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RESEARCH ARTICLE

Effect of irrigation level and weed management practices on wheat growth, yield and economics

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ABSTRACT

An experiment was conducted at Sardarkrushinagar Dantiwada Agricultural University (SDAU), Sardarkrushinagar, Gujarat during two consecutive winter *(Rabi)* seasons of the years 2014-15 and 2015-16. The experiment consisted of twenty-one treatments with three levels of irrigation (0.6, 0.8, 1.0 IW:CPE ratio) as main plot treatments and seven weed management practices as sub-plot treatments. A split-plot design with three replications was used. The crop irrigated at 1.0 IW: CPE recorded significantly higher growth parameters, yield attributes, grain and straw yield. Among weed management practices, hand weeding twice and metsulfuron-methyl 4 g/ha at 28 DAS recorded significantly higher yield attributes, grain and straw yield. Interaction between irrigation levels and weed control practices revealed that wheat irrigated at 1.0 IW: CPE in combinations with two hands weeding or metsulfuron-methyl 4 g/ha and clodinafop + metsulfuron-methyl (ready-mix) 60 g/ha produced significantly higher grain yield than other treatments. The economic analysis revealed that irrigation at 1.0 IW:CPE ratio recorded significantly higher net returns of ₹ 66188/ha and B:C 2.11. Among weed management treatment, metsulfuron-methyl 4 g/ha) PoE attained maximum net income of ₹ 34036/ha with B: C 2.16 and next best was clodinafop + metsulfuron-methyl (ready-mix) 60 g/ha which fetched next highest net income (₹ 30843/ha) and B:C (2.01).

Keywords: Clodinafop-propargyl, Herbicides, Irrigation, Metsulfuron-methyl, Weed management, Wheat

INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the most important staple food crops of India. The wheat is grown in India in 31.5 million ha and produced 107.6 million tons of wheat in 2019-2020 (GOI 2021), which is second highest in the world. The average productivity of wheat in India is 3.4 t/ha. The three main species of wheat, *viz*. *Triticum aestivum*, *Triticum durum* and *Triticum dicoccum* are cultivated in India, however, *Triticum aestivum* and *Triticum durum* are popularly grown in Gujarat. Water is one of the most important factors that are necessary for proper growth, balanced development and higher yields of all crops. Water deficiency affects plant growth and grain yield (Hussain *et al*. 2004). Irrigation management is one of the important managerial activities and effects the effective utilization of water by crop (Shirazi *et al.* 2014). In general, irrigation is being scheduled on the basis of the climatological approach (IW: CPE ratio) during the entire period of crop irrespective of the stage of growth. Proper scheduling of irrigation is necessary at both vegetative and reproductive phases to maintain the optimum moisture regime for better growth and development of the crop in the changing climatic scenario where abrupt variation in temperature takes place (Parihar and Tiwari 2003).

Besides irrigation, wheat crop is also negatively affected by biotic constraint such as weeds. Weeds not only compete with the crop plants for moisture and nutrients but also space and solar radiation. The wheat is mostly cultivated with irrigation in India in general and Gujarat in particular. The irrigated environment provides congenial conditions for weeds to proliferate and cause wheat yield reduction of 20 to 50% (Joshi 2002). Hence, managing weed is critical in attain higher productivity of crops with improved resources use efficiency, to meet the food and nutritional demand of increasing Indian population as well as increasing income of the farmers (Rao and Chauhan 2015). The hand weeding, normally practiced by farmers, is time-consuming and tedious and very costly due to the unavailability of labour in peak periods and high labour charges due to shifting of agricultural labours to industries for better and assured wages. Hence, the integrated weed management approach is advantageous because one technique rarely achieves complete and effective control of all weeds during crop season and even a relatively few surviving weeds can produce sufficient number of seeds to perpetuate the species (Walia *et*

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al. 1997). The recent studies on weed management showed that a single application of herbicide may not sufficient to control all weed flora present in field, but tank mix or sequential application of two or more herbicides may be needed to manage weeds effectively (Chand *et al.* 2004).

The water and weed management are critical to improve the wheat productivity, production and income of the farmers. Therefore, this study was conducted to understand the water-weed management relationship in field condition and identify suitable weed control methods and irrigation levels for optimal wheat production.

