Pak. J. Bot., 58(12): December 2026.

ARTICLE | DOI: http://dx.doi.org/10.30848/PJB2026-12(3)

THE IMPACT OF DIFFERENT SOWING DATES ON WHEAT YIELD FORMATION

BAOTING FANG[1], YAN-JING WANG[1,2], HAN-FANG WANG[1], HAI-YANG JIN[1], JIE HAN[2], FEI ZHENG[1*], XIANG-DONG LI[1*], SIMENG DU[1]

[1]Wheat Research Institute, Henan Academy of Agricultural Sciences, China, 450002.
[2]College of Life Sciences, Zhengzhou Normal University, China, 450044.

*Corresponding author's email: zhengfei@hnagri.org.cn; hnlxd@126.com

Abstract

Amid the increasing frequency of extreme weather events worldwide, significant year-to-year variations in environmental conditions have become apparent. The timing of wheat sowing plays a critical role in influencing its growth and development, thereby impacting China's food security. This study investigated the effects of different sowing dates on wheat growth, grain filling, and maturity in Xinxiang, Henan Province. By implementing five sowing date gradients, we analyzed the morphological and physiological changes in wheat and conducted initial assessments of its yield. The results indicate that October 15 represents the most suitable sowing date, leading to improved nitrogen utilization efficiency, higher leaf chlorophyll levels, enhanced stem reserve accumulation and translocation to grains, and increased grain yield. These findings advocate for selecting the optimal sowing time considering climatic and environmental factors, offering a scientific foundation for wheat cultivation.

Key words: Wheat; Different sowing dates; Morphological development; Yield

Introduction

Wheat stands as the second most significant grain crop in China. Its yield is affected by factors such as variety, soil conditions, climate, and sowing date (Qin *et al*., 2015). For various winter wheat cultivars, selecting the optimal sowing time is of great importance, which is affected by climate change and preceding crops (Luo *et al*., 2018).

Sowing date exerts a significant effect on the growth and final yield of winter wheat. An optimal sowing window enables efficient utilization of light and heat resources, thereby boosting productivity (Zhou *et al*., 2020). Climate change has reduced the applicability of traditionally recommended sowing dates (Nouri *et al*., 2017). Early sowing increases the risk of frost injury and grain shriveling, whereas late sowing leads to weak seedlings that are prone to winterkill (Fowler, 1982). Regional studies show divergent impacts: in southern Xinjiang, early sowing improves both yield and quality, while late sowing maintains quality but reduces yield. In Anhui, delayed sowing requires a higher seeding rate, and excessive delay causes substantial yield losses. Moreover, an earlier sowing date can increase soil moisture content, while a delayed one reduces it. Ultimately, timely sowing lowers the accumulated temperature requirement, optimizes population structure, and enhances both yield and quality (Reynolds *et al*., 2012; Noor *et al*., 2021).

With shifts in climate patterns and improvements in farming techniques, delayed sowing of winter wheat has become increasingly common. Although moderate delay can be beneficial, it generally reduces the number of effective spikes per unit area (Hunt *et al*., 2019). Therefore, addressing the dual challenges of maintaining high yield and good grain quality under late-sowing conditions is of great significance. Adapting sowing dates to local conditions is an essential measure (Liu *et al*., 2022). The optimal sowing window can reduce the accumulated temperature demand, optimize canopy structure, and contribute to better yield and quality (Akter & Islam, 2017). This study analyzed the effects of sowing date on plant architecture and yield formation of ‘Zhengmai 1860’ to determine its suitable sowing range and optimize cultivation practices.

Test materials and setup: A field experiment was conducted during the 2023–2024 growing season at the Modern Agricultural Experimental and Demonstration Base of the Henan Academy of Agricultural Sciences. The winter wheat cultivar ‘Zhengmai 1860’ provided by the Wheat Research Institute of the academy was used. Five sowing dates (5, 10, 15, 20, and 25 October) were set to explore the effects of different sowing dates on canopy morphological development and yield formation of wheat.

Test indicators and methods: The canopy Soil and Plant Analysis Development (SPAD) value, a non - destructive metric for assessing relative chlorophyll concentration, was measured to evaluate the photosynthetic capacity and nitrogen adequacy of wheat plants. A SPAD - 502 portable chlorophyll meter was utilized for this assessment, with six replicate measurements obtained per sample to ensure data reliability.

Canopy nitrogen content and leaf area at various positions were measured to evaluate their roles in the effects of sowing date on yield. Nitrogen content was measured using an N - Pen meter, and leaf area was calculated ($S = L \times W \times 0.75$) from six plant samples collected during the mid - and late - grain - filling stages. All measurements were conducted with three replicates.

Received: 08-12-2025 | Revised: 23-04-2026 | Accepted: 30-04-2026 | Online: 03-07-2026

