Adoption of Efficient Varieties, And Nitrogen Management For Improving Agronomic Attributes, And Yield of Winter Wheat

Hafeez Noor

Shanxi Agricultural University

Sun Min (✉ smsunmin2021@gmail.com)

Shanxi Agricultural University

Wen Lin

Shanxi Agricultural University

Zhiqiang Gao

Shanxi Agricultural University

Research Article

Keywords: Agronomic characters, Nitrogen fertilizer, Soil water storage, Variety, Yield

Posted Date: November 16th, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-963205/v1>

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Abstract

This study greenhouse experiment aimed to evaluate the biochemical impact of nitrogen (N) fertilization on different wheat cultivars. The experiment included two varieties (YH-618 and YH-20410) and three nitrogen levels, (N0, N210, and N280 Kg ha⁻¹). Our results indicated that wheat variety YH-20410 had the higher nitrogen uptake and efficiency, grain protein content, and yield at higher planting densities and will benefit farmers by forming stronger overall crops. For variety YH-20410, the soil water storage at the wintering stage was significantly highest at N280 kg ha⁻¹. In conclusion, variety YH-20410, wheat higher dry matter accumulation of each organ at maturity stage, and the dry matter accumulation of leaf, stem + leaf sheath. Compared to N0 and N180 Kg ha⁻¹, N210 kg ha⁻¹ significantly increased the N harvest index by 5.0% to 19.4% and N use efficiency by 2.9% to 9.1%, but there was no significant difference in N uptake efficiency. In conclusion, variety YH-20410 was beneficial to improve the harvest index and N productivity of wheat. Variety YH-20410, has also the greater number of spike number, grains per spike and 1000-grain weight, leading to high grain yield. Among nitrogen treatments, N280 Kg ha⁻¹ significantly increased the grain number per spike, 1000-grain weight and yield. Significantly increased grain gluten content, grain protein content and protein yield under of YH-20410 variety. In conclusion, reduced N fertilizer 280 kg ha⁻¹ and variety YH-20410 was beneficial to the improved the leaf area index, plant height, soil water storage, dry matter accumulation, and grain yield.

1 Introduction

Wheat (*Triticum aestivum* L.) is one of the most important staple foods in the world, which provides app. 20 % of the daily dietary protein for the humankind¹. It can be used to produce various flour-derived products such as biscuits, noodles and bread. It has been reported that the consumption of biscuits produced by soft wheat increased rapidly in China. According to the Chinese Baked Goods Sugar Products Industry Association, from 2004 to 2019, the biscuit production had increased from 1.05 to 12.5 million tons with an annual growth rate of 18.0 %. The middle and lower reaches of Yangtze River is the optimum ecological region for high-quality soft wheat production, with an annual planting area of ca. 400,000 ha².

Wheat are the most important food crops in Asia, providing food grains for more than 20% of the population worldwide³. In the North China Plain showed that, compared with conventional farmer practice (280 kg N ha⁻¹), sensor-based N management strategy (67 kg N ha⁻¹) decreased residual soil mineral-N content after harvest on average by 44 % (across 2 years). Furthermore, N was considerably greater (by 368 %) for the sensor-based fertilizer recommendation than for common farmer practice. Also, this strategy produced comparable grain yields. Similarly⁴ also showed that winter wheat N improved when mid-season fertilization was based on optically sensed in-season estimates of grain yield. Nitrogen rate, in fact, increased by more than 15 % compared with the Variety and N rate of 280 kg N ha⁻¹. As N increases, generally the ability of site-specific fertilization to maintain profitability with lower average N applications is expected to be improved⁵. Indicated that the model-based fertilizer prescription led to N

rate increased in about 53 % of the grids and enabled the design of N prescriptions adapted to plants demand. In different studies, lower N doses were applied on winter wheat based on crop reflection methods, producing the best efficiency in terms of grain production (as highest ratio: yield/applied N) and grain yields equivalent to the current standard method⁶.

The green leaf area, and duration have significant effects on the grain yield, and shaded leaves become senescent earlier compared to unshaded leaves⁷. Accelerated leaf senescence leads to a lower grain yield in wheat because of nutritional and hormonal signals⁸. Thus, reducing accelerated leaf senescence in dense plant populations is important for increasing the production of wheat. Nitrogen is important for enhancing the photosynthetic efficiency and leaf area⁹. Thus, it is very important to develop agronomic practices to balance grain quality and yield in wheat production.

