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Better cotton farming methods in terms of irrigation, fertilization and plant density: An impression and conclusion from recent research

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ABSTRACT
A significant portion of research has focused on cotton to achieve high yield, increase water use efficiency (WUE), nitrogen use efficiency (NUE) and phosphorus use efficiency (PUE). This review is based on the results of recent research and in order to determine the appropriate field operations of cotton plants in terms of irrigation, fertilization and plant density, to achieve maximum yield with high water use efficiency (WUE), nitrogen use efficiency (NUE) and phosphorus use efficiency (PUE). The results of these researches show: 1) Under water stress conditions, high density with low or no nitrogen consumption, but in optimal irrigation conditions, low density with nitrogen consumption, are preferred farming operations, both to increase yield and increase resource use efficiency. 2) in conditions of high nitrogen supply or high densities, in order to control overgrowth and strengthen reproductive organs, consumption of phosphorus or PSB bacteria is one of the useful agronomic operations in all irrigation regimes, but in these conditions, PUE in water stress condition is higher than optimal irrigation conditions. 3) The uptake and response of plants to nitrogen and phosphorus are mostly determined by the sink and the source, respectively. 4) High plant density and limited irrigation, increase the leaf to boll ratio (sink limitation), thus reducing NUE and increasing PUE. In recent years, different and sometimes contradictory results have been obtained from cotton field researches in this regard, and in this review, an attempt has been made to provide a brief and understandable interpretation of these contradictory results.
Keywords: Cotton, Irrigation, Nitrogen, Phosphorus, Plant Density.

INTRODUCTION
This brief introduction expresses the problem and the existing ambiguity. Cotton is a major source of fiber and oil (USDA, 2016). Nitrogen and phosphorus, as well as water deficiencies are the most important factors limiting cotton production in arid regions (Chen *et al.,* 2020). in the last few years, significant researches have been conducted on cotton plant to increase yield, water use efficiency (WUE), and nutrients uptake (Luo *et al*., 2018; Yao *et al.,* 2015; Yao et al., 2016; Chen *et al.,* 2019; Mai *et al.,* 2018).

The N and P uptake and biomass accumulation are disrupted under moisture deficit stress (Chen *et al.,* 2020; Wang *et al*., 2018). A large number of studies have shown that in deficit irrigation conditions, improving pre-flowering N uptake, post-flowering P uptake as well as increasing biomass accumulation after flowering play a major role in increasing the yield of cotton yield and other row crops such as maize (Yao *et al.,* 2015; Zhang *et al.,* 2017; Chen *et al.,* 2020; Iqbal *et al.,* 2020; Ciampitti *et al.,* 2013; Ciampitti et al., 2011). This goal can be achieved by performing several agricultural operations such as proper management of nutrients and selecting of appropriate planting density based on irrigation regime (Dai *et al.,* 2017**;** Luo *et al.,* 2018**;** Shi *et al.,* 2016; Dong *et al.,* 2012). Alghouht the interaction between plant density × fertilizer application on these processes as well as of the yield under water stress conditions has received little attention (Roche and Bange, 2022).

The purpose of this literature review is to find and suggest the most suitable agricultural operations from the point view of plant density and fertilization in low and medium irrigation conditions to achieve acceptable yield and optimal water and nutrients efficiency.

REACTION OF COTTON TO NITROGEN AND PHOSPHORUS IN WATER STRESS CONDITIONS
Improper use of chemical fertilizers can waste resources and have environmental consequences. Zhang *et al.,* (2017), Wang *et al.,* (2018) and He *et al.,* (2022) reported that nitrogen increases the leaf surface area and biomass under water stress by regulating osmosis and improving relative water content (RWC). Phosphorus also plays a key role in the better growth of the roots, increasing the nutrients/water uptake and reproductive biomass under drought conditions (Chen *et al.,* 2020; Wang *et al.,* 2018; Fang *et al.,* 2022). Nitrogen fertilizer improved shoot growth in cotton under water stress (Iqbal et al., 2020) (Figure 1). Increasing phosphorus fertilizer was useful for improving drought resistance and yield of cotton, especially for cultivars with high phosphorus use efficiency (PUE), field practices can be managed by considering the amount of water available and the amount of phosphorus fertilizer in a way that increases soil water uptake and phosphorus content of cotton cultivars and achieves higher yields (Wang *et al.,* 2021). Phosphorus fertilizer increased the density of cotton roots under water stress (Mai *et al.,* 2018). Ballester *et al.,* (2021) reported that no interaction was observed between irrigation regimes and N fertilizer on lint yield. But the use of N fertilizer in stress conditions should not be more than its use in optimal irrigation. For example, a 50 percent reduction in available water (base d on EPT) reduces the amount of nitrogen needed to

