

FREQUENT LIGHT IRRIGATION SCHEDULING TO IMPROVE EFFICIENCY OF WATER USE

E.H. Hobbs and K.K. Krogman

Research Station, Agriculture Canada, Lethbridge, Alberta T1J 4B1

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The relative merits of irrigating frequently with small amounts of water as compared to normal, longer irrigation intervals was investigated using utility spring wheat, cv. Pitic 62, in lysimeters outdoors and in the greenhouse. Water use by the crop was determined by weight and the extraction pattern within the soil profile using a neutron attenuation meter. When irrigation was continued to crop maturity and was applied more frequently but in smaller amounts than is usual, wheat yields were 18% higher in the outdoor experiment and 7% higher in the greenhouse. Water-use efficiency (grams of seeds per kilogram of water) did not differ significantly between treatments. Under both irrigation treatments, moisture was extracted preferentially from the upper portion of the soil profile. This was more pronounced under the frequent irrigation regime which used 88.3% of its requirements from the top 60 cm of soil compared to 74.6% for the normal regime. Because the frequent light irrigation technique may possess advantages in effective use of precipitation, controlling drainage, and maintaining nutrient supplies, it should be considered, especially where highly automated mechanical irrigation systems are in use.

INTRODUCTION

Since most of the water available for irrigation in southern Alberta has become allocated, the demand for improved efficiency in its use is increasing. Overwatering with subsequent deep percolation through the soil profile is one contributing cause of inefficiency. Although some leaching is necessary to maintain an appropriate salt balance in the crop root zone, this need not be part of each irrigation. In southern Alberta, individual rains of 50 mm or more and drainage from winter moisture accumulations may provide enough leaching in most years.

Deep percolation can be minimized by applying less water than is required to replenish the soil profile, but applying it frequently enough that moisture stress does not occur. Mechanized or automated sprinkler irrigation systems have provided the means to apply small amounts of water. Frequency of moisture replacement may vary from daily to several days. Some conflict exists in the literature, however, concerning the relative water-use efficiency (units of production per unit of water) of irrigating frequently but lightly. Keller (1965) reported that efficiency was directly related to depth of water stored at each irrigation, but Musick and Dusek (1971) increased water-use efficiency of sorghum by reducing water application depth from 10 to 5 cm. DeBoer et al. (1977) concluded that, for corn, water-use efficiencies were not affected by application depth.

Related advantages inherent in frequent irrigation have been discussed (Musick and Dusek 1971; Rawlins 1973; Rawlins and Raats 1975; Lebedev et al. 1976). Soil variability and moisture-holding characteristics become less important because it is only necessary to irrigate within the infiltration rate and to maintain a downward moisture flux. Variations in wind velocity and direction affect application uniformity differently for individual irrigations but overall uniformity improves as number of irrigations increases. Stored moisture and precipitation are used more efficiently because a larger storage capacity is available to accommodate precipitation occurring shortly after irrigation. Leaching of plant nutrients is minimized and drought

TABLE I. EFFECTS OF FOUR IRRIGATION TREATMENTS ON YIELD AND WATER USE OF PITIC 62 WHEAT GROWN IN WEIGHABLE LYSIMETERS OUTDOORS AND IN THE GREENHOUSE

| | Irrigation treatments | | | | | |
|--------------------------------------|-----------------------|--------|-------|-------|-------------|-------|
| | Outdoor location | | | | Greenhouse† | |
| | C | Ca | F | Fa | C | F |
| Plant weight (g) | 207b‡ | 169c | 238a | 172c | 185e | 196e |
| Grain weight (g) | 72b | 50c | 85a | 50c | 102e | 109e |
| 1000-kernel weight (g) | 28a | 19b | 27a | 19b | 38e | 38e |
| No. of heads | 89ab | 77b | 98a | 80b | 75e | 77e |
| No. of irrigations | 8b | 4c | 15a | 8b | 5f | 11e |
| Evapotranspiration (kg) | 96b | 74c | 109a | 78c | 80e | 80e |
| Water use efficiency (g grain/kg ET) | 0.75ab | 0.68bc | 0.78a | 0.64c | 1.28e | 1.36e |

†Analyzed separately.

‡Within rows, values followed by the same letter do not differ significantly ($P = 0.05$)

tolerance of crops becomes less important. Plants should function more efficiently because they will extract water mainly from shallow depths. From an operational standpoint, frequent light irrigations minimize the problems of poor traction of mechanical irrigation equipment in saturated soils.

