



## Original article

## Agronomical traits associated with yield and yield components of winter wheat as affected by nitrogen managements



Muhammad Saleem Kubar<sup>a</sup>, Meichen Feng<sup>a</sup>, Samy Sayed<sup>b</sup>, Akhtar Hussain Shar<sup>c</sup>, Nadir Ali Rind<sup>c</sup>, Hidayat Ullah<sup>c</sup>, Shahmir Ali Kalhoro<sup>d</sup>, Yongkai Xie<sup>a</sup>, Chenbo Yang<sup>a</sup>, Wude Yang<sup>a,\*</sup>, Fahad Ali Kalhoro<sup>e</sup>, Kristina Gasparovic<sup>f</sup>, Maria Barboricova<sup>f</sup>, Marian Brestic<sup>f</sup>, Ahmad El Askary<sup>g</sup>, Mohamed El-Sharnouby<sup>h</sup>

<sup>a</sup> College of Agriculture, Shanxi Agricultural University, Taigu 030801, PR China

<sup>b</sup> Department of Science and Technology, University College-Ranyah, Taif University, B.O. Box 11099, Taif 21944, Saudi Arabia

<sup>c</sup> Department of Molecular Biology & Genetics, Faculty of Science & Technology, Shaheed Benazir Bhutto University, Shaheed Benazirabad, Sindh, Pakistan

<sup>d</sup> Faculty of Agriculture, Lasbela University of Agriculture, Water and Marine Sciences, Uthal 90150, Baluchistan, Pakistan

<sup>e</sup> Department of Plant Breeding and Genetics, Faculty Crop Production, Sindh Agriculture University, Tandojam, Pakistan

<sup>f</sup> Department of Plant Physiology, Slovak University of Agriculture, A.Hlinku 2, 94976, Slovakia

<sup>g</sup> Department of Clinical Laboratory Sciences, College of Applied Medical Sciences, Taif University, P.O. Box 11099, Taif 21944, Saudi Arabia

<sup>h</sup> Department of Biotechnology, College of Science, Taif University, P.O. Box 11099, Taif 21944, Saudi Arabia

## ARTICLE INFO

## Article history:

Received 2 June 2021

Revised 4 July 2021

Accepted 5 July 2021

Available online 10 July 2021

## Keywords:

Winter wheat

Nitrogen application amount

Base dressing ratio

Yield

## ABSTRACT

Nitrogen fertilizer is one of the key elements to increase the yield and significance of winter wheat. The experiment was established in the split zone design and was repeated three times. The nitrogen application level is set to 4 treatments, 75, 150, 225 and 300 kg ha<sup>-1</sup> are arranged in the main plot, and different nitrogen application ratios are arranged in the sub-plots, respectively 5:5 (50%+50%) and 6: 4 (60% + 40%). Nitrogen fertilizer was applied before sowing, jointing stage, flowering stage and filling stage. The experimental plot is 12 m<sup>2</sup> (3 m × 4 m). The results showed that under the conditions of 225 kg/hm<sup>2</sup> nitrogen application and 60%+40% nitrogen application rate, the yield of Jintai 182 was the highest compared with other treatment groups. With the increase of nitrogen application rate, the number of ears, grains per ear, thousand-grain weight and grain yield all increase first and then decrease. Each factor reached the highest 225 N kg / hm<sup>2</sup>, 417.17, 30.74, 40.96 g and 6182.11 kg / hm<sup>2</sup>. Compared with 75 kg/hm<sup>2</sup> topdressing fertilizer, 225 kg/hm<sup>2</sup> is a more suitable nitrogen fertilizer application rate for winter wheat. Within a reasonable range of nitrogen fertilizer application, there is a significant positive correlation between nitrogen content and winter wheat yield. By studying the amount of nitrogen fertilizer and a reasonable ratio of base fertilizer to topdressing, the utilization rate of nitrogen fertilizer can be maximized and excessive application of nitrogen fertilizer can be avoided.

© 2021 The Authors. Published by Elsevier B.V. on behalf of King Saud University. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

## 1. Introduction

China's winter wheat has a large planting area and a large output, its area accounts for 13.3% of the world, and its total output accounts for 19% of the world (Stewart et al., 1994; Wang et al., 2005; Guixia et al., 2005) At the same time, China is also the coun-

try with the highest chemical fertilizer consumption in the world, and the amount of chemical fertilizer application accounts for 30.7% of the world (JuXT, et al., 2009; Jiangrong et al., 2010). Due to the relatively low level of fertilization in China and the relatively low utilization rate of chemical fertilizers, it has caused a lot of economic losses and also caused a lot of waste of resources and energy. Excessive application of chemical fertilizers on farmland will lead to a decrease in the fertilizer utilization rate of crops, and it will also cause serious soil and groundwater pollution. With the increase in the use of chemical fertilizers in China and the increasingly prominent problems with the use of chemical fertilizers, the pollution caused by excessive use of chemical fertilizers to the soil and water sources has attracted more and more attention. Therefore, the application of fertilizers must be aimed at increasing

\* Corresponding author.

E-mail address: [sxauywd@126.com](mailto:sxauywd@126.com) (W. Yang).

