Feature Review Open Access

Optimizing Sowing Techniques for Enhanced Maize Production

Jinhua Cheng, Wei Wang

Institute of Life Sciences, Jiyang College of Zhejiang A&F University, Zhuji, 311800, Zhejiang, China

Corresponding author: wei.wang@jicat.org

Maize Genomics and Genetics, 2025, Vol.16, No.5 doi: 10.5376/mgg.2025.16.0025

Received: 27 Aug., 2025

Accepted: 10 Oct., 2025

Published: 28 Oct., 2025

Preferred citation for this article:

Cheng J.H., and Wang W., 2025, Optimizing sowing techniques for enhanced maize production, Maize Genomics and Genetics, 16(5): 276-283 (doi: 10.5376/mgg.2025.16.0025)

Abstract With the increasing demand for food security and efficient agricultural development, the optimization of corn sowing technology has become an important means to improve yield and resource utilization efficiency as the world's main food crop. This study systematically reviews the development status and technical points of corn sowing methods, sowing density and row spacing configuration, sowing period control and intelligent sowing equipment, analyzes the adaptation mechanism of sowing parameters in different ecological regions, and explores the integrated application effect of sowing strategies through typical regionalized cases. Studies have shown that adjusting sowing technology according to local conditions not only significantly improves corn emergence rate and population structure, but also helps to achieve high yield, stable yield and sustainable development goals. This study hopes to provide theoretical support and technical reference for further innovation and practical promotion of corn sowing technology.

Keywords Corn; Sowing technology; Density optimization; Sowing period control; Smart agriculture

1. Introduction

Corn (*Zea mays* L.) is a very important crop. It can be used as food, animal feed, and is often used in industrial processing. The area and total yield of corn in the world are now slowly increasing (Tar et al., 2024). Corn can adapt to different climatic conditions and plays a big role in ensuring food security. As the climate warms and the population increases, how to grow corn well and increase yields becomes increasingly important (Huang et al., 2020; Xiao et al., 2020).

If you want high corn yields, the sowing method is critical. How to sow, when to sow, and how deep to sow will affect the emergence, later growth, and how many seeds can be produced in the end, how heavy the grains are, and how high the total yield is (Domokos et al., 2024; Wu et al., 2024). Studies have found that ridge cultivation and choosing the right sowing time can significantly increase crop yields and harvest rates; and precision sowing technology can also make seedlings more uniform and make corn more drought-resistant (Imran et al., 2021; Laghari et al., 2024). Reasonable adjustment of sowing period and sowing method is also a good way to cope with climate change and ensure stable corn yield (Ali et al., 2022; Zhang et al., 2023).

This study will systematically sort out the research progress and innovative application of corn sowing technology in recent years, analyze the global importance of corn, and focus on how different sowing methods, sowing timing and technological innovation affect yield and quality, hoping to improve corn productivity by optimizing sowing strategies.

2 Evolution and Adaptability of Sowing Methods

2.1 Development from broadcasting and drilling to precision sowing

The seeding method of corn has changed a lot in recent years. In the past, it was mostly broadcasting or row seeding, but now precision seeding is increasingly used. Although broadcasting is convenient, the seeds are not evenly distributed, many seedlings cannot emerge, and the yield cannot keep up. Row seeding is better than broadcasting. The seeds can be sown at similar depths and spacings, so that the seedlings grown are more uniform, and the yield and nutrient utilization rate are also higher (Laghari et al., 2024). Later, there were precision seeding and nutrient management tools, such as precision fertilization systems combined with row seeding, which can also be used in conjunction with fixed seedbeds to further increase yields and incomes, and are more environmentally friendly. Studies have shown that using these methods, the yield and income of corn and wheat rotation can be nearly 50% higher than traditional broadcasting (Jat et al., 2021). Another improvement method is ridge cultivation, which can make corn grow taller, have larger ears, more grains, and a higher emergence rate, and the effect is significantly better than broadcasting and row seeding.

