



Interactive effect of sowing and water stress on rate of LAI and yield of wheat (*Triticum aestivum*)

RAJKUMAR DHAKAR^{1*}, VINAY KUMAR SEHGAL¹, DEBASISH CHAKRABORTY¹
and JOYDEEP MUKHERJEE¹

ICAR-Indian Agricultural Research Institute, New Delhi 110 012, India

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ABSTRACT

Understanding the behavior of crops under interactive effect of different abiotic stresses is the need of hour. Present study aimed to examine the interactive effect of late planting and deficit irrigation on wheat (*Triticum aestivum* L.) growth and development in semi-arid environment. The field experimentation with two planting dates and three levels of irrigation was conducted during *rabi* 2015–16 and 2016–17. The results showed that response of water stress on wheat growth and development behaved in similar manner as of that in late planting. The reduction in LAI, biomass, yield and yield attributes was observed under independent effect of water stress as well as late planting with varied magnitude. Noticeably, late sowing had large influence on rate of LAI change in the order of 20% and 47% in greening and senescence phase, respectively than deficit irrigation. The slowdown of LAI change in greening phase is also associated with faster senescence in late phase of crop growth. However, the additive effect was observed under combined water deficit and late planting conditions. It may be concluded that the co-existence of limited water availability and late planting is most detrimental to wheat growth and development ultimately on crop yields in semi-arid environment. Therefore, suitable agronomic and breeding strategies must be devised to mitigate the hampering effect of combined reduced water availability and late planting conditions.

Keywords: Growth stage, Late sowing, Terminal heat Stress, Water stress

Planting times determine the favorable environmental conditions such as air temperature, photoperiod, solar radiation etc. experienced by the crop during growing season. Research has shown manifold effect of planting time on growth and yield of spring wheat (*Triticum aestivum* L.) (Raj *et al.* 1992 and Akhtar *et al.* 2006). Grain yield is affected due to change in source-sink balance when crops are planted either early or late. Late planting of wheat is generally associated with reduced yield because of shortened length of growing season and reduced grain filling duration owing to high temperature during reproductive stage. Late planting of wheat is also associated with less leaf surface area consequently reduced radiation interception and photosynthetic activity (Sorenson *et al.* 2000). Water deficit stress during critical growth stages of the crop can result into huge decline in crop yields. Water deficit stress also hinders leaf expansion, development, water and nutrient relations, dry matter accumulation, its partitioning and ultimately decreasing crop yields (Nagar *et al.* 2015 and Dhakar *et al.* 2018). However, the interactive effect of late planting and water stress is complex in nature and their

studies are less common (Prasad *et al.* 2008 and Hussain *et al.* 2019). The objective of present study to examine the combined effect of late planting and deficit irrigation on moisture use pattern, leaf area index, radiation interception and consequently on total dry matter and yield of wheat in semi-arid environment.

MATERIALS AND METHODS

A field experiment was conducted at the experimental farm of Division of Agricultural Physics of Indian Agricultural Research Institute, New Delhi, which comes under in semi-arid and subtropical climate, experiences cold winter and hot dry summer. Soil of the location is deep to very deep and sandy loam textured throughout the profile. Wheat (cv. HD 2967) was raised during the *rabi* 2015–2016 and 2016–17 in split plot design with irrigation as the main treatment and date of sowing as the sub-plot treatment.

Treatments: Three irrigation treatments were applied, viz. I5: five irrigations (at crown root initiation (CRI), tillering, booting, flowering and milking stages), I3: three irrigations (at CRI, tillering and flowering stages) and I1: one irrigation (at CRI stage). The two dates of sowing treatment were D1: Timely sown (20th Nov 2015) and D2: Late sown (9th Dec 2015) during *rabi* 2015–16 and D1: Timely sown (17th Nov 2016) and D2: Late sown (7th Dec 2016) during 2016–17.

Present address: ¹ICAR-Indian Agricultural Research Institute, New Delhi. *Corresponding author e-mail: rajdhakar.iari@gmail.com.

