How to cite: Şahin, E. & E. Karademir, 2024. Determination the effect of magnesium applications on yield, fiber quality and chlorophyll content in cotton. Ege Univ. Ziraat Fak. Derg., 61 (4): 461-474, https://doi.org/10.20289/zfdergi.1470053

Research Article
(Araştırma Makalesi)

Ege Üniv. Ziraat Fak. Derg., 2024, 61 (4):461-474
https://doi.org/10.20289/zfdergi.1470053

Determination of the effect of magnesium applications on yield, fiber quality and chlorophyll content in cotton*

Magnezyum uygulamalarının pamukta verim, lif kalite kriterleri ve klorofil içeriğine etkisinin belirlenmesi

* This article has been summarized from the first author's master dissertation.

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Received (Alınış): **19.04.2024** **Accepted** (Kabul Tarihi):**05.10.2024**

ABSTRACT

Objective: The objective of this investigation was to determine the effects of different applications of magnesium (Mg) on yield, yield attributes, fiber quality traits, chlorophyll content, and normalized difference vegetative index in cotton.

Material and Methods: In this study 7 different Mg applications were applied, and MAY 455 cotton cultivar and Magnesium Sulphate were used.

Results: It was determined that seed cotton yield, number of nodes of first fruiting branches, number of vegetative branches, number of bolls, height/node ratio, boll weight, fiber strength, uniformity, elongation, and spinning consistency index were affected by magnesium applications. The highest value in terms of the number of bolls, number of vegetative branches and height/node ratio was observed with 200 cc/da Mg application at the squaring stage, while the highest seed cotton yield was recorded with 200 cc/da Mg at flowering stage and Mg application lead to increase 60 kg/da in seed cotton yield. The highest spinning consistency index and uniformity was obtained with 600 cc/da Mg application at the squaring stage, other quality traits were affected by different doses or application stages.

Conclusion: Applying green parts during the squaring or flowering period may be advantageous since magnesium has a positive impact on the yield and certain fiber quality of cotton.

Keywords: Cotton, chlorophyll, fiber quality, magnesium, NDVI, yield

ÖZ

Amaç: Bu araştırmanın amacı, farklı magnezyum (Mg) uygulamalarının pamukta verim, verim kriterleri, lif kalite özellikleri, klorofil içeriği ve normalize edilmiş vejetasyon farklılık indeksi üzerindeki etkilerini belirlemektir.

Materyal ve Yöntem: Çalışmada 7 farklı Mg uygulaması yer almış, MAY 455 pamuk çeşidi ve Magnezyum Sülfat kullanılmıştır.

Araştırma Bulguları: Magnezyum uygulamalarının kütlü pamuk verimi, ilk meyve dalı boğum sayısı, odun dalı sayısı, koza sayısı, boy/nod oranı, koza ağırlığı, lif mukavemeti, üniformite, uzama ve iplik olabilirlik indeksini etkilediği belirlenmiştir. Koza sayısı, odun dalı sayısı ve boy/nod oranı bakımından en yüksek değer taraklanma döneminde 200 cc/da Mg uygulamasında elde edilirken, en yüksek kütlü pamuk verimi çiçeklenme döneminde 200 cc/da Mg uygulamasından elde edilmiştir. Mg uygulaması pamuk veriminde 60 kg/da artışa yol açmıştır. En yüksek lif üniformitesi ve iplik olabilirlik indeksi taraklanma döneminde 600 cc/da Mg uygulamasıyla elde edilmiş, diğer lif kalite özellikleri farklı dozlardan ve farklı uygulama dönemlerinden etkilenmiştir.

Sonuç: Pamuk üretiminde taraklanma veya çiçeklenme döneminde magnezyum uygulamasının pamuk verimini ve bazı lif kalite özelliklerini olumlu yönde etkilemesi nedeni ile yeşil aksama uygulanmasının faydalı olabileceği sonucuna varılmıştır.

Anahtar sözcükler: Pamuk, klorofil, lif kalitesi, magnezyum, NDVI, verim

INTRODUCTION

Magnesium is an essential macro element that affects the growth and development of plants, however it is known that further research is being done on other nutritional elements. For this reason, the concept of a forgotten element emerged and was used (Çakmak & Yazıcı, 2010; Guo et al., 2016). A defining reason for this gap in research is that Mg deficiency is often unrecognized or undiagnosed in agriculture. Indeed, acute Mg deficiency is typically associated with visible intervascular chlorosis and reduced growth, while the more common latent deficiency is often not visible and difficult to diagnose, but negatively affects crop yield (Çakmak & Yazıcı, 2010; Çakmak & Kirkby, 2008). Root growth in the plant decreases in magnesium deficiency, and it has been reported that monitoring root growth under Mg deficiency conditions may be a more reliable indicator than chlorosis (Çakmak et al., 1994).

Plant production frequently experiences both latent and acute magnesium shortages (Römheld & Kirkby, 2007). A common sign of magnesium insufficiency is intravenous chlorosis of the leaves. Since Mg acts as the central atom in the chlorophyll molecule, the development of chlorosis requires prior degradation of chlorophyll. Since Mg is strongly bound to this molecule, chlorosis appears to be a late response to Mg deficiency. In plants well-nourished with Mg, only approximately 20% of the total Mg is bound to chlorophyll, while the remaining approximately 80% is found in more mobile forms (Marschner et al., 1996; Marschner, 2012).

Symptoms of magnesium excess are generally rare. The most important negative effect of magnesium excess is that it prevents K and Ca uptake. The Mg concentration required for optimal plant growth is between 0.15 and 0.35% of the plant dry weight (Karaman, 2012).

Magnesium is a silver-white metal and is often used by mixing it with other metals. Its chemical symbol is Mg, atomic number is 12; this element, with an atomic weight of 23.312, is one of the lightest metals and has gained importance with this feature. Chlorophyll, which gives the green color to the leaf, contains magnesium. Since magnesium is included in the composition of chlorophyll, in case of its deficiency, not enough chlorophyll can be formed in the leaves and as a natural result, chlorosis problem occurs in the leaves. The most important function of magnesium is to be the central cation in the chlorophyll molecule. Magnesium is a mobile element in plants, so it accumulates most in the growth tips of plants and especially in young leaves. Magnesium is a mobile nutrient, and its remobilization occurs from older leaves to younger leaves (Taiz & Zeiger, 2010). It is transported to the seed from these regions during seed formation. Magnesium deficiency first manifests itself in older leaves.

