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Effects of Water and Nitrogen Utilized by Means of Dripping on Growth of Root and Canopy and Matter Distribution in Spring Wheat

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Abstract: In order to provide scientific strategies of water and nitrogen regulation, the effects of different amount of watering and nitrogen rate by means of drip irrigation on root/shoot growth and matter distribution in wheat were studied by using methods of soil drill sampling and growth analysis. The results indicated that reducing drip irrigation amounts and nitrogen rate would cause root weight decreased, shoot growth reduced and yield dropped. In water deficit irrigation treatments (2400 m^3/ha), root length and root surface area increased in flowering stage, but rapid declined in milking stage, that severely hampered leaf growth and grain grouting. In milking stage, appropriate irrigation amount (3600 m^3/ha) could maintain higher root weight, root length and root diameter that promoted root/shoot coordinated growing. Nitrogen deficiency significantly reduced dry matter accumulation amount of stem in flowering stage and root length and root surface area in milking stage, that was not conductive to the extension and fulfilling of roots functions and leaded to canopy severely premature aging. High nitrogen supply (urea 450 kg/ha) would cause vigorously growing of shoot and declining of the growth quality of spike and decreasing of the economic coefficient. Water and nitrogen had significant collaborative compensation effects on root/shoot growth and yield traits and the effects of regulating water by nitrogen supply on root traits was larger than on shoot, while regulating nitrogen by water supply on shoot traits was larger than on root, so in actual production, it was necessary to maintain a high level of nitrogen supply in flowering stage but a appropriate level of water supply in milking stage. The drip irrigation amounts and nitrogen rate and yield components indicators in high-yielding drip irrigation wheat field were put forward by analyzing quadratic polynomial equation built by the data of water and nitrogen two factors field experiments.

Keywords: Compensation effect, ratio of root to shoot, spring wheat, surface area index of root

INTRODUCTION

Drip irrigation in wheat field in Xinjiang arid area was a water-saving technique based on the development of cotton under film drip irrigation. This technique was a revolution to the irrigation of close planting crops, because drip irrigation could continuously send water and nutrient to crop root zone at any time and place and reduce soil water leakage and agricultural water waste (Skaggs *et al*., 2010), which optimized the fertilizer and water supply way at root zone, improved the relationship of wheat root characteristics with fertilizer and water using efficiency and achieved high yield and water saving effect (Liao *et al*., 2008; El-Rahman, 2009).

There were evident influence of water and nitrogen on close planting crops root/shoot growth and matter distribution (Li and Shao, 2000), appropriate amount of nitrogen fertilizer (urea 600 kg/ha) could increase total root weight and root weight in deep soil layer and improve wheat drought resistance. Excessive nitrogen (urea 1500 kg/ha) increased the root weight of top layer, but had little importance to drought resistance. Under severe water stress, it would lead to the increased injury rate to root cell membrane, deteriorated water relations in root zone, decreased water retention capacity of root and declined drought resistance eventually. Under light water stress, nitrogen application increased the wheat root dry weight, length, vitality and active absorption area while under severe stress it seriously decreased root volume and dry weight, which indicated that nitrogen nutrient, would partly improve wheat drought resistance to some extent (Zhang and Zhang, 2001). Drought also had significant influence on crop assimilate accumulation and distribution (Xü *et al*., 2000). Under drought condition dry matter weight of wheat stem at later milking stage output more, but leaf and leaf sheath output little. Moderate drought at early milking-maturation stage for spring wheat could promote the milking progress and speed and increase economic yield (Zhang and Kirham, 1994). Deficiency by regulation water at wheat seedling stage would reduce nitrogen absorption capacity, but after water recovery at the medium growth

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Table 1: Assignment of urea (kg/ha) and irrigation (m^3/ha) volume in different periods of spring wheat

