

Effect of N-fertigation Frequency on the Lint Yield, Chlorophyll, and Photosynthesis Rate of Cotton

O. Cetin^{1*}, N. Uzen¹, and M. G. Temiz²

ABSTRACT

The objectives of this study were to evaluate the effects of nitrogen fertigation frequency on lint yield, lint properties, chlorophyll content (SPAD readings), and the photosynthesis rate (PR) of cotton. This study was carried out in the Southeastern Anatolia Region of Turkey in 2011 and 2012 with drip-irrigated cotton. The maximum lint yield (1,856 kg ha⁻¹) was obtained with one lateral for every two rows and the application of equal doses every two irrigation cycles (10 days). Fertigation frequency of every two irrigation cycles (10 days) increased ($P \leq 0.05$) the fiber strength (32.3 g tex⁻¹), the fiber elongation (6.5%), and the fiber length (28.9 mm). The SPAD readings ranged from 40.1 to 54.9, depending on the treatment and experimental year. There was no significant difference ($P \leq 0.05$) among the SPAD readings. The PR ranged from 35.9 to 74.7 $\mu\text{mol m}^{-2} \text{s}^{-1}$, and there was no significant difference between the treatments. One possible reason for the lack of difference in PR, or SPAD, was that there was no difference in the total amount of nitrogen applied in the different treatments. The PR measured in cotton leaves may also change depending on the environmental conditions during measurement, prevailing ecological conditions, age, and location of the leaf on a plant.

Keywords: Cotton, Chlorophyll (SPAD), Drip irrigation, Nitrogen, Photosynthesis rate.

INTRODUCTION

Cotton is an important cultivation product to the general economy because it provides fiber for textiles. It is grown in the southeastern Anatolia Region of Turkey; approximately 50% of Turkish cotton production occurs in this region. Most of the cotton fields in the area are irrigated by surface irrigation. However, the use of drip irrigation and fertigation for cotton has increased enormously as a result of government subsidies. Drip irrigation and fertigation techniques are more common and complex compared with conventional methods such as surface irrigation and mechanical fertilizing. Thus, it is important to determine the effects of fertigation

frequency and/or method on lint yield and yield components.

A correct management of water and fertilizer application is the key to control water losses and prevent environmental hazards (Ebrahimian and Playan, 2014). Nitrogen (N) is a primary plant nutrient that plays a major role in achieving maximum economic yields. During the vegetative stage of growth, the rapid expansion of leaves requires large amounts of N and both fruit production and retention are dependent on leaf development and photosynthetic integrity (Oosterhuis *et al.*, 1983). Thus, the management of N is part of a balanced fertility program. This can lead to increased efficiency and profitability for farmers (Tisdale *et al.*, 1993).

¹ Department of Farm Structures and Irrigation, Agricultural Faculty, Dicle University, Diyarbakır, Turkey.

² Department of Field Crops, Agricultural Faculty, Dicle University, Diyarbakır, Turkey.

*Corresponding author, e-mail: oner_cetin@yahoo.com



Morrow and Krieg (1990) clarified the importance of timing in nutrient application for improving cotton lint yields. The ability of cotton plants to use N for seed and lint production is influenced by both the quantity and timing of N and water application (Guinn and Mauney, 1984; Mullins and Burmiester, 1990). Another important management practice to improve N efficiency is the appropriate timing of N injection through drip irrigation systems. The N requirement for cotton is not the same over the entire season (Albers *et al.*, 1993).

The N requirements of cotton plants vary depending on the growth rate and growth stage. Cotton leaves contain 60-85% of the total N before flowering; after flowering, the N content declines because it is translocated from the leaves to the developing bolls. A greater amount of N is required in the later growth stages when N supplies typically diminish and there is less root activity (Gerik *et al.*, 1998).

One aspect of N nutrition in cotton is its effect on lint quality. Fritschi *et al.* (2003) reported a positive linear relationship between fiber strength and N fertility level. Boman and Westerman (1994) showed no relationship between fiber strength and N application rate. Bauer and Roof (2004) observed lower lint quality, in terms of fiber length, length uniformity, and fiber strength, in plots that did not receive N fertilization.

Estimation of the total chlorophyll and N contents is a potentially important aspect for both growers and researchers. The soil plant analysis development (SPAD) meter is a simple, portable diagnostic tool for identifying crop N status. This meter measures the 'greenness' or relative chlorophyll concentration of leaves.

The study results carried out by Singh *et al.* (2002) showed that plant need-based N management through chlorophyll meter use reduced the N requirement of rice from 12.5 to 25 %, with no loss in yield. Brito *et al.* (2011) reported that use of the portable chlorophyll meters SPAD-502 and 1030 Clorofilog produced results associated with empirical models and allowed for rapid

prediction of the concentration of photosynthetic pigments in cotton leaves with high accuracy and without the use of chemical reagents or laboratory protocols. Significant correlations between total foliar extractable chlorophyll and chlorophyll content index values obtained with portable chlorophyll meters have been reported for a number of agricultural species including cabbage, cotton, and pea (Marquard and Tipton, 1987). Kariya *et al.* (1982) and Torres-Netto *et al.* (2005) have also reported that chlorophyll meters are now used extensively in agriculture; a hand-held device can quickly estimate the chlorophyll content of leaves, measuring leaf absorbance in two different wavelength regions using two light-emitting diodes.

Photosynthesis is an important chemical reaction in plants, and its measurement plays a critical role in agricultural production and scientific research (Wang *et al.*, 2006). The photosynthesis rate (PR) is affected by light, carbon dioxide, and temperature. As the light intensity increases, so does the PR.

Thus, the measurement of chlorophyll (SPAD) and PR are important parameters for researchers and growers, allowing appropriate crop and other agricultural management practices including fertigation, fertilization, irrigation, and selection of crop cultivars. The objectives of this study were to evaluate the effects of drip fertigation frequency for N on lint yield, lint properties, chlorophyll content, and the PR in cotton.