Experimental setup and methods

Technical Route

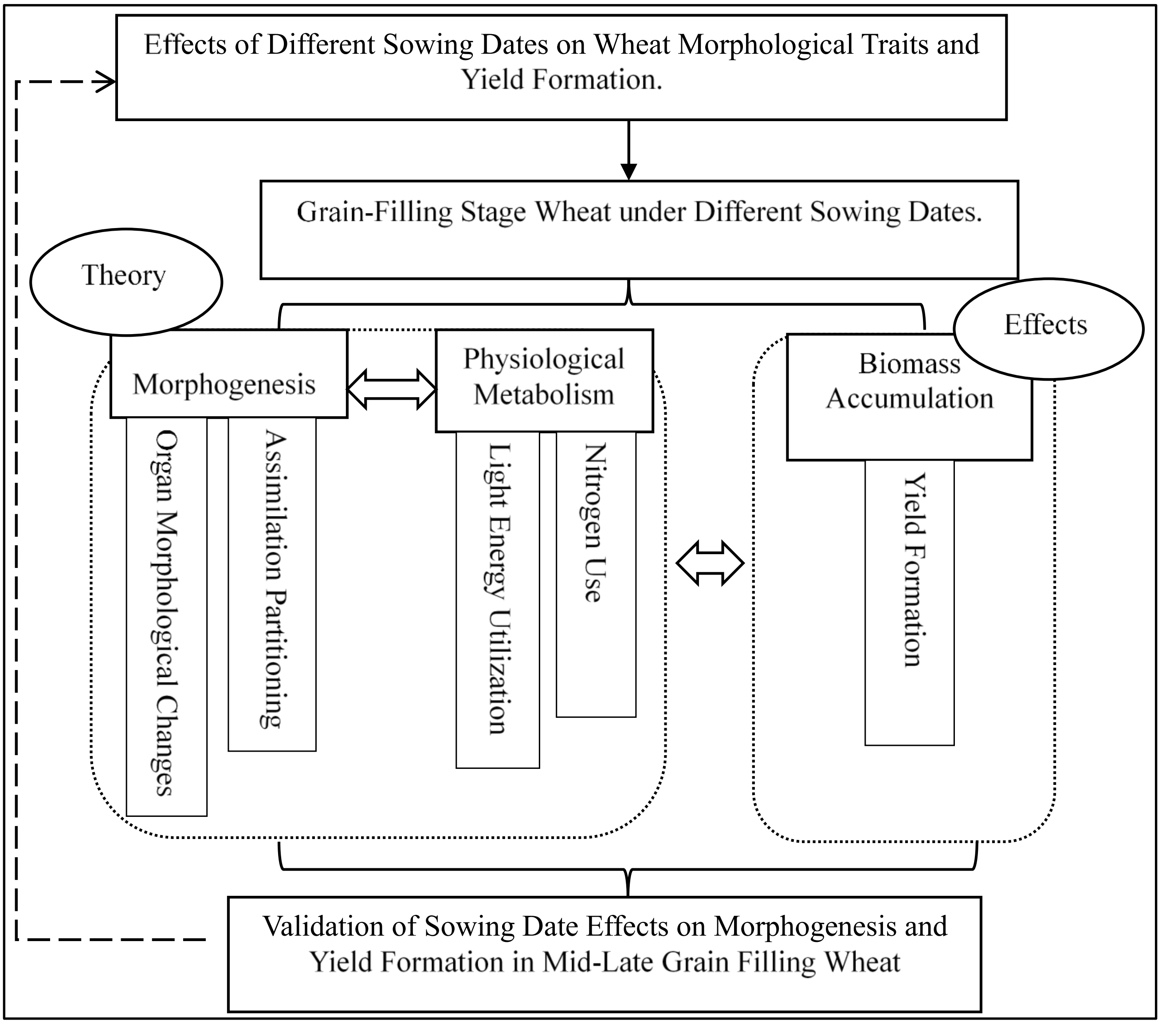

Fig. 1 Technical route of the experimental scheme.

Determination of Culm Morphology at Different Layers. Samples were collected at the mid-grain filling stage, late-grain filling stage, and maturity stage, with six plants selected for each sowing date. After the removal of leaves, the remaining culms were employed to measure the internode length (using a ruler) and internode diameter (using a vernier caliper) below the spike. Each section was measured three times, and the mean value was calculated.

Determination of Spike Morphology. At the maturity stage, six plants were sampled for each sowing date, and the spike length (from the base to the tip) was measured. Each spike was measured three times, and the average value was calculated while ensuring the structural integrity.

Determination of Yield and Quality Indicators. Upon reaching maturity, random samples were collected to measure the number of grains per spike, the number of effective spikelets, spike weight, and harvest index. Kernels were threshed for the measurement of length, width, and weight. Quality indicators were ascertained using a near - infrared grain analyzer.

Statistical analysis: Data were analyzed using Microsoft Excel, and statistical differences were examined by SPSS 16.0 through analysis of variance (ANOVA).

Results

Grains per spike: As shown in Fig. 2, grains per spike differed significantly among the various treatments, showing an overall upward trend. The value on 15 October reached its peak, which was significantly higher than those on 5, 10, and 25 October, but not significantly different from that on 20 October. It was substantially greater than those of all other sowing dates. Different letters above the bars (e.g., a, b, etc.) signify statistically significant differences at $p<0.05$.

Grain weight per plant: As shown in Fig. 3, grain weight per plant in different treatments showed a significant increasing trend, reaching the maximum on 15 October. This value presented significant disparities when compared with the data from the 10th and 20th, yet no significant difference was detected in comparison with the data from the 5th and 25th. These findings suggest that this sowing date facilitates a higher production capacity per wheat plant.

Leaf area change at different positions: Variation in flag leaf green leaf area. The data depicted in Fig. 4 suggest that during the mid-grain-filling stage, the area of the top-first leaf displayed notable differences among treatments, showing a pattern of initial augmentation followed by subsequent diminishment. The peak value was recorded on 15 October, which was significantly different from the values on 5 and 20 October, while the difference between the 10th and 20th was not statistically significant. Therefore, the treatment on the 15th was the most effective.

Penultimate leaf area dynamics. As depicted in Fig. 5, during the mid - grain filling stage, the area of the penultimate leaf varied significantly across different treatments, presenting irregular fluctuations. The value on October 15 reached the peak, showing a significant difference compared to those on the 5th, 10th, and 20th, yet no significant difference was found when compared to the 25th. In the late filling stage, notable differences in leaf area still persisted among certain treatments. Once again, the maximum value was recorded on October 15, which was significantly higher than those on the 5th and 10th. However, there was no significant difference between the 20th and 25th. Furthermore, during this later stage, the change in leaf area under the October 15 treatment was more stable and displayed a downward trend. In conclusion, the treatment implemented on October 15 demonstrated the optimal performance.

Third-leaf area dynamics. Figure 6 reveals notable variations in the area of the third top leaf among different treatments during the mid-grain filling stage, accompanied by an overall downward trend. The peak value on October 15 was significantly higher than those on the 5th and 10th. In the late stage, although the leaf areas further decreased, the treatment on October 15 maintained a stable and maximum value, which differed significantly from those on all other dates, indicating superior performance.

Fourth-leaf area dynamics. As depicted in Fig. 7, during the mid-grain filling stage, the area of the fourth top leaf exhibited significant variations among different treatments, presenting an overall downward trend. Throughout both grain-filling stages, the treatment with sowing on October 15 maintained the highest leaf area, showing a significant advantage over the treatment with sowing on October 10, while there was no statistically significant difference compared to the sowing on October 5. The sowing on October 15 maintained the maximum leaf area with minimal reduction, demonstrating both a significant edge over other treatments and superior stability, thus confirming it as the optimal regime.