MATERIAL AND METHODS

The field experiment was laid out in Plot C-9 at the Agronomy Instructional Farm, Sardarkrushinagar Dantiwada Agricultural University (SDAU), Sardarkrushinagar, Gujarat during the winter *(Rabi)* seasons of the years 2014-15 and 2015-16. Geographically, Sardarkrushinagar is situated at 24°-19' North latitude and 72°-19' East longitude with an elevation of 154.52 m above the mean sea level. The climate of the region is sub-tropical with extreme cold winter, hot and dry windy summer. In general, monsoon is warm and moderately humid with an average annual rainfall of 638 mm received in about 26 rainy days. The winter season sets in the months of October and sets back in the month of February and remain fairly cold and dry. The minimum temperature of the year is observed in the month of December or January and considered as the coldest months of the year (**Figures 1** and **2**).

The experimental field has an even topography with a gentle slope having good drainage. The soil was loamy sand in texture, low in organic carbon (0.25%) and available nitrogen (158 kg/ha), medium in available phosphorus (37.5 kg/ha), and high in available potash (226 kg/ha). The experiment was conducted in split-plot design with 3 replications. Wheat variety '*GW 322'* was sown at 22.5 cm row spacing in the experiment. The experiment consisted of twenty one treatment combinations comprised three levels of irrigation (0.6,0.8,1.0 IW: CPE ratio) as main plot treatments and seven weed management practices: hand weeding twice at 20 and 40 days after sowing (DAS), pre-emergence application (PE), (on the next after seeding), of pendimethalin 1000 g/ha, post-emergence application (PoE), at 28 DAS, of metsulfuron-methyl 4.0 g/ha, clodinafop- propargyl 60 g/ha, sulfosulfuron 75% + metsulfuron-methyl 5% WG (ready-mix) 32 g/ha, clodinafop-propargyl 15% + metsulfuron-methyl 1% (ready-mix) 60 g/ha,

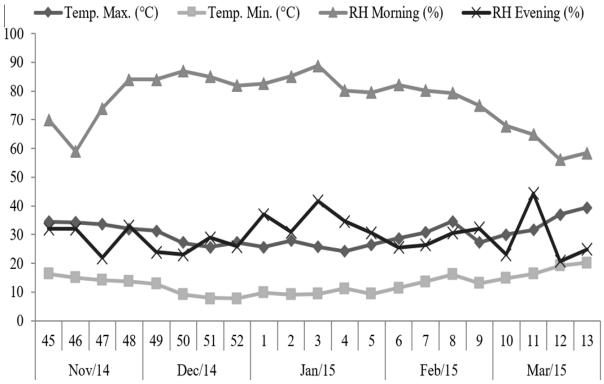

Figure 1. Mean weekly weather parameters recorded during crop growth period of 2014-15

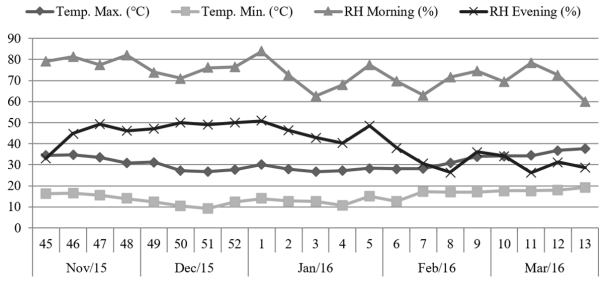

Figure 2. Mean weekly weather parameters recorded during crop growth period of 2015-16

weedy check as sub-plot treatments. The nitrogen 120 kg/ha was applied in 3 split (as urea). The phosphorus (P) (as single super phosphate) 60 kg P/ha and potash (K) (as muriate of potash) 30 kg/ha were applied as a basal dose for all the treatments. The sowing of wheat was done manually in dry moist soil, on 25th and 26th of November during the first and second year, respectively. Seeds were treated with fipronil 5% at 6 g/kg seed for termite and white grub control. Wheat was harvested during 21st March and 22nd March during the first and second year, respectively.

