Responses of soil water consumption of different wheat (*Triticum aestivum* L.) Varieties to nitrogen application levels

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Abstract

Background: SPAD value of flag leaf increased highest N rate was 280 kg ha^{-1}. 200-300 cm at maturity stage, indicating the importance of deep soil water storage for grain filling. Variety YH-20410 increased the soluble sugar content in grains protein, and dry gluten.

Aims: This study aimed to evaluate the biochemical impact of nitrogen (N) fertilization on different wheat cultivars. We investigated the influence of topsoil N availability on different varieties, and uptake by wheat (*Triticum aestivum* L.).

Methods: The experiment included two varieties (YH-618, and YH-20410) and three nitrogen levels, (N0, N210, and N280 kg ha^{-1}). The higher nitrogen uptake and soil water consumption, grain protein content, and yield at higher planting densities and will benefit farmers by forming stronger overall crops.

Results: Indicated that wheat variety YH-20410 had the higher nitrogen uptake and soil water consumption, grain protein content, and yield at higher planting densities and will benefit farmers by forming stronger overall crops. The results indicated that suitable nitrogen fertilizer could reduce soil water to jointing stage, provide more water use for wheat in later growth stage, and promote better soil water consumption from flowering to maturity stage. It also indicated that soil water storage decreased from 80-200 cm at flowering stage to 200-300 cm at maturity stage, indicating the importance of deep soil water storage for grain filling.

Conclusions: Nitrogen application amount 210 kg ha^{-1} combined to variety YH-20410 increased the soluble sugar content in grains at the filling stage, which was conducive to the accumulation of sucrose, and starch in grains; 210 kg ha^{-1} was beneficial to increase the content of wheat gluten in grains, obtain higher protein content and yield in grains, and increase the content of dry gluten in grains. The indicated that wheat variety YH-20410 had the higher nitrogen uptake and soil water consumption, grain protein content, and yield at higher planting densities and will benefit farmers by forming.

Highlights

- SPAD value of flag leaf increased highest N rate was 280 kg ha^{-1}.
- N210 enhances the photosynthetic characteristics of flag leaves, and promotes high yield.
- 200-300 cm at maturity stage, indicating the importance of deep soil water storage for grain filling.
- Variety YH-20410 increased the soluble sugar content in grains protein, and dry gluten.

Introduction

Winter wheat (*Triticum aestivum* L.) is one of the most important food crops in the world. It is an important food, and accounting for about one-fifth of food production in China. Nevertheless, the yields in this area is often unstable owing to limited and uneven precipitation distribution in fallow and growing season (Noor *et al.* 2020). Wheat are the most important food crops in Asia, providing food grains for more than 20% of the population worldwide (Guo *et al.* 2016).

N fertilization is a common practice to increase grain production, but its performance depends on soil water status (Halvorson et al. 2004). The importance of increasing crop yield and improving soil quality through fertilization has been confirmed. The increasing use of N fertilizer could significantly increase maize production (Zand et al. 2006), and already affects a large proportion of the world's food production (Erisman et al. 2008). Reported that variety N rate and fertilization increased grain yields by 50–60% in China, and reports from Europe showed that N fertilizers can increase crop yield significantly (Hai et al. 2010). N fertilization is well known to improve soil fertility (Malhi et al. 2011) however, using excessive N fertilizer can decrease the N utilization rate, which not only causes a huge waste of resources and economic losses, but can also adversely impact the environment (Godfray et al. 2010). With the rising atmospheric CO_2 concentrations, many scholars pay extensive attention to the 'CO_2 fertilization effect, the promotion of plant growth or productivity by the increase of atmospheric CO_2 concentrations, in the hope that it will compensate for the crop yield reduction caused by climate change to a certain extent (Lv *et al.* 2020). Leaf senescence involves a reduction in the leaf area at the bottom layer and eventually the whole plant. Environmental factors (nutrient stress, water, and temperature) regulate leaf senescence in crops. The green leaf area, and duration have significant effects on the grain yield, and shaded leaves become senescent earlier compared to unshaded leaves (Gregersen *et al.* 2013).

It was reported that N fertilizer SPAD significantly reduced the content of P_N, g_s, and E, as well as increasing the intercellular carbon dioxide concentration (C_i) in wheat cultivars. Nitrogen (N) deposition has dramatically altered terrestrial ecosystem properties and processes, such as plant nutrient cycling, photosynthetic carbon assimilation, and species diversity (Mao *et al.* 2018). The use of the SPAD chlorophyll meter has increased dramatically within agriculture and research during the last decade, and currently there are more than 200 published studies using the instrument in the scientific literature. Only a small fraction (10%) of these studies quantify the relationship between the leaf determined in vitro, and the SPAD readings. The studies that do perform such calibrations of the SPAD meter usually parameterize linear relationships (Wang et al. 2004), under nitrogen, the grain-filling process is sustained mainly by photosynthesis in the upper parts of wheat plants, such as the flag leaves and wheat ears. In leaf the N has a significant effect on wheat leaf senescence traits and patterns (Kitonyo *et al.* 2018). Insufficient or Deficient N inhibits the photosynthetic and radiation use efficiencies to reduce the grain yield, whereas the optimum N application concentration can increased the grain yield (Luo *et al.* 2018). 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 area (Wu *et al.* (2019). However, several studies showed that wheat ear is the important source of photosynthetic carbon assimilation during grain filling, especially if plants are under nitrogen fertilizer (Jia *et al.* 2015). (Tambussi *et al.* 2007). (Tao *et al.* 2018) reported that the tiller number and percentage of productive tillers, leaf area index, dry weight, and yield were increased by sowing without a significant decline in grain protein. Furthermore, it also enhanced the N in wheat have positive response (Raun *et al*. 2002).

This study examined two different sensitive cultivars of winter wheat (*Triticum aestivum* L.) to investigate effects of N fertilizers on crop yield, 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) soil water consumption (2) soluble sugar, sucrose, starch; and (3) SPAD nitrogen application rate of N280 kg ha^{-1} was more beneficial. The results would provide a novel view for achieving the balance between 210 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.

Measurements, And Experimental Design And Treatments

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 2019 to 2020, 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).