It is known that plants absorb magnesium from the soil in the form of Mg^{2+} ions. Magnesium is taken into plant root cells either actively by energy-requiring metabolic processes or passively by diffusion along a channel along a concentration gradient (from high Mg concentration to low Mg concentration). Some researchers have stated that Mg is passively taken up into root cells, but at a later stage, it is transferred from the cytoplasm to the vacuole by active uptake processes through carrier pumps present in the membrane such as H-ATPase and inorganic pyrophosphatase. Although the dissolved Mg level in the soil solution is higher than K, Mg migration into the root is less than K migration. It has been stated that changing Ca:Mg ratios in soil does not affect fiber yield, fiber quality properties and K uptake in cotton (Stevens et al., 2005). Prior studies have revealed that excess K in soil can limit the uptake of both Mg and Ca from the soil and vice versa. Antagonistic effects between Mg, Ca and K have also been reported by other researchers (Farhat et al., 2016; Chaganti & Culman, 2017).

The most ubiquitous enzyme on earth, ribulose-1,5-bisphosphate (RuBP) carboxylase, is a crucial Mg-activated enzyme involved in photosynthesis. As a result, magnesium deficiency adversely affects numerous vital physiological and biochemical processes in plants, which deteriorates growth and output. Generally, magnesium's role in metabolic processes stems from its ability to activate a multitude of enzymes (Çakmak & Yazıcı, 2010). For this reason, it is stated that there are new findings that it effects on issues such as the physiology of Mg uptake by plants and the role of Mg in stress physiology (heat, drought, low pH, high radiation, metal toxicity, etc.) (Granse & Führs, 2013).

It has been reported that magnesium increases resistance to diseases in plants and has both a direct and indirect effect on the disease, its response to changing environmental conditions may be different due to its antagonistic effect with other elements, and fusarium wilt pathogens are less effective in the presence of sufficient Mg (Huber & Jones, 2012).

The concentration of Mg in plant tissues varies not only according to the plant species and variety but also according to the developmental stage of the plant and its development period. Ahmed et al. (2020), reported that the amount of Mg in the leaves, stems and roots of cotton was 801.6 mg/kg, 765.4 mg/kg, 649.5 mg/kg, respectively, Mg deficiency causes browning, yellowing, and necrosis of the leaves, and photosynthesis decreased due to the accumulation of sugars and starches in photosynthetic products. Although the Mg concentration of the plant varies depending on the level of other mineral nutrients and environmental factors, it is also affected by climatic factors. Although the importance of magnesium as an essential phytonutrient in plants is well established, the effect of Mg on quality parameters has rarely been addressed (Gerendas & Führs, 2013).

The purpose of this study was to determine the effects of different applications of magnesium on seed cotton yield and fiber yield, yield attribute traits, fiber quality characteristics, chlorophyll content and NDVI value.

MATERIALS and METHODS

This experiment was conducted in 2021 in the experimental area of the Siirt University Faculty of Agriculture. In the research, MAY 455 upland cotton variety obtained from the private sector was used as plant material, and Magnesium Sulfate in liquid form was used as a magnesium source.

Soil samples were taken from the trial area from 0-30 cm soil depth before planting and some soil properties were analyzed at the university laboratory. The determined features are given below in Table 1.

Table 1. Main properties of the soil in the experimental area

Çizelge 1. *Deneme alanı topraklarının başlıca özellikleri*

Specifications	Value
Clay-Loam, %	59,4
Electrical conductivity, dS /m	0,37
pH	7,90
Lime, %	1,58
Organic matter, %	0,92
Phosphorus, P_2O_5 (kg da^{-1})	5,59
Potassium, K_2O (kg da^{-1})	27,28

**: Siirt University, Science and Technology Application and Research Center's Laboratory

Planting was performed with a cotton experimental planting machine on 13 April 2021, and each parcel, four rows with a length of 6 m was planted, inter-rows were fixed at 0.7 m during sowing and a 2 m gap was left between blocks. A total of 140 kg ha^{-1} nitrogen and 80 kg ha^{-1} phosphorus were supplied to the experiment. At the sowing, 80 kg ha^{-1} nitrogen and 80 kg ha^{-1} phosphorus were applied to the band with a seeder in the form of compose fertilizer, and the remaining nitrogen (60 kg ha^{-1} N) was applied in the form of urea before the first irrigation.

Climate data for 2021, when the experiment was conducted, and long- term climate data have been given in Figures 1 & 2. When the climate data for 2021 is compared to the long term, it can be observed that the minimum, maximum and average temperature values are above the long-term average (Figure 1).

When the total amount of precipitation is examined, it is seen that the amount of precipitation in the year when the experiment was conducted was behind the long term. The relative humidity values of the year in which the experiment was conducted were behind long-term in April, May, June, October and November, and above long- term in July, August and September (Figure 2).

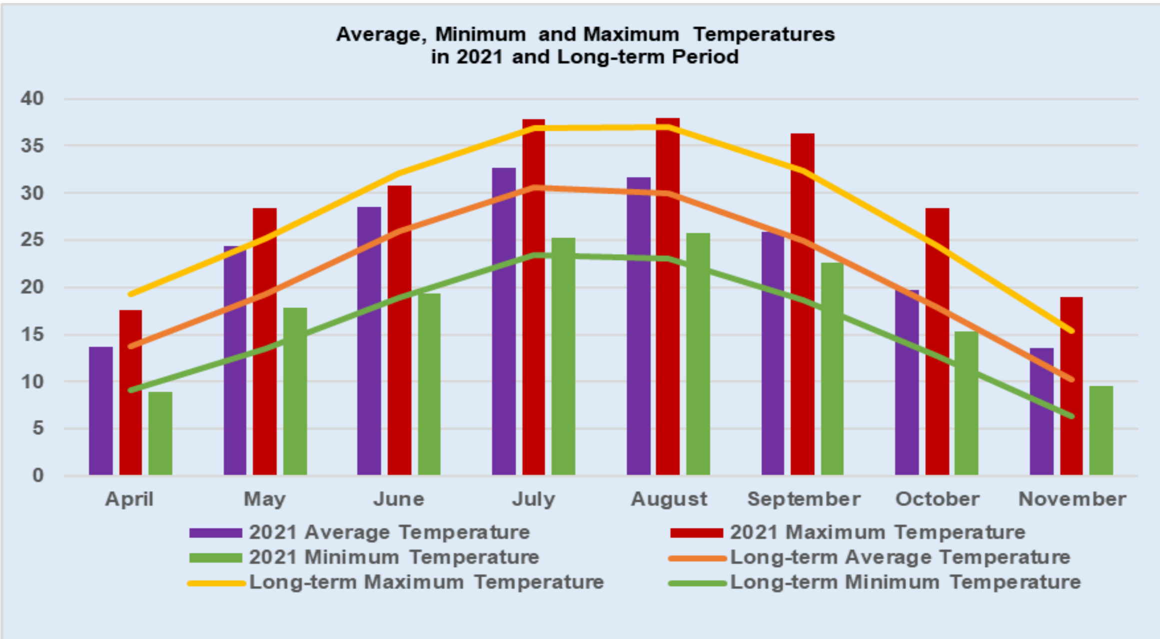

Figure 1. Minimum, maximum and average temperature during 2021 and long-years period.

