EFFECTS OF FREQUENCY AND DEPTH OF IRRIGATION ON GROWTH AND YIELD OF ONION (*Allium cepa* L.)

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DEDICATED TO

MY BELOVED PARENTS

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ABSTRACT

The experiment was conducted at the Horticulture Farm of Bangladesh Agricultural University to study the effects of frequency and depth of irrigation on growth and yield of onion cv. Taherpuri during October, 1990 to April, 1991. There were three different frequencies of irrigation viz. at 15%, 30% and 45% depletion of available soil moisture and three different depths of irrigation viz. 5 mm less than, equal to and 5 mm more than the soil moisture depletion in the root zone.

The frequency and depth of irrigation significantly affected the growth and yield of onion. Plant height, average length of leaves and bulb diameter increased significantly with irrigation at 15% depletion of soil moisture regime. Yield of onion bulbs was maximum (12.4 t/ha) by irrigation at 15% depletion of soil moisture regime along with a irrigation depth of 5 mm more than the amount of depletion of soil moisture in the root zone. The total water used at that treatment was 264.1 mm. Decreasing the depth of irrigation under same regime significantly decreased the yield. Although bulb yield increased by irrigation, but irrigation induced a higher percentage of splitted bulb. However, higher proportion of large size `A' (>44 mm in diameter) grade bulbs were obtained by irrigation. Maximum A grade bulbs (33.7%) were produced by irrigation at 15% depletion along with a irrigation depth of 5 mm more than the soil moisture depletion.

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ABBREVIATION INDEX

ASM = Available Soil Moisture

AW = Available Water

ER = Effective Rainfall

FC = Field Capacity

LSD = Least Significant Difference

NPR = Neutron Probe Reading

SMC = Soil Moisture Content

SMD = Soil Moisture Depletion

SWU = Soil Water Use

TWU = Total Water Use

WP = Wilting Point

CHAPTER I

INTRODUCTION

Onion (*Allium cepa* L.) is one of the most important crop belonging to the family Alliaceae. It is widely cultivated throughout Bangladesh. However, commercial cultivation is predominantly concentrated in greater districts of Dhaka, Faridpur, Rangpur, Pabna and Rajshahi. Onion in this country is largely used as spice.

Consumption of onion in Bangladesh is much higher than the total production in the country. The annual requirement of onion in Bangladesh is 450 thousand tons (Rahim, 1992), while only 143.0 thousand tons are being produced in the country at present (BBS, 1992). The deficit quantity is being imported from neighbouring countries.

Compared to many neighbouring countries, onion yield and production in Bangladesh is one of the lowest. FAO (1988) reported that between 1985 to 1988, the average yield of onion in Bangladesh was 4.04 t/ha, while in India, Sri Lanka and Pakistan the figures were 9.37, 7.82 and 11.05 t/ha, respectively.

Onion production in Bangladesh is fully dependent on local land races. The temperate long day type cultivar which are large in size and can produce higher yield per unit area are not acceptable at farmers level since these cultivars have very poor storage capability. On the other hand, local cultivars although small in size and low in yield are very good in storage quality.

The yield of the local onion can still be increased substantially if adequate cultural practices are followed for its cultivation.

In Bangladesh, onion is grown during winter season which is cool and dry in nature. Supplemental irrigation is often required to obtain substantial yield under such conditions. Onion readily responds to water stress. Onion roots spread more within the top soil when soil moisture is available throughout the growing period. At low moisture level onion roots grow deeper into the soil which could be as much as 40 cm (Bruce and Vipond, 1974).

Frequent irrigations are often recommended. In Nigeria, irrigation at 3 days interval was found to be better than 6 days interval (Chaudhury and Erinne, 1984). Increasing the frequency of water application does increase the availability of applied water and nutrients through establishment of relatively moist conditions in root zone throughout the cropping period (Goldberg *et al*. 1971). Withholding irrigation at any stage of onion growth may retard the process of bulbing and eventually reduce the bulb yield (Chung, 1989).

In Bangladesh a few reports are available regarding the frequency and depth of irrigation on growth and yield of onion. The present investigation is therefore, under taken to determine the effects of the frequency and depth of irrigation on the growth and yield of onion under the Bangladesh Agricultural University farm conditions.

CHAPTER II

REVIEW OF LITERATURE

Irrigation is one of the important factors in onion production. Crop water requirement is greatly influenced by many soil and climatic factors. There are many, but often conflicting, reports available regarding the extent of irrigation requirement for onion. Some of the relevant literature are presented in this chapter.

Chaudhury and Erinne (1984) from Nigeria reported that irrigation at every 3 days produced the highest bulb yield (21.9 t/ha) and bulb size. The yield was lowest (7.0 t/ha) with irrigation at every 6 days. Irrigation at every 3 or 6 days increased bolting and decreased storage life, whereas 4 or 5 days' irrigation intervals generally kept bolting below 20% and storage losses were least. Peak soil water use was 7 weeks after planting.

Singh *et al.* (1987) in India, carried out trials with onion cv. Pusa Red. The crop was flood-irrigated and fertilized with N at 0, 60, 90 and 120 kg/ha. Half of the N was applied at transplanting and the remainder in 2 equal doses at 30 and 60 days after transplanting. The crop received 1, 2, 3 or 4 irrigations with 50 mm of water at 20-days' intervals. The highest bulb yield of 19.2 t/ha was obtained from 4 irrigations accompanied with 120 kg N/ha.

El-Kalla and El-Kassaby (1985) in Egypt conducted a two-year study on irrigation and fertilizer requirement of onion cv. Behairy. Plants irrigated 1-5 times received N at 190.0 kg/ha applied in different methods. The highest yield of marketable bulbs (31.0 t/ha) was obtained with 4 irrigations plus nitrogen application in two equal splits. First instalment of nitrogen was applied at 35-40 days after planting and second instalment was applied one month later.

Gorbatenko and Skripnikov (1979) carried out experiments with onions grown from seeds. Maintenance of soil moisture level at 90% of field capacity resulted in shallow penetration (10-30 cm) of the main root mass. At 70% of field capacity the main root mass was found in the 20-40 cm soil layer.

Chung (1989) reported effects of irrigation on the yield, size grade distribution, bulb quality, chemical composition and storage of bulbs. Applying irrigation throughout the season increased total bulb yield from 52 to 84 t/ha while withholding the last two irrigations prior to maturity reduced the bulb yield from 57 to 44 t/ha. Irrigation affected total bulb yield by influencing the size grade distribution. In this study, irrigation had no effect on the incidence of bulb defects such as skin cracking, doubles and thick neck but increased the level of wastage during storage. There was a trend for irrigation to decrease the bulb dry matter content but to increase the hardness of bulbs. Irrigation had no effect on the chemical composition.

