The Pharma Innovation Journal 2022; 11(9): 2705-2711

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(9): 2705-2711

www.thepharmajournal.com
Received: 20-06-2022
Accepted: 24-08-2022

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Response of timely and late sown wheat (*Triticum aestivum* L.) in relation to different foliar applied nutrients, growth regulators and their spraying schedule on leaf area index, relative water content and canopy temperature

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Abstract
The field experiment was conducted to study the "Response of timely and late sown wheat (*Triticum aestivum* L.) in relation to different foliar applied nutrients, growth regulators and their spraying schedule on leaf area index, relative water content and canopy temperature" during 2020-21 and 2021-22 in *Rabi* season at G. B. Pant University of Agriculture and Technology, Pantnagar, Udham Singh Nagar, Uttarakhand. The experiment consisted of three factors *i.e*. two date of sowing, six foliar nutrition and two spraying schedule. The main plot consisted of date of sowing i.e. timely and late (Nov 23 and Dec 15) and sub-plot having two factors one foliar nutrition *i.e*. KCl @ 1%, ascorbic acid @ 10 ppm, thiourea @ 400 ppm, cycocel @ 1000 ppm, salicylic acid @ 400ppm and salicylic acid @ 800 ppm and second is spraying schedule *i.e*. vegetative + anthesis and anthesis stage alone. The experiment was laid out in factorial RBD design with three replications. Canopy temperature and relative water content was recorded 15 days after anthesis whereas leaf area index was recorded at different growth stages. The study revealed that during both the years of investigation, timely sown crop recoded significantly higher leaf area index and relative water content compared to late sown crop. Canopy temperature of timely sown crop was significantly lower than late sown crop. .Foliar applied nutrition significantly increased leaf area index and relative water content than control treatment. Among foliar applied nutrients higher dose of foliar applied salicylic acid @ 800 ppm significantly increased leaf area index at 70 and 90 DAS of wheat crop and was at par with foliar applied KCl @ 1% treatment. Similarly application of salicylic acid @ 800 ppm significantly improved relative water content and was at par with KCl @ 1% and thiourea @ 400 ppm. Foliar application of thiourea @ 400 ppm, KCl @ 1% and salicylic acid @ 800 ppm treatments help to reduce canopy temperature significantly than rest of the other foliar applied chemicals during both the years. Spraying schedule of foliar nutrition did not significantly respond to leaf area index, relative water content and canopy temperature.

Keywords: Wheat, potassium chloride, ascorbic acid, thiourea, cycocel, salicylic acid, leaf area index, relative water content and canopy temperature

Introduction
The productivity of wheat in India is very low compared to its potential due to mainly to its late planting in northern India which is known as wheat bowl of the country. Late planting wheat crop experiences rising temperature causes heat stress especially during grain development stage. High temperature experienced by crop may adversely affect many plant processes like chlorophyll synthesis, enzyme activation, transpiration, leaf tissue turgor pressure, canopy temperature and photosynthesis efficiency etc. reducing growth and development of plants. Thus, low grain yield of late sown wheat crop may be due to reduced assimilate supply and its duration to developing grain and productivity. In recent years certain foliar feeding of micro and macro nurients and growth regulators at different growth stages is advisable to mitigate heat stress at critical growth stage. Growth regulators like salicylic acid, ascorbic acid, thiourea and cycocel are most commonly used among these chemicals. The concentration of the chemicals and its application is very important to sustain crop productivity which help to reduce the effect of oxidative stress produced by biotic and abiotic factors and altered photosynthesis and respiration, antioxidant potential, total soluble proteins and amino acids. (Singh *et al*., 2021) [11], Das *et al*., 2020 and Asthir *et al*., 2013) [3].

Response of foliar applied nutrients and growth regulator largely depends on sowing time of crop, type of nutrients and their spraying schedule and concentration. Mostly growth regulators are required in very less qualities but their stage of application is very important to improve crop productivity and seed quality. Therefore, an experiment was conducted to study the response of timely and late sown wheat in relation to different foliar applied nutrients, growth regulators and their spraying schedule on leaf area index, relative water content and canopy temperature of crop.