MATERIALS AND METHODS

Experimental Site

This research was conducted over a 2-year period at the Research Farm of the Agricultural Faculty, Dicle University, in Diyarbakir, Turkey, during the 2011 and 2012 growing seasons.

The location of the site is 37° 54' N, 40° 14' E at an elevation of 660 m above sea level. The soil texture at this site is clay. The climate of the site is typical terrestrial

climatological properties. The average annual rainfall is 487 mm and it occurs mainly during the months of winter and spring season. The average annual (growing season) and daily maximum evaporation from a Class A pan are 976 and 8.4 mm, respectively.

The soil consists of 10% sand, 24% silt, and 66% clay in the top 0-30 cm. The bulk density ranged from 1.19 to 1.27 g cm⁻³ in the soil profile. The infiltration rate was 8 mm h⁻¹. There was no specific risk in terms of water table or soil salinity. The organic matter content, pH, and lime content of the soil were 1.67%, 7.9, and 7.8%, respectively.

Irrigation System

Irrigation water was supplied by drip tubing having a 0.2-mm wall thickness with emitters spaced at 50 cm; and the emitter flow was 3.2 L h⁻¹ to fit the soil properties. The 0.70 m spaced lateral was about 5-10 cm away from the crop row. The 1.40 m spaced laterals were spaced in the middle of alternate rows. Thus, there were two drip tube lateral spacing: 0.70 and 1.40 m. The operating pressure was 100 kPa at the head of the field (150 kPa at the pump). Water flow was measured with the mechanical water meter in each plot.

N Application Frequency

The application method treatments and N

fertigation ratio treatments were applied in blocks within each water supply. Pre-planting N and phosphorus (P) (one-fifth of the total fertilizer) was added to the soil during planting. The remaining fertilizer, containing N, P, and potassium (K) was applied by fertigation in several treatments (Table 1). For fertigation, a pressure differential was created by throttling the water flow in the control head and diverting a fraction of the water through a tank containing the fertilizer solution (Sne, 2006). Fertigation treatment for the application of N at each irrigation was started at the first irrigation and continued through the last irrigation, depending on the treatment. The fertilizer source used in the fertigation blends contained 19-5-5 N, P, and K.

Treatments and Irrigation Scheduling

The experiment was carried out using randomized blocks at split plots with three replications. The main plots contained lateral spacing and the sub-plots were allocated to frequencies of N application (Table 1).

Plots areas were:

Treatment A: 3.50×8.00 m= 28.00 m²

Treatment B: 4.2×8.00 m= 33.6 m²

Irrigation was applied based on the evaporation from a Class A pan for each 5-day period (Cetin and Bilgel, 2002). The percentage of canopy cover (Pc) was used to calculate amount of irrigation water applied for drip irrigation (Hartz, 1993). The Pc was

Table 1. The experimental treatments.

Main plots (Lateral spacing)	Sub-plots (Frequencies of nitrogen applications)
A : 0.70-m	a : Fertigation of nitrogen at each irrigation cycle (5 days)
B : 1.40-m	b : Fertigation of nitrogen at each 2 irrigation cycles (10 days)
	c : Fertigation of one-fifth of total nitrogen between the first irrigation and the first flowering, two-fifth between the first flowering and the first boll formation, and one-fifth between the first boll formation and the last irrigation (3 times).



measured as the average plant width in a row (shaded width) divided by the bed width (row spacing). The Pc was assigned a constant value of 35% (Keller and Bliesner, 1990) until the canopy cover exceeded 35%, after which it was set to the measured value. At that time, the actual measured canopy cover was used for all irrigation cycles.

The amount of irrigation water was sufficient to fill the field to a soil depth of 0-60 cm for the first irrigation. Thus, irrigation was started when the available water in the soil profile (0-90 cm) had decreased to 40% and was ended when 10% of the bolls were open ((Kanber *et al.*, 1991, Cetin and Bilgel, 2002, Bilgel *et al.*, 2005).

Measurement of the Chlorophyll Content and PR

A chlorophyll meter was used to measure the amount of chlorophyll at different stages of cotton growth. Readings were performed on ten selected plants and leaves in each plot. Thus, each plot represented an average reading from all these readings. The leaf chlorophyll content was measured using a Minolta SPAD-502 chlorophyll meter (Tokyo, Japan) on different dates according to blooming and boll formation. Leaf chlorophyll readings were taken on the fifth fully expanded leaf below the terminal of the plant according to Johnson and Saunders (2003).

The PR was measured using an Environmental Analysis and Remote Sensing-PPM-300 device (Karademir *et al.*, 2012). Both the chlorophyll content and PR were measured at 14.00 hr, for all measurement periods.

Agronomical Practices

Except for pre-planting fertilizing, fertigation was used for all fertilizers. Fertigation was performed by the pressure difference method using a fertilizer tank. Thus, injection of the fertilizers into the

system was realized by means of the input and output flows. All fertilizer requirements were determined according to the results of experiments carried out by Ozer and Dagdeviren (1986), Ozer (1992), and Karademir *et al.* (2005) in the same study area. Thus, the total amounts of N and P were 130 kg N ha⁻¹ and 80 kg P₂O₅ ha⁻¹, respectively. As mentioned before, one-fifth of the N and P was applied to the soil before sowing (Burt, 1998; Hartz and Hochmuth, 2005). The remaining amounts of fertilizer were applied by fertigation.

All of the cotton was harvested by hand when mature. Each sample was weighed and ginned. An approximately 1 kg of sub-sample was collected from each plot to determine the lint quality.

Statistical Analysis and Evaluation

Randomized blocks in split plots with three replicates were used to evaluate the effects of the treatments on yield. All data were analyzed using an ANOVA. Variance analyses were made for each experimental year. Additionally, Duncan's multiple test, an acceptable tool for comparisons of discrete data, was used to compare the different treatments (Yurtsever, 1984).