Experiments utilizing weighable lysimeters under automatic rain-shelters and in the greenhouse were conducted at Lethbridge, Alberta, to determine the efficiency of water use by wheat as influenced by two levels of irrigation frequency and two irrigation termination dates.

MATERIALS AND METHODS

Pitic 62 wheat was seeded in 1976 and 1977 in 16 weighable lysimeters 38 cm in diameter and 120 cm deep containing Ah horizon Chin loam soil and located under a rainshelter (Dubetz et al. 1968). The soil had a field capacity (1.5×10^4 Pa) of 20% by weight, a wilting point (1.5×10^6 Pa) of 7% and a density of 1350 kg/m^3 . The crop was thinned after emergence to 20 plants per lysimeter. Total soil moisture in the lysimeters was determined by weight (Voisey and Hobbs 1972) and moisture distribution within the profile was determined using neutron attenuation techniques from an

access tube centered in each lysimeter.

Four irrigation treatments in four replicates were:

C: Conventional; irrigate at 50% available soil moisture with sufficient water (about 9.5 cm depth) to replenish the soil profile to field capacity (FC). This treatment conforms to recommended farm practice and was considered to be a check;

Ca: Irrigate as in C but only until anthesis;
F: Frequent; irrigate at 50% available soil moisture and apply only enough water (about 4.8 cm depth) to replenish the soil profile to a mean value of 75% of FC; and

Fa: Irrigate as in F but only until anthesis.

The lysimeters were weighed at 1- or 2-day intervals as required to maintain the irrigation treatments. Neutron readings were scheduled twice per week but operational problems frequently dictated longer intervals. The crop was harvested at maturity and the total plant dry weight, grain weight, 1000-kernel weight, and number of heads was recorded. Total moisture use (ET) was determined and water-use efficiency, the ratio (g/kg) of grain produced to water used, was calculated.

An additional experiment consisting only of treatments C and F in triplicate was

TABLE II. PERCENT OF SOIL MOISTURE BY WEIGHT OBTAINED FROM FOUR SUCCESSIVE PROFILE DEPTHS UNDER TWO IRRIGATION REGIMES

| Irrigation interval | Irrigation treatments | | | | | | | |
|----------------------------------|-----------------------|----------|----------|-----------|---------|----------|----------|-----------|
| | C | | | | F | | | |
| | 0-30 cm | 30-60 cm | 60-90 cm | 90-120 cm | 0-30 cm | 30-60 cm | 60-90 cm | 90-120 cm |
| 8 Dec.-17 Jan. | 39 | 34 | 24 | 3 | 37 | 33 | 26 | 4 |
| 18-27 Jan. | - | - | - | - | 74 | 21 | 5 | 0 |
| 28 Jan.-3 Feb. | 43 | 32 | 20 | 5 | 61 | 22 | 10 | 7 |
| 4-9 Feb. | - | - | - | - | 57 | 24 | 11 | 8 |
| 10-15 " | 40 | 33 | 22 | 5 | 66 | 26 | 6 | 2 |
| 16-20 " | - | - | - | - | 59 | 26 | 9 | 6 |
| 21-23 " | 44 | 34 | 19 | 3 | 69 | 29 | 0 | 4 |
| 24-28 " | - | - | - | - | 59 | 29 | 9 | 3 |
| 1-4 Mar. | 42 | 34 | 22 | 2 | 66 | 30 | 4 | 0 |
| 5-8 " | - | - | - | - | 55 | 27 | 13 | 5 |
| 9-12 " | 40 | 32 | 21 | 7 | 59 | 32 | 4 | 5 |
| 13-17 " | - | - | - | - | 54 | 28 | 11 | 7 |
| 18-23 " | 41 | 34 | 21 | 4 | 57 | 30 | 9 | 4 |
| Average during irrigation cycles | 41.3 | 33.3 | 21.3 | 4.1 | 61.3 | 27.0 | 7.5 | 4.2 |
| 24-29 Mar. | 19 | 21 | 28 | 32 | 32 | 24 | 20 | 24 |

