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Research Communication

Growth, yield and economics in late-sown wheat (*Triticum aestivum*) as affected by irrigation levels and moisture-conservation practices

VIJAY SHARMA[1], V.C. DHYANI[2], SUMIT CHATURVEDI[3] AND GURVINDER SINGH[4]

Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Uttarakhand 263 145

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ABSTRACT

A trial using split-plot design was conducted during the winter season of 2016–17 on silty clay-loam soils at research farm of Pantnagar, located in the foothills (*tarai*) region of Uttarakhand, to evaluate growth, yield and economics of wheat (*Triticum aestivum* L.). Treatments comprised 3 irrigation practices (2, 3 and 4 irrigations) as main factor and 4 moisture-conservation practices (un-amended control, recommended fertilizers (RDF)–(N : P_2O_5 : K_2O 120 : 60 : 40 kg/ha), RDF + farmyard manure (FYM) 6 t/ha and RDF + paddy straw biochar (biochar)10 t/ha) as subfactors. Wheat growth and yield attributes were the highest in 4 irrigations and led to significantly higher grain yield, gross returns (GR), net returns (NR) and benefit: cost (BC) ratio. The RDF + FYM also resulted in the highest growth and yield attributes, yield, GR, NR and BC. Four irrigations had 44 and 36% higher moisture content at 0–15 and 15–30 cm depth respectively at 90 days. Compared to RDF, RDF + FYM had 18 and 13% higher moisture content at 0–15 and 15–30 cm depth respectively) at 90 days. Thus this study indicates that in late-sown wheat, 4 irrigations along with RDF + FYM could be an economically feasible practice for achieving high yield and economics under *tarai* condition of Uttarakhand.

Key words**:** Wheat, RDF FYM, Biochar, Irrigation levels, Yield, Net returns

Considerable area under wheat is late sown due to late harvesting/picking of previous crops in crop rotations like basmati rice–wheat, cotton–wheat, sugarcane–wheat, potato–wheat, vegetable pea–wheat (Singh *et al*., 2013) and thus crop gets exposed to end of the season heat stress or terminal heat stress (Farooq *et al.,* 2011). Wheat is able to maintain stable tissue water status during heat stress when water is ample but when water is scarce, heat stress becomes more severe (Wahid *et al*., 2007). Wheat is predominantly irrigated (94.19% area is irrigated) (http://agricoop.gov.in/sites/default/files/agristatglance2017.pdf, accessed on 19 July 2019) in India where 4 irrigations are applied at early vegetative stage late vegetative stage, flowering stage and yield formation stage (http://www.fao.org/land-water/databases-and-software/crop-information/wheat/en/accessed on 12 October 2020. Irrigation and windy conditions during early grain filling can cause lodging (Piñera-Chavez *et al*., 2016) and force farmers to avoid irrigation during that period. Moisture-conservation materials like farmyard manure (Zhang *et al*., 2014) and biochar (char produced from burning residues under limited oxygen supply) (Yu *et al*., 2013) have the capacity to increase water-holding capacity of the soil. Application of FYM and biochar can increase moisture content for crop at post-flowering stage.

Considering these points, objective was set to find out suitable moisture-conservation materials to substitute for the last irrigation (fourth) under late-sown wheat.

Therefore a field experiment was conducted during the winter (*rabi*) season of 2016–17 at the Research Farm of the Govind Ballabh Pant Univeristy of Agriculture and Technology, Pantnagar, Uttarakhand. The experimental area falls in *tarai* region, characterized by a subtropical and subhumid climate, in which summers are hot and dry; and winters are severely cold. The total rainfall of 76.2 mm was received in 7 rainy days during the experimental period. The highest amount of rainfall occurred in January (60.4 mm) which contributed 79.3% of the total rainfall during the crop period. December, March and April also shared 14.7%, 4.7% and 1.3% of the total rainfall during crop period respectively. The mean maximum and minimum

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[1]**Corresponding author's Email:** dhyanivipin@gmail.com
[1]Agriculture Officer, Government of Uttarakhand; [2,3]Associate Professor, [4]Senior Research Officer, Department of Agronomy

temperatures were 26.5° C and 11.1° C respectively. The mean relative humidity was 80% in the forenoon and 45.1% in the afternoon and the mean sunshine hours were 7.0. Soils are alluvial in origin and developed from calcareous, medium to moderately coarse-textured materials under predominant influence of tall forest vegetation and moderate to well-drained conditions, having *p*H 7.3, electrical conductivity 0.43 dS/m, available N, P and K were 234, 24 and 187 kg/ha respectively. Treatments included 3 irrigation practices (2 irrigations–one during early vegetative period and second just prior to head emergence through flowering period; 3 irrigations–first during early vegetative period, second just prior to head development through flowering period and third early yield-formation period; and 4 irrigations–first during early vegetative, second during late vegetative, third during flowering and fourth early yield-formation periods) as main plots and sub-plots consisted of 4 moisture-conservation practices (absolute control i.e. no fertilizer, recommended dose of fertilizer (RDF) + no amendment; RDF + FYM 6 t/ha; and RDF + biochar 10 t/ha.

