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Maximising water productivity of wheat crop by adopting drip irrigation

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ABSTRACT

The research work was carried out at ICAR-Central Institute of Agricultural Engineering, Bhopal during 2011-14. The data were collected using standard procedure and were analyzed by using Fisher's analysis of variance technique of RBD. Initial interest in the use of drip irrigation for row crops like wheat was motivated by its very low water productivity with traditional methods of irrigation. Maximizing water productivity is one of the most important priorities in developing countries like India, where the ground water levels are at alarming stage. Therefore, the aim of this study was to estimate the wheat yield in response to change in drip emitter spacing and compare the water productivity and water saving with conventional irrigated systems. Five irrigation treatments were considered in the present experiment. The treatment details were : T_1 : Conventional practices, T_2 : System of wheat intensification, T_3 : System of wheat intensification with drip emitters spaced at 20 cm, T_4 : System of wheat intensification with drip emitters spaced at 30 cm and T_5 : System of wheat intensification with drip emitters spaced at 40 cm. The greatest plantheight, number of tillers per metre square, number of effective tillers, chlorophyll content and root length were recorded under SWI with drip irrigation at 20 cm emitters spacing (T_3). Yield and yield contributing parameters were also higher with T_3 as compared with conventional practice (T_1) viz., number of grains per earhead,average earhead length, average earhead weight, average grain yield, straw yield and harvest index.Among the drip irrigation treatments, however, there was no significant difference of grain yield between T_3 and T_4 treatments indicating the drippers spaced at 30 cm could be recommended to lower the cost of the drip system in wheat crop.

Key words : Conventional practice, drip irrigation, system of wheat intensification (SWI), water productivity, wheat

INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the most important staple food grains of human race. India produced 95.4 million tonnes of wheat during the year 2015-16 and total productivity of Madhya Pradesh during 2014 was 20 q/ha. It is the second largest producer of wheat in the world. India is also the second largest in wheat consumption after China. Wheat contributes substantially to the national food security by providing more than 50% of the calories to the people who mainly depend on it (Anonymous, 2015).

Presently in India, area under wheat crop is irrigated by border irrigation, with very poor water use efficiency of about 66.5% (Zerihun *et al.*, 2005) because of huge conveyance and distribution losses (INCID, 1994; Rosegrant, 1997). India's water resources are facing extreme stress particularly in the context of agriculture. The country sustains 16% of the world's human population and 20% livestock population with just 3% of the world's water (Chauhan and Yadav, 2012). With changing lifestyles and rising water consumption in urban areas, water for agriculture is under threat from other users.

Micro irrigation (MI) is one of the demand management strategies to control water consumption in Indian agriculture which includes mainly drip and sprinkler irrigation method. Drip irrigation is most efficient among all the irrigation methods and reported to help in achieving yield gains of up to 100% and water savings of up to 40-80%. It also increases water use efficiency and saves associated fertilizer, pesticide, and labor. (Burney *et al.*, 2009; Lodhi *et al.*, 2014; Kumari *et al.*, 2014). Drip irrigation can be practiced successfully to irrigate wide range of crops especially in vegetables, orchard crops, flowers and plantation crops but on the other hand, limited studies had been conducted under field crops like wheat. Drip irrigation saves more than 20 percent of irrigation water (Kharrou *et al.*, 2011) as compared to surface irrigation in wheat crop, and for producing 1 kg of wheat about 1000 lit of irrigation water is required (Hoff, 2004). For total wheat production of India we can save 18976 Mm^3 of water per year by adopting drip irrigation method in wheat crop.

Only few studies have been carried out on the feasibility of drip irrigation systems (surface and subsurface drip); for the intensive field crop conditions (Camp, 1998; Alam *et al.,* 2000; Suarez-Rey *et al.*, 2000; Arafa *et al.,* 2009; Rahman *et al.,* 2009; Abdelraouf *et al.,* 2011).

MATERIALS AND METHODS

The research work was carried out at the Central Institute of Agricultural Engineering, Bhopal. Soils of the experimental site were classified as heavy clay soils with clay content varying between 49.7 to 53.7% and with the field capacity ranging from 28.5 to 31% which was situated at north of Bhopal at 77° 24′10″ E, 23°18′35″ N at an elevation of 495 m above mean sea level. The climate of Bhopal was pleasant throughout the year. During winter, ambient temperature varied between 10°C and 25°C and in summer between 25°C and 44°C. The annual rainfall in the region was about 1200 mm.