2.2 Regional ecological adaptation of sowing strategies

Today's sowing methods are increasingly "adapting to local conditions". Different places have different climates, so sowing time and methods should also be adjusted accordingly. This can better adapt to climate change and reduce the risk of yield reduction caused by changes in temperature and rainfall (Lv et al., 2019; Xu et al., 2021; Rao et al., 2022). For example, in China and India, adjusting the sowing date and selecting suitable new varieties can effectively offset the negative impact of climate change. Studies have found that delaying sowing and selecting good varieties can help maintain yield stability (Lv et al., 2019; Srivastava et al., 2022). For another example, in Argentina, farmers introduced genetically modified corn and flexibly arranged sowing dates so that corn can be planted in more semi-arid or sub-humid areas to avoid drought problems during the critical growth period (Otegui et al., 2021).

2.3 Impact on emergence uniformity and stand establishment

The selection of sowing methods will directly affect whether the seedlings are uniform. The uniform emergence of seedlings will ensure stable growth and guaranteed yield. Ridge cultivation and precision seeding can sow seeds more evenly and at a more appropriate depth, so that seedlings emerge faster and more evenly. Some studies have shown that the emergence rate of ridge cultivation can reach 89% (Laghari et al., 2024). If the seedlings emerge evenly, the field will not be messy, and corn will not compete for water and fertilizer. Precision seeding, which sows seeds at similar depths, can also make the seedlings in the entire field grow more uniformly. This early advantage will make the later growth smoother and the yield higher, and corn can also withstand problems such as drought and high temperature.

3 Optimization of Planting Density and Row Configuration

3.1 Trade-offs between plant competition and yield per area

Increasing the planting density and reducing the row spacing can often increase the number of ears and the efficiency of land use, thereby increasing the yield per unit area. However, when the density is too high, the corn will compete with each other for light, water and nutrients, which will affect individual development. If the corn is planted too densely, the number and weight of corn grains may decrease, and even more fertilizer may not necessarily alleviate this competition (Haegele et al., 2014). If you want to have a stable yield, you have to match the planting density and row spacing well and find a balance. This can prevent the corn from growing too crowded, especially when the climate is unstable, this approach is more secure (Haarhoff and Swanepoel, 2022; Noland et al., 2025).

3.2 Light interception efficiency and row spacing alignment

The width of the row spacing affects how the corn receives sunlight. Compared with wide row spacing, narrow row spacing such as 38 cm can increase the number of ears, improve yield, and make the spacing between plants more uniform, all of which are related to high yield (Noland et al., 2025). However, the effect may be different in different environments. Sometimes, a wide row spacing of 0.76 meters can receive more sunlight; in other places, a narrow row spacing of 0.52 meters allows the plants to form a better cover layer and capture more light (Haarhoff and Swanepoel, 2022). There are also some other arrangements, such as alternating narrow and wide rows or double row planting, which can also help improve radiation use efficiency (RUE) and improve the lighting environment. But their yield effects also depend on whether the planting density and climatic conditions are suitable (Liu et al., 2012; Haegele et al., 2014).

3.3 Constraints and physiological adjustments in high-density planting

When the density increases, corn will adjust itself, such as growing more leaves, increasing the leaf area index, or changing the canopy structure to adapt to more intense competition (Pelech et al., 2022). But this adjustment also has its limits. If the density is too high and exceeds the tolerance of the corn variety, the yield may stagnate or even begin to decline. Therefore, it is important to choose the right variety. Some hybrids can maintain the number and weight of grains when densely planted, while others cannot (Haegele et al., 2014). Reasonable arrangement of planting space, such as making the space around each corn plant more square and balanced, can also reduce the impact of crowding and help increase yields (Noland et al., 2025).

