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Effects of Nitrogen Management for Improving Soluble Sugar Content and Starch Content Yield of Winter Wheat (*Triticum aestivum* L.) Grains

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Abstract This study 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). 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 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, N210 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. 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 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 and variety YH-20410 was beneficial to the improved the leaf area index, plant height, soil water storage, dry matter accumulation, and grain yield.

Keywords: *wheat, nitrogen dense interaction, particle size distribution, viscosity parameter*

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1. Introduction

Starch is an important component of wheat kernel, accounting for about the kernel stem 65% to 70% of the weight is also the reason for determining the yield and quality of wheat one of the elements [1,2]. Starch size distribution and viscosity parameters of flour chemical characteristics determine its processing quality. Among them, starch is characteristic in industry application with steamed bread, noodles, bread quality and starch are important influence [3,4,5,6]. Viscosity parameters not only affect the appearance of noodles and steamed buns, but also it affects its texture and taste, so the starch viscosity parameter can be used as a surface evaluation index of quality of strips and steamed buns [7,8]. Wheat large and small starch granules it has different structural characteristics and physical and chemical properties, resulting in differences starch properties of wheat, in turn, affect wheat quality [9]. The cultivation environment affects the grain size distribution and chemical characteristics of wheat starch important factor of sex. Suitable nitrogen application rate and planting density can promote the growth and development of wheat and the formation of grain quality of wheat significant regulatory effect [10,11]. The study found that strong gluten wheat varieties after the application of nitrogen fertilizer, the B-type starch decreased significantly, while the moderate gluten and weak gluten variety of B type starch increased significantly, starch viscosity parameters also have [12]. Planting density on starch grain size distribution in wheat endosperm regulatory effect is obvious, and there are genotype differences in its influence [13]. In protein content of wheat grain after nitrogen fertilizer was applied within the suitable nitrogen application range content, wet gluten content and sedimentation value were significantly increased [14,15]. Augment planting density will reduce wheat dough formation time, stability time and settlement value [16].

Most previous studies focused on nitrogen fertilizer and planting density influence of degree on wheat quality and the interaction of nitrogen density on wheat lake particle size distribution and chemical properties of the powder are less studied. This test is small wheat variety huaimai-44 was used as the material with different nitrogen application and planting density Wheat grain under different nitrogen application and planting density was studied changes of starch grain distribution and viscosity parameters were studied effects of starch grain distribution and gelatinization characteristics on wheat grain were studied provides theoretical basis for high yield and high quality cultivation and deep processing and utilization of wheat.

2. Materials and Methods

2.1. Test Materials and Design

The experiment was conducted in Anhui Province from October 2020 to May 2021College of Technology farm. The test material was wheat variety Huaimai forty-four. The experiment was conducted in a randomized complete block design with three nitrogen levels (120, 180, and 240 kg ha^{-1} are listed as N1, N2, and N3, respectively) and three density levels (1.8 million, 2.4 million, and three million plants ha^{-1}, represented by D1, D2, D3). The area of the community is 9 m2, repeat three times. The previous stubble in the experimental field was corn, and the soil type was clay loam, soil surface organic matter, alkali-hydrolyzed nitrogen, available potassium and available phosphorus contents were 16.65 mg·kg^{-1} and 72.75 mg^{-1} respectively 96.05 mg·kg^{-1} and 17.45 mg·kg^{-1}. Nitrogen, phosphorus and potassium were urea (N 46%) and superphosphate, respectively. (P2O512%), potassium chloride (K2O 60%). Phosphate fertilizer (P2O5). Potassic fertilizer (K2O) was all under applied, and the application amount was 90 kg ha^{-1}, the basis ratio of nitrogen fertilizer was 7:3, and the application period was jointing stage. Wheat mechanical drill sowing November 6, 2020, June 1, 2021.

Daily harvest, other field management with conventional field production.

2.2. Determination Methods and Items

2.2.1. Extraction and Analysis of Starch Granules

The methods were improved extract starch. At maturity, weigh 2g wheat and put it into the marked wheat add an appropriate amount of distilled water into the centrifuge tube and soak for 24h to remove the seeds the skin and endosperm are homogenized in a mortar and filtered on a 200-mesh sieve cloth. The retained sediment is repeatedly ground 2 to 3 times. After 3000 centrifuge at rpm for 10min, remove the supernatant and add 5mL2μmol L-1 NaCl, vortex mixing, homogenate centrifugation, repeated many times. Same Methods the samples were cleaned with 0.2% NaOH 2% SDS and distilled water

Time [17,18]. Finally, clean with acetone three times, air dry, bag, store At -15°C. Us Baxter (BT-9300SE) laser is used particle size distribution meter is operated.

