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Research Paper

Effect of irrigation schedule and herbicides application on growth and productivity of wheat (*Triticum aestivum*) in semi-arid environment

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ABSTRACT

A field experiment was conducted during the winter (*rabi*) season of 2017–18 and 2018–19 at Chandra Shekhar Azad University of Agriculture and Technology Kanpur, Uttar Pradesh, to study the influence of irrigation scheduling and weed-management practices on growth and productivity of wheat (*Triticum aestivum* L.). The experiment was laid out in split-plot design with 4 irrigation scheduling in main plot and 8 weed-management practices in subplots. Results revealed that, application of 5 irrigations at crown root initiation (CRI) + jointing + booting+ flowering + milking stage resulted in the maximum plant height (79.9 cm at harvest), crop dry-matter accumulation (385.1 g/running m at harvest), number of leaves [230/running m at 80 days after sowing (DAS)], leaf area index (2.60 at 60 DAS), crop growth rate (4.09 g/m^2/day between 40-80 DAS), relative growth rate (2.66 g/g/day between 40-80 DAS), net assimilation rate (0.59 g/cm^2/day between 40-80 DAS) and the biological yield (6,899 kg/ha) over irrigation at CRI and active tillering stage and irrigation at CRI + jointing + booting, and it was statistically at par with irrigation at CRI + active tillering + booting + flowering stage. Among herbicidal treatments, significantly maximum value of crop-growth parameters and biological yield (7007 kg/ha) was recorded with the application of carfentrazone ethyl 20% + sulfosulfuron 25% WG @ 100 g a.i./ha at 35 days after sowing (DAS) followed by clodinafop- propargyl 15% + metsulfuron methyl 1% @ 400 g a.i./ha 35 DAS compared to the other herbicidal treatments. But hand weeding at 20 and 40 DAS showed superiority to herbicidal treatments during both the years.

Key words: Biological yield, Irrigation, Herbicides, Wheat

Globally wheat (*Triticum aestivum* L.) produced 764.4 million tonnes annually from an area of 219 million ha, with the normal efficiency of 3.47 t/ha which is consumed nearly by 2.5 billion of total populace (FAO, 2020). In India, wheat is cultivated in about 29.32 m ha area (14% of global area) produces 103.6 million tonnes (12.92% of world creation), with productivity of 3.53 tonnes/ha. It has a critical share in food bin with 36% share in the complete food grains which are produced from India, guaranteeing food and nourishment security (Sharma and Senthil, 2015; Sangwan *et al*., 2019). However, its growth and yield had been significantly affected by forced maturity, poor water, nutrient and pest management, and some parts of the country facing droughts over years. The low yield could be mainly due to the increased moisture scarcity and crop-weed competition throughout the growing season, which adversely affect plant growth and development (Tunio *et al*., 2020). About 30% of wheat production is lost due to lack of irrigation water, 40% yield loss due to lack of nutrient supply and up to 80% loss in yield due to weed infestation (Mitra *et al*., 2019). Irrigation frequency has a significant influence on the crop growth and yield of wheat (Kumar *et al*., 2019). Proper growth and development of wheat needs favourable soil-moisture in the root zone. Extractable water capacity of soil has significant influence on wheat yield (Verma *et al*., 2017). The moisture content in the soil gradually decreases with time in dry season, simultaneously soil-moisture tension increases and diminishes water-use proficiency and may likewise decrease the yield (Yadav *et al*., 2018). Irrigation scheduling at critical stages can also be used to maximize the crop growth and yield (Dhaliwal *et al*., 2020).

