

## Growth and yield of wheat (*Triticum aestivum*) as influenced by irrigation scheduling and organic manures under Semi-arid Eastern Plain Zone of Rajasthan

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### ABSTRACT

A field experiment was conducted under loamy sand soil during the winter (*rabi*) seasons of 2014–15 and 2015–16 at Jobner, Rajasthan, to study the effect of irrigation scheduling and organic manures on growth and yield of wheat (*Triticum aestivum* L.). The treatments, consisting of 5 irrigation scheduling, i.e. I<sub>1</sub> (irrigation at critical stages), I<sub>2</sub> [0.9 irrigation water: cumulative pan evaporation (IW:CPE) ratio], I<sub>3</sub> (0.6 IW:CPE ratio at vegetative phase + 0.8 IW:CPE ratio at reproductive phase), I<sub>4</sub> (0.6 IW:CPE ratio at vegetative phase + 1.0 IW:CPE ratio at reproductive phase) and I<sub>5</sub> (0.8 IW:CPE ratio at vegetative phase + 1.0 IW:CPE ratio at reproductive phase) in main plots, and 4 organic manures [control, FYM @ 15 t/ha, vermicompost (VC) @ 6 t/ha and FYM @ 7.5 t + VC @ 3 t/ha] in subplots, were replicated 4 times in split-plot design. The pooled mean results showed that irrigation applied at an 0.9 IW:CPE ratio (I<sub>2</sub>) recorded the maximum values of growth parameters (dry-matter accumulation and functional leaves) and yield (grain, straw, biological and harvest index) proved significantly superior to I<sub>1</sub>, I<sub>4</sub> and I<sub>3</sub>. However, the treatment I<sub>5</sub> with maximum plant height also remained equally effective with regard to above parameters. With regard to relative water content and total number of tillers the above treatment being at par with I<sub>1</sub> proved superior to rest of the treatments. Results further indicated that application of FYM at 7.5 t + VC at 3 t/ha (M<sub>3</sub>) resulted in significantly higher growth parameters (plant height, dry-matter accumulation and total number of tillers), yield (grain, straw, biological and harvest index) and being at par with M<sub>2</sub> (VC at 6 t/ha) proved superior to rest of the treatments. However, the above treatment (M<sub>3</sub>) recorded significantly higher functional leaves and relative water content (RWC) over M<sub>0</sub> (Control) and M<sub>2</sub>. Scheduling of irrigation to wheat either at 0.9 IW:CPE ratio throughout the growth or 0.8 IW:CPE ratio at vegetative phase + 1.0 IW:CPE ratio at reproductive phase resulted in significantly, higher yield (grain, straw and biological). Irrigating the crop with 0.8 IW:CPE ratio at vegetative phase + 1.0 IW:CPE ratio at reproductive phase was found most effective, as this schedule besides resulting in almost equal yields also curtailed 1 irrigation with the highest water-use efficiency. The treatment combination, I<sub>2</sub>M<sub>3</sub> recorded the significantly higher grain yield over rest of the treatment combinations except I<sub>2</sub>M<sub>2</sub>, I<sub>5</sub>M<sub>2</sub> and I<sub>5</sub>M<sub>3</sub>.

**Key words** : FYM, Growth, Irrigation Scheduling, RWC, Vermicompost, Wheat, Yield

Wheat (*Triticum aestivum* L.) is one of the most important staple food crops of the world as well as India. It is cultivated under diverse growing conditions of soil and climate. Among the various production inputs, balanced nutrient (N, P and K) and water are considered as the two key inputs, making maximum contribution to crop produc-

tivity. As irrigation water is scarce and costly input, its economic and scientific utilization and optimal allocation among the different crops grown becomes quite imperative. Wheat is highly sensitive to water stress during the critical root initiation (CRI) and flowering but excess irrigation may lead to heavy vegetative growth and shortening of reproductive period and ultimately decrease the yield. Thus, timing the length of irrigation interval with the stages of crop growth might bring about a reduction in the number of irrigations and results in an economic crop yield. Although a high water status throughout the growing season is necessary to maintain unimpaired crop growth and high economic yield, the imposition of some stress by longer irrigation intervals during vegetative or

