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Growth indices and yield of wheat (*Triticum aestivum* L.) as influenced by irrigation scheduling and organic manures

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Abstract
A field experiment was conducted under loamy sand soil during two consecutive *rabi* seasons of 2014-15 and 2015-16 at S.K.N. College of Agriculture, Jobner, Rajasthan study to the effect of irrigation scheduling and organic manures on growth, yield and quality of wheat. The treatments consisted of five irrigation scheduling i.e. I_1 (irrigation at critical stages), I_2 (0.9 IW/CPE ratio), I_3 (0.6 IW/CPE ratio at vegetative phase + 0.8 IW/CPE ratio at reproductive phase), I_4 (0.6 IW/CPE ratio at vegetative phase + 1.0 IW/CPE ratio at reproductive phase) and I_5 (0.8 IW/CPE ratio at vegetative phase + 1.0 IW/CPE ratio at reproductive phase) in main plots and four organic manures (control, FYM @ 15 t/ha, VC @ 6 t/ha and FYM @ 7.5 t + VC @ 3 t/ha) in sub plots were replicated four times in split plot design.

The pooled data results showed that irrigation applied at 0.9 IW/CPE ratio (I_2) recorded the maximum values of growth indices (matter accumulation per metre row length, leaf area index, leaf area duration, crop growth rate, relative growth rate and net assimilation rate) and yield (grain, straw, biological and HI) proved significantly superior over I_1, I_4 and I_3 except treatment I_5. Results further indicated that application of FYM at 7.5 t + VC at 3 t/ha (M_3) recorded significantly higher growth indices (matter accumulation per metre row length, leaf area index, leaf area duration, crop growth rate, relative growth rate and net assimilation rate), yield (grain, straw, biological and HI) and being at par with M_2 proved superior over rest of the treatments. 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 about significantly higher growth indices and 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 yields also curtailed one irrigation with highest water use efficiency.

Keywords: growth indices, FYM, irrigation scheduling, vermicompost, wheat, WUE and yield

Introduction
Wheat [*Triticum aestivum* (L.) emend. Fiori & Paol.) 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. In India, it is the second most important food crop after rice. It is an excellent health-building food containing approximately 78% carbohydrates, 11-12% protein (var. Raj-4037), 2% fat and minerals each and considerable amount of vitamins (Kumar *et al*., 2011) [9]. About 80 to 85% of wheat grains are ground into flour (atta) and consumed in the form of chapaties. Soft wheat is used for making chapaties, bread, cake, biscuits, pastry and other bakery products. Wheat straw is mainly used as fodder for livestock. 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 productivity. Wheat is highly sensitive to water stress during the 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. In principle, irrigation should take place while the soil water potential is still high enough to enable soil supply water fast enough to meet the local atmospheric demands without placing the plants under stress that would reduce yield and quality of crop. 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 maturation by way of narrowing or widening 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.

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, 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.

