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MANAGEMENT OF NITROGEN STRESS IN COTTON (*Gossypium hirsutum* L.) USING GREENSEEKER TECHNOLOGY

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ABSTRACT. This study was performed with GreenSeeker technology in order to determine the possibility of nitrogen stress management in cotton and to determine the differences between the normalized difference vegetative index (NDVI) and nitrogen doses determined with GreenSeeker, to determine the nitrogen deficiency and stress conditions by making use of the value of the NDVI in cotton production and to intervene when necessary and direct the producers in this regard. In the study six nitrogen doses (Control, 60, 120, 180, 240 and 300 kg ha^{-1}) were used. The results showed significant differences between N applications for leaf chlorophyll content (SPAD), NDVI-2 (in the boll formation period), number of bolls (NB), seed cotton (SCY) and fiber yield (FY). On the other hand, there were non-significant differences in terms of (LA) area, NDVI-1 (in the beginning of the flowering), plant height (PH), node number of first fruiting branches (NNFFB), number of monopodial branches (NMB) and number of sympodial branches (NSB), number of nodes (NN), height to node ratio (HNR), seed cotton boll weight (SCBW) and ginning percentage (GP). The highest SCY and FY obtained were from doses of 180 and 120 kg ha^{-1} N, the highest leaf chlorophyll content and number of bolls obtained were from doses of 120 kg ha^{-1} N. The highest values of NDVI-2 obtained were from doses of 120, 240 and 300 kg ha^{-1} N, respectively. There were non-significant differences between N doses for values of the NDVI-1 of flowering, but significant differences observed for values of NDVI-2 of boll formation periods. The findings obtained from this research indicated that leaf chlorophyll and NDVI of the boll formation period can be used for determining differences due to varying N doses in cotton production.

Keywords: cotton; nitrogen doses; NDVI; yield; fiber quality.

INTRODUCTION

It is possible to obtain optimum yield from cultivated products by growing the plant in a healthy way.

Disease, harmful and environmental stress factors (water stress, high temperature stress, low temperature stress, salinity, etc.) or deficiency in plant nutrients that may be encountered during the growth period can lead to yield and fiber quality loss.

In order for plants to grow and develop, the timely application of macro and micro nutrients in required doses is necessary to increase the optimum yield and fiber quality of cotton. It is known that six macronutrients (N, P, K, S, Ca, Mg) are necessary for this plant to grow and develop. Nitrogen is one of the most important elements that contributes significantly to plant physiology.

Nitrogen is a limiting element needed by plants and plays an important role in many basic processes such as protein synthesis, photosynthesis, carbon balance, as well as enzyme and hormone activity. The role of N in plant life is very important as it enters the structure of proteins. It also exists in the composition of purine, pyrimidine, porphyrins and coenzymes. As is known, purine and pyrimidines are present in the structure of RNA and DNA. It is found in the structure of compounds that are very important for the metabolism, such as porphyrins, chlorophyll and various cytochrome enzymes. Coenzymes are essential for the functioning of various enzymes. Nitrogen, which the cotton plant uses more than other nutrients, is an important element that has an impact on yield and quality. The cotton plant takes nitrogen in the form of ammonium (NH_4) and nitrate (NO_3) (Karaman, 2012).

The amount of N in the soil is not sufficient for the plants to grow in a healthy way and to produce high quality and high yields. In this respect, the N that the plant needs should be given to the soil in a balanced way with nitrogenous fertilizers. Since N is mobile in the plant, it is more abundant in the young organs of the plant than in the old ones (Hikosaka *et al.*, 1994)

The nitrogen demand of the cotton plant is not stable during the development period. Cotton does not need much N until squaring and first flowering period. The N requirement is low until the beginning of flowering. With flowering, N uptake increases and reaches its highest level during the boll forming period. It has been reported that 25%-40% of the seasonal N requirement is used during the first two weeks of flowering (Guthrie *et al.*, 1994).

Excessive N increases the vegetative growth of the plant, delays the harvest maturity of the crop, increases susceptibility to diseases and pests, makes defoliation difficult and leads to a decrease in yield (Porter, 2010). Energy use and cotton production costs increase with an excessive supply of N, and N has negative effects on the environment (Ballester *et al.*, 2017; Khan *et al.*, 2017). It is reported that by giving the right amount of N during plant development, photosynthesis capacity can be increased and healthy plants and leaves can be obtained (Ali, 2015).