4 Sowing Time Adjustment under Climatic Variation

4.1 Effects of sowing date on emergence and phenology

When corn is sown will directly affect the emergence time, growth process and yield. Generally speaking, early sowing can take advantage of sunlight and suitable temperature earlier, so that more grains and heavier grains are produced, which is conducive to stable and increased yields (Wu et al., 2023; 2024). Although late sowing will shorten the early growth period, it can extend the period of flowering and seeding. This can sometimes help corn avoid severe weather such as high temperature and dry heat. However, in high-latitude areas, late sowing may also cause crops to encounter early frost, increasing the risk of premature aging (Han et al., 2022). Studies have found that when the temperature rises, adjusting the sowing period can make corn grow faster, which can reduce some of the negative effects of climate (Abbas et al., 2017).

4.2 Adjusting sowing periods in response to climate change

Adjusting the sowing time is an important way to cope with climate change. For example, delaying sowing can allow corn to avoid high temperatures during the flowering or filling stages, which can increase yield potential under future climates (Tian et al., 2018; Xiao et al., 2022). Some places recommend early sowing, which can better utilize sunlight and heat and extend the sowing window (Wu et al., 2023). However, different regions have different answers to the best time to sow. For example, in high-latitude areas, early sowing and long-growing varieties can avoid early frost; while in low-latitude areas, mid-sowing and mid-maturity varieties can reduce the impact of high temperatures (Han et al., 2022). If sowing time, variety selection, planting density and other factors are taken into consideration, adaptability and yield can be further improved (Lv et al., 2019; Zhang et al., 2020; Xu et al., 2021).

4.3 Risk mitigation techniques for early and delayed sowing

Whether it is early or late sowing, there are risks. In order to mitigate these effects, some countermeasures can be considered. For example, medium-time sowing (mid-time sowing) is usually more stable, avoiding both high temperatures in the early stage and cold or early frost in the later stage. Studies in North China have found that mid-time and late sowing have higher yields than early sowing (Tian et al., 2018). When selecting varieties, you should choose according to local weather, so that you can avoid extreme temperatures and arrange the key growth period in the right time period (Lv et al., 2019; Han et al., 2022). There are now models that can predict light and temperature to help farmers determine the most appropriate sowing time (Wu et al., 2023). If sowing time, planting density, fertilizer management and variety selection are combined, the effect will be better and can better cope with the yield reduction caused by climate change (Xu et al., 2021; Abbas et al., 2023). These methods can help corn to have more stable emergence, smooth development, and improve overall stress resistance.

5 Technological Integration in Sowing Equipment

5.1 Precision seeders and variable rate control

Precision seeder technology is becoming more and more advanced. They combine a variety of sensors and control systems to place seeds and control distances more accurately. The machine controls the seeding and fertilization process by reading real-time data, so that the distance error between seeds is smaller and the qualified rate can reach more than 94% (Xie et al., 2024). Variable seeding technology is to flexibly adjust the seeding amount according to the soil and crop conditions of the plot. For example, less seeding is done in places with high fertility and more seeding is done in places with poor fertility. This can not only increase yield but also reduce waste (Munnaf et al., 2024). Now many devices can also be connected to soil moisture sensors to automatically adjust the sowing depth, which can make the seedlings uniform and strong, and improve drought resistance (Tar et al., 2024).

5.2 GPS-based navigation and autonomous sowing

GPS and Beidou navigation systems are very practical when sowing. They can help the seed drill to accurately locate, whether it is manually driven or automatically driven. Now in some places, more than 80% of the seed drills are equipped with automatic navigation, which not only saves about 17% of the operation time, but also avoids missed or repeated seeding, which improves the uniformity of seedlings and yield. There are also some robot seed drills equipped with GPS, laser scanners, and automatic control systems. They can navigate in the field and automatically adjust the width. They can sow seeds to the right position without human operation, which improves efficiency and reduces errors (Chen et al., 2022; Wang et al., 2022; Ayanniran et al., 2024).