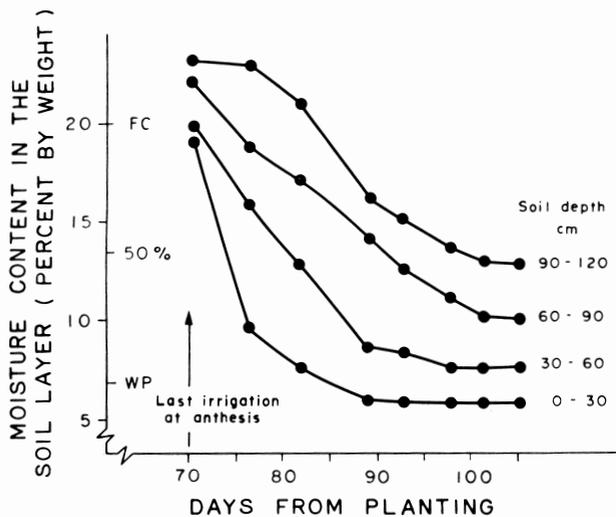


Figure 1. Moisture withdrawal by Pitic 62 wheat from four 30-cm soil depth increments after irrigation was stopped at anthesis for conventional irrigation treatment (Ca).

conducted in the greenhouse to monitor more precisely the moisture extraction from successive depths of the profile. The experimental technique was identical to that used in the outdoor lysimeters except that moisture was monitored both for total weight and for profile distribution before and after each irrigation and at 1- or 2-day intervals between irrigations.

RESULTS

Yield and Water-Use Efficiency

The data from the outdoor site were statistically similar for each year; consequently, a combined analysis of variance is presented (Table I).

When irrigation was terminated at anthesis (treatments Ca and Fa), moisture remaining in the 120-cm profile was insufficient to mature the crop satisfactorily. When compared to the check treatment C, total dry matter, grain weight, kernel size,

and water-use efficiency were all adversely affected. The similarity of results for Ca and Fa suggests that cessation of irrigation at anthesis overshadowed any influence that frequency of the earlier irrigation applications may have had.

When irrigation was continued beyond anthesis to crop maturity (treatments C and F), yield and water use increased and water-use efficiency improved. The frequent, partial irrigations produced more grain and used water as efficiently as did the check treatment.

In the greenhouse experiment, yields and water-use efficiency averaged slightly higher for frequent than for conventional irrigation, but the increases were not significant.

Soil Moisture Extraction

Soil moisture was used preferentially from the upper portion of the soil profile. Only after it had been largely depleted from the upper zones, to near or below the wilting

point, was any appreciable amount used from deeper in the profile. This is illustrated by the extraction pattern after irrigation ceased at anthesis (Ca) in the outdoor experiment (Fig. 1). The withdrawal pattern for the more frequently irrigated Fa was similar except that the upper two soil increments of Fa were never filled to FC by irrigation.

The moisture extraction pattern for a complete growth cycle is shown for treatments C and F in Figs. 2 and 3, respectively. Since the moisture content of all lysimeters was initially at FC, withdrawal during the first 40 days was similar and predominantly from the upper half of the profile. After imposition of the irrigation treatments, the frequently but lightly irrigated pots (F) lost an even greater proportion of their water from the top 60 cm of soil (Fig. 3). Very little of the water that was used from the lower depths was replaced by the light irrigations, whereas when the C pots were irrigated all depths of the profile were replenished (Fig. 2).

In the greenhouse, the percent of total water extracted during seven conventional irrigation cycles (C) averaged 41, 33, 21, and 4% for successive 30-cm depths (Table II). When irrigation was applied frequently but lightly (F), more than 60% of the requirements were withdrawn from the top 30 cm of soil and nearly 90% from the upper half of the profile. Moisture withdrawal from each depth remained relatively constant throughout the growth cycle as long as irrigation was continued. After irrigation was discontinued (last line, Table II) and mean soil moisture fell below 50% available, an increasingly larger proportion was extracted from the lower depths.

DISCUSSION

It is efficient irrigation practice and also operationally desirable to deplete soil moisture before harvest. Care must be taken, however, not to stop irrigating too soon. When irrigation of the lysimeters was terminated at flowering, a yield reduction occurred even though some available soil moisture remained below the 60-cm soil depth. Neither conventional nor frequent irrigation before anthesis counteracted the adverse effects of mid- to late-season moisture deficiency. This effect may be less pronounced under field conditions, where wheat could withdraw moisture from below the 120-cm limit imposed in these studies.