Materials and Methods

The experiment was conducted at Crop Research Centre of G.B. Pant University of Agriculture and Technology, Pantnagar during *Rabi* session 2020-21 and 2021-22. The experiment was laid out in factorial RBD design with two sowing dates (23 Nov. and 15 Dec.) as main plot and sub-plot having two factors one foliar nutrition *i.e.* KCl @ 1%, ascorbic acid@ 10ppm, thiourea @ 400 ppm, cycocel @ 1000 ppm, salicylic acid @ 400 ppm and salicylic acid @ 800 ppm and another spraying schedule *i.e.* vegetative + anthesis and anthesis alone (Table 1and Table 2). The crop was sown with 100 kg/ha seed rate in rows manually opened 20 cm apart. Recommended cultural practices for raising of wheat crop were followed. Leaf area index is a valuable measurement helping to assess canopy density and biomass. Leaf area was measured by an instrument Accu PAR LP-80 ceptometer which is a simple and easy way to directly measure intercepted PAR (Photosynthetically active radiation) and automatically calculates LAI based on the above and below-canopy PAR measurements along with other variables that relate to the canopy architecture and position of the sun. LAI was recorded at 30, 50, 70 and 90 DAS. Relative leaf water was measured by the method described by Yamasaki and Dillenberg (1999) [14] at 15 days after anthesis. Ten randomly selected fully expanded leaves from net plot were collected from the mid- section of the stem in order to minimize age effect. Values of fresh weight, turgid weight and dry weight were used to calculate relative water content and Canopy temperature was measured by using the testo- infrared thermometer. Canopy emits long-wave infrared radiation as a function of their temperature. The infrared thermometer senses the radiation and converted into an electrical signal, displayed as temperature. Canopy temperature was measured at 15 days after anthesis (ground completely covered by crop canopy). The data were recorded in the proper sunlight with clear sky.

Results and Discussions

Leaf area index

Time of sowing is a non-monetary input to improve crop growth and productivity. In the changing scenario high temperature experienced by crop may adversely affect many plant processes like chlorophyll synthesis, enzyme activation, transpiration, leaf tissue turgor pressure and photosynthesis efficiency.

Leaf area index was significantly influenced by sowing date and foliar applied nutrients and growth regulators however their spraying schedule did not respond significantly in this regard. Persistence of the assimilatory surface area (LAI) is a pre- requisite for prolonged photosynthetic activity as it intercepts radiation. With the perusal of data, it has been observed that timely sown wheat recorded significantly higher leaf area index at all growth stages compared to late sown wheat (Table1). During Ist year of observation 2020-21, the per cent reduction in LAI of late sown wheat was 14.4, 2.67, 1.89 and 22.7% in comparison to timely sown wheat, while there was 15.8, 2.14, 1.69 and 22.6% reduction in LAI during 2021-22 at 30, 50, 70 and 90 DAS, respectively (Fig.1). Thus leaf area plays a significant role in growth, development and yield formation and to determine grain quality. In late sown wheat, upto 30 days of vegetative phase, lower mean maximum temperature (18.9 °C and 20.3 °C in Dec 15 against 26.0 °C and 25.9 °C in Nov 23 during 2020-21 and 2021-22 respectively) might have slow down the leaf initiation rate and leaf development. Therefore late sown wheat had lower LAI than timely sown wheat. Further at later growth stages from 60 DAS to onward, leaf senescence and abscission observed in late sown wheat might be the reason to reduced LAI in delayed sowing. These results are in agreement with the findings of Tripathi and Verma (2007) [13], Jatti (2013) [6] and Prasad (2016) [9].