Manual sowing with the help of hand-held seed drill was done keeping the recommended spacing of 22.5 cm between rows. NPK nutrients were applied as per recommended dose of fertilizers, i.e. 120:60:60. Nitrogen was applied as urea fertilizer in three split doses (50% as basal during sowing, 25% during CRI stage and 25% during flowering stage). However, in case of one irrigation (I1) treatment, urea was applied as 50% basal and 50% as top dress during CRI stage synchronizing with irrigation. The 100% P and K were applied as basal dose at the time of sowing. The recommended cultural practices of weeding and plant protection measures were followed.

Field measurements

Phenology: The visually recorded phenological stages were: emergence, crown-root initiation (CRI), tillering, jointing, anthesis, soft dough, hard dough, and physiological maturity.

Leaf Area Index (LAI): The LAI was measured non-destructively by using plant canopy analyzer (LAI-2000)

instrument. The rate of LAI change during greening and senescence phase of crop growth was calculated as slope of regression line between LAI and days after sowing. The greening phase was considered from emergence to day of maximum LAI while senescence phase was considered as day to maximum LAI to physiological maturity.

Biomass and grain yield at harvest: Final biomass and grain yield was determined from two samples of mature wheat crop were harvested from $1 \times 1 \text{ m}^2$ area in each plot.

Statistical analyses: Analysis of variance (ANOVA) as applicable to split-plot design was performed using 'aov' function available in 'stats' package of statistical software 'R'. Tukey's 'Honest Significant Difference' method (using TukeyHSD function in 'R') was used to analyze the differences between the means of the levels of a factor at 5% probability level.

RESULTS AND DISCUSSION

Phenological development: The observations on phasic development of wheat as influenced by delay of sowing and