In order to achieve the objectives of the study, two irrigation methods were investigated "Flood irrigation method and surface drip irrigation method" and the wheat variety HI-1544 was used in the experiment. A field experiment with five treatments was carried out under flood irrigation two treatments based on T_1–Conventional practices, T_2–System of wheat intensification and under drip irrigation three treatments based on emitter spacing were T_3–System of wheat intensification with drip emitters spaced at 20 cm, T_4–System of wheat intensification with drip emitters spaced at 30 cm and T_5–System of wheat intensification with drip emitters spaced at 40 cm with four replications (Plate 1).

Field preparation including primary and secondary tillage operations were carried out before sowing of the wheat. One day old pre-germinated seeds were sown manually in T_2, T_3, T_4 and T_5 treatments at 25 x 25 cm spacing with single seed per hill and a seed rate of 10 kg/ha. Sowing in T_1 was carried out on at a spacing of 20 x 10 cm with single seed and the seed rate of about 100 kg/ha. The date of sowing for all the treatments was the same. Each treatment plot was replicated four times.

Plate 1. Overall view of wheat crop in different treatments.

Inorganic fertilizers were applied in all the plots with the recommended doses of 120 kg N, 60 kg P_2O_5 and 80 kg K_2O/ha in the form of urea, DAP and MOP, respectively. Half of the recommended dose of nitrogen and all of the phosphorus and potash were applied at the time of sowing, while the remaining N was applied at the time of tillering through broadcasting in T_1 and T_2 treatments and through the drip irrigation system in T_3, T_4 and T_5 treatments using water-soluble fertilizers. Rates and kinds of soil nutrient supplementation were thus not a variable in this experiment.

Immediately after crop establishment, five plants were randomly selected from each plot to be used for recording plant height, number of tillers, number of effective tillers, root length, earhead length, earhead weight, number of grains per earhead, 1000-grain weight, grain yield and straw yield. Plant height was measured by the meter scale from the ground surface to the top of the crop. Chlorophyll content, an indication of the growth status of the crop, was measured on 60 days after transplanting by SPAD meter. Root sample after 60 DAS was collected from different treatments by using auger. Debris and dead roots were manually removed from vital roots. Roots kept for deep soaking in saturated NACL (winRHIZO method) for one night. After drying, roots were placed on plane surface and then measured their length by meter scale. Soil temperature was measured by soil thermometer at a depth of 10 cm. The data collected were analyzed by using Fisher's analysis of variance technique, and RBD test with the confidence level set at 5% was used to compare the differences among treatment means (Chouhan *et al.*, 2015).

Wheat crop under drip irrigation system was irrigated as per crop water requirement advocated by FAO. The control valve of a particular treatment was opened for a calculated time so that required depth of irrigation will be supplied to the plot. Under flood irrigation method, five irrigations at critical stages were given to the wheat crop. A total 14.6 cm depth of irrigation water was applied to the treatments under drip irrigation system (T_3, T_4 and T_5) by operating the system for 15, 23 and 30 min, respectively. Whereas a total of 41.5 and 38.2 cm depth of irrigation was applied under conventional irrigation (i. e. T_1 and T_2, respectively). Weeds were controlled by manual weeding.

Layout of Experimental Design

An overhead tank was used as a water source for irrigation. Main line was of PVC pipes with 90 mm in diameter (OD) to convey the water from the source to the main control points in the field. Sub-main lines with 75 mm diameter (OD) were connected to the main and delivered irrigation water through LDPE laterals of 16 mm (OD) with 20 m length, built-in drippers with discharge of 2 lph at different spacings of 20, 30 and 40 cm at 1.0 bar operating pressure. The layout details of the experimental design are shown as in Fig. 1.