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Several types of weeds infest wheat, causing serious rivalry for sunlight, basic supplements, dampness and space which leads to reduction in wheat growth, yield and also its quality (Verma *et al*., 2015). Weeds having strong competition for growth resources adversely affect the growth and yield of wheat (Lakra and Husain, 2020; Shivran *et al*., 2020). Under water-stress condition, weeds can reduce crop yields more than 50% through moisture competition alone (Verma *et al*., 2017). At advance stage, plants are subjected to some unfavourable conditions for their growth such as high temperature, low winter rainfall, shortage of water for irrigation, the need to with holding irrigation for saving water and early land evacuation for cultivation of following crop. Earlier research has been identified that, the dry-matter production, optimum number of leaves to maximize photosynthetic efficiency, leaf-area index (LAI), crop-growth rate (CGR), relative growth rate (RGR) and net assimilation rate (NAR) are ultimate determinants and reflected in higher yield of wheat. There is absence of area explicit data on impact of water system plan and different weed-management practices on crop-growth parameters of wheat in irrigated condition. In view of this, the experiment was planned to consider the impact of irrigation scheduling and weed-management on development of wheat, so that viable management strategies could be identified to improve wheat growth and yield.

MATERIALS AND METHODS

The field experiment was conducted during the winter season of 2017–18 and 2018–19 at Students Instructional Farm of the Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh situated (26º20" 35" North latitude and 80º18'35" E and 125.9 m above mean sea-level) in the Indo-Gangetic Plain of the Central part of Uttar Pradesh. The soil is sandy with *p*H 7.1, low in organic carbon (OC) (0.35%), available nitrogen (172.4 kg/ha), medium in available phosphorus (12.8 kg/ha), potassium (156.5 kg/ha). sulphur (15.7 kg/ha) and zinc (0.456 ppm). The experiment was laid out in split-plot design, replicated 4 times, having 32 treatment combinations. Treatments consisted of 4 irrigation schedules, viz. I_1 (irrigation at CRI and active tillering stage); I_2 (irrigation at CRI + jointing + booting); I_3 (CRI + active tillering + booting + flowering stage); and I_4 (irrigation at CRI + jointing + booting + flowering + milking stage) were laid out in main plots, and weed-management practices, viz. W_1, weedy check; W_2, 2 hand-weedings–20 and 40 days after sowing (DAS); W_3, Sulfosulfuron @ 25 g a.i./ha at 35 DAS; W_4, Pendimethalin (pre-emergence) followed by *(fb)* WCPL-15 @ 400 g a.i./ha at 35 DAS; W_5, broadway (Carfentrazone ethyl 20% + Sulfosulfuron 25% WG) @ 100 g *a.i.*/ha at 35 DAS; W_6, Halauxafen + Penxasulam 23.5% @ 75 g a.i./ha at 35 DAS; W_7, Halauxafen-methyl 1.21% w/w + Fluroxypyr @ 82 g a.i./ha at 35 DAS; and W_8, Clodinafop-propargyl 15% + Metsulfuron methyl 1% @ 400 g a.i./ha 35 DAS, were allocated to sub-plots. Wheat variety 'K 1006' was sown in lines at 22.5 cm spacing using 100 kg/ha seed with seed-drill machine. All the plots were treated a like for inputs and agronomic practices except treatments. The climatic data were obtained from weather station of the university. The number of leaves were recorded randomly from 3 spots in each plot at 30, 60 and at 90 DAS per running meter. The dry-matter (g/m row length) acquired by plant was expressed on over-dry basis at different growth stages and biological yield at harvesting. The crop-growth rate (CGR), relative growth rate (RGR), net assimilation rate (NAR) and leaf-area index were estimated.

The recorded data were analysed by utilizing investigation of difference procedure in the computer-based statistical program (Gomez and Gomez, 1984). The data was analyzed at $P \leq 0.05$ by utilizing the LSD test.

RESULTS AND DISCUSSION

Plant height

Irrigation scheduling and weed-management practices influenced the plant height at various development stages (Fig. 1). Application of water at CRI + jointing + booting