5.3 Intelligent machinery and data-driven sowing optimization

Today's intelligent seed drills are not just machines, they are also equipped with computer systems, wireless sensors and remote control functions. Through CAN bus or wireless network, the machine can collect data in real time, such as what went wrong and whether the parameters need to be adjusted, and can also be monitored from a distance (Chen et al., 2022; Xie et al., 2024). Online soil mapping and zoning technology can also tell us where to plant more and where to plant less, which can not only ensure yield but also improve resource utilization (Munnaf et al., 2024). Laser sensors plus wireless systems can also control the amount and spacing of seeds, and can immediately alarm and respond if there is a problem (Xie et al., 2021). These technologies combined not only make corn planting faster and more accurate, but also make the production process more environmentally friendly, less labor-intensive, and more adaptable.

6 Case Studies on Region-Specific Sowing Optimization

6.1 Spring maize sowing density and timing in Northeast China

In Northeast China, sowing time and variety selection have a great impact on yield. If climate change is not intervened, corn yield may decrease by 11.5% to 34.6% by 2050. However, if the sowing date and variety rotation can be adjusted according to climate conditions, the yield may increase by up to 42.7% (Zhang et al., 2023). In high-latitude and mid-latitude areas, early sowing and the use of long-growing varieties are recommended; while in low-latitude areas, medium-sowing and medium-maturing varieties are more suitable. This practice can reduce the impact of high temperatures and reduce the risk of premature aging or frost (Figure 1) (Han et al., 2022). At present, the sowing date in Northeast China is basically consistent with the optimal sowing date predicted by the model, but there is still room for further improvement in yield by switching to more heat-resistant and drought-resistant varieties.

6.2 Smart seeding implementation in high-yielding North China Plain

In the North China Plain, in order to grow corn well and improve efficiency, sowing technology must be "intelligent". This includes choosing the right sowing date, arranging irrigation, and selecting good varieties. Model simulation found that spring corn is best planted from early May to early June. If irrigation is carried out in time during the critical growth period, not only will the yield be high, but also mechanized harvesting will be convenient (Wang et al., 2023). Properly delaying the sowing time can help avoid bad weather, and choosing high-yield and high-quality varieties such as "Zhengdan 958" can further increase the yield (Zhang et al., 2020). Using intelligent sowing technology together with precision irrigation and nitrogen fertilizer management can not only save water and fertilizer, but also stabilize grain quality and yield (Shen et al., 2020).

6.3 Adaptive mechanized sowing in Southwest hilly regions

The mountainous and hilly areas in southwest China have complex terrain and changeable climate. In these places, sowing machinery and plans must be adjusted according to local conditions. The sowing period here is greatly affected by soil moisture and temperature. Early sowing is required in dry areas, while late sowing is suitable for relatively wet areas, which is conducive to increasing yields (Shen et al., 2023). If mechanized sowing is used in conjunction with local irrigation conditions and suitable corn varieties, it can effectively deal with problems such as unstable rainfall and complex terrain. Even in a future with increasingly hotter climates and more droughts, yields can be kept stable (Huang et al., 2020; Zhang et al., 2023).