Nitrogen is an essential macronutrient that cotton production needs in higher and more consistent amounts than other nutrients (Hou *et al.*, 2007). N fertilisation significantly affects cotton growth, fiber yield and fiber quality (Bondada *et al.*, 1996). In addition, excessive N application reduces the intake of other nutrients, worsening granular soil structure and eventually compacts the soil, resulting in a decrease in yield and fiber quality (Guinn, 1982; Shu, 2008; Zhang *et al.*, 1999).

The growing season, climate, diversity, availability of nutrients, and soil moisture are just a few of the many elements, pests, and cultural practices that influence cotton plant growth and development (El-Zik, 1980). Crop growth is influenced by an interaction of weather, soil, variety, and cultural practices, sometimes causing plants to respond to their conditions in unexpected ways (Hodges *et al.*, 1993).

Remote sensing systems and precision agriculture technology are commonly used in plenty of countries, the production steps of crops are monitored with regard to the health of the plants and any unfavourable causation can be ameliorated. By using these systems and techniques, crop development can be followed, yield estimations can be done, the health of the crops can be protected, the existence of stress and the necessity of plant nutrients can be determined, and prompt intervention can be done when necessary.

GreenSekeer technology is one of these techniques. It has been used by developing countries in recent years and its use has been increasing day by day. GreenSekeer crop sensors measure the NDVI. There are different types of GreenSkeers: a handheld crop sensor is appropriate for small size experiments and is preferred for its high resolution and reliability (Huang ve Han, 2014). The GreenSkeer sensor is used to measure crop biomass and show it as the value of the NDVI. A GreenSeeker sensor not only gives an idea about the health and vitality of a plant, but also provides information about the proportion of fertilizer to be applied. In many previous studies, it has been reported that it is useful to use active crop sensors and handheld sensors (Green-Seeker) to determine nitrogen application amounts (Ali *et al.*, 2020; Zhou *et al.*, 2017).

GreenSekeer technology augments production and curtails the cost of production by allowing the producer to apply only the required N fertilizers to their crops or plants. This technology has been used worldwide in sensitive farming where the application of fertilizers, pesticides, herbicides, plant growth regulators, and defoliates is based on crop and field conditions (Rutto and Arnall, 2015). The handheld sensors (GreenSeeker) based Precision Nitrogen Management (PNM) strategy has been showed to significantly increase Nitrogen Use Efficiency (NUE) for wheat and rice when compared with farmer's practice (Zhou *et al.*, 2017).

This study was carried out to provide nitrogen stress management in cotton with GreenSeeker technology, to determine the differences between NDVI values and nitrogen dose in cotton, to benefit from GreenSeeker technology in nitrogen management and to determine the effects of different nitrogen doses in the cotton on yield, yield criteria and fiber technological properties and to guide producers regarding nitrogen management.

MATERIALS AND METHODS

The experiment was arranged as a randomized complete block design with four replications in the trial area of the Agriculture Faculty, Siirt University. MAY 344 upland cotton variety was used as the plant material and 6 different nitrogen doses (Control, 60, 120, 180, 240, 300 kg ha^{-1}) were used as the treatment. Before planting, samples of the soil were collected from 0-30 cm depth and analysed at the university laboratory. The analysis results of the soil taken prior to sowing can be seen in *Table 1*. The texture of the soil is sandy-clay, neutral in character. Planting was performed with a cotton experimental planting machine on 4 May 2018. On each plot, 4 rows with a length of 6 m were planted, and the intra-rows space was 15-20 cm. Nitrogen was administered in two equal tranches, one at planting and the other before the first irrigation during the squaring period.

Nitrogen applied during planting was applied in the form of ammonium sulphate, and nitrogen applied before the first irrigation was applied in the form of urea. Phosphorus in the form of Triple Super Phosphate was applied to all parcels during planting with dose of 60 kg ha^{-1} P_2O_5. In order to prevent the nitrogen doses from mixing, there were 2 rows between the parcels and a 2-m space between the blocks. Thinning was performed when the plants were 10-15 cm high. Regular pest control was carried out, but no pesticide was used because the loss threshold in terms of pests was not reached. Drip irrigation system were used for irrigation, the first irrigation was applied at the start of the squaring period and the application of water terminated at the 10% boll opening period. For irrigation, the field capacity was calculated and the plots irrigated when soil moisture was below the field capacity.

The average and extreme temperatures (*Figure 1*) as well as the atmospheric precipitation in May and October (*Figure 2*) exceeded the multiannual values.

In the study, the chlorophyll content and agronomic traits were measured from 10 randomly selected plants of each parcel and NDVI was measured from the center rows of the parcel and 60 cm above the crop.

Chlorophyll content (SPAD) measurements were recorded during the flowering period and observations were taken on the fifth fully expanded leaf beneath the terminal during the flowering period, with one reading per plant leaf according to Johnson and Saunders (2003). The values of the NDVI were determined twice: in the beginning of flowering and during the boll formation period.

