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IRRIGATION WATER REQUIREMENT FOR MAIZE CROP CULTIVATION

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Abstract

Agriculture is one of the most important driving factors for the growth of economy of Bangladesh. So, in order to achieve a profitable, sustainable, and growing as well as environment friendly agricultural framework it is a must to ensure the food security for the people of Bangladesh. Alongside it is a huge challenging task for the Government to tackle the food demand of the huge population of Bangladesh. So it is very much important to increase the crop production per unit area to ensure the food security of the people from the limited land area. Maize which is the faster growing and high yielding cereal crop as well as the third most important cereal crop of Bangladesh can be cultivated to meet the demand of cereal crop in the country. In this research work a study was conducted during the dry season (Rabi) at Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur, to assess the irrigation water requirement of maize crop and to observe the impact of tillage methods on water use and maize yield. The outcome of the study suggested that two times (I_2) water application with zero (T_1) tillage, minimum (T_2) and traditional tillage (T_3) practices gives a substantial amount of yield with minimum water application which is a very resourceful finding for maize cultivation. The amount of yield changes from 7.133 ton/ha for I_1, 8.19 ton/ha for I_2 and 8.31 ton/ha for I_3 has been found from the field experiment.

Introduction

Bangladesh is predominately an agricultural country. Food security has been identified as a significant factor by the Government of Bangladesh contributing to its socio economic stabilization as well as development (Kashem et al. 2011). Food security of the huge population of Bangladesh is closely interrelated with agriculture. Moreover, agriculture is straightly interconnected to the concerns like poverty mitigation, raising of standard of living of people and increasing generation of employment. It is, therefore, important to have a profitable, sustainable and environment friendly agricultural system in order to ensure long term food security. Although Bangladesh is about to reach to a status of Middle Income Country by 2021, agriculture is still is the core employer in the country for its people. Around 47.5% of the population is directly involved in agricultural activities. Moreover, livelihood of around 70% of the population is dependent on agriculture in one form or another. The contribution to GDP from the agricultural sector was 12.65 percent in 2013-2014 Fiscal Year (FY). The percentage was 16.33 of GDP for the overall contribution of the broad agricultural sector (BER 2014).

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For achieving the Millennium Development Goals (MDGs) and post MDGs, and turning Bangladesh into a middle income country by 2021, the GDP has to grow at a minimum rate of 7% per year to achieve the goals of MDGs and post MDGs. Agricultural growth rate has to be kept at a constant rate of 4-4.5% per year to achieve this GDP growth rate by keeping pace with the growing population (Miah, 2015). Total factor productivity (TFP) indices capture the effect of improvements in technology as well as investments in rural infrastructures. It has been found from the empirical evidence that TFP of Bangladesh crop agriculture grew at an annual rate of 0.57% during the last few decades i.e. from 1948 to 2008 (Rahman and Salim 2013).

To ensure the food security of the population of this country from the limited land area, production per unit area must be increased with a faster rate of production. Since maize is the third most important cereal crop in Bangladesh as well as a faster growing and high yielding cereal crop can be cultivated to eliminate the shortage of cereal crop in this country. There was an insignificant amount of maize production in the early nineteenth decade in Bangladesh, but during 1997-98, about 2,834 hectares of land were under maize cultivation with a production of 3,000 metric tons (BBS 1999). The area was expanded to 1, 37,000 hectares and the corresponding production was 7, 83,640 metric ton up to 2007 (DAE 2007). Among different agricultural elements of Bangladesh, irrigation is the key input for achieving higher yield of maize. Although a large number of experimental works on irrigation had been carried out for the various crop production but a little amount of experiment on irrigation for maize cultivation with tillage treatments had been done in Bangladesh. Therefore, an attempt has been made to evaluate the effect of irrigation water with suitable tillage practices on the yield of maize in this research paper.