2.2.2. Measurement of Viscosity Parameters

Starch viscosity parameters are marked by AACC operating steps quasi - procedural measurement. Say 3g wheat flour grinding mill put the powder into the aluminum box, add 25mL distilled water and stir evenly starch viscosity parameters were determined by Supper3 fast viscosity analyzer test was repeated three times for each sample.

2.2.3. Determination of Yield and Component Factors

Select wheat with uniform growth at heading stage and treat each weight compound area takes 1m2, and the survey is effective by measuring 1m per line with a wooden ruler ear grains were investigated at wheat maturity stage (May 29, 2021). The yield was measured at the mature stage, and each repeated plot was treated take 1m2, each row take 1m, sorting, drying, threshing, testing seeds, testing set thousand grain weight and repeat three times.

2.2.4. Determination of Quality Traits

Wheat is harvested at the ripe stage and stored in the freezer after harvest two months, using the DA7200 NIR score of the Swedish company Broadcom content of protein and wet gluten in wheat grain was determined by analyzer.

2.3. Data Processing

Use Excel2016 and DPS7.0 for data statistics analyze.

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 (Figure 1).Compared with N0 and N210, (25% N reduction), N280 12% N reduction significantly increased the plant height at the growth stages of pregnancy, flowering and maturity, and had no significant difference with N280 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 (Figure 2). 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%.

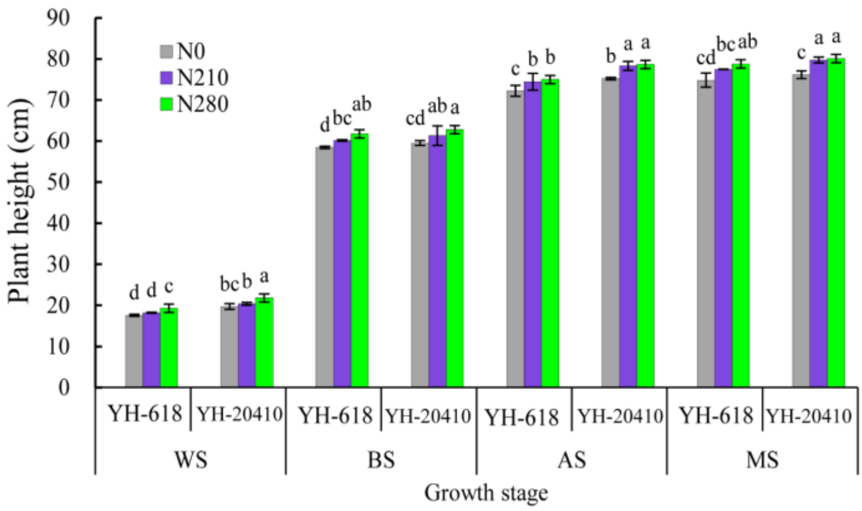

Figure 1. Effects of different nitrogen amount variety, on plant height at mature in growth period of wheat (Variety YH-618, YH-20410; N0, N210 and N280 indicated 0, 210 and 280 kg N ha^{-1}). Different letters indicate significant differences (p < 0:05) among treatments with in a growth stage by Fisher's least significant difference