Şekil 1. 2021 yılına ve uzun yıllara ait minimum, maksimum ve ortalama sıcaklık değerleri.

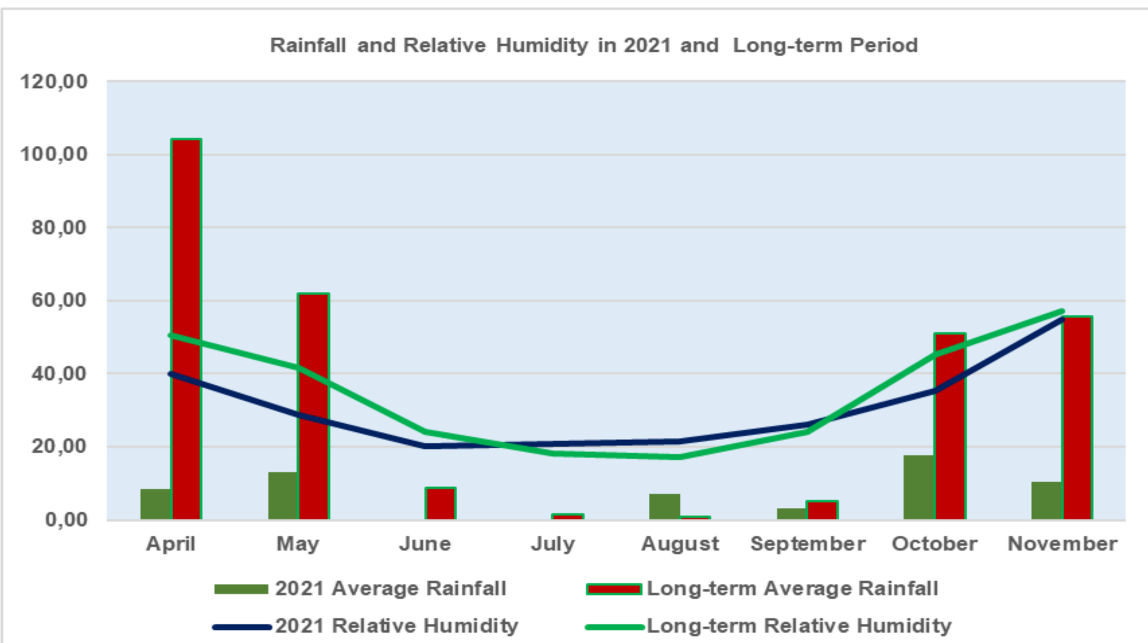

Figure 2. Average rainfall and relative humidity during 2021 and long-years period.

Şekil 2. 2021 yılına ve uzun yıllara ait yağış ve nispi nem değerleri.

Magnesium was applied as foliar treatment with the use of a back sprayer. It was compared with the control by applying doses of 200 cc, 400 cc and 600 cc da^{-1} during the squaring period of plant development and the flowering period. The experiment was conducted and analyzed according to the completely randomized block design with 4 repetitions and 7 different magnesium treatments were included in the experiment.

All maintenance operations in the trial were performed on time. Regular pest control was carried out, during the observations made in June, the *thrips* pest was found, and the pest was taken under control by insecticide. The furrow irrigation method was applied, irrigation started during the blooming period and terminated 10% of the bolls opening.

In the study, some agronomic characteristics were recorded from randomly selected 10 plants of each plot, and normalized difference vegetative index values (NDVI) were determined by a GreenSeeker, which is a handheld crop sensor from the center two rows of the plot and 60 cm above the cotton plant during the flowering stage, 15 days after the magnesium application. Chlorophyll content was determined according to Johnson & Sounders (2003) using the top 5th newly opened leaf and fully grown, ten randomly selected plants from each plot during the flowering stage (15 days after magnesium application) with the help of Minolta SPAD-502 instrument.

Harvesting was done manually and completed two times. The first picking was performed on September 15, when 60% of the bolls opened, and the remaining product was completed in the second harvest on October 2, 2021. First and second- hand harvested cotton was weighed separately and then converted into total yield. After the harvest was completed, samples of seed cotton were ginned with a small roller-gin to determine the ginning percentage. Fiber samples were analyzed for fiber quality properties with the Uster HVI 1000.

All data collected from the experiment were analyzed according to the completely randomized block design with 4 repetitions and groupings were made according to Duncan's multiple range tests at *p≤0.05.*

RESULTS and DISCUSSION

The differences between investigated traits and Duncan's test results are given in Tables 2-4.

Table 2. Average values and statistical levels of investigated agronomic traits

Çizelge 2. *İncelenen agronomik özelliklere ait ortalama değerler ve istatistiki gruplamalar*

Applications	PH	NMB	NSB	NNFFB	NN	HNR	BN	BW
1. Control	63.86±1.44	2.26±0.02^{bc}	10.60±0.19	6.33±0.40^{b}	16.93±0.49	3.78±0.03^{b}	8.86±0.34^{c}	7.13±0.07^{a}
2. Squaring (200 cc)	70.80±2.95	3.00±0.10^{a}	10.66±0.76	6.26±0.61^{b}	16.93±1.16	4.28±0.17^{a}	11.93±1.26^{a}	6.93±0.18^{abc}
3. Squaring (400 cc)	67.53±0.38	1.66±0.02^{c}	10.20±0.21	6.20±0.28^{b}	16.40±0.37	4.13±0.10^{ab}	8.66±0.18^{c}	6.96±0.08^{abc}
4. Squaring (600 cc)	70,66±1.41	2.93±0.35^{ab}	9.93±0.25	8.00±012^{a}	17.93±0.29	3.95±0.01^{ab}	8.80±0.79^{c}	6.63±0.11^{c}
5. Flowering (200 cc)	70.33±2.72	2.26±0.15^{abc}	11.06±0.64	6.40±0.21^{b}	17.46±0.45	4.04±0.09^{ab}	11.26±0.17^{ab}	7.00±0.05^{ab}
6. Flowering (400 cc)	66.80±1.95	2.73±0.38^{ab}	10.40±0.04	7.40±0.20^{ab}	17.80±0.31	3.77±0.05^{b}	10.00±0.33^{abc}	7.16±0.10^{a}
7. Flowering (600 cc)	67.40±1.86	2.00±0.11^{c}	9.53±1.69	6.46±0.45^{b}	17.33±1.04	3.93±0.16^{ab}	9.33±0.72^{bc}	6.63±0.10^{bc}
Mean	68.20	2.40	10.34	6.72	17.25	3.98	**9.83**	**6.92**
CV (%)	6.30	19.18	15.84	11.72	8.46	5.78	14.52	3.42
F value	ns	4.65**	ns	3.10*	ns	2.50*	3.29*	3.32*

*, **; Significant at $p \leq 0.05$ and $p \leq 0.01$, respectively

Different letters in the same column indicate that the difference between the means is statistically significant (p<0.05).