RESULTS AND DISCUSSION

Effects of N Fertigation Frequency on Lint Yield and Lint Properties

The N fertigation frequency significantly ($P < 0.05$) affected the lint yield in 2011 and 2012. The maximum lint yield was obtained from a drip line spacing of 1.40 m, with fertigation every two irrigation cycles in both experimental years.

Comparing the fertigation frequencies, fertigation at an irrigation cycle of 10 days resulted in the maximum yield in both experimental years. This treatment resulted in 12.5 and 19.4% increases in lint yield in 2011, compared with treatments Ba and Bc (Table

2), respectively. In 2012, a similar result was obtained; the increases were 36.2 and 12.5%, respectively. A reason for the lower lint yield at the higher fertigation frequency i.e., every 5 days, may be that a smaller amount of fertilizer was applied to the plots compared with the 10-day treatment regimen. That is, a smaller amount of N for each fertigation at 5-day intervals went into the plots. This may have caused lower uniformity in terms of N and lower absorption by the plants. The cotton plants in the plots with fertigation at an irrigation cycle of 10 days might use the N more efficiently considering the lint yields (Tables 2 and 3).

A fertilizer tank system was used for fertigation i.e. pressure differential method or by-pass system. In this method, the concentration of the solution decreases as the fertilizer dissolves, leading to poorer nutrient placement (Anonymous, 2013, Cetin *et al.*,

2013). Thus, the accuracy of application is limited. Because, more proportion of fertilizer for fertigation at each irrigation cycle (5 days) resulted smaller amounts of N in the soil compared with the other treatments.

Regarding the lint yields, significant differences were detected between the two experimental years. The main reason was likely the difference in sowing date, which was May 20th in 2011 because of the climatic conditions. This was quite late compared with May 10th in 2012. Many researchers, not only in this study area but also in other regions of the world, have shown that a delay in sowing can reduce yield (Yolcu, 1993; Karademir and Sakar, 1999; Hutmacher, 2001; Hassan *et al.*, 2003, Boman and Leser, 2003; Roche *et al.*, 2004; Edmisten, 2008). Another reason for the lower lint yield could be the smaller amount of irrigation water applied in 2011, because of the

Table 2. Lint yield and some quality properties of cotton (2011).

Treatments		Lint yield (kg ha ⁻¹)	Fiber thin	Fiber length	Fiber uniformity	Fiber strength	Fiber elongation
			Mic	(mm)	(%)	(g tex ⁻¹)	(%)
A ^a	a	1026 cd ^c	4.48	27.6	84.5	32.57	6.6
	b	931 d	4.47	26.9	84.8	31.4	6.7
	c	948 d	5.00	27.7	85.4	31.87	6.7
B ^b	a	1281 b	4.89	28.2	85.1	34.3	7.2
	b	1441 a	4.51	28.0	84.5	33.4	7.1
	c	1207 bc	4.54	29.0	84.0	34.4	6.9

^a Lateral spacing, 0.70-m, ^b Lateral spacing 1.40-m, ^c Same letters are not significantly different (*P<0.05) according to a Duncan's multiple range test.

Table 3. Lint yield and some quality properties of cotton (2012).

Treatments		Lint yield (kg ha ⁻¹)	Fiber thin	Fiber length	Fiber uniformity	Fiber strength	Fiber elongation
			Mic	(mm)	(%)	(g tex ⁻¹)	(%)
A ^a	a	1411	5.1	27.9	85.7	30.0	5.4
	b	1810	5.0	28.2	86.5	28.8	5.4
	c	1702	5.1	28.7	87.4	31.5	5.8
B ^b	a	1665	5.0	27.4	86.0	29.6	5.5
	b	2268	4.8	29.7	85.3	31.1	5.8
	c	2017	4.7	27.8	86.0	30.0	5.3

^a Lateral spacing, 0.70-m, ^b Lateral spacing 1.40-m,



shorter vegetation period and lower canopy cover. The lint properties are provided in Tables 2 and 3. Although there was no significant difference among the fertigation frequencies for any of the quality parameters analyzed, the observed increase in fiber strength, fiber elongation, and fiber length were considerable with a fertigation frequency of every two irrigation cycles (10 days). Similarly, Kienzler (2010) reported that the cotton fiber quality was of the lowest grade (31mm in length, 25 g tex⁻¹ strength, and 4.08 micronaire) and was unaffected by N treatment, application timing, or N fertilizer type. However, increasing the rate of N application significantly ($P \leq 0.05$) increased the fiber length, elongation, micronaire, and color characteristics, and reduced the fiber uniformity ratio (Tewolde and Fernandez, 2003). The effects of N on the properties of the fibers were small and inconsistent (Sawan et al., 2006). The yield potential changed dramatically, which obviously caused increases in nutrient uptake, especially for N. Thus, new nutrient management practices

must be developed for sustainable cotton production (Girma et al., 2007). Zhao and Oosterhuis (2000) reported also that the average boll weight and lint percentage were unaffected by low N treatment.

Chlorophyll (SPAD) readings

SPAD meter readings were performed in different dates and at different developmental stages in both experimental years. The readings ranged from 40.1 to 50.3 in 2011 and from 50.4 to 54.9 in 2012 (Figure 1). The readings in 2012 were a little higher than those in 2011; however, considering the variance analysis, there was no significant difference among the SPAD readings. The SPAD readings increased from measurements I through IV (Figure 1). This was especially evident in 2011, and could be probably dependent on the leaf N content. These findings are in accordance with the levels of N in the leaves and measurement stages (Figure 2). The reason

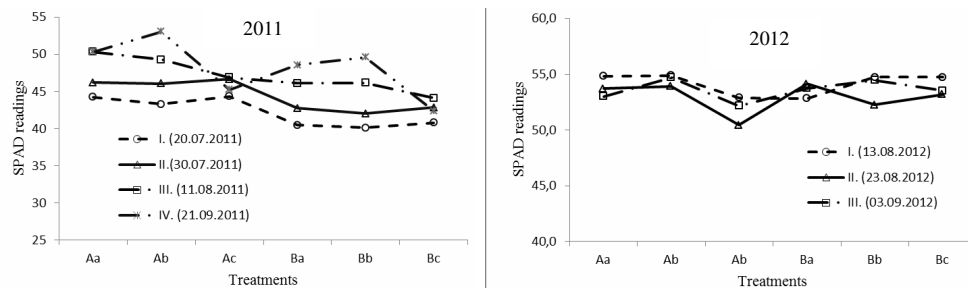


Figure 1. Effects of different lateral spacings and fertigation frequency on SPAD readings.