Previous studies showed that both GPC and grain yield (GY) can be increased by N fertilizer simultaneously under low to medium N rate (0–210 kg N ha⁻¹), but GPC was continuously increased with no further increase in GY under high N rate (210–280 kg N ha⁻¹)¹⁰. In China, the N application rate has been generally much higher than the recommended dose of 280 kg N ha⁻¹ in soft wheat production for higher GY¹¹, which may deteriorate the biscuit-making performance with obviously increasing GPC. Reducing N rate can significantly decrease GPC and wet gluten content (WGC) of soft wheat, which help to form softer dough and produce crisper biscuits^{12, 13}. N agronomic efficiency (NAE) is also enhanced by reducing N input¹⁴. However, reducing N rate also increased the risk of GY loss mainly owing to reductions in both number of spikes and grains¹⁵. Thus, it is very important to develop agronomic practices to balance grain quality and yield in soft wheat production. Nitrogen uptake and productivity of cereal crops could be enhanced by increasing plant density under reduced N supply, which has been confirmed in wheat¹⁶

N accumulation in each growth stage of wheat was significantly increased when N application rate was 280 kg ha⁻¹, and nitrogen accumulation in leaves before flowering, stem sheath and cob, and contribution to grain, N agronomic use efficiency (AUE), and N use efficiency (NUE) were also significantly increased. The results showed that the N harvest index and NUE increased significantly when N was reduced by 12.5%, reaching 5.0%-19.4% and 2.9%-9.1%, respectively¹⁷. Fertilizers constitute an integral part for improved crop production technology. Nitrogen (N) is an essential mineral nutrient for plant growth, expands soil fertility and crop productivity proper amount of fertilizer application is considered a key for high crop production¹⁸.

The objective of this study was to reveal the combined effects of reduced N rate N0, N210, and 280 kg N ha⁻¹, and increased variety on: (1) protein content and yield; (2) *GY, NUE, and NAE* (3) Nitrogen application rate of N280 kg ha⁻¹ was more beneficial. The results would provide a novel view for achieving the balance between 280 kg ha⁻¹ was beneficial to increase the content of gluten in grains, obtain higher protein content and protein yield in grains, and increase the content of dry gluten in grains.

Variety YH-20410 will benefit farmers by forming stronger overall crops, promoting the coordinated improvement of yield.

2 Measurements, And Experimental Design And Treatments

All methods were performed in accordance with the relevant guidelines. The experiment was conducted in the wheat experimental base of Shanxi agricultural university in Taigu, Shanxi Province, China (E112°34 'E, N37°25' N) from 2020 to 2021, which belonging to the temperate continental climate zone, with an average annual temperature of 10.4°C. The pond was planted in a pool 2 m deep, separated by concrete walls with a thickness of 20 cm, and an insulation layer of 10 cm added to the outer walls. The soil type in the pool was classified as silty clay loam (Chinese soil taxonomy). Table 1

Table 1
Soil nutrient properties from experimental location in Shanxi Taigu.

Soil nutrients	2019-2020	2020-2021
Organic matter (g kg ⁻¹)	12.64	12.53
Available phosphorous (mg kg ⁻¹)	14.28	14.15
Available potassium (mg kg ⁻¹)	219.6	225.56

The experiment had a split-plot design with three replications. All methods were performed in accordance with the relevant guidelines. The greenhouse experiment comprised of three nitrogen treatments. Three nitrogen treatments were 0, 210 and 280 kg ha⁻¹ (N0, N210, and N280 kg ha⁻¹ respectively), winter wheat (*Triticum aestivum* L.), two cultivar ‘Yunhan 20410’ ‘Yunhan 618’ were obtained from the Taigu Agriculture Bureau, Taigu, China. The area of each plot was 2_m × 4_m = 8_m². Experimental site in Fig. 1.

Before sowing, Pure P₂O₅ and K₂O were applied at the rate of 150 and 75 kg ha⁻¹ respectively, the nitrogen fertilizer was applied to the base fertilizer. The seeds were sown on November 8, 2020, planted in manual with row spacing of 20cm and sowing quantity of 225 k_m ha⁻¹. Irrigation was applied using a drip irrigation system, with application of 50 mm each time as measured with a water meter. All plants were harvested on June 2, 2021. The field was kept free from insects, pests, and diseases using pesticides as needed. During whole growing season, weed was well controlled by hand.

2.1 Agronomic characters of plants

Three rows of wheat plants in the sample area of 0.667_m² were selected to investigate the number of tillers in the population at the stages of wintering, jointing, booting, flowering and maturity, respectively, and 20 representative plants with uniform growth were selected to measure the plant height. The wheat plants whose plant height was measured were carefully divided into two groups, the roots were cut off,

the whole wheat plant was separated into organs, put into a kraft paper bag, written and processed, and put into the oven. The drying was done at 105°C for 30 min, and then dried at 75°C until the weight was constant. The wheat plants were taken out and weighed and the dry matter weight was recorded.