Wheat cultivar 'UP 2565' was sown manually on 24 December 2016 after mechanical line opening with the row spacing of 20.0 cm and seed rate of 125 kg/ha. The recommended dose of N (120 kg/ha) was applied in 2 splits–half basal and remaining at first irrigation. The entire dose of phosphorus and potassium (60 kg P_2O_5 and 40 kg K_2O/ha) was incorporated into the soil as basal just before sowing of the crop. The nitrogen, phosphorus and potassium was applied by broadcast method through urea, diammonium phosphate and muriate of potash respectively. Biochar and FYM were incorporated in soil manually prior to sowing. Irrigations were given as per treatments.Crop was harvested manually on 21 April 2017 and after threshing, cleaning and drying, the grain yield of wheat was measured at 14% moisture content and expressed in t/ha. Remaining all other cultural practices were carried out according to standard recommendations. The economics of wheat, viz. cost of cultivation (₹/ha), net returns (/ha) and benefit: cost ratio were calculated using standard procedure and formula.The data from the experiments were analyzed statistically, wherever treatment differences were found significant, the critical differences were worked out at 5% probability level (*P*=0.05).

Grain and biological yield of wheat differed significantly due to irrigations and moisture conservation practices (Table 1). However, interaction between irrigations and moisture-conservation practices was non-significant in this study. The highest grain and biological yields were recorded with 4 irrigations. The maximum grain yield was recorded in 4 irrigations and yield improvement in this treatment was 14.9% and 11.1% compared to 3 and 2 irrigations respectively. Higher grain yield under 4 irrigations was owing to better soil-moisture content, growth and yield attributes (Table 1) which translated in higher grain yield. Mubeen *et al.* (2013) reported that, irrigation at tillering, stem-elongation stage, booting and grain-filling stage recorded the higher yield of wheat. Grain and biological yields were also significantly affected by application of moisture-conservation materials. The highest grain yield was recorded under RDF + FYM treatment which were at par with RDF + biochar treatment followed by grain yield

Table 1. Effect of irrigation levels and moisture-conservation materials on crop growth, yield attributes, yields of wheat and soil-moisture content

Treatment	Growth at 90 DAS		Yield attributing characters			Yield (t/ ha)		Soil moisture content (%)			
	Tiller Number (no/m²)	NDVI	Spikes (no/m²)	Grains/ spike	1,000-grain weight (g)	Grain	Biological	90 DAS (0–15) cm	90 DAS (15–30) cm	Harvesting (0–15) cm	Harvesting (15–30) cm
Irrigation levels											
2 irrigations	309	0.34	241	35.0	39.98	2.68	7.48	7.52	9.47	4.08	7.66
3 irrigations	335	0.35	257	36.8	40.88	2.80	7.65	7.78	9.54	6.00	9.16
4 irrigations	352	0.39	272	36.6	42.49	3.15	8.42	13.92	14.91	7.68	10.59
SEm±	7.2	0.006	5.713	0.694	0.365	0.071	0.131	0.41	0.25	0.34	0.359
CD (P=0.05)	29	0.02	23	NS	1.47	0.29	0.53	1.64	0.99	1.37	1.45
Moisture-conservation materials											
Control	287	0.24	237	23.6	37.03	1.42	3.71	8.71	11.41	5.68	8.94
RDF	320	0.39	253	40.6	41.53	3.25	9.10	8.76	10.24	5.33	8.60
RDF + FYM	359	0.42	271	39.0	43.29	3.52	9.50	10.78	11.87	6.29	9.45
RDF + Biochar	362	0.39	266	41.3	42.61	3.31	9.10	10.71	11.70	6.37	9.55
SEm±	8.8	0.008	7.916	0.948	0.358	0.078	0.094	0.28	0.38	0.373	0.334
CD (P=0.05)	27	0.02	24	2.8	1.07	0.23	0.28	0.83	1.14	NS	NS

NDVI, Normalized difference vegetation index; DAS, days after sowing; RDF, recommended dose of fertilizer from RDF. The grain yield in RDF + FYM was 6.0 and 7.7% higher than that recorded under RDF + biochar and RDF. Enhanced growth with improved yield components led to higher grain yield (Table 1). Higher grain yield in RDF + FYM, and RDF + biochar treatments in comparison to RDF might also be owing to better moisture retention at post-anthesis stage resulting higher 1,000-grain weight (Table 1). The FYM not only retains moisture in soil (Singh *et al*., 2016) but also provides nutrient slowly synchronous with crop need (Singh *et al*., 2019). It also supports soil-microbial activity which helps in release of nutrients in a effective way (Gopinath *et al*., 2009). Biochar too is a stable nutrient source (Cheng *et al*., 2006) and retains soil moisture might have contributed to improvement of yield attributes and yield in RDF + biochar treatment. Our results confirm the findings of Olmo *et al*. (2014).

The irrigation levels and moisture-conservation materials showed significant effect on crop growth; however, the interaction was significant for normalized difference vegetation index (NDVI) value at 2 weeks after anthesis (WAA).