Table 1 – Main properties of the soil

Specification	Value
Clay (%)	43.51
Sand (%)	47.99
Silt (%)	8.49
pH	6.89
Electrical conductivity (mS cm-1)	463
Lime (%)	0.50
Organic matter (%)	1.02
Available phosphorus, P2O5 (kg ha-1)	22
Available potassium, K2O (kg ha-1)	860

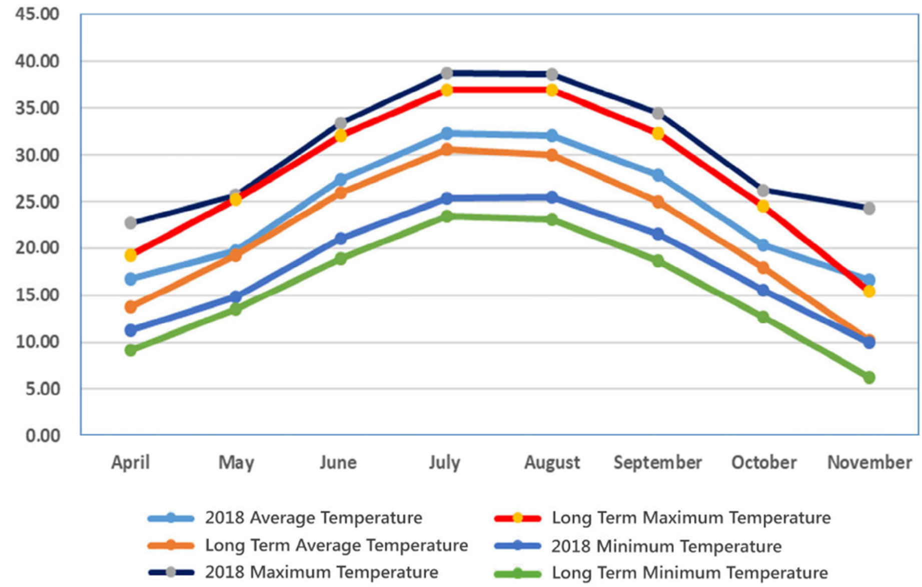

Figure 1 – The evolution of the air temperature (°C) in the experimental field

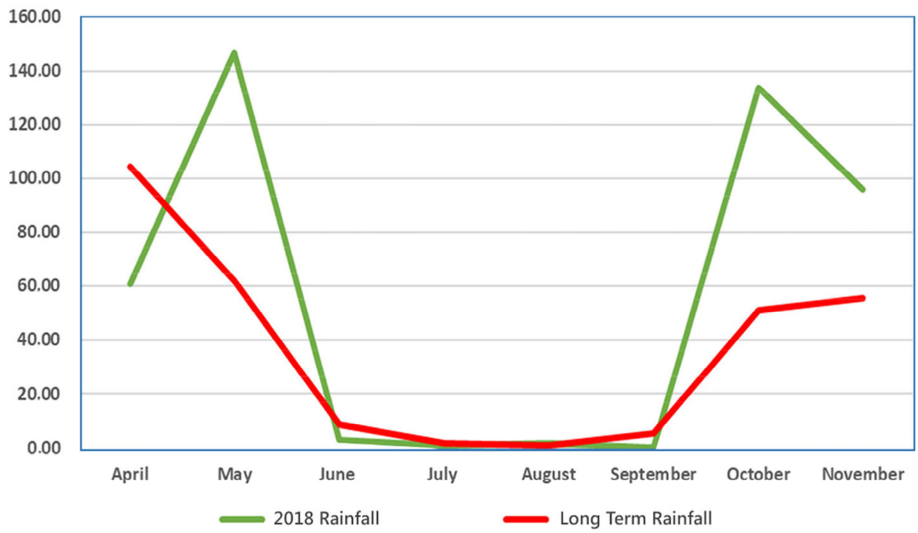

Figure 2 – Rainfalls regime (mm) in the experimental field

Leaf chlorophyll contents were measured by a Minolta SPAD-502 Plus Chlorophyll Meter (*Figure 3*), leaf area was determined by using Auto-Cad program (*Figure 4*) and the values of the NDVI were measured by a GreenSeeker Handheld Crop Sensor (*Figure 5*). A high NDVI means that the crop is not under stress or that the crop is healthy.