Ten representative plants were selected from the field every 10 days after flowering, and the length, width and number of leaves per plant were recorded, and the leaf area index (LAI) was calculated. After flowering, 10 ears with uniform growth were picked every 5 days, the grains were peeled and counted, and then dried for weighing, grain weight was recorded, and grain filling rate was calculated. and leaf area index (LAI) was calculated from following formula:¹⁹
$$LAI = \frac{\text{length} \times \text{width} \times \text{number of green leaves}}{\text{land area}}$$

2.2 Soil moisture

Soil gravimetric moisture content (GSW, %) was recorded and expressed in soil water storage (SWS, mm). Gravimetric water content was measured at 20 cm increments to a depth of 200 cm in the 45th, 108th day after previous harvesting. At the developmental stages of sowing, overwintering, jointing, heading, anthesis and maturity, the soil gravimetric moisture was also determined in each treatment. For each soil sample, the gravimetric water content was calculated as the ratio of the mass of water present to the dry (weight of fresh soil sample weight of dry soil sample) to the dry weight of the soil sample. Dry weight of soil sample was obtained after placing the fresh sample in an oven at 105°C for 72 h. For each plot, gravimetric water content at a given layer was determined by averaging the values from three random sampling points placed in the central between two plants in the row. Before the setup of plots, the soil bulk density was measured at 20 cm increments to a depth of 300 cm for the whole soil profile (0–200 cm depth). Soil water storage for a given layer was calculated as follows ²⁰:

$$SWS \text{ (mm)} = GSW \text{ (\%)} \times \rho_b \text{ (gcm}^{-3}\text{)} \times SD \text{ (mm)} \text{ (1)}$$

Where ρ_b is soil bulk density of given soil layer, and SD refers to soil depth.

2.3 Yield and yield component

At maturity, 20 plants from each plot were randomly sampled from the inner rows for the determination of yield components such as ear number, seed number per ear and weight of thousand seed. Plot grain yield was determined by harvesting all plants in the area of 20m², shelled using machine and the grain was air-dried for the determination of grain yield.

2.4 Wet gluten content processing quality

The bromophenol blue water solution and isopropanol lactic acid mixture, and the settling values were determined by shock. The landing value was measured using the Landing Numerical Measurer (FN-IV). The Micro dough LAB, a micro powder instrument was produced by a [Swedish company Botone (SCB)] and it was measured the fluidity of bread. The wet gluten content and gluten index were measured using the Gluten Index Meter (MJZ-II) Mian Jin zhi-2 gluten index analyzer china) quality analyzer. For Quality

analysis dough mixed from 200g flour was divided into small dough weighted based on 0.25g flour calculated as by using the following formula²¹:

$$\text{Wet gluten [\%]} = \frac{100 \% \text{ flour} + 2 \text{ ml water} + 10 \% \text{ salt}}{100} \times 0.25 \text{ g of flour}$$

The dry gluten was obtained by drying the wet gluten in an oven (*TD5G, Hunan Xiang Li Scientific instruments com., Lt China*) to constant weight at 100°C for 24h using the air oven drying method. The dried gluten was left cool for 1 h before taking its weight as the dry gluten content. The percentage of dry gluten obtund was calculated using following formula.

$$\text{Drygluten[\%]} = \frac{\text{Mass of dry gluten (g)}}{0.25 \text{ g flour}} \times 100$$

2.5 Nitrogen calculation

Values for nitrogen were calculated following ²² using the following formulae:

Plant nitrogen accumulation = plant biomass × Nitrogen content

Pre-anthesis accumulated nitrogen translocation (PANT) = nitrogen accumulation in vegetative organs at the anthesis stage – nitrogen accumulation in vegetative organs at the maturation stage

Contribution to N in kernels (%) of PANT

= PANT = Nitrogen accumulation in kernels × 100%

Nitrogen accumulation after anthesis (NAAA) = nitrogen accumulation in the plant at the maturation stage – nitrogen accumulation in the plant at the anthesis stage Contribution to N in kernels (%) of NAAA

= NAAA = nitrogen accumulation in kernels × 100%

N uptake efficiency

= Nitrogen accumulation in plant / applied amount of nitrogen

N use efficiency

= Grain yield / nitrogen accumulation in the plant

N productive efficiency

= Grain yield / applied amount of nitrogen

2.6 Statistical analysis

The different data were subjected to analysis of variance (*ANOVA*) as split-plot design using *DPS* and *SAS 9.0*. *Graphics* were constructed using *Microsoft Excel 2010*. Mean values were calculated and

significance of the difference between treatments was tested by LSD (least significant difference) method at the significance level of $P=0.05$.

3 Results

3.1 Effects of different nitrogen amount variety, on plant height at each growth stage Leaf area index (LAI) after anthesis stages.

Effects of different variety, and compared to variety YH-618, YH-20410, increased plant height in each growth stages of wintering, booting, flowering and maturity (Fig. 2). Compared with 0 kg ha^{-1} and 210 kg ha^{-1} (25% N reduction), 280 kg ha^{-1} 12% N reduction significantly increased the plant height at the growth stages of pregnancy, flowering and maturity, and had no significant difference with 280 kg ha^{-1} N application. Variety YH-20410 was beneficial to ontogeny of plants and increased plant height, and there was significant difference in plant height at booting, flowering and maturity stage between N application and N application was reduced by 12.5%.