PH: Plant height; NMB: Number of monopodial branches; NSB: Number of sympodial branches; NNFFB: Node number of first fruiting branches; NN: Number of nodes; HNR: Height/Node ratio; BN: Boll number; BW: Boll weight.

Plant height

Average values of plant height varied between 63.86 and 70.80 cm, depending on the magnesium applications, however, the differences between the treatments were not significant. It can be observed that the general average of the trial is 68.20 cm as shown in Table 2.

From the same table, it can be seen that the highest plant height value was obtained from the 200 cc/da magnesium application during the squaring period, which is the second application (70.80 cm), and the lowest value of plant height was observed from the control (63.86 cm). In the study, it was determined there was a slight increase in plant height values with magnesium application compared to the control, Sankaranarayanan et al. (2010) revealed that plant height was not affected by magnesium. Madaan et al. (2014) and Sadeghi et al. (2021) also revealed the same results, however, Jayalalitha & Narayanan (1996) and also Mobarak et al (2013), pointed out that plant height was slightly affected by magnesium deficiency in cotton. It was reported that in the registration trials of the MAY 455 cotton variety in 2021, the plant height varied between 86 and 100 cm, and in 2022 it varied between 100 and 117 cm (Anonymous, 2023). In this study, the plant height was found to be lower. These differences may have been due to planting time, cultural practices, climatic conditions etc.

Number of monopodial branches

As shown in Table 2, the differences between treatments are statistically significant at the 1% probability level for the number of monopodial branches. The average values for the number of monopodial branches in the plant changed between 1.66 and 3.00 number plant^{-1}, and the overall average value of the experiment was 2.40 number plant^{-1}.

The lowest value of the number of monopodial branches was recorded with the magnesium application at a dose of 400 cc/da during the squaring stage (1.66 number plant^{-1}) while the highest value was recorded from the magnesium application during the squaring stage at a dose of 200 cc/da. It is seen that magnesium applications applied in different doses and different plant development periods such as squaring and flowering have a significant effect on the number of monopodial branches. Rajakumar et al. (2010) reported that magnesium applications positively affected the number of monopodial branches.

Number of sympodial branches

It can be observed that there were no statistically significant differences in terms of the number of fruiting branches. The average values recorded for the number of fruiting branches per plant ranged from 9.53 to 11.06, and the overall average of the experiment was 10.34 number per plant^{-1} (Table 2).

For the number of fruiting branches, the lowest value (9.53 number plant^{-1}) was observed from the magnesium treatment applied at a dose of 600 cc/da during the flowering stage, and the highest value (11.06 number plant^{-1}) was recorded from the magnesium treatment applied to the during the flowering stage, at a dose of 200 cc/da, however, it can be observed that the differences between magnesium applications are not statistically significant.

Research findings appear to differ from those of Durmaz (2002) and Rajakumar & Gurumurthy (2008), who reported that magnesium applications positively affected the number of fruiting branches. The reason for this may be the type of cotton used as plant material in the study, climatic factors, differences in the cultural applications, and differences in nutrients in the soil.

Number of nodes of first fruiting branches

There were statistically significant differences between magnesium treatments for the number of nodes of the first fruiting branches as shown in Table 2. The values changed between 6.20 and 8.00 number plant^{-1}. The lowest value for the number of nodes of first fruiting branches was 6.20 number plant^{-1}, obtained from

400 cc/da magnesium treatment during the squaring stage, and the highest value for the number of nodes of first fruiting branches was 8.00 number plant^{-1}, obtained from 600 cc/da magnesium treatment during the squaring stage. The results of the study showed that magnesium applications affected the nodes number of first fruiting branches, which is known as an important earliness criterion in the plant.

Number of nodes

Table 2 shows that there were no significant statistically differences between magnesium treatments for the number of nodes. As shown the average values regarding the number of nodes varied between 16.40 and 17.93 number per plant^{-1}, and the overall average value of the trial was 17.25 number per plant^{-1}. The highest value (17.93) was obtained with magnesium application applied at a dose of 600 cc/da during the squaring stage, it is seen that the lowest value (16.40 number plant^{-1}) was obtained from 400 cc/da magnesium application during the squaring stage.

Height/node ratio

In Table 2, it can be seen that there was a significant statistical difference between the applications in terms of the height/node ratio (HNR) at the 5% significance level.

Average values obtained for the height/node ratio, which is an important indicator of plant development, depending on the treatments, ranged between 3.77 and 4.28 number per plant^{-1}; it is seen that the highest value was obtained from the application of magnesium at a dose of 200 cc/da during the squaring stage (4.28 number plant^{-1}) and this treatment was followed by magnesium application of 400 cc/da during the squaring period.

The lowest height/node ratio value (3.77 number plant^{-1}) was obtained with magnesium application during the flowering stage at a dose of 400 cc/da. It is seen that application of magnesium to cotton has a statistically significant effect on the height/node ratio (Table 2).

Number of bolls

The average values for the number of bolls vary between 8.66 and 11.93 number/plant; as a result of the statistical analysis, it is seen that there are statistically significance differences between the applications at the 5% probability and the overall average of the experiment is 9.83 number/plant.

The lowest boll number (8.66 number/plant) was obtained from magnesium application during the squaring period at a dose of 400 cc/da and the control, while the highest boll number (11.93 number/plant), was obtained from magnesium applied at a dose of 200 cc/da during the squaring stage and followed by magnesium application during the flowering stage at a dose of 200 cc/da (Table 2.

The results of this study coincide with the studies done by Rajakumar & Gurumurthy (2008), who reported that higher values were obtained in the number of bolls by applying magnesium and micronutrient elements to the green parts and Ali et al. (2019) indicated that the number of bolls increased with the combined application of magnesium and nitrogen to the leaves.

Boll weight

The average values obtained for boll weight ranged between 6.63 and 7.16 g, depending on the applications; It is seen that there are statistically significant differences between the applications at the 5% probability level and the overall average of this experiment is 6.92 g (Table 2).

