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Response of Biological Growth and Fiber Quality of Cotton to Different Application Rates of Nitrogen

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Abstract: This study was carried out to determine the response of biological growth and fiber quality of cotton (*Gossypium hirsutum*) to different application rates of nitrogen. Nitrogen was applied to the soil at the rates of 0, 100, 200 and 300 kg ha^{-1}. Statistical results of study showed that N application significantly ($P \leq 0.05$) increased boll numbers, boll weight per plant, seed cotton weight of boll, seed cotton yield and lint yield. Moreover, leaf blade N concentration was affected by N application rate and increased significantly. Results of study also showed that the highest seed cotton yield was obtained in case of 200 kg ha^{-1} N application rate and this application rate resulted in 19.6% increased seed cotton yield. Statistical results showed that effect of different application rates of N was not significant for all studied fiber properties (fiber length, fiber strength and fiber fineness). Generally, application of 200 kg ha^{-1} N resulted in the highest boll numbers, boll weight per plant, seed cotton yield and lint yield.

Key words: Cotton · Nitrogen · Biological growth · Fiber quality · Iran

INTRODUCTION

In Iran, main portion of soils suffer from lack of organic matter and show nitrogen (N) deficiency. For this reason, N is one of the most important elements for crop production and agricultural productions highly depend on this element [1]. Like most crops, cotton requires N for normal growth and development and farmers greatly rely on N fertilizers. Several studies have been done to study the effect of N on cotton [2-6]. N is required for all stages of plant growth and development because it is the essential element of both structural (cell membranes) and nonstructural (amino acids, enzymes, protein, nucleic acids and chlorophyll) components of the plant. Without sufficient N, deficiency symptoms such as stunting, chlorosis and fewer and smaller bolls are prevalent in cotton [7]. Also, cotton canopy development is strongly influenced by N uptake [8]. During the vegetative stage of growth, rapid expansion of the leaves requires large amounts of N and both fruit production and retention are dependent on leaf development and photosynthetic integrity [9]. Hearn [10] found that cotton requires about 90 kg ha^{-1} N for one bale of lint and about 140 kg ha^{-1} N for two bales of lint depending upon soil texture. However, N uptake can be as much as 230 kg ha^{-1} and N removal at harvest can be as much as half of total uptake. Among the plant nutrients, N plays a very important role in crop productivity. It is an important determinant of biological growth of irrigated cotton [11]. Typically, applications of 100 to 215 kg ha^{-1} N fertilizers are required to optimize lint yield [12-15].

In Iran, meager researches have been done to study the response of cotton to N and there is no recommended application rate. As N can agronomically and physiologically affect cotton, the main objective of this study was to determine the response of biological growth and fiber quality of cotton to different application rates of N and finding appropriate application rate of N for cotton production in the arid lands of Iran.

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Table 1: Soil physical and chemical properties of the experimental site during study years 2009 and 2010 (0-30 cm depth)

Date	pH	EC (dS m^{-1})	OC (%)	TNV (%)	P (ppm)	K (ppm)	Fe (ppm)	Zn (ppm)	Cu (ppm)	Mn (ppm)	B (ppm)	Soil texture
2009	7.3	3.4	0.72	17	10.6	200	4.4	0.90	1.4	12.3	0.4	Clay loam
2010	7.6	3.0	0.81	17	9.50	224	5.2	0.42	0.5	11.5	0.5	Clay loam

MATERIALS AND METHODS

Research Site: This study was conducted at the Research Site of Tehran Province Agricultural and Natural Resources Research Center, Varamin, Iran on a clay loam soil identified as average in total N (0.07%) for two successive growing seasons (2009 and 2010). The experimental site is located at latitude of 35°19' N, longitude of 51°39' E and altitude of 1000 m in arid climate (150 mm rainfall annually) in the center of Iran.

Weather Parameters: The mean temperature and monthly rainfall of the research site from sowing (May) to harvest (November) during study years (2009 and 2010) are indicated in Fig. 1.