The greenhouse experiment had a single-factor randomized block design with three replications. The experiment comprised of three nitrogen treatments. Three nitrogen treatments were 0, 210 and 280 kg N ha^{-1} (N0, N210, and N280 respectively), Winter wheat (*Triticum aestivum* L.), cultivar 'Yunhan 20410"Yunhan 618' were obtained from the Taigu Agriculture Bureau, Taigu, China. The area of each plot was 2m × 4 m=8 m^2. Experimental site in Figure 1.

Before sowing, Pure P_2O_5 and K_2O 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, 9, 2019, planted in manual with row spacing of 20cm and sowing quantity of 225 kg 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 in June 1, 2020. The field was kept free from insects, pests, and diseases using pesticides as needed. During whole growing season, weed was well controlled by hand.

Figure 1. The greenhouse location preparation at experimental site was located of Shanxi Agricultural University Taigu.

2.1 Agronomic traits: Twenty random plants with uniform growth were uprooted from the field and the plant height was measured by taking vertical distance from the rhizome to the top of the main stem. At the same time the length, width, and number of green leaves were measured and leaf area index (LAI) was calculated from following formula: following Eq. (1): (Noor *et al*., 2020c)

$$\text{LAI} = \frac{\text{length}\times\text{width}\times\text{number of green leaves}}{\text{land area}} \quad (1)$$

2.2 Soil water storage

Before plot preparation, a 3 m-deep profile pit was excavated, and soil samples were taken from 0 to 3 m depth in 0.2 m increments using the cutting ring method described by (Dam et al*.,* 2005) respectively before sowing stage, wintering stage, jointing stage, anthesis stage and maturity stage, and use a soil drill to take soil from a soil layer of 0.2-3 m, every 0.2 m as a soil layer, The soil profile shall be cut and levelled, and the samples shall be taken from the bottom to the top according to the designated level, drying method is used to determine soil moisture, soil samples in 105°C oven after weighing, let stand for 72 h, dry soil weight have been measured, and storage capacity of soil water storage following Eq. (2) and Eq. (3):

$$\text{GSW} = (\text{wet soil mass} - \text{drying soil mass}) / \text{drying soil mass} \times 100\% \quad (2)$$

$$\text{Soil Water Storage} = \text{GSW} \times \rho b \times \text{SD} \times 10^3 \quad (3)$$

Where: GSW is the soil water content (%), ρb is soil bulk density of given soil layer (g cm^{-3}) and SD refers to soil depth (m)

2.3 Sucrose, soluble sugar and starch

After flowering period listed growth consistent and the same day flowering of wheat spike and peeling grain was placed in the oven dried at 105 °C for 20 min and then at 80 °C for 12 hours for dry weight. The quality and speed of weighing samples greatly affect the overall quality of the test. Then the grain was weighed and phenol method was used to determine the content of sucrose, and ketone color method was used to determine the total soluble total sugar content. H_2SO_4-H_2O_2-Phenol blue color method was used to determine the seed protein and component content (Noor et al., 2020).

2.4 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 20m^2, shelled using machine and the grain was air-dried for the determination of grain yield.

2.5 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 formula (Noor *et al.*, 2020b):

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

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.

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

2.6 Photosynthetic characteristics: The net photosynthetic rate (P_N), transpiration rate (E), intercellular CO_2 concentration (C_i), and stomatal conductance (g_s) of the flag leaf were measured by *CI-340* hand-held photosynthesis measurement system (*LI-COR, Inc.,* Lincoln, Nebraska, USA) from 9:00 to 11:00 h. In order to compare photosynthetic characteristics of leaves with a similar developmental age, gas-exchange measurements of each cultivar were conducted immediately after the flag leaves fully expanded. The measurements of P_N, G_s, C_i, and E, were acquired in a system with a leaf chamber temperature of 25°C and the carbon dioxide concentration in the leaf chamber was kept at 380 μmol (CO_2) mol^{-1} by using a CO_2 injector with a high-pressure liquid CO_2 cartridge source. The photosynthetic active radiation was set at 1,500 μmol (photon) m^{-2} s^{-1} .The external humidity was noted as 40 –50%.

(H *et al.*, 2021).

Chlorophyll content SPAD value: The SPAD-502 measurements were conducted in the field between 10:00 and 16:00 h. The ad axial side of the leaves was always placed toward the emitting window of the instrument and major veins were avoided. Leaves at different development stages were selected, including premature, fully mature and senescent leaves. Leaves were detached and collected immediately after the SPAD-502 Tester measurements and were kept cool (– 0C) until sub-samples were punched in the laboratory. The punched leaf material was weighted and then immediately frozen and kept at –25C until chlorophyll extraction. The area of the punched wheat leaf material was determined using an area meter (*Delta-T Devices Ltd., Cambridge, England*), while two circular 1.0 cm diameter leaf discs from one side on the midrib were punched for birch and potato. The spatial distribution of punched leaf material matched the distribution of the SPAD-502.

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.

Results

Effects on nitrogen absorption of plants at various growth stages

The nitrogen accumulation in plants at different growth stages was significantly increased, and the difference between booting, and flowering stage was significant under N condition N280, variety YH-20410. The grain nitrogen accumulation was the highest in N280 under YH-20410 significantly, and the difference was no significant different treatments N210, N0 under variety YH-618. The plant nitrogen accumulation was the highest in variety YH-20410 at each growth stage, and the difference was significant from booting stage to maturity stage. In the YH-618, the nitrogen accumulation in grains decreased significantly with the increase of nitrogen application rate N280, and the nitrogen accumulation in plants at each growth stage decreased, and the difference between booting and maturity stage was significant It can be seen (Table 1). The increase of nitrogen application rate in YH-20410 promotes the absorption of nitrogen by plants.

Table 1 Effects of mulching during fallow period and nitrogen fertilizer N accumulation amount in plant at different growth stages. Different letters indicate significant differences (p < 0:05) among treatments within a growth stage by Fisher's least significant difference.