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maturation by way of narrowing or widening irrigation water: cumulative pan evaporation (IW:CPE) ratio could attain similar economic yields as well as saving of irrigation water and improving water-use efficiency. In general, irrigation is being scheduled on the basis of climatological approach (IW:CPE ratio) during entire period of crop irrespective of the stage of growth. But proper scheduling of irrigation is necessary at both vegetative and reproductive phases to maintain the optimum moisture regime for better growth and development of crop in the changing climatic scenario where abrupt variation in temperature takes place.

Modern agriculture based on chemicals is not sustainable because of many problems such as loss of soil productivity from excessive erosion and associated plant nutrient losses, surface and groundwater pollution from agricultural chemicals, fertilizers and sediment, impending shortage of non-renewable resources and low farm income from high production costs. As a result, there is increasing awareness of the need for alternative agricultural systems. Poor nutrient economy of light-textured soils necessitates the need for organic manures. Moreover, the food crops grown using organic inputs having less or no chemicals are being preferred over conventionally produced food by the end-users. Application of organic manures not only improves the soil organic carbon for sustaining the soil physical quality but also increases plant nutrients. In this context, farmyard manure (FYM) and vermicompost are of paramount importance for application in food crops. Addition of organic material to the soil such as farm yard manure (FYM) helps in maintaining soil fertility and productivity. It increases soil microbiological activities, plays key role in transformation, recycling and availability of nutrients to the crop. It also improves the physical properties like soil structure, porosity, reduces compaction and crusting and increases water-holding capacity of soil. Vermicompost has been advocated as good organic manure for use in the field crops. Earthworm-processed organic waste often referred to as vermicompost is finally divided peat like materials with high porosity, aeration, drainability and water-holding capacity. It contains nutrients in readily available form to the plants such as nitrate, exchangeable phosphorus, soluble K, Ca and Mg.

Thus, it is emphasized that wheat crop responded appreciably to the varying irrigation regimes. Based on climatological approach, most of the experiments were confined irrigating the crop at constant IW:CPE ratios throughout the crop period. Synergistically, the other component with concept of increasing need of organic farming, i.e. use of organic manures is equally important to enhance water utilization by the crop and reduce losses of water under light-textured soils of this zone as such evi-

dences in conjunction with modified approach of irrigation scheduling are meagre.