achieve maximum yield by 25 percent, and the cotton plant does not respond to N at 25 percent of available water (Singh *et al.,* 2010). While the reaction of cotton to phosphorus appears to increases in water stress. Under optimal irrigation conditions, maxium yield of cotton plant was obtained with moderate phosphorus supply (20 mg kg^{-1}) and under water stress, maximum yield was obtained with high phosphorus supply (40 mg Kg^{-1}) phosphorus supply (Jun *et al.,* 2017). The synergistic effect of nitrogen × Phosphorus fertilizer, N × PSB bacteria or N × mycorrhiza fungi lead to increased WUE and improved N and P absorption and their use efficiencies, thereby preventing a significant decrease in the yield under restricted irrigation (Shen and Li, 2011; Ding *et al.,* 2014; Shintu and Jayaram, 2015). In general, the simultaneous use of nitrogen and phosphorus fertilizers will have the greatest effect in reducing drought damages (Sareban *et al.,* 2022). The use of nitrate and ammonium can increase the phosphorus uptake of the plant by increasing the mineralization of organic phosphorus or the uptake of symbiotic phosphorus in the phosphate-solubilizing bacterial system and mycorrhiza fungi (Aguilera *et al.* 2022). Application of nitrate fertilizer in soil increased phosphatase activity by decreasing pH in rhizosphere and the rate of organic phosphorus mineralization, and increased the amount of available phosphorus (Yan *et al.,* 2021). Although drought stress destroyed the photosystem reaction center (PS2), its effects can be significantly reduced by using phosphorus and nitrogen fertilizers. Under water stress, the simultaneous application of nitrogen and phosphorus prevented the reduction of photosystem efficiency (**Figure 3**.) (Sareban *et al.,* 2022).

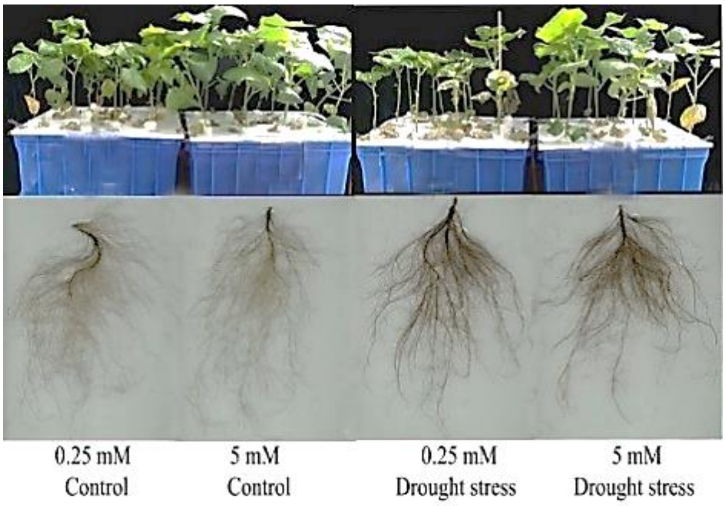

Fig. 1. Nitrogen fertilizer improved shoot growth in cotton under water stress (Iqbal *et al.*, 2020).

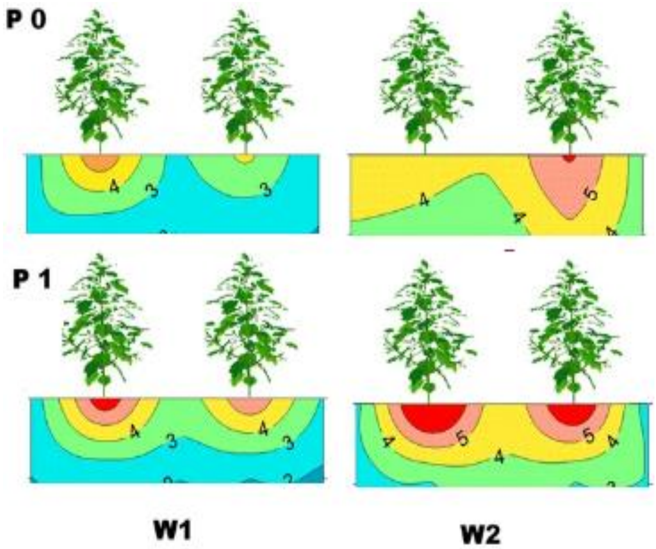

Fig. 2. Phosphorus fertilizer increased the density of cotton roots under water stress (Mai *et al.,* 2018). W1: Moderate Irrigation, W2: Water Stress, P0 and P1: without and with phosphorus consumption, respectively.

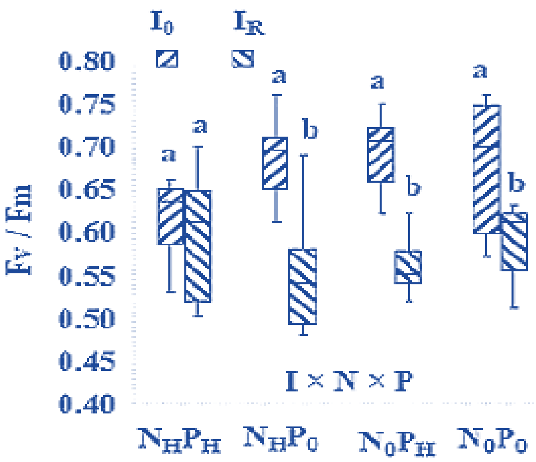

Fig. 3. Under water stress, the simultaneous application of nitrogen and phosphorus prevented the reduction of photosystem efficiency (fv / fm). **I_0** and **I_R**: moderate and restricted irrigation, respectively. **N_0** and **N_H**: without and with nitrogen consumption, respectively. **P_0** and **P_H**: without and with Phosphorus consumption, respectively. (Sareban *et al.,* 2022).