Variety	Nitrogen amount	WS	JS	BS	AS	MS	
						Grain	Total plant
YH-618	N0	12.28a	36.35a	83.01c	120.28c	125.73c	143.88c
	N210	13.69a	37.44a	87.99b	130.42b	140.33b	157.68c
	N280	14.81a	39.81a	94.08a	143.96a	158.95a	175.17a
	Mean	13.59	37.87	88.36	131.55	141.67	158.91
YH-20410	N0	11.24a	34.97a	79.71cd	111.41c	107.44c	132.29e
	N210	12.25a	36.45a	82.01c	122.13c	121.88c	146.48c
	N280	13.55a	39.45a	86.46b	136.88b	139.57b	165.06b
	Mean	12.35	36.96	82.73	123.47	122.96	147.94
	Total Mean	12.97	37.41	85.54	127.51	132.32	153.43

Nitrogen transport before anthesis and nitrogen accumulation after anthesis and contribution to grains

Different Variety, and nitrogen application rate had extremely significant effects on nitrogen accumulation, and contribution rate before after anthesis, and Variety × nitrogen application rate had extremely significant effects on nitrogen accumulation after anthesis (Table 2).Compared to variety YH-20410, variety YH-618 significantly increased the amount of nitrogen translocation before anthesis N280, 24.5%, and the contribution rate of nitrogen translocation before anthesis to grains was also significantly increased by 80.7%.Compared to N0 kg ha^{-1} N application) and 210 kg ha^{-1} (25% N reduction), N280 kg ha^{-1} (12.5% N reduction) significantly increased the amount of N translocation before anthesis by 5.0%-59.8%, and had no significant difference with N application. The contribution rate of N translocation before anthesis was also the highest. In conclusion, variety YH-20410 was beneficial to the increase of nitrogen translocation before anthesis, and contribution rate to grains, and when N reduction was 12.5% on the basis of N280 kg ha^{-1} N application, the nitrogen translocation before anthesis and contribution rate to grains were higher.

Table 2 Effects of variety during fallow period and nitrogen fertilizer on N moblization before anthesis and N accumulated amount after anthesis. Different letters indicate significant differences (p < 0:05) among treatments within a growth stage by Fisher's least significant difference.

Variety	Nitrogen amount	TABA (kg ha^{-1})	NABAG (%)	NAAA (kg ha^{-1})	NAAAG (%)
YH-618	N0	102.13c	81.23a	23.60c	18.77a
	N210	113.07b	80.57a	27.26b	19.43a
	N280	127.74a	80.36a	31.21a	19.64a
	Mean	114.31	80.72	27.36	19.28
YH-20410	N0	86.56d	80.56a	20.88d	19.44a
	N210	97.53c	80.02a	24.35c	19.98a
	N280	111.38b	79.81a	28.18b	20.19a
	Mean	98.49	80.13	24.47	19.87
	Total Mean	106.40	80.43	25.91	19.57

TABA Translation amount of N before anthesis from vegetative organsTABAG Translation amount of N before anthesis from vegetative organs to grainsNAAA; N accumulation amount after anthesis NAAAG N accumulation amount after anthesis to grains Different letters in the same column indicate significant difference at 0.05, *P<0.05; **P<0.01; The same below.

Nitrogen transport before anthesis N accumulation after anthesis and contribution to grains.

Different Variety and nitrogen application rate had extremely significant effects on nitrogen accumulation and contribution rate before and after anthesis, and Variety × nitrogen application rate had extremely significant effects on nitrogen accumulation after anthesis (Table 3).Compared to conventional sowing, wide sowing significantly increased the amount of nitrogen translocation before anthesis by 17.5%-24.5%, and the contribution rate of nitrogen translocation before anthesis to grains was also significantly increased by 80.7%. Compared to N0 kg ha^{-1} N application) and 210 kg ha^{-1} (25% N reduction), N280 kg ha^{-1} (12.5% N reduction) significantly increased the amount of N translocation before anthesis by 5.0%-59.8%, and had no significant difference with conventional N application. The contribution rate of N translocation before anthesis was also the highest. In conclusion, variety YH-20410, N280 kg ha^{-1} was beneficial to the increase of nitrogen translocation before anthesis and contribution rate to grains, and when N reduction was 12.5% on the basis of N application, the nitrogen translocation before anthesis and contribution rate to grains were higher.

Table 3 Effects of variety and nitrogen fertilizer on N moblization in various organs and their contributions to grain before anthesis

Variety	Nitrogen amount	Leaf		Stem + sheath		Spike	
		TA (kg ha^{-1})	CP (%)	TA (kg ha^{-1})	CP (%)	TA (kg ha^{-1})	CP (%)
YH-618	N0	22.89c	18.21b	58.89c	46.84b	20.35c	16.19b
	N210	28.22b	20.11a	59.26c	42.23c	25.59b	18.24a
	N280	32.27a	20.30a	65.53a	41.23c	29.93a	18.83a
	Mean	27.79	19.54	61.23	43.43	25.29	17.75
YH-20410	N0	18.84d	17.54b	53.19e	49.51a	14.53e	13.52b
	N210	23.70c	19.45a	56.37d	46.25b	17.46d	14.33a
	N280	27.36b	19.60a	62.96b	45.11b	21.06c	15.09a
	Mean	23.30	18.86	57.51	46.96	17.68	14.31
	Total Mean	25.55	19.20	59.37	45.19	21.49	16.03

TA： Translation amount；CP： Contribution proportion. Different letters in the same column indicate significant difference at 0.05, *P<0.05; **P<0.01; the same below.

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 210 kg ha^{-1} 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.

Table 4. Effects of nitrogen variety on soluble sugar content, sucrose content, and starch content of wheat. Different letters indicate significant differences (p < 0:05) among treatments within a growth stage by Fisher's least significant difference.

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

Effects of nitrogen rate variety on yield, and grain protein components

Compared to other nitrogen application rates, the N rate of N150 kg ha^{-1} increased the number of ears by 16%-31%, the number of grains per ears by 5%-6%, the 1000-grain weight by 5%-9%, and the yield by

21%-40%, and the number of ears, and yield reached significant levels (Table 5). Variety YH-20410 significantly increased the grain number per spike, and yield by 4%-16% and 2%-4%, respectively. There was no significant difference in grain number per spike and 1000-grain weight between the two treatments. Analysis of variance showed that nitrogen fertilizer significantly affected the grain number per spike, grains per spike and yield. Variety YH-20410 significantly affected 1000-grain weight and yield. The interaction of nitrogen, and variety YH-20410 significantly affected grain number per spike, 1000-grain weight, and yield. The nitrogen application rate of N150 kg ha^{-1} and Variety application rate of YH-20410 significantly increased the number of per spike area, which was beneficial to the construction of a reasonable population, and thus increased the grain yield. Moreover, the interaction of nitrogen, and variety YH-20410 could achieve high yield by regulating the number of spike and 1000-grain weight.