Effects of different variety, and N rate Compared to variety YH-618, YH-20410, significantly increased leaf area index (LAI) 0-30 days after flowering (Fig. 3). Compared to 0 kg ha^{-1} and 210 kg ha^{-1} (25% N reduction), 280 kg ha^{-1} (12% N reduction) significantly increased leaf area index (LAI) 0-30 days after flowering, and no significant difference with nitrogen application. In conclusion, variety YH-20410 nitrogen 280 kg ha^{-1} was beneficial to the improvement of leaf area index after flowering, and the leaf area index at 0-30 days after flowering had no significant difference with the nitrogen application when the nitrogen was reduced by 12.5%.

3.2 Effects of different nitrogen amount variety, on soil water storage of 0-200 cm at each growth stage and dry matter weight of each organ at maturity stage.

Soil water storage of 0-200 cm at different growth stages with different variety combined to different nitrogen application rates. Under variety YH-20410, the soil water storage at the wintering stage was significantly highest at N280, and lowest at N0 variety YH-618, the soil water storage at the jointing stage, flowering stage and maturity stage was significantly lowest at N280. The soil water at the jointing stage mainly consumed 20-80 cm soil layer, and the soil water at the flowering, and maturity stage mainly consumed 100-200 cm soil layer (Fig. 4). In variety YH-20410, N280 and N210 were the highest and lowest values for soil water storage at wintering and jointing stages, and N210 were also the lowest values at flowering and mature stages. The soil water storage at jointing stage was mainly stored below the soil layer of 100 cm, and the soil water in the soil layer of 40-80 cm was mainly consumed at jointing and flowering stages. In the flowering stage, 100-200 cm depth mainly consumed.

As shown in Table 2, the total dry matter accumulation of winter wheat in each treatment showed an increasing trend during growth period. Different planting. At jointing stage, dry matter was mainly distributed to stems and leaves. The proportion of the middle part was higher than that of the stem, then

the proportion of the leaf gradually decreased, and the proportion of the stem increased, and reached in the flag carrying stage. The proportion of stem and leaf decreased, and the proportion of panicle increased significantly after grain-filling, reaching 61.6%. All planting methods had significant effects on stem, leaf, spike and total dry matter weight of winter wheat ($P < 0.01$). In reproductive period YH-618, and YH-20410 were 5770.0 and 4491.2 kg ha⁻¹ (stem), respectively. 2526.9, 1736.5 kg ha⁻¹ (leaf); 6128.4, 4926.5 kg ha⁻¹ (spike); 12382.6, 9512.1 kg ha⁻¹ (total dry matter). The results showed that YH-618 > YH-20410. Compared to YH-20410, the dry weight of organs under YH-618 cultivation increased by 28.5% (stem), 45.5% (leaf), 24.4% (ear), 30.2% (total dry matter). The results showed that YH-618 cultivation mode could not only significantly improve dry matter. The total amount of material accumulation, but also can reasonably adjust the allocation proportion of each organ. Nitrogen application rate also significantly affected stem, leaf, spike and total dry matter weight of winter wheat ($P < 0.01$). The reproductive period .The mean dry weight of organs treated with N0, N210 and N280 kg ha⁻¹ was 4713.7, 4810.2 and 5868.1 kg ha⁻¹ (stem), respectively. 1807.9, 1988.8, 2598.4 kg ha⁻¹ (leaf); 5001.5, 5309.8, 6271.2 kg ha⁻¹ (spike); 9855.9, 10338.8, 12647.3 kg ha⁻¹ (total dry matter). N210 increased 2.4% compared with N0 (stem) Weight), 10.0% (leaf dry weight), 6.2% (ear dry weight), 4.9% (total dry matter). N280 increased by 22.0% compared with N210 kg ha⁻¹ (stem). Dry weight), 30.7% (leaf dry weight), 18.1% (ear dry weight), 22.3% (total dry matter). That was, the dry matter of each organ. It increased with the increase of nitrogen application rate, and the increase rate increased.

Table 2
Effects of planting patterns and nitrogen rates on dry matter accumulation and distribution of winter wheat

