Available online at www.ijpab.com

DOI: http://dx.doi.org/10.18782/2320-7051.2580

ISSN: 2320 – 7051

Int. J. Pure App. Biosci. **5 (2):** 173-179 (2017)

International Journal of Pure & Applied Bioscience

Research Article

OPEN ACCESS

Response of Irrigation Frequency and Nitrogen Levels on Relative Water Content, Canopy Temperature, Water Potential and Chlorophyll Content of Late Sown Wheat

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Received: 11.02.2017 | Revised: 23.02.2017 | Accepted: 25.02.2017

ABSTRACT

To study the response of irrigation frequency and nitrogen levels on relative water content, canopy temperature, water potential and chlorophyll content of late sown wheat, an experiment was carried out at the CCS Haryana Agricultural University, Hisar during Rabi seasons of 2010-11 and 2011-12. The experiment consisted of three irrigation frequencies viz. one irrigation at CRI, two irrigations at CRI and heading and four irrigations at CRI, late tillering, heading and milking stage in main plots and five nitrogen levels viz. control (0 kg N ha^{-1}), 50 kg N ha^{-1}, 100 kg N ha^{-1}, recommended dose of nitrogen (150 kg N ha^{-1}) and 200 kg N ha^{-1} in sub-plots was laid out in strip plot design with four replications. Results of experiment revealed that among the plant water relation parameters recorded at anthesis, the relative water content (RWC) and leaf water potential (LWP) at the level of two and four irrigations was significantly higher than one irrigation. The higher leaf water potential and relative water contents were associated with higher photosynthetic rate. However, canopy temperature (CT) and canopy temperature depression (CTD) at the level one irrigation was significantly higher than two and four irrigations. The nitrogen applied at the rate of 200 kg ha^{-1} maintained significantly higher LWP than control (0 kg N ha^{-1}). Chlorophyll index recorded on flag leaf decreased consistently with increase in plant age after anthesis. Chlorophyll index increased significantly with increased levels of irrigations at anthesis. Chlorophyll index was significantly higher upto 150 kg N ha^{-1} at 7, 14, 21 and 28 days after anthesis during both the years. The increase irrigation number from one to two, two to four and one to four irrigations increased the grain yield of wheat by about 25.1, 20.4 and 50.6 % during 2010-11 and 21.0, 21.9 and 47.5 % during 2011-12, respectively. Grain yield increased significantly upto 150 kg N ha^{-1}.

Key words: *irrigation frequency, nitrogen levels, relative water content, water potential, late sown wheat*

INTRODUCTION

Wheat is the most important food crop in India and improvement in its productivity has played a key role in making the country self-sufficient in food grain. However, in the past decade a general slowdown in increase the productivity of wheat has been noticed, particularly under environments relatively unfavourable for growth and development of wheat[1].

Cite this article: Kumar, M., Pannu, R.K., Singh, B. and Dhaka, A.K., Response of Irrigation Frequency and Nitrogen Levels on Relative Water Content, Canopy Temperature, Water Potential and Chlorophyll Content of Late Sown Wheat, *Int. J. Pure App. Biosci.* **5(2):** 173-179 (2017). doi: http://dx.doi.org/10.18782/2320-7051.2580

Late sowing of wheat is a major problem in the rice-wheat and cotton-wheat cropping system[2,3]. Irrigation water and fertilizers are the two vital but costly inputs in irrigated farming. Irrigation is necessary to grow crops because of insufficient amount of rain water and high atmospheric evaporative demand by crops. Proper growth and development of wheat needs favorable soil moisture in the root zone. Extractable water capacity of soil has significant influence on wheat grain yield and water productivity response to irrigation[4].

Relative water content is closely related to plant water potential. As plant water potential decreases, relative water content also decreases. Consequently, with a decrease in stomata conductance and a plant's inaccessibility to CO_2, photosynthesis decreases[5]. The relative water content and soluble protein of leaf were reduced under water deficit stress[6]. Reduced soil water availability will result in low plant leaf water potential, osmotic potential and relative water content[7]. Canopy temperature is a part of the canopy energy balance. As solar radiation is absorbed by leaves, leaf temperatures increase[8]. Leaf cooling takes place as some of the thermal energy drives transpirational water loss. Under water deficit conditions, stomata close in response to loss of turgor pressure, causing a lowering of transpiration rate and hence, an increase in canopy temperature[9]. This is the basis for the use of canopy temperature to determine plant water status.