Variation in spike morphology under different sowing dates: Figure 8 indicates that sowing on October 15 consistently produced the longest spikes throughout the grain-filling and maturity stages, frequently exhibiting significant advantages over other sowing dates. Its excellent and stable performance, marked by the largest amplitude of change, validates it as the optimal treatment.

Stem volume parameters across positions: First-internode stem volume dynamics. Figure 9 reveals that during the grain - filling stage, the sowing date corresponding to the highest stem volume changed (mid - stage: October 15; late stage: October 20). The 15 October treatment consistently attained the highest values during the mid-filling, late-filling, and maturity stages. It reached the highest value at maturity and, more importantly, maintained the most stable volume of the first internode below the spike throughout the growth period, which validates it as the optimal option.

Second - internode stem volume dynamics. As depicted in Fig. 10, the stem volume of the second internode demonstrated significant variations among different treatments. The treatment on October 15 consistently attained the highest values during the mid - filling, late - filling, and maturity stages, presenting significant disparities with several other dates (e.g., the 20th and 25th during the mid - stage; the 25th and 10th during the late - stage; the 25th at maturity). Furthermore, it manifested the most stable volumetric alterations throughout all growth stages. Consequently, the treatment on October 15 is recognized as the optimal one.

Third - internode stem volume dynamics. Figure 11 illustrates that the stem volume of the third internode below the spike exhibited substantial variations among different treatments. The sowing on October 15th consistently attained the highest values with excellent stability throughout the developmental stages. It demonstrated significant advantages over multiple comparison dates, thereby validating its status as the optimal regime.

Fourth - internode stem volume dynamics. Figure 12 indicates that the stem volume of the fourth internode below the spike differed substantially among treatments. The treatment on October 15 consistently presented the highest values during all three growth stages, namely the mid - filling, late - filling, and maturity stages. It showed significant disparities with the treatments on the 10th, 20th, and 25th during the mid - stage, and with the treatments on the 20th and 25th during both the late and maturity stages. Furthermore, it displayed the most stable volumetric dynamics throughout the observation period. Consequently, the treatment on October 15 is recommended as the optimal one.

Superior performance was concentrated on the sowing date of October 15, as ascertained through the analysis of stem volume variation across different positions. This sowing date can be ascribed to the augmented accumulation of stem volume, which indicates vigorous growth, high biomass, and strong photosynthetic activity, all of which are conducive to yield enhancement. Therefore, the treatment on October 15 is the optimal choice.

Variation in nitrogen use efficiency at different leaf positions: Figure 13 illustrates the preeminence of the October 15 treatment. The October 15 sowing treatment consistently attained the highest values in both the middle and late stages.

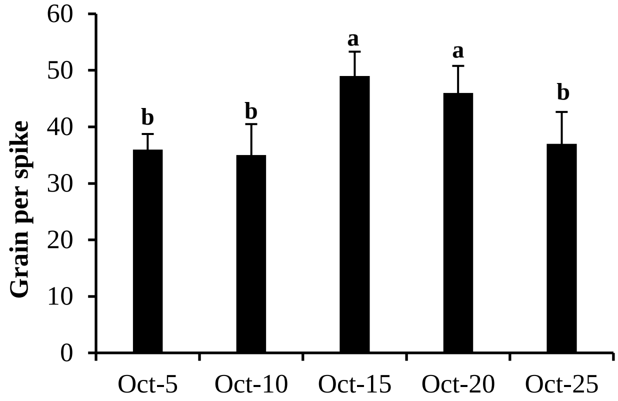

Fig. 2. Grains per spike of different sowing dates at maturity.

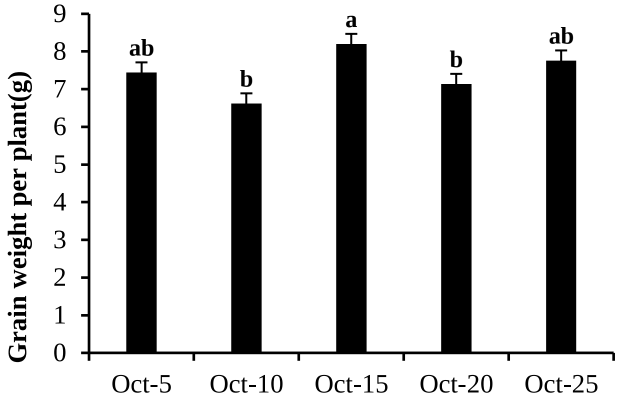

Fig. 3. Grain weight per plant of different sowing dates at maturity.

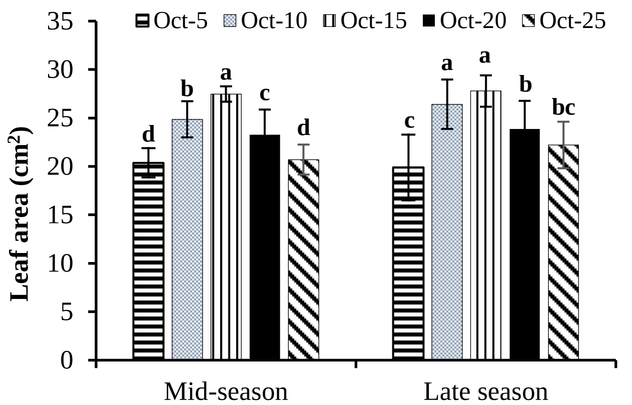

Fig. 4. Flag leaf area of different sowing dates in two seasons.

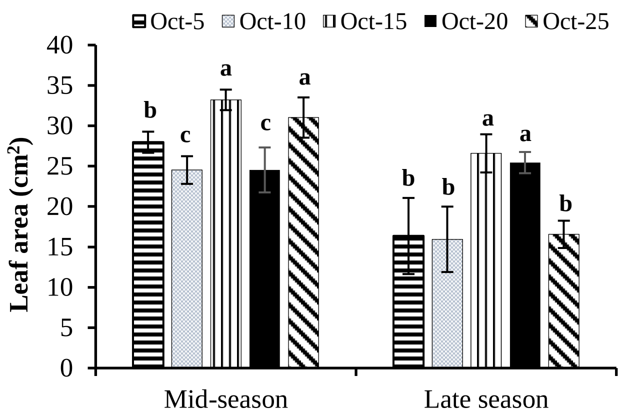

Fig. 5. Penultimate leaf area of different sowing dates in two seasons.