## MATERIALS AND METHODS

A field experiment was carried out during the winter (*rabi*) seasons of 2014–15 to 2015–16 at S.K.N. College of Agriculture, Jobner (26° 05' N, 75° 28' E and at an 427 m above mean sea-level), Rajasthan. The soil was sandy loam, having bulk density 1.52 Mg/m<sup>3</sup>, pH 8.03. The soil was poor organic carbon (0.23%), low available nitrogen (130.5 kg/ha) and phosphorus (15.1 kg/ha) and medium in a potassium (148.9 kg/ha). The experiment was laid out in split-plot design with 4 replications. The treatments comprising 5 irrigation scheduling, i.e. I<sub>1</sub> (irrigation at critical stages), I<sub>2</sub> [0.9 irrigation water: cumulative pan evaporation (IW:CPE) ratio], I<sub>3</sub> (0.6 IW:CPE ratio at vegetative phase + 0.8 IW:CPE ratio at reproductive phase), I<sub>4</sub> (0.6 IW:CPE ratio at vegetative phase + 1.0 IW:CPE ratio at reproductive phase) and I<sub>5</sub> (0.8 IW:CPE ratio at vegetative phase + 1.0 IW:CPE ratio at reproductive phase) and 4 organic manures, i.e. M<sub>0</sub> (control), M<sub>1</sub> (FYM at 15 t/ha), M<sub>2</sub> (VC at 6 t/ha) and M<sub>3</sub> (FYM at 7.5 t/ha + VC at 3 t/ha). Wheat variety 'Raj 4037' was sown on 16 December and 18 December during 2014 and 2015 and on harvested on 8 April and 10 April during 2015 and 2016 respectively. Seed @ 100 kg/ha was taken with 22.5 cm row spacing. The crop was raised with recommended package of practices of weed management, viz. application of isoproturon 0.75 kg/ha and 2, 4-D @ 0.8 kg/ha at 30 days after sowing. The field plots of size 4.0 m × 2.7 m were separated from each other by using 0.50 m buffer rows. Irrigations was applied as per treatment on the basis of IW:CPE ratio approach using 4.5 cm depth of irrigation water. Six irrigations in I<sub>1</sub> (irrigation at critical stages), 7 irrigations in I<sub>2</sub> (irrigation at 0.9 IW:CPE ratio), 4 irrigations in I<sub>3</sub> (irrigation at 0.6 IW:CPE ratio at vegetative phase + 0.8 IW:CPE ratio at reproductive phase), 5 irrigations in I<sub>4</sub> (irrigation at 0.6 IW:CPE ratio at vegetative phase + 1.0 IW:CPE ratio at reproductive phase) and 6 irrigations in I<sub>5</sub> (irrigation at 0.8 IW:CPE ratio at vegetative phase + 1.0 IW:CPE ratio at reproductive phase). A recommended dose of fertilizer was 90, 30 and 0 kg N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O/ha. Half dose of nitrogen and full dose of phosphorus was applied basal through urea and diammonium phosphate, remaining dose of nitrogen was top-dressed at the time of first and second irrigation. The farmyard manure (FYM) was applied 2 weeks before sowing and vermicompost just before sowing as per treatment. The FYM contains NPK @ 0.49, 0.28 and 0.42% and vermicompost NPK contains @ 1.21, 0.69 and 1.02% respectively. Growth parameters viz. plant height and dry-matter accumulation at harvesting of wheat under different treatments. Plant height was recorded from

each plot at 5 different selected plants. Dry-matter accumulation/m row length from the sample plants in each plot were recorded at harvesting stage and converted into m<sup>2</sup> area. The plant material was first air-dried, then chopped and oven dried at 72°C for 72 hr to a constant weight. Functional leaves/m row length at 80 days after sowing was counted. The fresh weight of 3 leaves/sample after cleaning was taken and then the leaves were kept in distilled water for 4 hr to obtain turgid weight. The turgid weight was recorded after blotting the excess water on the surface of the sample. Dry weight was obtained after drying the samples in oven at 70°C to constant weight and calculates the relative water content in express to percentage. Total number of tillers/m row length from the sample plants in each plot were recorded at harvesting and converted into m<sup>2</sup> area. The crop was harvested manually with the help of sickle when grain almost matured and straw had turned yellow and data on grain and straw yields were recorded. The sun-dried bundles were threshed and winnowed and seed so obtained was weighed. The straw yield was obtained by subtracting the seed yield from the biological yield. Consumptive use of water was worked out using the formula described by Dastane (1972) and than was calculating water-use efficiency. Grain and straw yields (kg/ha) were determined from the each plot and the yield (t/ha) was calculated. All the observation during individual years as well as in pooled analysis was statistically analyzed for their test of significance using the *F*-test (Gomez and Gomez, 1984). The significant of difference between treatment means were compared with *t* critical difference at 5% level of probability. Water-use efficiency (WUE) was worked out as:

$$\text{WUE} = \frac{\text{Economic yield (kg/ha)}}{\text{Consumptive use (mm)}}$$

## RESULTS AND DISCUSSION

### *Effect of irrigation scheduling on growth parameters*

The treatment I<sub>5</sub> (irrigation at 0.8 IW:CPE ratio at vegetative phase + 1.0 IW:CPE ratio at reproductive phase) recorded the maximum plant height at harvesting, being at par with I<sub>2</sub> proved significantly superior to rest of the treatments (Table 1). The optimum moisture supplies under more frequent irrigation treatments promoted the division and expansion of cell components and thereby stem elongation, which virtually increased the plant growth in terms of plant height (Bikrmeditya *et al.*, 2011). The significantly higher dry-matter accumulation at harvesting was recorded under treatment I<sub>2</sub> which remained at par with I<sub>5</sub> (Table 1). This might be owing to increase in leaf-area and uptake of nutrients through adequate moisture supply.

