Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
www.phytojournal.com
JPP 2021; 10(2): 670-674
Received: 08-01-2021
Accepted: 12-02-2021

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Interactive effect of irrigation and fertility levels on economic and qualitative yield of extremely late sown wheat (*Triticum aestivum* L.)

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DOI: https://doi.org/10.22271/phyto.2021.v10.i2i.13870

Abstract
Efficient water management, being one of the good agronomic management practices which leads to improve the performance of wheat. Late sowing has substantial effect on nutrient management of wheat. Application of N-P_2O_5-K_2O in balanced level has great impact on late sown wheat yield. Since high yielding varieties of wheat have been found highly responsive to nitrogen fertilization. But in absence of phosphorus, nitrogen becomes ineffective and most of the applied nitrogen remains un-utilized. The efficiency of both nitrogen and phosphorus is greatly enhanced in the presence of each other (Stoeva and Tonev, 2003). So, level of fertilization and irrigation is need to be optimize for higher fertilizer use efficiency and decrease the loss of water under late sown condition, in particular. A field experiment was carried out to investigate the "Interactive effect of irrigation and fertility levels on economic and qualitative yield of extremely late sown wheat (*Triticum aestivum* L.)'' and results revealed that low levels of irrigation and fertilizer doses recorded significantly lower plant height, tiller number, LAI and dry matter accumulation. On the other hand, use of four irrigation along with full recommended dose of fertilizers (120-60-40 kg N- P_2O_5-K_2O ha^{-1}) recorded higher growth parameters *viz.* plant height, tiller number, LAI(leaf area index) and dry matter accumulation as well as economic and qualitative yield of extremely late sown wheat.

Keywords: irrigation and fertility, economic and qualitative yield, sown wheat (*Triticum aestivum* L.)

Introduction
Wheat (*Triticum aestivum* L.) is a staple food of the world, and is the single most important cereal crop that has been considered as integral component of the food security system of the several nations. Wheat provides nearly 55% of the carbohydrate and 20% of food calories which is consumed by two billion people (36% of the world population) as staple food. There are number of factors responsible for low productivity of wheat in Uttar Pradesh, in particular. The late sowing of rice or use of long duration varieties of rice in rice-wheat cropping sequence delays the sowing of wheat from mid-November to December. It has been estimated that delay in sowing of wheat beyond 15 December, resulted in yield reduction of 50 kg grain/day/ha (Singh *et al.*, 2011) [26]. Proper timing and frequency of irrigation in relation to crop yield are crucial in irrigation scheduling for most effective use of available water in optimizing wheat production. Moisture and nutrients availability in soils are the major drivers to determine crop growth, yield and quality of wheat. A water deficit significantly decreases both growth and yield of crop plants (Boyer, 1982; Martin *et al.*, 2006) [8, 19]. Properly irrigated crop can significantly improve both crop yield and quality (Martin *et al.*, 2006) [19]. Irrigation in the field is required in many regions of the world and the extent of irrigated fields has increased significantly over the last fifty years (Yamaoka and Ochii, 2003) [29]. However, the sources becoming limited leads to reduced water availability for irrigation and increase in use of irrigation water are likely to be small in the 21st century. Thus, many efforts are being made to increase irrigation efficiency by improving irrigation scheduling (Proffitt *et al*., 1985; Oweis *et al*., 2000; Sato *et al*., 2006) [20, 21, 23]. Availability of adequate amount of moisture at critical stages of plant growth not only optimizes the metabolic process in plant cell but also increases the effectiveness of the mineral nutrients applied to the crop. Despite the importance of fertilization in maintaining the current productivity in agriculture, the significance of fertilizer application is limited because of shortage of usable water. Over the last decades, a number of studies have been conducted on the regulation of water and fertilizers for different regions, an attempt to increase crop yield (Aase and Pikul, 2000; Li *et al*., 2001a, 2001b) [1, 15, 16]. Balanced