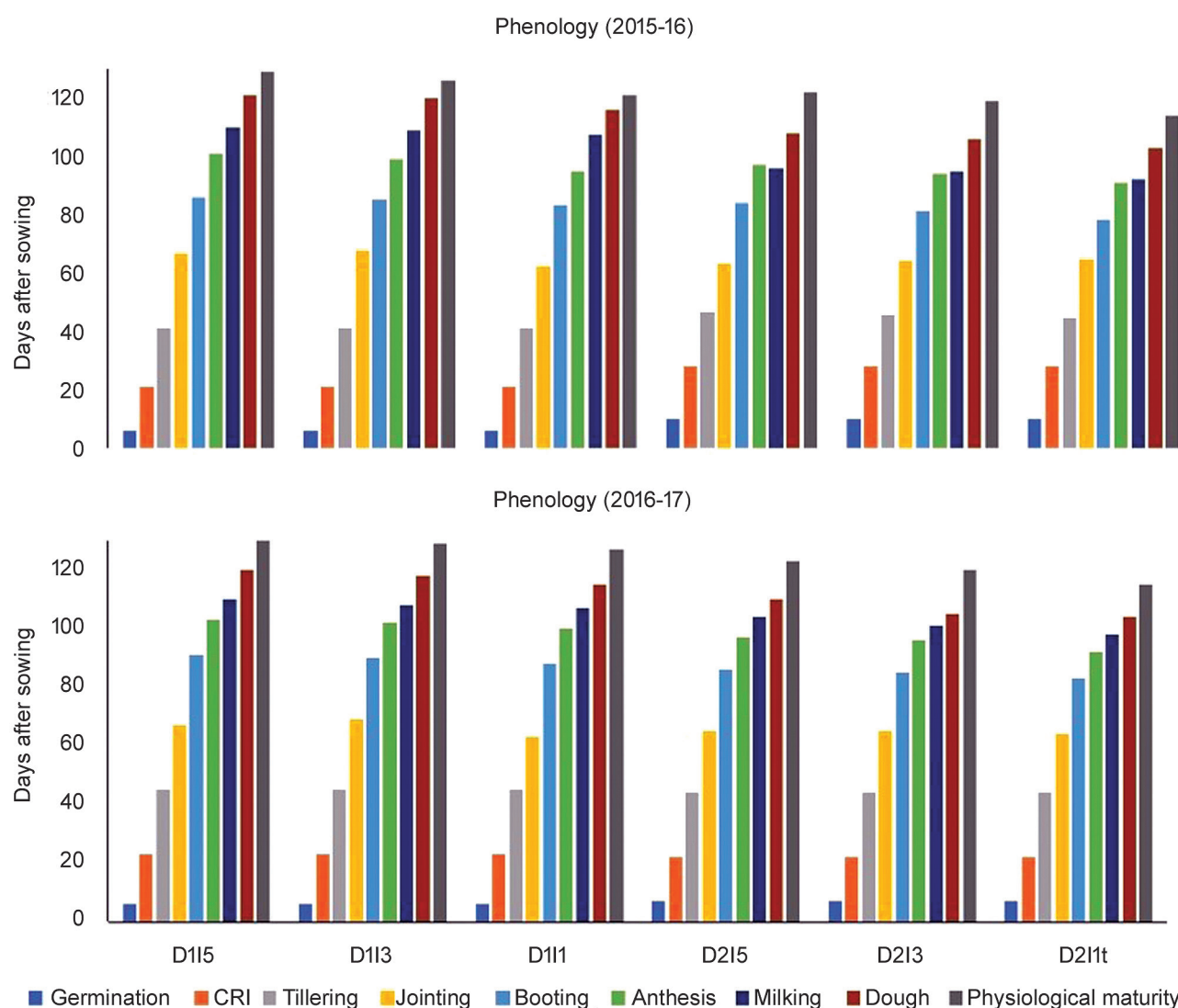


Fig 1 Phasic development of wheat crop under different dates of sowing and irrigation treatments in the season 2015-16 and 2016-17.