The lowest value for boll weight (6.63 g) was observed from the magnesium application during the squaring stage at a dose of 600 cc/da (6.63 g) and the magnesium application during the flowering stage at a dose of 600 cc/da, while the highest boll weight value was observed as 7.16 g from magnesium applied during the flowering stage at a dose of 400 cc/da.

Rajakumar & Gurumurthy (2008) and Singh et al. (2015) reported that higher values in boll weight were obtained by applying magnesium to the green parts of the plant.

Seed cotton boll weight

It is seen that the values obtained for seed cotton boll weight vary between 5.13 and 5.53 g, but the differences between magnesium applications are not statistically significant. While the lowest seed cotton weight per boll (5.13 g), was observed from the magnesium treatment during the squaring stage at a dose of 600 cc/da, the highest value (5.53 g), was observed from the control and from the magnesium application during the flowering stage at a dose of 400 cc/da (Table 2).

Number of seeds in boll

It is seen from the Table 3 that the values obtained in terms of the number of seeds in the boll changed between 28.53 and 31.10 number boll^{-1} depending on the treatments, but no significant differences were detected between magnesium applications. The lowest value in terms of number of seeds in the boll was observed from 600 cc/da magnesium application during the squaring stage, with a value of (28.53), while the highest value, with a value of (31.10) was observed from 200 cc/da magnesium treatment during the squaring stage. However, Sadeghi et al. (2021) reported that magnesium effectively increases photosynthesis and the delivery of assimilates to the seed due to the increase in enzymatic activity.

Table 3. Average values and statistical levels of investigated traits

***Çizelge 3.** İncelenen özelliklerin ortalama değerleri ve istatistiki gruplamalar*

Applications	SCBW	SB	FPP	GP	SPAD	NDVI	SCY	FY
1. Control	5.53±0.05	30.50±0.81	77.46±5.40	45.73±0.22	47.63±1.57	0.75±0.01	387.73±18.00^{bc}	177.24±8.14
2. Squaring (200 cc)	5.33±0.19	31.10±0.69	85.73±3.02	46.53±0.40	48.43±1.24	0.70±0.02	403.80±18.56^{abc}	187.75±7.64
3. Squaring (400 cc)	5.36±0.07	29.76±0.41	84.56±3.05	46.73±0.30	43.43±2.00	0.72±0.01	378.57±22.17^{c}	176.80±9.38
4. Squaring (600 cc)	5.13±0.15	28.53±0.52	84.58±1.01	46.00±0.15	45.86±2.50	0.76±0.01	443.29±20.94^{ab}	203.77±8.97
5. Flowering (200 cc)	5.46±0.06	30.06±0.13	85.31±4.11	45.73±0.45	47.26±1.84	0.76±0.00	446.74±5.90^{a}	204.33±4.64
6. Flowering (400 cc)	5.53±0.10	30.30±0.08	80.87±2.14	46.40±0.30	43.50±1.69	0.73±0.02	404.52±12.82^{abc}	187.63±4.82
7. Flowering (600 cc)	5.40±0.25	30.20±0.43	87.32±1.70	46.00±0.30	46.50±2.82	0.73±0.01	410.51±5.83^{abc}	188.89±3.40
Mean	**5.39**	**30.06**	**83.69**	**46.16**	**46.09**	**0.73**	**410.74**	**189.49**
CV (%)	5.89	3.62	8.34	1.50	9.45	4.60	8.50	8.05
F value	ns	ns	ns	ns	ns	ns	2.18*	ns

*, **; Significant at $p \leq 0.05$ and $p \leq 0.01$, respectively

Different letters in the same column indicate that the difference between the means is statistically significant ($p<0.05$).

SCBW: Seed cotton boll weight; SB: Seeds per boll; FPP: First picking percentage; GP: Ginning percentage; SPAD: Chlorophyll Content; NDVI: Normalized difference vegetative index; SCY: Seed cotton yield; FY: Fiber Yield.

First picking percentage

It can be seen from Table 3 that there were non-significant differences between magnesium treatments in terms of first picking percentage, which is known to be an important earliness criterion. The mean values of the first picking percentage values depending on the magnesium doses ranged between 77.46 and 87.32% and the overall average of the trial was 83.69%. In terms of first picking percentage, the highest result was observed from the magnesium application applied at a dose of 600 cc/da during the flowering stage (87.32%), and the lowest value was observed from the control application (77.46%).

Ginning percentage

The ginning percentage values obtained as a result of magnesium applications varied between 45.73 and 46.73% and the overall average of the experiment was 46.16%. The control application and magnesium application during the flowering stage at a dose of 200 cc/da showed the lowest value (45.73%) in terms of ginning efficiency, and the highest value (46.73%), was observed from the magnesium application at a dose of 400 cc/da during the squaring stage (Table 3). However, it can be observed that the differences between the applications are not statistically significant. Similar findings were reported by Singh et al. (2015).

Chlorophyll content (SPAD value)

Leaf chlorophyll content (SPAD) values varied between 43.43 and 48.43% depending on magnesium applications; however, it appears that the differences between treatments are not statistically significant. The highest leaf chlorophyll content (SPAD value) of 48.43% was obtained from magnesium applied during the squaring period at a dose of 200 cc/da, while the lowest leaf chlorophyll content (SPAD value) value of 43.43% was observed from 400 cc/da dose during the squaring stage.

In this study, it was determined that magnesium applied in different periods and at different doses did not have a significant effect on the chlorophyll content of the plant, and although the highest chlorophyll content (SPAD) value was obtained from magnesium applied during the squaring period at a dose of 200 cc/da, the differences were not statistically significant when compared to the control (Table 3).

Madaan et al. (2014) reported that elements such as N, Mg, and Fe have key roles in the structure and synthesis of chlorophyll. It has been reported by (Helmy et al., 1960; Reddy et al., 1996; Çakmak & Yazıcı, 2010; Rathika et al., 2013; Hauer Jâkli & Trankner, 2019; Ahmed et al., 2020) that magnesium has a dominant role in photosynthesis and plays an important role in chloroplast-related processes, which contain over 35% Mg in the leaves. The fact that no significant differences were found between the treatments in terms of chlorophyll content (SPAD value) in the study may be related to the amount of magnesium used in the application, the application method and time, the development period of the plant and the amount of magnesium in the soil.

Normalized Difference Vegetative Index (NDVI)

It is seen that normalized difference vegetative index (NDVI) values varied between 0.70 and 0.76 depending on magnesium applications, but the differences between the treatments were not significant. The highest NDVI was recorded from the magnesium application at a dose of 600 cc/da during the squaring stage (0.76) and the magnesium application at a dose of 200 cc/da during the flowering period, while the lowest NDVI value was recorded from the magnesium treatment applied at a dose of 200 cc/da during the squaring stage as 0.70 (Table 3).