Table 5 Effects of nitrogen variety on wheat yield, and composition. Different letters indicate significant differences ($p < 0:05$) among treatments within a growth stage by Fisher's least significant difference.

N rate	Variety	Ear Number [10^4 ha^{-1}]	Grain number per spike	1000-grain mass [g]	Yield [kg ha^{-1}]
N0	YH-618	620 e	34.90 b	43.43 d	8012.45 e
	YH-20410	630 d	35.25 b	44.71 c	8819.35 d
N210	YH-618	690 b	36.50 ab	45.81 b	9486.90 b
	YH-20410	707 a	37.20 a	46.76 a	9826.25 a
N280	YH-618	667 c	35.20 b	45.28 bc	8909.30 c
	YH-20410	686 b	36.75 ab	46.70 a	9434.00 b
ANOVA					
Nitrogen		**	**	ns	**
Variety		ns	ns	**	**
Nitrogen ×Variety		**	ns	**	**

There was no significant difference in grain protein content and grain protein yield between 210 kg ha^{-1} and 150 kg ha^{-1} treatments, but 150 kg ha^{-1} treatment was significantly higher than N0 kg ha^{-1} treatment. The grain protein content, and grain protein yield of variety YH-20410 were significantly higher than those of variety YH-20410. The grain protein content and grain protein yield of N150 kg ha^{-1} combined to variety YH-20410 were the highest, and significantly higher than those of other treatments (Table 6).There was no significant difference in the ratio of gluten to alcohol among nitrogen treatments, but 2.4 kg ha^{-1} variety YH-20410 was significantly higher than YH-618. The gluten to alcohol ratio of N150 kg ha^{-1} nitrogen fertilizer combined to variety YH-20410 was the highest, and significantly higher than that of other treatments. Nitrogen and variety YH-618 had no significant effect on grain albumin content. The grain globulin content of N150 kg ha^{-1} treatment was the highest, and significantly higher than that of N0 kg ha^{-1} and N210 kg ha^{-1} treatment. Variety YH-618 had no significant effect on globulin content in grains. Grain gliadin in N210 kg ha^{-1} and N150 kg ha^{-1} treatments was significantly higher than that in N0 kg ha^{-1} treatments. The grain gliadin content of variety YH-20410 was significantly higher than that of YH-618, but there was no significant difference between them only under 280 kg ha^{-1} nitrogen application. The glutenin content in variety YH-20410 was significantly higher than that in variety YH-618. The glutenin content of 150 kg ha^{-1} nitrogen fertilizer combined to YH-20410 was the highest, and significantly higher than that of other treatments. Analysis of variance showed that nitrogen treatment had extremely significant effects on grain albumin, globulin, glutenin, glutento ratio, grain protein content and protein yield. The contents of gliadin and gluten in grains were significantly affected by variety YH-20410 treatment. There were significant interaction between grain gliadin, glutenin, protein content and protein yield among treatments of variety YH-20410.

Table 6 Effects of nitrogen and variety on wheat grain protein. Different letters indicate significant differences (p < 0:05) among treatments within a growth stage by Fisher's least significant difference.

N rate	Variety	Albumin [%]	Globulin [%]	Gliadin [%]	Glutenin [%]	Glu/Gli [%]	Protein content[%]	Protein yield [kg ha^{-1}]
N0	YH-618	2.31a	1.86 b	3.75 d	4.45 d	1.24 e	12.65 e	1013.96 e
	YH-20410	2.42 a	1.92 b	3.96 c	4.64 c	1.36 b	13.84 d	1220.98 d
N210	YH-618	2.52 a	1.99 ab	4.30 b	5.54 c	1.26 c	14.22 c	1348.55 c
	YH-20410	2.58 a	2.07 a	4.50 a	5.82 a	1.44 a	15.60 a	1532.86 a
N280	YH-618	2.49 a	1.87 b	4.32 ab	5.01 d	1.16 d	13.70 d	1225.48 d
	YH-20410	2.54 a	1.91 b	4.43 ab	4.88 b	1.32 b	14.83 b	1398.58 b
ANOVA								
Nitrogen		**	**	ns	**	**	**	**
Variety		ns	ns	**	**	ns	ns	ns
Nitrogen ×Variety		ns	ns	**	**	ns	**	**

Discussion

Soil water consumption

Our study indicated that the difference in soil water storage is due to variable rainfall during the fallow period and growth period of wheat. The lowest yield in variety YH-618, might be attributed to the less water content in 0–300 cm soil profile at anthesis. The variation in grain yield with years could be attributed to the difference in precipitation rates and precipitation pattern (Hemmat & Eskandari, 2006). Water consumptions in the different soil layers. Water consumption in the different layers of the soil profile in 40-cm increments is plotted with depth in Figure 2. N applications had a significant effect on variety YH-20410, (Figure 3), since N application increased water consumption in the different layers above 200 cm, except during the growing season for both cultivars. In, at 200 cm soil depth, the N treatments still had higher soil water consumption than N210 treatment. A similar result was found by Zhou et al. (2011) with N fertilizer application decreasing water storage at soil depths of 200 cm after wheat harvesting. N application increased water consumption in the different soil layers (Fig. 3). Present results indicated that the soil water storage at anthesis and maturity was decreased with increasing N rate and a more significant decrease was observed in the year with high precipitation. Soil water consumption was enhanced by increasing the N rate and effect was more significant for soil water consumption from sowing to anthesis as compared to anthesis to maturity. Maximum water consumption at sowing to anthesis was recorded at 210 kg N ha^{-1} and anthesis to maturity at 280 kg N ha^{-1}. In the present study, the increase in water consumption was explained by the enhanced plant growth by N application and higher soil water storage at sowing. Similarly, He et al. (2016) and Li et al. (2004) reported that soil water consumption was increased by increasing plant growth owing to higher soil water at sowing under different soil management practices. This indicate that the excessive use of N fertilizer makes plants to consume more soil water and causes the soil desiccation of high-yielding winter wheat fields of rainfed dryland areas (He et al. 2016).

