

Effects of nitrogen fertilizer on physiological property and yield of wheat at the different soil moisture

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Summary The results of pot and pond trials are as follows. On equal amount of nitrogen (N) applied, the wheat nitrate reduction activity (NRA) and photosynthesis strength and other physiological properties are stronger and yields are higher at normal soil moisture than those at drought. At the same soil moisture, in a certain range of N applied, these properties of wheat increase with the increasing of N applied, but they descend when the amount of N applied exceeds a certain range.

Key words nitrogen fertilizer, soil moisture, wheat, yield, physiological property

Introduction

In the past researches, the majority was about individual effects of soil moisture or fertilizer on the wheat physiological properties, while the minority was about their interactive effects. In order to inquire into their interactive effects, in 1989-1991, we conducted pot and pond trials to research the effects of N applied on the wheat yields and physiological properties-NRA, chlorophyll contents, photosynthesis strength and the roots activity at normal soil moisture and drought, so as to provide the theoretical basis for the management of water and fertilizer of wheat.

Materials and methods

The trials were carried out on the farm of Henan Agricultural University in Zhengzhou. The soil used was silt loam, with medium fertility. The soil organic matter, total N, hydrolysis N, and field moisture capacity were 1.25%, 0.074%, 48.6×10^{-6} and 22%, respectively. The soil retention pattern followed:

$$\theta = 14.3522 \psi^{-0.2552}$$

where, θ —water content of soil (wind drying soil, %)

ψ —soil suction (10^5 Pa)

The pot and pond trials were carried out in the study. The height of pot was 25cm and the diameter was 23cm. In every pot, the weight of soil (wind drying soil) was 10kg whose unit weight was 1.3g/cm^3 . Two plastic pipes with small holes were inserted in the soil to supply water. The pot trial set up two factors—soil moisture and N. The soil moisture had two levels: (1) soil water suction (SWS) was 50MPa (relative moisture 77.2%) as normal soil moisture treatment (W_{n-1}); (2) SWS 240MPa (relative moisture 52%) as drought treatment (W_{d-1}). N had six levels: (1) no N (N_{1-0}); (2) N 60kg/ha (N_{1-4}); (3) N 120kg/ha

(N_{1-8}); (4)N 180 kg/ha(N_{1-12}); (5)N 240kg/ha(N_{1-16}); (6)N 300kg/ha(N_{1-20}). The trial had six repeats, three of these for sampling at growth period and the others at mature stage.

The round of the pond was built with cement. The soil thickness was 1.6m and the area of plot was 1.5m². There were also two factors in pond trial. The water treatments were the same as those of pot trial, but we used W_{n-2} and W_{d-2} to stand for them. N had four levels: (1)no N(N_{2-0}); (2)N 60kg/ha(N_{2-4}); (3)N 180kg/ha(N_{2-12}); (4)N 300kg/ha(N_{2-20}). There was no repeat.

The pots and ponds were under the moving artificial coverings in order to control soil moisture. On fine days the coverings were pushed aside and on rain days they were pushed on. The soil moisture contents were controlled in weighing pot and oven drying method respectively. N fertilizer was urea, 2/3 of it was applied at sowing and 1/3 at jointing stage.

The wheat variety tested was Jimai5418. According to the wheat growth period, the indicators were measured of NRA (sulphanilamide colorimetry), contents of protein (ultra-violet spectrophotometry), chlorophyll contents (spectrophotometry), photosynthesis strength (amelioration half leaf method) and roots activity (methylene blue).

Results

Effects of N on NRA at the different soil moisture

Nitrate reductase (NR) is an enzyme of restriction speed that assimilates nitrate in the body of plant. It possesses the key functions in the plant absorption and utilization to N. It is very sensitive not only to N but also to water. It is seen from Table 1 that on equal amount of N applied, NRA in the leaves is stronger at normal soil moisture than that at drought. This indicates that soil moisture can affect NRA. When the amount of N applied is in the range of 0–180kg/ha, NRA increases at the same soil moisture with the increasing of N applied, but it descends when the amount of N applied exceeds the range. This shows that the interaction of soil moisture and N has a best proportion. It is also seen from Table 1 that NRA in the leaves is significantly and positively correlated with the protein contents in the grains.

Table 1. Effects of N on NRA and protein contents

Treatment		NRA(NO_2-N) ($\mu g g^{-1} hr^{-1}$)	Protein content (%)	Correlation coefficient (r)
W_{n-2}	N_{2-0}	24.23	14.24	0.992**
	N_{2-4}	29.74	19.77	0.992**
	N_{2-12}	34.33	24.53	0.992**
	N_{2-20}	32.56	21.54	0.992**
W_{d-2}	N_{2-0}	17.20	8.25	0.980**
	N_{2-4}	19.73	10.23	0.980**
	N_{2-12}	25.44	15.74	0.980**
	N_{2-20}	24.18	15.21	0.980**

Notes: (1) The data in the table are the mean value of four samples at the milk stage.