Soares and Wanderly (1985) conducted a field trial in which two cultivars were compared with the following irrigation methods: (i) sprinkling, (ii) furrow irrigation, (iii) traditional basin flooding and (iv) basin flooding with the plants on beds. They found that basin methods gave the best mean yield. The authors reported that basin flooding method of irrigation caused high soil humidity which resulted in disease caused by *Colletotrichum gloeosporioides*.

Battilani and Lanzoni (1987) carried out an experiment with different fixed volumes and varying intervals of irrigation to find out the most suitable cultural co-efficient for an onion crop using an evapotranspiration pan. Determination of the watering volume was related to the quantity of water needed to reinstate a hypothetical thickness of soil explored by roots to field capacity. The intervals resulted from the daily evapotranspiration and thus from the time needed to consume the water available in the thickness considered. Onions respond strongly to irrigation with maximum evapotranspiration restitution greater than 100% and short watering intervals.

Hedge (1986) in India, carried out trials over 2 years with onion cv. Avka Pragti. The crop received 8 different irrigation treatments, at soil water potential from 0.45 to 0.65 bar. Application of irrigation resulted in maximum dry matter production, nutrient uptake and yield. Imposing soil moisture stress during early or late growing phases had an adverse effect on the 3 indices studied.

Trials were carried out by Bottcher *et al*. (1979) in Germany over 3 years under variable rainfall condition. Sprinkler irrigation (20 to 66.5 mm) increased the marketable yield about two times which was mainly due to increase in the diameter of the onions. Even in a wet year (263 mm rain) supplementary irrigation resulted in an extra yield. Sprinkling was most efficient when applied to a row width of 21 cm, allowing for a density of around 2 million plants/ha. Split N (80 kg N/ha) as a basal dressing prior to sowing and 50 kg as a top dressing were best for both yield and quality.

Kaniszewski and Perlowska (1988) irrigated onion at different soil moisture tension viz. 0.02, 0.04 or 0.06 M.Pa. In dry years (1982 and 1983), the highest yields were produced by irrigation applied at 0.02-0.04 M.Pa, but in the wet year (1981) irrigation did not increase yields. Irrigation produced greater yield increase on a mineral than on an organic soil. However, on both soils, it increased the size and improved the shape and uniformity of the bulbs. No cultivar differences in irrigation response were noted.

Perlowska and Kaniszewski (1988) reported that the soil moisture level during onion bulb growth had no effect on the number of skin layers or the health of stored onions. Irrigation increased the firmness of bulbs grown on a mineral soil but not on an organic soil. Cultivar Diana F_1 had firmer bulbs and showed better keeping qualities than cultivars Sochaczewska, Czerniakowska or Rivato. Crops grown on the mineral soil stored better than those grown on the organic soil.

Galbiatti and Castellane (1990) stated in their field trials with onion cultivar Piralopes, the plants received mineral fertilizer of $N:P_2O_5:K_2O$ at 30:240:115 kg/ha or the organic fertilizer that effluent resulting from anaerobic digestion of cattle manure of 60 m^3/ha, plus a control (no fertilization) and were irrigated at 25, 50, 100 or 125% of daily evapotranspiration (average of 5 mm). Mean bulb yield were 14.1, 14.2, 25.0 and 30.9 t/ha at the 4 respective irrigation levels, and 23.8, 21.8 and 17.7 t/ha with mineral, organic and no fertilization, respectively.

Karim *et al*. (1981) in an irrigation experiment on onion at Joydebpur, Gazipur obtained highest yield of bulb (12.6 t/ha) from 6 irrigations with a total amount of 17.92 cm water. The yield contributing parameters were largely influenced by irrigation frequency.

Narang and Dastane (1969) in India found that the optimum soil moisture requirement for onion was 0.65 bar tension at 8 cm soil depth.

Palled *et al*. (1988) in India conducted field experiments with the cv. Bellary Red during 1984 and 1985. They found that on an average irrigation based on an IW:CPE (Irrigation water: cumulative pan evaporation) ratio of 0.7 with 60 mm of water, increased the bulb yield by 8.0, 24.2 and 164.5 percent compared to irrigation based on IW:CPE ratios of 0.9, 0.5 and the unirrigated control, respectively. Application of 100 kg N/ha gave 12.2 and 26.4 percent higher yields than 75 and 50 kg N/ha, respectively. The consumptive use of water increased with increasing irrigation frequency but the maximum water use efficiency (38.3 kg ha^{-1} mm^{-1}) was recorded with an IW: CPE ratio of 0.7 over the 2 years.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at the Horticulture Farm of Bangladesh Agricultural University, Mymensingh during the period from October 25, 1990 to April 4, 1991.

Climate and Soil

Climate: The experimental site is situated in the subtropical climatic zone, characterized by heavy precipitation during the months from April to October and scanty precipitation during the rest of the months and weather remains more or less dry during the short duration of winter.

Soil: The soil of the experimental area belongs to the Sonatola series and AEZI Old Brahmaputra alluvial soil tract.

Soil texture was determined by Hydrometer method. Particle density of soil was determined by volumetric flask method. Bulk density of soil was determined by using core sampler. Particle density, bulk density and field capacity were 2.64 g/cm^3, 1.58 g/cm^3 and 28%, respectively. Particle size distributions of sand, silt, and clay were 60.0%, 32.0% and 8.0% respectively. Physical properties of the experimental soil are presented in Table 1.

TABLE 1. Physical properties of experimental soil

Sl. No.	Soil parameters	Inference	Methods/apparatus used
1.	Soil texture	Sand = 60% Silt = 32% Clay = 8%	Hydrometer method
2.	Field capacity (% moisture)	28.0	Field method
3.	Wilting point (% moisture)	18.0	According to Bruce and Vipond (1974)
4.	Soil pH	6.4	pH meter.
5.	Particle density (g/cm^3)	2.64	Volumetric flask method
6.	Bulk density (g/cm^3)	1.58	Core sampling method
8.	Porosity (%)	38.45	Relation between bulk density and particle density.

*Soil parameters were estimated in 0-12 cm depth.

Design and Treatment of the Experiment

The two factor experiment was laid out in a randomized block design with three replications. The plot size was 2m X 1m having a spacing of 80 cm between plots. The space between two blocks was 1m. Each plot was raised to 10 cm in height from the soil surface. Thick polythene sheet was used to surround each plot upto one meter depth in order to prevent seepage of irrigation water from plot to plot.