irrigation and nitrogen levels enhanced the yield attributes like number of tillers per unit area, spike bearing tillers, grain weight per spike, 1000-grain weight which ultimately reflects into yield (Waraich *et al*., 2007) [28]. Increasing irrigation and fertilizer rates increase the yield components like spikes m^{-2}, spike weight, number and weight of grains $spike^{-1}$ and number of fertile spikelets $spike^{-1}$ (Beher and Sharma, 1991) [6]. Wheat in areas of rainfed condition where rainfall received below 450mm did not respond to N fertilizer (Bellido *et al*., 1996) [7]. Increase in grain yield with increasing irrigation frequency and N rate have also been reported (Loveras *et al*., 2001) [17]. The moisture stress reduces grain yield when applied at any physiological growth stage, but the extent of damage varies from stage to stage (Malik and Ahmad, 1993; Angadi *et al*., 1991) [3, 18]. Low phosphorus supply has been significantly influencing the growth characters like plant height, tillers m^{-2}, leaf area under adequate moisture and P supply. Moisture and P interactions had a significant effect on shoot and root biomass and P uptake and these variables are closely related to each other (Kenedy *et al*., 2012) [12]. Mineral fertilizers play a major role in improving wheat yields, but imbalanced use of fertilizers, particularly N, P and occasionally K, poses a major constraint in harvesting the potential yields (Sharma *et al*., 2012, Kenedy *et al*., 2012) [6, 12, 24-26]. In intensively cultivated areas, large quantities of inadequately applied nutrients are mined from the soil until they become critically deficient. India is already in an era of multiple nutrient deficiencies, with deficiencies in N, P, K, S and Zn being the most widespread (Sharma *et al*., 2012, Kenedy *et al*., 2012) [6, 12, 24-26]. The vegetative growth and yield of crops are strongly influenced by the nutrient status of the soil and water supply. Soil water depletion is largely affected by leaf area as it is the photosynthetic' factory' of the plant which greatly influences yield (Annandale *et al*., 1984) [4]. Balanced fertilization is becoming more important under late sown condition, where crop requires shorter life spawn for vegetative and reproductive growth. On the other hand, optimum irrigation is the key factor to get higher yield by minimizing the terminal heat stress by maintaining lower soil temperature. Such findings underscore the fact that optimum irrigation and balanced fertilizer use for high yields is not only the first requirement; rather it is a prerequisite for improving the quality and efficiency. This paper reports the combined effect of irrigation and balanced fertilization on crop growth, grain yield and crude protein responses of extremely late sown wheat.

Material and Methods

Description of experimental site

A field experiment was conducted on a partially reclaimed sodic soil during *Rabi* season on 8th January of 2015-16 at Agronomy farm of Narendra Deva University of Agriculture and Technology, Kumarganj, Faizabad located at $26^0$47" N latitude and $82^0$12" E longitude on an elevation of about 113 meters above mean sea level. During the crop season, the lowest temperature (5.2 ^{0}C) was recorded in the month of December and January and the maximum (41.6 ^{0}C) in the month of April. The highest mean relative humidity (78.8%) was recorded in the month of December. The soil of experimental plot was silt loam with pH 8.1, Organic carbon 0.42%, available nitrogen (191.10 kg ha^{-1}), available phosphorus (16.47 kg ha^{-1}) and available potassium (183.30 kg ha^{-1}).