Figure 3 – Chlorophyll Content Measurement with SPAD

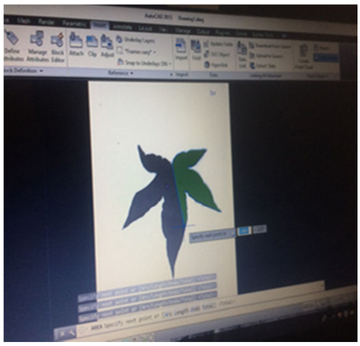

Figure 4 – Leaf area measurement

Figure 5 – NDVI measurement

NDVI (Normalized difference vegetative index) is determined by the formula

NDVI = (NIR-RED)/(NIR+RED)

NIR: Intensity of infrared light,

RED is the intensity of red light (Dobos *et al.*, 2012).

In this formula, NIR is the infrared reflectance = the reflectance in near infrared (770 ± 860 nm) and R = red wavelengths (620 ± 680 nm) (Ray and Pokharna, 1999).

The NDVI ranges from -1.0 to +1.0, with a high positive value representing healthy green vegetation, a low value (close to zero or slightly negative value) a non-vegetation surface such as water, snow, frost or cloud (Mather and Koch, 2011; Huang and Han, 2014). Reddy *et al.* (2003) and Iqbal *et al.* (2013) stated that the value of the NDVI in the first blooming period will be the best indicator for estimating fiber yield. In a study, the best time for estimating the yield of cotton plant was determined to be August, which corresponds to approximately one month before the harvest of the plant (Huang and Han, 2014). Two manual harvesting operations were carried out on October 3 and November 1. The seed cotton yield was measured on the plants in the rows in the middle of the plots. After harvesting, samples of seed cotton were ginned with a mini laboratory rollergin for ginning turnout. Fibers from hand-harvested plants on October 3 were analysed for quality characteristics with the Uster HVI 1000. The obtained data were statistically processed with JMP 7.0.1 software.

RESULTS

Chlorophyll Content (SPAD)

Under this aspect, significant statistical differences were found between the treatments, the chlorophyll content varying between 41.25 and 49.17 (*Table 2*). The average chlorophyll content was 45.84. The highest SPAD was obtained from nitrogen doses of 120 kg ha^{-1}. It was determined that different nitrogen doses used in the experiment caused a significant statistical difference in terms of SPAD in leaves. Among the applications, 120, 180 and 300 kg ha^{-1} N doses are in the same statistical group, while the control and 60 kg ha^{-1} N applications are in different groups.

Based on similar results, Muharam *et al.* (2014), claims that leaf nitrogen content and SPAD can be used as a good indicator of nitrogen in the plant. Zhou and Yin (2018), suggested that SPAD readings from the early flowering period to the late flowering period are the most effective method to determine the nitrogen status in the plant, and that it is most effective to obtain the SPAD from early squaring to mid-flowering period for yield estimation.

Statistically significant differences in chlorophyll content between treatments in the study shows that determining the SPAD may be a good indicator to determine the differences between nitrogen doses. The findings obtained are in parallel with the literature.

NDVI-1

The average values of the applications regarding NDVI-1 are given in *Table 2*. In terms of NDVI-1 there is no statistically significant difference between the treatments.

It is observed that the value of NDVI-1 varied between 0.72 (control variant) and 0.83 (obtained with the 4th application of 180 kg ha^{-1} N). It can be seen that the different nitrogen doses do not create a statistically significant difference in terms of the value of NDVI-1 in the leaf. It is thought that this may be related to the time of measurement of the NDVI and the development stage of the cotton plant. In the study, NDVI-1 was measuree at the beginning of flowering. Zhou and Yin (2018) reported that NDVI readings from the middle of flowering to the late flowering period are the appropriate period to determine the nitrogen status in the plant, and that the early squaring period gives reliable results to estimate the yield.

NDVI-2

In terms of NDVI-2, it can be seen that there is a statistical difference at 5% significance level between the applications. As shown in *Table 2*, the average values of NDVI-2 depending on the nitrogen dose varied between 0.69 and 0.79 and the overall mean of the trial was 0.76. The minimum NDVI was observed with the control application (0.69), while the highest values were obtained with the 3rd, 4th, 5th, and 6th applications. NDVI-2 readings were taken during boll formation period. Significant statistical differences were obtained between applications in the study in which NDVI-2 value was examined by applying different nitrogen doses. It was observed that the NDVI-2 value increased with increasing nitrogen doses.

Among the nitrogen doses, 120, 180, 240 and 300 kg ha^{-1} N shared the same group, while the control treatment without nitrogen was included in a different statistical level. This shows that a distinction can be made in terms of NDVI in 0 and 60 kg ha^{-1} nitrogen applications compared to higher N applications. However, it would be more difficult to discern a difference between the 120 kg ha^{-1} N and higher doses.