Treatment		Three leaf	Jointing	Booting	Flowering	Milking	Fully milking	Dough	Irrigation quota
N_0W_l	Urea	0	0	0	0	0	0	0	0
	Water	210.1	388.1	350.2	437.7	437.7	357.4	218.8	2400
N_0W_m	Urea	0	0	0	0	0	0	0	0
	Water	315.1	582.1	525.2	656.5	656.5	536.2	328.3	3600
N_0W_h	Urea	0	0	0	0	0	0	0	0
	Water	420.2	776.2	700.3	875.4	875.4	714.9	437.7	4800
$N_{225}W_l$	Urea	45	90	0	67.5	22.5	0	0	225
	Water	210.1	388.1	350.2	437.7	437.7	357.4	218.8	2400
$N_{225}W_m$	Urea	45	90	0	67.5	22.5	0	0	225
	Water	315.1	582.1	525.2	656.5	656.5	536.2	328.3	3600
$N_{225}W_h$	Urea	45	90	0	67.5	22.5	0	0	225
	Water	420.2	776.2	700.3	875.4	875.4	714.9	437.7	4800
$N_{450}W_l$	Urea	90	180	0	135	45	0	0	450
	Water	210.1	388.1	350.2	437.7	437.7	357.4	218.8	2400
$N_{450}W_m$	Urea	90	180	0	135	45	0	0	450
	Water	315.1	582.1	525.2	656.5	656.5	536.2	328.3	3600
$N_{450}W_h$	Urea	90	180	0	135	45	0	0	450
	Water	420.2	776.2	700.3	875.4	875.4	714.9	437.7	4800

stage, strong compensation effect of nitrogen absorption appeared (Pandey *et al*., 2001). The above studies were carried out in the conventional irrigation. Drip irrigation, due to the changes in supply way and field distribution of water and fertilizer, had significant difference on the distribution of water and nitrogen in field and wheat growth regulating effect with the conventional one (Zhang and Lü, 2011). In this research, the influence of water coupled with nitrogen on root and canopy growth and matter distribution for spring wheat by different water and nitrogen treatments was studied under drip irrigation in the field in order to provide scientific strategies of water and nitrogen regulation for high yield, as well as scientific basis for spring wheat irrigation technique.

MATERIALS AND METHODS

Test conditions: This test was conducted at the net room of the experimental station in Tarim University in 2011. The test point was a typical temperate inland climate, with the average annual temperature 11.2°C, the average annual rainfall 45.7 mm, average annual evaporation capacity 1988.4 mm and annual average relative humidity below 55%. The soil was sandy loam, with soil bulk density of 0-40 cm was 1.32 g/cm^3; field moisture capacity was 23.8% (weight capacity). The underground water level was about 8.0 m. The content of soil organic matter was 1.025% and total nitrogen, alkali hydrolysable nitrogen, available phosphorus and available potassium were 0.685, 49.27, 52 and 214.1 mg/kg, respectively.

Materials and design: Tall stalk variety Xin chun 19 (presented by Shihezi University) was chosen as tested material and sowed on March 8th. Each row was planted every 15 cm and 18 rows were arranged in each plot, where one drip irrigation belt was laid between 3 and 4 line every 6 rows with patterns of one tube for 6 line. The planting density was 5700000 strains/ha.

The orthogonal experiment with two factors and three levels were designed in this study: 3 levels for nitrogen drip irrigation:

- No nitrogen (N_0)
- Fertigation of urea 225 kg/ha (N_{225})
- Fertigation of urea 450 kg/ha (N_{450})

Three levels for water irrigation:

- Low water 2400 m^3/ha (W_l)
- Moderate water 3600 m^3/ha (W_m)
- High water 4800 m^3/ha (W_h)

There were 9 treatments in this experiment with 3 replicates for each treatment, adding up to 27 plots. The area of each plot was 13.5 m^2 (2.7×5 m). Random block design was used. The amount of drip irrigation was recorded by water meter. PVC polyester plate was used to prevent penetration between plots (Table 1).

Urea of 150 kg/ha and diammonium phosphate of 120 kg/ha as base fertilizers were utilized before sowing, 900-1500 g 2, 4D-butylate per ha was sprayed before jointing to get rid of weed. Water and nitrogen were utilized by drip irrigation in stages according to the requirement law of wheat.