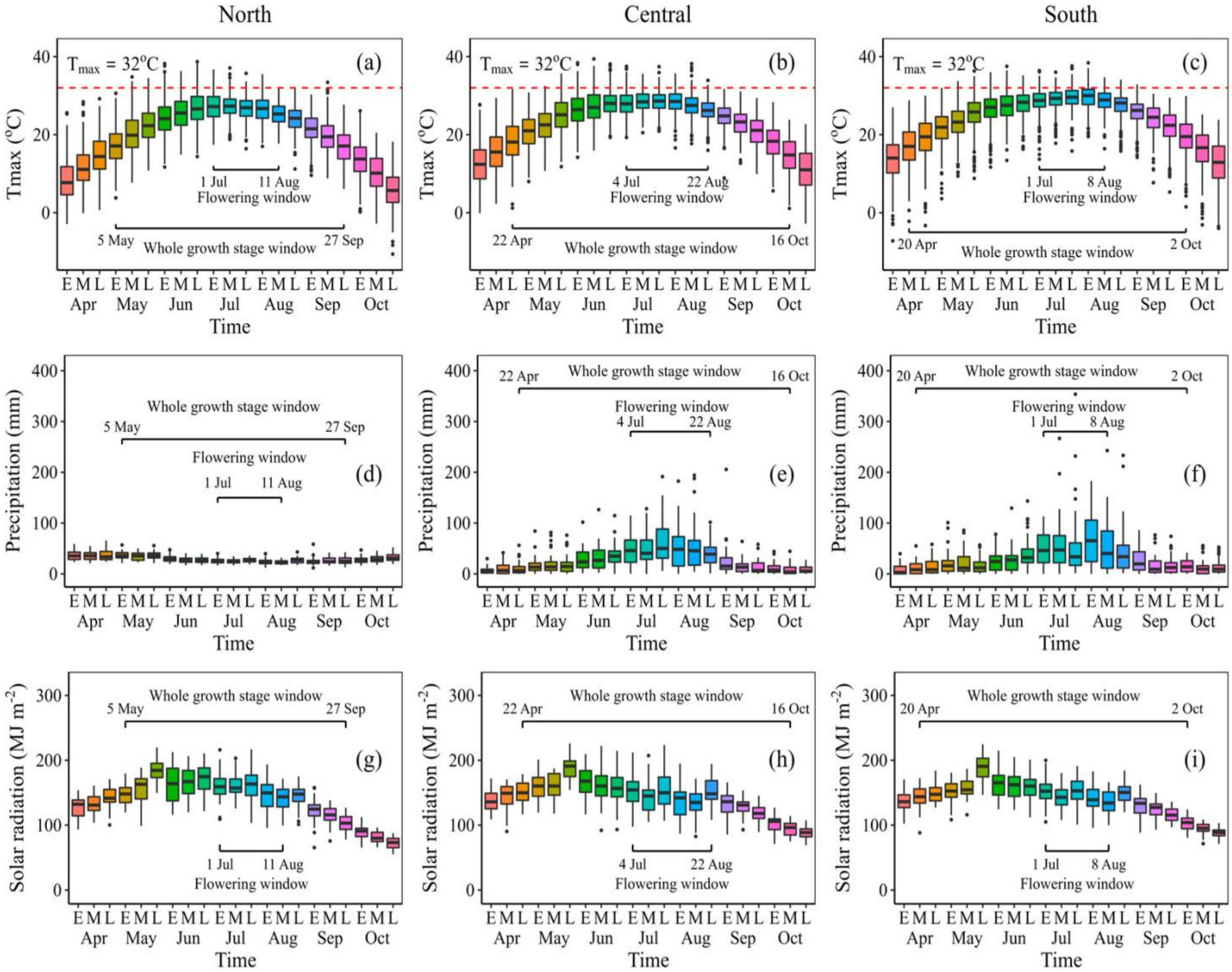

Figure 1 Distribution of maximum temperature (Tmax), precipitation and solar radiation in April–October (1980-2019) for the NEC: North, Keshan station (a, d, g); Central, Gongzhuling station (b, e, h); South, Shenyang station (c, f, i). E: the first ten days of a month; M: the middle ten days of a month; L: the last ten days of a month (Adopted from Han et al., 2022)

7 Concluding Remarks

Properly adjusting sowing time, choosing the right varieties, and using sowing methods are effective ways to increase corn yields and benefits. Many studies have found that these practices can help farmers reduce the risk of yield reductions caused by climate change. For example, in Northeast China, if the sowing period can be adjusted and the right varieties can be rotated, corn yields can be increased by up to 42.7%. The increase in yields in the entire corn-growing area may also be between 11.1% and 53.9%. If sowing optimization is combined with nitrogen fertilizer management, ridge planting, mulching and other technologies, yields can be further improved, incomes can be higher, and the impact on the environment is reduced.