These findings are in parallel with those of Porter (2010), who stated that there is a strong correlation between NDVI and nitrogen requirement in plant. Arnall *et al.* (2016). reported that the NDVI obtained during the white blooming period of cotton showed a strong correlation with the final yield, using the value of the NDVI to estimate the final yield of cotton during the season, and the potential of using it for the recommendation of the nitrogen dose in cotton. Foote et al. (2016) stated that the GreenSeeker sensor is sensitive to nitrogen and can be used to determine the nitrogen requirement of the product.

Leaf Area (LA)

It is seen that nitrogen applications applied at different doses do not cause a statistically significant difference in terms of LA and that no significant difference can be obtained between the applications in terms of this feature (*Table 2*).

As shown in *Table 2*, the single LA varied between 54.54 in control variant and 69.91 cm^2 where 120 kg ha^{-1} nitrogen dose was applied. Partially different results were obtained by Zhao and Oosterhuis (2000), who stated that there was a decrease in the LA in different nitrogen application methods, Gerik *et al.* (1998), and that low nitrogen dose caused a decrease in the LA (Wullschleger and Oosterhuis, 2008).

Plant Height (PH)

As shown in *Table 2*, different nitrogen doses do not cause a significant statistical difference in PH.

Depending on the nitrogen dose, the plant height varied between 71.09 and 92.21 cm and the general average value of the experiment was 84.89 cm. The lowest PH was obtained from the control application, despite the fact that there was no statistically significant difference between the applications (71.09 cm), on the other hand the highest value was obtained from 6^{th} application (92.21 cm) which is the N application of 300 kg ha^{-1}. No significant statistical difference has been obtained in terms of PH with different nitrogen doses applied.

Previous studies indicated that by applying N the plant height increased (Perumal, 1998; Liaqat *et al.*, 2018; Bronson *et al.*, 2015). The results of this study differ from that of previous studies. The reason for the non-significance of the difference between nitrogen doses in terms of PH may be related to the cotton variety used in the experiment, the climatic conditions effective in the trial year and irrigation.

Table 2 – The investigated traits mean values and statistical levels

Nitrogen Doses (kg ha^{-1})	CHLC (SPAD)	NDVI-1	NDVI-2	LA (cm^2)	PH (cm)	NMB	NSB	NNFFB
						number per plant		
Control	41.25 c	0.72	0.69 b	54.54	71.09	1.16	12.41	5.68
60	43.67 bc	0.79	0.73 ab	59.79	83.95	1.19	14.01	5.73
120	49.17 a	0.82	0.79 a	69.91	83.89	1.65	13.59	5.69
180	47.35 ab	0.83	0.78 a	66.64	90.28	0.99	15.79	5.73
240	46.25 ab	0.79	0.79 a	67.91	87.89	1.36	14.06	5.88
300	47.17 ab	0.82	0.79 a	67.38	92.21	1.61	15.28	6.33
Mean	45.84	0.79	0.76	64.36	84.89	1.33	14.19	5.84
CV (%)	6.13	6.32	5.26	17.51	12.54	39.09	11.41	11.13
LSD ($_{0.05}$)	4.23**	ns	0.06*	ns	ns	ns	ns	ns

*, **; Significant at p≤ 0.05 and p≤ 0.01, respectively CHLC: Chlorophyll Content (SPAD); NDVI-1: Normalized difference vegetative index in the beginning of the flowering; NDVI-2: Normalized difference vegetative index in the boll formation period; LA: Leaf area, PH: Plant height; NMB: Number of monopodial branches; NSB: Number of sympodial branches; NNFFB: Node number of first fruiting branches.

Number of Monopodial Branches (NMB)

In *Table 2*, it can be observed that different nitrogen doses used in practice do not create a statistically significant difference in term of NMB. The nitrogen dose, differentiated the NMB which varied between 0.99 to 1.65 number plant^{-1} and the general mean of the study was 1.33 number plant^{-1}. Although the nitrogen dose applied does not make a significant difference in the NMB, the lowest value was obtained from 180 kg ha^{-1} nitrogen dose (4th application) as 0.99 number plant^{-1}, and the highest value was obtained from 120 kg ha^{-1} nitrogen dose (3rd application) as 1.65 number plant^{-1}. However, different nitrogen doses used in this experiment did not cause a significant difference in NMB. These results differ from those of Durkal and Mert (2017), who reported that NMB increased with the increase in nitrogen dose.

Number of Sympodial Branches (NSB)

It can be observed from *Table 2* that different nitrogen doses do not cause a significant statistical difference in the NSB. Average values for the NSB formed in the plant depending on different nitrogen doses varied between 12.41 (control variant without nitrogen application) and 15.79 (180 kg ha^{-1} N, from the 4th application) number plant^{-1}; mean of the experiment was 14.19 number plant^{-1}.