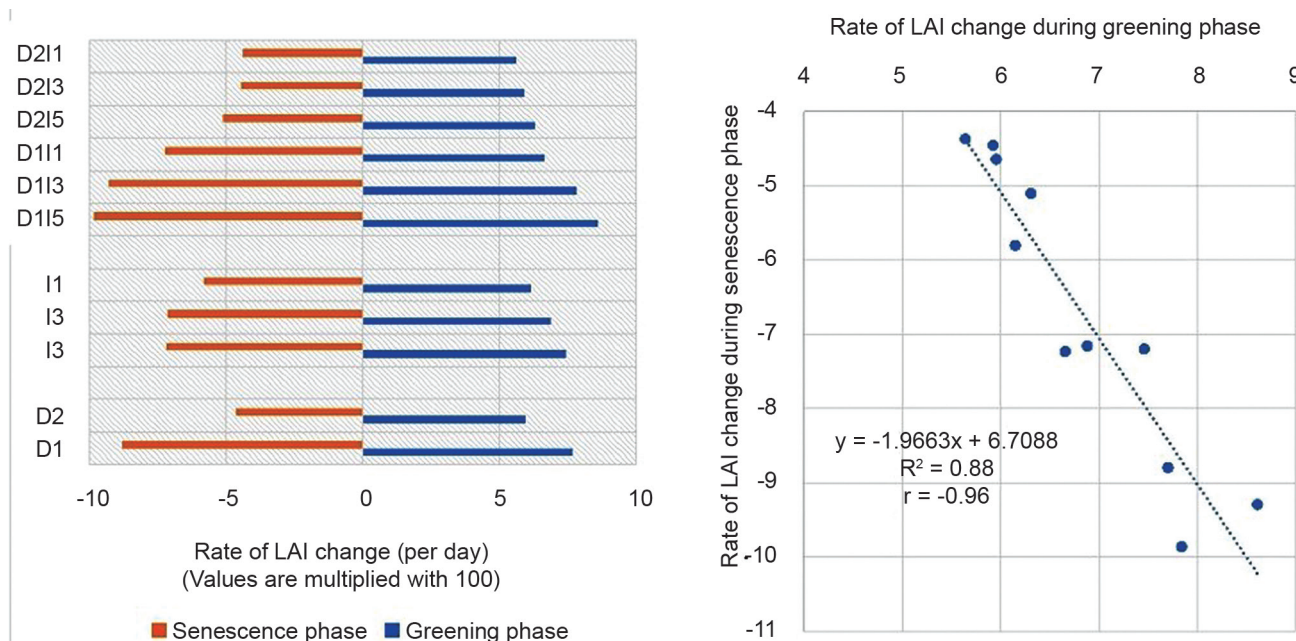


Fig 2 Rate of LAI change per day in greening and senescence phase, and regression and correlation between rate of LAI change in greening and senescence phase.

irrigation treatments in both the years are presented in Fig 1. Emergence was noted at 6 days after sowing (DAS) in normal sown crop in both the years. However, it was 10 and 7 days after sowing in late sown (D2) crop in 2015–16 and 2016–17, respectively. The 50% anthesis occurred at 101 and 103 days in D1I5 treatment in 2015–16 and 2016–17, respectively. Independent effect of irrigation and sowing date treatments was less conspicuous on shortening of duration of phenophase than that of their interactions. Their independent effects led to 8–9 days reduction in overall crop duration while their interactive effect resulted into 15–16 days reduction in overall crop duration in both the years. Acceleration of crop phenology and shortening of duration due to either water stress or delayed sowing is supported by results of many researchers (Rosales-Serna *et al.* 2004 and Farre and Faci 2006).

Rate of change in Leaf Area Index (LAI): The results on rate of change in LAI showed that stress owing to late planting and deficit irrigation caused slowdown of rate of LAI in greening phase while accelerated the LAI change in senescence phase (Fig 2). The significant correlation between rate of LAI change in greening and senescence phase ($r = 0.96$) was observed (Fig 2). It can be inferred that lower rate of LAI development in greening phase is also associated with faster senescence in late phase of crop growth. The delay in sowing caused about 22% reduction in rate of LAI change in greening phase while deficit irrigation (I5 to I1) caused only 10% reduction. During senescence phase, late sowing caused about 47% increase in rate of LAI change while it was only 19% due to deficit irrigation. It means late sowing has more influence on rate of LAI change than deficit irrigation with pronounced effect in senescence phase than greening phase.

Biomass production at harvest: Data (Table 1) shows that wheat biomass is significantly reduced with delay in sowing in the order of 15–17%. The irrigation levels also had significant effect on above-ground biomass production in both the years. Irrespective of date of sowing, the order in biomass production was I5>I3>I1. Irrigation level from I5 to I1 declined the biomass production by 31% and 19% in 2015–16 and 2016–17, respectively. While, lower irrigation level from I5 to I3 reduced the biomass production by 14% and 7% in 2015–16 and 2016–17, respectively. The lesser decline in 2016–17 was attributed to more rainfall received during that year which moderated the effect of water stress. The biomass production varied between 9 t/ha (I1 of 2015–16) and 14.6 t/ha (I5 of 2016–17). The interaction of sowing date and irrigation levels also had significant effect on above-ground biomass production. In 2015–16, biomass production varied between 8.25 t/ha (D2I1) and 14 t/ha (D1I5) with mean value of 11.1 t/ha averaged over all the treatments. Whereas, it varied between 10.3 t/ha and 15.8 t/ha in 2016–17 with mean value of 13.3 t/ha. The greater biomass in normal sown crop may be attributed to more accumulated light interception due to lengthened crop growing season (Pradhan *et al.* 2018).