The cumulative pan evaporation values were calculated from daily pan evaporation measured with the help of USWB class 'A' open pan evaporimeter installed at the meteorological observatory, which was in the proximity of the experimental plot. The quantity of irrigation water applied in surface flooding was measured by a 7.5 cm head Parshall flume. A fixed depth of 50 mm irrigation water was applied to each treatment based on IW:CPE ratio of 0.6, 0.8 and 1.0. PE herbicide was sprayed next DAS (days after sowing) and PoE herbicides were sprayed on 28 DAS at spray volume of 500 l/ha. Spraying was done by manually operated knapsack sprayer. The weed biomass and crop data were collected as per standard procedures. The weed index was calculated by following the formula given by Gill and Kumar (1969). The weed control efficiency was calculated following the formula is given by (Mani *et al.* 1981).

The Benefit: Cost Ratio (B:C) is the ratio of gross realization to the total cost of cultivation that was calculated by using the following formula.

$$B:C = \frac{\text{Gross realization (₹/ha)}}{\text{The total cost of cultivation (₹/ha)}}$$

RESULTS AND DISCUSSION

Effect of irrigation levels

Growth attributes characters, *viz.* plant height, number of effective tiller/m^2, ear length and 1000-grains weight of wheat were significantly higher when irrigation scheduled at IW/CPE ratio of 1.0, over two irrigation schedules tried (**Table 1**). The highest grain (3.6 t/ha) and straw (4.8 t/ha) yields were recorded with the irrigations scheduled at the IW/CPE ratio of 1.0, which were significantly superior over rest of the irrigation schedules (**Table 1**). The remarkable increase in yields with higher levels of irrigation might be attributed to the favourable effect on yield attributes, *viz.* plant height, effective tillers, ear length, grain weight/ear, 1000-grains weight and grains/ear. Moreover, maintenance of adequate available soil moisture in the root zone would be conducive for proper uptake as well as utilization of nutrients, which has a variable impact on growth component and yield attributes for better yield. The positive linear response of wheat grain yield to irrigation has been reported by Bandyopadhyay and Mallick (2003), Parihar and Tiwari (2003), Singh *et al.* (2003) and Verma *et al.* (2011).

The economic evaluation of different levels of irrigation showed that gross and net returns increased with an increase in the level of irrigation (**Table 4**) with highest gross and net returns of ₹ 66188/ha and ₹ 34794/ha, respectively with 1.0 IW:CPE ratio. The B:C was also highest with the application of irrigation using 1.0 IW:CPE ratio.

Effect of weed management treatments

Among weed management practices, hand weeding twice at 20 and 40 DAS produced significantly higher effective tiller/m^2, ear length, grains/ear and grain weight/ear except plant height and 1000-grainsweight (**Table 1**) and it was on with metsulfuron-methyl 4 g/ha; clodinafop-propargyl 15% + metsulfuron-methyl 1% (ready-mix) 60 g/ha and sulfosulfuron 75% + metsulfuron-methyl 5% WG (ready-mix) 32 g/ha. The weed-free environment created by these treatments has minimized the weed-crop competition which led to better growth of the crop. The created weed-free environment also provided a better edaphic and nutritional environment in the wheat root zone. The results are in agreement with those reported by Bharat and Kachroo (2007), Chopra *et al.* (2008), Malik *et al.* (2008) and Bharat and Kachroo (2010).

The pooled data indicated that hand weeding twice at 20 and 40 DAS recorded significantly higher wheat grain (3.5 t/ha) and straw yield (4.7 t/ha) compared to other weed control practices except metsulfuron-methyl 4 g/ha. The increase in yields

Table 1. Wheat growth, yield attributes and yield as influenced by irrigation levels and weed management practices (pooled data of two year)