COTTON RESPONSE TO PLANT DENSITY IN WATER STRESS CONDITIONS

In recent decades, single plant yield of cotton has been almost constant, which had made it possible to increased plant density to improve yield (Zhi *et al.,* 2016). However, in moderate irrigation conditions, with increasing density (> 5 plants m^{-2}), the number of bolls per square meter increases, but due to the decrease in the bolls weight, the plant yield did not change (Dong *et al.,* 2010; Zhi *et al.,* 2016). Sometimes, in adequately irrigated plants, the increase in density does not significantly affect the number of bolls per square meter. For example, it has been reported that at high densities compared to low densities, water stress reduces the number of reproductive branches to 67% and the ratio of vegetative biomass to total biomass by 95% in 125 days after planting (Li *et al.,* 2019). Some evidence confirms that high plant density can be beneficial in water deficient conditions, for example, Chen *et al.,* (2019) found that the combination of limited irrigation and high plant density increased yield and WUE by 22% and 34%, respectively. Zhang *et al.,* (2017) also reported that under conditions of water restriction and high density, LAI in upper and middle layers of canopy increases and the allocation of photosynthetic materials to reproductive organs, yield and WUE increases. High planting density caused an increase in leaf area index (LAI) and a larger size of cotton canopy, this can reduce soil water evaporation (Li *et al.,* 2022). Therefore, increasing the density due to increasing leaf area index and light distribution and absorption in the middle and upper parts of the canopy is one of the ways to achieve high irrigation water use efficiency (WUE) in cotton production (Li et *al.,* 2022). Limited irrigation in the early stages of growth can increase root distribution to utilize moisture stored deep in the soil. At high densities, the reduction in irrigation rate after the boll formation stage, despite the reduction in stomatal opening and transpiration, has less effect on dry matter accumulation and yield, leading to relatively high water use efficiency (Castin *et al.* 2014; Lima *et al.,* 2015). Increasing the density of cotton plants under water stress, has been useful for fiber yield (Table 1) (Chen *et al.,* 2019).

Table 1. Increasing the density of cotton plants under water stress, has been useful for fiber yield. I (Irrigation), D: Plant Density, D_{12}, D_{24} and D36 are low, middle and high plant densities, respectively. I425 and I500 are restricted (425 mm) and moderate irrigation (500 mm), respectively (Chen *et al.,* 2019).

Irrigation pattern	Planting density	Seed yield 2014	Seed yield 2015
I_{500}	D_{12}	5118.6 ± 678.1 b	5641.1 ± 511.2 c
	D_{24}	5834.3 ± 366.7 a	6304.0 ± 455.1 a
	D_{36}	5185.8 ± 387.7 b	5821.0 ± 427.4 b
I_{425}	D_{12}	4785.4 ± 484.5 c	5270.0 ± 256.1 d
	D_{24}	5240.8 ± 580.4 b	5576.0 ± 433.7 c
	D_{36}	5852.4 ± 652.6 a	6455.8 ± 622.8 a
I		ns	ns
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THE ROLE OF PLANT DENSITY UNDER WATER STRESS DEPENDS ON LEAF/BOLL SYSTEM

Cotton yield, and maturity are affected by the source/sink relationship (Chen *et al.,* 2021; Mangi *et al.,* 2021). The source/sink relationship can reflect the coordination of vegetative and reproductive growth of cotton and affect the yield and quality of cotton (Brar *et al*., 2020).

Photosynthesis, as the most important source, plays an important role in supplying photosynthetic materials to the reproductive sink, which affects cotton yield and fiber quality, and carbon assimilation in the subtending leaves plays an important role in filling the sinks (Mangi *et al., 2021*). The source / sink relationship can reflect the coordination of vegetative and reproductive growth of cotton and affect the yield and quality of cotton.

In water-stress conditions that cause young flowers and bolls retention on top of the canopy, a higher density can be useful (Basal *et al.,* 2015). At high densities, mostly young bolls are located in smaller numbers at the top of canopy (zhi *et al.,* 2016), which leads to increase in allocation of leaf nitrogen to the process of photosynthesis in the upper parts of the canopy. As a result, more photosynthetic materials is located to the bolls of the lower canopy (Yao *et al.,* 2015; Zhi *et al.,* 2016).