Photosynthesize SPAD characteristics:

Leaf area is important wheat structural feature closely associated with the ability of leaves to collect light and photosynthesize (Yang *et al*. 2018). As nitrogen rate compared to Variety, and SPAD the leaf area index of winter wheat increased under N280 especially in the middle, and late growth stage. The leaf area under variety YH-20410 were also higher than the variety YH-618. The differences in leaf area under the different planting method could be attributed to the differences in the wheat distribution. Wheat with variety YH-20410 intercept light more properly with higher photosynthesis rate and leaf area index. (Fan *et al*. 2019) studies that the optimize doses of nitrogen to increase the yield of winter wheat crop. Thus, we used three nitrogen application concentrations set as N0, N210, N280, respectively to analyze the photosynthetic characteristics and yield-related traits in winter wheat. Therefore, the SPAD with N280 kg ha^{-1} would be a valuable management practice to improve wheat yield. (H *et al*. 2021). The use of the SPAD chlorophyll meter has increased dramatically within agriculture and research during the last decade, studies that do perform such calibrations of the SPAD meter usually parameterize linear relationships (Wang et al. 2004).The results of this study showed that the leaf area index was increased until bolting stage and then decreased. The reduction in leaf area index at later growth stage is due to leaf senescence. reported that the photosynthesis rate were higher under SPAD, and photochemical efficiency and chlorophyll contents at the heading and anthesis stages The better plant distribution effectively intercept radiation N, and improves photosynthesis efficiency and growth. The results of this study showed that the Photosynthetic active radiation was found positively related with the leaf area index and number of spikes (Noor *et al.* 2020).

Effects of nitrogen fertilizer yield formation characteristics of wheat

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-filling (Ma et al. 2018). 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 products. Previous studies showed that both grain protein content GPC and grain yield (GY) can be increased by N fertilizer simultaneously under low to medium N rate (0–200 kg N ha^{-1}), but grain protein content (GPC) was continuously increased with no further increase in GY under high N rate (210–280 kg N ha^{-1}). 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 GY (Su et al. 2019). 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 (Zheng et al. 2020). N agronomic efficiency (NAE) is also enhanced by reducing N input however, reducing N rate also increased the risk of GY loss mainly owing to reductions in both number of spikes and grains (Zorb et al. 2018). 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.) (Zhou et al. 2019). In particular, this management strategy could raise profitability of crop production thanks to the increased efficiency of N recovery by the crop. (Morris et al. 2006) in the North China Plain showed that, compared with conventional farmer practice (210 kg N ha^{-1}), sensor-based N management strategy (280 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. Similarly, (Liang et al. 2005). More specifically, this strategy consisted of applying moderate prescriptive dose of fertilizer N at planting and crown root initiation stages, and a corrective sensor-guided application at two stages corresponding to 2nd or 3rd irrigation events. (Raun et al. 2002) 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 210 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 improved (Bongiovanni 2004). The previously described research indicated that the model-based fertilizer prescription lead to N 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 method (Thomason et al. 2011). 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 £11 ha^{-1} which could be offset by the N rate reduction together with a small (by only 1 %) increase of yield. On this matter, (Mullen et al. 2003). Results showed that supplying fertilizer N only when a crop response is expected may improve use efficiency and also profitability. 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.

Conclusion

Our results demonstrate that specific findings showed 210 kg ha^{-1} enhances the photosynthetic characteristics of flag leaves and promotes high yield. SPAD nitrogen application rate of N280 kg ha^{-1} was more beneficial to the different growth stages of wheat (*Triticum aestivum* L.). The results indicated that suitable nitrogen fertilizer could reduce soil water to jointing stage, provide more water use for wheat in later growth stage, and promote better soil water consumption from flowering to maturity stage. It also indicated that soil water storage decreased from 80-200 cm at flowering stage to 200-300 cm at maturity stage, indicating the importance of deep soil water storage for grain filling. Nitrogen application amount 210 kg ha^{-1} combined to variety YH-20410 increased the soluble sugar content in grains at the filling stage, which was conducive to the accumulation of sucrose, and starch in grains; 210 kg ha^{-1} was beneficial to increase the content of wheat gluten in grains, obtain higher protein content and yield in grains, and increase the content of dry gluten in grains. The indicated that wheat variety YH-20410 had the higher nitrogen uptake and soil water consumption, grain protein content, and yield at higher planting densities and will benefit farmers by forming.

Declarations

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Author Contributions Conceptualization, H.N; methodology, S.M, H.N; validation, S.M; data curation, H.N.; writing the manuscript, S.M.; editing, W.L, supervision, Z.G. All authors have read and agreed to the published version of the manuscript. Declarations Conflict of interest. The authors declare no conflict of interest.

Conflict of interest: The authors declare that they have no conflict of interest

Abbreviations

AS – anthesis stages; C_i – substomatal CO_2 concentration; E – transpiration rate; F – Flowering; g_s – stomatal conductance; J – jointing; M – maturity; P_N – net photosynthetic rate; W – wintering;