All these contributed for full turgidity and opened leaves, which might have increased the photosynthetic activity of plants, resulting higher dry-matter accumulation. Mollah and Paul (2008) also reported similar results.

The irrigation at 0.9 IW:CPE ratio (I<sub>2</sub>) being statistically at par with I<sub>1</sub> and I<sub>5</sub> treatments recorded significantly higher functional leaves at 80 DAS (Table 1). The increase in functional leaves might be due to the fact that sufficient availability of moisture increased the absorption of nutrients and resulted in fully turgid and higher number of green leaves with their enlarged size which led to higher leaf area. The treatment I<sub>2</sub> (irrigation at 0.9 IW:CPE ratio) resulted in the maximum relative content at 60 DAS and being at par with I<sub>1</sub> and I<sub>5</sub> proved significantly superior to the remaining treatments (Table 1). In case of irrigation at critical stage and 0.9 IW:CPE ratio, though maintained higher relative water content compared to other treatments as it received more amount of water has been also reported by Waraich and Ahmad (2010).

Significantly higher total number of tillers/square m<sup>2</sup> was recorded under the treatment I<sub>2</sub> which being at par with I<sub>1</sub> proved significantly superior to the remaining treatments (Table 1). This might be owing to adequate availability of water and better conductive rhizosphere environment for higher uptake of nutrients which in turn boost the growth, leading to the development of more number of tillers. The results are in conformity with those of Kumar *et al.* (2015) in wheat.

### *Effect of organic manures on growth parameters*

The treatment M<sub>3</sub> (FYM @ 7.5 t/ha + vermicompost @ 3 t/ha) recorded the maximum plant height at harvesting and being at par with M<sub>2</sub> proved significantly superior to the remaining treatments (Table 1). This may be attributed to better physico-chemical properties of soil and nutrient availability after the decomposition of organic matter and supply of readily available nutrients through FYM and vermicompost. Yadav *et al.* (2009) also reported similar findings. At harvesting significantly higher dry-matter accumulation was recorded under the treatment M<sub>3</sub> (FYM @ 7.5 t + vermicompost @ 3 t/ha) which superseded over rest of the treatments while it remained at par with M<sub>2</sub>. The favourable effect of organic manure on dry matter which accounts for improved photosynthetically active leaf area for longer period during vegetative and reproductive phases, led to more absorption and utilization of radiant energy which ultimately resulted in higher dry-matter accumulation (Singh *et al.*, 2013). The maximum number of functional leaves at 80 DAS was recorded under treatment M<sub>3</sub> (FYM @ 7.5 t/ha + vermicompost @ 3 t/ha) which remained at par with M<sub>1</sub> superseded the M<sub>0</sub> and M<sub>2</sub> treatment. It was clearly indicated that there was a need for

adding organic manures to the soil, which increased the availability of nutrients considerably resulting in positive effect on green leaves of wheat (Channabasanagowda *et al.*, 2008). The significantly higher RWC was recorded with the application of FYM @ 7.5 t/ha + vermicompost @ 3 t/ha ( $M_3$ ) which superseded the remaining treatments, while it remained at par with  $M_1$  over  $M_0$  and  $M_2$ . This may be attributed to better root growth, resulting in higher water and nutrient uptake. Higher root density had a large influence on plant water status through its effect on water uptake from soil. Soil physical properties like organic carbon, hydraulic conductivity and water retention might have improved with application of FYM or vermicompost (Patidar and Mali, 2004). At harvesting, significantly higher total number of tillers  $m^2$  was recorded under the treatment  $M_3$ , which proved superior to rest of the treatments, while it remained at par with  $M_2$  (Table 1). This might be owing to adequate availability of water and better conductive rhizosphere environment for higher uptake of nutrients which in turn boost the growth, leading to the development of more number of tillers. These results are in agreement with the findings of Singh *et al.* (2013).