Previous studies

Hassan et al. (2003) monitored the maize and wheat cultivation on raised bed with irrigation. They showed that maize on raised beds consumed less irrigation water in comparison to basins. The water savings of raised beds over basins was ranged from 16% to 83%, with an average value of 32%. There were seasonal variations in irrigation depths because of different rainfall amounts and distributions in each season. The least irrigation water was applied in 2002 and555 mm rainfall was occurred. The number of irrigations applied was sometimes higher in raised beds but the amount of water applied in irrigation was always less than basins. The average amount of water per irrigation was 46 mm for beds and 78 mm for basins. The seasonal differences in total irrigation amount were varied because of the rainfall occurrences and its distribution over each period. Overall irrigation water applied to raise beds was probably the result of reduced evaporation, less wetted area and soil configuration in the raised beds, and over- irrigation in the basins. From the above experiment, it was found that in the raised bed irrigation for maize cultivation saved substantial amount of water in comparison to basin bed irrigation system for maize cultivation.

Islam et al. (2006) conducted an experiment at Regional Agricultural Research Station (RARS), Barisal, during Rabi season for the period of 2006-07 and 2007-08 to study the effect of different moisture regime and tillage on soil physical properties and its impact on the yield of wheat. Twenty treatments combinations comprising four tillage practices namely zero tillage (tillage by country plough having 5 to 6 cm depth), tillage by power tiller (10 to 12 cm depth), tillage by chisel (20 to 25 cm depth) and five levels of irrigation on the basis of IW/CPE ratio of 0.4, 0.6, 0.8, 1.0 and rain fed condition were tested in a split plot design with three replications. Irrigation and tillage had significantly influenced the yield and yield contributing characters of wheat. The highest yields were recorded as 4.5 t ha^{-1} and 4.6 t ha^{-1} with tillage (T_3) and irrigation (I_3), respectively. In case of the interaction effects of tillage and irrigation, the highest yields were recorded as 4.8 t ha^{-1} and 4.85 t ha^{-1} during 2006-07 and 2007-08, respectively from $T_3 I_3$. It was observed that the influence of tillage and/or irrigation had no significant effect on soil physical parameters during two years of conducting the experiment.

Methodology

A field experiment was conducted in the central research station of Bangladesh Agricultural Research Institute, Joydebpur, Gazipur during 2010-2011 to assess the water requirement for maize crop with various tillage practices mainly concerning to conservation of water for agricultural use. The experiment was set up in a Split Block Design (SBD) for tillage with a split plots arrangement of nine treatment combinations comprising of three replications. The unit plot size was 3m x 4m. Using the principle of 'randomization', each experimental plot was allocated a treatment such that a particular treatment did appear not more than once in a particular block considered in any direction. The layout plan of the experimental plots is shown in Figure1. Tillage practices have been assigned in the main plot and irrigations have been applied in the sub plots intensively since water saving is the main concern.

Treatment combination comprises of three methods of tillage T_1 (zero tillage or no tillage), T_2 (minimum tillage) and T_3 (traditional tillage practices). Also thee irrigation treatments which have been applied based on growth stages. BARI butta -6 seed were planted on 08 November, 2010. The maize was harvested on 06 April, 2011. The yield contributing characters were analyzed after harvesting. The yield contributing characters are plant height, grain per cob, 100 grains weight, numbers of plant per plot, line of grain per cob and number of cob per plant. The yield of maize per hectare was determined after threshing the maize.