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Figures

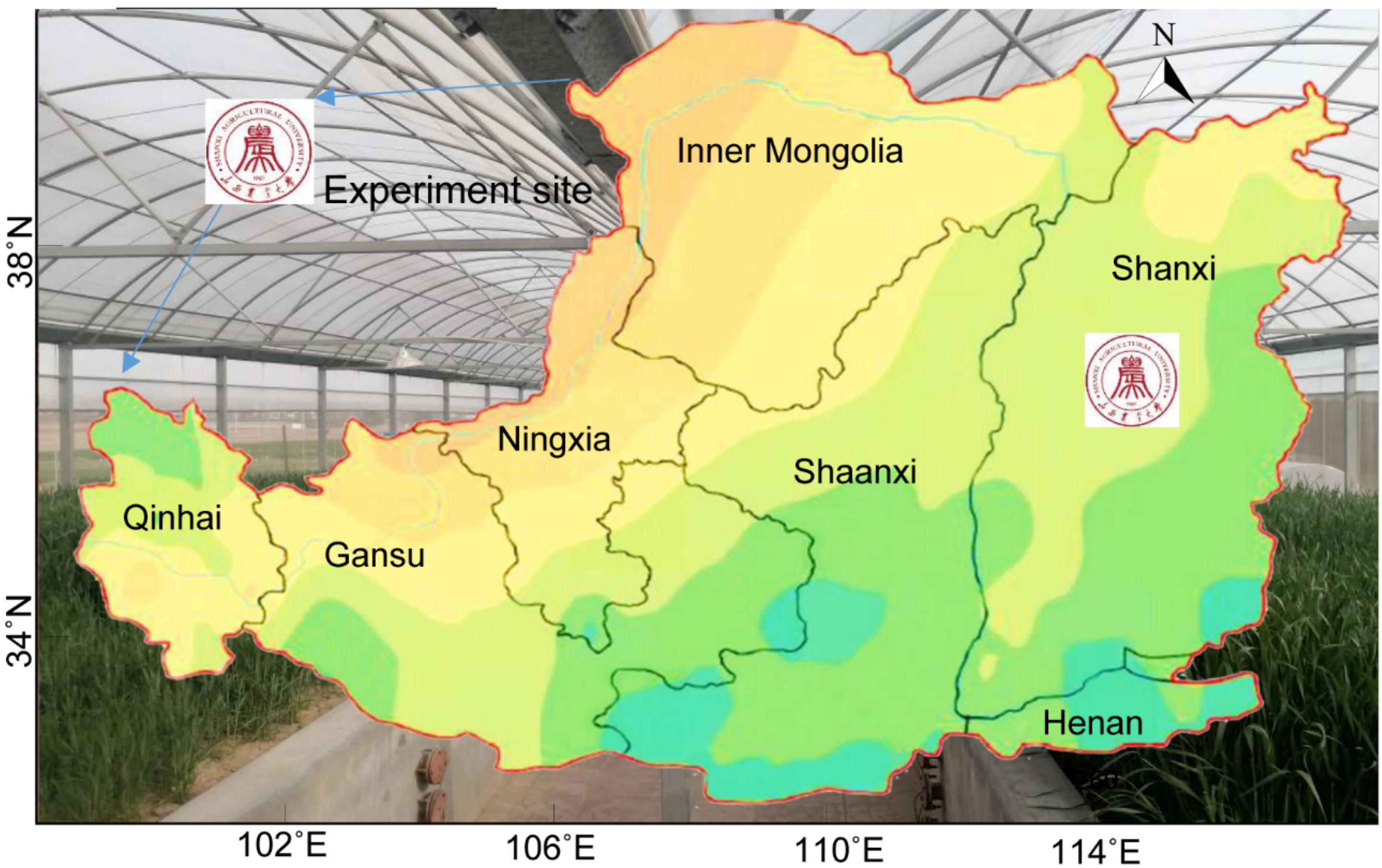

Figure 1

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

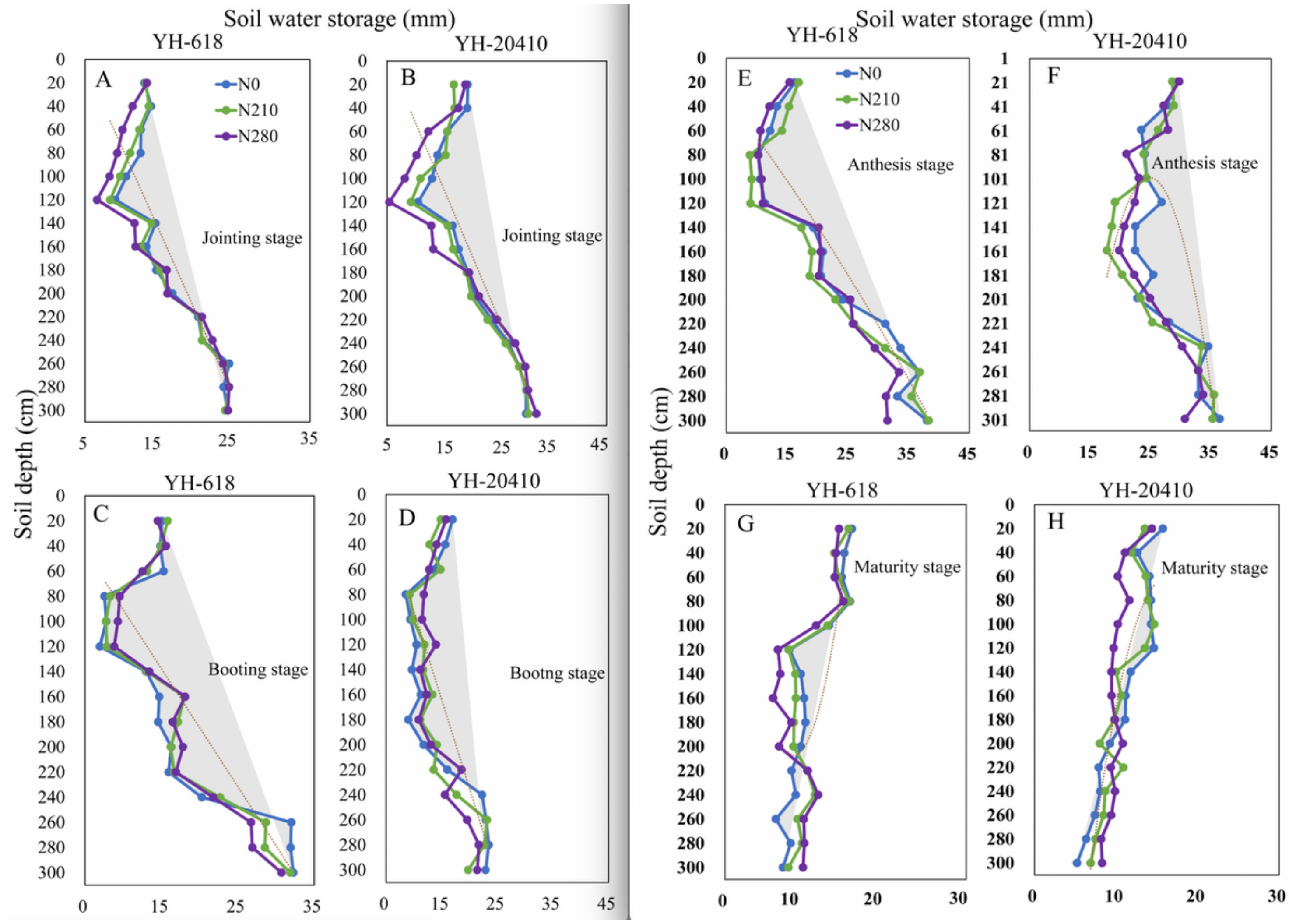

Figure 2

Effects of different nitrogen amount variety, on soil layer of 0-300 cm 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