Seed cotton yield

Table 3 shows that the statistical difference between magnesium applications in terms of seed cotton yield is significant at the 5% probability level. It can be seen from the same table that the average values obtained for seed cotton yield depending on magnesium applications range between 378.57 and 446.74 kg/da, and the general average seed cotton yield value of the trial is 410.74 kg/da. The highest seed cotton yield value was obtained from the 200 cc/da magnesium application during the flowering period (446.74 kg/da), while the lowest seed cotton yield (378.57 kg/da) was recorded from 400 cc/da magnesium application during the squaring stage. In the registration document of the MAY 455 cotton variety, it is reported that the yield varies between 550 and 650 kg/da (Anonymous, 2023). The lower yield was obtained in this study, and this is due to the fact that the minimum, average and maximum temperature values in 2021 were above long-term as shown in Figure 1. Planting time, irrigation time and irrigation amount and other cultural practices are also important factors on yield.

In the experiment, it is seen that magnesium applications have a significant effect on seed cotton yield. Among magnesium applications, the highest seed cotton yield was obtained with the application of 200 cc/da during the flowering stage, and there was a difference of 68.17 kg/da between the lowest and highest seed cotton yield.

Findings that magnesium increases productivity have also been reported by many researchers (Durmaz, 2002; Deshpande et al., 2015; Singh et al., 2016; Kajana, 2020; Swetha et al., 2020, Wang et al., 2020).

Fiber yield

In Table 3, it can be observed that the average values of fiber yield changed between 176.80 and 204.33 kg da^{-1} depending on magnesium treatments and the average fiber yield value obtained from the trial was 189.49 kg da^{-1}.

The highest value in fiber yield was observed from the 200 cc/da magnesium application during the flowering period (204.33 kg da^{-1}), this application was followed by the 600 cc/da during the squaring period (203.77 kg da^{-1}), it can be observed that the lowest value for fiber yield was observed from 400 cc/da magnesium application (176.80 kg da^{-1}) during the squaring period. It can be seen in Table 3 that there are no statistically significant differences between the magnesium treatments in terms of fiber yield.

Ali et al. (2019) reported that they achieved an increase in fiber cotton yield by applying magnesium in combination with nitrogen and potassium.

Fiber quality properties

Magnesium applications differed significantly in terms of strength, elongation, uniformity and spinning consistency index; however, micronaire, fiber length, short fiber index, yellowness, and reflectance did not differ significantly between applications (Table 4).

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

Çizelge 4. *Lif kalite özelliklerine ait ortalama değerler ve istatistiki gruplamalar*

Applications	FF	FL	STR	ELG	UNF	SFI	YLW	RF	SCI
1. Control	5.32±0.02	29.72±0.13	34.30±0.75^{b}	5.93±0.08^{ab}	83.03±0.27^{b}	6.43±0.31	8.63±0.16	77.80±0.33	140.00±2.59c
2. Squaring (200 cc)	5.26±0.13	28.80±0.26	33.76±0.50^{b}	5.63±0.05^{c}	84.46±0.39^{a}	7.40±0.38	8.96±0.14	78.50±0.17	144.33±3.27^{abc}
3. Squaring (400 cc)	5.14±0.04	28.88±0.24	33.70±0.52^{b}	6.16±0.09^{a}	84.40±0.14^{a}	7.10±0.19	8.46±0.09	78.26±0.61	144.66±1.46^{bc}
4.Squaring (600 cc)	5.04±0.04	29.52±0.32	36.10±0.30^{ab}	5.86±0.04^{bc}	84.73±0.20^{a}	6.70±0.43	8.53±0.06	78.53±0.26	156.00±2.12^{a}
5. Flowering (200 cc)	5.25±0.08	29.41±0.08	35.83±1.02^{ab}	5.93±0.11^{ab}	84.56±0.24^{a}	6.20±0.12	8.83±0.09	77.43±0.67	151.66±5.13^{abc}
6. Flowering (400 cc)	5.19±0.02	29.41±0.23	36.13±0.57^{ab}	5.76±0.03^{bc}	84.30±0.09^{a}	6.80±0.26	8.93±0.12	77.93±0.63	151.66±1.32^{abc}
7. Flowering (600 cc)	5.08±0.10	29.29±0.30	37.13±1.30^{a}	5.66±0.01^{bc}	84.43±0.10^{a}	7.23±0.28	8.86±0.09	76.70±0.08	155.66±5.70^{ab}
Mean	**5.18**	**29.29**	**35.28**	**5.85**	**84.27**	**6.83**	**8.74**	**77.88**	**149.14**
CV (%)	3.17	1.78	4.77	2.75	0.59	0.09	2.93	1.26	5.04
F value	ns	ns	2.50*	5.17**	5.12**	ns	ns	ns	2.70*

*, **; Significant at P ≤0.05 and *p*≤ 0.01, respectively

Different letters in the same column indicate that the difference between the means is statistically significant (p<0.05).

FF: Fiber fineness; FL: Fiber length; STR: Fiber strength; ELG: Elongation; UNF: Uniformity; SFI: Short fiber index; YLW: Yellowness; RF: Reflectance; SCI: Spinning consistency index.

Fiber strength

The average values obtained regarding the fiber strength value, depending on the applications, varied between 33.70 and 37.13 g/tex. It is seen that there are statistical differences between the treatments at the 5% significance level and the overall average of the trial is 35.28 g/tex. In terms of fiber strength, the lowest value of 33.70 g/tex was observed from 400 cc/da magnesium treatment during the squaring stage, while the highest value of 37.13 g/tex was observed from 600 cc/da application during the flowering stage (Table 4).

Kajana (2020) reported that fiber quality parameters such as fiber strength are improved with MgO nanoparticles according to the sulfate form of Mg fertilizers, and it is similar to the research findings. Sankaranarayanan et al. (2010) reported that fiber strength was not affected by the application of micronutrients, and the research results seem to differ.

Fiber elongation

Depending on the magnesium treatment, fiber elongation values varied from 5.63 to 6.16%; significant differences between the applications are observed at the 1% significance level, and the trial's overall average is 5.85%. It was shown that applying 200 cc/da of magnesium during the squaring stage produced the lowest value of fiber elongation (5.63%) while applying 400 cc/da of magnesium over the same period produced the maximum value of 6.16% (Table 4).

These results differ from those of Sankaranarayanan et al. (2010), who reported that fiber elongation was not affected by the application of micronutrient elements.