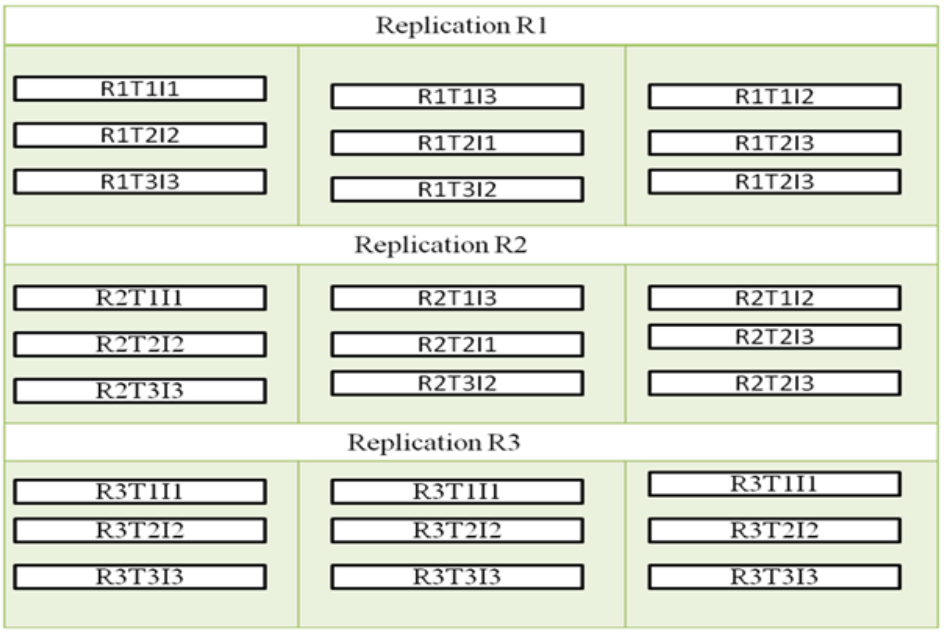


Figure 1. Layout of experiment

Design: SBD
No. of Treatments: 09
No. of Replication: 03
No. of Plots: 27
Size of Each Plot: 3m × 4m
[N.B: Drawings are not done in scale]

Land preparation and application of fertilizer

The land preparation was started one week prior to maize seeds sowing. At first, the selected land was flooded (02 cm) by applying water in sufficient amount to soften the soil and treated by using power tiller to facilitate tilling. When the field was tilled and maize seeds were sown; fertilizer was mixed properly. The dosages of fertilizer were applied according to FRG (Fertilizer Recommendation Guide) - 2005, Bangladesh Agricultural Research Council (BARC) recommendations. A sufficient amount of water (02 cm) was applied uniformly over the whole experimental field for the survival of maize seedling after seven days of sowing.

Irrigation water application

Volumetric method was used to determine the depth of irrigation water. Three types of irrigation treatments were applied based on growth stages depending on the root zone depth at different stages.

Three level of irrigation treatments were:
I_1 = only one time irrigation was applied at 25 days after sowing.

I_2 = Two times irrigation were applied at 25days after sowing and 50 days after sowing.
I_3 = Three times irrigation were applied at 25 days after sowing, 50 days after sowing and 85 days after sowing.

Irrigation water was applied according to BARI (2005) rules.
Depth of irrigation water required for soil to reach the field capacity was determined by the equation (1).

$$\square = \frac{\square\square\% - \square Ci\%}{100} \times \square\square \times \square \quad \text{eq. (1)}$$

Where,
d = Depth of water to be applied, cm; FC = Field capacity of the soil in%; MC_i = Moisture content of the soil at the time of irrigation in %; A_s = Apparent specific gravity; D = Root zone depth of maize crop, cm.

The application of irrigation water was carried out with bucket by measuring the water in volume (liter). The depth of water calculated by equation (1) was converted into liter (volume) by unit conversion.

No runoff and deep percolation were allowed since irrigation water was applied to reach the soil moisture up to field capacity. Weed was controlled manually with BARI invented weeder from each plot for two times during experiment. Soil moisture was measured before and after application of irrigation water by gravimetric method in each replication.

Tillage practices

Soil tillage is the manipulation of soil which is generally considered as necessary to obtain optimum growth conditions for all crops including maize. The growth of crops concerns about agricultural sustainability, environmental pollution, soil erosion and also tillage practice with proper management strategies and proper selection which can ensure optimum water use and reduction of runoff losses.

Three methods of tillage practices were used in the experiment. They were:

T_1 = Zero tillage/ no tillage (strip tillage) i.e. no disturbances of soil, only sowing operation which was carried out by power tiller operated inclined plate planter.

T_2 = Minimum tillage i.e. minimum tillage and sowing operation. Both were carried out simultaneously by power tiller operated inclined plate planter.

T_3 = Traditional tillage operation (farmers practices) i.e. three to four times tillage with power tiller and sowing operation. Sowing operation was carried out manually by hands.