Treatments		N0		N210		N280	
		YH-618	YH-20410	YH-618	YH-20410	YH-618	YH-20410
Jointing stage	Stem	1662.7bc	1062.8d	1716.2b	1142.4d	2136.7a	1513.7c
	Leaf	2159.5c	1544.9d	2433.9b	1692.6d	3181.3a	2414.0b
	Total	3822.2c	2607.7e	4150.0b	2835.0d	5318.0a	3927.7bc
Flag stage	Stem	4596.4cd	3901.5de	5223.1bc	3250.8e	6155.5a	5452.8ab
	Leaf	2289.0c	1594.9d	2512.7bc	1834.3d	2986.0a	2660.4b
	Total	6885.4d	5496.4e	7735.7c	5085.1f	9141.5a	8113.2b
Heading stage	Stem	6435.1b	4773.3c	5932.7b	4272.5c	7274.2a	5964.5b
	Leaf	2335.9b	1480.7c	2561.8ab	1457.2c	2809.5a	2496.4ab
	Ear	2224.9c	1744.9d	2305.2c	1769.8d	2839.0a	2502.9b
	Total	10995.8b	7998.9c	10799.7b	7499.5c	12922.7a	10963.8b
Flowering stage	Stem	6039.8b	4400.3d	6658.7b	5158.6c	7344.7a	6632.8b
	Leaf	2135.5b	1325.7c	2344.3b	1450.7c	2764.8	2234.8b
	Ear	2296.7c	1812.6d	2568.4b	1988.4c	2909.4a	2789.2ab
	Total	10472b	7538.6c	11571.3b	8597.7c	13018.9a	11656.8b
Filling stage	Stem	7477.2a	5363.6b	8106.0a	5753.9b	7589.7a	7735.9a
	Leaf	2232.7b	1261.2c	2543.0b	1419.4c	3435.3a	2185.0b
	Ear	5720.2b	3687.6d	6306.1a	4839.0c	6199.4ab	6570.9a
	Total	15430.0b	10312.4d	16955.2a	12012.3c	17224.4a	16491.8ab
Maturity stage	Stem	6125.1ab	4726.4cd	6310.9ab	4196.3d	7076.0a	5540.2d
	Leaf	2058.0ab	1276.6c	2370.1a	1245.0c	2330.9a	1682.8b
	Ear	12400.1b	10125.0c	13869.6a	8831.5d	13902.2a	12456.4b
	Total	20583.3b	16128.0c	22550.7a	14272.8d	23309.1a	19679.3b
Note: N0: No nitrogen; N180: Reduction nitrogen25%; N210: Reduction nitrogen12.5%; Different letters in the same column indicate significant difference at 0.05, *P<0.05; **P<0.01; the same below.							

3.3 Effects of different nitrogen amount variety, on nitrogen transport before anthesis and nitrogen accumulation after anthesis

Effects of different variety, and nitrogen application rate had extremely significant effects on the accumulation, and contribution rate of nitrogen before anthesis, and after anthesis, and different variety × nitrogen application rate had extremely significant effects on the accumulation of nitrogen after anthesis (Table 3). Compared to variety YH-618, YH-20410, significantly increased the amount of nitrogen transport before flowering by 17.5%-24.5%, and the contribution rate of nitrogen transport before flowering to grain was also significantly increased by 80.7%. Compared to 0 kg ha⁻¹, and 210 kg ha⁻¹ the N application rate of 210 kg ha⁻¹ (12.5% N reduction) significantly increased the amount of N transport before flowering by 5.0%-59.8%, and the difference was not significant to N rate, and the contribution rate of N transport before flowering to the grain was also the highest. In conclusion, variety YH-20410, was beneficial to the increase of nitrogen transport before flowering and contribution to grain, and the nitrogen transport before flowering, and contribution to grain were higher when 12.5% nitrogen was reduced based on nitrogen application.

Table 3

Effects of different nitrogen amount variety, on pre-anthesis accumulated nitrogen translocation and nitrogen accumulation after anthesis of wheat

Variety	N rate	PANT		NAAA	
		TA (kg ha ⁻¹)	CP (%)	TA (kg ha ⁻¹)	CP (%)
YH-618	N0	73.42 d	58.03 f	52.99 a	41.97 a
	N210	90.64 c	65.23 d	48.37 b	34.77 b
	N280	111.75 b	74.22 b	38.8 cd	25.78 e
YH-20410	N0	91.15 c	62.16 e	55.48 a	37.84 b
	N210	110.3 b	71.12 c	44.78 b	28.88 cd
	N280	131.29 a	80.69 a	31.56 e	19.31 f
Analysis of variance ANOVA					
Nitrogen		**	**	**	**
Variety		**	**	**	**
Nitrogen × Variety		ns	ns	**	ns
Note: PANT: Pre-anthesis accumulated nitrogen translocation amount from vegetative organs to grains; NAAA: Nitrogen accumulation amount after anthesis; TA: Translation amount; CP: Contribution proportion; The same below.					

3.4 Effects of different nitrogen amount variety, on nitrogen use efficiency (NUE)

Effects of different variety had a very significant effect on N harvest, and N application rate had a very significant effect on N harvest index and N use efficiency (Table 4). Compared with variety YH-618, YH-20410, significantly increased N harvest index by 5.0%-6.6% and N partial productivity by 0.7%-5.3%. Compared with 0 kg ha⁻¹, and 180 kg ha⁻¹ (25% N reduction), 210 kg ha⁻¹ (12.5% N reduction) significantly increased the N harvest index by 5.0–19.4% and N use efficiency by 2.9–9.1%, but there was no significant difference in N uptake efficiency. In conclusion, variety YH-20410, was beneficial to improve the N harvest index and N productivity of wheat, and the N harvest index and N use efficiency were significantly increased when the N was reduced by 12.5% based N application.