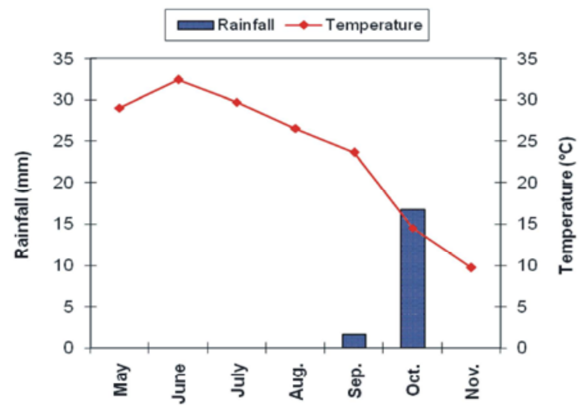

Fig. 1: Mean monthly rainfall and temperature from sowing to harvest (mean of 2009 and 2010)

Soil Sampling and Analysis: The soil of the experimental site is classified as an Aridisol (fine, mixed, active, thermic, typic haplocambids). A composite soil sample (from 36 points) was collected from 0-30 cm depth 30 days prior to planting during the study years and was analyzed in the laboratory for pH, EC, OC, TNV, P, K, Fe, Zn, Cu, Mn, B and particle size distribution. Details of soil physical and chemical properties of the research site during the years of study (2009 and 2010) are given in Table 1.

Field Methods: The experiments were laid out in a randomized complete block design (RCBD) with three replications. Different treatments were four levels of N fertilizer, i.e. 0, 100, 200 and 300 kg ha^{-1} N as Urea. Each of the 100, 200 and 300 kg ha^{-1} N were split into two applications, i.e. one third at pre-planting and two third at pinhead square. Application rates were maintained on the same plots by banding application. The treatments were carried out on the same plots in the 2009 and 2010 growing seasons. The size of each plot was 12.0 m long and 6.0 m wide. A buffer zone of 3.0 m spacing was provided between plots. In both growing seasons, one of the most commercial varieties of cotton cv. Varamin was planted manually on May 5, 2009 and May 7, 2010. Plots consisted of 6 rows of cotton planted with row spacing 0.8 m. Plots were over seeded and then thinned by keeping plant to plant distance 20 cm, or a population of 62,500 plants ha^{-1}, at approximately the first or second true leaf stage. Management was consistent with typical agronomic practices used for upland production in the region. For all treatments, irrigation scheduling was based on the basis of soil water content monitoring. Also, pest and weed control operations were performed based on common local practices and commendations. All other essential operations were kept identical for all the treatments.

Observation and Data Collection: Leaf samples were obtained by removing 20 leaves from the uppermost fully expanded main stem leaves from each plot. After all bolls matured, all seed cotton at 10 meter lengths of the four center rows was hand harvested at approximately 70% open boll for biological growth analyses. Yield was determined by hand harvesting the four center rows from each plot twice and weighing the seed cotton. Twenty plants in each plot were randomly selected in mid-September of each year for measurement of number of open bolls. Boll weight per plant and fiber data were obtained from 20 hand-harvested boll samples collected from 0.5 m of the two outer rows. Lint yields were calculated by multiplying the lint percentage by seed cotton weights. Fiber properties for each sample were determined in High Volume Instruments (HVI).

Statistical Analysis: All data were subjected to the Analysis of Variance (ANOVA) following Gomez and Gomez [16] using SAS statistical computer software. Moreover, means of the different treatments were separated by Duncan's Multiple Range Test (DMRT) at $P \leq 0.05$.

RESULTS AND DISCUSSION

Boll Numbers: Statistical results of study indicated that different application rates of N significantly ($P \leq 0.05$) affected boll numbers (Table 2). Results showed that boll numbers significantly increased with increasing N application rate. The highest boll numbers (19.8) was obtained in case of 200 kg ha^{-1} N treatment but there was no significant difference between 200 and 300 kg ha^{-1} N treatments. The lowest boll numbers (12.9) was obtained in case of 0 kg ha^{-1} N treatment (Table 2). These results are in agreement with those obtained by Oosterhuis and Steger [17] who concluded that N application considerably increased boll numbers.

Boll Weight per Plant: Results of study also showed that different application rates of N significantly influenced boll weight per plant (Table 2). Results indicated that boll weight per plant significantly increased by increasing N application rate. The highest boll weight per plant (6.90 g) was recorded in case of 200 kg ha^{-1} N treatment but there was no significant difference among 100, 200 and 300 kg ha^{-1} N treatments. The lowest boll weight per plant (6.26 g) was recorded in case of 0 kg ha^{-1} N treatment (Table 2). These results are also in line with those reported by Oosterhuis and Steger [17] that N application noticeably increased boll weight per plant.

Seed Cotton Weight of Boll: Statistical results of study indicated that different application rates of N significantly affected seed cotton weight of boll (Table 2). Results showed that seed cotton weight of boll significantly increased with increasing N application rate. The highest seed cotton weight of boll (4.49 g) was obtained in case of 200 kg ha^{-1} N treatment but there was no significant difference among 100, 200 and 300 kg ha^{-1} N treatments. The lowest seed cotton weight of boll (4.11 g) was obtained in case of 0 kg ha^{-1} N treatment (Table 2).

