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Research Article

Effect of Nitrogen Fertilizer and Deficit Irrigation on Vegetative Growth of Winter Wheat

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ABSTRACT

Deficit irrigation is an important limiting factor for crop growth and production in some regions of the world. It elicits several morphological responses in crop plants. Most of these responses are adaptive mechanisms to withstand water deficit or drought and to ensure both survival and reproduction. Application of nitrogen fertilizer has advantages like improving crop growth and grain yield. In view of this, a greenhouse experiment was conducted at the experimental farm of Agricultural Engineering department, Hohai University, Nanjing, China to study the effects of nitrogen fertilizer and drought on the growth of wheat. The experiment was laid out in a randomized complete block design with three blocks and six treatments combinations. Treatments included two factors: factor a: deficit irrigation in three levels: no stress (a1), mild stress (a2) and serious stress (a3) and factor b: nitrogen fertilizer (control (b1), 240 kg/ha (b2)). Analysis of variance showed that the effect deficit irrigation and fertilizer was significant on total plant biomass.

Key words: Deficit irrigation, Green house, Nanjing, Nitrogen fertilizer, Vegetative growth, Wheat

INTRODUCTION

Wheat (*Triticum aestivum.* L) is one of the most important staple food grains of human race. It contributes substantially to the food security crops in the world. In 2013, the global annual production of wheat was 718.13 million tons, thus, feeding about one fifth of the human population (FAO, 2014). The rapidly increasing population will need to double the current wheat production until 2050 to ensure food supply for future generations (Beddington, 2011).

Wheat is quite sensitive to water stress. Therefore, it needs frequent irrigation for good growth and yield (Alderfasi and Nielsen, 2001). Usman, 2013; Yu *et al.*, 2013 stated that water shortage is among the major abiotic stress that limits the productivity of cereals. It often causes nutrient deficiency particularly phosphorus (Haefele *et al*., 2006). Average wheat yields throughout the world approach only 30 to 60% of maximum attainable yields, with water deficits and elevated temperatures causing the greatest reduction (Saddique *et al*., 2000).

The percentage of drought affected areas in the world has doubled from the 1970s to the early 2000s (Isendahl and Schmidt, 2006). Therefore, an appropriate management of irrigation is necessary to preserve water resources, quantitatively and qualitatively, and to produce more food with the available water. Regulated deficit irrigation can be a possible option to get more crops per drop of water (Al-Harbi *et al*., 2015). It helps to reduce water consumption and minimize adverse effects on yield. Irrigating the crop only at drought sensitive growth stages and withheld water at other stages can help to manage water resources to meet crop requirement (Du *et al.*, 2010). Ali *et al.*, (2007) identified the stages tillering, stem elongation, booting, and grain formation as moisture sensitive stage in wheat crop.

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In addition to deficit irrigation, efficient nitrogen fertilization is crucial for economic plant production and the protection of ground and surface waters (Alley *et al.*, 1999). Nitrogen fertilizer rate and timing are the major tools available after planting for manipulating plant growth and development to produce a greater grain yield per unit area (Alley *et al.*, 1999). Many studies have revealed the increase in yield due to increase in nitrogen rate (Dumond *et al.*, 2016; Awais *et al.*, 2017) but it is not linear. So optimized rate of nitrogen, particularly in scenario of limiting water can help to sustain productivity as the loss of nitrogen due to leaching is dependent on availability of water and nitrogen management practices (Behers and Panda, 2009).

Informations about the effects of nitrogen fertilizer and deficit irrigation on vegetative growth of winter wheat under controlled conditions are scanty. Thus, the objectives of the study are:

(1) To examine the effects of nitrogen fertilizer with or without deficit irrigation on vegetative growth of wheat.
(2) To investigate the impacts of nitrogen fertilizer with or without water stress on total biomass of winter wheat.

MATERIALS AND METHODS

Experimental site

A greenhouse experiment was conducted at the experimental farm of Agricultural Engineering department, Hohai University, Nanjing, China ($31^0$95' N latitude and $118^0$83' E longitude). The climate is sub humid with an average rainfall of 1106 millimeter (mm). The soil of the experimental site is clay loam with 33.81% clay, 65% silt, 0.97% sand and a pH (1:2.5 soil: water) of 7.96. Wheat variety 158 was used as a test crop.

Experimental details

The experimental design is a randomized block design with three replications. Six treatments have considered :(1) No fertilizer - No stress (-F-S), (2) Plus fertilizer - No stress (+F-S), (3) No fertilizer - Mild stress at seedling stage (-F+S1), (4) Plus fertilizer - Mild stress at seedling stage (+F+S1), (5) No fertilizer - Serious stress at seedling stage (-F+S2), (6) Plus fertilizer - Serious stress at seedling stage (+F+S2). Each plot is 2.25m x 1.5 m. The seed was sown in rows of 25 cm width and at a depth of sowing of 5 cm. Prior to sowing; urea was applied in rows 10 cm deep at the rate of 375 kg/ha for all plots.