Following irrigation treatments were arranged in experimental plots:

F_1 = Irrigation at 15% depletion of available soil moisture (ASM);

F_2 = Irrigation at 30% depletion of ASM;

F_3 = Irrigation at 45% depletion of ASM;

D_{-1} = Each irrigation amount is equal to 5 mm less than that required in D_o;

D_o = Each irrigation amount is equal to the prevailing soil moisture depletion (SMD) in the root zone (40 cm) soil;

D_{+1} = Each irrigation amount is equal to 5 mm more than that required in D_o.

Variety

Onion cultivar Taherpuri was used in the experiment.

Sowing of Seeds

Seeds were sown in the seed beds on October 25, 1990. Proper manuring, thinning, watering and weeding were practised as and when necessary to raise healthy seedlings.

Land Preparation

The land was opened by a country plough in the 3rd week of December 1990 and ploughed several times to bring it to appropriate tilth. The weeds and stubbles were removed.

Transplanting of Seedlings

Healthy seedlings, after a slight trimming of leaves and roots, were transplanted to the experimental plots on 10 January 1991. The depth of transplanting was about 1.5 cm from the surface of the soil. Plant to plant spacing was 10 cm and row to row spacing was 20 cm.

Manures and Fertilizers

The crop was fertilized with well decomposed cowdung, urea, triple superphosphate (TSP) and muriate of potash (MP) at the following rates (Rashid, 1976).

Cowdung	10 t/ha
Urea	225 kg/ha
TSP	125 kg/ha
MP	150 kg/ha

Cowdung was incorporated into the soil during land preparation. Total doses of triple superphosphate, muriate of potash and 1/3 of urea were applied to the soil 7 days before transplanting. Rest of the urea were top dressed in two equal instalments, 3 and 5 weeks after the transplanting.

Intercultural Operations

Weeding and mulching were done regularly. Insecticides and fungicides were applied whenever necessary to control insect, pests and diseases.

Irrigation

Irrigation requirements (frequency and depth i.e. time to irrigate and quantity to be applied) were determined on the basis of soil moisture status in each treatment. Soil moisture was measured by neutron-scattering method using a neutron probe, manufactured by Nucletronics ApS (Copenhagen, Denmark). Regular probe reading was taken at 5 days interval from transplanting to harvesting. Plots under a frequency treatment were irrigated when the prevailing moisture status reached or fell just below the critical level of allowable depletion of ASM for that treatment.

Determination of Field Capacity

A small plot of 2m x 1m size, called the calibration plot, was selected at a corner of the experimental field in order to determine field capacity. This plot was surrounded by a 15 cm high bund. Two access tubes were installed in it and the plot was flooded for several hours, allowing water to infiltrate into the soil. As a result, the upper soil became saturated to some depth due to continuous infiltration. When the water on the surface just receded, the plot was covered by a polythene paper to prevent evaporation. Then neutron probe readings, called counts, were taken through the two access tubes regularly at 12 hours interval at depths of 10, 20 and 30 cm to monitor soil moisture changes. The initial counts, which corresponded to saturated condition, were higher. The subsequent counts became gradually smaller as the gravitational water drained down. After two days, the counts did not change indicating that the soil reached at field capacity. So, this value of count (count = 467) was considered to be corresponding to field capacity.

Calibration of Neutron Probe

When soil moisture reached at field capacity, polythene cover was removed from the calibration plot and the soil was allowed to dry by evaporation. Thereafter, neutron probe readings, accompanied by soil sampling, were taken at interval of several days. The moisture contents of the collected samples were determined by gravimetric method. Series of neutron probe reading, thus obtained, constitute the x values and the corresponding soil moisture contents (SMC) the y values of the calibration equation, defined by

$$y = a + bx \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

The x and y values are presented in Table 2, and details of calculations of SMC (%) on the basis of neutron probe reading (NPR) are presented in Appendix 5. The constants a and b of equation ... (1) are determined by least squares regression from the following equations.

$$b = \frac{\Sigma\, x_i y_i}{\Sigma\, x_i^2} = 0.06$$

$$\text{and} \quad a = \bar{y} - b\bar{x} = 0.0$$

The equation becomes

$$y = bx = 0.06x$$

At field capacity, neutron probe count (x = 467) corresponds to

$$y = 0.06 \times 467 = 28.02 \text{ percent of soil moisture (by weight).}$$

TABLE 2. Values of neutron probe count and corresponding soil moisture content (SMC) in percent

Count x	SMC (%) y
458	27.48
445	26.70
446	26.76
433	25.98
431	25.86
462	27.72
399	23.94

Calculation of Critical Soil Moisture Level

The soil of the experimental plot was sandy loam and the field capacity was determined to be 28 percent. Wilting point was assumed to be 18 percent for this texture (Bruce and Vipond, 1974).

So,

Soil moisture at field capacity (FC) = 28 percent.

Soil moisture at wilting point (WP) = 18 percent.

Available water (AW) = (FC-WP) percent.

The soil moisture content or critical level of moisture for treatment F_1 (allowing 15% depletion of ASM).

$= FC - (FC - WP)(15/100)$

$= 28 - (28 - 18)(0.15)$

$=$ 26.5 percent (by weight).

Similarly, soil moisture content or critical soil moisture levels for the treatments F_2 (30% depletion of ASM) and F_3 (45% depletion of ASM) treatments were calculated to be 25 percent and 23.5 percent by weight, respectively.

Determination of Irrigation Requirements

Root zone depth was considered to be 40 cm for onion (Bruce and Vipond, 1974).

At the time of irrigation, the amount of water to be applied was determined from the allowable soil moisture depletion (SMD) for any given treatment, the root zone depth (40 cm) and the soil bulk density, using the following equation.

$$d = \frac{(M_1 - M_2)\ D\ A}{100} \times 10$$

where,

d = Soil moisture depletion at the time of irrigation in mm.

M_1 = Soil moisture content at field capacity (percent).

M_2 = Critical level of moisture in each treatment (percent). [allowing percentage depletion of available water].

D = Depth of soil to be wetted (assumed root zone depth), cm.

A = Soil bulk density in g/cm^3.

10 = Conversion from cm to mm.

TABLE 3. Irrigation requirements for various treatments involving frequency and depth

Frequency	Depth	Amount of water to be applied (mm)
F_1 (allowing 15% depletion of ASM)	D_{-1}	5
	D_o	10
	D_{+1}	15
F_2 (allowing 30% depletion of ASM)	D_{-1}	15
	D_o	20
	D_{+1}	25
F_3 (allowing 45% depletion of ASM)	D_{-1}	25
	D_o	30
	D_{+1}	35

Calculation of Total Water Use:

The total water use of onion (consumptive use of water) was computed by adding the total amount of irrigation, the effective rainfall received during the growing season and the contribution of soil moisture. This may be expressed by the following relationship.

$$TWU = SWU + ER + IR$$

where,

TWU = total water use (mm)

SWU = soil water use (mm)

ER = effective rainfall (mm)

IR = total irrigation water applied (mm).