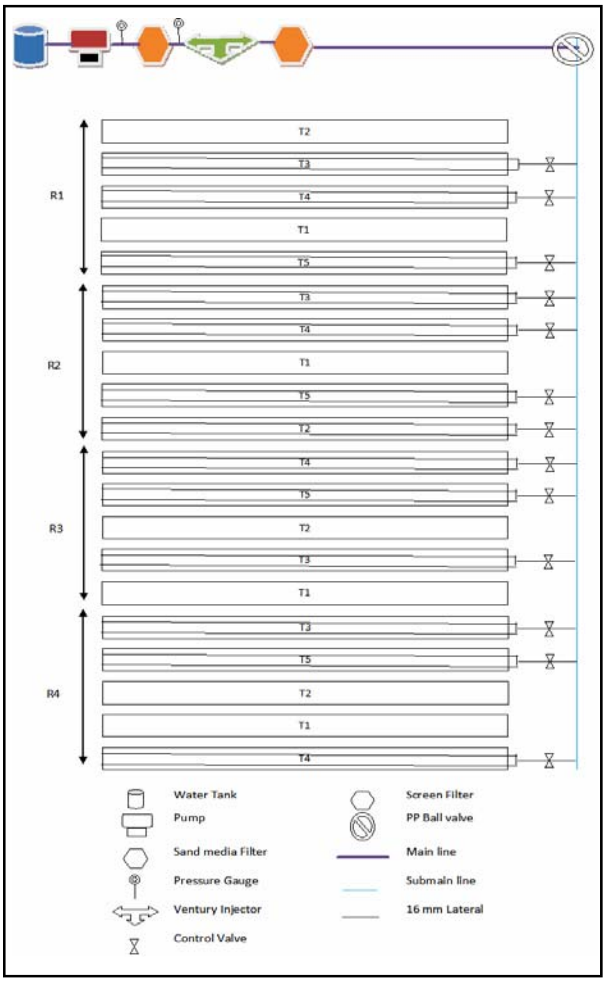

Fig. 1. Layout of experimental field.

RESULTS AND DISCUSSION

Growth Contributing Parameters

Influence of different treatments on wheat crop on growth parameters is given in Table 1. The different irrigation practices along with associated crop management had a significant effect on plant height. The greatest plant height was recorded in treatment T_3 (96.25 cm) possibly due to the optimizing plant population and geometry under SWI with drip emitter spaced at 20 cm which gave more even distribution of water to the plants. However, soil temperature did not significantly vary across the different treatments. Chlorophyll

Table 1. Influence of growth contributing parameters by different irrigation practices

Treatment	Plant height at maturity (cm)	Soil temperature (°C)	SPAD value at 60 DAS	Root length (cm) at 60 DAS
T_1	89.35	32.80	42.20	14.25
T_2	92.50	33.24	42.40	14.67
T_3	96.25	33.47	43.38	17.50
T_4	94.50	33.20	43.08	16.25
T_5	93.40	33.00	43.37	16.00
S. Em±	0.67	0.08	0.10	0.09
C. D. (P=0.05)	2.07	NS	0.32	0.30

NS : Not Significant.

values as measured by a SPAD meter and highest SPAD value measured under T_3 (43.38) followed by T_4 (43.05) and there were no significant differences between T_1 and T_2 and T_3 and T_4. Root length was also greatest under T_3 (17.50 cm), at par with T_4 (16.25 cm) and T_5 (16.00 cm) which was significantly influenced in T_1 and T_2 and there was no significant difference between T_4 and T_5 treatments.

Yield Contributing Parameters

It has been seen in many studies that flooding is not the most favourable condition for growing wheat crop. Drip irrigation technology reduces the amount of irrigation and improves yield (Liao *et al.,* 2008; Wang *et al.,* 2010, 2011). The finding of the present study confirms that different irrigation methods and regimes have a significant influence on crop yield parameters. System of wheat intensification methods adopted with drip irrigation emitters spaced 20 cm apart, gave the greatest number of tillers/m^2 recorded under T_3 (476) followed by T_4 (464) and T_5 (452) (Plate 2). Lowest number of tillers was recorded in T_1 (432). Maximum number of effective tillers per square meter was recorded in T_3 (460) but no difference between T_4 and T_5. Also the highest grains per earhead (61.05) and earhead weight (3.50 g) were recorded under T_3 followed by T_4, T_5, T_2 and T_1 as seen in Table 2.

T_1 **T_2** **T_3** **T_4** **T_5**

Plate 2. Wheat crop tillers under different treatments (side view).

Table 2. Yield and yield contributing characters influenced by different irrigation practices

Treatment	No. of tillers/m^2	Earhead weight (g)	No. of effective tillers/m^2	No. of grains/ ear	1000-grain weight (g)	Grain yield (t/ha)	Straw yield (t/ha)	Harvest index (%)
T_1	432	2.65	426	52.30	44.30	4.51	5.62	44.53
T_2	444	2.50	433	56.25	45.82	4.85	5.85	45.34
T_3	476	3.50	460	61.05	46.69	5.61	6.08	47.98
T_4	464	3.12	453	60.25	46.42	5.44	6.04	47.34
T_5	452	2.87	444	60.00	46.22	5.33	5.93	47.30
S. Em±	8.00	0.05	5.37	0.13	0.24	0.03	0.09	0.08
C. D. (P=0.05)	24.66	0.16	16.54	0.39	0.74	0.10	0.28	0.23

These findings are consistent with the results reported by Wang *et al.* (2013 a,b) indicating that in the excessive irrigation in the grain filling stage, the grain nutrition supply reduces, eventually leads to decrease in grain weight Further analysis of wheat yield components showed that earheads and number of grains per earhead and ear weight were also sensitive to different methods of irrigation application, which was reflected in highest 1000-grain weight, harvest in drip irrigated treatment of T_3 and were significantly higher over T_1 and T_2 treatments, however, not much significant difference between T_4 and T_5 treatments. Grain yield (t/ha) was greatest under T_3 followed by T_4 and T_5 than T_2 and T_1. SWI method cultural practice with drip emitters at 20 cm spacing gave the highest grain yield of 5.61 t/ha, while conventional practices (T_1) with flood irrigation resulted in the lowest grain yield of 4.51 t/ha and straw yield was highest in T_3 and at par with T_4 and T_5.