Some studies confirm that cotton does not have optimal water and nutrient use efficiency due to Sink limitation. For example, when 25% of the leaves were removed at the flowering stage, there was no difference in the number of bolls per plant, boll weight and yield compared to control (Honghai *et al*., 2011). However, thining of the buds -reduced the export and disctribution of assimilates to the bollsand led to lower yield (Hongahi *et al.* 2011). on the other hand, the increasing plant density increases the Leaf/Boll ratio and leads to a further limitation of the sink (Gwathmey and Clement, 2010). Since the size of the sink determines the requirements, uptake and response of plants to N (Oosterhuis and Bondada and, 2001), and high plant density seems to reduce the response of cotton to N fertilizer (Pan *et al.,* 2017). However, other experiments reported that high plant density reduced the photosynthetic material required for bolls, and despite the high Leaf/Boll ratio, due to the concentrated and simultaneous boll formation and the bottom of the canopy, as well as the lower photosynthetic capacity of the lower canopy leaves, restricts the source (Gwathmey and Clement, 2010; Zhi *et al.,* 2016). Xiang *et al.,* (2010) reported that the total nitrogen, soluble sugar content and their exportation to remaining bolls increased at 40 days after post-anthesis in decreased boll treatment (high Leaf/Boll ratio), suggesting that high plant density leads to source limitation.

THE RESPONSE OF COTTON TO N DEPENDS ON PLANT DENSITY

Dai *et al.,* (2017) stated that the advantage of simultaneous use of N fertilizer and high densities is questionable (Dai *et al.,* 2017), many other studies have shown that in high plant densities the use of high nitrogen and phosphorus fertilizer, in conditions of water restriction, not only, did not increase the yield, but also led to a more severe decrease in yield due to stress (Dong *et al.,* 2010; shah *et al.,* 2017).The maximum values of leaf photosynthesis, water, and nitrogen use efficiency were obtained under low nitrogen rate with high plant density (Shah *et al.,* 2017). Increase the density and reduction in N rate led to more grain yield and higher nutrients and water use efficiency in corn and cotton (Dai *et al.,* 2017; Shi *et al.,* 2016). In low-fertility soils, increasing the density from 4.5 to 7.5 plants and increasing N consumption from 0 to 240, resulted in a 10% increase in cotton yield, but in the fertile soils did not affect the yield (Dong *et al.,* 2010). Doubling the density from 5 to 10 and tripling the fertilizer application from 250 to 750 kg ha^{-1} resulted in maximum corn yield, but NUE was very low (Chen *et al.,* 2011).

In densities above 7.5 plants per square meter reduce nitrogen accumulatio in maize after silking by up to 40% and biomass accumulation reduces the biomass accumulation by up to 8% (Yan *et al.*, 2017). The increase plant density to more than 9 plants per square meter, due to interplant competition caused a decrease in yield NUE and biomass and its transfer to the grain during grain filling (Yan *et al.,* 2017). Increased plant density and N rate reduced boll load, which had highly significant negative correlation with late-season leaf photosynthesis (Dong *et al.,* 2012). High density and high nitrogen consumption increase vegetative growth, dry matter and nitrogen accumulation due to larger canopy. While the same canopy in the reproductive stage may accelerate leaf aging, reduces biomass accumulation and N uptake after flowering (Dai *et al.,* 2017; *Shi et al.,* 2016). Higher plant densities significantly increased pre-silking N uptake, but had a relatively little impact on post-silking N uptake in corn, high plant density decreased the ability of maize for use of soil N (Yan *et al.,* 2017). Nitrogen consumption or increase in density alone or both of them prevented the reduction of rwc in water stress conditions, but in the absence of these two methods, rwc decreased (Sareban *et al.,* 2022) (Figure 4). The planting density must been determined by careful study and based on the yield potential of the cultivar, the length of growth season in the region and the maximum dose of nitrogen consumption. based on a combination of Galdi *et al.,* **(**2022) and Zhang *et al.,* (2021) reports, simultaneous use of high density (more than 6 plants m^{-2}) and low nitrogen consumption (less than 210 kg ha^{-1}) is a promising option to increase the yield and quality of cotton fibers, especially in areas with short growing seasons (less than 180 days) or varieties with low yield potential (less than 1600 kg ha^{-1}).

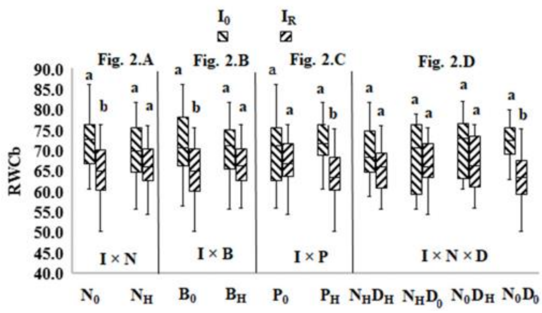

Fig. 4. Nitrogen consumption or increase in density alone or both of them prevented the reduction of RWC in water stress conditions, but in the absence of these two methods, rwc decreased(Sareban et al., 2022).**I_0 and I_R**: moderate and restricted irrigation, respectively. **N_0 and N_H**: without and with nitrogen consumption, respectively. **D_0 and D_H:** Low (5 plants m^{-2}) and high (10 plant m^{-2}) plant density, respectively. (Sareban *et al*., 2022).