Now, many new seeders are equipped with intelligent functions, such as automatic adjustment of sowing depth and monitoring of soil moisture. These devices can help corn seedlings emerge more evenly, improve drought resistance, and save water and fertilizer. By analyzing real-time data and using model predictions, farmers can flexibly adjust sowing time and input according to the situation of each plot of land, thereby achieving higher yields and more reasonable resource utilization. Considering that the rural labor force is decreasing, such technologies are becoming more and more important. They can not only improve work efficiency, but also reduce labor costs.

Looking ahead, continuing to promote intelligent seeding systems, using data for precise management, and combining local seeding methods and varieties with strong stress resistance will be an important means to cope with climate change and ensure stable and high yields of corn. By developing precision agriculture and optimizing seeding technology, we can better ensure food security, save resources, and promote the sustainable development of corn production.

Acknowledgments

We are grateful to Dr. J. Chen for his assistance with the serious reading and helpful discussions during the course of this work.

Conflict of Interest Disclosure

The authors affirm that this research was conducted without any commercial or financial relationships that could be construed as a potential conflict of interest.

References

Abbas G., Ahmad S., Ahmad A., Nasim W., Fatima Z., Hussain S., Rehman M., Khan M., Hasanuzzaman M., Fahad S., Boote K., and Hoogenboom G., 2017, Quantification the impacts of climate change and crop management on phenology of maize-based cropping system in Punjab, Pakistan, Agricultural and Forest Meteorology, 247: 42-55.
https://doi.org/10.1016/J.AGRFORMET.2017.07.012

Abbas G., Ahmed M., Fatima Z., Hussain S., Kheir A., Ercişli S., and Ahmad S., 2023, Modeling the potential impact of climate change on maize-maize cropping system in semi-arid environment and designing of adaptation options, Agricultural and Forest Meteorology, 341: 109674.
https://doi.org/10.1016/j.agrformet.2023.109674

Ali M., Ahmed M., Ibrahim M., Baroudy A., Ali E., Shokr M., Aldosari A., Majrashi A., and Kheir A., 2022, Optimizing sowing window, cultivar choice, and plant density to boost maize yield under RCP8.5 climate scenario of CMIP5, International Journal of Biometeorology, 66: 971-985.
https://doi.org/10.1007/s00484-022-02253-x

Ayanniran F., Adekunle A., Bello S., and Adisa K., 2024, Development of a robotic maize seed planter, FUOYE Journal of Engineering and Technology, 9(1): 96-102.
https://doi.org/10.4314/fuoyejet.v9i1.15

Chen J., Zhang H., Pan F., Du M., and Ji C., 2022, Control system of a motor-driven precision no-tillage maize planter based on the CANopen protocol, Agriculture, 12(7): 932.
https://doi.org/10.3390/agriculture12070932

Domokos Z., Şimon A., Chețan F., Ceclan O., Filip E., Călugăr R., Vâtcă S., and Duda M., 2024, The influence of sowing date on the primary yield components of maize, Agronomy, 14(9): 2120.
https://doi.org/10.3390/agronomy14092120

Haarhoff S., and Swanepoel P., 2022, Plant population and row spacing affects growth and yield of rainfed maize in semi-arid environments, Frontiers in Plant Science, 13: 761121.
https://doi.org/10.3389/fpls.2022.761121

Haegele J., Becker R., Henninger A., and Below F., 2014, Row arrangement, phosphorus fertility, and hybrid contributions to managing increased plant density of maize, Agronomy Journal, 106(5): 1838-1846.
https://doi.org/10.2134/AGRONJ2013.0382

Han X., Dong L., Cao Y., Lyu Y., Shao X., Wang Y., and Wang L., 2022, Adaptation to climate change effects by cultivar and sowing date selection for maize in the Northeast China Plain, Agronomy, 12(5): 984.
https://doi.org/10.3390/agronomy12050984

Huang M., Wang J., Wang B., Liu D., Yu Q., He D., Wang N., and Pan X., 2020, Optimizing sowing window and cultivar choice can boost China's maize yield under 1.5 °C and 2 °C global warming, Environmental Research Letters, 15: 024015.
https://doi.org/10.1088/1748-9326/ab66ca