The improved LAI and photosynthetic capacity was associated with timely and proper dose of nutrients to developing crop plant. In present investigation, foliar spray of nutrients and growth regulators significantly increased LAI over control at 70 and 90 DAS. Among foliar treatments, during both the years foliar spray of KCl @ 1% exhibited highest LAI at 70 and 90 DAS which was at par with salicylic acid @ 800ppm foliar treatment (Fig.2). Foliar spray of nutrients accomplished the requirement of balanced crop nutrition and increased vegetative growth. In the present investigation, the highest values of LAI was observed at higher dose of foliar applied salicylic acid i.e. @ 800 ppm contrary to this Amin *et al.* (2013) [2] reported that foliar application of salicylic acid @ 200ppm significantly increased LAI compared to corresponding untreated control plants in maize crop. As salicylic acid participate in the regulation of stomatal closure, nutrient uptake, cell metabolic rate, chlorophyll and protein synthesis, transpiration and phtosynthesis which in turn utilized for building of new cells. Similarly Abdelmegeed and ElShamey (2022) [1] observed that foliar spray of cycocel @ 500ppm significantly increased LAI over the control in rice crop.

At all growth stage, spraying schedule of different foliar nutrition showed more leaf area index when spraying was done twice i.e. at vegetative + anthesis than scheduling of spray at anthesis stage alone however the differences were non-significant during both the year.

Among the control treatments, timely + no spray treatment recorded significantly higher LAI in comparison to late sown + no spray treatment at 70 and 90 DAS, during both the years. At 30 DAS, significantly higher LAI was observed with timely + no spray treatment in comparison to late sown + no spray treatment during 2021-22. The LAI during rest of the growth stages during both the years remained non-significant.

Comparison of control mean vs foliar treatment mean in regard to LAI differed significantly from each other during both the years. The LAI of foliar treatment mean was significantly higher than control mean at 70 and 90 DAS during both the year. Whereas at 30 DAS and 50 DAS the differences were non-significant in this regard.

Table 1: Effect of sowing date, foliar nutrition and spraying schedule on leaf area index at 30, 50, 70 and 90 DAS in wheat variety UP-2565

Treatment	Leaf Area Index							
	30 DAS		50 DAS		70 DAS		90 DAS	
	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22
Sowing date								
Timely (Nov 23)	0.97	0.95	2.24	2.23	4.23	4.14	2.55	2.52
Late (Dec 15)	0.83	0.80	2.18	2.16	4.15	4.07	1.97	1.95
SEm±	0.01	0.01	0.01	0.02	0.03	0.02	0.01	0.01
C. D. at 5%	0.02	0.02	0.02	0.05	0.07	0.07	0.03	0.02
Foliar nutrition								
KCl @1%	0.89	0.88	2.19	2.16	4.39	4.29	2.37	2.36
Ascorbic Acid @10 ppm	0.90	0.87	2.23	2.20	4.08	3.95	2.20	2.17
Thiourea @ 400 ppm	0.89	0.89	2.20	2.20	4.16	4.12	2.25	2.23
Cycocel @ 1000 ppm	0.89	0.87	2.20	2.18	4.13	4.02	2.27	2.24
Salicylic Acid @400 ppm	0.89	0.87	2.20	2.19	4.12	4.03	2.12	2.11
Salicylic Acid @800 ppm	0.92	0.88	2.24	2.23	4.27	4.22	2.34	2.33
SEm±	0.01	0.01	0.01	0.03	0.04	0.04	0.02	0.01
C. D. at 5%	NS	NS	NS	NS	0.13	0.11	0.05	0.04
Spraying schedule								
Vegetative + Anthesis	0.89	0.87	2.21	2.18	4.21	4.14	2.27	2.25
Anthesis	0.90	0.88	2.21	2.10	4.17	4.07	2.25	2.23
SEm±	0.01	0.01	0.01	0.02	0.03	0.02	0.01	0.01
C. D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS
Control vs Control								
Timely sown + no spray	0.94	0.93	2.21	2.14	3.89	3.79	2.21	2.20
Late sown + no spray	0.88	0.80	2.15	2.10	3.58	3.55	1.76	1.75
SEm±	0.02	0.02	0.03	0.06	0.09	0.08	0.03	0.03
C. D. at 5%	NS	0.05	NS	NS	0.25	0.22	0.09	0.08
Control vs Foliar treatments								
Treatment mean	0.90	0.87	2.21	2.19	4.19	4.11	2.26	2.24
Control mean	0.91	0.86	2.18	2.12	3.73	3.67	1.98	1.97
SEm±	0.02	0.01	0.02	0.05	0.06	0.06	0.02	0.02
C. D. at 5%	NS	NS	NS	NS	0.18	0.16	0.07	0.06