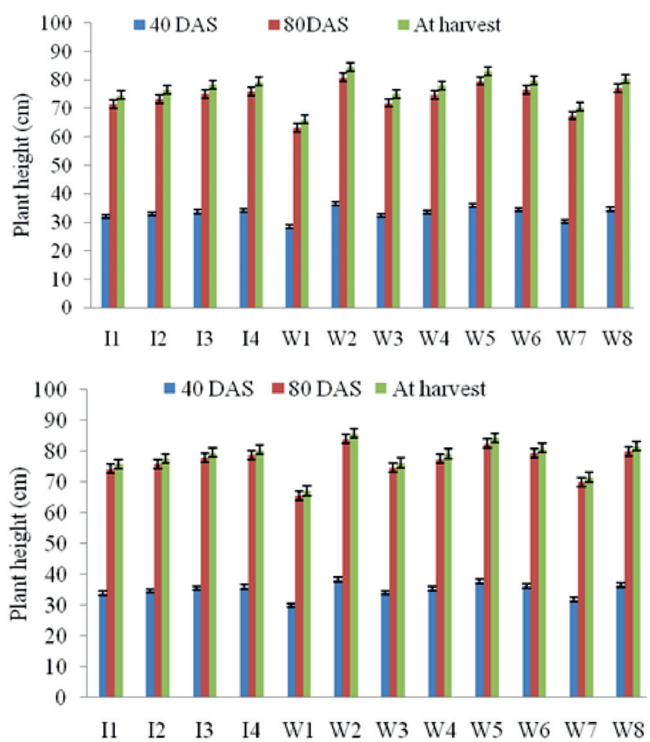

Fig. 1. Effect of irrigation and weed management on plant height during 2017–18 (top) and 2018–19 (bottom): Details of treatments are given under materials and methods

*Error bars indicating the LSD P<0.05

+ flowering + milking stage (I_4) resulted in the maximum plant height which was statistically at par with irrigation at CRI + active tillering + booting + flowering stage (I_3) and significantly superior to irrigation at CRI+ jointing + booting (I_2) and irrigation at CRI and active tillering (I_1). The maximum plant height under I_4 treatments might be owing to the availability of sufficient moisture in the soil root zone which enhance cell-division and all other metabolic activities in the plant. Irrespective of the treatment, all the weed-management options significantly increased the plant height as compared with the weedy check. Among the herbicidal treatments, the application of Carfentrazone ethyl 20% + Sulfosulfuron 25% WG @ 100 g a.i./ha at 35 DAS produced significantly tallest plants as compared to the other herbicidal treatments. Higher plant height with the application of this herbicide might be because of the less weed completion under this treatment which shifted crop-weed competition in favour of crop. Under less weed competition crop plants utilize all the growth factors and achieve the maximum plant height. The combined use of herbicides decreased the weed populace consequently a increment in plant stature of wheat and yield (Singh *et al*., 2017; Bari *et al*., 2020).

Number of tillers

Application of water at CRI + jointing + booting + flowering + milking stage (I_4) resulted in significantly highest number of tillers as compared to the irrigation applied at CRI + jointing + booting stage (I_2) and CRI and active tillering stage (I_1), whereas it was statistically at par with the treatment where 5 irrigations were applied at CRI + active tillering + booting + flowering stage (I_3) (Fig. 2) Kumar *et al*., (2017) and Verma *et al*., (2017) also reported that, application of sufficient water at critical growth stages in wheat improves crop growth and yield. Among the weed-management treatments, 2 hand-weedings – 20 and 40 DAS proved superior to other herbicidal treatments with respect to number of tillers. Among the different herbicidal treatments, application of Carfentrazone ethyl 20% + Sulfosulfuron 25% WG @ 100 g a.i./ha at 35 DAS recorded maximum number of tillers/m. This might be owing to the better weed control, which provided sufficient space to crop for better tillering. On the other hand, minimum number of tillers was found under weedy check was due to the heavy infestation of weeds which compete with crop plant for resources (Mahbod *et al*., 2014).