Test methods: The growth process of spring wheat was observed and plant height and leaf number were recorded after emergency. Representative 5 plants were chosen as samples at each growth period in each plot. After weighing the fresh organs, they were put in 105°C ovens for 15 min, then 80°C for 48 h to constant weight. At mature stage 3 representative points for samples were chosen and cut off plants of 1 m^2 area in each plot and threshed for calculating yield and then weigh dry weight.

Soil drilling method for root and image processing method were used to study root system characteristics at wheat flowering (May 18th) and milking period (June 13th). The soil drill diameter was 4.8 cm, with sample room 15 cm high and 271.7 cm^3 by volume. Two spots located at 7.5 and 37.5 cm from drip irrigation belt were selected to drill root samples and at each spot 3 drilling (drill interval 3 cm) was got side by side perpendicular to plant rows in the center of rows, which obtained 6 drilling from 2 spots. Each drilling soil was laid respectively by 10 cm each layer and 4 layers were drilled in total, then finally the same layer of soil sample were mixed. After rinsed by running water on the 200 sieve mesh, the root samples was put carefully in a glass plate by tweezers, then black and white TIF images were obtained by scanning in 300 dpi pixel and root morphological characteristics such as root length and average diameter et al were also calculated by DT-SCAN2.04 image analysis software (Delta-T Devices Ltd.) (Wang *et al*., 2011b), at last the root of different layers were put into the drying oven, where dried at 105°C for half an hour then to 65°C dried to constant weight.

Data analysis: Root length density (RLD, mm/cm^3) was calculated by the formula "$L/(D\pi r^2)$" (among the formula "L" was root length, cm; "D" was sampling soil depth, cm; "r" was soil drill radius, cm); Root surface area (RS, cm^2) was calculated by the formula "πRL" ("R" was root mean diameter, cm; Root Area Index (RAI) equaled root surface area per unit area/ area occupied with soil; ratio of root to shoot could be calculated by dry weight above ground/dry root weight; Economic coefficient was got by the ratio between grain dry weight and total dry weight of root and canopy. Software DPS10.0 and Duncan multiple comparison method were used in statistical analysis. Microsoft Excel 2003 was used for mapping.

RESULTS AND ANALYSIS

Influence on root growth index in different water and nitrogen treatments: According to Table 2, at flowering stage no matter how much nitrogen was utilized, root dry weight in high water treatment reached maximum 0.373-0.395 g/plant strain, while in low water treatment root length, root diameter, root surface area, root length density and root surface area index were all the largest, which were 0.49-1.17, 0.41-0.45, 1.16-2.15, 0.62-1.42 and 0.95-1.83 times higher than those of in high water treatment respectively.

During the grain milking stage in moderate water treatment root length, root surface area, root length density, root surface area index reached maximum and root dry weight showed little difference in moderate water and high water treatments, but in low water treatment root dry weight reached minimum which only was 0.66-0.73 times of high water treatment. Meanwhile, no matter how much water was irrigated at flowering stage, root dry weight and root surface area increased, root length decreased, root diameter and root surface area index changed little along with nitrogen increased, but at milking stage root length, root diameter, root length density and root surface area sharply reduced with nitrogen reduction. Each index in no nitrogen treatment was 49-82%, 22.5-65.8%, 43.6-79.0% and 9.3-39.3% that of high nitrogen treatment. On the whole, lack of water or nitrogen caused dry root weight to decrease. Deficiency of nitrogen would easily cause root length, root diameter and root length density decreased. Water shortage at flowering stage caused root length, root length density increased, root diameter grew thinner suffered by light drought and thicker by severe drought. When water shortage happened at milking stage, root length and root length density firstly increased and then decreased while the root diameter decreased with water reducing. In addition, whether at flowering or milking stage, root dry weight in low water-high nitrogen treatment or in high water without nitrogen treatment was higher than in treatment of low water without nitrogen, which indicated water and nitrogen had collaborative compensation effect on the root (Li and Shao, 2000). Root growth characteristic values in low water-high nitrogen treatment (regulating water by fertilizer) were higher than those of in high water-low nitrogen treatment (regulating fertilizer by water) and the phenomenon reflected that compensation effect of nitrogen on low water inhibiting root growth was higher than the effect of water on low nitrogen inhibition.