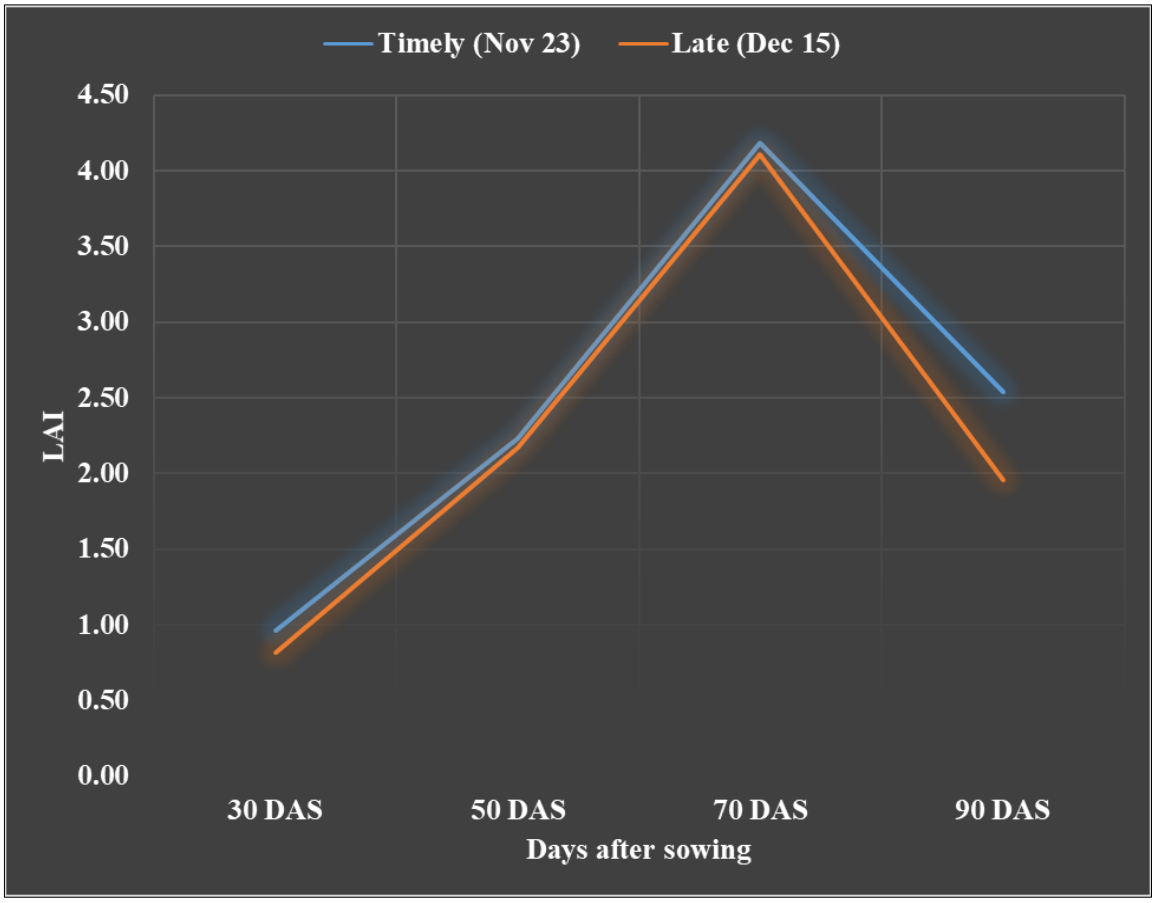

Fig 1: Effect of sowing date on leaf area index at 30, 50, 70 and 90 DAS in wheat variety UP-2565(Mean of two years data)