#### Effect of irrigation scheduling on yield

Significantly higher grain yield was recorded under treatment  $I_2$  with the respective value of 4.45 t/ha being at par with  $I_3$  proved significantly superior to the remaining treatments (Table 2). However, the above treatment i.e.  $I_2$

superseded all other treatments except  $I_5$ . Hence,  $I_5$  also remained equally effective treatment with regard to grain yield. It was also found that with sufficient moisture in the soil profile under higher irrigation frequency, plant nutrients particularly N, P and K were more available and might have translocated to produce more grain yield. Secondly, higher yield with higher levels of irrigation might be owing to its key role in root development by reducing mechanical resistance of soil, higher transpiration, greater nutrient uptake and more photosynthesis because of metabolic activities in plant (Bhunja *et al.*, 2006). The other reason of yield increase might be that irrigation scheduled at 0.9 IW:CPE ratio and 1.0 IW:CPE ratio at reproductive phase created longer reproductive period with larger photosynthetic surface and reproductive storage capacity to attain higher allocation of net photosynthates to grain yield. The similar result was reported by Mishra and Kushwaha (2016).

The irrigation at 0.9 IW:CPE ratio ( $I_2$ ) recorded the maximum straw yield (6.34 t/ha) being at par with  $I_3$  but significantly higher than rest of the treatments (Table 2). By and large,  $I_2$  and  $I_3$  were the equally effective treatments in respect of straw yield. Higher straw yield under optimum level of irrigation schedules might be owing to better healthy vegetative crop growth in terms of dry matter obviously resulted in more straw yield (Narolia *et al.*, 2016). The treatment  $I_2$  exhibited the maximum biological yield (10.80 t/ha) and being at par with  $I_3$  (10.62 t/ha)

**Table 1.** Effect of irrigation scheduling and organic manures on growth parameters of wheat (on pooled basis)

Treatment	Plant height at harvest (cm)	Dry-matter accumulation at harvest (g/m <sup>2</sup> )	Functional leaves/m row length at 80 DAS	Relative water content (%) at 60 DAS	Total number of tillers/m <sup>2</sup> at harvest
<i>Irrigation scheduling</i>					
$I_1$	85.5	1,021	361	75.2	428
$I_2$	87.8	1,109	374	78.5	440
$I_3$	78.8	877	346	65.5	381
$I_4$	81.6	977	349	68.2	401
$I_5$	89.5	1,077	366	73.9	413
SEm	0.9	14	4	1.5	6
CD (P=0.05)	2.5	42	12	4.5	17
<i>Organic manures</i>					
$M_0$	80.4	861	337	65.3	382
$M_1$	85.0	1,038	366	75.2	417
$M_2$	86.0	1,063	361	71.5	423
$M_3$	87.1	1,087	373	76.9	429
SEm±	0.4	9	3	1.3	3
CD (P=0.05)	1.2	25	8	3.8	7

DAS, Days after sowing

$I_1$ , (irrigation at critical stages);  $I_2$ , (0.9 IW:CPE ratio);  $I_3$ , (0.6 irrigation water: cumulative pan evaporation (IW:CPE) ratio at vegetative phase) + 0.8 IW:CPE ratio at reproductive);  $I_4$ , (0.6 IW:CPE ratio at vegetative + 1.0 IW:CPE ratio at reproductive phase); and  $I_5$ , (0.8 IW:CPE ratio at vegetative + 1.0 IW:CPE ratio at reproductive phase);  $M_0$  (control);  $M_1$ , (FYM @ 15 t/ha);  $M_2$ , (vermicompost @ 6 t/ha);  $M_3$ , (FYM @ 7.5 t/ha + vermicompost @ 3 t/ha)