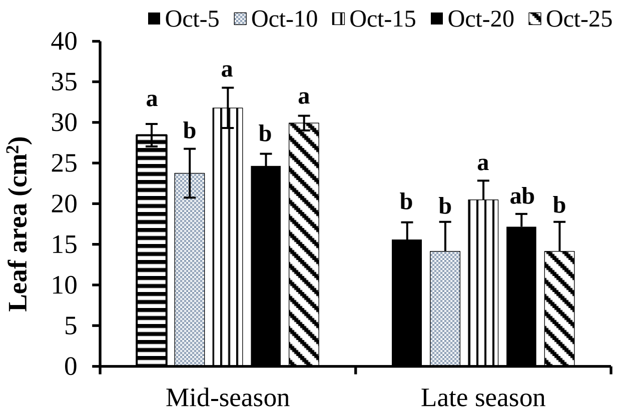

Fig. 6. Third top leaf area of different sowing dates in two seasons.

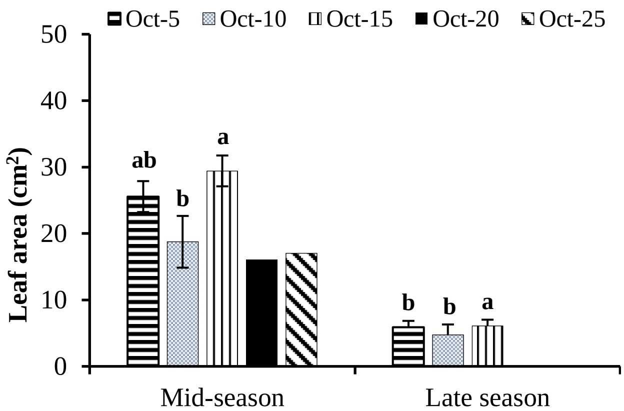

Fig. 7. Fourth top leaf area of different sowing dates in two seasons.

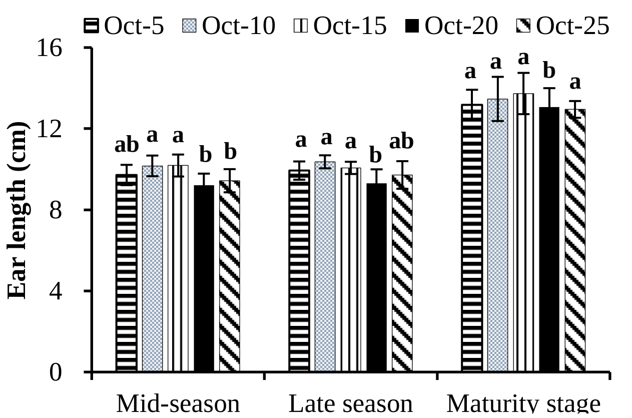

Fig. 8. Variation in spike length with growth stage and sowing date.

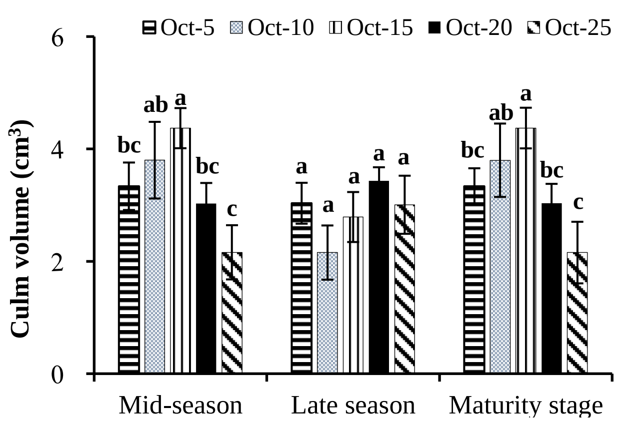

Fig. 9. Volume of the first internode below the spike.

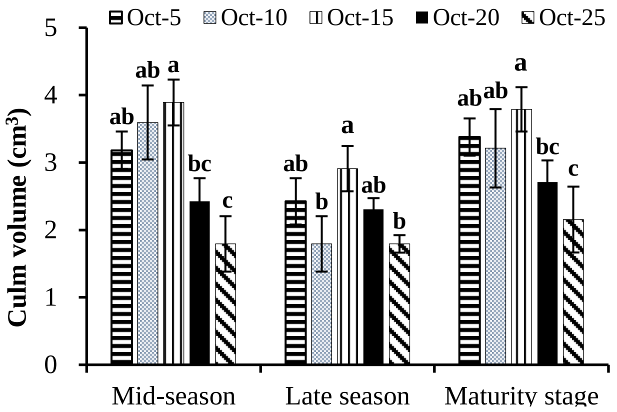

Fig. 10. Volume of the second internode below the spike.

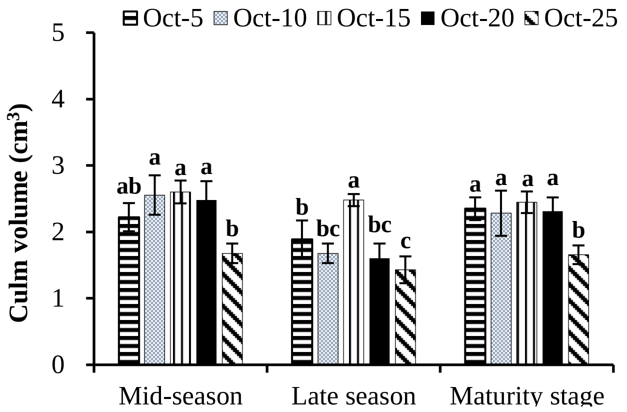

Fig. 11. Third-internode stem volume of different sowing dates.