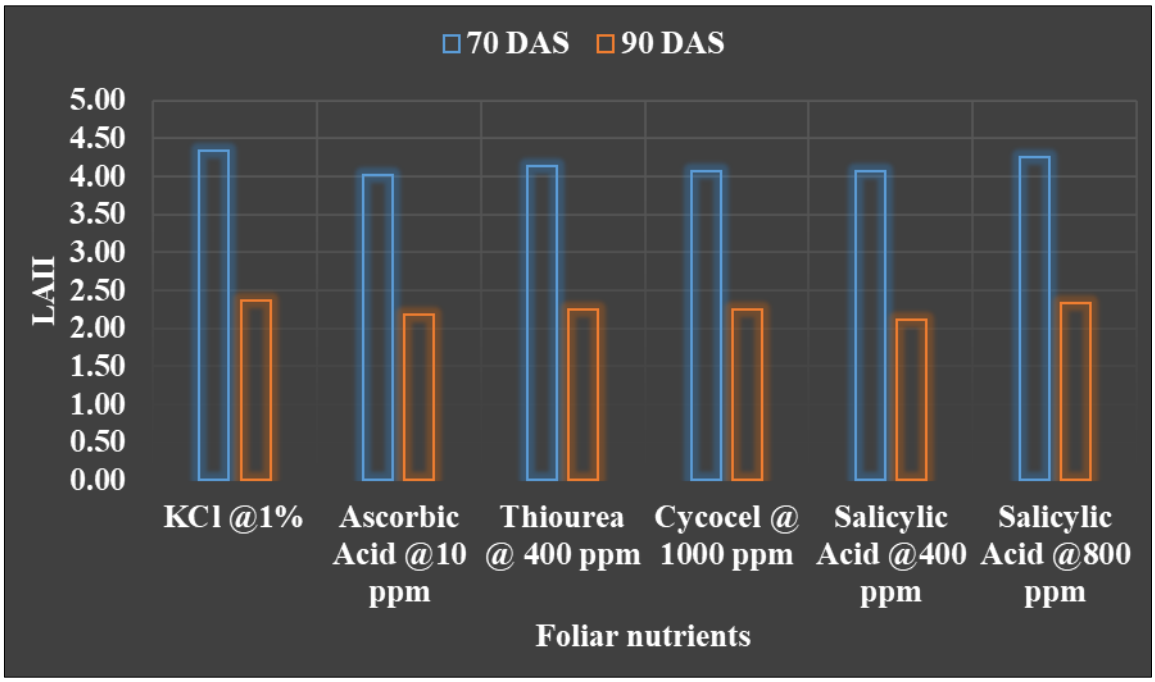

Fig 2: Effect of foliar nutrition on leaf area index at 70 and 90 DAS in wheat variety UP-2565 (Mean of two years data)

Relative water content

The relative water content controls the leaf tissue turgor pressure which ultimately maintains the activities of leaf resulting to higher photosynthetic efficiency. The relative water content of leaf was significantly influenced by sowing dates during both the years of investigation. Significant reduction in relative water content was noticed in late sown crop in comparison to timely sown crop (Table 2). Timely sown wheat recorded significantly higher relative water content by 2.90 and 5.33% during 2020-21 and 2021-22, respectively, compared to the late sown wheat (Fig. 3). This might be attributed to higher maximum temperature in Dec 15 sown crop (33.4 °C and 34.0 °C during 2020-21 and 2021-22, respectively) than Nov 23 sown crop (29.6 °C and 27.5 °C during 2020-21 and 2021-22 respectively) coupled with low relative humidity at 2.0 PM/7.0 AM in Dec 15 sown crop (84/23% and 80/31% during 2020-21 and 2021-22 respectively) than Nov 23 sown crop (83/46% and 92/48% during 2020-21 and 2021-22 respectively) on the day of observation. Similar results were reported by Kumar *et al*. (2008) [8], and Samrat *et al*. (2010) [10] in wheat crop.