Peer review under responsibility of King Saud University.



crop yield, improving crop nutrient utilization efficiency, and reducing the impact on soil and environment. Fertilizers are plant foods. Organic fertilizers have been used in agriculture in China for thousands of years. In ancient times, people used this method to maintain soil fertility. However, it is difficult to greatly increase wheat production by relying solely on the material flow of agriculture (Dad, 2019). The application of chemical fertilizers provides a new source of nutrients for crops and can make the soil produce more fertility. Chemical fertilizers cannot be used in excess, and must be applied reasonably according to the needs of crop growth and development. When the amount of fertilization is within a certain range, the crop yield will increase with the increase of the amount of nitrogen application (JuXT, et al., 2009). However, when the application of chemical fertilizers exceeds a certain amount, the application of chemical fertilizers will lead to a decline in crop yields, resulting in reduced utilization efficiency of chemical fertilizers, waste of fertilizer resources, and pollution of the soil environment. Long-term application of large amounts of chemical fertilizers will exceed the crop's absorption capacity and soil retention capacity, not only fail to achieve yield increase effects, but also cause a large amount of chemical fertilizers to remain in the soil (Bo et al., 2019; Khan et al., 2018; Liu et al., 2019; Chen et al., 2018; Man et al., 2015). Due to the excessive use of chemical fertilizers, especially nitrogen fertilizers in the production of winter wheat, it will result in the waste of nitrogen fertilizer resources, which will lead to the greatly reduced utilization rate of chemical fertilizers, and will also cause serious pollution to the soil environment.

Nitrogen is an indispensable element in the growth process of winter wheat. It is an integral part of all amino acids and proteins, as well as an important part of chlorophyll, hormones, nucleic acids and enzymes (Gongqing et al., 2017; Li et al., 2018; Svetla et al., 2016). Reasonable application of nitrogen fertilizer can promote the growth and development of winter wheat roots, stems, leaves and other vegetative organs, and also plays a very important role in the protein content and structure of seeds. At the same time, the nitrogen nutrition status of winter wheat is also an important indicator reflecting the nutrition status of winter wheat. In wheat production, the supply of nitrogen fertilizer in the soil and the base chasing ratio when applying nitrogen fertilizer can directly affect the yield and quality of winter wheat. The role of nitrogen fertilizer is to promote the growth of wheat roots, stems, leaves and tillers, increase the green area, and promote photosynthesis and nutrient accumulation (Zhanling et al., 2015; Xu et al., 2018; Kubar, 2021). In all stages of winter wheat reproductive growth, the reasonable application of nitrogen fertilizer can increase the number of winter wheat spikes and flowers and increase the seed setting rate. Because nitrogen fertilizer is essential, when nitrogen is insufficient, the plant grows poorly, the stem is short, the leaves are narrow, the leaves are slightly hard, the number of roots is small, the maturity is early, and the yield is low. Nitrogen is an essential nutrient during the development of winter wheat. Nitrogen plays a very important role in many aspects of winter wheat reproductive growth. The application of nitrogen fertilizer is also an important factor that determines wheat yield and quality (Minjuan et al., 2019; Gongqing et al., 2017; Khalofah, 2021). Reasonable application of nitrogen fertilizer can promote the yield and quality of winter wheat, so as to achieve high-quality and efficient production goals. Appropriate amount of nitrogen can promote the growth and development of winter wheat roots, stems and leaves, increase the green area of plants, increase photosynthesis and nutrient accumulation, promote the differentiation and development of tillers, and also benefit the growth and development of reproductive organs.

Winter wheat growth and development needs different fertilizer requirements in different periods. Winter wheat turning green,

jointing to booting stage is the most vigorous period of winter wheat reproductive growth. Previous studies have pointed out that this period is a strong period for winter wheat to absorb fertilizer. Analysis of the yield components shows that top dressing at the jointing stage can significantly increase the number of spikes and grains of winter wheat (Xianghua et al., 2008). The application amount of nitrogen fertilizer and the ratio of base application are a very important factor affecting the grain yield of winter wheat. The effect of topdressing nitrogen fertilizer at different growth stages has different effects on winter wheat grain yield. Reasonable nitrogen fertilizer management is conducive to increasing wheat grain yield and improving wheat quality (Jiangrong et al., 2010). In the later stage of winter wheat growth, the vegetative growth of winter wheat basically stagnate after heading, this stage is centered on the formation of grain weight. Removal of nitrogen during the top dressing period and increasing the proportion of top dressing nitrogen fertilizer can significantly increase winter wheat yield (Suzhen et al., 2005). The selection of excellent varieties and reasonable application of nitrogen fertilizer are the prerequisites for high yield of wheat, and the effect on wheat grain yield reaches a very significant difference (Fang et al., 2010). The results of this study show that the application of nitrogen fertilizer in a reasonable range will significantly increase winter wheat yield and its yield components.

According to the previous article, we know that the middle and late stages of winter wheat growth are the key period of wheat growth and the period when winter wheat has the greatest demand for fertilizer. Therefore, the main periods of this experimental study are the jointing and flowering periods of winter wheat and the filling period. As mentioned above, when the application rate of nitrogen fertilizer is within a certain reasonable range, the yield of winter wheat will increase as the application rate of nitrogen fertilizer increases. When the application amount of nitrogen fertilizer exceeds a certain value, the effect of increasing the application amount of nitrogen fertilizer is not obvious, but it will lead to a decrease in the utilization efficiency of nitrogen fertilizer, and a large amount of nitrogen fertilizer resources will be lost, resulting in ecological pollution. In this experiment, the winter wheat "Jintai 182" in different periods of different nitrogen fertilizer application rates and yields under different nitrogen fertilizer topdressing conditions and yield component factors in different periods can be used to find the most effective winter wheat under current conditions. The best nitrogen fertilizer application rate and application ratio, so as to maximize the utilization of nitrogen fertilizer and avoid excessive application of nitrogen fertilizer.