THE RESPONSE OF COTTON TO P DEPENDS ON PLANT DENSITY

Phosphorus application improves reproductive organ biomass, nutrient accumulation and grain yield in cotton (Mai *et al.,* 2018). However, little is khown about the the interactions of between plant density and phosphorus fertilizer on cotton. Increasing the plant density for corn can increase uptake of phosphorus from the soil. Application of P at a density of eight plants per square meter had 15-29% higher grain yield than its application at a density of 4-6 plants per square meter (Muhammad-Asif, *et al.,* 2009), which shows that the at high densities, the use of P fertilizer is recommended. At high-densities, P uptake is recommended to prevent a decrease in the boll size and increase the number of reproductive branches, the number of bolls per square meter, and ultimately to cotton improve cotton yield (Khan *et al.,* 2019). Increasing the density from 3 to 6 plants per square meter had no effect on the accumulation of phosphorus in the dry matter, but the density of 9 plants per square meter caused a sharp increase in phosphorus in the pick bloom stage (Khan *et al.,* 2019) (**Figure 5**)

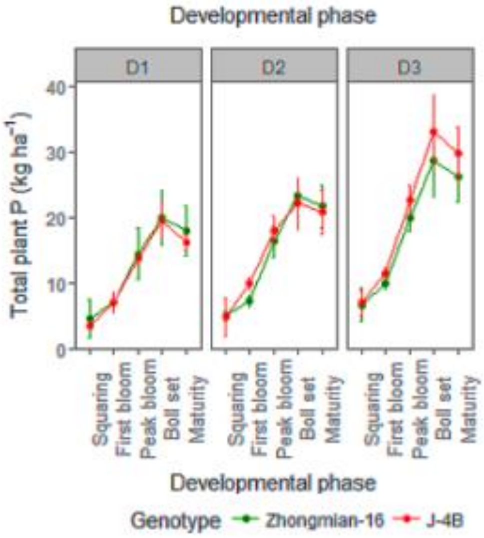

Fig. 5. Increasing the density from 3 (D1) to 6 (D2) plants per square meter had no effect on the accumulation of phosphorus in the dry matter, but the density of 9 (D3) plants per square meter caused a sharp increase in phosphorus in the pick bloom stage (Khan *et al.,* 2019).

CONCLUSION

water stress reduces fertilize bolls and increases boll shedding, thereby increasing the leaf to boll ratio. Therefore, the relationship between source and sink or leaf/boll ratio can be optimized to improve yield and increase water use efficiency by proper N and P consumption and proper planting densities. The purpose of this literature review was to explain the effect of soil water availability on the plant density and the interaction of nitrogen and phosphors fertilizers through the relationship between source and sink, to determine the best crop operations in order to achieve high yield with high water use efficiency, NUE and PUE.

According to our review, it can be concluded:

a) Under water stress, high density with low or no N consumption and vice versa, in optimal irrigation conditions, low density with N consumption, are preferable crop operations to increase yield and resource use efficiency in cotton.

b) In conditions of high N supply or/and high density, application of phosphorus fertilizer and PSB bacteria consumption is a useful crop operation in all irrigation regimes to control overgrowth and increase reproductive organs, with higher PUE in water stress than optimal irrigation conditions.

c) Uptake and the response of cotton to N and P are mostly determined by sink and source, respectively. High Plant density and restricted irrigation increase leaf/boll ratio (sink limitation), thereby decrease NUE and increase PUE.

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REFERENCES

Aguilera, P., Becerra, N., Alvear, M., Ortiz, N., Turrini, A., Azcón-Aguilar, C., Borie, F. (2022). Arbuscular mycorrhizal fungi from acidic soils favors production of tomatoes and lycopene concentration. *Journal of the Science of Food and Agriculture*, *102*(6), 2352-2358.

Ballester, C., Hornbuckle, J., Brinkhoff, J., & Quayle, W. C. (2021). Effects of three frequencies of irrigation and nitrogen rates on lint yield, nitrogen use efficiency and fiber quality of cotton under furrow irrigation. *Agricultural Water Management*, *248*, 106783.

Brar, H. S., Kumar, D., & Singh, P. (2020). Dataset of source-sink manipulation through growth retardant for enhancing productivity and profitability of cotton in north west, India. *Data in brief*, *31*, 105914.

Basal, H., Sezener, V., Canavar, O., Kızılkaya, K., & Dagdelen, N. (2014). Effects of water stress and plant density on cotton (Gossypium hirsutum L.) cultivars differing in maturity and seed size: I. Yield components and fiber quality parameters. *International Journal of Agriculture Innovations Research*, *3*(3), 755-760.

Ciampitti, I. A., & Vyn, T. J. (2011). A comprehensive study of plant density consequences on nitrogen uptake dynamics of maize plants from vegetative to reproductive stages. *Field Crops Research*, *121*(1), 2-18.