Foliar nutrition of chemicals was done at vegetative + anthesis and anthesis stage alone. Therefore, effect of foliar nutrition on relative water content was found significant during both the years.

Among foliar treatments, during both the years foliar spray of salicylic acid @ 800ppm exhibited higher relative water content which was at par with thiourea @ 400 ppm and KCl @ 1% treatments \ (Table 2 and Fig. 4). Potassium play a very important role in enhancing various enzyme activities required for photosynthesis, protein and carbohydrate synthesis. Potassium is the main osmotic solute in plants, its accumulation in the cell has led to osmotic water uptake and generated the cell turgor required for growth and stomatal opening. In the preset investigation higher relative water content might be due to its regulating the osmotic potential and hydraulic conductivity of membranes and make changes in plant water permeability that improve plant water relations in wheat crop. Suryavanshi and Buttar (2018) [12] also reported that foliar spray of KNO_3 @ 2% and thiourea @ 20 mM improve relative water content as compared to control without spray in wheat crop. Kaya *et al*. (2015) [7] also reported that foliar application of thiourea @ 500 mg/L on leaves of 10-day old maize seedlings significantly enhanced relative water content of leaf.

Spraying schedule of different foliar nutrition at vegetative + anthesis and anthesis alone did not show significant effect on relative water content at all growth stages during both the year.

Among the control treatments, the relative water content was significantly higher with timely + no spray treatment to late sown + no spray treatment during both the years. Comparison of control vs foliar treatment in regard to relative water content mean showed that the relative water content of foliar treatment mean was significantly higher than control mean during both the years of investigation.

Canopy temperature

Canopy temperature is an important index which responded to change in plant water potential and thus help to detect water status in plant. There is a close, inverse relationship between canopy temperature and transpiration cooling. Sowing date has considerable influence on canopy temperature which is the driving force to modulate assimilate production, development rate, grain filling and ultimately the grain yield and seed quality of a crop. In the present investigation, canopy temperature of the crop was significantly influenced by date of sowing and foliar spray of nutrients and growth regulators while their spraying schedule did not responded significantly in this regard.

Timely sown wheat recorded significantly lower canopy temperature by 4.0 and 3.5 °C during 2020-21 and 2021-22, respectively compared to the late sown wheat (Table 2). Mean of two years data clearly indicates increased canopy temperature in late sown wheat on Dec 15 as compared to Nov 23(Fig.3). It could be due to higher mean maximum temperature affecting stomata functioning and consequently reduced transpiration rate. Sowing dates have considerable

influence on canopy temperature which is the driving forces to modulate assimilates production, development rate, grain filling and ultimately the grain yield and seed quality of crop. Significantly lower mean canopy temperature at post anthesis period in timely sown crop than late sown wheat crop are in conformity with the finding of Gautam *et al*. (2015) [4] and Jangid and Srivastava (2018) [5].

Nutrient and growth regulators were supplied at vegetative + anthesis and anthesis stage alone through foliage. Foliar applied nutrients and growth regulators reduced canopy temperature in comparison to control treatments. Among foliar nutrients and growth regulation all the foliar applied nutrient reduced canopy temperature significantly except application of Ascorbic acid @ 10 ppm during 2020-21. The lowest value of canopy temperature was recorded in thiourea @400 ppm treatment and salicylic acid @400 ppm which recorded the highest canopy temperature (Fig.4). Whereas during 2021-22, the minimum canopy temperature was found in salicylic acid @ 800 ppm treatment and the maximum temperature was observed in Ascorbic acid @ 10 ppm treatment.