Table 4
Effects of different nitrogen amount variety, on nitrogen use efficiency of wheat

Variety	N rate	N uptake efficiency (kg kg ⁻¹)	Nitrogen harvest index	N use efficiency (kg kg ⁻¹)	N productive efficiency (kg kg ⁻¹)
YH-618	N0	—	0.67 e	39.64 e	—
	N210	1.16 a	0.74 cd	41.36 c	47.83 b
	N280	1.07 a	0.80 b	42.69 b	45.69 bc
YH-20410	N0	—	0.71 d	40.33 d	—
	N210	1.19 a	0.78 b	42.16 b	50.38 a
	N280	1.10 a	0.84 a	43.37 a	47.51 b
Analysis of variance ANOVA					
Nitrogen		ns	**	ns	ns
Variety		ns	**	**	ns
Nitrogen × Variety		ns	ns	ns	ns

3.5 Effects of different nitrogen amount variety, N agronomic use efficiency at maturity

Effects of different variety and nitrogen application rate had extremely significant effects on spike length, number of fertile spike and number of sterile spikes at the wintering, jointing, flowering and maturity stages of wheat, but variety × nitrogen application rate had no significant effects on them. Compared

with variety YH-618, YH-20410, significantly increased ear length and bearing spikelet number, and significantly reduced the number of sterile spike (Table 5). Compared with 0 kg ha⁻¹ and 180 kg ha⁻¹ (25% N reduction), 210 kg ha⁻¹ (12.5% N reduction) significantly increased ear length and Sterility spikelet number but had no significant difference with conventional N application. In conclusion, variety YH-20410, was beneficial to increase the spikelet length and the number of fertile spike mature stage, and there was no significant difference between spike length and Bearing spikelet number when nitrogen was reduced by 12.5% based on N application.

Table 5

Effect of nitrogen application amount reduction on the N agronomic use efficiency at mature of wheat

Variety	N rate	Spike Length (cm)	Bearing spikelet number	Sterility spikelet number
YH-618	N0	6.8 d	14.2 d	1.80 a
	N210	6.9 d	14.4 d	1.60 ab
	N280	7.2 bc	17.4 bc	1.51 bc
YH-20410	N0	7.1 c	16.2 c	1.40 bc
	N210	7.3 b	17.3 bc	1.30 c
	N280	7.6 a	19.4 a	1.00 d
Analysis of variance ANOVA				
Nitrogen	**		**	**
Variety	*		**	**
Nitrogen ×Variety	ns		ns	ns

3.6 Effects of different nitrogen amount variety, on yield components.

Nitrogen application rate had significant or extremely significant effects on Spike number, grain number per ear, 1000-grain weight and yield, and variety × nitrogen application rate had significant effects on yield. Compared with variety YH-618, YH-20410, significantly increased spike number by 2.3–3.2%, grain number per spike by 10.4–13.6%, 1000-grain weight by 6.6–9.2% and yield by 7.3–14.7% (Table 6). Under variety YH-20410, nitrogen application significantly increased the Spike number Compared to 0 kg ha⁻¹ and 180 kg ha⁻¹ (25% N reduction), 210 kg ha⁻¹ (12.5% N reduction) significantly increased grain number per spike by 6.8%-11.2%, 1000-grain weight by 6.8%-10.3% and yield by 10.3%-23.4%. And there was no significant difference with nitrogen application. Under variety YH-20410 conditions, compared to other treatments, nitrogen application significantly increased the number of panicles by 3.4%-10.8% and the yield by 4.8%-33.7%. Compared to 0 N application and 25% N reduction, 12.5% N reduction significantly

increased the grain number per spike and 1000-grain weight but had no significant difference with N application. In conclusion, variety YH-20410, was beneficial to the increase of spike number, grain number per spike and 1000-grain weight, thus achieving high yield, and the grain number per spike, 1000-grain weight and yield were significantly higher when the nitrogen was reduced by 12.5% based N rate, and there was no significant difference between them.

Table 6
Effects of different nitrogen amount variety, on yield and components of wheat

Variety	N rate	Spike number (10^4 ha^{-1})	Grain number Per spike	1000-grain weight (g)	Yield (kg ha^{-1})
YH-618	N0	630.75 e	26.28 d	38.22 e	6305.00 e
	N210	654.75 d	28.18 cd	39.67 d	7182.50 d
	N280	675.75 c	29.23 c	40.59 cd	8050.00 c
YH-20410	N0	651.00 d	29.85 c	40.91 cd	7232.50 d
	N210	671.25 c	31.10 b	42.29 b	8090.00 c
	N280	691.50 b	33.20 a	43.76 a	8925.00 a
Analysis of variance ANOVA					
Nitrogen		**	**	**	**
Variety		*	**	**	**
Nitrogen $\times$ Variety		ns	ns	ns	*

Compared to different variety YH-618, YH-20410, significantly increased the contents of clear, ball, alcohol and gluten, protein content by 4.8%-13.9% and protein yield by 17.5%-26.2% (Table 7). Compared to 280 kg ha^{-1} significantly increased grain clearance, alcohol solution, gluten content, grain protein content and protein yield under variety YH-20410 conditions, and the difference was not significant compared to N rate. Variety YH-618 gliadin contents under N application, and there was no significant difference between them. In conclusion, variety YH-20410 was beneficial to increase the contents of protein, and components in grains, and there was no significant difference between the contents of protein and components in grains when the nitrogen was reduced by 12.5% based N rate.