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 (26^0 05' North, longitude of 75^0 28' East and at an altitude of 427 metres above mean sea level), Rajasthan. The soil was sandy loam having bulk density 1.52 Mg/m^3, pH 8.3. The soil was poor organic carbon (0.23%), low available nitrogen (130.5 kg/ha) and phosphorus (15.1 kg/ha) and medium in potassium (148.9 kg/ha). The experiment was laid out in split-plot design with four replications. The treatments comprising five irrigation scheduling i.e. I_1 (irrigation at critical stages), I_2 (0.9 IW/CPE ratio), I_3 (0.6 IW/CPE ratio at vegetative phase + 0.8 IW/CPE ratio at reproductive phase), I_4 (0.6 IW/CPE ratio at vegetative phase + 1.0 IW/CPE ratio at reproductive phase) and I_5 (0.8 IW/CPE ratio at vegetative phase + 1.0 IW/CPE ratio at reproductive phase) and four organic manures i.e. M_0 (control), M_1 (FYM at 15 t/ha), M_2 (VC at 6 t/ha) and M_3 (FYM at 7.5 t/ha + VC at 3 t/ha). Wheat variety "Raj-4037" was sown on 16^{th} December and 18^{th} December during 2014 and 2015 and on harvested at 8^{th} April and 10^{th} April during 2015 and 2016, respectively. Seed @ 100 kg/ha was taken with 22.5 cm row spacing. 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 was used. The field plots of size 4.0 m x 2.7 m were separated from each other by using 0.50 m buffer rows. Irrigations applied as per treatment on the basis of IW/CPE ratio approach using 4.5 cm depth of irrigation water. Six irrigations in I_1 (irrigation at critical stages), seven irrigations in I_2 (irrigation at 0.9 IW/CPE ratio), four irrigations in I_3 (irrigation at 0.6 IW/CPE ratio at vegetative phase + 0.8 IW/CPE ratio at reproductive phase), five irrigations in I_4 (irrigation at 0.6 IW/CPE ratio at vegetative phase + 1.0 IW/CPE ratio at reproductive phase) and six irrigation in I_5 (irrigation at 0.8 IW/CPE ratio at vegetative phase + 1.0 IW/CPE ratio at reproductive phase). A recommended dose of fertilizer was 90:30:0 kg N, P_2O_5 and K_2O/ha. Half dose of nitrogen and full dose of phosphorus was applied as basal dose through urea and DAP, remaining dose of nitrogen was top dressed at the time of first and second irrigation. The farm yard manure (FYM) was applied two 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. Yield attributes viz. Number of effective tillers per metre row length, number of grains per ear, ear length and test weight of wheat under different treatments. 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) [4] and than was calculating water use efficiency. Grain and straw yield (kg/ha) was determined from the each plot and the yield tonnes per hectare 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) [6]. 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 per formula.

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

Results and Discussion

Growth indices

Effect of irrigation scheduling

Treatment I_2 (Irrigation at 0.9 IW/CPE ratio) significantly increased the matter accumulation per metre row length, leaf area index, leaf area duration, crop growth rate, relative growth rate and net assimilation rate over I_3, I_4 and I_1 and it was found statistically at par with I_5 (Table 1). This might be due to increase in LAI 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 to higher dry matter accumulation. The minimum dry matter was noted with I_3 (Irrigation at 0.6 IW/CPE ratio at vegetative phase + 0.8 IW/CPE ratio at reproductive phase). The higher dry matter recorded under I_2 and I_5 as compared to other treatments might be due to profused vegetative growth and more vertical growth on account of optimum moisture supply under more frequent irrigations as mentioned earlier (Kumar *et al*., 2012 and Vishuddha *et al*., 2014) [8, 16]. Leaf area index is the efficiency of photosynthetic process and depends on the extent of photosynthetic surface. Leaf area index in the vegetative phase of wheat which determines the quantum of intercepted photosynthetically active radiation, which is a yield determining factor. Hence, the higher photosynthetic activity per unit area and more dry matter production led to increase in growth indices viz. LAD, CGR, RGR and NAR. These results are in conformity with the findings of Vishuddha *et al*. (2014) [16] and Kumar *et al*. (2015) [7] who also reported the maximum values of growth indices.

Effect of organic manures

Growth indices viz. matter accumulation per metre row length, leaf area index, leaf area duration, crop growth rate, relative growth rate and net assimilation rate were significantly affected by application of organic manures. The treatment M_3 (FYM @7.5 t/ha + vermicompost @ 3 t/ha) significantly increased the matter accumulation per metre row length, leaf area index, leaf area duration, crop growth rate, relative growth rate and net assimilation rate while remaining at par with M_2, proved superior over rest of the treatments (Table 1). It is an established fact that organic manures improve the physical, chemical and biological properties of soil and supplies almost all the essential nutrients for growth and development of plants. Application of organic manures (farm yard manure and vermicompost) might have improved the soil properties. Moreover, vermicompost contains plant growth hormones and beneficial microbes which might have helped in increasing growth indices. These results are in agreement with those reported by Patidar and Mali (2004) [13] and Sain and Chaplot (2014).