Spraying schedule of different foliar nutrition at vegetative + anthesis and anthesis alone did not show significant effect on canopy temperature during both the years. Among the control treatments i.e. timely sown + no spray and late sown + no spray, the canopy temperature was significantly lower with timely + no spray treatment to late sown + no spray treatment during both the years, 2020-21 and 2021-22.Comparison of control vs foliar treatment in regard to canopy temperature mean showed that the canopy temperature of foliar treatment mean was significantly lower than control mean during both the years during 2020-21 and 2021-22.

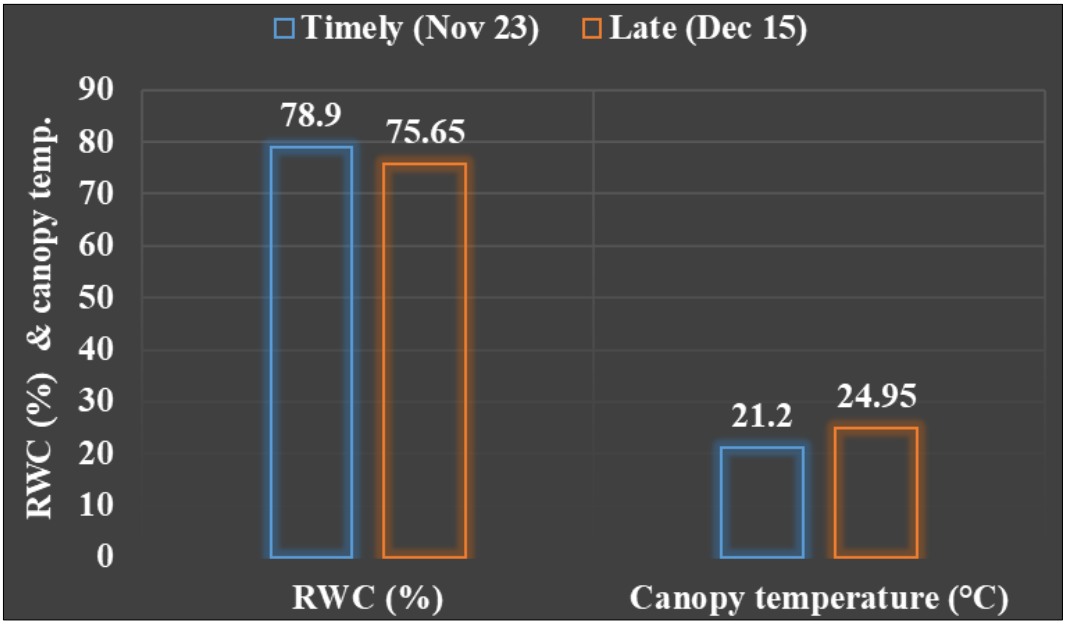

Fig 3: Effect of sowing date on relative water content RWC (%) and canopy temperature (^{O}C) at 15 days after anthesis in wheat variety UP-2565 (Mean of two years data)