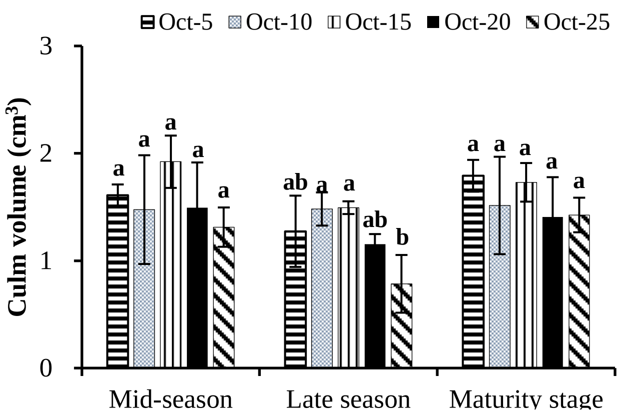

Fig. 12. Fourth-internode stem volume of different sowing dates.

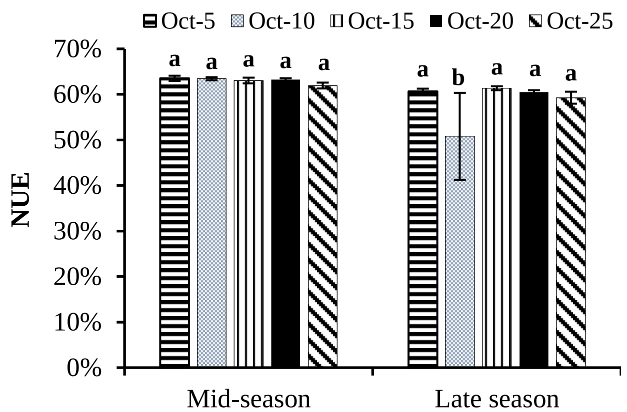

Fig. 13. Flag leaf NUE of different sowing dates.

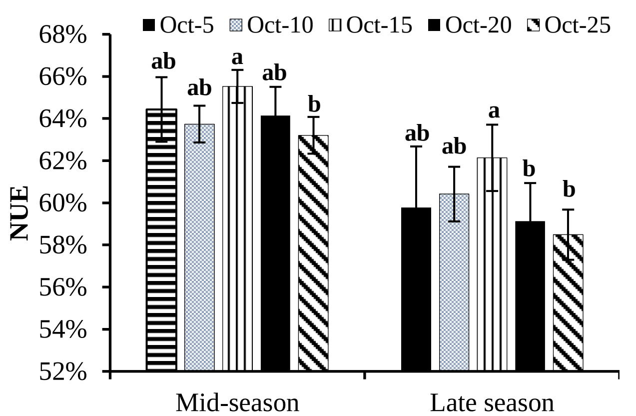

Fig. 14. NUE of the penultimate leaf of different sowing dates.

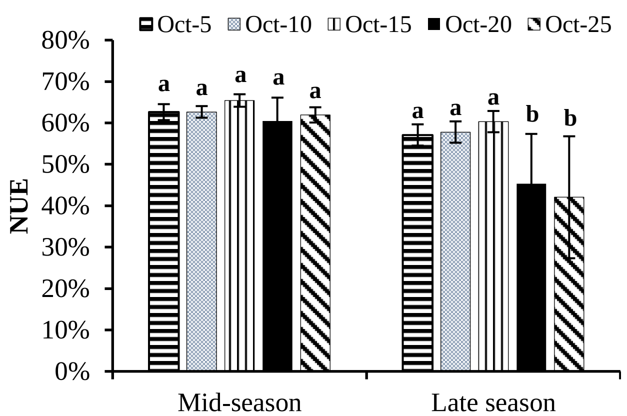

Fig. 15. NUE in the third top leaf of different sowing dates in two seasons.

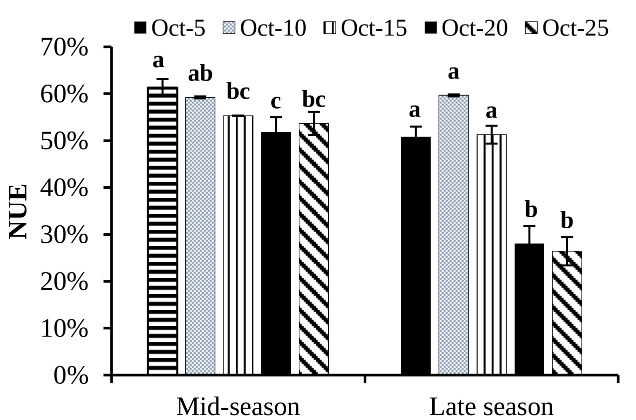

Fig. 16. NUE in the Fourth Top Leaf of different sowing dates in two seasons.

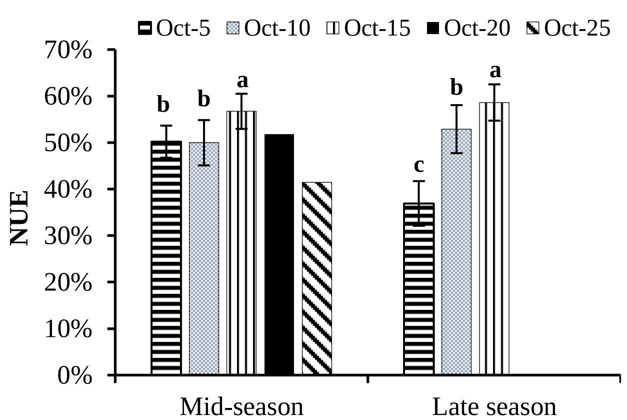

Fig. 17. NUE in the Fifth Top Leaf of different sowing dates in two seasons.

Figure 14 indicates that during the mid - grain filling stage, there were no significant differences in the NUE of the penultimate leaf among treatments, and it generally remained stable. The NUE value on October 15 was the highest and significantly differed from that on the 5th. In the late filling stage, significant differences among treatments emerged. The NUE value on October 15 reached the maximum and significantly differed from those on the 5th, 20th, and 25th. Additionally, for this sowing date, the NUE showed minimal and more stable variation during the late stage. Consequently, the treatment on October 15 is more advantageous.