Table 1: Effect of irrigation scheduling and organic manures on growth indices of wheat (on pooled basis)

Treatments	Dry Matter Accumulation/m row length (g)	Leaf Area Index (LAI)	Leaf Area Duration (LAD)	Crop Growth Rate (g/m²/day)	Relative Growth Rate (mg/g/day)	Net Assimilation Rate (g/m² leaf area/day)
Irrigation Scheduling						
I_1	231	4.44	133	2.08	11.07	2.79
I_2	250	4.69	143	2.31	11.73	3.11
I_3	198	4.14	120	1.47	8.94	2.36
I_4	220	4.32	128	1.94	10.58	2.66
I_5	243	4.55	138	2.22	11.35	3.02
SEm ±	3.82	0.05	1.83	0.06	0.21	0.10
CD (P = 0.05)	11.50	0.14	5.50	0.18	0.62	0.29
Organic Manures						
M_0	196	4.19	123	1.62	9.93	2.48
M_1	234	4.45	133	2.04	10.68	2.72
M_2	240	4.51	136	2.16	11.07	2.93
M_3	245	4.57	138	2.20	11.25	3.03
SEm ±	2.03	0.02	0.98	0.05	0.19	0.08
CD (P = 0.05)	6.08	0.07	3.76	0.14	0.54	0.22

I_1 (irrigation at critical stages), I_2 (0.9 IW/CPE ratio), I_3 (0.6 IW/CPE ratio at veg. + 0.8 IW/CPE ratio at rep. phase), I_4 (0.6 IW/CPE ratio at veg. + 1.0 IW/CPE ratio at rep. phase) and I_5 (0.8 IW/CPE ratio at veg. + 1.0 IW/CPE ratio at rep. phase), Mo (control), M_1 (FYM @ 15 t/ha), M_2 (vermicompost @ 6 t/ha), M_3 (FYM @ 7.5 t/ha + vermicompost @ 3 t/ha)

Yield

Effect of irrigation scheduling

The significantly higher grain yield was recorded under treatment I_2 (Irrigation at 0.9 IW/CPE ratio) with the respective value of 4.45 t/ha being at par with I_5 proved significantly superior to rest of the treatments. 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 (Table 2). 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 due to its key role in root development by reducing mechanical resistance of soil, higher transpiration, greater nutrient uptake and more photosynthesis due to metabolic activities in plant (Bhunia *et al.* 2006) [2]. The other reason of yield increase might be that scheduling irrigation 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 findings by Mishra and Kushwaha, (2016) [11].

The irrigation at 0.9 IW/CPE ratio (I_2) recorded the maximum straw yield (6.34 t/ha) which was at par with I_5 but significantly higher over rest of the treatments. By and large, I_2 and I_5 were the equally effective treatments in respect of straw yield. Higher straw yield under optimum level of irrigation schedules might be due to better healthy vegetative crop growth in terms of dry matter obviously resulted into more straw yield (Narolia *et al*., 2016) [12]. The treatment I_2 (Irrigation at 0.9 IW/CPE ratio) recorded the maximum biological yield (10.80 t/ha) and being at par with I_5 (10.62 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 HI was noticed in I_2 (Irrigation at 0.9 IW/CPE) over I_3 and I_4, but it was at par with I_1 and I_5 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) [10]. The treatment I_2 (Irrigation at 0.9 IW/CPE ratio) exhibited maximum value of consumptive use (398 mm) over all other treatments while the minimum consumptive use was brought about by I_3 (369 mm). Thus consumptive use of water increased with increasing in quantity of irrigation water. This might be due to more number of irrigations which increased consumption of water due to better growth of crop and simultaneously the loss of water through evaporation under treatment I_2 (Bandyopadhyay and Mallick, 2003 and Singh *et. al*., 2012) [1, 14]. Treatment I_5 (Irrigation at 0.8 IW/CPE ratio at vegetative phase + 1.0 IW/CPE ratio at reproductive phase) recorded the significantly highest WUE (11.34 kg/ha/mm). While the lowest WUE (10.24 kg/ha/mm) was registered under treatment I_3. Water use efficiency refers largely to the production per unit of water consumed by a crop. The highest WUE in the treatment I_5 might be due to the fact that crop was supplied with adequate soil moisture without moisture stress during reproductive phase. Moreover, the above treatment utilized lesser water consumptively as compared to I_2. Hence, proportionately higher yield with the judicious use of limited water resulted to significantly highest WUE (Bikrmaditya *et al*., 2011) [3] was also of the same opinion.