Table 7
Effect of nitrogen application amount reduction on grain protein and its component contents at maturity of wheat

Variety	N rate	Albumin (%)	Globulin (%)	Gliadin (%)	Glutenin (%)	Glu/Gli	Protein (%)	Protein yield (kg ha ⁻¹)
YH-618	N0	1.73 d	1.35 d	3.68 d	3.76 e	1.02 b	11.72 d	739.73 e
	N210	1.91 c	1.48 c	3.85 c	4.05 d	1.05 a	12.14 cd	872.28 d
	N280	2.08 b	1.55 bc	4.21 b	4.24 c	1.01 c	12.75 c	1026.53 c
YH-20410	N0	1.84 cd	1.47 c	3.94 c	4.09 d	1.04 a	12.28 cd	888.26 d
	N210	2.06 b	1.6 b	4.23 b	4.32 b	1.02 b	13.41 b	1084.83 b
	N280	2.27 a	1.74 a	4.47 a	4.47 a	1.00 c	14.52 a	1295.92 a
Analysis of variance ANOVA								
Nitrogen		**	**	**	**	*	**	**
Variety		**	**	**	**	**	**	**
Nitrogen × Variety		ns	ns	ns	*	*	ns	*

4 Discussion

4.1 Effects of nitrogen reduction on yield, and quality of winter wheat

The results showed that the variety YH-20410 with 12.5% nitrogen reduction increased the amount of nitrogen accumulation in various organs at the maturity stage, the amount of nitrogen transportation before flowering and the contribution rate of nitrogen to the grain, and the difference was not significant with the conventional nitrogen application. This may be due to the increase in total water consumption during the growth period after wide sowing, which promoted the uptake and utilization of nutrients in aboveground plants, and thus increased the nitrogen accumulation of plants²³. The optimum nitrogen application rates vary with the increasing production, and effect of higher nitrogen fertilizer application rate proved better because fertility has improved the plant growth by promoting the absorption²⁴. Wheat grain protein can be categorized as albumins, globulins, gliadins, and glutenins according to their solubility properties. Albumins and globulins are soluble proteins comprising various variety, and inhibitors, which have crucial structural, and metabolic functions during grain-filling²⁵. Thus, it is very important to develop agronomic practices to balance grain quality and yield in soft wheat production. Nitrogen uptake and productivity of cereal crops could be enhanced by increasing plant density under

reduced N supply, which has been confirmed in rice (*Oryza sativa* L.)²⁶. Therefore, we hypothesized that spike number per unit area could be significantly improved by increasing N in wheat, which may partially compensate for grain yield GY loss caused by reducing N rate²⁷. Hence, there may be interaction effect on wheat quality between N rate and varieties.

4.2 Effects of different nitrogen fertilizer characteristics of wheat:

The optimum nitrogen application rates varies with the increasing production, and effect of higher nitrogen fertilizer application rate proved better because fertility has improved the plant growth by promoting the absorption and transportation of fertilizer by the root system²⁸. Wheat grain protein can be categorized as albumins, globulins, gliadins, and glutenins according to their solubility properties. Albumins and globulins are soluble proteins comprising various variety, and inhibitors, which have crucial structural, and metabolic functions during grain-filling²⁵. Gliadins and glutenins, called gluten proteins, interact to form a viscoelastic gluten network in dough, which are essential in determining the baking quality of wheat flour products²⁹. In China, the N application rate has been generally much higher than the recommended dose of 280 kg N ha⁻¹ in soft wheat production for higher grain yield GY³⁰.

4.3 Effects of different nitrogen fertilizer rate, and yield formation of wheat:

Showed that increasing N application rate in the range of 280 kg ha⁻¹ could significantly increase grain yield, and when N application rate exceeded 280 kg ha⁻¹, grain yield was not significantly increased. The results showed that compared with 0 kg ha⁻¹ and 210 kg ha⁻¹, 280 kg ha⁻¹ significantly increased grain number per spike by 6.8%-11.2%, 1000-grain weight by 6.8%-10.3% and yield by 10.3%-23.4%. And there was no significant difference with conventional nitrogen application³¹. The range of 280 kg ha⁻¹, wheat gliadin, glutenin and grain protein content increased with the increase of nitrogen application rate, and the protein content exceeded 12.5%, and starch peak viscosity and final viscosity also increased with the increase of nitrogen application rate. The protein content, peak viscosity and final viscosity of starch were not significantly different from those of 280 kg ha⁻¹ when the N rate was increased to 280 kg ha⁻¹²⁶ showed that the starch content, wet gluten content, sedimentation value, water absorption rate, dough formation time and stabilization time increased when the nitrogen application rate increased in the range of 280 kg ha⁻¹, and all quality parameters decreased when the nitrogen application rate continued to increase. The results showed that when nitrogen was reduced by 12.5%, the contents of amylose, amylopectin and total starch were increased, and the settling value, water absorption rate, dough formation and stabilization time, starch thinning value, peak time, and gelatinization temperature were increased. It indicated that the appropriate nitrogen application rate was beneficial to increase grain yield and improve grain quality.