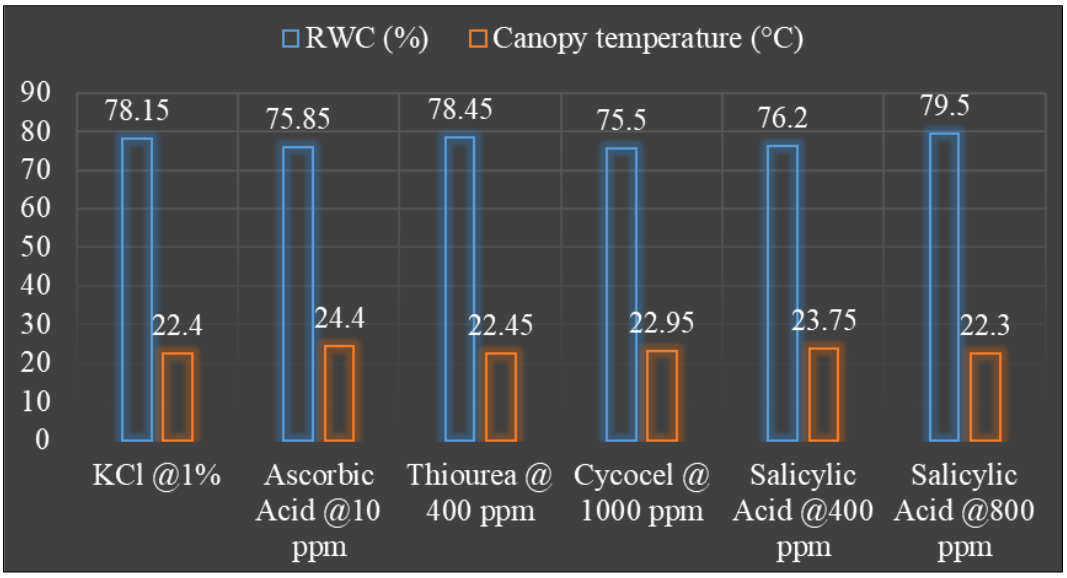

Fig 4: Effect of foliar nutrition on relative water content RWC (%) and canopy temperature (^{O}C) at 15 days after anthesis in wheat variety UP-2565 (Mean of two years data)

Table 2: Effect of sowing date, foliar nutrition and spraying schedule on relative water content RWC and canopy temperature in wheat variety UP-2565

Treatment	RWC (%)*		Canopy temperature (°C)*	
	2020-21	2021-22	2020-21	2021-22
Sowing date				
Timely (Nov 23)	79.1	78.7	21.3	21.1
Late (Dec 15)	76.8	74.5	25.3	24.6
SEm±	0.3	0.3	0.3	0.3
C. D. at 5%	0.9	0.8	0.8	0.9
Foliar nutrition				
KCl @1%	78.8	77.5	22.7	22.1
Ascorbic Acid @10 ppm	76.7	75.0	24.6	24.2
Thiourea @ 400 ppm	79.1	77.8	22.3	22.6
Cycocel @ 1000 ppm	75.8	75.2	23.5	22.4
Salicylic Acid @400 ppm	77.1	75.3	23.8	23.7
Salicylic Acid @800 ppm	80.2	78.8	22.8	21.8
SEm±	0.5	0.4	0.5	0.5
C. D. at 5%	1.6	1.3	1.4	1.5
Vegetative + Anthesis	78.4	77.0	23.2	22.8
Anthesis	77.5	76.2	23.3	22.9
SEm±	0.3	0.3	0.3	0.3
C. D. at 5%	NS	NS	NS	NS
Control vs Control				
Timely sown + no spray	74.7	74.2	25.2	23.7
Late sown + no spray	71.0	70.7	29.5	27.7
SEm±	1.1	0.9	1.0	1.0
C. D. at 5%	3.1	2.5	2.8	2.9
Control vs Foliar treatments				
Treatment mean	77.9	76.6	23.3	22.8
Control mean	72.9	72.4	27.4	25.7
SEm±	0.8	0.7	0.7	0.7
C. D. at 5%	2.3	1.9	2.0	2.1

RWC=Relative water content: *relative water content and canopy temperature was recorded 15 days after an thesis

Conclusion

Higher leaf area index and relative water content was noticed in timely sown crop, whereas, reverse trend was observed in canopy temperature compared to late sown crop. Foliar applied chemicals improved leaf area index and relative water content in comparison to control treatment. Among foliar nutrition, salicylic acid @ 800 ppm and KCl @ 1% increased leaf area index and relative water content significantly at reproductive phase of wheat crop which may contribute to yield and yield attributes. These foliar nutrients also help to reduce canopy temperature of the crop significantly.

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