Nitrogen is a key element in plant nutrition. Nitrogen is an important constituent of chlorophyll and plays a vital role in all metabolic processes. Proper use of nitrogen fertilizer is also considered for farm profitability and environment protection[10]. Irrigation water dissolved the fertilizers and was made available to the crop for proper growth and development. Synergistic interactions between irrigation and nitrogen levels on grain yield have been reported[11]. Therefore, an attempt has been made to evaluate the response of irrigation frequency and nitrogen levels on relative water content, canopy temperature, water potential and chlorophyll content of late sown wheat.

MATERIALS AND METHODS

Experiment was conducted during 2010-11 and 2011-12 at CCS Haryana Agricultural University, Hisar (India) located in Indo-Gangetic plains of North-West India with latitude of $29^0$10' North and longitude of $75^0$46' East at 215.2 meters above mean sea level. The soil of the field was sandy loam, slightly alkaline in pH (7.9), low in organic carbon, poor in available nitrogen and medium in available phosphorus and available potassium. The experiment consisting of three irrigation frequency *viz.* one irrigation at CRI, two irrigations at CRI and heading and four irrigations at CRI, late tillering, heading and milking in main plots and five nitrogen levels *viz*. control (0 kg N ha^{-1}), 50 kg N ha^{-1}, 100 kg N ha^{-1}, recommended dose of nitrogen (150 kg N ha^{-1}) and 200 kg N ha^{-1} in sub-plots was laid out in strip plot design with four replications. Late sown wheat variety WH 1021 was sown with seed drill @ 125 kg ha^{-1} on 23rd Dec. during both the years. Half N and full P were applied as basal dose as per treatment. Remaining half N dose was top dressed after 1st irrigation. To control weeds, one hand weeding was done at 30 days after sowing (DAS). Other management practices were adopted as per recommendations of wheat crop. Relative water content was calculated as described by Weatherly[12]. From fully expanded flag leaves the leaf sample were taken in 5 cm diameter plastic petri–plates. Weighed immediately to determine the fresh weight. After substracting the weight of empty petri-plates, the leaf sample were then floated on distilled water for about four hours at room temperature in the diffused light. The turgid leaves were weighed and dried at 65^0C in an oven to a constant weight. The RWC was calculated by the following formula:

$$\text{RWC (\%)} = \frac{\text{Fresh weight} - \text{Dry weight}}{\text{Turgid weight} - \text{Dry weight}} \times 100$$

The pressure chamber method as described by Scholander[13] was used for recording leaf water potential in different treatments. It was measured once at anthesis stage. The 3-4 flag leaves were used during mid day hours (12:00 noon-1:00 pm) for measuring leaf water potential. The canopy temperature and canopy temperature depression (CTD) of the crop in different treatments were measured from a distance of about one metre with infra red thermometer (Telatemp AG) during noon hours at anthesis stage. Chlorophyll content of flag leaf of 5 marked plants in each plot was recorded using the chlorophyll meter (CCM 200) at an interval of 7 days starting from anthesis till complete senescence of flag leaf. The crop was threshed plot-wise with a mini-plot thresher. The grain yield obtained was weighed and converted into kilogram per hectare. The ANOVA test was done by statistical software of OPSTAT.