Seed Cotton Yield: Results of study showed that different application rates of N significantly influenced seed cotton yield (Table 2). Results indicated that seed cotton yield significantly increased by increasing N application rate. The highest seed cotton yield (4363 kg ha^{-1}) was recorded in case of 200 kg ha^{-1} N treatment and there was no significant difference between 200 and 300 kg ha^{-1} N treatments. Therefore, for reaching the highest seed cotton yield use of 200 kg ha^{-1} N can be recommended. The lowest seed cotton yield (3642 kg ha^{-1}) was recorded in case of 0 kg ha^{-1} N treatment (Table 2). The maximum increase in seed cotton yield with 200 kg ha^{-1} N treatment was about 19.6% as compared to 0 kg ha^{-1} N treatment.

Lint Yield: Statistical results of study indicated that different application rates of N significantly affected lint yield (Table 2). Results showed that lint yield significantly increased with increasing N application rate. The highest lint yield (1659 kg ha^{-1}) was obtained in case of 200 kg ha^{-1} N treatment but there was no significant difference between 200 and 300 kg ha^{-1} N treatments. Therefore, for reaching the highest lint yield use of 200 kg ha^{-1} N can be recommended. The lowest lint yield (1489 kg ha^{-1}) was obtained in case of 0 kg ha^{-1} N treatment (Table 2). Results of this study suggested that greater lint yields at elevated levels of N may have been due to the greater number of bolls per plant. These results are in line with the results reported by Boquet *et al*. [18] that application of optimal N rates may have beneficial effects on lint yield by producing larger bolls at a greater number of fruiting sites.

Leaf Blade N Concentration: Results of leaf blade chemical analyses showed that different application rates of N significantly affected leaf blade N concentration (Table 2). The highest leaf blade N concentration (4.21 mg kg^{-1}) was recorded in case of 300 kg ha^{-1} N treatment and the lowest leaf blade N

Table 2: Effect of different application rates of N on biological growth components of cotton (mean of 2009 and 2010)

Application rate of N (kg ha^{-1})	Boll numbers * (plant^{-1})	Boll weight per plant * (g)	Seed cotton weight of boll * (g)	Seed cotton yield * (kg ha^{-1})	Lint yield * (kg ha^{-1})	Leaf blade N concentration * (mg kg^{-1})
0	12.9 c	6.26 b	4.11 b	3642 c	1489 c	2.22 c
100	17.2 b	6.50 ab	4.41 ab	4151 b	1596 b	3.16 b
200	19.8 a	6.90 a	4.49 a	4363 a	1659 a	3.61 b
300	19.6 a	6.80 a	4.47 a	4358 a	1649 a	4.21 a

NS = Non-significant

* = Significant at 0.05 probability level

Means in the same column with different letters differ significantly at 0.05 probability level according to DMRT.

Table 3: Effect of different application rates of N on fiber quality of cotton (mean of 2009 and 2010)

Application rate of N (kg ha^{-1})	Fiber length ^{NS} (mm)	Fiber strength ^{NS} (g tex^{-1})	Fiber fineness ^{NS}
0	29.6 a	28.1 a	5.2 a
100	29.5 a	28.6 a	5.4 a
200	29.2 a	28.7 a	5.3 a
300	30.1 a	29.1 a	5.4 a

NS = Non-significant

* = Significant at 0.05 probability level

Means in the same column with different letters differ significantly at 0.05 probability level according to DMRT.

concentration (2.22 mg kg^{-1}) was recorded in case of 0 kg ha^{-1} N treatment (Table 2). Oosterhuis *et al*. [9] studied the distribution of N in plant components. They found that leaf blade N concentration significantly increased by increasing N application rate.

Fiber Properties: Statistical results of study showed that effect of different application rates of N was not significant for all studied fiber properties, i.e. fiber length, fiber strength and fiber fineness (Table 3). Earlier studies found no or inconsistent effects of the N application rate on fiber length [19, 20]. Similarly, other researchers found no relationship between fiber strength and N application rate [20, 21]. Also, increased N application rates were reported to have no effect at all on micronaire or to increase or decrease micronaire readings [20, 22]. Boman *et al*. [22] reported that micronaire readings were reduced by applied N in low-micronaire environments and increased by applied N in high-micronaire environments.

CONCLUSION

For reaching the highest boll numbers, boll weight per plant, seed cotton yield and lint yield of cotton in the arid lands of Iran use of 200 kg ha^{-1} N was found as the most appropriate and beneficial application rates of N.

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