Analysis of water and nitrogen treatment on root growth index variation (coefficient of variation) showed that (Table 3), the coefficient of variation CV% at flowering stage reached maximum by water treatment. Namely, at this stage the root growth index was mainly affected by the influence of water, among which root surface area and the surface area index, root length density and diameter were sensitive to water. At this stage water shortage had a significant impact on root morphogenesis and function; whereas, during milking stage root growth index variation showed to be the maximum caused by nitrogen level change. That is to say, at this stage the root traits were mainly influenced by nitrogen supply levels. Lack of nitrogen would accelerate the decline of wheat root system and eventually effect nutrient absorption and utilization at later stage.

Influence on shoot growth index in different water and nitrogen treatments: Shortage of water and nitrogen could cause wheat aboveground organs growth reduction (Table 4). Such as, at the flowering stage stems, leaves and spike dry weight in low water treatment were only 0.69-0.88, 0.40-0.53 and 0.78-0.79 of high water treatment and those index in no nitrogen treatment were only 0.70-0.89, 0.78-0.89 and 0.77- 0.96 of high nitrogen treatment. Growth of shoot organ was mainly restricted by water and nitrogen, but the changes of spike weight varied from vegetative organs under the condition of spike coordinating growth and assimilate prior distribution (Zhang *et al*., 2010). At flowering stage, with nitrogen increased spike weight increased, but excessive nitrogen dripped (in high nitrogen treatment) would lead to imbalance between wheat

Table 2: Changes of root growth index in different water and nitrogen treatments

Growing stage	Treatment Nitrogen	Water	Root dry weight (g)	Root length (mm)	Root diameter (mm)	Root surface area (mm^2)	Root length density (mm/cm^3)
Flowering stage	N_0	W_l	0.353ab	8892.5e	0.739c	f20637.1	6.336d
		W_m	0.333a	4985.1c	0.310a	4849.3b	3.552b
		W_h	0.373cd	4096.8ab	0.509b	6547.2c	2.919a
	N_{225}	W_l	0.389cde	7543.2d	0.751c	17799.3e	5.375c
		W_m	0.369bc	4189.2b	0.322a	4238.1a	2.985a
		W_h	0.409e	3854.3a	0.521b	6309.6c	2.746a
	N_{450}	W_l	0.375cd	7785.7d	0.747c	18278.3e	5.547c
		W_m	0.355ab	4985.1c	0.318a	4983.6b	3.552b
		W_h	0.395de	5203.6c	0.517b	8456.2d	3.708b
Milking stage	N_0	W_l	0.185a	4188.3c	0.471de	6197.7d	2.984c
		W_m	0.196abc	5270.5d	0.443d	7333.7e	3.755e
		W_h	0.190ab	2587.1a	0.183a	1486.2a	1.843a
	N_{225}	W_l	0.193abc	4535.9c	0.386c	5506.4c	3.232d
		W_m	0.209cde	6418.7e	0.558f	11250.5f	4.573f
		W_h	0.208cd	4535.9c	0.497e	7089.0e	3.232d
	N_{450}	W_l	0.202bc	3710.8b	0.302b	3518.5b	2.644b
		W_m	0.223de	6394.2e	0.673g	13518.0g	4.556f
		W_h	0.227e	5312.0d	0.812h	13552.6g	3.785e

In each growing stage, values followed by different letters in the same column are significantly different at $p<0.05$

Table 3: Coefficient of variation (%) of root growth index in different water and nitrogen treatments

Stage	Factor	Root dry weight	Root length	Root diameter	Root length density	Root surface area
Flowering stage	Nitrogen	2.90	12.88	0.60	15.01	12.98
	Water	3.56	27.28	33.49	32.07	63.45
Milking stage	Nitrogen	6.61	37.96	59.30	42.41	78.09
	Water	3.40	13.52	16.94	13.62	26.14

Table 4: Changes of dry weight of shoot organ in different water and nitrogen treatments