RESULTS AND DISCUSSION

Weather

Mean weekly maximum temperature ranged between 11.2 ^{0}C (1st SMW, late emergance stage) to 41.1 ^{0}C (18th SMW, at maturity) in 2010-11 and 17 ^{0}C (2nd SMW, at CRI) to 36.8 ^{0}C (18th SMW, at maturity) in 2011-12, respectively. However, mean minimum temperature ranged between 3.2 ^{0}C (3rd SMW, tillering) to 23.7 ^{0}C (18th SMW) in 2010-11 and 1.2 ^{0}C (52nd SMW, at emergence) to 18.2 ^{0}C (18th SMW) in 2011-12, respectively. Amount of rainfall as well as its distribution during the crop growth season is very important for growth and development of the crop. During *Rabi* season of 2010-11, total rainfall received was 116.3 mm with 12 rainy days. The vegetative phases received 80.3 mm rainfall. The highest rainfall was received during 52nd SMW which coincide with emergence of crop. Rest of the rainfall was received from flag leaf to physiological maturity. During *Rabi* 2011-12, total rainfall was only 47.7 mm with 3 rainy days. Only one rainy day was occurred during tillering phase and rest two was at late maturity phase. The vegetative and reproductive phases received 14.4 and 33.3 mm rainfall, respectively in 2011-12. The highest rainfall of 25.5 mm was recorded during dough stage. *Rabi* 2010-11 received more rainfall than normal (63.7 mm) than that of *Rabi* 2011-12. However, the distribution of rainfall was very poor in both the years. The mean weekly highest sunshine hours were recorded at physiological maturity (9.9 and 9.8 hrs) and lowest just after emergence (1.2 and 1.8 hrs) during 2010-11 and 2011-12, respectively. The seasonal cumulative pan evaporation values were 331 mm in 2010-11 and 383 mm in 2011-12, respectively. The mean weekly wind speed values remained in the range of 2.5 to 9.2 km hr^{-1} in 2010-11. However, the range of mean weekly wind speed was low (1.2 to 7.3 km hr^{-1}) in 2011-12.

Effect on plant water relations

The plant water relation parameters namely relative water content (RWC), leaf water potential (LWP), canopy temperature (CT) and canopy temperature depression (CTD) were studied at anthesis under different irrigation and nitrogen levels are given in Table 1. These plant water relation parameters were recorded at anthesis stage. RWC and WP of leaf under one irrigation at anthesis were significantly lower than two and four irrigations levels. However, RWC and leaf water potential under two irrigations and four irrigations were statistically at par during both year of study. However, CT was significantly lower in higher frequencies of irrigations than one irrigation during both the years. Whereas, CT of two and four irrigations crop were statistically at par. CTD of two and four irrigations levels were significantly lower than one irrigation. Two and four irrigations irrigation frequencies received the irrigation recently have maintained higher plant water status *i.e.* RWC, LWP, CT and CTD and faster rate of transpiration compared to one irrigation at CRI. The higher soil water status under higher frequency of irrigations (4 irrigations) and also in recently irrigated two irrigations crop over one irrigation maintained significantly higher plant water status. All these plant water status parameters were found highly associated with each other as CT and RWC (r = 0.96), CT and LWP (r = 0.98), CTD and RWC (r = 0.96), CTD and LWP (r = 0.97) and RWC and LWP (r = 0.95). The relative water content of leaf was reduced under water deficit stress[6]. An increase in the intensity of drought stress on wheat cultivars, there was a decrease in relative water content[14]. Reduced soil water availability will result in low plant leaf water potential, osmotic potential and relative water content[7]. Significantly higher canopy temperature in one irrigation crop over two and four irrigation crop might be due to water stressed plant will reduce transpiration and will typically have a higher temperature than the non-stressed crop[15].

Relative water content and leaf water potential at anthesis was highest in 200 kg N ha^{-1} and recommended dose of chemical fertilizer. This significantly higher leaf water potential in 200 and 150 kg N ha^{-1} than control indicate that for better plant status maintenance, plant require higher amount of available nutrients as this fact is quite clear with lowest LWP and RWC in control *i.e.* 0 kg N ha^{-1}, which is significantly lower than 150 and 200 kg N ha^{-1} during both the years. The CT of control *i.e.* 0 kg N ha^{-1} was maximum followed by 50 kg N ha^{-1}, 100 kg N ha^{-1}, 150 kg N ha^{-1} and 200 kg N ha^{-1}. But the differences were non significant among the doses of nitrogen. However, in general the increased dose of Nitrogen have cooler canopy than in lower doses. CTD decreased with increased N dose. However, CTD of 150 and 200 kg N ha^{-1} was significantly lower than control. The canopy was more cooler where higher doses of nitrogen was applied. This more cooling of canopy might be due to better plant water status maintenance and higher regulation of stomata, which has transpired more water because of synergestic interaction between nutrient availability and stomatal regulation. RWC of stressed plants dropped from 98 to 75% with the decrease in number of irrigation and nitrogen nutrition[16].