## 2. Materials and methods

### 2.1. Experimental locations

The field trial was conducted at the Taigu Experimental Agricultural Station (N 37°25', E 112°33') of Shanxi Agricultural University, Shanxi Province, China from 2018 to 2019. The study area has a temperate continental monsoon climate, with an annual average temperature of 13 °C or 12 °C, an average annual precipitation of 442 mm and 600 mm, a potential evapotranspiration of 1840.2 mm and 1872.2 mm, and sunshine duration of 2672 h and 2697 h, respectively, at the Taigu base. The survey area is a mountainous arid area, with the characteristics of semi-arid weather in the Northeast Loess Plateau. From the seasonal month to the fallow season (July to August), rainfall reaches 60% to 70%. The established soil contains 7.7 pH, 51.12 mg kg<sup>-1</sup> available nitrogen, 19.34 mg kg<sup>-1</sup> available phosphorus and 7.7 mg kg<sup>-1</sup> soil surface organic matter.

## 2.2. Experimental design

Field trials were conducted at Taigu Experimental Agricultural Station of Shanxi Agricultural University, Shanxi Province, China. The experiment adopted a split zone design and was repeated three times. The nitrogen application level is set to four treatments of 75, 150, 225 and 300 kg ha<sup>-1</sup>. They are arranged in the main plot, and different nitrogen application ratios are arranged in the sub-plots, 5:5 (50%, 50%) and 6:4 respectively. (60%, 40%). Nitrogen fertilizer was applied before sowing, jointing stage, flowering stage and filling stage. The experimental plot is 12 m<sup>2</sup> (3 m × 4 m). All experiments in this work are to study the effect of nitrogen fertilizer management on the grain yield composition of winter wheat in calcareous cinnamon soil.

## 2.3. Yield and growth components

The yield components are grain number spike<sup>-1</sup>, spike number product<sup>-1</sup>, and 1000 grain weight. The grain yield is measured by harvesting winter wheat crops in the central bank of each row. At maturity, one square meter of winter wheat plants from all repeated treatments were randomly designated for harvest. These plants are harvested by cutting at the soil level with a sickle. Disconnect the ear tips from the straw, keep them in a separate paper bag, dry them at 78 °C for 24 h, and then manually thresh each sample. The observation results are recorded on the following parameters: when the crop is mature, the number of ears in each plot of each ear of randomly selected plants has been calculated, and the average value has been removed. Yield and growth components calculate the grain ear 1 of each randomly selected plant when the crop is mature, and calculate the average value. Randomly collect 1000 grains from each plot and weigh them to calculate the seed index in grams. The grain obtained from each plot is balanced. On the basis of the grain yield of each plot, the grain yield per hectare is calculated in kilograms.

## 2.4. Statistical analysis

The data provided in this study is the average of three replicates. ANOVA was used to analyze all data for randomized block design. The significance of each source is determined by F-test. Duncan's Multiple Range Test (DMRT) Significant Difference was used as a post hoc mean separation test (P < 0.05) using SAS 9.3 (SAS Institute, Cary, North Carolina, USA). The treatment was compared based on the significant difference and the least significant difference (LSD P < 0.05). Before evaluating ANOVA, a Shapiro-Wilk test is performed to evaluate the normality of variance. Use Microsoft Excel 2013 for data calculations. All statistical analyses were performed using SPSS version 19.0 and SAS version 9.3.

## 3. Results

### 3.1. Effect of nitrogen management on winter wheat yield

Fig. 1 reflects the final yield of winter wheat. From the point of view of the fertilization amount and nitrogen application level in different periods, different nitrogen fertilizer application rates and different base application ratios have significant effects on winter wheat yield. Jintai 182 "The top dressing started at the jointing stage with a base-to-top ratio of 6: 4 and the highest yield of seed reached 632 kg / hm<sup>2</sup> at 225 kg / hm<sup>2</sup>. The fertilizer started at the filling stage with a base-to-top ratio of 5: 5 and the amount of nitrogen was under the condition of 75 kg / hm<sup>2</sup>, the grain yield was the lowest, which was 5777.93 kg / hm<sup>2</sup>. Compared with the lowest yield of 5777.93 kg / hm<sup>2</sup>, the winter wheat yield increased

by 9.12% at the nitrogen application rate of 225 kg / hm<sup>2</sup> and the base-to-dressing ratio of 6: 4. We can see from It can be seen from Table 1 that under the conditions of 225 kg nitrogen fertilizer per hectare and a nitrogen fertilizer to topdressing ratio of 6:4 in the jointing and filling period, the winter wheat yield is the highest, and the nitrogen fertilizer treatment has a significant effect on winter wheat yield. The analysis of variance showed that the amount and ratio of nitrogen application had a significant effect on grain yield (kg ha<sup>-1</sup>), and the interaction between the amount and ratio of nitrogen application was also significant (Fig. 1).