Development stage	Treatment Nitrogen	Water	Canopy dry weight (g)	Stem dry weight (g)	Leaf dry weight (g)	Spike dry weight (g)	Total (g)
Flowering stage	N_0	W_l	1.364a	0.681a	0.184b	0.499b	1.716a
		W_m	1.584bc	0.794c	0.362ef	0.429a	1.916b
		W_h	1.804d	0.772bc	0.397fg	0.634cd	2.177cde
	N_{225}	W_l	1.565b	0.724ab	0.140a	0.702e	1.954bc
		W_m	1.816de	0.899d	0.317d	0.600c	2.185de
		W_h	2.067e	0.940de	0.353e	0.774f	2.476fg
	N_{450}	W_l	1.654c	0.767bc	0.235c	0.651cde	2.029bcd
		W_m	1.935de	1.005e	0.413gh	0.517b	2.290ef
		W_h	2.216f	1.108f	0.448h	0.660de	2.611g
Milking stage	N_0	W_l	1.386a	0.387a	0.228b	0.771a	1.571a
		W_m	1.923bc	0.468bcd	0.362e	1.094b	2.119bc
		W_h	2.084c	0.495cd	0.441g	1.148b	2.275c
	N_{225}	W_l	1.770b	0.425ab	0.184a	1.161b	1.963b
		W_m	2.307d	0.514de	0.317d	1.475c	2.516d
		W_h	2.468de	0.550ef	0.397ef	1.522c	2.676de
	N_{450}	W_l	1.876bc	0.463abc	0.279c	1.134b	2.078bc
		W_m	2.413de	0.561ef	0.413g	1.440c	2.636de
		W_h	2.574e	0.604f	0.492h	1.478c	2.801e

In each growing stage, values followed by different letters in the same column are significantly different at $p<0.05$

vegetative growth and reproductive growth, which tend to appear unsuccessful transformation to reproductive growth, exuberant growth of stem and leaf, spike organ growth restricted and spike weight dropped. While at milking stage, spike weight presented low-high-low tendency with the increase of nitrogen. In other words, too high or too low nitrogen didn't conduce to grain milking. Whether at flowering stage or grain milking stage, spike weight all decreased in shortage of water treatment, especially severe at milking stage. In addition, shoot growth amount in low water-high nitrogen treatment and high water without nitrogen treatment was higher than that of low water without nitrogen treatment, which indicated water increase slowed down the growth inhibition by nutrient stress. Similarly, nutrients increase could also slow down water stress inhibition (Sadras, 2004), but the phenomenon that shoot trait values in high water-low nitrogen were higher than those of high nitrogen-low water, reflected the former (regulating fertilizer by water) effect was bigger in the bidirectional compensation.

From the extent of influence on canopy organ growth in water and nitrogen single factor experiment (Table 5), low water and less nitrogen greatly affected the growth of stem and leaf at flowering stage and affected leaf and spike weight greatly at milking period, among which the variation of leaf dry weight was the biggest in water treatment at flowering stage and in nitrogen treatment at milking stage, indicating at

Table 5: Coefficient of variation (%) of dry weight of shoot organ in different water and nitrogen treatments

Stage	Factor	Canopy dry weight	Stem dry weight	Leaf dry weight	Spike dry weight	Total
Flowering stage	Nitrogen	6.98	13.45	10.21	6.08	6.16
	Water	9.59	9.85	25.76	8.70	8.25
Milking stage	Nitrogen	7.29	8.61	22.12	9.39	7.21
	Water	11.18	6.86	8.45	9.70	10.52

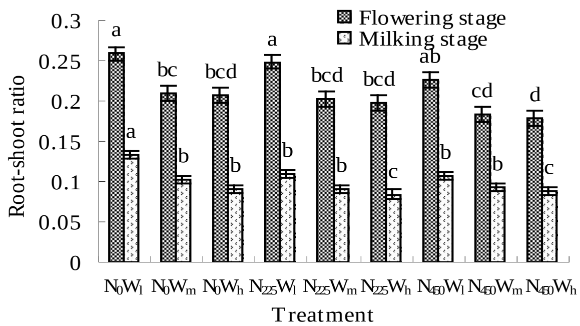

Fig. 1: Effects of different water and nitrogen on the growth of root and shoot of spring wheat
Vertical lines indicate the standard error; Square columns with same colors and letters are not significantly different at p<0.05