Treatment	Plant height (cm) at harvest	Effective tillers /m^2	Ear length (cm)	No. of grains/ ear	Grain weight per ear (g)	1000-grains weight (g)	Grain yield (t/ha)			Straw yield (t/ha)			Harvest Index (%)
							2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	
Irrigation level													
I_1: 0.6 IW:CPE ratio	77.96	246.8	7.00	27.25	1.02	37.41	2.65	255	2.60	3.74	3.73	3.74	41.02
I_2: 0.8 IW:CPE ratio	83.27	263.2	7.81	28.67	1.08	37.74	2.97	2.29	2.94	4.11	3.98	4.04	41.97
I_3: 1.0 IW:CPE ratio	89.42	300.5	8.46	29.56	1.12	38.40	3.64	3.58	3.61	4.78	4.78	4.78	42.96
LSD (p=0.05)	5.01	17.2	0.49	1.021	0.04	0.46	0.27	0.35	0.18	0.46	1.49	0.28	NS
Weed management													
W_1: Hand weeding twice 20 and 40 DAS	84.52	310.0	8.09	29.58	1.12	38.14	3.55	3.47	3.51	4.73	4.64	4.68	42.77
W_2: Pendimethalin 1000 g/ha PE at next DAS	83.07	275.0	7.62	28.15	1.07	37.78	3.08	3.05	3.07	4.25	4.25	4.25	41.66
W_3: Metsulfuron-methyl 4 g/ha PoE at 28 DAS	84.47	306.5	8.00	29.34	1.11	38.02	3.48	3.41	3.44	4.65	4.59	4.62	42.66
W_4: Clodinafop-propargyl 60 g/ha applied at 28 DAS	82.43	203.1	7.50	27.30	1.02	37.64	2.44	2.32	2.38	3.43	3.39	3.41	41.14
W_5: Sulfosulfuron 75% + metsulfuron-methyl 5% WG 32 g/ha applied at 28 DAS	83.95	297.4	7.79	28.92	1.08	37.90	3.29	3.24	3.26	4.49	4.45	4.47	42.17
W_6: Clodinafop-propargyl 15% + metsulfuron-methyl 1% 60 g/ha applied at 28 DAS	84.20	300.3	7.89	29.06	1.10	37.93	3.36	3.29	3.33	4.55	4.47	4.51	42.37
W_7: Weedy check	82.21	199.1	7.41	27.10	1.01	37.54	240	2.29	2.34	3.37	3.34	3.35	41.10
LSD (p=0.05)	NS	15.2	0.44	1.07	0.04	NS	0.21	0.21	0.15	0.32	0.35	0.23	NS
Interaction													
LSD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	0.26	NS	NS	NS	NS

DAS: Days after seeding; PE: Pre-emergence; PoE: Post-emergence

Table 2. Interaction effect of irrigation and weed management treatments (I × W) on wheat grain yield (pooled data of two year)

Irrigation levels (I)	Grain yield (t/ha)						
	Weed management treatments (W)						
	W_0	W_1	W_2	W_3	W_4	W_5	W_6
I_1	3.06	2.26	2.97	2.14	2.80	2.84	2.12
I_2	3.36	3.14	3.36	2.22	3.13	3.19	2.15
I_3	4.12	3.81	4.00	2.79	3.86	3.95	2.76
LSD (p=0.05)				0.26			

with these treatments may be attributed to the reduced in crop-weed competition due to broad-spectrum control of both broad and narrow leaf weeds and concomitant increase in nutrient availability to the crop plants resulting in a marked improvement in the crop yield attributes, *viz.* effective tillers, ear length, and grains weight/ear and yield. Those reported by Singh and Ali (2004), Malik *et al.* (2008), Bharat and Kachroo (2010), Bharat *et al.* (2012), Paighan *et al.* (2013), Singh (2013) and Padheriya *et al.* (2014). The lowest grain and straw yields were recorded with a weedy check treatment.

The weed biomass was significantly influenced by weed management treatments (**Table 3**). The highest weed biomass was recorded in weedy check, whereas hand weeding twice at 20 and 40 DAS recorded minimum (10.07 kg/ha). Among the herbicide, metsulfuron-methyl 4 g/ha measured lowest weed biomass (26.46 kg/ha) as per pooled data. The highest weed control efficiency (WCE) was obtained with hand weeding twice at 20 and 40 DAS whereas, in herbicides treatments, metsulfuron-methyl 4 g/ha applied at 28 DAS recorded maximum WCE (95.11%) followed by clodinafop-propargyl 15% + metsulfuron-methyl 1% (ready-mix) 60 g/ha and sulfosulfuron 75% + metsulfuron-methyl 5% WG (ready-mix) 32 g/ha. The weed index (WI) in different weed treatment, metsulfuron-methyl 4 g/ha applied at 28 DAS recorded lower value (2.00 %) as against 33.12% by weedy check. The clodinafop-propargyl 15% + metsulfuron-methyl 1% (ready-mix) 60 g/ha and sulfosulfuron 75% + metsulfuron-methyl 5% WG (ready-mix) 32 g/ha had recorded the second and third WI value than other treatments of this study.