Figure 15 demonstrates that during the mid - grain filling stage, there were no significant differences in the NUE of the third top leaf among different treatments. The NUE presented a gradual and stable decrease as the sowing dates were postponed. The highest NUE value was documented on October 15, while the lowest was noted on the 20th. In the late filling stage, significant disparities among treatments became apparent. The treatment with a sowing date of October 15 attained the maximum NUE, showing significant differences compared to the treatments with sowing dates on the 20th and 25th, but no significant differences compared to those on the 5th or 10th. Additionally, the NUE for the October 15 sowing date exhibited minimal and more stable fluctuations in the late stage. Consequently, the treatment with a sowing date of October 15 is regarded as the optimal one.

Figure 16 indicates that the NUE of the fourth top leaf varied notably among treatments during the mid-grain filling stage, generally declining with the delay of sowing. The value on October 5 was the highest, significantly different from the lowest value on the 20th, but not significantly different from those on the 15th or 25th. In the late filling stage, significant differences still existed among treatments. The treatment on October 10 achieved the maximum NUE and showed significant differences from all other dates (5th, 15th, 20th, and 25th). Furthermore, the sowing date of October 10 exhibited minimal and more stable NUE variation during the late stage, while the treatment on October 5 showed a substantial decrease. Therefore, the treatment on October 10 is more advantageous.

Figure 17 indicates that the nitrogen use efficiency of the fifth leaf differed significantly among treatments during the grain - filling stage, generally showing a decreasing trend with the delay of sowing. The treatment sown on October 15 consistently attained the highest values in both the middle and late stages, which were significantly different from the lowest values (treatment sown on October 5) and the values of the treatment sown on October 10. Additionally, it displayed minimal fluctuations and higher stability in the late stage. Consequently, the treatment sown on October 15 is the most optimal.

Variation in photosynthetic pigment content at different leaf positions: Variation in Chlorophyll Content in the Flag Leaf. Figure 18 indicates that during the mid - grain - filling stage, there were no significant differences in chlorophyll content among treatments. The maximum and minimum values were recorded on October 5 and October 20, respectively. In the late grain - filling stage, the treatment on October 15 attained the highest chlorophyll content, which was significantly different from the treatments on October 5 and October 25. Furthermore, the chlorophyll content of the top - leaf under this sowing date demonstrated the most substantial change during the late stage. A comprehensive analysis validates the superiority of the October 15 treatment.

Variation in Chlorophyll Content in the Second Top Leaf. Figure 19 indicates that during the mid - grain - filling stage, the chlorophyll content in the penultimate leaf varied significantly across different treatments. Generally, it showed a decreasing trend with the delay of sowing time. The highest chlorophyll content was observed on October 5, followed by that on October 15, while the lowest was recorded on October 20. The chlorophyll content on October 20 differed significantly from that on October 5, but there was no significant difference compared with the values on the 10th, 15th, or 25th.

In the late grain - filling stage, the treatment on October 15 achieved the highest chlorophyll content, which was significantly different from that of the October 25 treatment. Compared with the mid - stage, the chlorophyll content in the October 5 treatment declined substantially during the late stage, while the October 15 treatment remained relatively stable. Therefore, the treatment on October 15 is regarded as the optimal one.

Variation in Chlorophyll Content of the Third Uppermost Leaf. Figure 20 indicates that during the middle grain - filling stage, the chlorophyll content of the third uppermost leaf varied notably among different treatments. There was an overall decrease in chlorophyll content with the delay of sowing time. The treatment with sowing on October 15 had the highest chlorophyll content value, which was significantly different from the lowest value recorded on October 20, but not significantly different from the values of the treatments on October 10 or 25. In the late stage, the treatment with sowing on October 15 still had the highest chlorophyll content, showing significant differences from both the October 20 and October 25 treatments. Although the chlorophyll content decreased in all treatments during the late stage, the sowing date of October 15 showed the most stable trend. Consequently, the treatment with sowing on October 15 is regarded as the optimal one.

Variation in the Chlorophyll Content of the Fourth Uppermost Leaf. Figure 21 indicates that the chlorophyll content of the fourth uppermost leaf exhibited significant variations among treatments during both grain - filling stages, generally showing a decline with the delay in sowing. The treatment sown on October 10 consistently attained the highest values, significantly differing from the lowest values in the mid - stage and from most other treatments in the late stage. While the chlorophyll content decreased for other sowing dates in the late stage, the treatment sown on October 10 maintained stable levels. Consequently, the treatment sown on October 10 is regarded as the optimal one.

Variation in the Chlorophyll Content of the Fifth Uppermost Leaf. Figure 22 indicates that the chlorophyll content of the fifth uppermost leaf varied notably among treatments during both grain - filling stages, presenting a general downward trend with the postponement of sowing. The treatment with sowing on October 15 consistently attained the highest values, showing significant differences from the treatments with sowing on October 5 and 10 in both stages. Although the chlorophyll content decreased in all treatments during the late stage, the sowing date of October 15 displayed the most stable tendency. Consequently, the treatment with sowing on October 15 is regarded as the optimal one.

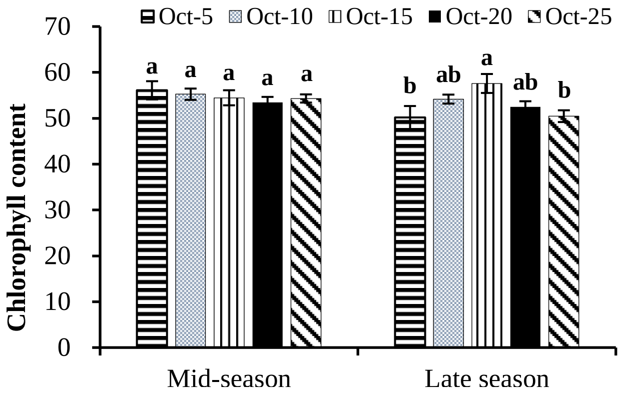

Fig. 18. Variation in Chlorophyll Content in the Flag Leaf of different sowing dates in two seasons.