Chen, B., Wang, Q., Tang, X., Ye, Z., Stiles, S., & Feng, G. (2021). Growth and sink-source relationship of cotton (Gossypium hirsutum L.) under mulched drip irrigation in response to phosphorus fertilization and cultivar. *Journal of Plant Nutrition*, *45*(2), 259-272.

Chen, X. P., Cui, Z. L., Vitousek, P. M., Cassman, K. G., Matson, P. A., Bai, J. S., Zhang, F. S. (2011). Integrated soil–crop system management for food security. *Proceedings of the National Academy of Sciences*, *108*(16), 6399-6404.

Chen, Y., Kong, X., & Dong, H. (2018). Removal of early fruiting branches impacts leaf senescence and yield by altering the sink/source ratio of field-grown cotton. *Field Crops Research*, *216*, 10-21.

Chen, Z., Khan, A., Shi, X., Hao, X., Tan, D. K. Y., Luo, H. (2020). Water-nutrient management enhances root morpho-physiological functioning, phosphorus absorption, transportation and utilization of cotton in arid region. *Industrial Crops and Products*, *143*, 111975.

Chen, Z., Niu, Y., Zhao, R., Han, C., Han, H., & Luo, H. (2019). The combination of limited irrigation and high plant density optimizes canopy structure and improves the water use efficiency of cotton. *Agricultural Water Management*, *218*, 139-148.

Ciampitti, I. A., Murrell, S. T., Camberato, J. J., Tuinstra, M., Xia, Y., Friedemann, P., Vyn, T. J. (2013). Physiological dynamics of maize nitrogen uptake and partitioning in response to plant density and nitrogen stress factors: II. Reproductive phase. *Crop Science*, *53*(6), 2588-2602.

Dai, J., Li, W., Zhang, D., Tang, W., Li, Z., Lu, H., Dong, H. (2017). Competitive yield and economic benefits of cotton achieved through a combination of extensive pruning and a reduced nitrogen rate at high plant density. *Field Crops Research*, *209*, 65-72.

Ding, X., Zhang, L., Zhang, S., & Feng, G. (2014). Phytate utilization of maize mediated by different nitrogen forms in a plant–arbuscular mycorrhizal fungus–phosphate-solubilizing bacterium system. *Journal of Plant Interactions*, *9*(1), 514-520.

Dong, H., Kong, X., Li, W., Tang, W., & Zhang, D. (2010). Effects of plant density and nitrogen and potassium fertilization on cotton yield and uptake of major nutrients in two fields with varying fertility. *Field Crops Research*, *119*(1), 106-113.

Dong, H., Li, W., Eneji, A. E., & Zhang, D. (2012). Nitrogen rate and plant density effects on yield and late-season leaf senescence of cotton raised on a saline field. *Field Crops Research*, *126*, 137-144.

Fang, Y. U. A. N., Kai, Z. H. A. N. G., Chao, M. A., Nan, Z. H. A. N. G., Jiandong, S. H. E. N. G., & Wentai, Z. H. A. N. G. (2022). Effects of organic fertilizer addition on field phosphorus status and yield under different amounts of phosphorus fertilization in cotton field in Xinjiang, China. *Journal of Agricultural Resources and Environment*.

Galdi, L. V., dos Santos Cordeiro, C. F., e Silva, B. D. S., de La Torre, E. J. R., Echer, F. R. (2022). Interactive effects of increased plant density, cultivars and N rates in environments with different cotton yield recovery potential. *Industrial Crops and Products*, *176*, 114394.

Gwathmey, C. O., & Clement, J. D. (2010). Alteration of cotton source–sink relations with plant population density and mepiquat chloride. *Field Crops Research*, *116*(1-2), 101-107.

He, J., Hu, W., Li, Y., Zhu, H., Zou, J., Wang, Y., Zhou, Z. (2022). Prolonged drought affects the interaction of carbon and nitrogen metabolism in root and shoot of cotton. *Environmental and Experimental Botany*, *197*, 104839.

Honghai, L. U. O., Rui-Hai, Z. H. A. O., Jun-Hua, L. I., Ya-Li, Z. H. A. N. G., & Wang-Feng, Z. H. A. N. G. (2011). Effects of source and sink manipulation on distribution of assimilate and endogenous hormone contents of high yield cotton in xinjiang. *Journal of Nuclear Agricultural Sciences*, *25*(2), 331.

Iqbal, A., Dong, Q., Wang, X., Gui, H., Zhang, H., Zhang, X., Song, M. (2020). High nitrogen enhance drought tolerance in cotton through antioxidant enzymatic activities, nitrogen metabolism and osmotic adjustment. *Plants*, *9*(2), 178.

Iqbal, B., Kong, F., Ullah, I., Ali, S., Li, H., Wang, J., & Zhou, Z. (2020). Phosphorus application improves the cotton yield by enhancing reproductive organ biomass and nutrient accumulation in two cotton cultivars with different phosphorus sensitivity. *Agronomy*, *10*(2), 153.