Effects of water application on maize yield contributing characters

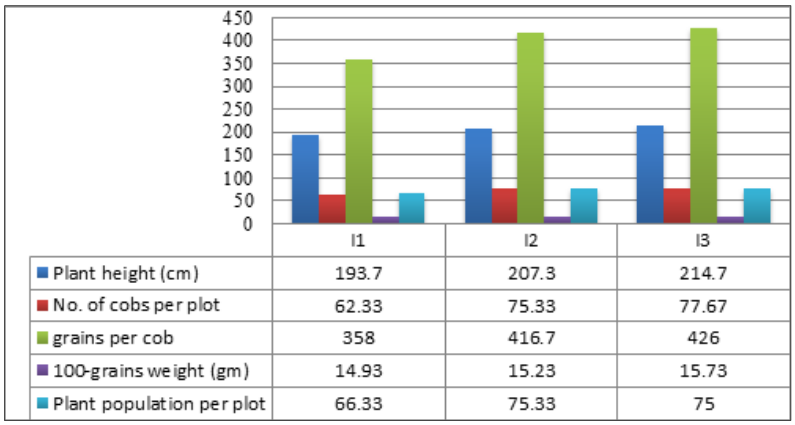
The effects of water application on the yield and yield contributing characters of maize have been shown in the Table 1 and Figure 2. The yield contributing characters of maize were significantly affected with the variations of water application. The lowest yield (7.133 ton/ha) was found in lowest amount of water application treatment (I_1). The maximum yield of maize was found 8.310 ton/ha in maximum amount of water application treatment (I_3). In I_2 treatment, the maize yield was recorded as 8.190 ton/ha that was the nearest value of I_3 irrigation treatment. The yield was increased rapidly with the increase of water application up to a certain level and then the yield was not sufficiently increased with the increased application of water.

Maximum plant height (214.7 cm) was found for I_3 irrigation treatment and minimum plant height (193.7 cm) was found in I_1 irrigation treatment. Number of plants per plot varies with the variation of water application up to a certain level and afterwards it does not depend on water application. Plants per plot were minimum (66) in one water application treatment (I_1) and the numbers were 75.33 and 75.00 in two (I_2) and three times (I_3) of water application treatment respectively. Maximum number of plants depends only on the availability of water, not on maximum number of water application. The maximum number of cob per plot was found in I_2 and I_3 treatments as 75.33 pieces and 77.67 pieces respectively and the lowest number of cobs 62.33 pieces was found in I_1 irrigation treatment shown in Table 1. Number of cobs was increased with the increase of water application. Maximum number of cobs does not indicate the higher yield because more than one cob in a single plant is unhealthy and it decreases yield. So, maximum water application does not give the maximum yield. Therefore, the optimum water application is required for maximum yield.

Maximum numbers of grains/cob were found in maximum water application that indicates little size of grains. So for greater yield and maximum benefit the optimum water application is essential. Another yield contributing character (100-grain weight) was found highest (15.73 gm) in I_3 irrigation practices which was very much similar with I_2 irrigation practices (15.23 gm) and lowest (14.93 gm) in I_1 irrigation practices.

Table1. Effect of water application on the yield and yield contributing characters of maize

Treatment	Plant height (cm)	Plants/ plot	Cobs/ plot	Grain/cob	100-grain weight (gm)	Yield (ton ha^{-1})
I_1	193.7	66.33	62.33	358.0	14.93	7.133
I_2	207.3	75.33	75.33	416.7	15.23	8.190
I_3	214.7	75.00	77.67	426.0	15.73	8.310



	I1	I2	I3
Plant height (cm)	193.7	207.3	214.7
No. of cobs per plot	62.33	75.33	77.67
grains per cob	358	416.7	426
100-grains weight (gm)	14.93	15.23	15.73
Plant population per plot	66.33	75.33	75

Figure 2. Effect of different amount of irrigation water on maize yields parameters