Wheat plant growth at 90 days in terms of tiller count and NDVI value was significantly better under 4 irrigations (0.39) among the different irrigation regimes and in RDF + FYM treatments (0.42) among different moisture-conservation practices.

The NDVI value at 2 weeks after anthesis showed positive interaction between irrigation levels and moisture-conservation materials. Treatment RDF+FYM performed significantly better in terms of NDVI value under 2 and 3 irrigations regime; however, under 4 irrigations, RDF and RDF + FYM were statistically at par (Fig. 1). The FYM treatment held more water (Table 1) and thus provided better growth apart from providing extra nutrients under reduced water supply (2 and 3 irrigations).

The effect of irrigation levels on soil-moisture content was found significant at 90 days and at harvesting. Depth of 15–30 cm had higher soil moisture compared to 0–15 cm depth. Crop grown with 4 irrigations recorded the highest soil-moisture content both at 90 days and at harvesting

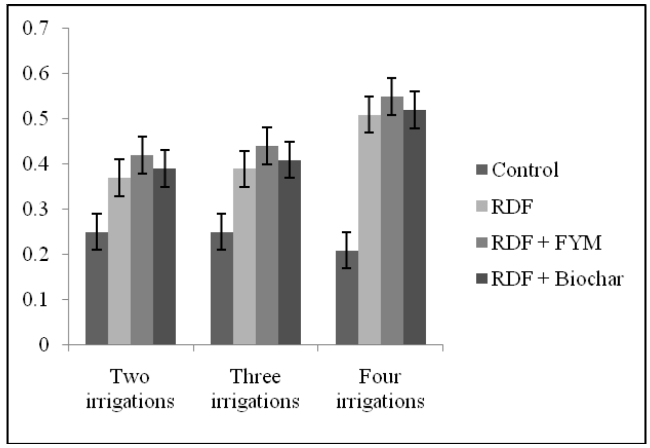

Fig. 1. Interaction between irrigation levels and moisture-conservation materials on normalized difference vegetation index (NDVI) value at 2 weeks after anthesis of crop growth (error bars are CD values)

stage at 0–15 and 15–30 cm depth. At both stages (90 days and harvesting), soil-moisture content in plots applied with 4 irrigations were significantly higher than 2 and 3 irrigation levels for both upper as well as lower depths. The effect of moisture-conservation materials was found significant only at 0–15 cm depth at 90 days. At 90 days, soil-moisture content (0–15 cm soil depth) in RDF + FYM treatment was statistically at par with RDF + biochar and

Table 2. Effect of irrigation levels and moisture-conservation materials on cost of cultivation, gross return, net return and benefit: cost ratio (B:C) ratio in wheat

Treatment	Gross return (× 10^3₹/ ha)	Net returns (× 10^3₹/ ha)	Benefit: cost ratio
Irrigation levels			
2 irrigations	62.7	43.9	2.34
3 irrigations	64.8	46.1	2.46
4 irrigations	72.1	53.4	2.85
SEm±	0.9	0.9	0.05
CD (P=0.05)	2.9	2.9	0.15
Moisture-conservation materials			
Control	32.1	13.4	0.72
RDF	76.1	57.4	3.06
RDF + FYM	81.1	62.3	3.32
RDF + biochar	76.9	58.1	3.10
SEm±	1.1	1.1	0.06
CD (P=0.05)	3.4	3.4	0.18

superior to rest of the treatments. While at 15–30 cm, RDF + FYM, RDF + biochar treatments and control were statistically at par and superior to RDF (Table 1). All moisture-conservation practices were at par in terms of soil-moisture content at harvesting stage at both upper and lower depths. Water remains in deep layers as the soil dries (Lynch *et al.,* 2012), thus 15–30 cm layer had higher soil-moisture content. The FYM and biochar in RDF + FYM and RDF + biochar treatments, respectively, conserved moisture and thus led to higher soil-moisture content compared to RDF. Higher soil-moisture content in the control than RDF can be ascribed to less growth in control compared to RDF and thus would have lost less water through transpiration. Tesfahunegn (2019) also reported decreased soil-moisture content with increasing fertilizer rates.

Among all the treatments, the highest gross returns, net returns and benefit: cost ratio were obtained under 4 irrigations and RDF+ FYM treatments. Four irrigations resulted in 10.0 and 13.6% higher gross returns and net returns, respectively, compared to 3 irrigations (Table 2). Also RDF + FYM treatment fetched 6.0 and 7.8 higher gross returns and net returns, respectively, compared to RDF alone.

Higher grain and straw yields also fetched higher gross returns under 4 irrigations and RDF + FYM treatments.

On the basis of study, it can be concluded that under late-sown crop 4 irrigations at early vegetative stage, late vegetative stage, flowering stage and early yield-formation stage along with RDF + FYM (6 t/ha) and biochar (10 t/ha) resulted in significantly better growth, yield attributes, grain yield, gross and net returns and benefit: cost ratio. At reduced irrigation levels (2 and 3 irrigations), an application of RDF + FYM exhibited significantly better NDVI value than RDF, but could not obtain higher grain yield.

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