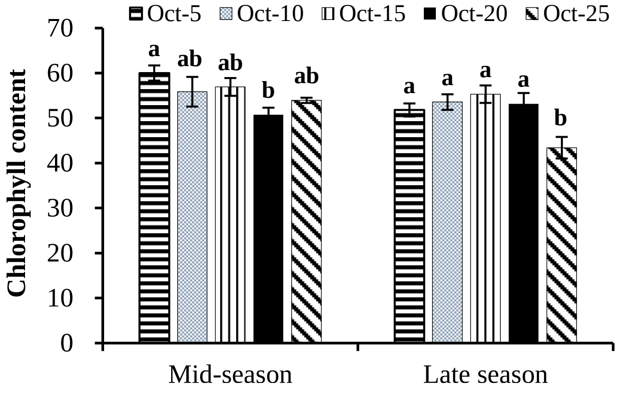

Fig. 19. Variation in Chlorophyll Content in the second top leaf of different sowing dates in two seasons.

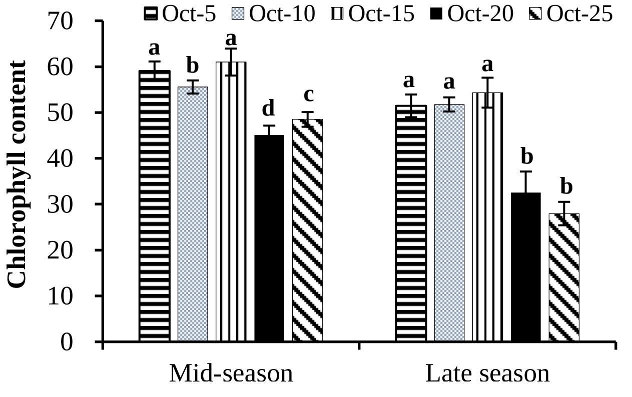

Fig. 20. Variation in Chlorophyll Content in the third top leaf of different sowing dates in two seasons.

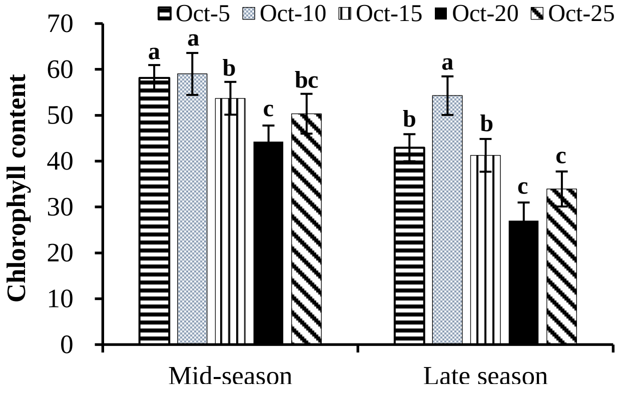

Fig. 21. Variation in Chlorophyll Content of the fourth top leaf of different sowing dates in two seasons.

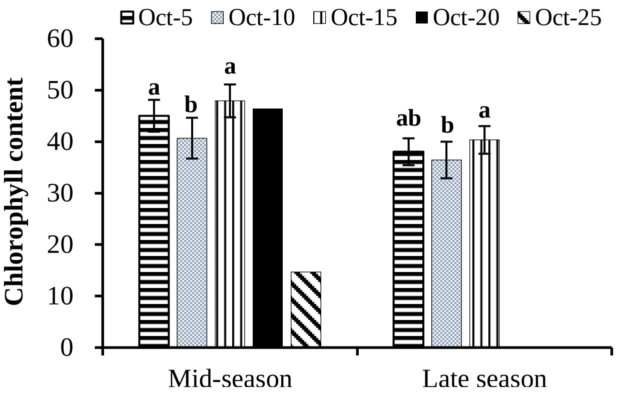

Fig. 22. Variation in Chlorophyll Content of the fifth top leaf of different sowing dates in two seasons.

Results and Discussion

The content of photosynthetic pigments and nitrogen utilization efficiency are crucial factors determining the photosynthetic efficiency and yield formation in wheat (Makino, 2011). Alterations in sowing dates significantly influence the processes of photosynthetic pigment synthesis and nitrogen metabolism, thereby regulating dry matter accumulation and yield components (Bashan & De-Bashan, 2010). This research reveals that sowing on October 15 effectively stimulates chlorophyll accumulation, enhances photosynthetic capability (Rahman *et al*., 2009), improves nitrogen uptake and utilization efficiency, and promotes protein synthesis and dry matter accumulation, establishing a physiological basis for yield enhancement (Yin *et al*., 2018). These results are in line with previous studies suggesting that optimal sowing dates facilitate chlorophyll and nitrogen accumulation (Kibe *et al*., 2006 , Dai *et al*., 2017).

From the perspective of canopy structure and dry matter partitioning, wheat sown on October 15 demonstrates superior spike length, leaf area, and stem morphology, which are conducive to light capture and utilization (Sieling *et al*., 2016), as well as the efficient translocation of photosynthetic products to grains (Liu *et al*., 2016). This sowing date guarantees that the critical growth stages of wheat take place under appropriate temperature and light conditions, circumventing excessive vegetative growth resulting from early sowing or insufficient biomass accumulation due to late sowing(Dennett, 1999). This coordination between morphological development and dry matter accumulation is consistent with the conclusions of other studies regarding the advantages of optimal sowing dates for canopy establishment and biomass production (Pal *et al*., 2017 , Ehdaie & Waines, 2001).

Regarding yield performance, sowing on October 15 notably enhances grain yield by optimizing key components including productive panicles, grains per spike, and thousand - kernel weight (Bashir *et al*., 2010). The optimal sowing date facilitates sufficient growth and nutrient accumulation, thereby optimizing yield - related traits. In contrast, late sowing results in a substantial yield decline owing to a shortened growth cycle (Zhiipao *et al*., 2023). This study systematically expounds on the comprehensive impacts of sowing date on the physiological traits, morphological development, and yield formation of wheat, offering a theoretical foundation and practical guidance for formulating sowing strategies adapted to local conditions.

Funding: Innovation Team of Henan Academy of Agricultural Sciences; Position for Wheat High-Yield Cultivation under the Wheat Industrial Technology System of Henan Province; Innovative Research Project for College Students at Zhengzhou Normal University （DCZ2024001, DCY2024003）

Conflict of Interest: The authors declare that they have no conflict of interest.