Effective rainfall estimate was calculated from the measured rainfall and the prevailing SMD (Appendix 6). If the rainfall is less than depletion, all of it will be effectively used. But if the amount of rainfall is more than the prevailing SMD, the plant will use only a part to cover the depletion. Soil water is defined as the reserve water in the soil. The quantity of soil water used by onion in each treatment was calculated by subtracting the soil moisture reserve in root zone prevailing at the time of harvest from that at the time of transplanting.

Harvesting

The matured crop was harvested on 4 April 1991. The maturity of the crop was ascertained by the sign of drying out of most of the leaves and the collapse of the tops at the neck.

Data Collection

Data were collected on the following characters:

1. Height of plant (cm): The height of plant from ground level to tip of the longest leaf.

2. Number of leaves per plant: Total number of leaves per plant at each time excluding the dead leaves.

3. Average length of leaves (cm): Total length of all the leaf blades, divided by the number of leaves per plant.

4. Bulb diameter (mm): Average diameter of bulb measured at the widest point.

5. Percent split bulb.

6. Percent grading of bulb.

7. Weight of bulb per plant (g).

8. Weight of bulb per plot (kg).

9. Yield of bulb per hectare (ton).

   Parameters in serial number 7-8 have been recorded during final harvest of the crop. Yield of bulb per hectare has been calculated from yield of bulb per plot in each treatment.

Statistical Analysis

The data of various plant characters were statistically analyzed to find out the level of significance in the variation resulted from the experimental treatments. The means of all treatments were calculated and the differences between treatment pairs were compared by least significant difference (LSD) test.

CHAPTER IV

RESULTS

This chapter includes the experimental results. In this section available soil moisture status, total water use of the crop and the response of plant characters to different frequency and depth of irrigation treatments are briefly presented.

Soil Moisture Status and Total Water Use

Soil moisture status, effective rainfall, irrigation and total water use of onion under different treatments are presented in Table 4. In experimental plots, soil moisture status varied depending upon natural precipitation or application of irrigation. Higher moisture content of soil was observed as and when it received water from irrigation or precipitation. Highest moisture status was observed in 15% depletion regime (F_1) with irrigation treatment at 5 mm more than the soil moisture depletion (SMD). Irrigation at 15% and 30% depletion regimes started on 22 January and 9 March respectively. Total number of irrigations applied in different treatments are shown in Appendix 3. Experimental plots under 45% depletion regimes with a depth of 5 mm less than the SMD, equal to SMD and a depth of 5 mm more than the SMD (i.e. F_3D_{-1}, F_3D_o and F_3D_{+1} treatment) never reached to the required critical level, and therefore, no irrigation was required to apply. The total water use (TWU) values varied with the variation of the amount of irrigation applied to the soil. The total water use of onion under different treatments are

TABLE 4. Total water use (TWU) of onion in different irrigation treatments

Frequency of irrigation	Depth of irrigation	SMC at the time of trans-planting (%)	SMC at the time of har-vesting (%)	Soil water use (mm)	Effec-tive rain-fall (mm)	Total irriga-tion water applied (mm)	Total water use (mm)
	5 mm less than the SMD (D_{-1})	26.28	24.84	9.1	67	60	136.1
15% depletion (F_1)	Equal to SMD (D_0)	27.36	25.56	11.4	67	110	188.4
	5 mm more than the SMD (D_{+1})	27.48	24.78	17.1	67	180	264.1
	5 mm less than the SMD (D_{-1})	26.22	24.78	9.1	67	15	91.1
30% depletion (F_2)	Equal to SMD (D_0)	26.64	24.48	13.7	67	100	180.7
	5 mm more than the SMD (D_{+1})	25.98	25.08	5.7	67	50	122.7
	5 mm less than the SMD (D_{-1})	26.34	24.36	12.5	67	-	79.5
45% depletion (F_3)	Equal to SMD (D_0)	26.64	24.00	16.7	67	-	83.7
	5 mm more than the SMD (D_{+1})	27.00	24.96	12.9	67	-	79.9

presented in Figure 1. The highest amount of water (Soil water + rain + irrigation) was 264.1 mm used by the onion at 15% depletion regime with a depth of 5 mm more than the SMD and the lowest amount of 79.5 mm being recorded at 45% depletion regime with a depth of 5 mm less than the SMD.

Effects on Growth and Yield

Effects of the frequency and depth of irrigation on onion growth and yield are presented in Table 5 and 6.

There was significant variation in the height of onion plant due to differences in the frequency of irrigation. Tallest plant was observed at 15% depletion regime while the shortest in 45% depletion regime. The depth of irrigation had no effect on the plant height. From the combined effects it was found that maximum plant height (37.0 cm) was produced by irrigation at 15% depletion along with an irrigation depth of 5 mm more than the SMD. This was closely followed by an irrigation depth equal to SMD, in the root zone, under the same irrigation frequency.

The number of leaves per plant varied from 7.6 to 5.4 in different treatments. However, statistical analysis showed no significant variations in the number of leaves due to differences in frequency and depth of irrigation. No significant interaction between frequency and depth of irrigation was observed with respect to number of leaves per plant.

Frequency of irrigation produced highly significant variation in the average length of leaves. Maximum length of leaves was found at 15% depletion which was statistically similar to that of 30% depletion regime. The depth of irrigation had no effect on the length of leaves. There was no significant interaction between frequency and depth of irrigation. However, from the combined effect, it was found that the highest length of leaves (25.1 cm) was produced by irrigation at 15% depletion with a depth 5 mm more than the SMD in the root zone (Table 6).

There was significant variation in the percent split bulb of onion due to differences in frequency and depth of irrigation (Table 5). Highest percentage of split bulb (30.9) was found in irrigation at 15% depletion. Percentage split bulb reduced significantly in higher depletion regimes. Increase in the depth of irrigation significantly increased the percent split bulb. Highest percent of split bulb (31.1) was observed at an irrigation depth of 5 mm more than the SMD. No significant interaction between frequency and depth of irrigation was observed in respect of percent split bulb of onion.

Frequency of irrigation had a highly significant effect on the diameter of onion bulb. The bulb diameter was higher with irrigation at 15% depletion than that irrigated at 30% and 45% depletions. Bulb diameter remained unaffected by the depth of irrigation. Maximum bulb diameter (51.5 mm) was obtained by irrigation at 15% depletion with a depth of 5 mm more than the SMD (Table 6). The second highest diameter was produced by the same frequency of irrigation along with a depth equal to the SMD. Increase in the depth of irrigation at 15% depletion regime caused a significant increase in bulb diameter. However, similar trend was not observed at higher depletion regimes.