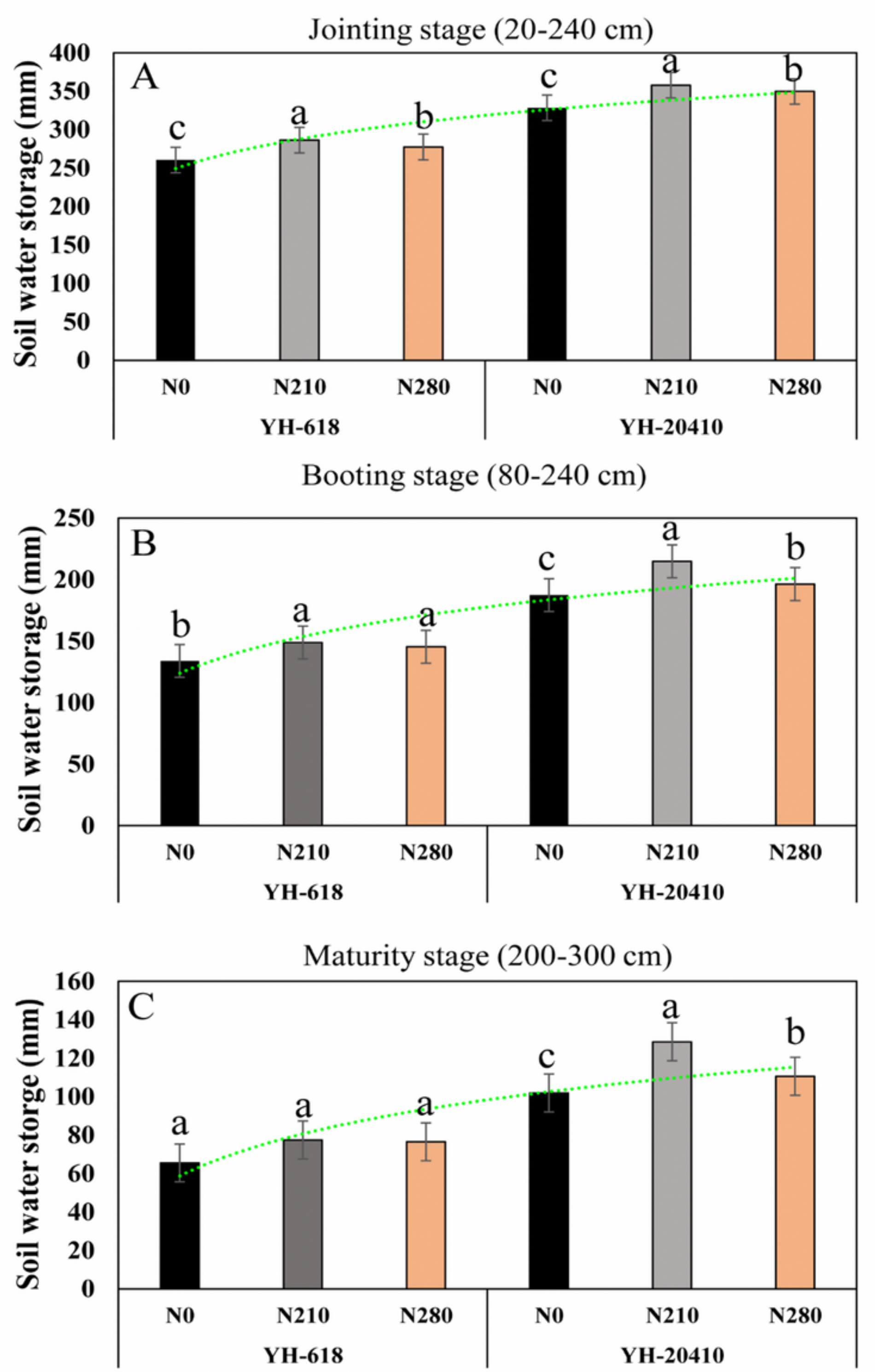

Figure 3

Effects of different nitrogen amount variety, on soil water storage at three growth stages 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

