:* 1063-1064.

Salter, P.J. Goode, J.E. 1967. Crop responses to water at different stages of growth. Commonwealth Bureau of Horticulture and Plantation Crops Research Reviewal.

Scott, W.R., Dougherty, C.T., Langer, R.H.M., Meiger, G. 1973. Wheat yield as affected by sowing rate, irrigation and time of White Clover introduction *N.Z. Journal of Experimental Agriculture 1:* 369-376.

Stoker, R. 1973. Responses of viner peas to water during different phases of growth. *N.Z. Journal of Experimental Agriculture 1:*73-76.

Stoker, R. 1977. Irrigation of gardne peas on a good cropping soil. *N.Z. Journal of Experimental Agriculture 5:* 233-236.