These results differ from the findings that the number of fruit branches increases as the nitrogen doses increase (Karademir *et al.*, 2006; Bibi *et al.*, 2011; Durkal and Mert, 2017). This may be because of the used plant material in the research and climatic conditions.

Number of Nodes of First Fruiting Branches (NNFFB)

In *Table 2* it can be seen that different nitrogen doses used in the experiment do not cause a statistically significant difference in the NNFFB. Depending on the nitrogen dose, the NNFFB varied between 5.68 in control variant and 6.33 number plant^{-1} from the 6th application where 300 kg ha^{-1} nitrogen was applied; general mean was 5.84 number plant^{-1}.

These findings are similar to those of Karademir *et al.* (2006) who reported that there was no significant differences between nitrogen doses in terms of this feature. But it is contradictory to that of Durkal and Mert (2017), who reported that the NNFFB increases with the increase of nitrogen doses.

Number of Bolls (NB)

It can be seen from *Table 3* that there is a statistical difference at the 1% significance level between the applications in terms of the NB. Depending on the nitrogen dose, the NB in the plant varied between 11.88 and 18.40 number plant^{-1} and the general average as 14.69 number plant^{-1}. Among the applications, the highest value was obtained from applying a nitrogen dose of 120 kg ha^{-1} (3rd application), with 18.40 number plant^{-1}. This application was followed by 300 kg ha^{-1} (6th application), with 15.76 number plant^{-1} and 180 kg ha^{-1} (4th application), with 15.46 number plant^{-1}. These applications shared the same statistical group that can be viewed in the same table. The lowest NB was obtained from 60 kg ha^{-1} nitrogen as well as from the control application: 11.88 and 11.89 number plant^{-1}, respectively.

These two applications were in the same statistical group. It can be seen that nitrogen doses in the experiment caused significant differences in the NB and that they fall into 3 different statistical groups. Increasing the nitrogen dose increased the NB compared to the control. Similar values obtained Bibi *et al.* (2011), Durkal and Mert (2017) and Liaqat *et al.* (2018).

Number of Nodes (NN)

As shown in *Table 3* the different nitrogen doses do not create a significant statistical difference in the NN in the plant. Mean values of the NN formed in the plant, depending on the nitrogen dose, varied between 17.81 (control variant) and 21.71 number plant^{-1} (from the 6th application, 300 kg ha^{-1} nitrogen dose) and the general mean of the experiment was 19.87 number plant^{-1}. It has been determined that the different nitrogen doses do not have a significant effect on the NN formed in the plant. However, Bondada *et al.* (1996), El-Zahi *et al.* (2012), and Liaqat *et al.* (2018) reported that an increased nitrogen dose increased the NN in the plant.

Height to Node Ratio (HNR)

In *Table 3*, it is shown that there was no statistically significant difference in terms of HNR. The average values of HNR varied between 3.99 and 4.43 number plant^{-1}, and the general mean of the experiment was 4.27 number plant^{-1}.

In terms of HNR, the control application yielded the lowest value (3.99 number plant^{-1}) and fifth application produced the highest value (4.43 number plant^{-1}). Ayissa and Kebede (2011)'s results differed from those of this study.

Boll Weight (BW)

There was no statistical difference between the nitrogen applications in terms of BW. The boll weight varies between 6.60 g (control variant) and 7.20 g (240 kg ha^{-1} nitrogen dose) and the general average of the trial is 6.92 g (*Table 3*). There was a slight increase in the BW depending on the different nitrogen doses used in the application.

These results of the study differ from those who reported that the cotton BW increased with the increase of nitrogen dose (Saleem *et al.*, 2010; Bibi *et al.*, 2011; Görmüş *et al.*, 2016; Durkal and Mert, 2017).

Seed Cotton Boll Weight (SCBW)

There was no statistically significant difference between applications in terms of SCBW as can be seen in *Table 3*. The SCBW obtained depending on different nitrogen doses varied between 5.04 (control variant) and 5.40 g (240 and 300 kg ha^{-1} N) and the general mean value was 5.27 g. These results differ from those of Durkal and Mert (2017), who reported that the SCBW increases as the nitrogen doses increase.

Ginning Percentage (GP)

The mean values of the GP depending on the nitrogen dose varied between 42.54% and 44.32% and the general mean of the experiment was 43.13%. (*Table 3*). In terms of the GP, the lowest result was obtained from the 5th application (42.54%) and the highest was obtained from the control application (44.32%).