Effect of organic manures

The significantly higher values (4.57 and 6.58 t/ha) of grain and straw yield were recorded due to application of FYM @

7.5 t/ha + vermicompost @ 3 t/ha (M_3) which superseded over rest of the treatments while it remained at par with M_2 (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 *et al.* (2004) [15].

The significantly higher values of biological yield (11.12 t/ha) were recorded under the treatment M_3 (FYM @7.5 t/ha + vermicompost @ 3 t/ha) which superseded over rest of the treatments while it remained at par with M_2. Treatment M_3 represented an increase in the biological yield by 29.02 and 5.16 per cent, respectively over M_0 and M_1 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) [8]. The treatment M_3 (FYM @ 7.5 t/ha + vermicompost @ 3 t/ha) recorded the maximum harvest index which remaining at par with M_2 proved significantly superior over rest of the treatments. HI 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) [10] in wheat. The results on consumptive use represent that the maximum consumptive use (409 mm) by crop was shown by the treatment M_0 (control) over rest of the treatments. The minimum consumptive use was obtained where FYM 7.5 t + vermicompost 3 t/ha (M_3) was applied. Lower consumptive use in organic manure treated plots might be due to better conservation of soil moisture and reduced evaporation as compared to no manure treatment (Vishuddha *et al*., 2014) [16]. The significantly highest WUE was obtained under treatment M_3 (12.40 kg/ha/mm). The reason may be ascribed to the fact that proportionate increase in grain yield was greater than the evapo-transpiration due to combined application of FYM and vermicompost. Thus, WUE enhanced significantly over sole application of organic manures or no organic manure treatment where increase in yield was lesser than the loss of water through ET (Ebtisam *et al*., 2013) [5].

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)

Treatments	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)	HI (%)	Consumptive use (mm)	Water use efficiency (kg/ha/mm)
Irrigation Scheduling						
I_1	4.24	6.06	10.31	41.16	380	11.14
I_2	4.45	6.34	10.80	41.29	398	11.20
I_3	3.78	5.76	9.55	39.61	369	10.24
I_4	4.14	6.05	10.20	40.66	378	10.95
I_5	4.37	6.25	10.62	41.18	385	11.34
SEm $\pm$	0.07	0.07	0.12	0.15	-	0.04
CD (P = 0.05)	0.20	0.19	0.38	0.45	-	0.12
Organic Manures						
M_0	3.48	5.12	8.62	40.50	409	8.53
M_1	4.29	6.26	10.57	40.71	365	11.73
M_2	4.43	6.42	10.87	40.86	379	11.79
M_3	4.57	6.58	11.12	41.07	369	12.40
SEm $\pm$	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_1 (irrigation at critical stages), I_2 (0.9 IW/CPE ratio), I_3 (0.6 IW/CPE ratio at veg. + 0.8 IW/CPE ratio at rep. phase), I_4 (0.6 IW/CPE ratio at veg. + 1.0 IW/CPE ratio at rep. phase) and I_5 (0.8 IW/CPE ratio at veg. + 1.0 IW/CPE ratio at rep. phase), Mo (control), M_1 (FYM @ 15 t/ha), M_2 (vermicompost @ 6 t/ha), M_3 (FYM @ 7.5 t/ha + vermicompost @ 3 t/ha)

Conclusion

Based on the results of two years investigation, 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 about significantly higher growth indices and 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 yields also curtailed one irrigation with highest water use efficiency.

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