Jun, W., Ping, L., Zhiyong, L., Zhansheng, W., Yongshen, L., Xinyuan, G. (2017). Dry matter accumulation and phosphorus efficiency response of cotton cultivars to phosphorus and drought. *Journal of Plant Nutrition*, *40*(16), 2349-2357.

Khan, A., Kong, X., Najeeb, U., Zheng, J., Tan, D. K. Y., Akhtar, K., Zhou, R. (2019). Planting density induced changes in cotton biomass yield, fiber quality, and phosphorus distribution under beta growth model. *Agronomy*, *9*(9), 500.

Li, N., Li, J., Tung, S. A., Shi, X., Hao, X., Shi, F., ... & Luo, H. (2022). Optimal irrigation amount can increase cotton lint yield by improving canopy structure and microenvironment under non-film deep drip irrigation. *Journal of Cleaner Production*, 132156.

Li, P., Dong H., Zheng, C., Sun, M., Liu, A., Wang, G., Zhao, X. (2017). Optimizing nitrogen application rate and plant density for improving cotton yield and nitrogen use efficiency in the North China Plain. *Plos one*, *12*(10), e0185550.

Li, T., Zhang, Y., Dai, J., Dong, H., & Kong, X. (2019). High plant density inhibits vegetative branching in cotton by altering hormone contents and photosynthetic production. *Field Crops Research*, *230*, 121-131.

Luo, Z., Liu, H., Li, W., Zhao, Q., Dai, J., Tian, L., & Dong, H. (2018). Effects of reduced nitrogen rate on cotton yield and nitrogen use efficiency as mediated by application mode or plant density. *Field Crops Research*, *218*, 150-157.

Mai, W., Xue, X., Feng, G., Yang, R., & Tian, C. (2018). Can optimization of phosphorus input lead to high productivity and high phosphorus use efficiency of cotton through maximization of root/mycorrhizal efficiency in phosphorus acquisition?. *Field Crops Research*, *216*, 100-108.

Mangi, N., Nazir, M. F., Wang, X., Iqbal, M. S., Sarfraz, Z., Jatoi, G. H., ... & Shuli, F. (2021). Dissecting Source-Sink Relationship of Subtending Leaf for Yield and Fiber Quality Attributes in Upland Cotton (Gossypium hirsutum L.). *Plants*, *10*(6), 1147.

Muhammad-Asif, A., Malhi, S. S., & Khattak, R. A. (2009). Effects of phosphorus fertilizer source and plant density on growth and yield of maize in Northwestern Pakistan. *Journal of plant nutrition*, *32*(12), 2080-2093.

Oosterhuis, D. M., & Bondada, B. R. (2001). Yield response of cotton to foliar nitrogen as influenced by sink strength, petiole, and soil nitrogen. *Journal of plant nutrition*, *24*(3), 413-422.

Rosolem, C. A., & Mikkelsen, D. S. (1989). Nitrogen source-sink relationship in cotton. *Journal of plant nutrition*, *12*(12), 1417-1433.

Roche, R., & Bange, M. (2022). Effects of Plant Density, Mepiquat Chloride, Early-Season Nitrogen and Water Applications on Yield and Crop Maturity of Ultra-Narrow Cotton. *Agronomy*, *12*(4), 869.

Sareban, H., Madani, A., Vazin, F. (2022). Response of cotton to irrigation, fertilization and plant density in a semi-arid region of Iran. Agriculturae Conspectus Scientificus, 87(2).

Shah, A. N., Yang, G., Tanveer, M., Iqbal, J. (2017). Leaf gas exchange, source–sink relationship, and growth response of cotton to the interactive effects of nitrogen rate and planting density. *Acta Physiologiae Plantarum*, *39*(5), 1-10.

Shen, Y. F., Li, S. Q. (2011). Effects of the spatial coupling of water and fertilizer on the chlorophyll fluorescence parameters of winter wheat leaves. *Agricultural Sciences in China*, *10*(12), 1923-1931.

Shi, D. Y., Li, Y. H., Zhan, J.g W., Peng, L. I. U., Bin, Z., Dong, S. T. (2016). Increased plant density and reduced N rate lead to more grain yield and higher resource utilization in summer maize. *Journal of Integrative Agriculture*, *15*(11), 2515-2528.

Shintu, P. V., & Jayaram, K. M. (2015). Phosphate solubilising bacteria (Bacillus polymyxa)-An effective approach to mitigate drought in tomato (Lycopersicon esculentum Mill.). *Trop. Plant Res*, *2*, 17-22.

Singh, Y., Rao, S. S., & Regar, P. L. (2010). Deficit irrigation and nitrogen effects on seed cotton yield, water productivity and yield response factor in shallow soils of semi-arid environment. *Agricultural water management*, *97*(7), 965-970.

United State Department of Agriculture (USDA), 2016. National Agricultural Statistics Service. USDA-NASS 1400 Independence Ave., SW Washington, DC 20250.

Wang, H., Wu, L., Cheng, M., Fan, J., Zhang, F., Zou, Y., Wang, X. (2018). Coupling effects of water and fertilizer on yield, water and fertilizer use efficiency of drip-fertigated cotton in northern Xinjiang, China. *Field Crops Research*, *219*, 169-179.