Imran, Amanullah, Khan A., Mahmood T., Tawaha A., and Khanum S., 2021, Adequate fertilization, application method and sowing techniques improve maize yield and related traits, Communications in Soil Science and Plant Analysis, 52(19): 2318-2330.
https://doi.org/10.1080/00103624.2021.1925688

Jat R., Bijarniya D., Kakraliya S., Sapkota T., Kakraliya M., and Jat M., 2021, Precision nutrient rates and placement in conservation maize-wheat system: effects on crop productivity, profitability, nutrient-use efficiency, and environmental footprints, Agronomy, 11(11): 2320.
https://doi.org/10.3390/agronomy11112320

Laghari A., Buriro M., Laghari G., and Talpur K., 2024, Impact of different NPK levels and sowing methods on maize growth, yield, and quality characteristics, Pakistan Journal of Biotechnology, 21(1): 61-66.
https://doi.org/10.34016/pjbt.2024.21.01.824

Liu T., Song F., Liu S., and Zhu X., 2012, Light interception and radiation use efficiency response to narrow-wide row planting patterns in maize, Australian Journal of Crop Science, 6: 506-513.

Lv Z., Li F., and Lu G., 2019, Adjusting sowing date and cultivar shift improve maize adaption to climate change in China, Mitigation and Adaptation Strategies for Global Change, 25: 87-106.
https://doi.org/10.1007/s11027-019-09861-w

Munnaf M., Wang Y., and Mouazen A., 2024, Robot driven combined site-specific maize seeding and N fertilization: an agro-economic investigation, Computers and Electronics in Agriculture, 219: 108761.
https://doi.org/10.1016/j.compag.2024.108761

Noland R., Dowdy M., and Harris G., 2025, Maize row spacing and seeding rate informed by space-per-plant geometry, Agronomy, 15(2): 374.
https://doi.org/10.3390/agronomy15020374

Otegui M., Riglos M., and Mercau J., 2021, Genetically modified maize hybrids and delayed sowing reduced negative drought effects across a rainfall gradient in temperate Argentina, Journal of Experimental Botany, 72(14): 5180-5188.
https://doi.org/10.1093/jxb/erab139

Pelech E., Evers J., Pederson T., Drag D., Fu P., and Bernacchi C., 2022, Leaf, plant, to canopy: a mechanistic study on aboveground plasticity and plant density within a maize–soybean intercrop system for the Midwest, USA, Plant, Cell & Environment, 46(2): 405-421.
https://doi.org/10.1111/pce.14487

Rao A., Chandran M., Bal S., Pramod V., Sandeep V., Manikandan N., Raju B., Prabhakar M., Islam A., Kumar S., and Singh V., 2022, Evaluating area-specific adaptation strategies in rainfed maize under future climates in India, The Science of the Total Environment, 836: 155511.
https://doi.org/10.1016/j.scitotenv.2022.155511

Shen H., Xu F., Zhao R., Xing X., and Ma X., 2020, Optimization of sowing date, irrigation, and nitrogen management of summer maize using the DSSAT-CERES-Maize model in the Guanzhong Plain, China, Transactions of the ASABE, 63(4): 789-797.
https://doi.org/10.13031/trans.13654

Shen H., Xu Y., Wang Y., Cheng G., Li S., Jiang K., and Ma X., 2023, Optimization of sowing date for spring maize in China's Loess Plateau based on presowing temperature and soil water content, Journal of the Science of Food and Agriculture, 103(6): 3157-3167.
https://doi.org/10.1002/jsfa.12427

Srivastava R., Mequanint F., Chakraborty A., Panda R., and Halder D., 2022, Augmentation of maize yield by strategic adaptation to cope with climate change for a future period in Eastern India, Journal of Cleaner Production, 339: 130599.
https://doi.org/10.1016/j.jclepro.2022.130599