The yield of onion bulb was significantly affected by the frequency and depth of irrigation. Maximum weight of bulb per plant (20.1g) was produced at 15% depletion regime which was significantly higher than those at 30% and 45% depletion regimes (Table 5). Increase in depth of irrigation has brought about an increase in the weight of bulbs per plant, however, there was no significant difference between the irrigation depths, equal to and 5 mm more than the SMD in the root zone.

The frequency and depth of irrigation had a significant interaction for the weight of bulb per plant. Increase in the depth of irrigation was more effective in increasing bulb weight at frequency treatment of 15% depletion of available soil moisture (ASM), while it was less responsive in frequency treatments of 30% and 45% depletions of ASM. Higher yield of onion bulbs per hectare was obtained from higher frequency and higher depth of irrigation. Irrigation at 15% depletion produced maximum yield. The interaction between frequency and depth of irrigation was highly significant in respect of yield per hectare. Increase in the depth of irrigation was found to be more effective at higher frequency of irrigation, particularly at 15% depletion regime. At this regime, the yields were similar when irrigated with depths of 5mm less than the SMD (8.6 t/ha) or equal to the SMD (8.8 t/ha). However, the yield per hectare increased to a maximum (12.4 t/ha) when irrigation water was applied at a depth of 5 mm more than the SMD in the root zone.

Effects on Bulb Size

Onion bulbs produced under different irrigation regimes and depth were graded according to their sizes. It was found that frequency of irrigation significantly affected size grades of onion bulb (Appendix 2). Higher percentages of A grade bulbs (>44 mm diameter) were produced at 15% depletion regime. The Table of combined effect of frequency and depth of irrigation revealed that maximum A grade bulbs (33.7%) was produced by irrigation at 15% depletion along with a irrigation depth 5 mm more than the SMD (Table 7).

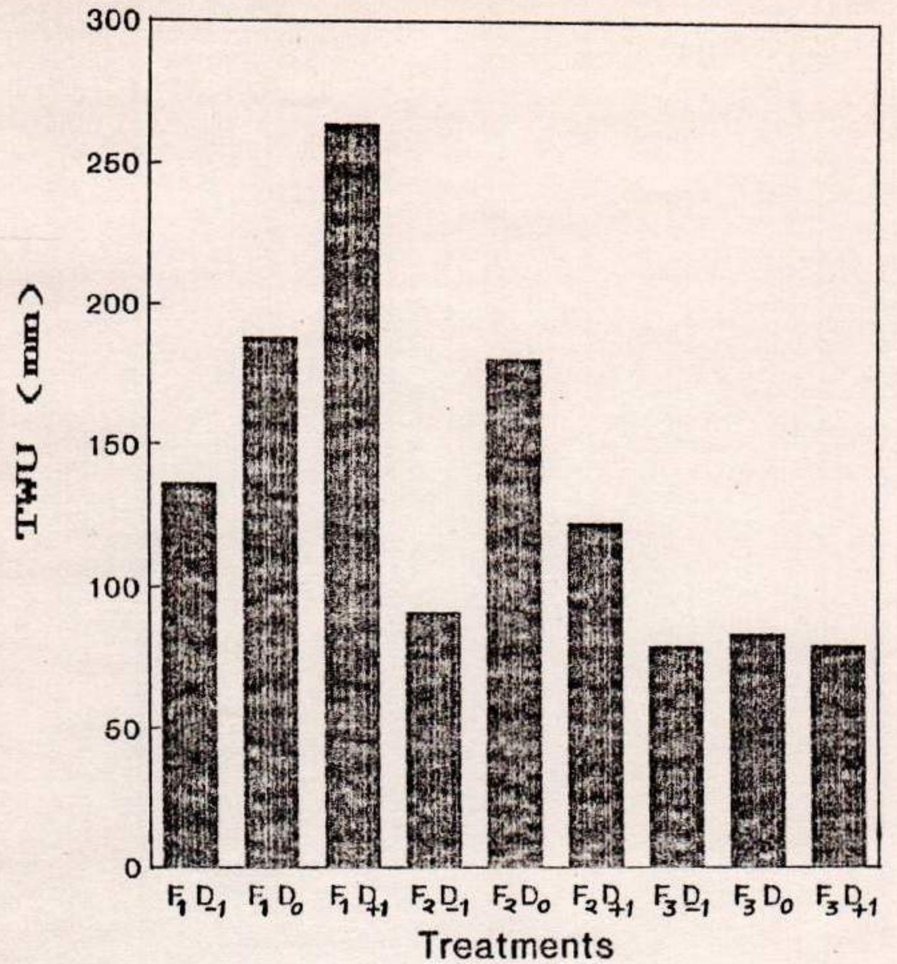

Fig. 1. **The total water use (TWU) of onion under different treatments.**

F_1 = Irrigation at 15% depletion of available soil moisture (ASM);

F_2 = Irrigation at 30% depletion of ASM;

F_3 = Irrigation at 45% depletion of ASM;

D_{-1} = Each irrigation amount is equal to 5 mm less than that required in D_o;

D_o = Each irrigation amount is equal to the prevailing soil moisture depletion (SMD) in the root zone (40 cm) soil;

D_{+1} = Each irrigation amount is equal to 5 mm more than that required in D_o.

TABLE 5. Main effects of frequency and depth of irrigation on growth and yield of onion

Frequency of irrigation	Height of plant (cm)	Number of leaves per plant	Average length of leaves (cm)	% split bulb*	Bulb diameter (mm)	Weight of bulb/plant (g)	Weight of bulb/plot (kg)	Bulb yield/ha (ton)
15% depletion (F_1)	35.9	7.1	24.7	30.9	48.3	20.1	2.0	9.9
30% depletion (F_2)	34.6	6.6	23.8	26.5	43.3	14.9	1.5	7.3
45% depletion (F_3)	31.9	6.0	22.0	23.4	42.2	14.8	1.5	7.2
LSD (0.05)	3.1	-	1.2	5.0	3.2	1.7	0.2	0.9
(0.01)	4.2	-	1.7	6.9	4.4	2.3	0.2	1.2
Level of significance	*	NS	**	*	**	**	**	**
Depth of irrigation								
5 mm less than the SMD (D_{-1})	33.5	6.6	23.3	24.2	43.7	15.4	1.5	7.6
Equal to SMD (D_0)	34.9	6.7	23.7	25.4	45.0	16.5	1.6	8.1
5 mm more than the SMD (D_{+1})	34.0	6.5	23.5	31.1	45.2	17.8	1.8	8.8
LSD (0.05)	-	-	-	5.0	-	1.7	0.2	0.9
(0.01)	-	-	-	6.9	-	2.3	0.2	1.2
Level of significance	NS	NS	NS	*	NS	*	*	*

*Arcsin transformed data.