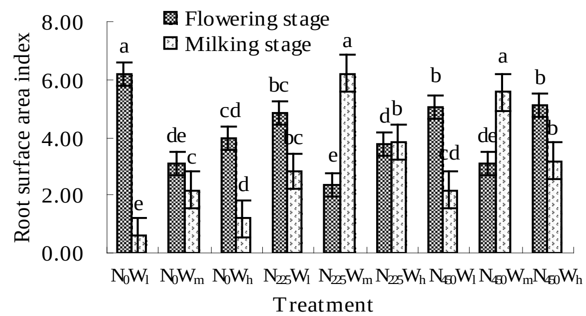

Fig. 2: Effects of different water and nitrogen on the root surface area index of spring wheat
Vertical lines indicate the standard error; Square columns with same colors and letters are not significantly different at p<0.05

flowering stage leaf growth was mainly affected by the influence of soil moisture while at milking stage mainly by the influence of soil nitrogen level, which was because the flowering period was the maximum period of wheat group LAI (Xie *et al*., 2005) and at this stage water stress seriously affected group LAI and lead to poor growth of shoot (poor growth and dwarf plant in actual wheat drought field); milking period was the period for plant to transfer from vegetative to reproductive development when assimilate was sent to spike from vegetative organs and leaf function gradually weakened and at this stage deficiency of nitrogen accelerated leaf senescence and rapid drop of leaf dry weight. Generally speaking, the effect of water factor on shoot organ growth was higher than the amount of nitrogen for the two factors.

Influence on biomass distribution and ratio of root to shoot: The ratio of root to shoot represents wheat biomass distribution affected by water and nitrogen. From Fig. 1, the ratio at milking stage was significantly lower than that of flowering stage, which was because the flowering period was a nutrient demand maximum period for plant (Jack, 1988) and high ratio of root to shoot ensured root to absorb enough water and nutrient; The ratio of low water no fertilizer treatment (N_0W_1) was significantly higher than other treatments and even 45% higher than high water and high nitrogen treatment ($N_{450}W_h$), which indicated water and nitrogen deficiency caused wheat biomass to be transported to root and to promote root growth, so as to enhance the absorption ability of root to satisfy the moisture and nutrient demand, which was one of ecological performance for wheat to adapt the drought barren environment (Wang *et al*., 2011b). No matter how much nitrogen was dripped, the ratio of root to shoot by high water treatment decreased by 25.1-27.2% and 22.3-46.0% that of low water treatment at flowering and milking stage respectively; The ratio in high nitrogen treatment decreased by 14.1-15.9% and 3.6-23.7% than no nitrogen treatment at flowering and milking stage without considering water effects. These results showed during matter distribution, loss of water contributed more for biomass to transport to root than nitrogen loss. So, water regulation was very important. Besides, root growth rate affected by water and nitrogen at milking period was significantly higher that of flowering stage, which also explained the phenomenon that the shoot speed of growing old was faster than root stressed by water and nitrogen.

Effects of different water and nitrogen on the root surface area index of spring wheat: Corresponding with crop Leaf Area Index (LAI), root surface area index is root surface area per unit area on behalf of the root uptake function to a certain extent (Zhang *et al*., 2005). In this experiment, different from LAI influenced by water (Wang *et al*., 2011a), water stress promoted root area index increase at flowering stage (which in low water increased 28.4-56.6% than in high water treatment), while at milking period caused root surface area index decrease (which in low water reduced 26.6-49.1% than in high water treatment). Soil nitrogen nutrition could promote root area index increase and delay the root function decline, especially at milking stage with sufficient nitrogen supply the root surface area was significantly higher than that in low nitrogen treatment. Such as at this period root surface area index in high nitrogen treatment was 2.54-3.26 times of no nitrogen treatment and root kept high absorption function resulting in growing green and late maturity, severely lodging at wheat later period (Fig. 2).