(2) Standard in test of significance: $r_{0.01} = 0.917$

Effects of N on chlorophyll contents and photosynthesis strength

There are significant effects of soil moisture and N on chlorophyll contents. It can be seen from Table 2 that on equal amount of N applied, whether at jointing stage, booting stage or heading stage, chlorophyll contents are higher at normal soil moisture than those at

drought, which shows that drought can restrain chlorophyll forming. Chlorophyll contents rise with the increasing of N applied when the amount of N applied is in the range of 0—180 kg/ha at the same soil moisture and they descend if the amount of N applied exceeds the range, which indicates that the effects of soil moisture and N on chlorophyll contents have a fit proportion.

Table 2. Effects of N on chlorophyll contents ($\text{mg}\cdot\text{g}^{-1}$)

Treatment		Jointing stage	Booting stage	Heading stage
W_{n-2}	N_{2-0}	1.02	1.42	1.02
	N_{2-4}	1.10	1.53	1.23
	N_{2-12}	1.21	1.86	1.66
	N_{2-20}	1.06	1.30	1.10
W_{d-2}	N_{2-0}	0.97	1.30	0.91
	N_{2-4}	1.01	1.47	1.11
	N_{2-12}	1.11	1.67	1.51
	N_{2-20}	1.00	1.22	1.00

In usual cases, chlorophyll contents are positively correlated with photosynthesis strength. Table 3 pointed out that on equal amount of N applied, photosynthesis strength is stronger at normal soil moisture than that at drought. At the same soil moisture, when the amount of N applied is in the range of 0—180kg/ha, photosynthesis strength strengthens with the increasing of N applied, but it weakens when the amount of N applied exceeds the range. This shows that under the condition of different soil moisture, the effects of N on photosynthesis strength have an appropriate point. The combination of the proper soil moisture and amount of N applied can raise photosynthesis strength. This is of great significance to raising yields and accumulating drymatter.

Table 3. Effects of N on photosynthesis strength (CO_2 $\text{mg}\cdot\text{dm}^{-2}\cdot\text{hr}^{-1}$)

Treatment		Jointing stage	Booting stage	Heading stage	Milk stage
W_{n-2}	N_{2-0}	6.46	12.68	15.04	7.11
	N_{2-4}	9.14	12.67	15.62	10.06
	N_{2-12}	11.18	20.35	19.09	13.03
	N_{2-20}	—	3.52	7.21	—
W_{d-2}	N_{2-0}	6.34	11.52	12.53	5.76
	N_{2-4}	6.34	11.63	14.20	6.05
	N_{2-12}	9.69	18.50	17.36	9.25
	N_{2-20}	1.76	3.44	7.19	2.00

Effects of N on root activity

Robust roots can enhance the ability for wheat to absorb water and nutrients, add drymatter accumulation and raise yields. Table 4 shows clearly that on equal amount of N applied, the total absorption area and active absorption area of wheat root are modestly larger at normal soil moisture than those at drought, the total specific area and active specific area are smaller at normal soil moisture than those at drought. At the same soil moisture, the total root absorption area, active absorption area, total specific area and active specific area increase with the increasing of N applied. This proves that the effects of N on the activity of roots are higher than those of soil moisture.

Table 4. Effects of N on the activity of roots

Treatment		Total absorption area (m ² /pot)	Active absorption area (m ² /pot)	Percentage of active absorption (%)	Total specific area (cm ⁻¹)	Active specific area (cm ⁻¹)
W _{n-1}	N ₂₋₀	12.62	6.32	50.13	3823	1917
	N ₂₋₄	12.71	6.38	50.20	3971	1994
	N ₂₋₈	12.84	6.41	49.96	3890	2004
	N ₂₋₁₂	13.06	6.51	49.87	3840	2040
	N ₂₋₁₆	13.18	6.73	51.08	3993	1980
	N ₂₋₂₀	13.20	6.86	52.00	4258	2214
W _{d-1}	N ₂₋₀	12.31	6.29	51.13	3970	2030
	N ₂₋₄	12.33	6.24	50.58	4110	2079
	N ₂₋₈	12.83	6.41	49.98	4275	2137
	N ₂₋₁₂	13.00	6.51	50.05	4333	2169
	N ₂₋₁₆	13.10	6.71	51.24	4366	2237
	N ₂₋₂₀	13.11	6.75	51.50	4682	2411

Note: The results are determined at flowering stage.