These findings are in parallel with those of Karademir *et al.* (2006) and Durkal and Mert (2017).

Table 3 – The investigated traits mean values and statistical levels

Nitrogen Doses (kg ha^{-1})	NB (number plant^{-1})	NN	HNR	BW (g)	SCBW (g)	GP (%)	FY (kg ha^{-1})	SCY (kg ha^{-1})
Control	11.89 c	17.81	3.99	6.60	5.04	44.32	1364.6 c	3080.9 c
60	11.88 c	19.21	4.36	6.73	5.10	43.66	1447.8 c	3314.5 c
120	18.40 a	19.29	4.38	6.90	5.31	42.87	1801.8 a	4202.6 a
180	15.46 ab	21.39	4.22	6.98	5.34	42.71	1914.2 a	4486.9 a
240	14.78 bc	19.80	4.43	7.20	5.40	42.54	1777.4 a	4177.6 a
300	15.76 ab	21.71	4.26	7.13	5.40	42.68	1615.8 b	3783.3 b
Mean	14.69	19.87	4.27	6.92	5.27	43.13	1653.6	3841.0
CV (%)	14.70	9.05	6.55	6.21	6.64	2.27	5.79	5.72
LSD ($_{0.05}$)	3.25**	ns	ns	ns	ns	ns	144.4**	331.0**

*, **; Significant at $p \leq 0.05$ and $p \leq 0.01$, respectively NB: Number of bolls; NN: Number of Nodes; HNR: Height/node ratio; BW: Boll weight; SCBW: Seed cotton boll weight; GP: Ginning percentage; FY: Fiber Yield; SCY: Seed cotton yield.

The results of this study are in conflict with those of Saleem *et al.* (2010), who reported that the GP was affected by the nitrogen dose. The reason for this conflict may be due to the difference in the material used or ginning by different ginning machine in the study.

Fiber Yield (FY)

In *Table 3*, it can be observed that there is a statistical difference at the 1% significance level between applications in terms of FY. The average values varied between 1364.6 in control variant and 1914.2 kg ha^{-1} from the 4th application of 180 kg ha^{-1}N and these results are followed by the 3rd and 5th applications; general average was 1653.6 kg ha^{-1}. The nitrogen doses used in the experiment had a statistically significant effect on FY and different statistical groups were formed. The control application and the lowest nitrogen dose of 60 kg ha^{-1} nitrogen were included in the same group.

The fact that the highest FY value in the study was obtained from 180 and 120 kg ha^{-1} nitrogen doses and that FY decreased at higher levels of these doses shows that these doses are the optimum dose. Similar findings were obtained by (Bondada *et al.*, 1996; Karademir *et al.*, 2006; Durkal and Mert, 2017). The findings of the presented research are partially similar to the findings of (Madani and Oveysi, 2015), which reported that increasing the nitrogen dose decreases the FY.

Seed Cotton Yield (SCY)

It can be seen that different nitrogen doses have a significant effect on SCY and cause statistical differences at 1% significance level between applications (*Table 3*). Average yield varied between 3080.90 kg ha^{-1} in control variant and 4486.90 kg ha^{-1} from the 4th application, 180 kg ha^{-1} N application. The application was followed by the third application (4202.60 kg ha^{-1}) with 120 kg ha^{-1} N and 5th application with 240 kg ha^{-1} N, and it was determined that these three nitrogen dose applications were in the same statistical group. Depending on the nitrogen dose applied, it can be seen that the general average of SCY is 3841.00 kg ha^{-1}.

When compared with the control, it was observed that a nitrogen dose of 240 kg ha^{-1} led to an increase in yield of 1406.00 kg ha^{-1}, while a nitrogen dose of 120 kg ha^{-1} resulted in an increase of 1121.70 kg ha^{-1}. It is seen that these results show similarities with the findings that the yield of seed cotton increases as the nitrogen doses increase in (Perumal, 1998; Bibi *et al.*, 2011; Durkal and Mert, 2017; Omadewu *et al.*, 2019).

Fiber Quality (FQ)

No significant differences between the nitrogen doses for FQ properties except fiber strength. Fiber strength varied between 27.10 g tex^{-1} (120 kg ha^{-1} N) to 29.17 g tex^{-1} (from 240 kg ha^{-1} N) (*Table 4*).

DISCUSSION

The results indicate that there are statically significant differences between applications for leaf SPAD, NDVI-2, NB, SCY and FY, while the differences are non-significant for NDVI-1, LA, PH, NMB, SMB, NNFFB, NB, HNR, BW, SCBW and ginning turnout. The results of fiber quality properties indicated that there were non-significant differences among nitrogen doses for all fiber quality properties except fiber strength.