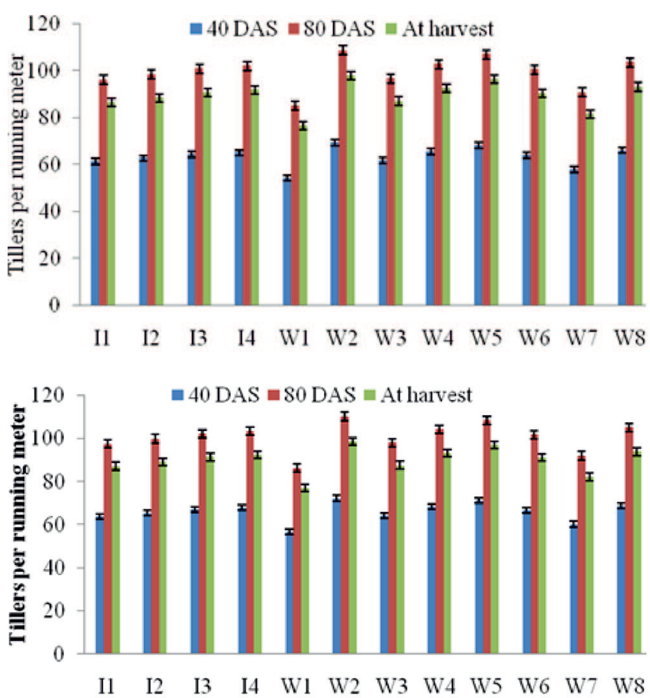

Fig. 2. Effect of irrigation and weed management on tillers during 2017–18 (top) and 2018–19 (bottom): Details of treatments are given under materials and methods

*Error bars indicating the LSD P<0.05

Dry-matter accumulation

Irrespective of treatments, there was a gradual increase in dry-matter production up to harvesting (Table 1). Application of irrigation at CRI + jointing + booting + flowering + milking stage (I_4) produced significantly highest total dry matter (385.1 g/m running length). Dry-matter production decreased with decreasing irrigation number from 5 to 2 irrigations, it might be due to the availability of sufficient water for plant uptake which enhanced the plant height, number of tillers and leaf area–all these parameters are positively correlated with dry-matter production. Five irrigations might have collectively resulted in better growth and development of plant because of sufficient supply of water has vital role as solvent of plant nutrient and carrier of food material (Singh *et al*., 2017). Among the herbicidal treatments, Carfentrazone ethyl 20% + Sulfosulfuron 25% WG @ 100 g a.i./ha at 35 DAS significantly increased the dry-matter over the other herbicidal treatments. Higher number of tillers and leaf–area, particularly early in the growing season, resulted from different herbicide treatments might have led to higher dry-matter accumulation on account of higher radiation interception over a prolonged period of time. Better resource acquisition and utilization might have contributed to more crop growth and dry-matter accumulation by wheat. Similar results confirm the findings of Singh *et al.,* (2017a) and Verma *et al.,* (2017) who reported higher dry-mater accumulation in wheat with combined application of herbicides. The combined application of herbicides in wheat reduced the weed population which reduced the mining of water and nutrients by weeds and enhanced their availability to crop plant thus helped in increasing leaf-area, resulting in higher photo-assimilates

Table 1. Effect of irrigation schedule and weed-management practices on crop dry weight net assimilation rate and biological yield (mean data of 2 years)