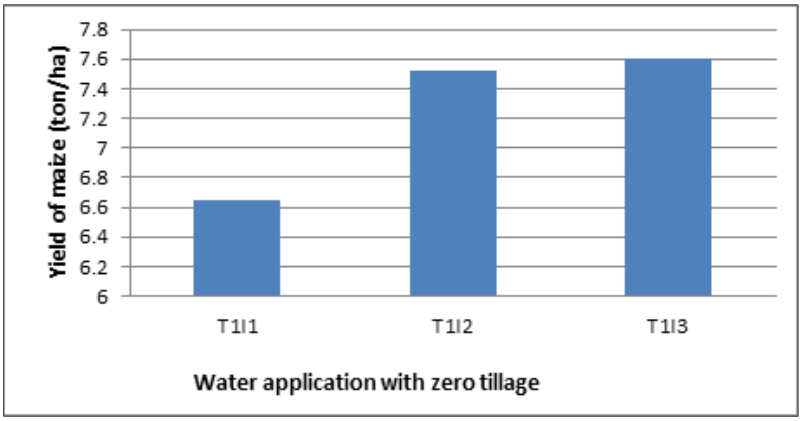


Figure 3. Effect of water with zero tillage on maize yield in the experiment

In zero tillage practice, three types of water applications were done. The three types of water applications were i) I_1 = one irrigation, ii) I_2 = two irrigation and iii) I_3 = three irrigation. The effects of irrigation on maize yields with zero tillage are presented in Figure 3. The maize yields were 6.65 t ha^{-1}, 7.52 t ha^{-1} and 7.6 t ha^{-1} for I_1, I_2 and I_3 irrigation treatments respectively. Maize yield of I_2 irrigation was statistically similar with I_3 irrigation except I_1 irrigation. Yield was increased with the increase of water application. One irrigation treatment practice with zero tillage is not suitable because the yield is lowest in this treatment combination. Two and three- times water application with zero tillage has nearly the similar effects on the maize yield.

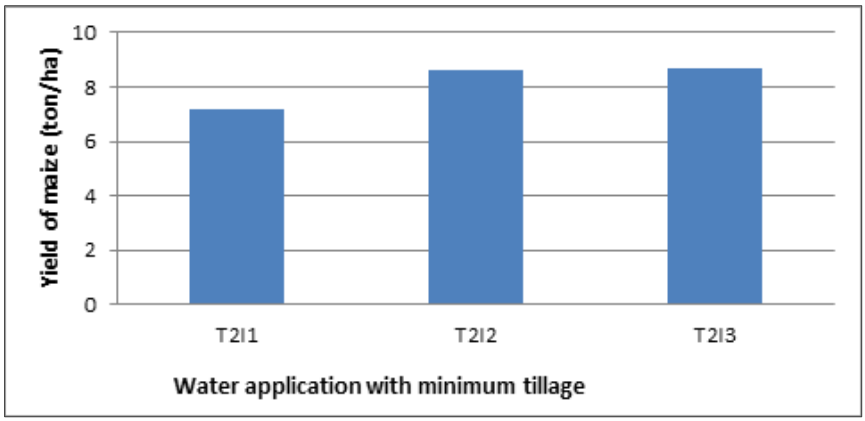


Figure 4. Effect of water with minimum tillage on maize yield in the experiment

In minimum tillage practice, the three level of irrigation water applied. The maize yield were 7.20 t ha^{-1}, 8.60 t ha^{-1} and 8.65 t ha^{-1} for I_1, I_2 and I_3 irrigation treatments respectively (Figure 4). Maize yield of I_2 irrigation was statistically very similar with I_3 irrigation except I_1 irrigation. A minor yield variation was found in two and three times water application. Minimum tillage with two times and three times water application gave the same results in yields and yield contributing characters of maize. The lowest amount of maize yield was recorded in minimum tillage with one time water application.

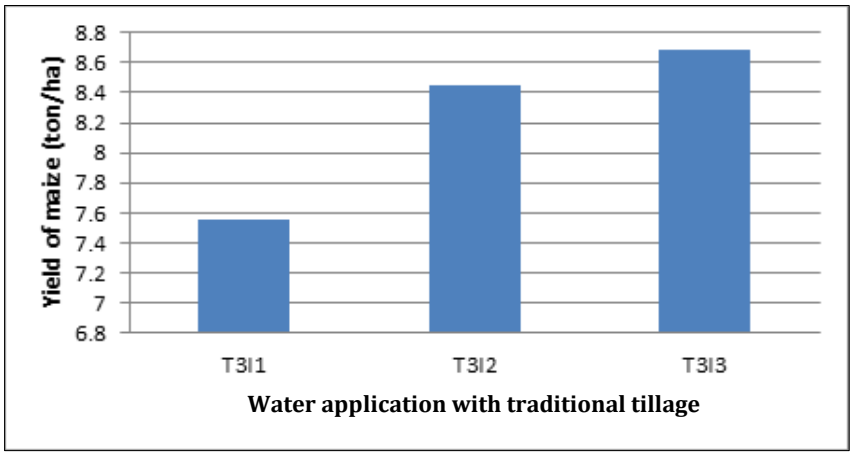


Figure 5. Effect of water with traditional tillage on maize yield in the experiment