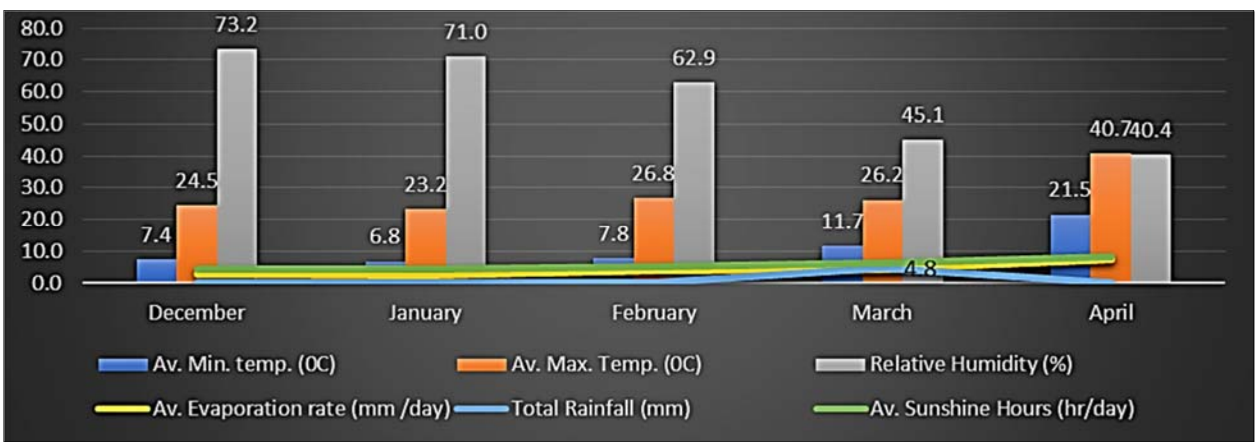

Fig 1: Mean monthly meteorological data prevail during crop season

Experimental details

The experiment was laid out in split plot design with four irrigation levels (I_1: CRI - 21 DAS, I_2: two irrigations at CRI - 21 DAS and at flowering - 64 DAS, I_3: three irrigations at CRI - 21 DAS, late jointing - 55 DAS and at milk stage - 80 DAS and I_4 : four irrigations at CRI -21 DAS, tillering - 38 DAS, flowering - 64 DAS and milk stage - 80 DAS), in main plot and three fertilizer levels (D_1: 25% less than RDF of N-P_2O_5-K_2O *i.e.* 90:45:30, D_2: 100% RDF of N-P_2O_5-K_2O fertilizers *i.e.* 120:60:40 and D_3: 25% more than RDF of N-P_2O_5-K_2O *i.e.* 150:75:50 kg ha^{-1}) in sub-plots with three replications. The experimental field was prepared at proper tilth after pre sowing irrigation. Nitrogen, phosphorus, and potassium were applied in the form of urea, single super phosphate and muriate of potash. Half dose of nitrogen was applied at the time of sowing and remaining amount was top dressed after first irrigation. Full dose of phosphorus and potassium was applied as basal dose during the experimentation. Irrigations were given as per the scheduled time *i.e.,* crown root initiation - 21 DAS, tillering 38 DAS, late jointing 52 DAS, flowering 66 DAS and milk stage 80 DAS. The wheat variety Unnat Halna (K-9423) was sown at proper moisture on 8 January, 2015. Sowing was done in row 20cm apart and 4-5cm deep in furrows @ 120 Kg ha^{-1} in all the plots. Post emergence herbicide Total (Sulfosulfuron 75% + Metsulfuron metyl 5% WG.) @ 39.566 g ha^{-1} was used to manage the weeds of cropped field. Other management practices were adopted as per recommendations of the wheat crop.

Data collected

Growth parameters like culm height (cm), tillers count (no. m^{-1} row) and dry matter yield (g m^{-1} row length) were measured at harvest stage by adopting standard procedure while, leaf area index was measured at 60 DAS by automatic leaf area metre. Grain yield, straw yield and biological yield of wheat were determined at harvest stage in the crop field where wheat plants were sampled on an area of 0.5 m^2 per plot to determine dry mass production and yield components. Harvest index was calculated as grain yield divided by total dry biomass of the crop. Nutritive yield parameters were traced out from main product of wheat (grain yield) by estimating the nitrogen content in grain and further multiplied with grain yield that gave protein content. Protein yield was worked out by multiplying the seed grain yield to their respective protein content. Carbohydrate yield was calculated by multiplying the uniform carbohydrate content i.e., 78% in wheat grain to the grain yield.

Results and Discussion

Weather condition effect on crop

From the meteorological records, it is clear that crop faced lower optimum temperature and high relative humidity in early crop establishment stage till fourth week of January and thereafter, temperature started to rise, while relative humidity increased up to end of January thereafter it continued to go down. The total amount of rainfall received during the crop season was 4.8mm thus the total moisture generated were 54.8mm, 105.8mm, 155.8mm, and 205.8mm for I_1, I_2, I_3 and I_4 levels. On the later stage of crop higher temperature associated with hot desiccating winds and low humidity hastened the reproductive phase and enforced the crop for early maturity proving them as the major factor for the lower productivity of late sown wheat under low water supply condition. Application of four and three irrigation with balanced fertilizer levels enables the crop to face high temperature stress or terminal heat stress.

Growth parameters

Application of irrigation and fertilizers reflects significant interactive effects on growth parameters *viz.,* plant height, tiller numbers, leaf area and dry matter production in extremely late sown wheat. Four irrigations at CRI, tillering, flowering and milk stage with balanced fertilizer dose as 100% of recommended dose of N-P_2O_5-K_2O fertilizers *i.e.,* 120-60-40 recorded higher plant height (79.20 cm) and dry matter (100.40 g m^{-1}row length) while maximum tiller count and leaf area index was recorded under 25% higher N-P_2O_5-K_2O fertilizers of the recommended dose. Conjoint application of four and three irrigation with 100% RDF of N-P_2O_5-K_2O and 25% more than RDF of N-P_2O_5-K_2O fertilizers showed significant superiority over two and one irrigation with different fertilizer doses but failed to get significant differences among each other. This might be due to maintenance of optimum moisture in four and three irrigation provide suitability to mineralise applied nutrients and maintaining longer time availability for the crop. The results are in agreement with findings of Saren *et al.* (2004) [22]; Brahma *et al.,* (2007) [9]; Kumar *et al.,* (2016) [2, 13]; Kenedy and Maral (2018) [12].