Treatments	Crop dry weight (g/m row)			NAR ($g/cm^2/day$)			Biological yield (kg/ha)
	40 DAS	80 DAS	At harvesting	0–30 DAS	30–60 DAS	60–90 DAS	
Irrigation schedule							
I_1, 2 irrigations (CRI + active tillering)	18.1	176.9	357.9	0.180	0.546	0.271	6,233
I_2, 3 irrigations (CRI + jointing + booting)	18.6	178.6	365.1	0.182	0.562	0.274	6,529
I_3, 4 irrigations (CRI + active tillering + booting + flowering)	19.8	183.4	384.2	0.192	0.589	0.305	6,722
I_4, 5 irrigations (CRI + jointing + booting + flowering + milking)	19.9	183.7	385.1	0.193	0.590	0.305	6,899
CD (P=0.05)	0.75	4.86	8.12	0.006	0.010	0.006	231
Weed-management practices	0.0	0.0	0.0				
W_1, Weedy check	18.5	171.2	360.2	0.179	0.543	0.278	5,766
W_2, 2 hand-weedings (20 and 40 DAS)	20.9	190.8	386.2	0.207	0.585	0.303	7,532
W_3, Sulfosulfuron @ 25 g/ha at 35 DAS	18.8	177.7	370.2	0.184	0.571	0.283	6,400
W_4, Pendimethalin (pre-em) *fb* WCPL-15 @ 400 g/ha at 35 DAS	19.2	181.0	371.3	0.185	0.574	0.288	6,503
W_5, Carfentrazone ethyl 20% + Sulfosulfuron 25%WG @ 100 g a.i./ha at 35 DAS	19.6	187.3	376.9	0.188	0.580	0.295	7007
W_6, Halauxafen + Penxasulam 23.5% @ 75 g a.i./ha at 35 DAS	19.0	178.8	372.8	0.183	0.571	0.286	6581
W_7, Halauxafen-methyl 1.21% w/w + Fluroxypyr @ at 35 DAS	18.2	175.6	368.9	0.182	0.570	0.284	6181
W_8, Clodinafop- propargyl 15% + Metsulfuron methyl 1% @ 400 g a.i./ha 35 DAS	18.6	182.8	377.9	0.186	0.582	0.292	6798
CD (P=0.05)	0.40	3.01	3.00	0.002	0.004	0.003	196

and thereby resulted in more dry-matter production (Choudhary *et al.,* 2021).

Number of functional leaves and leaf-area index

Application of irrigation at 5 critical stages i.e. CRI + jointing + booting + blooming + milking, recorded significantly highest number of functional leaves/m at all the stages of observation as compared to the other irrigation treatments (Fig. 3). Water is very important component for cell-division and cell-elongation in every plant. In present study, number of leaves and leaf-area index increased with increasing number of irrigation. This might be owing to the availability of sufficient water by which plant absorb sufficient nutrients from soil and make it available for further growth of plant. Among the weed-management practices, the maximum number of leaf/m as well as LAI were noted in the hand-weeded plots where 2 hand weedings at 20 and 40 DAS were done (Fig. 4). Hand-weeding during early crop-growth stage had significant effect on weed suppression thus crop plants get enough resources and space to flourish. Among the herbicidal treatments, application of Carfentrazone ethyl 20% + Sulfosulfuron 25% WG @ 100 g a.i./ha at 35 DAS recorded significantly maximum number of leaf and LAI over other herbicidal treatments.

Crop-growth, relative growth rate and net assimilation rate

Among irrigation treatments application of 5 irrigations at CRI + jointing + booting + flowering + milking stage (I_4) resulted in significantly highest Crop-growth (CGR), relative growth rate (RGR) and net assimilation rate (NAR). Successive decrease in number of irrigations reduced the values of CGR, RGR and NAR and hence, 2 irrigations irrigation - at CRI and active tillering stage (I_1)-had the lowest value of these parameters (Figs. 5, 6; Table 1 respectively). Water is a fundamental constituent of protoplasm and its adequate supply is essential for hyperplasia and hypertrophy. Therefore, optimum availability of water to wheat might have improved the photosynthetic area of plants that cumulatively added to accumulation of drymatter and higher plant height which ultimately increased the CGR, RGR and NAR of crop (Singh *et al*., 2010).