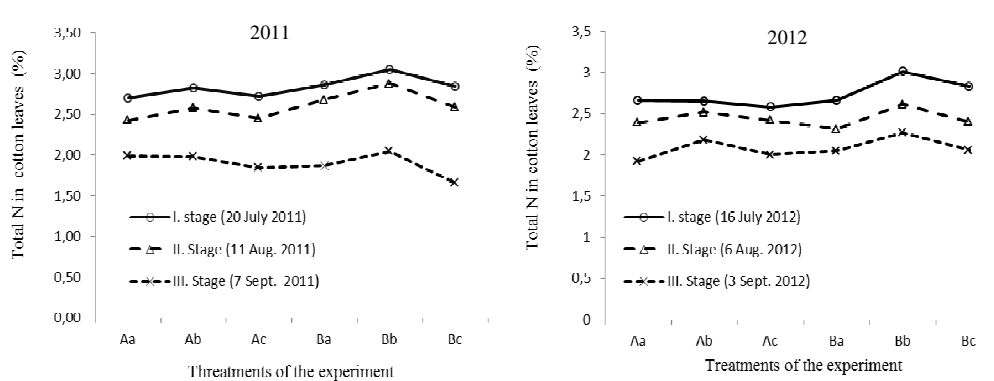


Figure 2. Total N contents of cotton leaves according to the treatments and experimental years.

that there was no significant difference in SPAD readings may be because there was no difference in the amounts of N applied to all treatments. In addition, total N in cotton leaves ranged from 1.85 % through 3.05 % according to the treatments and experimental years. Although the treatment of fertigation for each 2 irrigation cycle (10 days) resulted in considerably higher content of nitrogen in the cotton leaves compared to the other treatments (Figure 2), there were no significant differences between treatments in terms of SPAD readings.

There was no difference within the plots having different N fertigation frequencies during the first week of blooming. The readings during the other periods were lower than in the previous periods.

On the other hand, Karademir *et al.* (2008) determined leaf chlorophyll contents of different cotton varieties using a chlorophyll meter (SPAD) in the same study area. Their results ranged from 40.5 to 45.1. Our SPAD readings were roughly similar. They stated that having the lowest leaf chlorophyll content reading at the second week of blooming was not an indicator of low yield, nor was the highest chlorophyll content reading an indicator of high yield. Basbag *et al.* (2008) also studied SPAD readings in the same region and they obtained SPAD values of 43.1-51.9 for various cotton cultivars. They stated that the SPAD values of normal-leaf cotton genotypes were higher than those of okra-leaf genotypes. Positive correlations were found between SPAD values and single leaf area (effective resistance, $r=0.774^{**}$) and seed cotton yield ($r=0.792^{**}$).

SPAD values can change depending on the water potential, light density, and time of measurement. Establishing a precise and universal critical SPAD index is a complex process due to the narrow range of values separating N deficiency from surplus and the great number of variables affecting the index, including changes in leaf irradiance and water status (Martinez and Guiamet, 2004), environmental conditions, and statistical procedures (Fontes and Ronchi, 2002).

Considering different crops, the SPAD readings at specific physiological stages in tomato ranged from 32.6 to 60.2. These results indicate that SPAD meters can provide a quantitative measure of the N requirement of tomato plants as long as appropriate critical values are established. The plant canopy needs to be evaluated visually and improved (Fontes and Araujo, 2006). Significant correlations between total foliar extractable chlorophyll and chlorophyll content index values obtained with portable chlorophyll meters have been reported for a number of agricultural species, including cabbage, cotton, and pea (Marquard and Tipton, 1987).

The mathematical relationships observed between chlorophyll content index values and total chlorophyll and/or N content values vary between species (Marquard and Tipton, 1987; Schaper and Chacko, 1991; Shaahan *et al.*, 1999; Yamamoto *et al.*, 2002) and within species during the growing season (Dwyer *et al.*, 1995; Bullock and Anderson, 1998), with growth stage (Chapman and Barreto, 1997), growing condition (Campbell *et al.*, 1990; Simorte *et al.*, 2001), and genotype (Peng *et al.*, 1993). Thus, relationships must be quantified for each species of interest, and, once determined, the relationship cannot be generally applied even within the same species.

Photosynthesis Rate (PR)

The PRs ranged from 46.2 to 74.7 in 2011 $\mu\text{mol m}^{-2} \text{s}^{-1}$, and from 35.9 to 47.2 $\mu\text{mol m}^{-2} \text{s}^{-1}$ in 2012 (Figure 3). According to the variance analysis, there was no significant effect of N fertigation on PR. As in the chlorophyll (SPAD) readings, one reason that there was no difference between the leaf N content and PR may be that there was no difference in the amount of N applied to the treatments. As mentioned in SPAD readings, there were no significant differences among the treatments in terms of total N in the leaves of cotton.