Wang, H., Wu, L., Wang, X., Zhang, S., Cheng, M., Feng, H., ... & Xiang, Y. (2021). Optimization of water and fertilizer management improves yield, water, nitrogen, phosphorus and potassium uptake and use efficiency of cotton under drip fertigation. *Agricultural Water Management*, *245*, 106662.

Xiang, Z., Li, Z., Shuhong, W., Jinyou, W., Yonghui, W., Yuan, C., Dehua, C. (2010). Effect of source-sink regulation on the transportation and allocation of boll-leaf photosynthetic products in cotton.

Yan, P., Pan, J., Zhang, W., Shi, J., Chen, X., & Cui, Z. (2017). A high plant density reduces the ability of maize to use soil nitrogen. *PLOS one*, *12*(2), e0172717.

Yan, X., Yang, W., Muneer, M. A., Zhang, S., Wang, M., & Wu, L. (2021). Land-use change affects stoichiometric patterns of soil organic carbon, nitrogen, and phosphorus in the red soil of Southeast China. *Journal of Soils and Sediments*, *21*(7), 2639-2649.

Yao, H., Zhang, Y., Yi, X., Hu, Y., Luo, H., Gou, L., Zhang, W. (2015). Plant density alters nitrogen partitioning among photosynthetic components, leaf photosynthetic capacity and photosynthetic nitrogen use efficiency in field-grown cotton. *Field Crops Research*, *184*, 39-49.

Yao, H., Zhang, Y., Yi, X., Zhang, X., & Zhang, W. (2016). Cotton responds to different plant population densities by adjusting specific leaf area to optimize canopy photosynthetic use efficiency of light and nitrogen. *Field Crops Research*, *188*, 10-16.

Zhang, H., Khan, A., Tan, D. K., & Luo, H. (2017). Rational water and nitrogen management improves root growth, increases yield and maintains water use efficiency of cotton under mulch drip irrigation. *Frontiers in Plant Science*, *8*, 912.

Zhang, Z., Chattha, M. S., Ahmed, S., Liu, J., Liu, A., Yang, L., ... & Yang, G. (2021). Nitrogen reduction in high plant density cotton is feasible due to quicker biomass accumulation. *Industrial Crops and Products*, *172*, 114070.

Zhi, X. Y., Han, Y. C., Li, Y. B., Wang, G. P., Du, W. L., Li, X. X., Lu, F. E. N. G. (2016). Effects of plant density on cotton yield components and quality. *Journal of Integrative Agriculture*, *15*(7), 1469-1479.

أفضل أساليب زراعة القطن من حيث الري والتسميد وكثافة النبات: انطباع وخاتمة من بحث حديث

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ركز جزء كبير من الأبحاث على القطن لتحقيق إنتاجية عالية ، وزيادة كفاءة استخدام المياه (WUE) ، وكفاءة استخدام النيتروجين (NUE) وكفاءة استخدام الفوسفور .(PUE) تستند هذه المراجعة إلى نتائج الأبحاث الحديثة ومن أجل تحديد العمليات الميدانية المناسبة لنباتات القطن من حيث الري والتسميد وكثافة النبات ، لتحقيق أقصى إنتاجية مع كفاءة عالية في استخدام المياه (WUE) ، وكفاءة استخدام النيتروجين (NUE) وكفاءة استخدام الفوسفور .(PUE) تظهر نتائج هذه الأبحاث: 1) تحت ظروف الإجهاد المائي ، تعتبر الكثافة العالية مع انخفاض أو عدم استهلاك النيتروجين ، ولكن في ظروف الري المثلى ، والكثافة المنخفضة مع استهلاك النيتروجين ، عمليات زراعية مفضلة ، لزيادة الغلة وزيادة كفاءة استخدام الموارد. 2) في ظروف الإمداد العالي بالنيتروجين أو الكثافة العالية ، من أجل التحكم في النمو الزائد وتقوية الأعضاء التناسلية ، يعتبر استهلاك الفوسفور أو بكتيريا PSB أحد العمليات الزراعية المفيدة في جميع أنظمة الري ، ولكن في هذه الظروف ، PUEفي حالة الإجهاد المائي أعلى من ظروف الري المثلى. 3) يتم تحديد امتصاص واستجابة النباتات للنيتروجين والفوسفور في الغالب بواسطة الحوض والمصدر ، على التوالي. 4) كثافة النبات العالية والري المحدود ، زيادة نسبة الورقة إلى اللوز (الحد من الحوض) ، وبالتالي تقليل NUE وزيادة .PUE في السنوات الأخيرة ، تم الحصول على نتائج مختلفة وأحيانًا متناقضة من الأبحاث الميدانية للقطن في هذا الصدد ، وفي هذه المراجعة ، جرت محاولة لتقديم تفسير موجز ومفهوم لهذه النتائج المتناقضة.

الكلمات المفتاحية: القطن ، الري ، النيتروجين ، الفوسفور ، كثافة النبات.