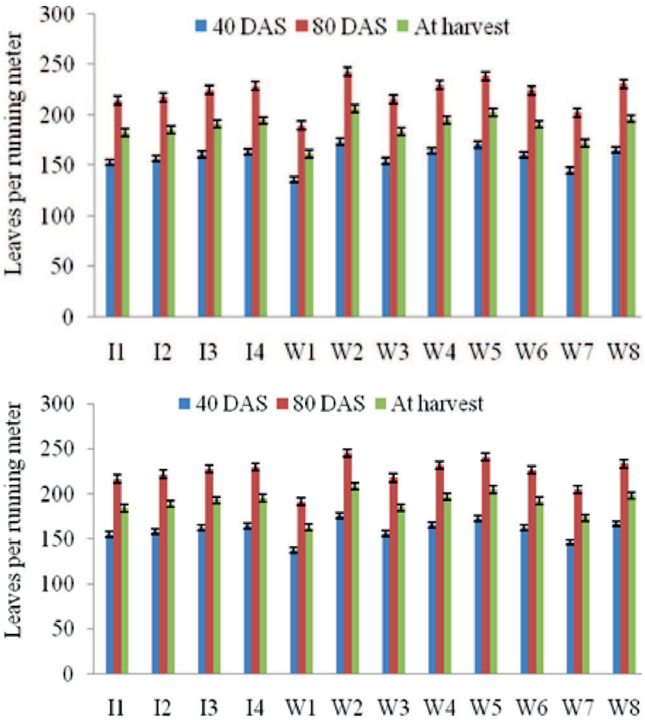

Fig. 3. Effect of irrigation and weed management on number of leaves during 2017–18 (top) and 2018–19 (bottom): Details of treatments are given under materials and methods

*Error bars indicating the LSD P<0.05

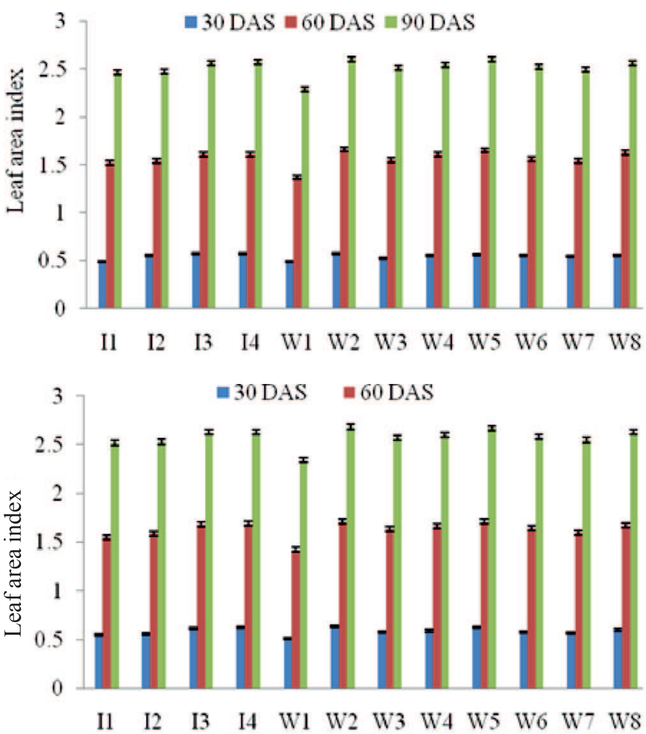

Fig. 4. Effect of irrigation and weed management on leaf-area index during 2017–18 (top) and 2018-19 (bottom): Details of treatments are given under materials and methods

