**EFFECT OF DIFFERENT IRRIGATION SCHEDULES ON WATER USE AND YIELD OF WHEAT**

Mohammad Jamal Khan *, Tahir Sarwar *, Aneela Shahzadi *, and Abdul Malik **

**ABSTRACT**

The research was conducted on clay loam soil of NWFP Agricultural University Farm during Rabi, 1997-98 to study the effect of different irrigation schedules on water use and yield of wheat. Experiments were conducted with one wheat variety, four irrigation intervals i.e. three weeks (W), four weeks (W), five weeks (W), and six weeks (W), and two pan levels i.e. equal to pan evaporation (P) and half of the pan evaporation (P₃). The crop coefficients were determined by gravimetric method. Actual evapotranspiration (ETa) was calculated by water balance method and pan evaporation method. Water use was calculated from crop and climatic data. The direct methods include soil moisture depletion studies, tanks and lysimeter method, field experimental plot and inflow-outflow from large areas. While indirect methods include Pan evaporation, Blaney-Criddle and Penmen methods. Pan evaporation method is the simplest method in which evaporation is determined by the change in level of water surface. Actual evapotranspiration, Irrigation Scheduling, Pan Evaporation, Water Use Efficiency, Wheat

**INTRODUCTION**

Pakistan is although counted as an extensive irrigated country along with United States, Indonesia, Soviet Union, Mexico and Egypt, yet in its dry regions water is not sufficient even to provide initial requirements of agricultural crops. This deficiency retards not only the growth of the plants but also results in poor harvests thereby causing a great financial loss to the poor tiller of the soil. Even in the regions where irrigation water is available throughout the year, the cultivators fail to provide the optimum requirements because lack of knowledge about the quantities and timings of irrigation.

The irrigation scheduling is the process of determining when to irrigate and how much water to apply per irrigation. Proper irrigation scheduling is essential for the efficient use of water, energy and other production inputs. Three major considerations influencing irrigation schedule are: (a) water needs of crop; (b) availability of water for irrigation; and (c) capacity of the root zone to store water. Water needs of crop are of paramount importance in determining the time of irrigation during the crop-growing season in irrigation project.

The term consumptive use can be applied to the water requirements of a crop, a field, a farm, a project, or a valley. It is the sum of two terms, transpiration from the plant and evaporation from adjacent soil streams etc. Consumptive use of water can be determined by direct measurement or calculated from crop and climatic data. The direct methods include soil moisture depletion studies, tanks and lysimeter method, field experimental plot and inflow-outflow from large areas. While indirect method includes Pan evaporation, Blaney-Criddle and Penmen methods. Pan evaporation method is the simplest method in which evaporation is determined by the change in level of water surface.

Wheat (*Triticum aestivum* L.) is one of the most cultivated cool-season crop originated from the Middle East. It has somewhat longer growing period and minimum heat requirement than the other small grain crops. In Pakistan wheat is grown on an area of 7.8 Mha while in NWFP it is grown on an area of about 0.75 Mha which is 11% of total wheat cultivated area in the country. In NWFP 40% area under wheat crop is irrigated and remaining 60% is rainfed (*Hamid et al* 1983). The irrigation requirements of wheat crop vary with the types of soil and season in which it is grown. The time and amount of irrigation water play an important role in the production of wheat crop in the arid and semi-arid areas.

Raghuwansh (1989) found that irrigation with cumulative pan evaporation of 0.8, and 1.0 or 1.2 (6, 9 and 10 irrigation, respectively) gave average grain yields of 0.99, 1.12 and 1.23 t ha⁻¹, respectively. According to Gill (1992) irrigation depth based on evaporation ratios of 0.75 to 0.90 produced the highest grain yields. Walia and Cheema (1992) found that grain yield, root weight