TABLE 6. Combined effects of frequency and depth of irrigation on growth and yield of onion

Frequency of irrigation	Depth of irrigation	Height of plant (cm)	Number of leaves per plant	Average length of leaves (cm)	% split bulb*	Bulb diameter (mm)	Weight of bulb/plant (g)	Weight of bulb/plot (kg)	Bulb yield/ha (ton)
15% depletion (F_1)	5 mm less than the SMD (D_{-1})	34.2	6.7	24.0	28.5	42.5	17.4	1.7	8.6
	Equal to SMD (D_0)	36.6	6.9	24.9	26.1	51.0	17.9	1.8	8.8
	5 mm more than the SMD (D_{+1})	37.0	7.6	25.1	38.0	51.5	25.0	2.5	12.4
30% depletion (F_2)	5 mm less than the SMD (D_{-1})	33.5	6.7	23.0	23.1	44.5	13.3	1.3	6.4
	Equal to SMD (D_0)	35.6	6.7	23.8	24.1	41.5	15.9	1.5	7.6
	5 mm more than the SMD (D_{+1})	34.7	6.5	24.7	32.2	44.0	15.9	1.6	7.8
45% depletion (F_3)	5 mm less than the SMD (D_{-1})	32.9	6.2	23.0	21.0	44.0	15.7	1.5	7.7
	Equal to SMD (D_0)	32.4	6.5	22.3	26.1	42.5	16.2	1.6	8.0
	5 mm more than the SMD (D_{+1})	30.3	5.4	20.6	23.1	40.0	12.5	1.2	6.1
LSD (0.05)		5.3	1.6	2.1	8.7	5.6	2.9	0.3	1.5
(0.01)		7.3	2.2	2.9	12.0	7.7	4.1	0.4	2.1

*Arcsin transformed data.

TABLE 7. Percent grading of bulb under different treatments

Frequency of irrigation	Depth of irrigation	Grade (%)			
		A	B	C	D
15% depletion (F_1)	5 mm less than the SMD (D_{-1})	29.8	34.2	31.2	24.0
	Equal to SMD (D_o)	25.8	34.8	31.9	26.3
	5 mm more than the SMD (D_{+1})	33.7	34.3	30.5	19.3
30% depletion (F_2)	5 mm less than the SMD (D_{-1})	15.0	30.6	36.6	32.9
	Equal to SMD (D_o)	24.7	32.4	34.2	27.4
	5 mm more than the SMD (D_{+1})	23.1	32.9	33.5	28.8
45% depletion (F_3)	5 mm less than the SMD (D_{-1})	19.1	34.5	36.1	27.9
	Equal to SMD (D_o)	23.1	31.5	35.0	28.8
	5 mm more than the SMD (D_{+1})	13.7	31.2	39.9	30.3

Grade A (diameter > 44 mm)
Grade B (diameter 44 - > 33 mm)
Grade C (diameter 33 - > 21 mm)
Grade D (diameter 21 - < 21 mm)

*Arcsin transformed data.

CHAPTER V

DISCUSSION

Production of onion bulbs responds positively to irrigation. Several authors have studied the effects of irrigation on production of onion and attempted to quantity the irrigation requirement of this important spice crop (Battilani and Lanzoni, 1987.; Chaudhury and Erinne, 1984.; Chung, 1989.; Karim *et al*. 1981.; Singh *et al*. 1987). Frequency and quantity of irrigation water were found to vary depending upon cultivars and the climatic conditions (El-Kalla and El-Kassaby, 1985.; Hedge, 1986.; Kaniszewski and Perlowska, 1988.; Palled *et al*. 1988.; Perlowska and Kaniszewski, 1988.; Soares and Wanderly, 1985). In the present experiment, highest yield was obtained by irrigation at 15% depletion along with a depth of 5 mm more than the SMD. Irrigation was applied twelve times in this treatment during the period from 22 January to 23 March, 1991. The interval between two irrigations varied from 2-5 days unless there was water from natural rainfall (Appendix 3). Under the higher depletion regime of 30% ASM, application of irrigation ranged from 1 to 5 times at different depths where production of onion was significantly low. Under the present experimental condition 45% depletion regime was never reached. The crop growth in this plot was sustained by the availability of water from natural precipitation and reserve soil water. In fact, yields from 45% depletion regime was very close to 30% depletion regime. Noticeable increase in the yield was observed only in 15% depletion regime. The results of the present experiment indicates that onion cv. Taherpuri requires frequent irrigation in order to improve production.

It was interesting to note the responses of irrigation depth at higher frequency of application. Application of water upto depth of 5 mm more than the SMD was more conducive than lower depths. Thus it can be concluded that, to increase yield of onion, it should be irrigated at higher frequency with higher depths.

CHAPTER VI

SUMMARY

The experiment was carried out at the Horticulture farm of Bangladesh Agricultural University, Mymensingh during the period from October 1990 to April 1991 to study the effects of frequency and depth of irrigation on growth and yield of onion cv. Taherpuri. There were three different frequency levels of irrigation viz. 15%, 30% and 45% depletion of ASM and three different depths of irrigation viz. 5 mm less than, equal to and 5 mm more than the SMD in the root zone.

Seeds were sown in the seed bed on October 25, 1990 and seedlings were transplanted to the experimental plots on January 10, 1991. The experiment was laid out in randomized block design with three replications. The dimension of each plot was 2m X 1m having a spacing of 80 cm between plots. Plant to plant spacing was 10 cm and row to row spacing was 20 cm.

Soil moisture status of the experimental plot was monitored with neutron probe. The soil of the experimental plot was sandy loam and its bulk density was 1.58 g/cm^3. The field capacity of this soil was determined to be 28 percent.

Data were collected on different characters, such as height of plant, number of leaves per plant, average length of leaves, percent split bulb, bulb diameter, weight of bulb per plant, weight of bulb per plot, bulb yield per hectare, percent grading of bulb.