Fiber uniformity

Fiber uniformity values varied between 83.03 and 84.73%, and it is seen that there are significant statistical differences between the applications at the 1% probability level and the overall average of the trial is 84.27%. While the lowest value in terms of fiber uniformity was obtained from the control application with 83.03%, the highest value with 84.73% was obtained from the 600 cc/da magnesium application during the squaring stage. It was found in this investigation that magnesium applying magnesium raised the fiber uniformity value (Table 4).

Gerendas & Führs (2013) reported that the effect of magnesium on quality characteristics may be indirect by improving the nutritional element level of the product.

Spinning consistency index

Table 4 shows that there is a statistically significant difference at the 5% probability level between the treatments in terms of the spinning consistency index (SCI). Depending on the magnesium applications, the SCI varied between 140.00 and 156.00, and the overall average of the experiment was 149.14. While the lowest value in terms of SCI was obtained from the control application with 140.00, the highest SCI value with 156.00 was obtained from the magnesium applied during the squaring stage at a dose of 600 cc/da. This application was followed by magnesium application at a dose of 600 cc/da at the flowering stage with a value of 155.66 and they were in the same statistical group (Table 4).

It is seen that magnesium applications lead to an increase in the spinning consistency index and significant differences are obtained compared to the control.

CONCLUSION

Results in this investigation indicated that magnesium applications had a significant effect on the number of monopodial branches, number of nodes of the first fruiting branches, HNR, number of bolls, boll weight, seed cotton yield, fiber strength, uniformity, elongation, and SCI. Other characteristics examined in the research include plant height, number of nodes, number of fruiting branches, seed cotton boll weight, number of seeds in the boll, first picking percentage, ginning outturn, chlorophyll content (SPAD value), NDVI value (normalized difference vegetative index) and fiber yield was not affected by magnesium applications. It was determined that the fiber length, fiber fineness, short fiber index, fiber reflectance, and fiber yellowness values, which are among the fiber quality criteria, were not statistically affected by magnesium treatments.

In the study, the highest value in terms of the number of bolls, number of monopodial branches and height/node ratio were observed with 200 cc/da Mg treatment during the squaring stage. The highest values in terms of the number of nodes of first fruiting branches, uniformity and SCI values were obtained from 600 cc/da Mg application during the squaring stage and the highest elongation value was observed from 400 cc/da Mg application during the squaring stage. While the highest value in boll weight was recorded with the application of 400 cc/da Mg during the flowering stage, the highest fiber strength was recorded during the flowering stage with the dose of 600 cc/da.

In the study, seed cotton yield was affected by magnesium applications and seed cotton yield varied between 378.57 and 446.74 kg/da. The highest value for seed cotton yield, 446.74 kg/da, was obtained from magnesium applied at a dose of 200 cc/da during the flowering stage and this application was followed by magnesium application at a dose of 600 cc/da during the squaring stage, with 443.29 kg/da. There was a difference of 68.17 kg/da between the lowest and highest seed cotton yield.

It has been concluded that magnesium treatment significantly and positively affects the seed cotton yield and some important fiber quality properties of the cotton plant, and therefore, it may be beneficial to apply it to the green parts of the plant during the squaring or flowering stage in cotton production.

Data Availability

Data will be made available upon reasonable request.

Author Contributions

Conception and design of the study: ES, EK; sample collection: ES, EK; analysis and interpretation of data: ES, EK; statistical analysis: ES, EK; visualization: ES, EK; writing manuscript: ES, EK.

Conflict of Interest

There is no conflict of interest between the authors in this study.

Ethical Statement

We declare that there is no need for an ethics committee for this research.

Article Description

This article was edited by Section Editor Prof. Dr. Fatma AYKUT TONK.

REFERENCES

Ahmed, N., M. A. Ali, S. Danish, U. K. Chaudhry, S. Hussain, W. Hassan, F. Ahmad & N. Ali, 2020. "Role of Macronutrients in Cotton Production, 81-104". In: Cotton Production and Uses, Chapter 6. (Eds. S. Ahmad & M. Hasanuzzaman,) Springer, Singapore, 641 pp. https://doi.org/10.1007/978-981-15-1472-2_6.

Ali, H., M. S. Tahir, S. Hussain, R. N. Shabbir, A. Areeb & A. Sher, 2019. Combined foliar applied nitrogen, potassium and magnesium improved yield, fiber quality and water use efficiency of cotton under water limited environment. International Journal of Agriculture and Biology, 22 (1): 115-121. https://doi.org/10.17957/IJAB/15.1040.

Anonymous, 2023. Cotton Registration Report. Republic of Türkiye Ministry of Agriculture and Forestry Variety Registration and Seed Certification Center, Ankara, 28 pp.

Çakmak, İ. & A. M. Yazıcı, 2010. Magnesium: A forgotten element in crop production. Better Crops, 94 (2): 23-25.

Çakmak, İ. & E. A. Kirkby, 2008. Role of magnesium in carbon partitioning and alleviating photooxidative damage. Physiologia Plantarum, 133: 692-704. https://doi.org/10.1111/j.1399-3054.2007.01042.x.

Cakmak, I., C. Hengeler & H. Marschner, 1994. Partitioning of shoot and root dry matter and carbohydrates in bean plants suffering from phosphorus, potassium and magnesium deficiency. Journal of Experimental Botany, 45 (9): 1245-1250. https://doi.org/10.1093/jxb/45.9.1245.

Chaganti, V. N. & S. W. Culman, 2017. Historical perspective of soil balancing theory and identifying knowledge gaps: A review. Crop, Forage & Turfgrass Management, 3: 1-7. https://doi.org/10.2134/cftm2016.10.0072.

Deshpande, A. N., R. S. Masram & B. M. Kamble, 2015. Effect of fertilizer levels and foliar application on morphological characters, nutrient content and yield of cotton. International Journal of Bio-resource and Stress Management, 6 (2): 230-239. http://dx.doi.org/10.5958/0976-4038.2015.00041.X.

Durmaz, M., 2002. Effect of Different Doses of Mg Applications on Yield and Quality in Cotton Plants. Cukurova University, Institute of Science, (Unpublished) MSc thesis Adana, 48 pp.

Farhat, N., A. Elkhouni, W. Zorrig, A. Smaoui, C. Abdelly & M. Rabhi, 2016. Effects of magnesium deficiency on photosynthesis and carbohydrate partitioning. Acta Physiologiae Plantarum, 38 (145): 1-10. https://doi.org/10.1007/s11738-016-2165-z.

Gerendas, J. & H. Führs, 2013. The significance of magnesium for crop quality. Plant and Soil, 368: 101-128. https://doi.org/10.1007/s11104-012-1555-2.