*Error bars indicating the LSD P<0.05

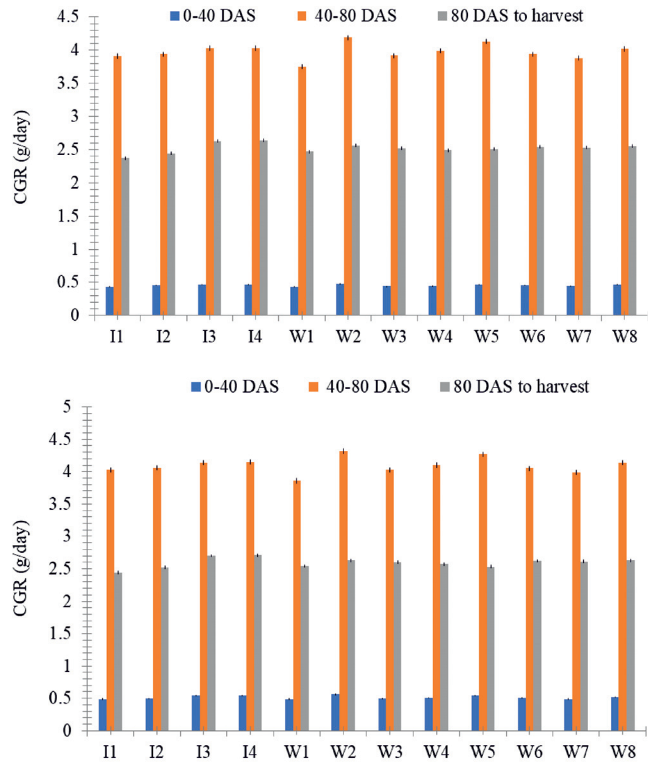

Fig. 5. Effect of irrigation and weed management on crop-growth rate during 2017–18 (top) and 2018–19 (bottom): Details of treatments are given under materials and methods

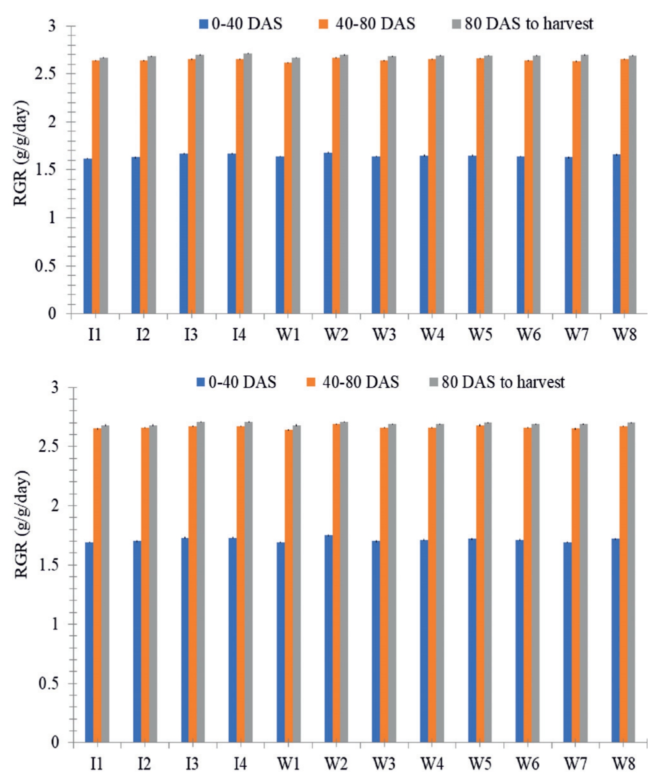

Fig. 6. Effect of irrigation and weed management on crop-growth rate during 2017–18 (top) and 2018–19 (bottom): Details of treatments are given under materials and methods

Weed-management practices exerted significant effect on growth rate of wheat. The maximum CGR, RGR and NAR of wheat were recorded when weeds were eliminated by hand (at 20 and 40 DAS), followed by the use of herbicides. Among the herbicidal treatments, application of broadway (Carfentrazone ethyl 20%+ Sulfosulfuron 25% WG) @ 100 g a.i./ha at 35 DAS showed its superiority to the other herbicides in terms of CGR, RGR and NAR. This might because of reduction of competition between wheat and weeds for space, moisture, nutrients and light because crop growth and yield are significantly affected by weeds (Zager *et al*., 2020).

Biological yield

The different irrigation treatments had significant effect on biological yield in both the years. It is clear from data that, the maximum biological yield was recorded with the application of irrigation at 5 stages (I_4,) being 2.25 and 2.88%, 5.95 and 4.81% and 11.57 and 7.77% higher than that of I_3, I_2 and I_1 respectively (Table 1). Higher yield of wheat with 5 irrigations attributed to higher photosynthetic activity of plants owing to optimum soil moisture for all the metabolic activities which leads to greater growth and development of the plants. Further, optimum moisture availability might improve the source-sink relationship and facilitate higher translocation of photosynthates from leaves to reproductive parts that leads to higher crop productivity. However, due to shortage of water under lower level of irrigation (I_1 and I_2) may decrease the formation and translocation of growth substances, which disturbed the metabolic activity of plants, ultimately plant growth is adversely affected. These outcomes are in congruity with the earlier findings. Among weed-management practices, hand-weedings at 20 and 40 DAS recorded significantly highest yield compared to the other treatments, whereas among the herbicidal treatments, application of Carfentrazone- ethyl 20% + Sulfosulfuron 25% WG 100 g a.i./ha at 35 DAS resulted in the highest crop yield, followed by Clodinafop-propagyl 15% + Metsulfuron methyle 1% 400 g a.i./ha at 35 DAS. These outcomes are in line with the results of