### 3.2. Effect of nitrogen application on grain number spike<sup>-1</sup> of winter wheat

Fig. 2 reflects the effects of nitrogen application and basal top-dressing ratio on the grain number spike<sup>-1</sup> of winter wheat in different periods. From the perspective of the amount of nitrogen application and basal topdressing ratio at different times, the application amount of nitrogen has a significant effect on the grain number spike<sup>-1</sup> of winter wheat. "Jintai 182" began to apply fertilizer at the jointing stage, the base-to-dressing ratio was 6: 4, and the maximum grain number spike<sup>-1</sup> of winter wheat reached 42.33 g when the nitrogen application rate was 225 kg /hm<sup>2</sup>. Nitrogen application started at the filling stage. Under the condition of nitrogen fertilizer application rate of 75 kg/hm<sup>2</sup>, the basal supplementation ratio of winter wheat was 5:5, and the number of grains per spike<sup>-1</sup> of winter wheat was the lowest at 36.07 g. Compared with the lowest yield of 36.07 g, when the nitrogen application rate was 225 kg/hm<sup>2</sup> and the bottom to dressing ratio was 6:4, the number of grains per spike<sup>-1</sup> of winter wheat increased by 8.52%. It is known that under the condition of applying 225 kg of nitrogen per hectare at the jointing and filling stages and the ratio of nitrogen to topdressing is 6:4, the number of grains per hectare of winter wheat can reach the highest spike<sup>-1</sup>. The results of variance analysis showed that the effect of nitrogen level and nitrogen ratio on the grains number spike<sup>-1</sup> of winter wheat was at the 0.01 or 0.05 probability levels, while the nitrogen treatments and ratios had significant effect on the grains spike<sup>-1</sup> of winter wheat. While the interaction of treatment and ratio had a significant presented (Fig. 2).

It can be seen from Fig. 3 that under the condition that the application rate of nitrogen fertilizer is 225 kg/hm<sup>2</sup> and the base-to-dressing ratio is 6: 4, the maximum number of winter wheat spikes at the jointing stage is 423.67. Under the conditions of nitrogen application rate of 75 and basal chasing ratio of 5: 5, the minimum number of winter wheat spikes was 284.67. Compared with the minimum number of spikes of 284.67, the number of winter wheat spikes in winter wheat with nitrogen application rate of 225 kg /hm<sup>2</sup> and basal chasing ratio of 6: 4 increased by 67.19%. Under the conditions of nitrogen application rate of 300 kg /hm<sup>2</sup> and basal chasing ratio of 6: 4, the yield of panicle number in the same period was lower than that of 225 kg/hm<sup>2</sup> basal chasing ratio of 6: 4, and the number of panicles increased first. And the trend is decreasing again. It shows that nitrogen management has a significant effect on the number of winter wheat spikes. The differences between treatments were at the 0.05 probability levels. Analysis of variance showed that nitrogen level had significant regulating effect on spike plant<sup>-1</sup>, while the effect of nitrogen ratio on non-significant, and the interaction effect between nitrogen level and nitrogen ratio had no significant effect on spike plant-1 presented (Fig. 3).

Fig. 4 reflects the effect of nitrogen application and basal top-dressing ratio on the 1000 grain weight of winter wheat spikes at different stages. Winter wheat began to topdress at the jointing stage, the basal topdressing ratio was 6: 4, and the ear weight was 225 kg/hm<sup>2</sup>. The maximum is 33.65 g. Fertilization started at the

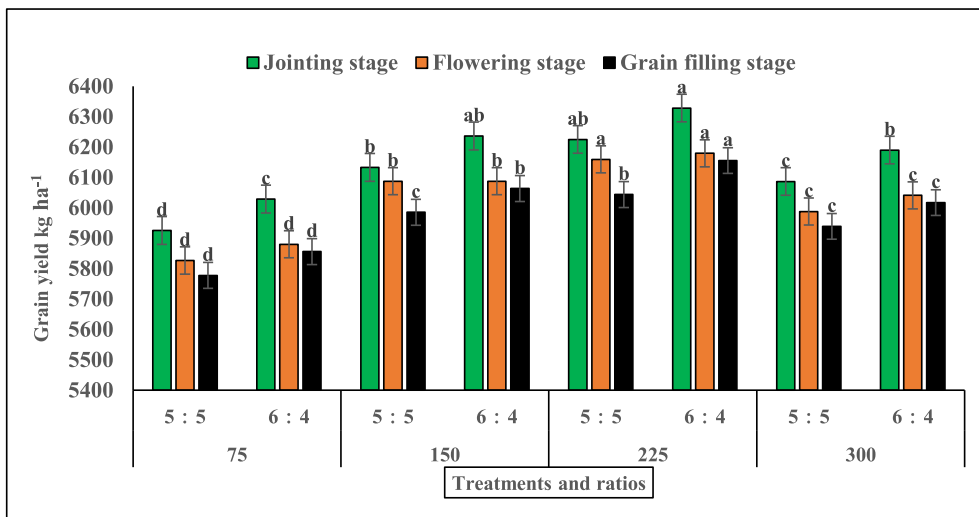


Fig. 1. Effect of nitrogen application in different periods on final yield of winter wheat 5 + 5 and 6 + 4' represents 50% + 50% and 60% +40%. JS: Jointing stage; FS: Flowering stage; GFS: Grain filling stage. Means values in a separate columns followed by the similar letters are not significantly different at p < 0.05.

Table 1 Significance of F-value from analysis of variance of various parameters of winter wheat as affected by nitrogen management.