Effects of N on protein contents in wheat grains

The contents of the crude protein in wheat grains are closely connected with soil moisture and N. Table 5 shows that at the same soil moisture, the contents of crude protein and yields increase with the increasing of N applied but they reduce when the amount of N applied at drought exceeds 240kg/ha. On equal amount of N applied, they are higher at drought than those at normal soil moisture, while the yields of crude protein are lower at drought. The main reason is that drought restrains the formation and accumulation of the starch, and so the contents of starch in grains are reduced and the protein contents are raised, so that the grain quality is improved. On equal amount of N applied, the crude protein yields are still higher than those at drought because the absolute wheat yields are higher at normal soil moisture than those at drought.

Table 5. Effects of N on crude protein contents in wheat grains

Treatment		Yield (kg/ha)	Crude protein contents		Yields of crude protein	
			(%)	Rate of increase (%)	kg/ha	Rate of increase (%)
W _{n-1}	N ₁₋₀	2962.65	9.69	—	287.10	—
	N ₁₋₄	3934.95	11.46	18.27	451.05	57.10
	N ₁₋₈	4959.75	12.31	27.04	610.65	112.71
	N ₁₋₁₂	5046.75	13.28	37.05	670.20	133.44
	N ₁₋₁₆	5187.60	13.74	41.80	712.80	148.28
	N ₁₋₂₀	4847.55	14.42	40.87	661.65	130.46
W _{d-1}	N ₁₋₀	1762.80	11.86	—	209.10	—
	N ₁₋₄	2070.90	14.02	18.21	290.40	38.88
	N ₁₋₈	2268.65	14.59	23.12	331.05	58.32
	N ₁₋₁₂	2518.95	15.62	31.70	393.45	88.16
	N ₁₋₁₆	2289.75	17.10	44.18	391.51	87.23
	N ₁₋₂₀	2204.85	12.31	3.79	271.35	29.77

Effects of N on wheat yields

It can be known from Table 6 that on equal amount of N applied, wheat yields are higher at normal soil moisture than those at drought. In the certain range of N applied, they increase in the range of 0—240kg/ha at normal soil moisture and in the range of 0—180kg/ha at drought with the increasing of N applied, but they are reduced when the amount of N applied exceeds the above-mentioned range. Thus it can be seen that the yields are still increased when the amount of N applied is 240kg/ha at normal soil moisture, but they are reduced when the amount of N applied is 180kg/ha at drought, which shows that the interactive effects of soil moisture and N have a suitable proportion.

Table 6. Effects of soil moisture and N on wheat yields

Amount of N applied (kg/ha)	Yield (kg/ha)		N Effects (kg/ha)		Water effects (kg/ha)
	W_{n-1}	W_{d-1}	W_{n-1}	W_{d-1}	
0	2962.65	1762.80	—	—	1199.85
60	3934.95	2070.90	987.30	308.10	1864.05
120	4959.75	2268.75	1997.10	505.95	2691.00
180	5046.75	2518.95	2084.10	756.15	2527.80
240	5187.60	2289.75	2224.95	526.95	2897.85
3003	4847.55	2204.85	1884.90	442.05	2642.70

The analysis of variance for both soil moisture and N shows that the simple effects of soil moisture and N as well as their interactive effects are significant. Only when they have an appropriate proportion, can high yields of wheat be achieved.

Discussion and conclusions

NRA, photosynthesis strength and the contents of chlorophyll in wheat leaves are higher at normal soil moisture than those at drought on equal amount of N applied. At the same soil moisture, when the amount of N applied is in the range of 0—180kg/ha, the aforementioned physiological characters strengthen with the increasing of N applied, but they drop when the amount of N applied exceeds the range.

On equal amount of N applied, the total absorption area of wheat roots and active absorption area are larger at normal soil moisture than those at drought, but on the contrary, the total specific area and active specific area are smaller at normal soil moisture.

The contents of crude protein in wheat grains are higher at normal soil moisture than those at drought. When the amount of N applied is in the range of 0—240kg/ha at drought and in the range of 0—300kg/ha at normal soil moisture, the crude protein contents rise with the increasing of N applied. They decrease when the amount of N applied exceeds the range of 0—200kg/ha at drought.

The yields of wheat are higher at normal soil moisture than those at drought on equal amount of N applied. When the amount of N applied is in the range of 0—240kg/ha at normal soil moisture and in the range of 0—180kg/ha at drought, they rise with the increasing of N applied, and they decrease when the amount of N applied exceeds the range mentioned above.

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