The highest SCY and FY values were obtained from 180 and 120 kg ha^{-1} N, while the highest SPAD and NB were obtained from 120 kg ha^{-1} N. The highest value of NDVI-2 was obtained from 120, 240, 300 and 180 kg ha^{-1} N. It was observed that there were non-significant differences between nitrogen doses for NDVI-1 measured at the beginning of flowering, significant statistical differences were obtained in terms of NDVI-2 measured during the boll forming period. In particular, there were clear differences with higher doses in applications where nitrogen was not applied at all and low doses such as 60 kg ha^{-1}. The findings observed from the experiment indicate that determining the chlorophyll content SPAD in the leaf and the value of the NDVI during the boll forming period can be used to detect nitrogen differences.

The obtained results indicate that there are non-significant differences between nitrogen doses at beginning of flowering period for NDVI, but significant differences in the NDVI at the boll forming period.

Table 4 – Mean values and statistical levels of fiber quality properties

Nitrogen Doses (kg ha^{-1})	FF (mic.)	FL (mm)	STR (g/tex)	ELG (%)	UNF (%)	SFI (%)	RF (Rd)	YLW (+b)	SCI (%)
Control	4.68	28.95	28.82 a	5.85	84.97	6.20	81.60	7.25	135.25
60	4.71	29.02	29.15 a	5.80	84.75	6.75	80.30	7.37	139.00
120	4.63	29.21	27.10 b	6.02	84.02	7.15	81.35	7.62	131.50
180	4.78	29.36	28.40 ab	5.80	84.67	5.87	81.22	7.82	137.00
240	4.80	29.53	29.17 a	5.82	84.72	6.27	80.32	7.97	139.25
300	4.61	29.76	28.60 a	5.85	85.47	6.07	80.77	7.62	142.00
Mean	4.70	29.30	28.54	5.85	84.77	6.38	80.92	7.61	137.33
CV (%)	6.17	2.28	3.08	4.95	1.23	12.53	2.21	5.78	5.33
LSD ($_{0.05}$)	ns	ns	1,30 *	ns	ns	ns	ns	ns	ns

*, **; Significant at P ≤0.05 and *p*≤ 0.01, respectively FF: Fiber fineness; FL: Fiber length; STR: Fiber strength; ELG: Elongation; UNF: Uniformity; SFI: Short fiber index; RF: Reflectance; YLW: Yellowness; SCI: Spinning consistency index.

This has given the impression that the period of the onset of flowering is an early period for making the decision on a lack of nitrogen. The application of the 2nd fertilizer doses to the parcels before flowering and the subsequent irrigation may have also caused the difference to be obtained. This indicates that it will be more appropriate to determine the NDVI after this period. Obtaining differences between nitrogen doses in terms of the SPAD in the plant shows that the SPAD can be used as a good indicator for nitrogen management.

The highest SCY and FY values were obtained from 180, 120 and 240 kg ha^{-1} N. The SCY and FY decreased at higher nitrogen doses. In terms of the NB, the highest value was obtained from 120 kg ha^{-1} N fallowed by 180 and 300 kg ha^{-1}. The highest SCY obtained from 180 kg ha^{-1} nitrogen doses was 4486.90 kg ha^{-1} and from 120 kg ha^{-1} N, it was 4202.60 kg ha^{-1}, in this case SCY increased 284.30 kg ha^{-1} due to the increasing 60 kg ha^{-1} N.

When the seed cotton yield, FY, number of bolls, SPAD and NDVI-2 were evaluated together, it was concluded that the nitrogen dose at 120 kg ha^{-1} was the most appropriate dose. Thus, the SPAD and the value of the NDVI during the boll formation period can be used to detect nitrogen differences.

CONCLUSIONS

It has been determined that the nitrogen dose applied to cotton has a significant effect on the SPAD, NDVI measured in the boll forming period, the NB, SCY, FY and fiber strength. In terms of these properties, the highest values were obtained from nitrogen doses of 180 and 120 kg ha^{-1}. The highest fiber strength was obtained from the nitrogen dose of 240 kg $ha^{-1.}$ It was determined that the nitrogen dose did not have a significant effect on other FQ properties. It has been observed that determining the chlorophyll content and NDVI value during the boll formation period are good indicators for determining the difference between the nitrogen doses. In the study, NDVI was measured with GreenSeeker instrument twice: at the beginning of flowering and during the boll forming period. It is considered that measuring the NDVI at certain intervals (weekly or 10 days apart) starting from the flowering period will be a recommended practice for nitrogen management and this recommendation should be taken into consideration in future studies.

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