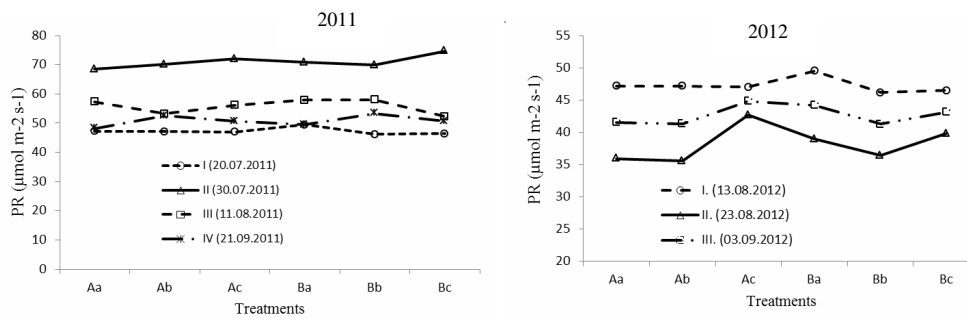


Figure 3. Effects of different lateral spacings and fertigation frequency of nitrogen on photosynthesis rate.

On the other hand, Karademir *et al.* (2012) reported that the PR could vary depending on the cotton cultivar. They tested different cultivars for PR and photosynthetically active radiation (PAR), and they concluded that there were significant differences among cotton cultivars in terms of PR and PAR. These findings were confirmed by Bharud (2012). Karademir *et al.*, (2012) showed that photosynthesis could be used as indicator of heat tolerance. However, Bibi *et al.* (2008) reported that photosynthesis sensitivity was not practical for screening large numbers of genotypes for temperature tolerance. This inconsistency may stem from differences in the photosynthesis measurement devices used.

Measurements of PR may be dependent on variations in temperature and moisture stress (Grace *et al.*, 2007). An analysis of the parameters contributing to the increasing and decreasing pattern of net photosynthesis with leaf age indicated the primary involvement of leaf area expansion, leaf N content, light intensity, and stomatal conductance to CO₂ (Wullschleger and Oosterhuis, 1990).

Leaf tissue concentrations of the three major plant nutrients (N, K, and P) must be maintained at sufficient levels for optimum photosynthesis. Under deficient soil fertility conditions, supplemental fertilization can increase overall growth due to both increased leaf area production

and an increased PR per unit leaf area (Pettigrew and Gerik, 2007).

An insufficient N supply during cotton reproductive growth depresses the leaf area, leaf net PR, and leaf chlorophyll content, but increases the leaf total nonstructural carbohydrate concentration. A decreased leaf PR due to N deficiency may be associated with earlier leaf senescence and slower carbohydrate translocation from leaves to fruits. As a result, fruit abscission in N-deficient cotton plants increase and lint yield decrease compared with plants receiving sufficient N. Thus, according to a soil nutrient analysis and cotton production recommendations, adequate N during boll development is essential for photosynthesis and yield development (Zhao and Oosterhuis, 2000). No relationship between N and leaf PR could be determined because there was no difference in the amounts of N applied in this study.

At a high light intensity, photosynthesis reaches its maximum rate. The maximum PR also determines the growth power of a plant species. (Vries, 2013).

The net photosynthetic yield measured at cotton leaves may change depending on the environmental conditions during measurement, the prevailing ecological conditions, and the age and location of the leaf on the plant. Furthermore, the impact of temperature on photosynthetic activity in a cotton plant may vary. Thus, leaf photosynthesis does not remain constant as a leaf grows and develops.

CONCLUSIONS

Drip fertigation was better in terms of productivity and had an economic advantage over conventional methods. However, the timing of N fertilizer injection is a management question that producers need guidance on. The results of this study show that N should be applied in equal doses every two irrigation cycles (10 days) by fertigation if a pressure differential tank system is used. The accuracy of application of N fertigation will depend on the injection devices and/or methods used.

There was no significant difference among the fertigation frequencies for any of the quality parameters analyzed. However, increased fiber strength (32.3 g tex^{-1}), fiber elongation (6.5%), and fiber length (28.9 mm) were observed with a fertigation frequency of every two irrigation cycles (10 days). The SPAD readings ranged from 40.1 to 54.9 depending on the treatment and experimental year. There was no significant difference among the SPAD readings. The PR ranged from 35.9 to $74.7 \mu\text{mol m}^{-2} \text{ s}^{-1}$, and there was no significant difference between the treatments. One reason why different treatments had no differences in the PR and SPAD readings may be that there were no differences in the amount of N they received.

The PR measured at cotton leaves may change depending on the environmental conditions during the measurement period, prevailing ecological conditions, and the age and location of the leaf on the plant. Furthermore, the impact of temperature on photosynthetic activity in a cotton plant may vary. Establishing a precise and universal critical SPAD index is complex because SPAD readings can be affected by N, leaf irradiance, water status, environmental conditions, and statistical procedures.

ACKNOWLEDGEMENTS

This study includes a part of the Scientific Report of Research Project (10-ZF-166) carried out from 2011 to 2012 in the Experimental Station of Agricultural Faculty, Dicle University, Diyarbakır, Turkey. In addition, this research project was supported by the Dicle University Scientific Research Projects Coordination Office (DUBAP).