Parameter	N-rates (N)	Ratios (R)	N × R
Yield (kg ha <sup>-1</sup> )	1656.07***	15.99 ***	14.43***
Spike plant <sup>-1</sup>	76.01 ***	0.72 NS	0.60NS
Grains Spike <sup>-1</sup>	544.35***	10.90***	5.62***
1000 seed weight	267.86***	31.77 ***	9.33 ***

Note: \*, \*\* and \*\*\* represent significance levels at alpha 0.05, 0.01, and 0.001 obtained through honestly significant difference (HSD) test. 'NS' represents non-significance.

filling stage, the base-to-dressing ratio was 5: 5, and the lowest 1000-grain weight was 21.27 g under the condition of 75 kg/hm<sup>2</sup> nitrogen application. Compared with the minimum yield of 21.27 g, the 1000-grain weight of winter wheat increased by 63.23% at a nitrogen application rate of 225 kg/hm<sup>2</sup> and a base-to-dressing ratio of 6: 4. From the figure, we can know that in the jointing period, the application of 225 kg of nitrogen fertilizer per hectare, and the ratio of nitrogen fertilizer to base ratio of 6: 4, the ear weight of winter wheat reached the highest, proving that

nitrogen management has a role in ear weight of winter wheat Significant impact. Analysis of variance showed that nitrogen level affect the 1000 seed weight (g) at the 0.01 or 0.05 probability levels, N treatments, ratio and interaction of treatments and ratio had significant effect with the F value to be 267.86\*\*\*, 31.77\*\*\* and 9.33\*\*\* (Table 1), respectively.

#### 4. Discussion

Within a certain range, crop yield increases with increasing nitrogen application, but after a certain range, the yield increase is not significant or even reduced (Qi et al., 2004; Chen et al., 2016; Rutting et al., 2018; Kartseva et al., 2021). The conclusions we have drawn in this study are basically consistent with the laws summarized by the predecessors. Through the research, it is found that under the condition of the nitrogen fertilizer base chasing ratio of 6: 4, the yield component increases more than the nitrogen fertilizer base chase ratio of 5: 5. With the increase of nitrogen application, the number of spikes, number of spikes per kernel, 1000-grain weight, and grain yield showed a trend of increasing

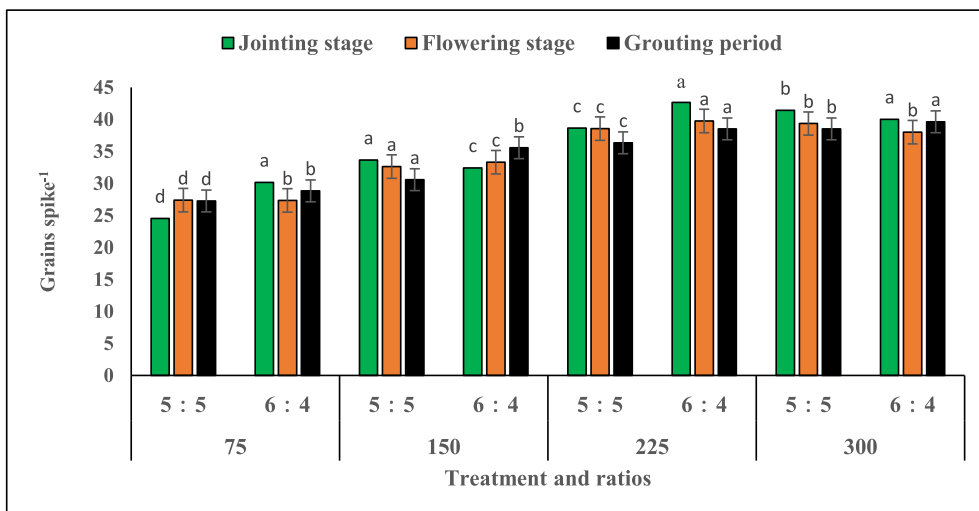


Fig. 2. Effect of nitrogen treatment on grains number per spike of winter wheat in different growth stages. 5 + 5 and 6 + 4' represents 50% + 50% and 60% +40%. JS: Jointing stage; FS: Flowering stage; GFS: Grain filling stage. Means values in a separate columns followed by the similar letters are not significantly different at p < 0.05.

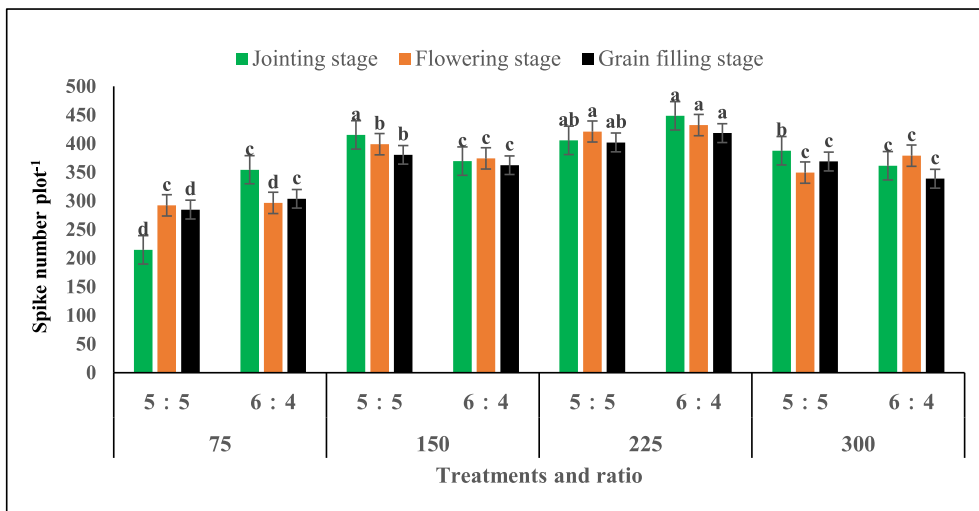


Fig. 3. Effect of nitrogen treatment on spike number of winter wheat in different periods 5 + 5 and 6 + 4' represents 50% + 50% and 60% +40%. JS: Jointing stage; FS: Flowering stage; GFS: Grain filling stage. Means values in a separate columns followed by the similar letters are not significantly different at p < 0.05.