Economics plays an important role in the adoption of effective weed management treatments by the farmers. Significantly higher net income (₹ 34036/ha) and B:C (2.16) were recorded by metsulfuron-methyl 4.0 g/ha followed by metsulfuron-methyl 4.0 g/ha and clodinafop-propargyl 15% + metsulfuron-methyl 1% (ready-mix) 60 g/ha with net income of ₹ 30843/ha and B:C of 2.01.

Table 3. Effect of weed management treatments on weed biomass, weed control efficiency and weed index in wheat

Weed management	Weed biomass (kg/ha) at harvest	Weed control efficiency (%)	Weed index (%)
Hand weeding twice 20 and 40 DAS	10.07	98.14	0.00
Pendimethalin 1000 g/ha PE	193.16	64.29	12.61
Metsulfuron-methyl 4 g/ha PoE at 28 DAS	26.46	95.11	2.00
Clodinafop-propargyl 60 g/ha at 28 DAS	421.44	22.09	32.05
Sulfosulfuron 75% + metsulfuron-methyl 5% WG 32 g/ha at 28 DAS	126.68	76.58	7.05
Clodinafop-propargyl 15% + metsulfuron-methyl 1% 60 g/ha at 28 DAS	100.92	81.34	5.31
Weedy check	540.94	0.00	33.12
LSD (p=0.05)	16.80	-	-

Table 4. The gross return, net returns and B:C ratio as influenced by irrigation levels and weed management treatments

Treatment	Cost of cultivation (x10^3 `/ha)	Gross returns (x10^3 `/ha)	Net returns (x10^3 `/ha)	B:C
Irrigation level				
0.6 IW:CPE ratio	29.19	47.91	18.72	1.64
0.8 IW:CPE ratio	30.29	53.95	23.65	1.78
1.0 IW:CPE ratio	31.39	66.19	34.79	2.11
LSD (p=0.05)	-	3.23	3.23	0.10
Weed management				
Hand weeding twice 20 and 40 DAS	34.28	64.42	30.14	1.87
Pendimethalin 1000 g/ha PE at next DAS	30.32	56.41	26.09	1.85
Metsulfuron-methyl 4 g/ha PoE at 28 DAS	29.12	63.15	34.04	2.16
Clodinafop-propargyl 60 g/ha applied at 28 DAS	29.84	43.89	14.05	1.47
Sulfosulfuron 75% + metsulfuron-methyl 5% WG 32 g/ha applied at 28 DAS	30.01	59.97	29.96	1.99
Clodinafop-propargyl 15% + metsulfuron-methyl 1% 60 g/ha applied at 28 DAS	30.22	61.06	30.84	2.01
Weedy check	28.28	43.20	14.92	1.52
LSD (p=0.05)	-	2.62	2.62	0.09

Selling price of grain and straw were ₹ 17.0/kg and ₹ 1.0/kg, respectively

Interactions

The treatment combination of 1.0 IW: CPE ratio with hand weeding twice recorded significantly higher grain yield of 4.12 t/ha (**Table 2**) and it was at par with the treatment combination of 1.0 IW: CPE ratio with metsulfuron-methyl 4.0 g/ha (grain yield of 4.0 t/ha) and 1.0 IW: CPE ratio with clodinafop-propargyl 15% + metsulfuron-methyl 1% (ready-mix) 60 g/ha (grain yield of 4.0 t/ha). This might be due to an increase in yield attributes. Hence the crop should be irrigated at 1.0 IW:CPE ratio and weed control be done using hand weeding twice at 20 and 40 DAS. These findings are in agreement with the results reported by Singh and Singh (2004) and Nadeem *et al.* (2007).

Conclusion

It was concluded that for getting higher wheat grain and straw yield, the crop should be irrigated at 1.0 IW: CPE ratio and should be kept free from weed competition by using hands weeding twice at 20 and 40 DAS or with the application of metsulfuron-methyl 4 g/ha or clodinafop-propargyl 15% + metsulfuron-methyl 1% 60 g/ha (ready-mix) at 28 DAS.

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