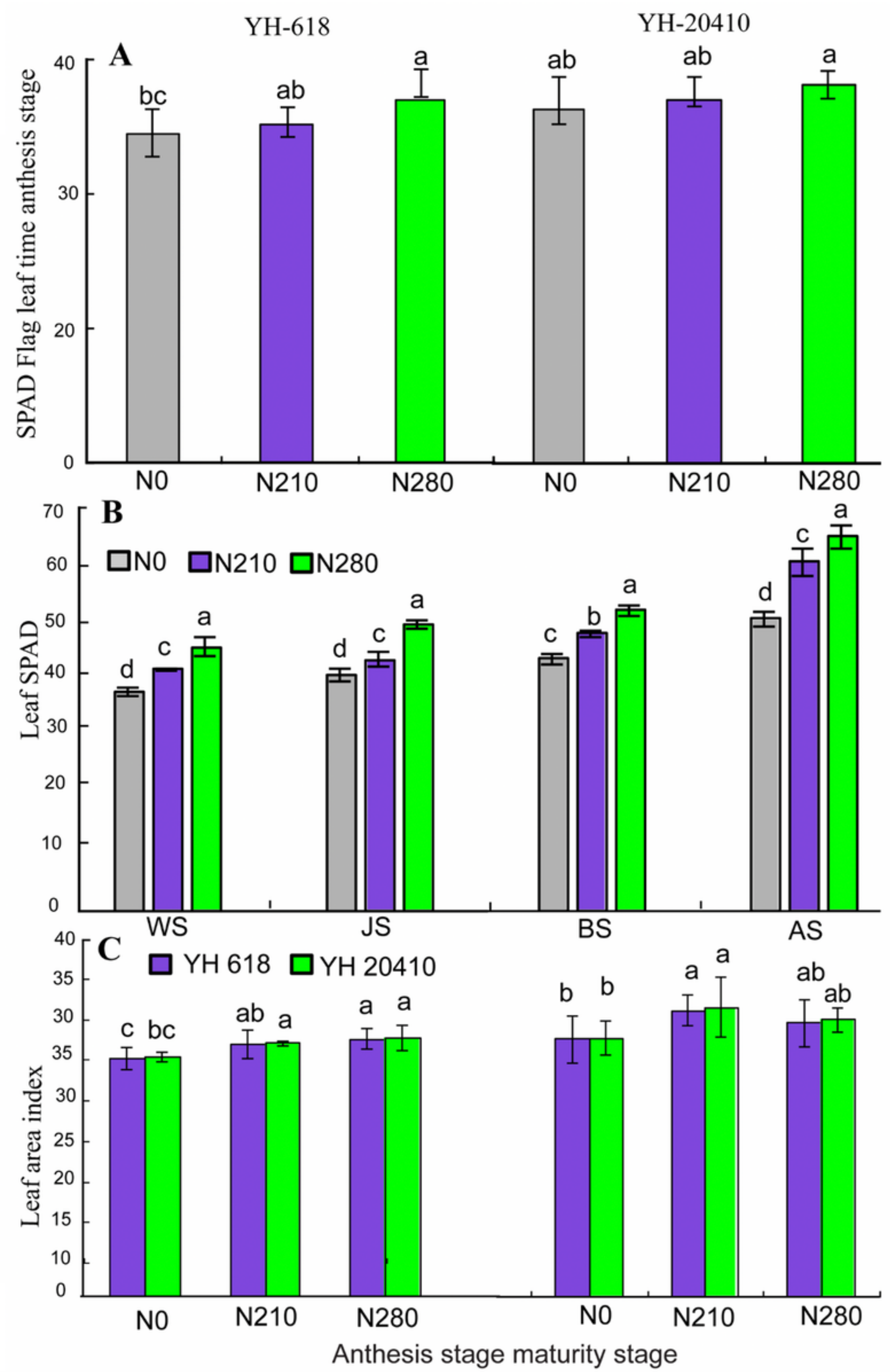

Figure 4

Effects of nitrogen and variety on SPAD value of flag leaf, leaf area index (LAI), at anthesis and maturity stage. All data represent means ± standard errors of three replicates. Values with different letters on the same sampling day indicate significant differences at $P<0.05$

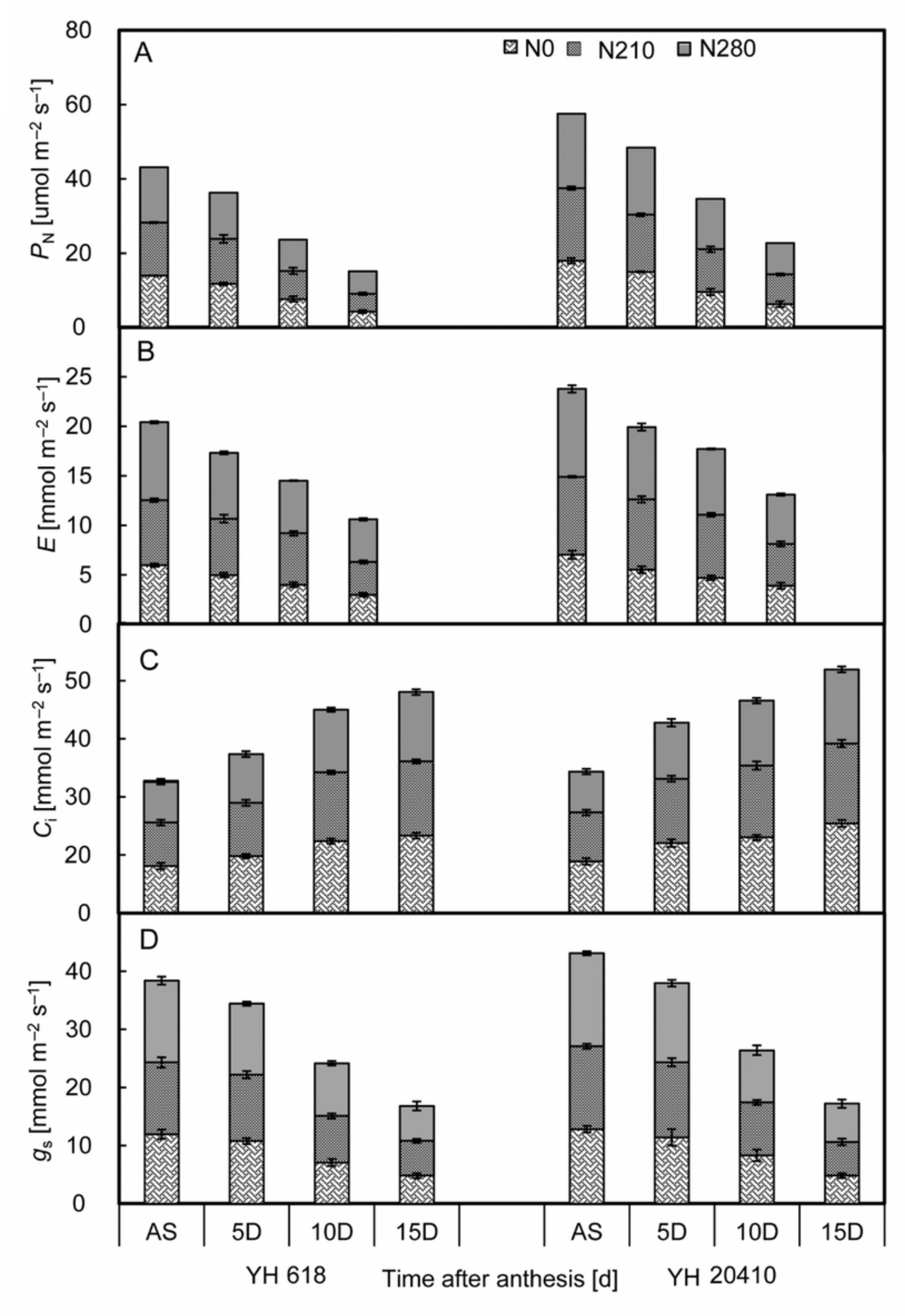

Figure 5

Effect of nitrogen rate on Net photosynthesis (PN) (A), substomatal CO2 concentration (Ci) (B), transpiration rate (E), (C), and stomatal conductance (gs) (D) in flag leaves of winter wheat time after anthesis at different growth stages. During the grain-filling period. All data represent means ± standard errors of three replicates. Values with different letters on the same sampling day indicate significant differences at P<0.05