Tar I., Vad A., and Csaba I., 2024, The effect of different sowing depth on the yield and yield-forming elements of maize, Acta Agraria Debreceniensis, 1: 173-176.
https://doi.org/10.34101/actaagrar/1/12560

Tian B., Zhu J., Nie Y., Xu C., Meng Q., and Wang P., 2018, Mitigating heat and chilling stress by adjusting the sowing date of maize in the North China Plain, Journal of Agronomy and Crop Science, 205(1): 77-87.
https://doi.org/10.1111/JAC.12299

Wang J., Dong X., Qiu R., Lou B., Tian L., Chen P., Zhang X., Liu X., and Sun H., 2023, Optimization of sowing date and irrigation schedule of maize in different cropping systems by APSIM for realizing grain mechanical harvesting in the North China Plain, Agricultural Water Management, 276: 108068.
https://doi.org/10.1016/j.agwat.2022.108068

Wang W., Wu K., Zhang Y., Wang M., Zhang C., and Chen L., 2022, The development of an electric-driven control system for a high-speed precision planter based on the double closed-loop fuzzy PID algorithm, Agronomy, 12(4): 945.
https://doi.org/10.3390/agronomy12040945

Wu W., Yue W., Bi J., Zhang L., Xu D., Peng C., Chen X., and Wang S., 2024, Influence of climatic variables on maize grain yield and its components by adjusting the sowing date, Frontiers in Plant Science, 15: 1411009.
https://doi.org/10.3389/fpls.2024.1411009

Wu Y., Zhou G., Song Y., Ren S., Geng J., Zhao H., and Song X., 2023, A simulation study on optimization of sowing time of maize (*Zea mays* L.) for maximization of growth and yield in the present context of climate change under the North China Plain, Agronomy, 13(2): 385.
https://doi.org/10.3390/agronomy13020385

Xiao D., Bai H., Liu D., Tang J., Wang B., Shen Y., Cao J., and Feng P., 2022, Projecting future changes in extreme climate for maize production in the North China Plain and the role of adjusting the sowing date, Mitigation and Adaptation Strategies for Global Change, 27: 21.
https://doi.org/10.1007/s11027-022-09995-4

Xiao D., Liu D., Wang B., Feng P., and Waters C., 2020, Designing high-yielding maize ideotypes to adapt changing climate in the North China Plain, Agricultural Systems, 181: 102805.
https://doi.org/10.1016/j.agsy.2020.102805

Xie C., Yang L., He X., Cui T., Zhang D., Li H., Xiao T., and Wang H., 2024, Maize precision seeding scheme based on multi-sensor information fusion, Journal of Industrial Information Integration, 43: 100758.
https://doi.org/10.1016/j.jii.2024.100758

Xie C., Zhang D., Yang L., Cui T., He X., and Du Z., 2021, Precision seeding parameter monitoring system based on laser sensor and wireless serial port communication, Computers and Electronics in Agriculture, 190: 106429.
https://doi.org/10.1016/j.compag.2021.106429

Xu F., Wang B., He C., Liu D., Feng P., Yao N., Zhang R., Xu S., Xue J., Feng H., Yu Q., and He J., 2021, Optimizing sowing date and planting density can mitigate the impacts of future climate on maize yield: a case study in the Guanzhong Plain of China, Agronomy, 11(8): 1452.
https://doi.org/10.3390/AGRONOMY11081452

Zhang C., Gao J., Liu L., and Wu S., 2023, Simulating the effects of optimizing sowing date and variety shift on maize production at finer scale in Northeast China under future climate, Journal of the Science of Food and Agriculture, 104(6): 3637-3647. https://doi.org/10.1002/jsfa.13247

Zhang L., Zhang Z., Luo Y., Cao J., and Li Z., 2020, Optimizing genotype-environment-management interactions for maize farmers to adapt to climate change in different agro-ecological zones across China, The Science of the Total Environment, 728: 138614. https://doi.org/10.1016/j.scitotenv.2020.138614