REFERENCES

1. Albers, W.D., Hefner, S. and Kolbe, D. 1993. *Fertility Management in Cotton*. University of Missouri Extension Services.
2. Anonymous. 2013. *Soil Analysis Key to Nutrient Management Planning. The Potash Development Association*. Leaflet 24. Available on 10.12.2013: <http://www.pda.org.uk/leaflets>
3. Basbag, S., Ekinci, R. and Oktay, G. 2008. Relationships between Some Physio-morphological Traits and Cotton (*Gossypium hirsutum* L.) Yield. *International Cotton Advisory Committee, Tenth Regional Meeting*, September 28-October 1, 2008, Alexandroupoli, Greece.
4. Bauer, P.J. and Roof, M.E. 2004. Nitrogen, Aldicarb, and Cover Crop Effects On Cotton Yield And Fiber Properties. *Agron. J.* 96:369-376.
5. Bharud, R. W. 2012. Studies on Photosynthesis Efficiency in *G. hirsutum* Cotton Hybrids. *International Cotton Advisory Committee, Eleventh Regional Meeting*, November 5-7, 2012, Antalya, Turkey,
6. Bibi, A. C., Oosterhuis, D. M. and Gonias, E. D. 2008. Photosynthesis, Quantum Yield of Photosystem II and Membrane Leakage as Affected by High Temperatures in Cotton Genotypes. *J. Cotton Sci.*, **12**: 150-159.
7. Bilgel, L., Nacar, A. S. and Ogur, N. O. 2005. Effects of Water Stress on Some Cotton Varieties under Harran Plain Conditions. Research Project Report, Research Institute of Soil and Water Resources, Sanliurfa, 45 PP. (in Turkish with English Abstract).
8. Boman, R., and Leser, J. 2003. *Management of Late Cotton in 2003*. Texas A and M Research and Extension Center, Lubbock, TX
9. Boman, R. K. and Westerman, R. L. 1994. Nitrogen and Mepiquat Chloride Effects on the Production of Nonrank, Irrigated, Short-season Cotton. *J. Prod. Agric.*, **7**: 70-75.
10. Brito, G. G., Sofiatti, V., Brandão, Z. N., Silva, V. B., Silva, R. M. and Silva, D. A. 2011. Non-destructive Analysis of Photosynthetic Pigments in Cotton Plants. *Acta Scientiarum Agron.*, **33**(4).
11. Bullock, D. G. and Anderson, D. S. 1998. Evaluation of the Minolta SPAD-502 Chlorophyll Meter for Nitrogen Management in Corn. *J. Plant Nutr.*, **21**(4): 741-755.



12. Burt, M.C. 1998. *Fertigation Basics*. ITRC Paper 98-001, Irrigation Training and Research Center (ITRC), California Polytechnic University, San Luis Obispo, CA, USA.
13. Campbell, R. J., Mobley, K. N., Marini, R. P. and Pfeiffer, D. G. 1990. Growing Conditions Alter The Relationship between SPAD-501 Values And Apple Leaf Chlorophyll. *HortSci.*, **25(3)**: 330-331.
14. Cetin, O., Uzen, N. and Karaer, M. 2013. Application Techniques of Fertigation. Scientific Papers, Faculty of Land Reclamation and Environmental Engineering, University of Agronomic Sciences and Veterinary Medicine of Bucharest, Land Reclamation, *Earth Observation and Surveying, Environmental Engineering, Series E*, **II**: 77-81
15. Cetin, O. and Bilgel, L. 2002. Effects of Different Irrigation Methods on Shedding and Yield of Cotton. *Agric. Water Manag.*, **54(1)**: 1-15.
16. Chapman, S. C. and Barreto, H. J. 1997. Using a Chlorophyll Meter to Estimate Specific Leaf Nitrogen of Tropical Maize during Vegetative Growth. *Agron. J.*, **89**: 557-562.
17. Dwyer, L. M., Anderson, A. M., Ma, B. L., Stewart, D. W., Tollenar, M. and Gregorich, E. 1995. Quantifying the Nonlinearity in Chlorophyll Content Meter Response to Corn Leaf Nitrogen Concentration. *Can. J. Plant Sci.*, **75**: 179-182.
18. Ebrahimian, H., and Playán, E. 2014. Optimum Management of Furrow Fertigation to Maximize Water and Fertilizer Application Efficiency and Uniformity. *J. Agr. Sci. Tech.*, **16**: 591-607
19. Edmisten, K. 2008. *Cotton*. North Carolina Cooperative Extension Service, College of Agriculture and Life Sciences, North Carolina State University.
20. Fontes, P. C. R. and Araujo, C. 2006. Use of a Chlorophyll Meter and Plant Visual Aspect for Nitrogen Management in Tomato Fertigation. *J. Appl. Hort.*, **8(1)**: 8-11.
21. Fontes, P. C. R. and Ronchi, C. P. 2002. Critical Values of Nitrogen Indices in Tomato Plants Grown in Soil and Nutrient Solution Determined by Different Statistical Procedures. *Pesquisa Agropecuária Brasileira*, **37(10)**: 1421-1429.
22. Fritschi, F. B., Roberts, B. A., Travis, R. L., Rains, D. W. and Hutmacher, R. B. 2003. Response of Irrigated Acala and Pima Cotton to Nitrogen Fertilization: Growth, Dry Matter Partitioning, and Yield. *Agron. J.*, **95**: 133-146
23. Gerik, J. T., Oosterhuis, D. M. and Torbert, H. A. 1998. Managing Cotton Nitrogen Supply. In: "Advances in Agronomy", (Ed.): Sparks, D. L.. Academic press, San Diego, CA.
24. Girma, K., Teal, R. K., Freeman, K. W., Boman, R. K. and Raun, W. R. 2007. Cotton Lint Yield and Quality as Affected by Applications of N, P, and K Fertilizers. *J. Cotton Sci.*, **11**: 12-19
25. Grace, J., Nichol, C., Disney, M., Lewis, P., Qualife, T. and Bowyer, P. 2007. Can We Measure Terrestrial Photosynthesis from Space Directly, Using Spectral Reflectance and Fluorescence? *Glob. Change Biol.*, **13**: 1484-1497
26. Guinn, G. and Mauney, J. R. 1984. Fruiting of Cotton. II. Effects of Moisture Status on Flowering. *Agron. J.*, **68**: 701-705.
27. Hartz, T. K. 1993. Drip Irrigation Scheduling For Fresh-market Tomato Production. *HortSci.*, **28**: 35-37.
28. Hartz, T. K. and Hochmuth, G. J. 2005. *Fertility Management of Drip-irrigated Vegetables*. Vegetable Research and Information Center, UC Davis, USA, 6 PP.
29. Hassan, M., Nasrullah, M., Iqbal, M. Z., Muhammad, T., Iqbal, M. and Ahmad, S. 2003. Effects of Different Sowing Dates on Cotton (*Gossypium Hirsutum L.*) Cultivars. *Asia. J. Plant Sci.*, **2(6)**: 461-463.
30. Hutmacher, B. 2001. California Cotton Review. The Newsletter of the UC Cooperative Extension Cotton Advisors, **59**.
31. Johnson, J. R. and Saunders, J. R. 2003. *Evaluation of Chlorophyll Meter for Nitrogen Management in Cotton*. Available on 10.12.213: <http://msucares.com/nmrec/reports>
32. Kanber, R., Tekinel, O., Baytorun, N., Kumova, Y. and Alagoz, T. 1991. *Use of Class A Pan on Water Consumptive Use and Irrigation Intervals*. GAP Publication No: 44, Project Report, Southeastern Anatolia Project, Regional Development Administration, Adana. (in Turkish with English Abstract)
33. Karademir, E. and Sakar, D. 1999. Effects of Nitrogen and Sowing Dates on Cotton Yield and Fibre Qualities. *3rd Congress of Field Crops*, 15-19 November 1999, Adana, Turkey, **II**: 247-252. (in Turkish with English Abstract)
34. Karademir, E., Karademir, C., Ekinci, R., Basbag, S. and Basal, H. 2012. Screening Cotton Varieties (*Gossypium hirsutum L.*) for Heat Tolerance Under Field Conditions. *African J. Agric. Res.*, **7(47)**: 6335-6342.