Plant parameters measurements started 3 weeks after plant emergence, which is when 40% of plants have 5 leaves. Plant diameter was measured with Vernier Caliper at 5 cm above the ground, while plant height was measured with a measuring tape.

Plant height, number of leaves and plant diameter were measured every three weeks. Plants were exposed to stress at seedling stage at 31 Days after planting (DAP). At the end of stress time, that is at 45 DAP, urea (CO $(NH_2)_2$) at the rate of 240 kg/ha was applied to plots. Shoot biomasses were taken, oven dried for 48 hours at 65°C and thereafter weighed.

Water applied

Table 1 shows the amount of irrigation applied to different treatments during the growing of wheat.

Table 1: Amount of irrigation in millimeters applied to different treatments during the growing of winter wheat

Date	Treatments a)					
	-F-S	+F-S	-F+S1	+F+S1	-F+S2	+F+S2
November 20	24	24	24	24	24	24
December 25	30	27	24	26	0	0
January 22	13	16	0	0	0	0
March 14	54	54	44	52	45	46
April 2	56	55	45	47	40	38
April 11	28	19	35	26	20	12
April 22	49	47	42	50	47	33
May 9	51	50	44	38	44	33
Total b) (mm)	305	292	258	263	220	186

a) –F-S (no fertilizer no stress); +F-S (plus fertilizer no stress); -F+S1 (no fertilizer plus mild stress); +F+S1 (plus fertilizer plus mild stress); -F+S2 (fertilizer plus serious stress); +F+S2 (plus fertilizer plus serious stress) b) mm (millimeters).

Statistical analyses

All statistical analyses were performed using General Linear Models (GLM) procedures in SPSS, Version 20 package. Two-way ANOVA analyses were carried out over all six treatments to test explicitly the effects of nitrogen fertilizer and deficit irrigation on growth parameters of wheat. Water application and fertilizer application were treated as fixed factors in all the analyses while plant diameter, plant height, number of leaves, number of tillers, and total shoot biomass as dependent variables. Correlation analyses were carried out between number of tillers and plant diameter or plant height or number of leaves.

RESULTS AND DISCUSSION

Number of tillers and plant diameter

Tables 2 and 3 showed the number of tillers and plant diameter of the six treatments. Nitrogen has significant effects on number of tillers at 3 Weeks After Planting (WAP). Nitrogen is known to promote tillering, improved length and width of leaves which in turn increases the plant height and dry matter which are responsible for increase in straw yield. Deficit irrigation significantly affects number of tillers at 18 Weeks After Planting (WAP). The highest number of tillers (2.25) was observed on "no fertilizer no stress" treatment at 3 WAP, while le lowest value (1.17) was recorded on "no fertilizer plus mild stress" treatment at 18 WAP. Deficit irrigation, fertilization and their interaction did not have any significant effect on plant diameter during the whole growth of wheat. However, there is a significant positive correlation ($P<0.01$) between number of tillers and plant diameter during the whole growth of wheat.

Plant height and number of leaves

Tables 4 and 5 showed the plant height and number of leaves of the six treatments. Water application significantly affects plant height at 3, 6 and 18 WAP. After water recovery, mild stress treatment has the highest plant height (93.21 cm). Water stress at vegetative and reproductive stages significantly decreased the plant height and spike length. Reasons could be elongation and extension of cell which reduced plant tissue development and growth. Our results concur with those of Carmier *et al.* (2006) who reported that irrigation influenced plant height and dry matter. Tahir *et al.* (2006) reported 53%

Table 2: Number of tillers of winter wheat with respect to varying treatments during the growing season

	Treatments [a)]					
WAP [b)]	-F-S	+F-S	-F+S1	+F+S1	-F+S2	+F+S2
3	2.25	1.42	1.83	1.58	2.25	1.50
6	2.25	1.58	1.83	1.58	2.00	2.00
9	2.08	1.58	1.92	1.58	2.08	2.17
12	2	1.33	1.67	1.58	2	1.92
15	1.27	1.73	1.33	1.25	1.83	1.92
18	1.18	1.36	1.17	1.08	1.64	1.67

[a)] –F-S (no fertilizer no stress); +F-S (plus fertilizer no stress); -F+S1 (no fertilizer plus mild stress); +F+S1 (plus fertilizer plus mild stress); -F+S2 (fertilizer plus serious stress); +F+S2 (plus fertilizer plus serious stress). [b)] WAP (Weeks after planting).

Table 3: Plant diameter in millimeter of winter wheat with respect to varying treatments during the growing season

	Treatments [a)]					
WAP [b)]	-F-S	+F-S	-F+S1	+F+S1	-F+S2	+F+S2
3	3.33	3.46	4.04	3.50	3.00	3.67
6	3.58	3.54	3.50	3.75	3.17	3.25
9	3.27	3.17	3.15	3.35	3.29	3.40
12	3.34	3.02	3.13	3.15	3.10	2.63
15	3.45	3.61	3.54	3.71	2.88	3.29
18	3.48	3.45	3.50	3.50	3.70	3.29

[a)] –F-S (no fertilizer no stress); +F-S (plus fertilizer no stress); -F+S1 (no fertilizer plus mild stress); +F+S1 (plus fertilizer plus mild stress); -F+S2 (fertilizer plus serious stress); +F+S2 (plus fertilizer plus serious stress). [b)] WAP (Weeks after planting).