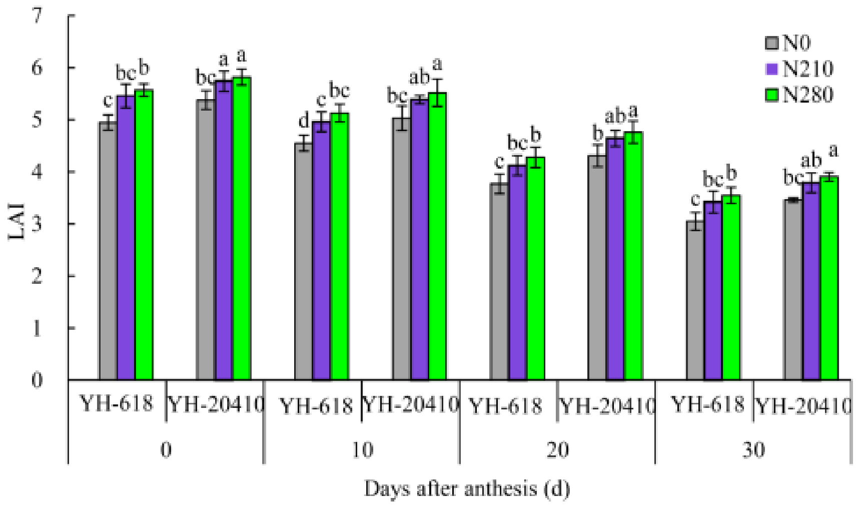

Figure 2. Effects of different nitrogen amount variety, on leaf area index after (LAI) anthesis of wheat. (Variety YH-618, YH-20410; N0, N210 and N280 indicated 0, 210 and 280 kg N ha^{-1}). Different letters indicate significant differences (p < 0:05) among treatments with in a growth stage by Fisher's least significant difference

As shown in (Table 1), 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.

3.2. 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% to 3.2%, grain number per spike by 10.4% to 13.6%, 1000-grain weight by 6.6% to 9.2% and yield by 7.3% to 14.7% (Table 2).Under variety YH-20410, nitrogen application significantly increased the Spike number Compared to 0 kg ha^{-1} and N180 (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.

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 3).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 1. 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.

Table 2. 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	330.75 e	26.28 d	38.22 e	3305.00 e
	N210	354.75 d	28.18 cd	39.67 d	4182.50 d
	N280	375.75 c	29.23 c	40.59 cd	5050.00 c
YH-20410	N0	351.00 d	29.85 c	40.91 cd	4232.50 d
	N210	371.25 c	31.10 b	42.29 b	5090.00 c
	N280	391.50 b	33.20 a	43.76 a	5925.00 a
Analysis of variance ANOVA					
Nitrogen (N)		**	**	**	**
Variety (V)		*	**	**	**
N×V		ns	ns	ns	*

Table 3. 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 (N)		**	**	**	**	*	**	**
Variety (V)		**	**	**	**	**	**	**
N×V		ns	ns	ns	*	*	ns	*

Table 4. Effects of nitrogen variety on soluble sugar content, sucrose content, and starch content of wheat

Variety	N rate	Soluble sugar content (mg g^{-1})	Sucrose content (mg g^{-1})	Starch content (%)
YH-618	N0	49.60 e	22.24 b	60.27 d
	N210	52.90 e	23.21b	63.03 c
	N280	55.20 d	25.60 a	68.35 ab
YH-20410	N0	57.35 c	26.74 a	69.31 a
	N210	59.82 ab	25.80 a	66.68 b
	N280	60.23 a	26.90 a	67.21 b
Analysis of variance ANOVA				
Nitrogen (N)		**	**	ns
Variety (V)		ns	ns	ns
N×V		ns	**	**

3.3. Effect of Different Nitrogen Variety on Soluble Sugar Content, Sucrose, and Starch Content

At the maturity stage, the soluble sugar of grains was the highest in the N210 kg ha^{-1} treatment, and the lowest in the N0 kg ha^{-1} treatment, and there was a significant difference among the three treatments (Table 4). However, there was no significant difference in grain soluble sugar between YH-618 at maturity, but there was significant difference between them under N150kg ha^{-1} nitrogen application. The soluble sugar content of seeds in N210 kg ha^{-1} nitrogen fertilizer and 2.4 kg ha^{-1} variety YH-20410 was the highest, and significantly higher than that in other treatments. At maturity stage, there was no significant difference in grain sucrose between 210 kg ha^{-1} and 210 kg ha^{-1} treatments, but it was significantly higher than N0 kg ha^{-1} treatments, and there was no significant difference between YH-618 treatments. The sucrose content of grain at maturity was significantly higher in high N treatment 210 kg ha^{-1} combined to YH-618 than in low N treatment N0 kg ha–1.The grain starch content at maturity stage was the highest at 210 kg ha^{-1} and the lowest at N0 kg ha^{-1}. There was no significant difference between N0, the difference was not significant except for the N rate of N0 kg ha^{-1}, and the N rate of N210 combined to variety YH-20410 of reached the highest. Variance analysis showed Variety YH-20410 nitrogen fertilizer had a significant effect on soluble sugar content, and sucrose content of grain at maturity stage, but no significant effect on starch content of grain at maturity stage. The effects of variety YH-618 on soluble sugar, sucrose and starch contents of mature grains were not significant. There was a significant interaction between the content of sucrose, and starch in the mature stage.