The results showed that the height of onion plant varied significantly due to differences in the frequency of irrigation. Maximum plant height (37.0 cm) was produced by irrigation at 15% depletion of ASM along with an irrigation depth of 5 mm more than the SMD. The number of leaves per plant varied from 5.4 to 7.6 in different treatments. Highest length of leaves (25.1 cm) was produced by irrigation at 15% depletion of ASM with a depth of 5 mm more than the SMD, which was statistically similar to that at 30% depletion regime. Highest percentage of split bulb (30.9) was found at 15% depletion. Percent split bulb reduced significantly in higher depletion regimes. Maximum bulb diameter (51.5 mm) was obtained by irrigation at 15% depletion of ASM with a depth of 5 mm more than the SMD. The yield of onion bulb was affected highly significant by the frequency and depth of irrigation. Maximum weight of bulb per plant (20.1g) was produced at 15% depletion regime, which was significantly higher than those at 30% and 45% depletion regimes. Increased yield of onion bulbs per hectare was obtained from higher frequency and higher depth of irrigation. Highest yield of bulbs (12.4 t/ha) was produced by irrigation at 15% depletion of ASM along with a depth of irrigation of 5 mm more than the SMD in the root zone.

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Appendix 1. Analysis of variance of the data on growth and yield of onion as influenced by depth and frequency of irrigation

		Mean sum squares							
Source of variance	Degree of freedom	Height of plant (cm)	Number of leaves per plant	Average length of leaves (cm)	% split bulb[1]	Bulb diameter (mm)	Weight of bulb/ plant (g)	Weight of bulb/ plot (kg)	Bulb yield/ha (ton)
Block	2	29.5	1.5	12.0**	314.6**	69.5**	50.8**	0.5**	12.6**
Treatment	8	13.9	1.1	6.2**	84.8*	48.3**	38.6**	0.4**	10.0**
Frequency (F)	2	39.1*	2.5	17.2**	125.4*	96.6**	82.7**	0.9**	21.6**
Depth (D)	2	4.3	0.1	0.3	122.7*	6.1	12.3*	0.1*	3.2*
F X D Interaction	4	6.1	0.7	3.8	45.5	45.3*	29.6**	0.3**	7.7**
Error	16	9.5	0.9	1.5	25.2	10.4	2.9	0.02	0.8

*Significant at 5% level of probability.
**Significant at 1% level of probability.
[1]Arcsin transformed data.

Appendix 2. Analysis of variance of the data on different grades of onion bulbs as influenced by frequency and depth of irrigation

Source of variance	Degree of freedom	Mean sum squares			
		% A grade	% B grade	% C grade	% D grade
Block	2	180.4*	43.6	194.8**	33.0
Treatment	8	126.9**	7.6	26.9	45.4*
Frequency	2	311.8**	15.8	77.9*	114.7**
Depth	2	24.8	0.2	2.6	10.4
F X D Interaction	4	85.5	7.2	13.5	28.2
Error	16	30.0	10.8	17.4	15.1

*Significant at 5% level of probability.
**Significant at 1% level of probability.

Grade A (diameter > 44 mm).
Grade B (diameter 44 - > 33 mm).
Grade C (diameter 33 - > 21 mm).
Grade D (diameter 21 - < 21 mm).

Appendix 3. Accounts of irrigation water applied

Frequency	15% depletion			30% depletion			45% depletion		
Depth	5mm less than the SMD (mm)	Equal to SMD (mm)	5mm more than the SMD (mm)	5mm less than the SMD (mm)	Equal to SMD (mm)	5mm more than the SMD (mm)	5mm less than the SMD (mm)	Equal to SMD (mm)	5mm more than the SMD (mm)
22.1.91	5	10	15	-	-	-	-	-	-
31.1.91	5	10	15	-	-	-	-	-	-
10.2.91	5	-	-	-	-	-	-	-	-
12.2.91	-	-	15	-	-	-	-	-	-
17.2.91	5	10	15	-	-	-	-	-	-
20.2.91	5	10	15	-	-	-	-	-	-
24.2.91	5	10	15	-	-	-	-	-	-
04.3.91	5	10	15	-	-	-	-	-	-
09.3.91	5	10	15	-	20	-	-	-	-
13.3.91	5	10	15	-	20	-	-	-	-
17.3.91	5	10	15	-	20	25	-	-	-
21.3.91	5	10	15	15	20	25	-	-	-
28.3.91	5	10	15	-	20	-	-	-	-
Total No. of irrigation applied	12	11	12	1	5	2	-	-	-

Appendix 4. Daily humidity, rainfall, pan evaporation during the experimental period

Date	January' 1991			February' 1991			March' 1991			April' 1991		
	Humidity (%)	Rainfall (mm)	Pan evaporation (mm)	Humidity (%)	Rainfall (mm)	Pan evaporation (mm)	Humidity (%)	Rainfall (mm)	Pan evaporation (mm)	Humidity (%)	Rainfall (mm)	Pan evaporation (mm)
1	78	-	1.6	82	5.8	2.5	75	-	3.7	85	2.5	4.4
2	83	1.0	1.5	87	-	2.3	73	-	3.3	87	-	3.9
3	88	0.4	1.2	89	2.0	2.1	63	-	5.5	88	-	4.4
4	80	-	3.2	86	7.1	1.5	66	-	3.6	82	1.6	4.6
5	79	-	2.0	81	-	2.9	72	-	3.4	86	0.2	4.5
6	72	-	3.2	76	-	3.2	65	-	5.0	85	-	3.6
7	75	-	2.9	76	-	2.0	60	-	5.3	84	12.2	2.6
8	71	-	2.2	81	-	2.0	62	-	3.5	81	-	5.7
9	73	-	2.1	76	-	1.9	63	-	4.2	85	6.2	3.0
10	82	-	1.0	77	-	2.3	68	-	3.0	83	16.8	4.7
11	78	-	2.3	79	-	3.1	78	-	4.0	74	-	3.9
12	76	-	1.5	85	-	1.3	72	-	5.0	73	-	5.7
13	75	-	1.5	75	-	3.9	79	9.0	3.2	74	-	5.0
14	64	-	3.5	64	-	3.4	70	-	5.7	71	-	4.9
15	60	-	3.4	62	-	5.3	72	-	4.1	80	-	7.1
16	61	-	3.0	63	-	3.8	71	-	5.2	63	-	6.3
17	69	-	2.5	67	-	3.4	70	-	4.9	58	-	6.0
18	76	-	2.3	70	-	4.6	66	-	4.0	54	-	6.5
19	71	-	1.5	71	-	2.6	64	-	6.7	60	-	4.5
20	68	-	1.8	70	-	5.7	67	-	4.8	54	-	8.2
21	71	-	1.6	66	-	4.7	66	-	5.7	77	-	4.3
22	71	-	1.3	71	-	3.3	65	-	5.4	73	-	5.4
23	71	-	1.8	78	-	3.3	67	-	2.3	79	-	7.3
24	65	-	3.1	72	-	2.5	86	17.8	0.9	80	5.0	6.5
25	75	-	3.1	74	-	3.0	83	-	2.3	83	-	5.0
26	70	-	2.1	66	-	4.7	70	-	4.6	81	-	5.1
27	66	-	2.7	66	-	5.0	76	-	4.5	75	-	6.9
28	70	-	3.2	73	2.4	1.6	71	-	4.6	74	-	6.1
29	73	-	2.9	-	-	-	76	14.6	4.7	82	1.2	2.1
30	77	-	3.2	-	-	-	81	-	2.4	76	-	2.4
31	78	-	1.6	-	-	-	85	5.8	4.1	-	-	-

Source: Weather Station, BAU Campus, Mymensingh.