Grain yield and yield attributes

Grain yield: The grain yield varied between 1.6 t/ha (D1I1) and 5.5 t/ha (D1I5) with an average value of 3.5 t/ha across the treatment in 2015–16. While it varied between 2.5 t/ha and 6.3 t/ha with an average value of 4.45 t/ha in 2016–17 (Table 1). Grain yield is significantly reduced with delay in sowing in both the years. D1 treatment registered 18% higher yield over D2 treatment in 2015–16, while it was about 23% in 2016–17. Grain yield is also significantly

Table 1 Wheat biomass and yield as influenced by (a) sowing dates, (b) irrigation levels and (c) interactions of sowing date and irrigation in the season 2015-16 and 2016-17. The same letters above the bar in the graph indicate the non-significant differences among the treatments at $P < 0.05$

	Seed wt./spike (g)		Seed no./spike		1000 seed weight (g)		Yield (kg/ha)		Biomass (kg/ha)	
	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
<i>Date of sowing</i>										
D1	1.51 ± 0.07 ^A	1.52 ± 0.12 ^A	44.87 ± 1.35 ^A	46.09 ± 3.25 ^A	31.3 ± 1.72 ^A	34.62 ± 0.5 ^A	3805 ± 106 ^A	4926 ± 237 ^A	12029 ± 241 ^A	14633 ± 292 ^A
D2	1.6 ± 0.06 ^A	1.34 ± 0.06 ^B	43.84 ± 0.77 ^A	43.1 ± 1.47 ^A	31.16 ± 0.73 ^A	34.2 ± 0.61 ^A	3219 ± 160 ^B	3985 ± 291 ^B	10186 ± 494 ^B	12041 ± 494 ^B
<i>Irrigation treatments</i>										
I5	1.72 ± 0.1 ^A	1.67 ± 0.06 ^A	44.57 ± 1 ^A	45.1 ± 1.93 ^A	33.39 ± 0.77 ^A	35.76 ± 0.48 ^A	5166 ± 118 ^A	5756 ± 225 ^A	13064 ± 352 ^A	14633 ± 298 ^A
I3	1.59 ± 0.03 ^A	1.49 ± 0.09 ^A	44.1 ± 0.89 ^A	44.43 ± 2.69 ^A	33.3 ± 0.78 ^A	35.46 ± 0.19 ^A	3708 ± 154 ^B	4642 ± 264 ^B	11259 ± 638 ^B	13542 ± 313 ^B
I1	1.35 ± 0.1 ^B	1.13 ± 0.11 ^B	44.4 ± 1.28 ^A	44.25 ± 2.45 ^A	27.01 ± 2.14 ^A	32.02 ± 1.01 ^B	1662 ± 128 ^C	2968 ± 314 ^C	8999 ± 233 ^C	11836 ± 323 ^C
<i>Interactions</i>										
D1I5	1.53 ± 0.05 ^{AB}	1.81 ± 0.09 ^{AB}	45.3 ± 0.97 ^A	46.37 ± 2.2 ^A	33.4 ± 1.22 ^A	37.57 ± 0.47 ^{ABC}	5504 ± 139 ^A	6289 ± 49 ^A	14084 ± 239 ^{AB}	15833 ± 321 ^{AB}
D1I3	1.64 ± 0.05 ^A	1.56 ± 0.11 ^C	44.77 ± 1.17 ^A	46.33 ± 3.99 ^A	33.08 ± 1.47 ^A	34.59 ± 0.05 ^A	4184 ± 132 ^B	5045 ± 46 ^B	12251 ± 500 ^C	14700 ± 407 ^C
D1I1	1.35 ± 0.1 ^A	1.18 ± 0.14 ^{BC}	44.53 ± 1.9 ^A	45.57 ± 3.56 ^A	27.43 ± 2.49 ^A	31.7 ± 0.99 ^A	1726 ± 48 ^C	3444 ± 351 ^C	9750 ± 225 ^B	13367 ± 148 ^{BD}
D2I5	1.92 ± 0.14 ^B	1.53 ± 0.03 ^{AB}	43.83 ± 1.04 ^A	43.83 ± 1.67 ^A	33.38 ± 0.31 ^A	33.94 ± 0.49 ^{AC}	4828 ± 97 ^{BC}	5224 ± 314 ^{BC}	12044 ± 465 ^{AB}	13433 ± 275 ^{BD}
D2I3	1.54 ± 0.01 ^{AB}	1.42 ± 0.07 ^A	43.43 ± 0.61 ^A	42.53 ± 1.38 ^A	33.52 ± 0.1 ^A	36.33 ± 0.32 ^B	3233 ± 177 ^{BD}	4239 ± 404 ^C	10267 ± 776 ^A	12383 ± 220 ^A
D2I1	1.35 ± 0.1 ^{AB}	1.08 ± 0.07 ^{ABC}	44.27 ± 0.67 ^A	42.93 ± 1.34 ^A	26.59 ± 1.79 ^A	32.33 ± 1.02 ^{BC}	1598 ± 207 ^D	2493 ± 177 ^{BD}	8248 ± 240 ^{BC}	10306 ± 497 ^D