4. Discussion

Starch grain size distribution and physicochemical properties of wheat grain are affected by genes type control is also affected by cultivation environment factors, and environmental factors influence is greater than genotype [19]. Studies have shown that increased nitrogen fertilizer can promote growth of wheat type A starch granules increases their number and surface area by one hundred fraction, reduce the number, volume and surface area of B-type starch granules score ratio [20]. With the increase of planting density level, wheat A-type lake powder particles have increased [13]. This study shows that with the level of nitrogen application percentage of volume and surface area of wheat B type starch granules was increased percentage of volume and surface area of A-type starch granules showed an upward trend Upward trend; With the increase of planting density level, wheat grain B percentage of starch granule volume and surface area increased first and then decreased, A volume percentage of starch granules decreased first and then increased. In type B in starch grains, nitrogen application and planting density were 2.8-10 μm starch effect of starch granule group was greater than that of starch granule group <2.8μm. In the A-lake influence of nitrogen and density on starch granule group >22μm was higher starch granules of 10~22μm are large. Nitrogen application and planting density on starch percentage of grain number had no significant effect, possibly due to wheat grain deposition number of starch grains <2.8μm accounted for a larger proportion in the powder grains. It can be seen that nitrogen application is beneficial to the growth of starch granules of type and densification is beneficial to the growth of starch granules of type B formation and growth of type starch granules are favorable. Viscosity parameter is an important index for evaluating starch quality [21]. The viscosity parameters of starch are affected by growing environment, nitrogen fertilizer, planting density, Effects of agronomic measures. Nitrogen application had certain effect on starch quality of wheat improvement effect [22]. This is the adjustment of wheat flour viscosity with nitrogen fertilizer control effect is related [23]. This study shows that with the increase of nitrogen application level high, wheat grain starch peak viscosity, trough viscosity, and final viscosity iso-viscosity parameters were obviously increased. With the increase of planting density level high, grain starch peak viscosity, trough viscosity, final viscosity and so on

The index of degree parameters decreased significantly, among which the amount of nitrogen applied was 240 kg ha^{-1} wheat seeds under planting density of 1.8 million plants hm^{-2} grain starch gelatinization has the best properties. Nitrogen application and planting density can improve grain yield and quality of wheat it plays an important role in building a reasonable group structure and promoting production synergistic improvement of three elements of quantity. Studies have shown that nitrogen application can promote small number of ears, grains per ear and 1000-grain weight of wheat were greatly increased, and the yield was eventually increased [24]. The increase of planting density, wheat yield and number of grains per spike. It showed a trend of first rising and then decreasing [14]. In this study, with the level of nitrogen application grain yield, spike number, spike number and 1000-grain weight of wheat were all increased upward trend is consistent with the results of previous studies. But with the planting dense with the increase of degree, the number of ears, the number of grains per ear and the 1000-grain weight of wheat showed an increasing trend. It showed a downward trend, and the yield showed a downward trend and then an upward trend, which was consistent with previous studies fruit is different. This may be due to an increase in planting density, although small number of wheat ears increased significantly, but because of the light transmittance and ventilation in the field poor, light energy effect weakened, resulting in smaller ears and fewer grains per ear, it affects grain filling and is not conducive to wheat yield formation. Visible, suitable nitrogen application amount and planting density can be beneficial to wheat yield high. Increased nitrogen application significantly increased wheat grain protein content, wet gluten content and sedimentation value [15]. With the increase of planting density, Wheat grain protein content, wet gluten content and sedimentation value were presented first rising and then falling trend [25]. This study shows that in 120~240 kg ha^{-1} nitrogen application range, increased nitrogen application can improve wheat grain contents of protein and wet gluten were consistent with the results of previous studies. Dan species effect of plant density on the content of protein and wet gluten was not significant. It is inconsistent with the results of previous studies. This may be due to different research density levels set by the study are different, and the specific reasons remain to be explored one step deeper study.

5. Conclusion

This study showed that nitrogen application and increased planting density were modulated grain size distribution characteristics of wheat starch were controlled, the starch viscosity parameter was changed number, that is, the application of nitrogen increased the viscosity parameters such as the peak viscosity of starch,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.

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