Table 1: Interaction effect of irrigation and fertility levels on growth and yield of late sown wheat

Treatment	Plant height (cm)	Tillers m^{-1} row	LAI At 60 DAS	Dry matter (gm^{-1})
I_1D_1	44.75	66.00	2.88	50.93
I_1D_2	56.61	70.20	3.48	58.63
I_1D_3	61.39	71.80	3.90	63.02
I_2D_1	55.55	69.30	3.28	67.26
I_2D_2	63.78	74.60	3.85	70.35
I_2D_3	69.70	77.10	3.91	74.83
I_3D_1	65.87	71.80	3.37	74.18
I_3D_2	71.16	76.40	4.28	88.60
I_3D_3	70.68	81.10	4.09	94.00
I_4D_1	67.95	76.80	4.00	79.73
I_4D_2	79.20	83.55	4.50	100.40
I_4D_3	76.43	83.65	4.65	99.34
Sem±	3.32	1.63	0.12	5.65
CD (*P*=0.05) I x D	9.58	4.72	0.35	16.31

Yield parameters

There was progressive increase in grain and straw yield due to increase in irrigation levels and fertilizer dose as well. Maximum grain yield, straw yield and biological yield were recorded where four irrigations and 100% RDF of N-P_2O_5-K_2O and 25 % more than RDF of N-P_2O_5-K_2O fertilizers of the recommended dose were applied followed by three irrigation and lowest with one and 25% less than RDF of N-P_2O_5-K_2O fertilizers. This might be due to supply of adequate moisture and balanced nutrient, which enhanced growth parameters and yield attributes and ultimately expressed in maximum grain and straw yield. Similar findings were reported by Laghari *et al.* (2010) [14], and Ahmad and Kumar (2015) [2, 13]. Harvest index speaks the conversion efficiency of dry matter to grain portion. All the irrigation levels and fertilizer levels brought remarkable difference in harvest index. Highest harvest index was noticed under four irrigations followed by three, two and one. This might be due to the fact that adequate moisture supply under the higher irrigation levels as well as nutrient availability increased the grain yield than that of biological yield.

Table 2: Interactive effect of irrigation and fertility levels on economic and qualitative yield late sown wheat

Treatment	Grain yield (t ha $^{-1}$)	Straw yield (t ha^{-1})	Biological yield (t ha $^{-1}$)	Harvest index (%)	Protein yield (t ha^{-1})	Carbohydrate yield (t ha^{-1})
I_1D_1	0.91	2.07	2.98	33.96	0.08	71.06
I_1D_2	1.22	2.37	3.59	33.04	0.12	95.32
I_1D_3	1.26	2.41	3.68	33.94	0.15	119.57
I_2D_1	1.36	2.56	3.91	32.68	0.16	143.83
I_2D_2	1.65	2.61	4.26	38.68	0.21	168.09
I_2D_3	1.79	2.71	4.50	39.79	0.25	192.35
I_3D_1	1.75	2.64	4.28	40.26	0.25	216.61
I_3D_2	2.17	3.11	5.28	41.28	0.31	240.86
I_3D_3	2.23	3.34	5.58	39.94	0.36	265.12
I_4D_1	1.92	2.95	4.87	39.31	0.33	289.38
I_4D_2	2.44	3.37	5.82	42.77	0.43	313.64
I_4D_3	2.57	3.39	5.96	43.88	0.45	337.90
Sem±	0.09	0.10	0.11		0.03	11.43
CD (P=0.05) I x D	0.26	0.28	0.31		0.09	33.02

On the other hand, qualitative yield also increased by optimum irrigation and balanced fertilizer application. Use of four and three irrigation along with100% RDF of N-P_2O_5-K_2O and 25 % more than RDF of N-P_2O_5-K_2O fertilizers recorded higher protein and carbohydrates yield than two and one irrigation with respective fertilizer doses.

Conclusion

The results of the present study indicated that to overcome the problem of late sowing that the four irrigation along with 100% (120:60:40) recommended dose of N-P_2O_5-K_2O fertilizer is most effective in increasing economic and qualitative yield under extremely late sown condition of wheat. The maximum grain yield and protein yield can be obtained under four irrigation with 25% more than of N-P_2O_5-K_2O fertilizer under extreme late sown condition of wheat.

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