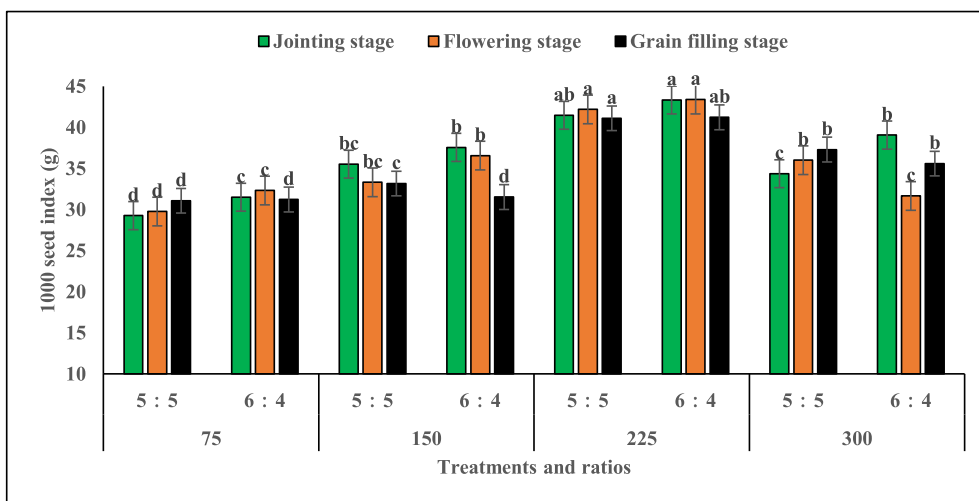


Fig. 4. Effects of different nitrogen treatments and ratios on grains number spike<sup>-1</sup> of winter wheat. 5 + 5 and 6 + 4' represents 50% + 50% and 60% +40%. JS: Jointing stage; FS: Flowering stage; GFS: Grain filling stage. Means values in a separate columns followed by the similar letters are not significantly different at p < 0.05.

first and then decreasing. All the factors reached the highest when the nitrogen application rate was 225 kg / hm<sup>2</sup>, respectively 417.17, 30.74, 40.96 g and 6182.11 kg / hm<sup>2</sup> increased 50.97%, 56.03%, 18.61% and 14.35% respectively without top dressing, indicating that 225 kg / hm<sup>2</sup> is a more suitable nitrogen application rate for winter wheat. Compared with top dressing at flowering stage and filling stage, early top dressing at jointing stage can effectively increase winter wheat yield. Previous studies have pointed out that due to differences in climatic conditions and wheat varieties in different regions, there are also differences in the amount of nitrogen fertilizer applied (Mozumdar, 2012; Martin, 2014; Cheng et al., 2014; Tilmana et al., 2011; Carranca, 2012; Godfray and Garnett, 2014; Sarwar et al. 2021; Kocheva et al. 2020). The maximum wheat output in Hefei, Anhui is nitrogen fertilizer at 247–292 kg/hm<sup>2</sup> (Liang, 2016; Zhou et al., 2018).

In this study, the climatic conditions and soil environment of the Taigu Experimental Base were obtained, and the yield and constituent factors of "Jintai 182" nitrogen application rate in the soil environment of the Taigu area at 225 kg/hm<sup>2</sup> base ratio of 6: 4 It reaches the maximum value, which is lower than the data in the southern region, but with Fengjiao et al. (2015), using four wheat

varieties for different nitrogen application rates, the optimal nitrogen input threshold for winter wheat yield and quality in North China is 180–270. Compared with kg / hm<sup>2</sup>, this experiment is basically consistent with previous studies. Other studies have pointed out that an appropriate increase in nitrogen supply in the later period (such as topdressing from booting stage to flowering stage) plays an important role in improving wheat quality (Xue et al., 2016; Yuan et al., 2014; Gholizadeh, 2017; Jialing and Wu, 2018; Guo et al., 2018; Kalaji et al. 2017; Zivcak et al. 2014). Therefore, in different periods of winter wheat growth, the combination of appropriate nitrogen fertilizer base ratio and nitrogen fertilizer application rate can achieve the efficient use of fertilizers, produce environmentally friendly, high-quality and high-quality winter wheat.

### 5. Conclusion

In conclusion, Findings of present study indicated that nitrogen nutrition significantly enhanced the growth, yield components of winter wheat. the nitrogen dose of 225 kg ha<sup>-1</sup> and the proportion

of 60%:40%:0%: 0% (quantity applied at sowing, at jointing, flowering and grain filling stage) effectively promoted the spike number plant<sup>-1</sup>, grain number spike<sup>-1</sup>, 1000 grains weight and grain yield components of winter wheat. Based on the necessity of agronomical characteristics, 225 kg N ha<sup>-1</sup> was satisfactory to provide sufficient biomass and agronomical characteristics to achieve high yield. Therefore, this study significantly reported the effects of different nitrogen rates and ratios on agronomical traits on winter wheat in Shanxi China. In addition this combination of growing stages, nitrogen doses and ratio could meritoriously increase the grain yield of winter wheat. Besides this, it is not clear in what way the impacts of nitrogen rates and ratios might be progressive, or the step to which the integrative effects of nitrogen levels and ratios would mark the satisfactory response for agronomical characteristics. Furthermore, less information is available about the integrative approach of nitrogen rates and ratios which could increase yield potentials.

### Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

### Acknowledgments

This work was funded by Taif University Researches Supporting Project number (TURSP-2020/82), Taif University, Taif, Saudi Arabia. This work was supported by the project EPPN2020-OPVal-VA - ITMS313011T813 and VEGA 1/0683/20. This research was supported by National Natural Science Foundation of China (31871571). Key Technologies R & D Program of Shanxi Province (201903D211002).

### References

- Guixia, Cui, Runying, Zhen, et al., 2005. Status and development trend of wheat production at home and abroad. *Food Res. Develop.* 26 (02), 13–17.
- Cheng, W.L., Yu, S., Bo, C., et al., 2014. Effects of nitrogen fertilizers on the growth and nitrate content of lettuce. *Int. J. Env. Res. Pub. Health.* 11, 4427–4440.
- Carranca, C., 2012. Nitrogen use efficiency by annual and perennial crops. In *farming for food and water security*. *Spr. Sci. Busi. Media.* 8, 57–82.
- Chen, Z., Wang, H., Liu, X., et al., 2016. The effect of N fertilizer placement on the fate of urea-15n and yield of winter wheat in southeast china. *PLoS One.* 11, e0153701.
- Chen, W., Zhang, J., Deng, X., 2018. The spike weight contribution of the photosynthetic area above the upper internode in a winter wheat. *The Crop. Jour.* 7, 89–100.
- Godfray HCJ, Garnett T. Food security and sustainable intensification. *Philosophical Transactions of the Royal Society. Biol. Sci.*, 2014, 369: 20120273–20120273.
- Zhanling, Guo, Changlin, Kou, Xiangning, Zhang, et al., 2015. High-yield and environment-friendly nitrogen application rate of wheat in the fluvo-aquic soil area. *Henan Agricultural Sciences* 26 (11), 17–19.
- Gholizadeh, A., 2017. Leaf chlorophyll and nitrogen dynamics and their relationship to lowland rice yield for site specific paddy management. *Info. Proc. Agri.* 4, 259–268.
- Guo, B.B., Zhu, Y.J., Feng, W., et al., 2018. Remotely estimating aerial n uptake in winter wheat using red-edge area index from multi-angular hyperspectral data. *Front. Plant. Sci.* 9, 675.
- JuXT, Xing GX, Chen XP, et al. Reducing environmental risk by improving N management in intensive Chinese agricultural systems. *Proceedings of the National Academy of Sciences of the United States of America*, 2009, 106(09): 3041–3046.
- Jialing, Y., Wu, J., 2018. The sustainability of agricultural development in china: the agriculture environment nexus. *Sust. bility.* 10, 1–9.
- Khalofah, A.Khan, M.I., Arif, M., Hussain, A., Ullah, R., Irfan, M., Mahpara, S., Shah, R. U., Ansari, M.J., Kintl, A. and Brtnicky, M., 2021. Deep placement of nitrogen fertilizer improves yield, nitrogen use efficiency and economic returns of transplanted fine rice. *Plos one* 16 (2), e0247529. <https://doi.org/10.1371/journal.pone.0247529>.
- Khan, T.U., Jan, M.T., Khan, A., et al., 2018. Integrated management of fertilizer nitrogen and poultry manure enhance wheat production. *Pak. J. Agr. Res.* 31, 207–215.
- Kartseva, T.; Dobrikova, A.; Kocheva, K.; Alexandrov, V.; Georgiev, G.; Brestič, M.; Misheva, S. Optimal Nitrogen Supply Ameliorates the Performance of Wheat Seedlings under Osmotic Stress in Genotype-Specific Manner. *Plants* 2021, 10, 493. <https://doi.org/10.3390/plants10030493>
- Kocheva, K., Kartseva, T., Nenova, V., Georgiev, G., Brestič, M., 2020. Misheva M: Nitrogen Assimilation and Photosynthetic Capacity of Wheat Genotypes under Optimal and Deficient Nitrogen Supply. *Physiol. Mol. Biol. Plants.* <https://doi.org/10.1007/s12298-020-00901-3>.
- Kalaji H.M., Dabrowski P., Center M.D., Samborska I.A., Lukasik I. A., Brestic M., Zivcak M.: A Comparison Between Different Chlorophyll Content Meters Under Nutrients Deficiency Conditions. *Journal of Plant Nutrition*, 2017, 1024 – 1034, <http://dx.doi.org/10.1080/01904167.2016.1263323>
- Liu, L., Ji, H., An, J., et al., 2019. Response of biomass accumulation in wheat to low-temperature stress at jointing and booting stages. *Envi. Exp. Bot.* 157, 46–57.
- Kubar, M.S.Shar, A.H., Kubar, K.A., Rind, N.A., Ullah, H., Kalhor, S.A., Wang, C., Feng, M., Gujar, A., Sun, H. and De Yang, W., 2021. Optimizing nitrogen supply promotes biomass, physiological characteristics and yield components of soybean (*Glycine max* L. Merr.). *Saudi Journal of Biological Sciences.* <https://doi.org/10.1016/j.sjbs.2021.06.073>.
- Li, W., Xue, C., Pan, X., et al., 2018. Application of controlled-release urea enhances grain yield and nitrogen use efficiency in irrigated rice in the yangtze river basin China. *Front. Plant. Sci.* 9, 13–25.
- Minjuan, Lu., Shuai, Chen, Siying, Xin, et al., 2019. Effects of nitrogen application rate on winter wheat yield, quality and soil nitrogen balance. *J. Hebei Agri. Univ.* 4 (02), 16–21.