35. Karademir, C., Karademir, E., Doran, I. and Altikat, A. 2005. Effects of Different Doses of Nitrogen and Phosphorus on Yield and Fibre Properties Under Diyarbakır Conditions. *J. Agric. Faculty, Gaziosmanpaşa Univ.*, **22(1)**: 55-61. (in Turkish with English Abstract)
36. Karademir, E., Karademir, C., Ekinci, R. and Gencer, O. 2008. Relationships between Leaf Chlorophyll Content, Yield and Yield Components of Cotton (*Gossypium hirsutum* L.). *10th Meeting of Inter-Regional Cooperative Research Network on Cotton*, 28 September-1 October, Greece.
37. Kariya, K., Matsuzaki, A. and Machida, H. 1982. Distribution of Chlorophyll Content in Leaf Blade of Rice Plant. *Japan. J. Crop Sci.*, **51(1)**: 134-135.
38. Keller, J. and Bliesner, R. D. 1990. *Sprinkle and Trickle Irrigation*. Chapman and Hall, 115 Fifth Avenue, New York, NY 10003.
39. Kienzler, K. M. 2010. Improving the Nitrogen Use Efficiency and Crop Quality in the Khorezm Region, Uzbekistan. Ecology and Development Series no. 72, Rheinische Friedrich-Wilhelms-Universität Bonn, Bonn.
40. Marquard, R. D. and Tipton, J. L. 1987. Relationship between Extractable Chlorophyll and In Situ Method to Estimate Leaf Greenness. *HortSci.*, **22**: 1327.
41. Martinez, D. E. and Guamet, J. J. 2004. Distortion of the SPAD 502 Chlorophyll Meter Readings by Changes in Irradiance and Leaf Water Status. *Agronomie*, **24(1)**: 41-46.
42. Morrow, M. and Krieg, D.R. 1990. Cotton Management Strategies for a Short Growing Season Environment: Water-Nitrogen Considerations. *Agron. J.*, **84**: 52-56.
43. Mullins, G. L. and Burmester, C. H. 1990. Dry Matter, Nitrogen, Phosphorous, and Potassium Accumulation by Four Cotton Varieties. *Agron. J.*, **82**: 729-736.
44. Oosterhuis, D. M., Chipamaunga, J. and Bate, G. C. 1983. Nitrogen Uptake in Field-Grown Cotton. I. Distribution of in Plant Components in Relation to Fertilization and Yield. *Exp. Agric.*, **19**: 91-101.
45. Ozer, S. M. and Dagdeviren, I. 1986. *Requirement of Nitrogen for Cotton under Harran Plain Conditions*. Report Series No: R-17, Publication No: 25, The Research Institute of Rural Affairs, , Sanliurfa, Turkey. (in Turkish with English Abstract).
46. Ozer, M.S. 1992. Requirement of Phosphorus for Cotton under Harran Plain Conditions. Report Series No: R-47, Publication No: 71, The Research Institute of Rural Affairs, , Sanliurfa, Turkey. (in Turkish with English Abstract).
47. Peng, S., Garcia, F. V., Laza, R. C. and Cassman, K. G. 1993. Adjustment for Specific Leaf Weight Improves Chlorophyll Meter's Estimate of Rice Leaf Nitrogen Concentration. *Agron. J.*, **85**: 987-990.
48. Pettigrew, W. T. and Gerik, T. J. 2007. Cotton Leaf Photosynthesis and Carbon Metabolism. *Adv. Agron.*, **94**: 209-236.
49. Roche, R., Bange, M., Milroy, S.P., Roberts, G. and Constable, G. 2004. Management for Ultra Early Cotton Systems. *Proceedings of the 4th International Crop Science Congress*, 26 September -1 October, 2004, Brisbane, Australia.
50. Sawan, Z. M., Mahmoud, M. H. and El-Guibali, A. H. 2006. Response of Yield, Yield Components, and Fiber Properties of Egyptian Cotton (*Gossypium barbadense* L.) to Nitrogen Fertilization and Foliar-applied Potassium and Mepiquat Chloride. *J. Cotton Sci.*, **10**: 224-234.
51. Schaper, H. and Chacko, E. K. 1991. Relation between Extractable Chlorophyll and Portable Chlorophyll Meter Readings in Leaves of Eight Tropical and Subtropical Fruit-Tree Species. *J. Plant Physiol.*, **138**: 674-677.
52. Shaahan, M. M., El-Sayed, A. A., Abou El-Nour, E. A. A. 1999. Predicting Nitrogen, Magnesium and Iron Nutritional Status in Some Perennial Crops Using a Portable Chlorophyll Meter. *Sci. Hortic.*, **82**: 339-348.
53. Simorte, V., Bertoni, G., Dupraz, C. and Masson, P. 2001. Assessment of Nitrogen Nutrition of Walnut Trees Using Foliar Analysis and Chlorophyll Measurements. *J. Plant Nutr.*, **24**: 1645-1660.
54. Singh, B., Singh, Y., Jagdish, K., Ladha, J. K., Bronson, K. F., Balasubramanian, V., Singh, J., Charan, S. and Khind, C. S. 2002. Chlorophyll Meter- and Leaf Color Chart-Based Nitrogen Management for Rice and Wheat in Northwestern India. *Agron. J.*, **94**: 821-829.
55. Sne. M. 2006. Micro Irrigation in Arid and Semi-arid Regions, Guidelines for Planning and Design, ICID, Holland.
56. Tewolde, H. and Fernandez, C.J. 2003. Fiber Quality Response of Pima Cotton to Nitrogen and Phosphorus Deficiency. *J. Plant Nutr.*, **26(1)**: 223-235
57. Tisdale, S. L., Nelson, W. L., Beaton, J. D. and Havlin, J. L. 1993. *Soil Fertility and*