Table 2. Yield attributes and grain yield of maize as influenced by sequential application of pre-and post-emergence herbicides

	Treatment	Grassy weeds at 50 DAS (No./m^2)*	Broad-leaved weeds at 50 DAS (No./m^2)*	Grains/ row	Grains/ cob	Grain weight/ cob (g)	Grain yield (t/ha)
T_1	Weedy check	6.53	5.89	29.9	368.9	90.7	4.30
T_2	Weed free check	0.71	0.71	37.0	502.5	137.6	6.70
T_3	Atrazine (1,500 g/ha) as pre-emergence (PE)	4.14	0.88	31.3	408.0	102.4	5.70
T_4	Atrazine (750 g/ha) + Pendimethalin (750 ml/ ha) as PE	3.31	1.05	33.5	440.1	112.8	5.80
T_5	Atrazine (1,500 g/ha) as PE *fb* 2,4-D Amine (400 g/ha) as post-emergence (PoE) at 25 DAS	4.43	0.71	33.3	439.4	113.0	6.10
T_6	Halosulfuron (67 g/ha) as PoE at 25 DAS	4.85	1.77	31.2	403.0	100.2	4.80
T_7	Atrazine (1,500 g/ha) as PE *fb* Halosulfuron (67 g/ha) 25 DAS as PoE	5.11	0.71	33.2	434.9	116.1	6.00
T_8	Tembotrione (120 g/ha) as PoE at 25 DAS	4.45	3.03	34.4	455.9	118.4	5.40
T_9	Pendimethalin (1,000 ml/ha) as PE *fb* Atrazine (750 g/ha) + 2,4-D Amine (400 g/ha) at 25 DAS as PoE	2.96	2.68	35.7	481.1	131.5	6.20
T_{10}	Atrazine (1,500 g/ha) as PE *fb* Tembotrione (120 g/ha) as PoE at 25 DAS	2.94	0.88	36.2	499.1	137.0	6.50
	SEm±	0.116	0.124	1.62	38.21	11.77	0.20
	CD (P=0.05)	0.245	0.261	4.30	80.28	24.74	0.42

DAS: Days after sowing and Fb: Followed by.*Transformed values: $\sqrt{X + 0.5}$

Singh *et al*. (2020), Shivran *et al*. (2020) and Sharma *et al*. (2020). Weedy check recorded the lowest crop yield. Relative weed-free circumstance under herbicidal treatments decreased the harvest weed rivalry and accordingly increased the vegetative development and yield credits fundamentally influenced the biological yield of wheat (Verma, 2014; Singh *et al*., 2017b; Zager *et al*., 2020).

The extent of relationship as depicted in showed that wheat biological yield had positive relationship with crop dry weight (r = 0.010). Correlation coefficient indicated that unit increase in crop dry weight of wheat correspondingly enhanced biological yield by 12.99 kg ha^{-1}.

The results of this study demonstrate that, cultivation of wheat with the application of 5 irrigation at CRI + jointing + booting+ flowering+ milking stage resulted in higher crop growth and biological yield of wheat. Likewise, application of Carfentrazone- ethyl 20% + Sulfosulfuron 25% WG 100 g a.i./ha at 35 DAS showed higher crop growth and biological yield over other herbicide option.

Application of Atrazine @ 1.5 kg/ha pre-emergence fb Tembotrione 120 g/ha PoE at 25 DAS (T_{10}) significantly recorded lower number of grassy weed count while weedy check. There were no broad leaved weeds in T_5, T_7 and T_{10} at 50 DAS. These results are in conformity with Nagalakshmi *et al*. (2006).

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