- Suzhen, Li, Ailian, Zhou, Lin, Wang, et al., 2005. Effects of different sowing dates and sowing rates on grain yield components of different types of super wheat. *Shandong Agricultural Sciences* 5, 12–15.
- Qi, Lin, Libai, Hou, Wei, Han, et al., 2004. Effects of nitrogen application rate on wheat grain yield and quality under different fertility soils. *J. Plant Nutrition Fertilizer* 10 (6), 561–567.
- Wang, Shengrui, Yan, Changzhou, Jin, Xiangcan, et al., 2005. Misunderstandings about chemical fertilizers as pollutants. *Chinese Journal of Soil Science* 36 (05), 799–802.
- Xianghua, Ma., Qiufeng, Zhou, Baolin, Wang, et al., 2008. Effects of fertilization factors on grain yield and quality of strong gluten wheat. *Chinese Agri. Sci. Bull.* 24 (9), 214–216.
- Mozumdar, L., 2012. Agricultural productivity and food security in the developing world *Front Plant Science. Bang. J. Agr. Econ.* 1, 53–69.
- Martin, W., 2014. A calculation tool for analyzing nitrogen use efficiency in annual and perennial crops. *Agro.* 4, 470–477.
- Man, J., Shi, Y., Yu, Z., et al., 2015. Dry Matter production, photosynthesis of flag leaves and water use in winter wheat are affected by supplemental irrigation in the huang-huai-hai plain of China. *PLoS One.* 10, e0137274.
- Rutting, T., Aronsson, H., Delin, S., 2018. Efficient use of nitrogen in agriculture. *Nutr. Cycl. Agroecosyst.* 110, 1–5.
- Svetla, K., Nevenka, G., Marina, M., 2016. Uptake and utilization efficiency of nitrogen and phosphorus in barley genotypes. *J. Cent. Euro. Agr.* 17, 346–355.
- Sarwar, N., Rehman, A., Farooq, O., Wasaya, A., Hussain, M., El-Shehawi, A.M., Ahmad, S., Brestic, M., Mahmoud, S.F., Zivcak, M., Farooq, S., 2021. Integrated nitrogen management improves productivity and economic returns of wheat-maize cropping system. *Journal of King Saud University - Science.* <https://doi.org/10.1016/j.jksus.2021.101475>.
- Stewart W M, Xie Ling, et al. Contribution of fertilizer to crop yield. 1994(3): 31-33.
- Jiangrong, Shi, Yongkang, Ren, Fang, Wang, 2010. Research progress on regulation of super-high-yield wheat by nitrogen nutrition. *Shanxi Agri. Sci.* 38 (3), 80–82.
- Tilmana, D., Christian, B., Jason, H., et al., 2011. Global food demand and the sustainable intensification of agriculture. *Proc. Nat. Aca. Sci.* 108, 20260–20264.
- Gongqing, Wang, Zhisong, Zheng, Meng, Li, et al., 2017. The effect of nitrogen on the growth and development, yield and quality formation of wheat. *Henan Agri.* 16 (03), 15–18.
- Dad, K.Wahid, A., Khan, A.A., Anwar, A., Ali, M., Sarwar, N., Ali, S., Ahmad, A., Ahmad, M., Khan, P.A. and Ansari, M.J., 2019. Nutritional status of different biosolids and their impact on various growth parameters of wheat (*Triticum aestivum* L.). *Saudi journal of biological sciences* 26 (7), 1423–1428. <https://doi.org/10.1016/j.sjbs.2018.09.001>.
- Fang, Wang, Yulan, Zhao, Lihong, Kong, et al., 2010. The influence of nitrogen management on wheat yield and yield components. *Shanxi Agri. Sci.* 38 (4), 30–41.
- Liang, Wu., 2016. The effect of nitrogen application rate on nitrogen loss and nitrogen fertilizer input threshold under rice-wheat rotation. *J. Anhui Agri. Univ.* 24 (3), 53–66.
- Xu, H.C., Dai, X.L., Chu, J.P., et al., 2018. Integrated management strategy for improving the grain yield and nitrogen-use efficiency of winter wheat. *J. Integ. Agr.* 17, 315–327.
- Fengjiao, Xu., Guangcai, Zhao, Qizhuo, Tian, et al., 2015. Effects of nitrogen application rate on yield and processing quality of different quality types of wheat. *J. Plant Nutrit. Fertilizer* 18 (2), 300–306.
- Xue C, Schulte aufm Erley G, Rucker S, et al. Late nitrogen application increased protein concentration but not baking quality of wheat *Journal of Plant Nutrition and Soil Science*, 2016, 179(4): 591-601.
- Yuan, W., Dejian, W., Peihua, S., et al., 2014. Estimating rice chlorophyll content and leaf nitrogen concentration with a digital still color camera under natural light. *Plant. Meth.* 10 (1), 1–36.
- Zivcak, M., Olsovska, K., Slamka, P., Galambosova, J., Rataj, V., Shao, H.B., Kalaji, H.M., Brestic, M., 2014. Measurements of chlorophyll fluorescence in different leaf

- position may detect nitrogen deficiency in wheat. *Zemdirbyste – Agri.* 101 (4), 437–444.
- Bo, Zhou, Ning, Lai, Shuhuang, Chen, Xia, Sun, et al., 2019. Effects of nitrogen application rate on winter wheat yield and nitrogen utilization in drip irrigation. *Jiangsu Agri. Sci.* 47 (04), 14–17.
- Zhou, B., Serret, M.D., Pie, J.B., et al., 2018. Relative contribution of nitrogen absorption, remobilization, and partitioning to the ear during grain filling in Chinese winter wheat. *Front. Plant. Sci.* 9, 1351.