Soil moisture extraction under conventional irrigation conformed fairly closely to the traditional 40, 30, 20, and 10% contribution from successive depths (Doorenbos and Pruitt 1975). But, under frequent irrigation, almost 20% more of the total was extracted from the top half of the profile. This preferential use from the upper levels caused the surface soil of conventionally irrigated treatments to become intermittently drier than that of the more frequently irrigated treatments. The conventionally irrigated plants were required to extract a greater proportion of their water requirements from greater depths, particularly the 60- to 90-cm region. Both the increased stress and the greater extraction depth require that plants expend more energy. This presumably was reflected

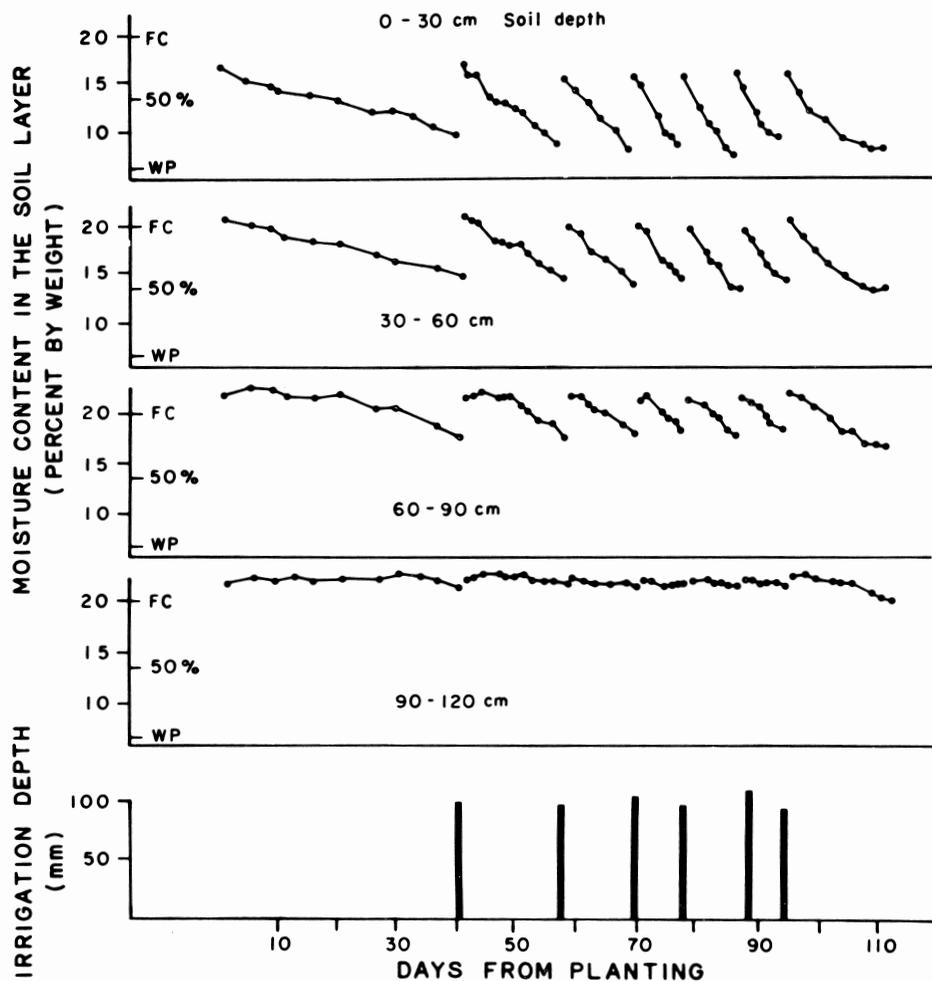


Figure 2. Moisture withdrawal from successive 30-cm depths by Pitic 62 wheat when irrigated to 100% available moisture from 50% available moisture in conventional irrigation treatment (C).

in reduced water consumption and lower yield.

The frequently irrigated treatment (F) used more water than the conventionally irrigated treatment (C) but also produced 18% and 7% more grain in the outdoor lysimeters and the greenhouse lysimeters, respectively. Evaporation from the soil surface would cause some increase in water loss for treatment F because of the greater number of days on which the soil surface was wet. Surface evaporation ceases to be a factor, however, once a full plant canopy is established (Jensen 1975; Rawlins and Raats 1975). Since a full canopy was established after only two irrigations had been applied, evaporation was probably not an important factor contributing to increased water use.

The conventional irrigation procedure, represented by treatment C, replenishes the soil moisture at each irrigation after it has been about 50% depleted. This practice intermittently refills the whole profile and maintains the lower depths at a continuously high moisture content (Fig. 2). This creates a situation in which, after each irrigation, some water is inevitably lost to deep percolation. Any precipitation that occurs at this time will also be subject to surface drainage or may infiltrate to deeper layers. If

leaching is required, drainage water can be a desirable carrier of excess salts from the root zone. But leaching is frequently unnecessary and in these instances drainage causes a nutrient loss that may also cause pollution elsewhere. Run-off or subsurface drainage constitutes an energy loss both directly in physical water supply and indirectly in nutrient supply.