Table 4: Plant height in centimeter of winter wheat with respect to varying treatments during the growing season

	Treatments [a)]					
WAP [b)]	-F-S	+F-S	-F+S1	+F+S1	-F+S2	+F+S2
3	40.52	39.32	37.96	35.57	35.53	32.09
6	47.79	47.48	46.46	42.27	42.77	37.47
9	58.29	57.29	60.50	55.75	57.75	50.79
12	82.09	77.71	85.88	80.21	82.46	77.46
15	84.62	83.41	93.21	86.75	90.08	83.92
18	84.14	80.05	92.83	88.54	89.91	84.96

[a)] –F-S (no fertilizer no stress); +F-S (plus fertilizer no stress); -F+S1 (no fertilizer plus mild stress); +F+S1 (plus fertilizer plus mild stress); -F+S2 (fertilizer plus serious stress); +F+S2 (plus fertilizer plus serious stress). [b)] WAP (Weeks after planting).

Table 5: Number of leaves of winter wheat with respect to varying treatments during the growing season

	Treatments [a)]					
WAP [b)]	-F-S	+F-S	-F+S1	+F+S1	-F+S2	+F+S2
3	4.50	3.67	4.25	3.75	4.25	3.83
6	6.50	5.17	5.08	5.42	5.83	5.50
9	8.75	7.25	8.33	7.75	9.75	9
12	6.18	5.58	6.75	6.42	8.08	8
15	4.73	5. 64	5.25	4.92	6.33	6.92
18	4.18	3.28	4.08	4	4.64	5.75

[a)] –F-S (no fertilizer no stress); +F-S (plus fertilizer no stress); -F+S1 (no fertilizer plus mild stress); +F+S1 (plus fertilizer plus mild stress); -F+S2 (fertilizer plus serious stress); +F+S2 (plus fertilizer plus serious stress). [b)] WAP (Weeks after planting).

Table 6: Total plant biomass and grain yield of winter wheat with respect to varying treatments during the growing season.

	Treatments [a)]					
Plant biomass	-F-S	+F-S	-F+S1	+F+S1	-F+S2	+F+S2
T plt biomass [b)]	3185.19	2577.78	4294.81	2774.81	3266.67	2450.37
Grain yield	3171.91	2406.13	3228.53	2132.74	2556.50	1953.6

[a)] –F-S (no fertilizer no stress); +F-S (plus fertilizer no stress); -F+S1 (no fertilizer plus mild stress); +F+S1 (plus fertilizer plus mild stress); -F+S2 (fertilizer plus serious stress); +F+S2 (plus fertilizer plus serious stress); [b)] T Plt biomass (total plant biomass).

reduction in plant height and spike length with increasing amount of irrigation. Water stress reduced growth through disturbing the balance of reactive oxygen species and antioxidant defense. Deficit irrigation affects number of leaves at 12, 15 and 18 WAP. The interaction of fertilizer and deficit irrigation was significant 18 WAP. Plant height are significantly positively ($P<0.01$) correlated with number of leaves during the growth of wheat.

Total plant biomass and grain yield

Mean shoot biomass and grain yield are presented in Table 6. Fertilizer applications have a significant effect on total plant biomass and grain yield. This trend is in agreement with those reported by Bokhtiar and Sakurai (2005) on sugarcane and Barros *et al*., 2007 on intercropped maize/cowpea. Nitrogen is an important component of major structural, genetic, and metabolic compounds in plant cells, including chlorophyll, amino acids, adenosine triphosphate, and nucleic acids such as DNA (Marschner, 1995).

In the present study, deficit irrigation significantly affects total plant biomass. Panda *et al*., 2003 stated that, an appropriate deficit irrigation system with fresh water can increase irrigation efficiency without significantly decreasing yield. Responses of wheat growth to water deficits vary depending on wheat species and growth stages. Ahmadi *et al.* (2006) stated that there was a significant reduction in grain yield and 1000 grain weight under drought stress treatment condition. In the present study, Mild stress at seedling stage produces higher biomass (1449.5 kg/ha). This might be due to the compensatory effects cause by water stress which improved physiological activity of plant tissue. Water stress at seedling stage had additional benefits of stimulating root system development and substantially enhanced root-to-shoot ratio, which helps plants to withstand drought occurring at stem elongation stage. There is a significant positive correlation ($P<0.01$) between number of biomass and grain yield wheat.

Conclusions

The effects of combinations of nitrogen fertilizer and deficit irrigation on vegetative growth of wheat were studied in the green house. Fertilizer applications have a significant effect on total plant biomass. Mild stress at seedling stage produces higher biomass. Deficit irrigation of wheat should coincide with earlier growth stages to ensure minimal yield reduction. Further field studies are needed to extrapolate the findings to a wider range of seasonal and site conditions.

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