Table 6: Growth and yield traits of the different treatments

Treatment Nitrogen	Water	Plant height (cm)	Spike length (cm)	Number of spikelet	Grain weight per spike (g)	Grains per spike	1000-grain weight (g)	Grain yield (kg/hm^2)	Economic coefficient
N_0	W_l	81.3f	6.0e	13.7e	0.671e	17.3e	38.9e	3304.1e	0.355cd
	W_m	100.3cd	6.9de	14.7de	0.866d	20.2d	42.9cd	4511.8d	0.348d
	W_h	107.1bc	7.3bcd	15.6bcd	0.930cd	20.3cd	45.2ab	5053.9c	0.354cd
N_{225}	W_l	89.3ef	6.9de	14.9cd	0.952cd	22.7b	41.1d	5042.2c	0.397a
	W_m	108.3bc	7.8abcd	15.9abc	1.147ab	25.5a	45.1ab	6249.9a	0.385ab
	W_h	115.1ab	8.2ab	17.0ab	1.211a	25.6a	47.4a	6792.0a	0.386ab
N_{450}	W_l	92.0de	7.1cde	15.4bcd	0.879d	22.2bc	39.4e	4549.0d	0.365bc
	W_m	111.1abc	8.0abc	16.5ab	1.074bcd	25.0a	43.3bc	5756.7b	0.348d
	W_h	117.8a	8.3a	17.6a	1.138ab	25.1a	45.6a	6298.8a	0.344d

In each growing stage, values followed by different letters in the same column are significantly different at p<0.05

Table 7: Quadratic polynomial equation parameters

Item	Equation parameters a	b	c	d	e	f	R^2
Yield	6249.9000	874.9000	-622.500	-332.700	-1115.6000	0	0.9974**
Plant height	108.3100	12.8980	-5.382	-6.130	-2.6146	0	0.9871**
Grain weight per spike	1.1469	0.1295	-0.104	-0.066	-0.1766	0	0.9917**
Economic coefficient	0.3855	-0.0050	0	0.006	-0.0370	0.0049	0.9927**
Spike length	7.7795	0.6241	-0.525	-0.249	-0.3477	0	0.9651**
Number of spikelet	15.9170	1.0508	-0.916	0	-0.3313	-0.0917	0.9488**
Grains per spike	25.5370	1.4531	-2.422	-1.378	-2.9341	0	0.9612**
1000-grain weight	45.0950	3.1161	-0.214	-0.830	-2.0063	0	0.9712**

Influence on yield trait by water and nitrogen: According to the results of wheat morphological and yield traits in different water and nitrogen treatment listed in Table 6, water and nitrogen supply significantly affect the plant height and yield traits. At the same level of nitrogen fertilization, the less water was supplied; the value of plant height, spike length, spikelet number, 1000-grain weight and yield was smaller. Nitrogen application eased the weak of plant height and yield, but too much nitrogen supply, yield presented the declined tendency (the average yield of N_0, N_{225} and N_{450} was 4289.9, 5863.63 and 5543.9 kg/ha); Regardless of the amount of nitrogen, water deficit obviously affected grain weight increase. 1000-grain weight in low water treatment was only 86.5% of high water treatment; and the number of grains per spike in different nitrogen conditions changed greatly. These results indicated that high nitrogen levels was important ensure for increasing seed-setting rate and grain number per spike. Looking from varied economic coefficient, the value was higher in suitable nitrogen and water deficit treatment. The might reason was that high nitrogen caused very strong vegetative growth and low nitrogen was not conducive to individual organ growth. Both could not reasonably regulate nutrient to transport to grain, so causing economic coefficient decreased. The degree of water deficiency inhibited the vegetative growth and improved nutrient transfer rate to seed correspondingly, so the economic coefficient increased in a certain degree.

By two polynomial stepwise regression analysis on the orthogonal test of two factors, the simulation equation $y = a + bX_1 + cX_2 + dX_1^2 + eX_2^2 + fX_1X_2$ was established between water (X_1), nitrogen (X_2) factors and root and shoot growth traits and yield constitute factors (y) (Table 7). Through calculating the extreme for the output equation, the highest yield amounted to 6249.9 kg/ha when irrigation quantity was 5177.6 m^3/ha and fertigation of urea 287 kg/ha. When the amount of water and urea for highest yield was content into establishing binomial equation, the data was obtained as follows: height was 108.3 cm, spike length 7.8 cm, spikelet number was 15.9, spike weight was 1.15 g, grain number per spike was 25.5, 1000-grain weight was 45.1 g and economic coefficient was 0.386.