Water Productivity and Water Energy Productivity

Water productivity is the amount of grain yield obtained per unit of irrigation water supplied to the crop. Water-energy productivity is the amount of grain yield that is obtained from a unit of energy (kWh) consumed during the irrigation. Fig. 2 shows that water productivity decreases as emitter spacing increases and is found minimum in treatment T_1 (1.05 kg/m^3). The magnitude of mean values was in order $T_1 \cong T_2 < T_5 < T_4 < T_3$. This may be due to the higher water losses in deep percolation and in evaporation from the soil in conventional irrigation. From the analysis, it reveals other fact that the good management of irrigation water leads to high water productivity and could be achieved by saving irrigation water under drip irrigation (Chouhan *et al.*, 2015). Water productivity was highest under T_3 (3.25 kg/m^3) followed by T_4 (3.21 kg/m^3). However, among the treatments, T_3, T_4 and T_5, the calculated differences in water productivity and water-energy productivity were not significant.

Economics of Drip Irrigated Wheat

The highest net returns (Rs. 49513.4/ ha/year) were obtained under SWI with drip irrigation emitter spaced at 20 cm followed by SWI with drip irrigation emitter spaced at 30 cm (Table 3). In case of treatments, T_3, T_4 and T_5 included only the 20% cost of drip irrigation system with the assumption of the fact that the life of drip irrigation system was around 10 years, and the same system could be utilized for irrigation in other field/horticultural crops after harvesting of wheat crop.

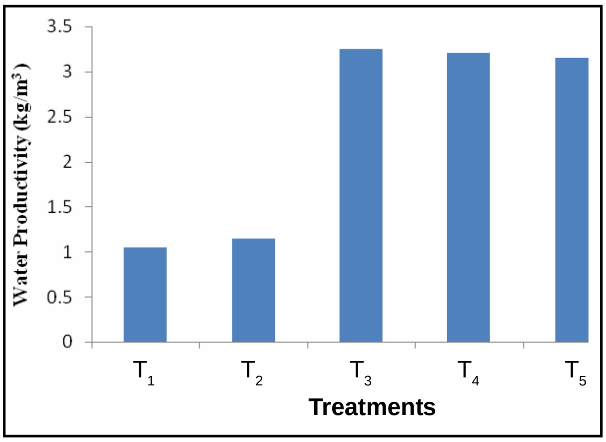

Fig. 2. Effect of different treatments on water productivity.

CONCLUSION

The present study found consistent evidence that the adaptation of drip irrigation combined with wheat sowing and managed according to system of wheat intensification practices offered substantial agronomic and economic advantages. Plant growth and yield contributing parameters such as number of tillers per square meter, number of effective tillers, number of grains per earhead, earhead weight, earhead length, grain yield, straw yield and harvest index were found to be significantly higher in drip irrigated treatments. Apart from water productivity and water energy productivity both were higher in case of drip irrigated wheat cultivation with young seed sowing at 25 x 25 cm spacing with drip emitters spaced at 20 cm.

Among the drip irrigated treatments, there was no significant difference in grain yield between the T_3 and T_4 treatments which indicated that spacing drippers at 30 cm could be recommended as the cost of installing a drip system would be relatively cheaper with more widely spaced drippers. These results were further tested with further experimentation and

Table 3. Economics of wheat cultivation with drip irrigation system over conventional irrigation

Treatment	Cost of cultivation (Rs./ha/year)	Gross monetary returns (Rs./ha/year)	Net monetary returns (Rs./ha/year)	B : C ratio
T_1	22071.0	67725	45654.0	3.06
T_2	29844.0	72735	42891.0	2.43
T_3	34550.0	84180	49513.4	2.42
T_4	34150.0	81540	47413.4	2.38
T_5	33750.0	79920	46063.4	2.36

Assumption : Rs. 1500/q grain yield.

evaluation because the implications of this work could be rather far reaching. The evidence assembled and analyzed here suggested that system of wheat intensification crop management with drip irrigation was a promising adaptation for reducing the wheat crop's demand for water and energy, which are increasingly demanded and costly, while the same time it raised grain yield. However, long term multi-location trials will be needed to arrive at percentage of water and energy saving that are achievable under varied and specific conditions.

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