influenced by irrigation levels. Irrespective of date of sowing, the order in grain yield was $I5 > I3 > I1$. Lower irrigation level from I5 to I1 declined the yield by 67 % and 48% in 2015-16 and 2016-17, respectively. While, lower irrigation level from I5 to I3 reduced the yield by 28% and 19% in 2015-16 and 2016-17, respectively. Comparison of the effect of lower irrigation treatment on biomass and yield showed that detrimental effect of less irrigation was almost double on grain yield than that on biomass production. Interaction of sowing date and irrigation treatments also showed significant effect on grain yield in both the years of experimentation. However, D1I1 and D2I3 showed non-significant differences in grain yield in 2016-17.

Seed number per spike: Independent effect of sowing date, irrigation levels and their interactions did not show any significant effect of seed number per spike in both the years of study.

Seed weight per spike: Delay in sowing had significant effect on seed weight per spike in 2016-17 but had non-significant effect in 2015-16. Delay in sowing caused about 11% decline in seed weight per spike in 2016-17. There was non-significant difference between I5 and I3 treatments in both the years. But I1 treatment registered significant difference from I3 and I5 treatments. I1 treatment recorded

about 15% and 21% lower seed weight per spike over I3 and I5 treatments, respectively in 2015-16 whereas, it was about 24% and 32% in 2016-17. Interaction treatments did not show any definite pattern of significant differences among the treatments.

1000-grain weight (test weight): Delay in sowing had non-significant effect on 1000-grain weight in both the years. Results on irrigation treatment showed that there was non-significant difference between I5 and I3 treatments in both the years. But I1 treatment registered significant difference from I3 and I5 treatment in 2016-17 only. I1 treatment recorded about 9% and 10% lower seed weight per spike over I3 and I5 treatments, respectively in 2016-17. Interaction treatments did not show any significant differences among the treatments in 2015-16.

The reduction in grain yield due to late planting may be due to source limitation caused by smaller leaf surface area for interception of light and photosynthetic activity and overall shortening of length of growing season (Stone *et al.* 1999 and Pradhan *et al.* 2018). Reduction in yield and yield components due to water stress was also reported in wheat by many workers (Kalra *et al.* 2007 and Ghosh *et al.* 2020). El-Gizawy (2009) reported that maximum numbers of tillers and number of spike/m², test weight (1000-seed

weight) and grain yield was obtained in mid-November sown wheat and delayed sowing resulted in a significant decrease in yield and yield attributes.

In present study, response of water stress on wheat was observed as similar to response of late planting with varied magnitude in terms of shortening of overall crop duration and acceleration of crop growth stages. The response was also seen as reduction in LAI, biomass and grain yield and yield attributes. The interactive effect of irrigation treatments and late planting showed additive effect on growth and development of wheat. Such responses in late planting was caused because of altered environmental conditions such as low temperature during early growth, high temperature during reproductive stage, lower water availability and solar radiations. Conspicuously, stress due to late sowing and deficit irrigation caused the slowdown of rate of LAI development during greening phase while it was accelerated during senescence phase.

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