* Department of Water Management, NWFP Agricultural University, Peshawar - Pakistan
** Department of Agriculture Engineering, University of Engineering & Technology, Peshawar - Pakistan
and water use of wheat were highest with irrigation at four weeks after sowing + subsequent irrigations at 80 mm cumulative pan evaporation with 120 kg N ha\(^{-1}\) and with weed control. Patel and Upadhyay (1993) conducted experiment on wheat that was irrigated at irrigation water : cumulative pan evaporation (IW : CPE) ratio of 0.8, 1.2 or 1.6 and was given 90, 120 or 150 kg N and 45, 60 or 75 kg P\(_2\)O\(_5\) per ha. They found that yield increased significantly with increasing irrigation up to 1.2 IW : CPE and N fertilizer rate up to 120 kg ha\(^{-1}\) but was not significantly affected by P rates. Hundal and Rajwant (1993) found that wheat irrigated at irrigation water (IW) : calculated pan evaporation (CPE) ratio of 0.5, IW:CPE ratio of 1.0 up to booting followed by IW : CPE ratio of 0.5 up to maturity produced grain yield of 3.45, 3.80 and 4.10 t ha\(^{-1}\), respectively, compared with 2.63 t ha\(^{-1}\) from the rainfed crop. According to Deshmukh and Padole (1993), in a field trial on a clay loam soil, wheat was irrigated at cumulative pan evaporation (CPE) of 50, 75, 100 or 125 mm. Grain yield increased from 2.07 t ha\(^{-1}\) to with irrigation at 125 mm CPE to 3.23 t with irrigation at 50 mm CPE. Parsad (1993) in the field trial conducted on silty loam found that combination of manual weed control + irrigation at 150 mm CPE + 150 kg N resulted in the greatest wheat grain yields.

The most suitable time for wheat sowing in Peshawar region is from Oct 15 to Nov 15. Generally, farmers apply water to a field until all the field is covered with water including any high spot without knowing the actual requirement of crop and growth stage. This study was conducted to make easy the process of calculating the potential evapotranspiration for farmers so that they supply the actual demand of water according to the need of crop. Main objectives of the study were to determine actual evapotranspiration, crop coefficient and yield and yield components of wheat crop under different irrigation schedules.

**MATERIALS AND METHODS**

Experiments were conducted at the Research Farm of NWFP Agricultural University, Peshawar to determine the effect of different irrigation schedules on evapotranspiration, growth and yield of wheat crop during Rabi Season of 1997-1998. The research site is located at latitude of 34° 01’ N and longitude of 71° 33’ E. The area gets its irrigation water from Warsak Gravity Canal.

**Treatments**

The experimental design selected for this study was a randomized complete block design with eight treatments (four levels of irrigation intervals and two levels of cumulative pan evaporation). Four irrigation intervals were: irrigation after three (W_1), four (W_2), five (W_3) and six (W_4) week interval and full cumulative pan evaporation (P_1) and half cumulative pan evaporation (P_2) and replicated thrice. A field of 2970 m\(^2\) was divided into 24 equal plots each measuring size 15 m x 7 m. The soil of the experimental field was clay loam. Wheat variety “Inqilab” was sown in rows on November 15, 1997 with the help of grain drill at seed rate of 100 kg ha\(^{-1}\) and uniform dose of fertiliser was applied to the experimental plots.

**Data Collection**

Bulk density was determined with the help of core sampler and soil moisture with gravimetric method. Samples for determination of moisture contents were regularly taken from different locations and at three depths i.e. 0-0.25, 0.25-0.50 and 0.50-1.00 m.

Potential Evapotranspiration (ETo) was determined by using the following equation.

\[
ETo = Kp \times Ep \quad \text{(1)}
\]

Where

- \(Ep\) = Pan evaporation in mm day\(^{-1}\); and
- \(Kp\) = Pan coefficient.

Crop coefficient which is the ratio of actual evapotranspiration occurring under a specific crop at a specific stage of growth to potential evapotranspiration at that time is given by the following relationship.

\[
Kc = \frac{ETa}{ETo} \quad \text{(2)}
\]

- \(Kc\) = Crop coefficient for a specific crop and for a particular growth stage;
- \(ETa\) = Actual evapotranspiration in mm day\(^{-1}\); and
- \(ETo\) = Potential evapotranspiration for the same period in mm day\(^{-1}\), determined using pan evapotranspiration data.

**Yield and its Component**

Wheat yield and yield components data was collected from one meter square area of each plot at two locations. Data on the following yield components was recorded: Number of grains per plant; Number of grains per spike; Grain weight per spike; Grain yield in kg ha\(^{-1}\).