proved significantly superior to rest of the treatments. Since biological yield is a function of grain and straw yield, representing vegetative and reproductive growth of the crop, the profound influence of balanced nutrition led to realization of higher biological yield. The significantly higher harvest index was noticed in under I<sub>2</sub> treatment over I<sub>3</sub> and I<sub>4</sub>, but it was at par with I<sub>1</sub> and I<sub>5</sub> treatments (Table 2). With the sufficient water applied in the reproductive phase, more amount of assimilates were diverted towards sink. Thus, harvest index enhanced significantly as compared to other treatments. Harvest index of rest of the treatments was more or less same (Mehta *et al.*, 2010).

*Effect of organic manures on yield*

The significantly higher values (4.57 and 6.58 t/ha) of grain and straw yield were recorded with the application of FYM @ 7.5 t/ha + vermicompost @ 3 t/ha (M<sub>3</sub>) which superseded the remaining the treatments, while it remained at par with M<sub>2</sub> (Table 2). It is well known that addition of FYM and vermicompost could increase the micronutrient concentration in the soil and increase the adsorption power of soil for cations and anions, particularly, phosphates and nitrates and they were released slowly for the benefit of the crop during entire growth period. These results are in close proximity with those of Singh and Agrawal (2004).

The significantly higher values of biological yield (11.12 t/ha) were recorded under the treatment M<sub>3</sub>, which superseded the remaining the treatments, while it remained

at par with M<sub>2</sub> (Table 2). Treatment M<sub>3</sub> revealed an increase in the biological yield by 29.02 and 5.16% respectively, over M<sub>0</sub> and M<sub>1</sub> with the corresponding magnitude of 2501 and 546 kg/ha. Since biological yield is a function of grain and straw yield, representing vegetative and reproductive growth of the crop, the profound influence of balanced nutrition led to realization of higher biological yield (Kumar and Pannu, 2012). The treatment M<sub>3</sub> (FYM @ 7.5 t/ha + vermicompost @ 3 t/ha) recorded the maximum harvest index which remaining at par with M<sub>2</sub> proved significantly superior to rest of the treatments (Table 2). The harvest index indicates the percentage of total biological yield, partitioned to the economic part of the plant, viz. the grain, in terms of dry matter (Verma *et al.*, 2015) in wheat.

*Interaction effect of irrigation scheduling and organic manures*

The treatment combination, I<sub>2</sub>M<sub>3</sub> recorded the significantly higher grain yield (4,880 kg/ha) over rest of the treatment combinations except I<sub>2</sub>M<sub>2</sub>, I<sub>5</sub>M<sub>2</sub> and I<sub>5</sub>M<sub>3</sub> (Table 3). The minimum grain yield was recorded under I<sub>3</sub>M<sub>0</sub> (3,296 kg/ha). Higher levels of irrigation in concurrence with manuring played key role in root development by reducing mechanical resistance of soil, higher transpiration and greater nutrient uptake more photosynthesis owing to metabolic activities in the plant and translocation of photosynthates to the new developing sinks might be the

**Table 2.** Effect of irrigation scheduling and organic manures on grain, straw and biological yield, harvest index, consumptive use and water use efficiency of wheat (on pooled basis)