Traditional tillage means five times tillage of soil and then sowing by hand which is a general practice of the farmers in our country. The effects of traditional tillage with one, two and three times water application for maize cultivation was observed. Traditional tillage with one time water application gave the lowest yield (7.55 t ha^{-1}) and the yields were 8.45 t ha^{-1} and 8.68 t ha^{-1} in two (I_2) and three times (I_3) water

application with traditional tillage (Figure 5). Two (I_2) and three (I_3) times water application with traditional tillage have given the very similar results in yield and yield contributing characters. The yield was increased rapidly from one time water application to two times water application. The yield did not increase substantially from two times (I_2) water application to three times (I_3) water application. This result indicates the more water application is not beneficial for maize cultivation. One time (I_1) water application is also not sufficient water application for maize production because the yield is not substantial in one time water application.

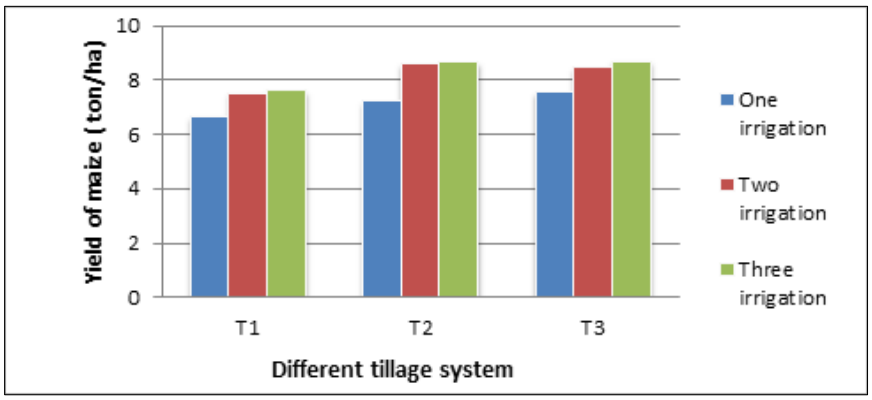


Figure 6. Effect of irrigation on maize yields with different tillage practices

The effects of tillage system with three levels of water application on maize yield were observed. The three types of tillage system were zero tillage (T_1), minimum tillage (T_2) and Traditional tillage (T_3) and three levels of water application were one time (I_1) water application, two times (I_2) water application and three times (I_3) water application. In every tillage system, the lowest yield was found in one time water application and the highest yield was found in three times water application. The yield for two times water application was very much similar with three times water application in each type of tillage system. The yield of maize was varied with the different amount of water application (Figure 6).

Conclusions

The rationale use of water for agriculture is a dire need at present days because the useable water resource is diminishing very rapidly. Therefore, the scientific application of water in agriculture sector is important for saving the water resources and for minimizing of cost of agricultural production. The cultivation of high yielding grain crops like maize is very important to meet the need of cereal grains for the people. From this research paper, it can be revealed that irrigation water has a significant effect on maize yield and yield contributing characters. Plant height, plant population, cobs per plot, grains per cob, 100-grain weight and yield has been affected significantly by the variation of water application. Unsatisfactory and poor results of maize yield contributing characters were found for one time (I_1) water application. The higher values of maize yield contributing characters were found for

three times (I_3) water application. Satisfactory results of maize yield contributing characters were also found for two times (I_2) water application. I_3 (three times water application) irrigation was sufficient for higher yield maize cultivation but a huge amount of water was required in this practices. Statistically same significance for maize yield contributing characters was found in two times (I_2) and three times (I_3) water application. Among the three irrigation practices (I_1, I_2 and I_3) I_2 irrigation practice (irrigation applied two times, 25 days after sowing and 50 days after sowing) was found as preferable water application practice for maize cultivation in dry season of Bangladesh. Tillage has significant effects on maize yield and maize yield contributing characters. T_1 (zero) tillage is not preferable because lowest amount of yield has been found in zero tillage treatment. Statistically same effect was found on maize yield for minimum tillage (T_2) practice and traditional tillage (T_3) practice. Two times (I_2) water application with zero (T_1), minimum (T_2) and traditional tillage (T_3) practices gave a substantial amount of yield with minimum water application.

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