**RESULTS AND DISCUSSIONS**

The actual evapotranspiration ETa was found minimum 0.71 mm/day during 15-30 November and gradually increased from 1 to 7 mm day\(^{-1}\) during the month of December to April (Fig.1). Daily evapotranspiration from the date of planting to harvesting indicates that evapotranspiration was low initially, increased gradually and decreased toward harvest due to physiological maturity of crop.
Average water used by W3, W4, W5 and W6 were 518, 484, 496 and 479 mm, respectively (Table I). There was very little difference in seasonal water used between different irrigation treatments. However, the seasonal water used by W3 was higher than W6. Maximum value of 518 mm of water used by wheat was obtained from W3 and minimum value of 496 mm from W6. In general, the frequent soil wet condition under W3 consumed more water as compared to W6.

Fig. 2 shows the cumulative increase in ETa from the date of planting till harvesting. It is clear from the results that there was no significant difference between water used by W1P1, W1P2, W3P1, W3P2 and W5P2, W6P1, W6P2. First reason is the low demands of crop water requirement initially. It was difficult to supply such small quantity of water uniformly. Another reason could be frequent and unexpected rainfall throughout the growing season, which made it difficult to maintain the difference of irrigation according to full pan evaporation data and half of it. The actual evapotranspiration (ETa) of wheat for W1P1 was low as 0.71 mm day−1 at the start of growing season then it gradually increased up to 8.7 mm day−1 from the date of planting and then decreased. Similar trend was reported by Doorenbos and Pruitt (1982) who reported that the water requirements of wheat/barely for maximum production varied between 450 and 600 mm per season depending on climate and length of growing period.

**Crop Coefficient**

The crop coefficient value of W1P1 increased up to 1.88 and 1.80 respectively, and then decreased to 0.59 at maturity. Whereas the Kc value of W1P1 and W2P2 started as 0.43 then goes up to 1.92 and 1.97 and then showed down ward trend at maturity. At last the Kc value of W1P1, W2P2 started at 0.43 increased up 1.79, 1.80 and then decreased to 0.59 at maturity. Fig. 3 shows the average Kc value for W3, W4, W5 and W6 are 1.02, 0.98, 0.97 and 0.46. This result shows a decrease in crop coefficient with increase in crop irrigation interval. The crop coefficient for all of eight treatments increased up to middle season and then started decreasing at the end. The decrease in Kc showed the low water requirement of crop during maturity. These results seem to be in accordance with the results of Doorenbos and Pruitt (1982) who reported that the crop coefficient of wheat was 1.05 at mid season and 1.1 at maturity or harvest stage.

**Grain Yield**

The statistical analysis revealed significant effect of irrigation schedules on grain yield. Further analysis by using Duncan’s Multiple Range test for yield (Table II) showed that there was significant among the different treatments, except W4 and W5. Low grain yield from W2 plots indicate that increased frequency of irrigation negatively affected the grain yield. Similarly low yield in W6 plots, observed, could be due to increase in moisture stress due to late irrigation intervals. Highest yield (4018 kg/ha) was obtained from W3 and followed by W4 plots. The lowest (3287 kg/ha) yield was obtained from plots irrigated after each three weeks (W3). It is clear from the data that too early and late irrigation is harmful for the maximum return and the irrigation should be given at right time for maximum yield.

**Number of Grains Per Spike (NGPS)**

Different irrigation intervals significantly affected the number of grains per spike (Table II). Further analysis by using Duncan’s Multiple Range (DMR) test showed that number of grains per spike obtained from plots irrigated after five weeks intervals is highest and is significantly different from rest of the others. This means interval of five weeks is best suitable for good grain number per spike. The maximum number grains (44) were obtained from plots irrigated after five weeks interval is followed by 39 grains per spike obtained from plots irrigated after six weeks interval. Lowest number of grains 35 grain per spike is obtained from plots irrigated after three week interval. The possible reason for this result may be that tillering reduces the number of grains per spike.