Under the frequent irrigation procedure, treatment F, the continuously unfilled storage capacity of 25% available soil moisture became distributed at least partially throughout the profile (Fig. 3). For the loam soil used in this experiment, the capacity available to store precipitation varied from 48 to 96 mm depending upon elapsed time since irrigation. This would be sufficient to prevent deep percolation most of the time. At Lethbridge, Alberta, which has slightly higher precipitation than most of the irrigated northern Great Plains, single-day precipitation during the irrigation season exceeds 50 mm in only about 1 in 5 years. Precipitation events exceeding 50 mm but involving more than 1 day occur in about 4 of 5 years. (Anonymous 1973).

Under the conditions of these experiments, frequent light irrigations

appear to have some advantages over conventional irrigation frequencies while maintaining yield and water-use efficiency. Natural precipitation would be used more efficiently. Drainage through the profile would be controlled more effectively, thereby reducing nutrient loss, environmental pollution, and the requirement for expensive artificial drainage.

About 40% of Alberta's irrigated area is mechanically equipped to use this technique. It would not be feasible where timely delivery of water to farms or the farm distribution system is physically limited, or where frequent leaching to maintain a satisfactory salt balance is necessary. The practice would be more applicable to shallow- than to deep-rooted crops.

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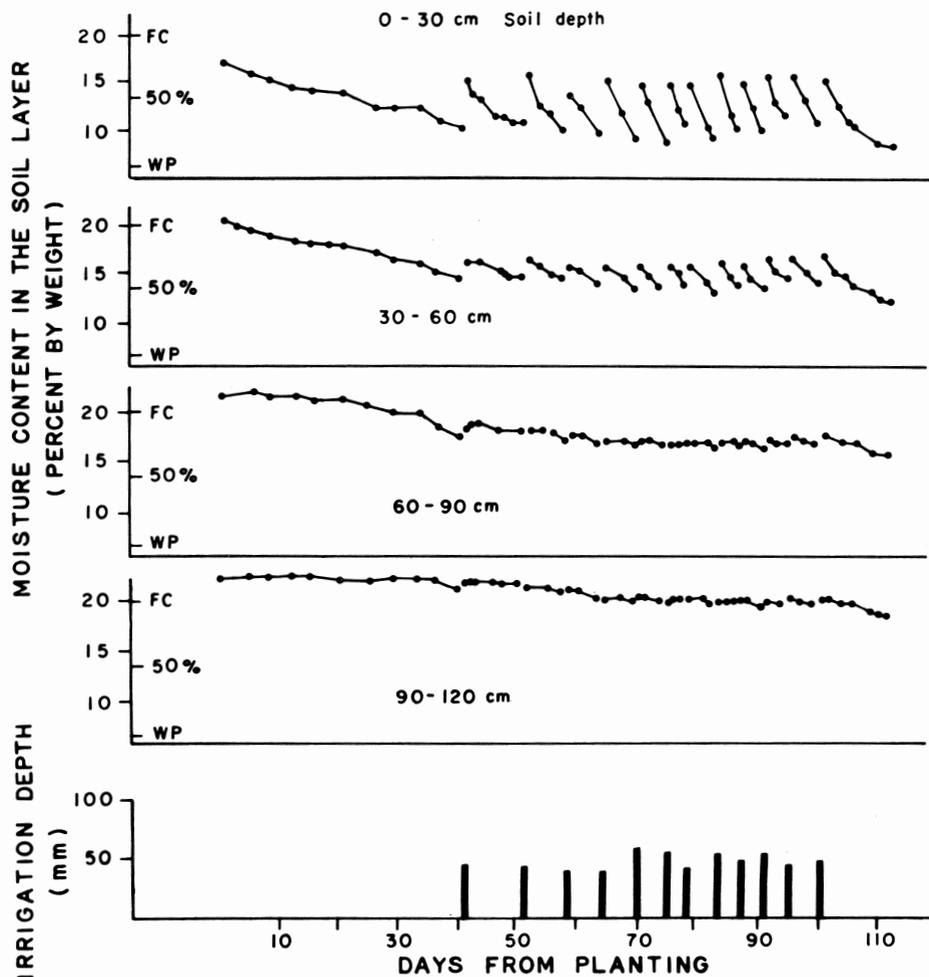


Figure 3. Moisture withdrawal from successive 30-cm depths by Pitic 62 wheat when irrigated to 75% available moisture from 50% available moisture in the frequently irrigated treatment (F).

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