CONCLUSION

Soil moisture and nitrogen level were the most important factors for crop growth. Appropriate water and nitrogen supply could coordinate plant vegetative growth and reproductive growth; promote efficient utilization of water and nitrogen, improved yield and quality (Campell *et al*., 1977). In this experiment, relationship of root and shoot growth was explored by designing different levels of water and nitrogen on spring wheat and the results showed as follows:

- Water and nitrogen deficiency caused root weight decreased. With water decrease root length increased at flowering stage and firstly increased and then decreased at the milking period. But with nitrogen reduction, root length and root diameter were decreased, especially at milking period. This indicated water and nitrogen played different roles on root growth. In shortage of water treatment at flowering stage root system generated a large number of branches and expanded the root length to establish strong root system to meet nutrient needs for seed formation, but in late growth the terminal root (thin root) appeared premature and caused average root diameter increased. During the milking period, high nitrogen level was conducive to maintaining high root length, slow root senility and continual growth of shoot organ. The influence of water and nitrogen on wheat root production had concern with growth period. At flowering stage root growth was greatly affected by water while at milking stage greatly affected by soil nitrogen supply.

- Water shortage and less nitrogen significantly inhibited shoot organ growth and caused insufficient growth. At flowering stage mainly affected the growth of stems and leaves and at milking stage mainly on matter accumulation of leaf and spike. Too much nitrogen supply caused assimilates distribution and spike weight reduction. In the two factors, water had higher effect on shoot organ growth than nitrogen.
- Water and nitrogen had collaborative compensation effect (Tamaki *et al*., 1999) on shoot growth of spring wheat. The drip of nitrogen fertilizer could alleviate growth inhibition by water deficit. Similarly, water could also improve growth effect promoted by nitrogen. But the compensation effect was different to root and shoot. The effect of regulating water by nitrogen was bigger on root and the effect of regulating nitrogen by water was bigger on shoot, (water relieving weakened effect of shoot growth suffered by nitrogen stress >nitrogen inducing inhibition effect of root growth by water stress). So in the actual production at the key period of root growth and function which at flowering stage (Anderson, 1987) proper water supply (high water easily caused plant fell to ground) should be maintained and nitrogen supply should be paid much attention to give full play to the “regulating water by fertilizer” effect. At late period, when physiological function was weakened (at middle and late milking stage), soil nutrient supply should be reduced to develop the “regulating fertilizer by water effect” by appropriate water supply.
- The ratio of root to shoot at flowering stage was significantly higher than that of milking stage. Moderate deficiency of water and nitrogen contributed to improve the ratio, but the excessive deficiency or high water and nitrogen were not conducive for assimilate transportation to the root and improvement of the ratio, especially more prominent at later stage of spring wheat growth. Water regulation on the ratio of root to shoot was more obvious between water and nitrogen factor.
- At flowering stage water stress promoted root area index increased whereas at milking period promoted this index decrease. Because at flowering period (of root morphology and function maximum period) water deficit stimulated root hydrotropism (Zhang *et al*., 2002), which performance root growing thinner, intensified branches and extension to the deeper soil layer and eventually resulting in root surface area increases. At later milking stage, crops root grew old gradually. Due to persistent drought less water caused plant senescence, root surface area index fell sharply and the plant premature senility. Nitrogen nutrients mainly promoted root area index increased and the high nitrogen treatment during milking period still maintained higher root area index, causing plant growing green and late maturity.
- Lack of water and nitrogen all caused the decline in output. Water deficit had great effects mainly on plant height, grain weight, spike length and nitrogen deficiency mainly affected the grain number per spike and economic coefficient. In addition, the high nitrogen levels could cause decline on the grain weight per spike and economic coefficient. Through the growth and yield simulation equation set up under the influence of water and nitrogen by mathematical analysis method, water and nitrogen application amount under high yield were obtained by simulation, which was 5177.6 m^3/ha and 287 kg/ha with the output of 6249.9 kg/ha, plant height of 108.3 cm, grain number per spike 25.5, 1000-grain weight of, 45.1 g, economic coefficient of 0.386.

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