Effect on chlorophyll index

Chlorophyll index of flag leaf of wheat measured at anthesis and onwards at 7 days interval are given in Table 2. Chlorophyll index increased significantly with increased irrigation frequency at anthesis during both the years. A sharp fall in chlorophyll index at 21 and 28 days after anthesis was may be due to degradation of chlorophyll and beginning of senescence because of prevalence of high day temperature (35-40^{o}C) after anthesis. A decrease of chlorophyll content with minimum irrigation level implies a lowered capacity for light harvesting. Since the production of reactive oxygen species is mainly driven by excess energy absorption in the photosynthetic apparatus, this might be avoided by degrading the absorbing pigment[17]. An increase in the intensity of drought stress on wheat cultivars, there was a decrease in total chlorophyll content[14].

Chlorophyll index of 200 kg N ha^{-1} at anthesis was 11.1, 37.1, 84.3 and 217% higher than recommended dose *i.e.* 150 kg N ha^{-1}, 100, 50 kg N ha^{-1} and control *i.e.* 0 kg N ha^{-1} in 2010-11 and 7.4, 20.1, 48.0 and 160% in 2011-12, respectively. Application of nitrogen directly increased the chlorophyll content and leaf surface area resulting in increased photosynthesis process leading to more sugar formation. Chlorophyll index at reproductive stage of wheat is significantly related with grain yield (r = 0.82). As higher chlorophyll content at reproductive phase have longer crop maturity duration, which will continue to add more biomass due to continuous photosynthetic process as this is evident from significant positive association with grain yield (r = 0.85). Nitrogen nutrition and irrigation influences the content of photosynthetic pigments, the synthesis of the enzymes taking part in the carbon reduction, the formation of the membrane system of chloroplasts, *etc*. thus the increase in growth and yield owing to the application of N-fertilizers may be attributed to the fact that these nutrients being important constituents of nucleotides, protein, chlorophyll and enzymes, involves in various metabolic processes which have direct impact on vegetative and reproductive phases of plants[18,19]. N fertilizer reflected in cooler canopy and higher chlorophyll contents[20].

Grain Yield (kg ha^{-1})

The grain was slightly higher in 2011-12 than 2010-11 (Table 3). This may be because of comparatively better weather conditions like lower minimum temperature during the crop season, which causes less respiration losses. Grain yield increased significantly with increased irrigation frequency. The higher irrigation frequency fulfilled timely crop water requirement, which resulted into better growth. The increase in irrigation number from one to two, two to four and one to four irrigations increased the grain yield of wheat by about 25.1, 20.4 and 50.6 % during 2010-11 and 21.0, 21.9 and 47.5 % during 2011-12, respectively. Grain yield under high irrigation were significantly greater than that under deficit irrigation[21]. As a result of high ET and limited irrigation, crops will not grow reliably under water-stressed conditions. This indicates that it is difficult to obtain satisfactory grain yield without irrigation, suggesting that supplemental irrigation is necessary. The higher irrigation frequency maintained better plant relations in term of CT, CTD and LWP, which helped in opening of stomata and increased rate of photosynthesis which ultimately resulted in higher grain yield. This fact can be supported by significant association between grain yield and canopy temperature (r = -0.58), grain yield and CTD (r = -0.57) and grain yield and LWP (r = 0.63). Grain yield increased significantly with increased nitrogen doses upto 150 kg N ha^{-1} during 2010-11 and 2011-12. The grain yield at 150 and 200 kg N ha^{-1} were statistically similar. Minimum grain yield was recorded in control (0 kg N ha^{-1}). The higher grain yield in higher dose of nitrogen was because of more availability of nutrients for their growth and development. The higher yield with increasing levels of irrigation and N dose may be attributed to better water and nutrient availability, which gave rise to better plant growth and yield. Similar results have been reported in wheat by other researcher[22,23].