Author's Contributions: Baoting Fang and Yanjing Wang contributed to the conceptualization of the study. Hanfang Wang provided supervision throughout the research process. Simeng Du was responsible for visualization, while Haiyang Jin and Han Jie contributed to the methodology. Baoting Fang and Yanjing Wang handled the editing of the manuscript. Xiangdong Li and Fei Zheng contributed to reviewing and editing, Baoting Fang performed the statistical analysis.

References

Akter, N. and M.R. Islam. 2017. Heat stress effects and management in wheat: a review. *Agron. Sustain. Dev.*, 37: 37.

Bashan, Y. and L.E. De-Bashan. 2010. How the plant growth-promoting bacterium Azospirillum promotes plant growth: a critical assessment. *Adv. Agron.*, 108: 77-136.

Bashir, M.U., N.A. Nadeem Akbar, A.I. Asif Iqbal and H. Zaman. 2010. Effect of different sowing dates on yield, yield components of direct seeded coarse rice (*Oryza sativa* L.). *Pak. J. Agric. Sci.*, 4: 5.

Dai, X., Y. Wang, X. Dong, T. Qian, L. Yin, S. Dong, J. Chu and M. He. 2017. Delayed sowing can increase lodging resistance while maintaining grain yield and nitrogen use efficiency in winter wheat. *Crop J.*, 5: 541-552.

Dennett, M.D. 1999. Effects of sowing date and the determination of optimum sowing date. In: Wheat. CRC Press: 123-140.

Ehdaie, B. and J. Waines. 2001. Sowing date and nitrogen rate effects on dry matter and nitrogen partitioning in bread and durum wheat. *Field Crops Res.*, 73: 47-61.

Fowler, D. 1982. Date of seeding, fall growth, and winter survival of winter wheat and rye. *Agron. J.*, 74: 1060-1063.

Hunt, J.R., J.M. Lilley, B. Trevaskis, B.M. Flohr, A. Peake, A. Fletcher, A.B. Zwart, D. Gobbett and J.A. Kirkegaard. 2019. Early sowing systems can boost Australian wheat yields despite recent climate change. *Nat. Clim. Chang.*, 9: 244-247.

Kibe, A., S. Singh and N. Kalra. 2006. Water-nitrogen relationships for wheat growth and productivity in late sown conditions. *Agric. Water Manag.*, 84: 221-228.

Liu, E., X. Mei, C. Yan, D.Z. Gong and Y.Q. Zhang. 2016. Effects of water stress on photosynthetic characteristics, dry matter translocation and WUE in two winter wheat genotypes. *Agric. Water Manag.*, 167: 75-85.

Liu, K., M.T. Harrison, B. Wang, R. Yang, H. Yan, J. Zou, D.L. Liu, H. Meinke, X. Tian, S. Ma, Y. Zhang, J. Man, X. Wang and M. Zhou. 2022. Designing high-yielding wheat crops under late sowing: a case study in southern China. *Agron. Sustain. Dev.*, 42: 29.

Luo, Q., G. O'Leary, J. Cleverly and D. Eamus. 2018. Effectiveness of time of sowing and cultivar choice for managing climate change: Wheat crop phenology and water use efficiency. *Int. J. Biometeorol.*, 62: 1049-1061.

Makino, A. 2011. Photosynthesis, grain yield, and nitrogen utilization in rice and wheat. *Plant Physiol.*, 155: 125-129.

Noor, H., Q. Wang, M. Islam, M. Sun, W. Lin, A.X. Ren, Y. Feng, S.B. Yu, N. Fida, S.F. Dong, P.R. Wang, L. Li, Z.X. Wang, R.R. Zhang, Q.L. Zhao, P.C. Ding and Z.Q. Gao. 2021. Effects of sowing methods and nitrogen rates on photosynthetic characteristics, yield and quality of winter wheat. *Photosynthetica.*, 59: 277-285.

Nouri, M., M. Homaee, M. Bannayan and G. Hoogenboom. 2017. Towards shifting planting date as an adaptation practice for rainfed wheat response to climate change. *Agric. Water Manag.*, 186: 108-119.

Pal, R., G. Mahajan, V. Sardana and B.S. Chauhan. 2017. Impact of sowing date on yield, dry matter and nitrogen accumulation, and nitrogen translocation in dry-seeded rice in North-West India. *Field Crops Res.*, 206: 138-148.

Qin, X., F. Zhang, C. Liu, H. Yu, B. Cao, S. Tian, Y. Liao and K.H.M. Siddique. 2015. Wheat yield improvements in China: Past trends and future directions. *Field Crops Res.*, 177: 117-124.

Rahman, M., A. Hossain, M. Hakim, M.A. Kabir, M.R. Shah and M.M.R. Shah. 2009. Performance of wheat genotypes under optimum and late sowing condition. *Int. J. Sustain. Crop Prod.*, 4: 34-39.

Reynolds, M., J. Foulkes, R. Furbank, S. Griffiths, J. King, E. Murchison, M. Parry and G. Slafer. 2012. Achieving yield gains in wheat. *Plant Cell Environ.*, 35: 1799-1823.

Sieling, K., U. Böttcher and H. Kage. 2016. Dry matter partitioning and canopy traits in wheat and barley under varying N supply. *Eur. J. Agron.*, 74: 1-8.

Yin, L., X. Dai and M. He. 2018. Delayed sowing improves nitrogen utilization efficiency in winter wheat without impacting yield. *Field Crops Res.*, 221: 90-97.

Zhiipao, R., V. Pooniya, N. Biswakarma, D. Kumar, Y.S. Shivay, A. Dass, G. Mukri, K.K. Lakhena, R.K. Pandey, A. Bhatia, P. Govindasamy, A. Burman, S. Babu, R.D. Jat, A.K. Dhaka and K. Swarnalakshmi. 2023. Timely sown maize hybrids improve the post-anthesis dry matter accumulation, nutrient acquisition and crop productivity. *Sci. Rep.*, 13: 1688.

Zhou, B., X. Sun, J. Ge, C. Li, Z. Ding, S. Ma, W. Ma and M. Zhao. 2020. Wheat growth and grain yield responses to sowing date-associated variations in weather conditions. *Agron. J.*, 112: 985-997.