**Grain Weight per Spike (GWPS)**

It is clear that irrigation intervals significantly affected the weight of grain per spike (Table II). Further analysis by DMR test shows that weight of grain per spike obtained from plots irrigated after five weeks intervals was significantly different from plots irrigated after three weeks intervals. The maximum GWPS of 1.71 g was recorded at W5 plots, followed by 1.57 g obtained from W6 plot and lowest GWPS of 1.45 g was obtained from W3 plots.

**Number of Tiller per Plant (NTPP)**

The statistical analysis revealed significant effect of irrigation schedule on number of tiller per plant further analysis by using DMR test (Table II) shows that plots irrigated at three weeks interval had highest number of tillers (17.66) and it was significantly different from plots irrigated after four, five and six weeks interval, respectively. It is clear from the results that abundant moisture favoured increased tillering that is why lowest number of tillers were recorded from plots irrigated at six week interval.

**Water Use Efficiency (WUE)**

Water use efficiencies for wheat at different irrigation schedule are given in Table III. The
results showed that the highest water use efficiency of 8.10 kg ha\(^{-1}\) mm\(^{-1}\) was obtained when the crops was irrigated after five week interval while the lowest value of 6.03 kg ha\(^{-1}\) mm\(^{-1}\), was obtained from the plots irrigated after three weeks interval. These results indicated that the water use efficiency was increased when the irrigation intervals increased.

CONCLUSION AND RECOMMENDATIONS
The seasonal evapotranspiration of wheat irrigated after three (W\(_3\)), four (W\(_4\)), five (W\(_5\)) and six (W\(_6\)) weeks were 518, 484, 496 and 479 mm, respectively. The average seasonal crop coefficients for wheat were 1.02, 0.98, 0.97 and 0.95 for W\(_3\), W\(_4\), W\(_5\) and W\(_6\) treatments, respectively. The result indicates that highest yield of wheat of 4017 kg ha\(^{-1}\) was obtained from W\(_5\) plots and lowest 3376 kg ha\(^{-1}\) was obtained when irrigated after each three and six weeks interval. This result showed that too late and early irrigation is harmful for wheat crop. The highest and lowest number of grains per spike and weight of grain per spike were obtained from W\(_5\) and W\(_3\) plots, respectively. This indicates that over irrigation decrease number and weight of grain per spike. Highest number of tillers and more lodging were observed in W\(_3\) plot that shows which increased moisture favours the number of tiller and lodging percentage. It is concluded from the study that optimum yield of wheat can be obtained when crops is irrigated at five weeks interval, with seasonal rainfall of \(\geq\) 300 mm.

![Fig. 1](image1.png)
**Fig. 1** Actual evapotranspiration (ET\(_a\)) during the wheat growing season

![Fig. 2](image2.png)
**Fig. 2** Cumulative ET\(_a\) under different irrigation intervals.
Fig. 3  Seasonal variation in crop coefficient (Kc) of wheat irrigated at different intervals

Table I.  Cumulative actual evapotranspiration of wheat at different irrigation intervals and depths.

<table>
<thead>
<tr>
<th>Irrigation Interval (weeks)</th>
<th>Irrigation Depth applied as per cumulative pan evaporation (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P₁</td>
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<tr>
<td>W₃</td>
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<tr>
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<td>W₆</td>
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Table II. Effect of irrigation intervals on yield and yield components of wheat

<table>
<thead>
<tr>
<th>Irrigation Interval (weeks)</th>
<th>NGPS Yield (kg/ha)</th>
<th>NTTP Yield (kg/ha)</th>
<th>WGPS Yield (kg/ha)</th>
<th>Yield (kg ha⁻¹)</th>
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<tr>
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<td>3906 a</td>
</tr>
<tr>
<td>W₅</td>
<td>44.00 b</td>
<td>14.91 b</td>
<td>1.71 a</td>
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<tr>
<td>W₆</td>
<td>39.33 b</td>
<td>14.16 b</td>
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</table>

Table III. Effect of irrigation intervals on water use efficiency of wheat

<table>
<thead>
<tr>
<th>Irrigation Interval (weeks)</th>
<th>Water Use (mm)</th>
<th>Grain Yield (kg/ha)</th>
<th>Water Use Efficiency (Kg/ha/mm)</th>
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<td>W₃</td>
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<td>W₄</td>
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REFERENCES