Table 1: Effect of irrigation frequency and nitrogen levels on plant water relations of late sown wheat at anthesis

Treatments	Relative Water Content (%)		Leaf Water Potential (M Pa)		Canopy Temperature (^{0}C)		Canopy Temperature Depression (^{0}C)	
	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12
Irrigation frequency								
1 Irrigation	74.6	77.2	-1.43	-1.30	27.0	26.4	-0.66	-0.56
2 Irrigations	84.7	85.5	-0.98	-0.95	25.9	25.5	-1.84	-1.52
4 Irrigations	85.2	86.1	-0.89	-0.99	25.8	25.4	-1.89	-1.56
CD at 5%	**1.3**	**0.6**	**0.11**	**0.10**	**0.4**	**0.3**	**0.34**	**0.20**
Nitrogen levels								
0 kg N/ha	81.4	82.7	-1.17	-1.22	26.5	26.1	-1.24	-0.93
50 kg N/ha	81.5	82.9	-1.12	-1.12	26.3	25.9	-1.37	-1.11
100 kg N/ha	81.5	83.0	-1.10	-1.07	26.2	25.7	-1.48	-1.27
150 kg N/ha	81.6	83.0	-1.07	-1.01	26.1	25.6	-1.58	-1.38
200 kg N/ha	81.6	83.1	-1.04	-0.98	26.1	25.6	-1.64	-1.43
CD at 5%	**NS**	**NS**	**0.08**	**0.15**	**NS**	**NS**	**0.30**	**0.27**

Table 2: Effect of irrigation frequency and nitrogen levels on Chlorophyll Index of flag leaf at different intervals after anthesis of late sown wheat

Treatments	Days after anthesis (DAA)									
	0		7		14		21		28	
	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12
Irrigation frequency										
1 Irrigation	42.7	40.9	39.5	38.2	28.4	31.8	15.7	17.1	6.51	6.83
2 Irrigations	46.5	44.5	42.8	42.7	30.4	34.2	18.7	20.3	7.14	7.60
4 Irrigations	48.5	50.4	47.0	44.6	33.7	37.5	19.3	21.0	7.25	8.00
CD at 5%	**NS**	**2.8**	**5.1**	**3.7**	**4.7**	**5.1**	**2.2**	**2.5**	**NS**	**NS**
Nitrogen levels										
0 kg N/ha	20.7	22.7	19.3	20.6	14.6	16.1	9.2	9.8	4.05	4.30
50 kg N/ha	35.7	40.0	33.3	34.1	24.5	27.7	14.9	15.2	6.50	7.25
100 kg N/ha	48.0	49.3	45.5	43.4	30.5	36.2	18.9	20.3	7.44	8.00
150 kg N/ha	59.2	55.1	56.7	52.7	40.0	44.1	22.4	24.8	8.21	8.67
200 kg N/ha	65.8	59.2	60.7	58.4	44.6	48.7	24.2	27.2	8.62	9.17
CD at 5%	**3.8**	**6.1**	**4.5**	**6.7**	**5.9**	**4.9**	**2.2**	**2.5**	**1.18**	**1.05**

Table 3: Effect of irrigation frequency and nitrogen levels on grain yield of late sown wheat

Treatments	Grain yield (kg ha^{-1})		
	2010-11	2011-12	Pooled
Irrigation frequency			
1 Irrigation	2544	2704	2624
2 Irrigations	3183	3272	3228
4 Irrigations	3832	3989	3911
CD at 5%	**190**	**183**	**136**
Nitrogen levels			
0 kg N/ha	1932	2026	1979
50 kg N/ha	2946	3064	3005
100 kg N/ha	3474	3623	3549
150 kg N/ha	3737	3893	3815
200 kg N/ha	3843	4002	3922
CD at 5%	**156**	**137**	**120**

CONCLUSION

Soil water deficit induced by limited irrigation at different stages of crop growth, significantly reduced flag leaf water potential and relative water contents. The reduction in water potential and relative water contents reduced the stomatal conductance, decreased transpiration which ultimately limited access of photosynthetic apparatus to CO_2; consequently, decreased rate of photosynthesis and final grain yield. Among the plant water relations parameters recorded at anthesis, the relative water content and leaf water potential at the level of two and four irrigations was significantly higher than one irrigation during both years. However, canopy temperature and canopy temperature depression at the level one irrigation was significantly higher than two and four irrigations. The nitrogen applied at the rate of 200 kg ha^{-1} maintained significantly higher leaf water potential than control *i.e.* 0 kg N/ha during both the years. Chlorophyll index recorded on flag leaf decreased consistently in all the treatments with increase in plant age after anthesis. Chlorophyll index increased significantly with increased levels of irrigations at anthesis. Chlorophyll index was significantly higher upto 150 kg N ha^{-1} at 7, 14, 21 and 28 days after anthesis during both the years.

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