Gransee, A. & H. Führs, 2013. Magnesium mobility in soils as a challenge for soil and plant analysis, magnesium fertilization and root uptake under adverse growth conditions. Plant and Soil, 368: 5-21. https://doi.org/10.1007/s11104-012-1567-y.

Guo, W., H. Nazim, Z. Liang & D. Yang, 2016. Magnesium deficiency in plants: An urgent problem. The Crop Journal, (2): 83-91. https://doi.org/10.1016/j.cj.2015.11.003.

Hauer-Jákli, M. & M. Tränkner, 2019. Critical leaf magnesium thresholds and the impact of magnesium on plant growth and photo-oxidative defense: a systematic review and meta-analysis from 70 years of research. Frontiers in Plant Science, 10: 766. https://doi.org/10.1016/j.cj.2015.11.003

Helmy, H., H. E. Joham & W. C. Hall, 1960. Magnesium Nutrition of American Upland and Egyptian Cottons. Texas Agricultural Experiment Station, No: 411, 16 pp.

Huber, D. M. & J. B. Jones, 2012. The role of magnesium in plant disease. Plant Soil, 368 (1): 73-85. https://doi.org/10.1007/s11104-012-1476-0.

Jayalalitha, K. & A. Narayanan, 1996. Growth and mineral composition of magnesium deficient cotton plants grown in solution culture. Annals of Plant Physiology, 10 (1): 11-16.

Johnson, J. R. & J. Saunders, 2003. Evaluation of chlorophyll meter for nitrogen management in cotton. Annual Report, 162-163.

Kajana, D., 2020. Foliar application of magnesium oxide nanoparticles on nutrient element concentrations, growth, physiological, and yield parameters of cotton. Journal of Plant Nutrition, 43 (20): 3035-3041. https://doi.org/10.1080/01904167.2020.1799001.

Karaman, M. R., 2012. Plant Nutrient Elements and Nutritional Physiology in Plants. Plant Nutrition. Gübretaş Guide Book Series, No: 2, 92 pp.

Madaan, S., S. S. Sıwach, R. S. Sangwan, O. Sangwan, C. Devraj, S. R. Pundir, A. Jain & K. Wadhwa, 2014. Effect of foliar spray of nutrients on morphological and physiological parameters. Journal of Cotton Research and Development, 28 (2): 268-271.

Marschner, H., 2012. Mineral Nutrition of Higher Plants. Academic, Elsevier, Australia, 649 pp. https://doi.org/10.1016/C2009-0-63043-9

Marschner, H., E. A. Kirkby & I. Çakmak, 1996. Effect of mineral nutritional status on shoot-root partitioning of photoassimilates and cycling of mineral nutritiens. Journal of Experimental Botany, 47: 1255-1263. https://doi.org/10.1093/jxb/47.special_issue.1255.

Mobarak, Z. M., M. M. Shaaban, M. M. El-Fouly & E. A. A. A. El-Nour, 2013. Improving growth and nutrient content of maize and cotton plants through magnesium nitrate foliar fertilization. American Journal of Plant-Nutrition and Fertilization Technology, 3 (2): 22-32. http://dx.doi.org/10.3923/ajpnft.2013.22.32

Radhika, K., S. Hemalatha, S. Maragatham & A. Kanimozhi, 2013. Foliar application of micronutrients in cotton-a review. Research and Reviews: Journal of Agriculture and Allied Sciences, 2 (3): 23-29.

Rajakumar, D. & S. Gurumurthy, 2008. Effect of plant density and nutrient spray on the yield attributes and yield of direct sown and polybag seedling planted hybrid cotton. Agricultural Science Digest, 28 (3): 174-177.

Rajakumar, D., S. Gurumurthy, B. J. Pandian & G. Thiyagarajan, 2010. Population dynamics and nutrient spray on the yield and economics of direct sown and transplanted hybrid cotton TCHB 213. Indian Journal of Agricultural Research, 44 (3): 206- 210.

Reddy, A. R., K. R. Reddy, R. Padjung & H. F. Hodges, 1996. Nitrogen nutrition and photosynthesis in leaves of pima cotton. Journal of Plant Nutrition, 19 (5): 755- 770. https://doi.org/10.1080/01904169609365158.

Römheld, V. & E. A. Kirkby, 2007. “Magnesium functions in crop nutrition and yield, 151-171”. In: Proceedings of a Conference in Cambridge (7th Dec. 2007), 575 pp.

Sadeghi, F., A. Rezeizad & M. Rahimi, 2021. Effect of Zinc and Magnesium fertilizers on the yield and some characteristics of wheat (*Triticum aestivum* L.) seeds in two years. International Journal of Agronomy, 2021: 8857222 (1-6). https://doi.org/10.1155/2021/8857222.

Sankaranarayanan, K., C. S. Praharaj, P. Nalayini, K. K. Bandyopadhyay & N. Gopalakrishnan, 2010. Effect of magnesium, zinc, iron and boron application on yield and quality of cotton (*Gossypium hirsutum*), Indian Journal of Agricultural Sciences, 80 (8): 699-703.

Singh, K., P. Rathore & R. K. Gumber, 2015. Effects of foliar application of nutrients on growth and yield of Bt cotton (*Gossypium hirsutum* L.) Bangladesh Journal of Botany, 44 (1): 9-14. https://doi.org/10.3329/bjb.v44i1.22717

Singh, K., S. Malik, A. Singh & P. Rathore, 2016. Influence of foliar feeding of nutrients on growth yield attributes and seed cotton yield of American Cotton. Journal of Cotton Research and Development, 30 (1): 69-72.

Stevens, G., T. Gladbach, P. Motavalli & D. Dunn, 2005. Soil Calcium: Magnesium Ratios and Lime Recommendations for Cotton. The Journal of Cotton Science, 9: 65-71.

Swetha, D., P. Laxminarayana, G. E. C. H. Vidyasagar, S. N. Reddy & H. K. Sharm, 2020. Impact of secondary and micronutrients on productivity and quality of Bt cotton: A review. International Journal of Economic Plants, 7 (2): 91-93. http://dx.doi.org/10.23910/2/2020.0364

Taiz, L. & E. Zeiger, 2010. Plant Physiology. 5th Edition, Sinauer Associates, Inc. Sunderland, 782 pp.

Wang, Z., M. Ul Hassan, F. Nadeem, L. Wu, F. Zhang & X. Li, 2020. Magnesium fertilization improves crop yield in most production systems: a meta-analysis. Frontiers in Plant Science, 10: 1727. https://doi.org/10.3389/fpls.2019.01727