Appendix 5. Average neutron probe reading (NPR) and soil moisture content (SMC) in percent

Treat-ment	F_1D_{-1} NPR	F_1D_{-1} SMC (%)	F_1D_0 NPR	F_1D_0 SMC (%)	F_1D_{+1} NPR	F_1D_{+1} SMC (%)	F_2D_{-1} NPR	F_2D_{-1} SMC (%)	F_2D_0 NPR	F_2D_0 SMC (%)	F_2D_{+1} NPR	F_2D_{+1} SMC (%)	F_3D_{-1} NPR	F_3D_{-1} SMC (%)	F_3D_0 NPR	F_3D_0 SMC (%)	F_3D_{+1} NPR	F_3D_{+1} SMC (%)
10.1.91	438	26.28	456	27.36	458	27.48	437	26.22	444	26.64	443	25.98	439	26.34	444	26.64	450	27.00
15.1.91	443	26.58	449	26.94	439	26.34	450	27.00	443	26.58	435	26.10	440	26.40	444	26.64	450	27.00
20.1.91	441	26.46	447	26.82	441	26.46	464	27.84	444	26.64	432	25.92	438	26.28	443	26.58	448	26.88
22.1.91	442	26.52	448	26.88	427	25.62	-	-	-	-	-	-	-	-	-	-	-	-
26.1.91	442	26.52	449	26.94	442	26.52	446	26.76	440	26.40	438	26.28	439	26.34	442	26.52	444	26.64
30.1.91	440	26.40	439	26.34	440	26.40	-	-	-	-	-	-	-	-	-	-	443	26.58
02.2.91	449	26.94	448	26.88	448	26.88	446	26.76	441	26.46	434	26.04	440	26.40	444	26.64	451	27.06
09.2.91	439	26.34	445	26.70	448	26.88	446	26.76	438	26.28	426	25.56	440	26.40	437	26.22	445	26.70
12.2.91	443	26.58	444	26.64	435	26.10	-	-	-	-	428	25.68	-	-	-	-	-	-
16.2.91	434	26.04	438	26.28	446	26.76	439	26.34	431	25.86	426	25.56	433	25.98	430	25.80	444	26.64
20.2.91	434	26.04	435	26.10	424	25.44	432	25.92	426	25.56	425	25.50	428	25.68	429	25.74	432	25.92
24.2.91	437	26.22	437	26.22	428	25.68	433	26.76	422	26.28	427	25.56	431	25.86	427	25.62	436	26.16
02.3.91	424	25.44	434	26.04	420	25.20	427	25.62	421	25.26	424	25.44	423	25.38	425	25.50	428	25.68
07.3.91	421	25.26	428	25.68	441	26.46	426	25.56	415	24.90	425	25.50	424	24.44	420	25.20	426	25.56
12.3.91	427	25.62	432	25.92	433	25.98	421	25.26	411	24.66	419	25.14	408	24.48	415	24.90	416	24.96
17.3.91	417	25.02	422	25.32	403	24.18	418	25.08	409	24.54	417	25.02	405	24.30	411	24.66	412	24.72
20.3.91	420	25.20	423	25.38	401	24.06	415	24.90	410	24.60	415	24.90	403	24.18	408	24.48	408	24.48
23.3.91	418	25.08	421	25.26	396	23.76	412	24.72	409	24.54	410	24.60	399	23.94	404	24.24	404	24.24
27.3.91	426	25.56	432	25.92	416	24.96	423	25.38	413	24.78	429	25.74	414	24.84	420	25.20	424	25.44
03.4.91	414	24.84	426	25.56	413	24.78	413	24.78	408	24.48	418	25.08	406	24.36	400	24.00	416	24.96

Appendix 6. Estimation of soil moisture depletion (SMD) and effective rainfall (ER)

Treatment		F_1D_{-1}		F_1D_0		F_1D_{+1}		F_2D_{-1}		F_2D_0		F_2D_{+1}		F_3D_{-1}		F_3D_0		F_3D_{+1}	
Date	Rain-fall (mm)	SMD (mm)	ER (mm)	SMD (mm)	ER (mm)	SMD (mm)	ER (mm)	SMD (mm)	ER (mm)	SMD (mm)	ER (mm)	SMD (mm)	ER (mm)	SMD (mm)	ER (mm)	SMD (mm)	ER (mm)	SMD (mm)	ER (mm)
01.2.91	5.8	13.5	5.8	13.8	5.8	13.5	5.8	12.7	5.8	14.9	5.8	15.7	5.8	15.3	5.8	14.2	5.8	13.3	5.8
03.2.91	2.0	8.3	2.0	8.7	2.0	8.7	2.0	9.5	2.0	11.3	2.0	14.7	2.0	11.7	2.0	10.2	2.0	7.6	2.0
04.2.91	7.1	7.8	7.1	8.2	7.1	8.2	7.1	9.0	7.1	10.8	7.1	13.5	7.1	11.2	7.1	9.7	7.1	7.1	7.1
28.2.91	2.4	16.5	2.4	11.7	2.4	19.9	2.4	13.4	2.4	16.1	2.4	20.7	2.4	18.8	2.4	20.3	2.4	16.9	2.4
13.3.91	9.0	18.5	9.0	16.7	9.0	16.3	9.0	20.8	9.0	24.6	9.0	21.6	9.0	25.8	9.0	23.1	9.0	22.7	9.0
24.3.91	17.8	20.1	17.8	18.9	17.8	28.4	17.8	22.3	17.8	23.5	17.8	23.1	17.8	27.3	17.8	25.4	17.8	25.4	17.8
29.3.91	14.6	21.8	14.6	19.5	14.6	25.6	14.6	22.9	14.6	26.7	14.6	20.6	14.6	26.3	14.6	24.0	14.6	22.5	14.6
31.3.91	5.8	12.2	5.8	9.9	5.8	16.0	5.8	13.3	5.8	17.1	5.8	11.0	5.8	16.7	5.8	14.4	5.8	12.9	5.8
01.4.91	2.5	9.3	2.5	7.0	2.5	13.1	2.5	10.4	2.5	14.2	2.5	18.1	2.5	13.8	2.5	11.5	2.5	10.0	2.5