- Fertilizers*. Fifth Edition. MacMillan Publishing Company, NY.
58. Torres-Netto, A., Camprostrini, E., Oliveira, J. G. and Smith, R. E. B. 2005. Photosynthetic Pigments, Nitrogen, Chlorophyll A Fluorescence and SPAD-502 Readings in Coffee Leaves. *Scientia Horticulturae*, **104(2)**: 199-209.
59. Vries, A. R. G. 2013. *Measuring Fluorescence and Photosynthesis*. EARS Plant Photosynthesis Monitoring Ltd, Kanaalweg 1, Delft, Netherlands. Available on 17.12.2013: www.ears.nl
60. Wang, J., Xing, D. and Xu, W. 2006. Development of a Portable Photosynthesis Rate Measurement Device. *Proc. SPIE 6047, Fourth International Conference on Photonics and Imaging in Biology and Medicine*, 60473W (October 27, 2006) Tianjin, China
61. Wullschleger, S. D. and Oosterhuis, D. M. 1990. Photosynthesis of Individual Field-grown Cotton Leaves during Ontogeny. *Photosynthesis Res.*, 23(2): 163-170.
62. Yamamoto, A., Nakamura, T., Adu-Gyamfi, J. J. and Saigusa, M. 2002. Relationship between Chlorophyll Content in Leaves of Sorghum and Pigeonpea Determined By Extraction Method and by Chlorophyll Meter (SPAD-502). *J. Plant Nutr.*, **25**: 2295-2301.
63. Yolcu, S. 1993. *Sowing Date on Cotton Crop*. Project Report, Akçakale Agricultural Research Institute, Sanliurfa, Turkey. (in Turkish)
64. Yurtsever, N. 1984. *Experimental Statistical Methods*. Pub. No: 121, Technical Pub. No: 56, Soil and Fertilizer Research Institute, Ankara. (in Turkish).
65. Zhao, D. and Oosterhuis, D.M. 2000. Nitrogen Application Effects on Leaf Photosynthesis, Nonstructural Carbohydrate Concentrations and Yield of Field-Grown Cotton. *Proceedings of the 2000 Cotton Research Meeting*, Arkansas, USA, AAES Special Report 198. 69-71.

اثر فواصل زمانی کودآبیاری نیتروژن روی عملکرد الیاف، کلروفیل و نرخ فتوسنتز پنبه

۱. ستین، ن. اوزن، م. گ. تمیز

چکیده

هدف تحقیق حاضر ارزیابی اثر فواصل زمانی کودآبیاری نیتروژن روی عملکرد و کیفیت الیاف، مقدار کلروفیل (اعداد قرائت شده SPAD) و نرخ فتوسنتز (PR) در پنبه بود. این پژوهش در منطقه جنوب شرقی آناطولی ترکیه در سال های ۲۰۱۱ و ۲۰۱۲ با استفاده از آبیاری قطره ای روی پنبه انجام شد. بیشترین عملکرد الیاف (۱۸۵۶ کیلوگرم در هکتار) در تیماری بود که یک لترال(لوله فرعی در آبیاری قطره ای) دور ردیف را آبیاری می کرد و مقدار کود در هر نوبت یکسان بود و کود آبیاری هر دو آبیاری یک بار انجام می شد(فواصل ۱۰ روزه). این فاصله کود آبیاری (ده روز یکبار) به طور معنی داری ($P \leq 0.05$) استحکام تار یا لیف (۳۲/۳ برحسب g/tex) و رشد طولی تار (۶/۵٪) و طول تار(۲۸/۹ میلی متر) را افزایش داد. اعداد قرائت شده SPAD بسته به سال اجرای آزمایش و تیمارها بین ۴۰/۱ تا ۵۴/۹ تغییر می کرد. تفاوت معنی داری ($P \leq 0.05$) بین اعداد قرائت شده SPAD به دست نیامد. همچنین، PR بین ۳۵/۹ تا ۴۷/۷ میکرومول برمتر مربع برثانیه تغییر داشت ولی تفاوت معنی داری بین تیمارها نشان نداد. یک دلیل احتمالی برای نبودن تفاوت در PR و اعداد SPAD تیمارهای مختلف این است که مقدار نیتروژن مصرف شده در آنها یکسان بود. نیز گفتنی است که PR اندازه گیری شده در برگ های پنبه می تواند با تغییر شرایط محیطی در طی اندازه گیری، شرایط زیست بومی محل، سن برگ ها، و موقعیت برگ روی بوته نوسان و تغییر کند.