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)	Harvest index (%)	Consumptive use (mm)	Water use efficiency (kg/ha-mm)
<i>Irrigation scheduling</i>						
I <sub>1</sub>	4.24	6.06	10.31	41.16	380	11.14
I <sub>2</sub>	4.45	6.34	10.80	41.29	398	11.20
I <sub>3</sub>	3.78	5.76	9.55	39.61	369	10.24
I <sub>4</sub>	4.14	6.05	10.20	40.66	378	10.95
I <sub>5</sub>	4.37	6.25	10.62	41.18	385	11.34
SEm±	0.07	0.07	0.12	0.15	-	0.04
CD (P=0.05)	0.20	0.19	0.38	0.45	-	0.12
<i>Organic Manures</i>						
M <sub>0</sub>	3.48	5.12	8.62	40.50	409	8.53
M <sub>1</sub>	4.29	6.26	10.57	40.71	365	11.73
M <sub>2</sub>	4.43	6.42	10.87	40.86	379	11.79
M <sub>3</sub>	4.57	6.58	11.12	41.07	369	12.40
SEm±	0.06	0.06	0.09	0.12	-	0.03
CD (P=0.05)	0.18	0.17	0.30	0.35	-	0.11

I<sub>1</sub>, (irrigation at critical stages); I<sub>2</sub>, (0.9 IW:CPE ratio); I<sub>3</sub>, (0.6 irrigation water: cumulative pan evaporation (IW:CPE) ratio at vegetative phase) + 0.8 IW:CPE ratio at reproductive); I<sub>4</sub>, (0.6 IW:CPE ratio at vegetative + 1.0 IW:CPE ratio at reproductive phase); and I<sub>5</sub>, (0.8 IW:CPE ratio at vegetative + 1.0 IW:CPE ratio at reproductive phase); Mo (control); M<sub>1</sub>, (FYM @ 15 t/ha); M<sub>2</sub>, (vermicompost @ 6 t/ha); M<sub>3</sub>, (FYM @ 7.5 t/ha + vermicompost @ 3 t/ha)

**Table 3.** Combined effect of irrigation scheduling and organic manures on grain yield (on pooled basis)

Irrigation Scheduling	Grain yield (t/ha)			
	Organic Manures			
	M <sub>0</sub>	M <sub>1</sub>	M <sub>2</sub>	M <sub>3</sub>
I <sub>1</sub>	3.49	4.30	4.41	4.60
I <sub>2</sub>	3.67	4.59	4.80	4.93
I <sub>3</sub>	3.30	3.79	3.92	4.05
I <sub>4</sub>	3.37	4.29	4.46	4.53
I <sub>5</sub>	3.64	4.37	4.72	4.80
SEm±			0.11	
CD (P=0.05)			0.31	

I<sub>1</sub>, (irrigation at critical stages); I<sub>2</sub>, (0.9 IW:CPE ratio); I<sub>3</sub>, (0.6 irrigation water: cumulative pan evaporation (IW:CPE) ratio at vegetative phase) + 0.8 IW:CPE ratio at reproductive); I<sub>4</sub>, (0.6 IW:CPE ratio at vegetative + 1.0 IW:CPE ratio at reproductive phase); and I<sub>5</sub>, (0.8 IW:CPE ratio at vegetative + 1.0 IW:CPE ratio at reproductive phase); M<sub>0</sub> (control); M<sub>1</sub>, (FYM @ 15 t/ha); M<sub>2</sub>, (vermicompost @ 6 t/ha); M<sub>3</sub>, (FYM @ 7.5 t/ha + vermicompost @ 3 t/ha)

possible reasons for the above interactions. These results are in accordance with those of Dixit *et al.* (2014).

Based on the results of 2 years, it can be concluded that scheduling of irrigation to wheat either at 0.9 IW:CPE ratio throughout the growth or 0.8 IW:CPE ratio at vegetative phase + 1.0 IW:CPE ratio at reproductive phase brought significantly higher yield (grain, straw and biological). So far as saving of irrigation water is concerned, irrigating the crop with 0.8 IW:CPE ratio at vegetative phase + 1.0 IW:CPE ratio at reproductive phase was most effective as the above schedule besides producing almost equal yield also curtailed 1 irrigation with highest water-use efficiency. The treatment combination, I<sub>2</sub>M<sub>3</sub> recorded the significantly higher grain yield than rest of the treatment combinations except I<sub>2</sub>M<sub>2</sub>, I<sub>3</sub>M<sub>2</sub> and I<sub>5</sub>M<sub>3</sub>.

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