The pioneering one about increasing profitability through the site-specific management of wheat fertilization³². These results were obtained despite differences between N treatments were always

significant³³ found that a large reduction in N inputs (up to 48.6 %) was due to in-season system to evaluate the crop and optimize N rates compared with the practices normally applied by farmers. A further reduction (up to 19.6 %) was possible through site-specific application. This method maximized spring N fertilizer use efficiency and reduced within-field grain yield variance, compared with field-specific management. Similarly, in a field trial in the UK, the application of N by using sensors saved 15 kg N ha⁻¹ without a negative influence on yield, which increased the N. In addition, there were potential environmental benefits through a 52 % reduction of the residual N in the soil. The author reported a cost of sensing of N210 ha⁻¹ which could be offset by the N rate reduction together with a small (by only 1 %) increase of yield. On this matter³⁴. Results showed that supplying fertilizer N only when a crop response is expected may improve use efficiency and profitability³⁵. From all the above, it can be summarized that field studies in which sensor-based N management systems were compared with common farmer practices have indicated significant increases in the N.

5 Conclusion

In conclusion, the soil water storage at the wintering stage was significantly highest at N280 KG HA⁻¹, variety YH-20410, was beneficial to increase the dry matter accumulation of each organ at maturity stage, and the dry matter accumulation of leaf, stem + leaf sheath. Variety YH-20410, was beneficial to improve the N harvest index and N productivity of wheat. Increase of spike number, grain number per spike and 1000-grain weight, thus achieving high yield, and the grain number per spike, 1000-grain weight and yield were significantly higher when the nitrogen was reduced by 12.5% based N rate. N280 KG HA⁻¹ significantly increased grain clearance, alcohol solution, gluten content, grain protein content and protein yield under variety YH-20410 conditions.

Abbreviations

AS, anthesis stages; F, Flowering; J, jointing; M, maturity; GN, grain number; TGW, thousand grain weight; GY, grain yield; NAE, nitrogen agronomic efficiency; NUE, nitrogen use efficiency GPC, grain protein content GN, grain number; TGW, thousand grain weight; GY, grain yield; NAE, nitrogen agronomic efficiency; GPC, grain protein content; WGC, wet gluten content; W – wintering;

Declarations

Authors' Contributions Hafeez Noor: methodology, formal analysis, investigation, writing-Original draft preparation. Hafeez Noor: writing- original draft preparation. Min Sun: conceptualization.

Aixia Ren :investigation. Wen Lin: investigation. Zhiqiang Gao: project administration. Min Sun: supervision, writing— reviewing and editing.

Funding The authors are thankful to 'Modern Agriculture Industry Technology System Construction' (No. CARS-3124), The National Key Research and Development Program of China (No. 2018YFD020040105),

The Sanjin Scholar Support Special Funds Projects, National Natural Science Foundation of China (No. 31771727), The '1331' Engineering Key Innovation Cultivation Team Organic Dry Cultivation and Cultivation Physiology Innovation Team (No. SXYBKY201733) for financial support of this study.

Data Availability (Data Transparency) Data could be available on demand.

Ethics Approval Not applicable.

Consent to Participate Not applicable.

Consent for Publication Not applicable.

Conflict of Interest Authors have no conflict of interest.

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Figures

Figure 1

Location preparation at experimental site was located of Shanxi Agricultural University Taigu.

Figure 2

Effects of different nitrogen amount variety, on plant height at mature in growth period of wheat (Variety YH-618, YH-20410; N0, N210 and N280 indicated 0, 210 and 280 kg N ha⁻¹). Different letters indicate significant differences ($p < 0.05$) among treatments with in a growth stage by Fisher's least significant difference.

Figure 3

Effects of different nitrogen amount variety, on leaf area index after (LAI) anthesis of wheat. (Variety YH-618, YH-20410; N0, N210 and N280 indicated 0, 210 and 280 kg N ha⁻¹). Different letters indicate significant differences ($p < 0.05$) among treatments with in a growth stage by Fisher's least significant difference.

Figure 4

Effects of different nitrogen amount variety, on soil water storage of 0-200 cm depth at different growing stage. Soil water storage at different stage of winter wheat. Different letters indicated significant differences among treatments by Fisher's LSD test.