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A Preliminary Study on the Effectiveness of Harpin Protein and Potassium Thiosulphate Foliar Applications on Yield and Quality Characteristics in Second Crop Cotton (*Gossypium hirsutum L.*)

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Abstract: The foliar applications such as harpin protein and potassium thiosulfate (KTS) play a crucial role in cotton growing under especially adversely soil conditions. This study was conducted to evaluate the different combinations of harpin protein and KTS for yield, yield components and fiber quality in second crop cotton (*Gossypium hirsutum* L.). The differences among treatments were significant for first picking percentage, seed cotton yield and fiber fineness. The applications of harpin protein at peak squaring and harpin protein at first flowering + after 21 days harpin protein were increased first picking percentage of cotton. The highest seed cotton yield was recorded in harpin protein at peak squaring with 423,16 kg da^{-1}, whereas the fibers became coarser with the harpin protein and KTS applications. Results obtained from the current study indicated the potential effect of harpin protein and KTS on increasing the seed cotton yield.

Keywords: Fiber quality, foliar spray, harpin protein, potassium thiosulfate, seed cotton yield

İkinci Ürün Pamukta (*Gossypium hirsutum* L.) Verim ve Kalite Özelliklerine Harpin Proteini ve Potasyum Tiyosülfat Yaprak Uygulamasının Etkinliği Üzerine Bir Ön Çalışma

Öz: *Özellikle olumsuz toprak koşullarında yetiştirilen pamuklarda harpin protein ve potasyum tiyosülfat gibi yaprak uygulamaları önemli bir role sahiptir. Bu çalışmada harpin protein ve potasyum tiyosülfat'ın farklı kombinasyonlarının ikinci ürün pamukta verim, verim komponentleri ve lif kalitesi yönünden değerlendirilmesi amaçlanmıştır. Taraklanma doruğunda ve çiçeklenme başlangıcında + 21 gün sonra olmak üzere harpin proteini uygulamasının birinci el kütlü oranını artırdığı saptanmıştır. En yüksek kütlü pamuk verimi 423,16 kg da-1 ile çiçeklenme doruğunda harpin proteini uygulanan parsellerden elde edilirken harpin proteini ve KTS uygulamalarının lifleri kabalaştırdığı belirlenmiştir. Kütlü pamuk verimini artırmak için harpin proteini ve KTS uygulamalarının olumlu bir etkiye sahip olduğu sonucuna varılmıştır.*

Anahtar Kelimeler: *Lif kalitesi, yaprak gübrelemesi, harpin proteini, potasyum tiyosülfat, verim*

INTRODUCTION

The world's cotton production, planting area and lint yield for the marketing year 2021/22 are forecast at 25.5 million tons, 33.3 million ha and 765 kg ha^{-1}, respectively (Anonymous, 2021a). Cotton production in Turkey reached 0.8 million tons in about 359 thousand ha of area, and lint cotton yield was 2230 kg.ha^{-1} according to the 2019/20 report Turkish Statistical Institute (Anonymous, 2021b). The percentage of self-sufficiency of cotton in Turkey tends to decrease continuously. Söke district (26.0 thousand ha) together with Aydın province (54.0 thousand ha) has important cotton growing areas in Turkey.

Cotton growers use foliar fertilization as an alternative application to soil fertilization in especially adversely soil conditions such as alkalinity and salinity. Bioactivators and foliar fertilizers are widely used to increase the yield and quality in cotton growing areas of the Aydın-Söke region, which is an important cotton producer in the Aegean Region of Turkey (Albayrak, 2014). In many of these applications, KTS applications and harpin protein attract attention to increase yield and quality.

Harpin, a completely natural protein structure, is 403 amino acids long and has a molecular weight of approximately 44 kD. It is water soluble and granular. It is preferred because of its low toxicity and less residue (Wei et al., 1992). Bioactivators such as harpin protein are defined as substances of organic or inorganic origin that are produced naturally by the organisms themselves, which stimulate, inhibit or otherwise modify physiological functions in organisms, which can be effective even at extremely small concentrations. Harpin applications increase photosynthesis, nutrient uptake, root development and seed germination. Also, it positively affects early flowering and fruit development, and provide earliness in fruit ripening (Wei et al., 1992). Bednarz et al. (2002) reported that harpin protein was not effective on yield and quality in their study on cotton.

The susceptibility to drought and diseases increases because of potassium deficiency. However, potassium deficiency reduces the efficiency of nitrogen use, causing a decrease in fiber quality and yield (Wang et al., 2013). If potassium is limited during active fiber growth, there is a decrease in the turgor pressure of the fiber resulting in less cell elongation

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and shorter fiber formation at maturity. Because potassium is the primary osmotic for fiber growth and provides the necessary turgor pressure for fiber elongation, optimum cotton yield and fiber quality are largely dependent on adequate potassium uptake during the entire growing season (Bhandal and Malik, 1988). It was reported that potassium deficiency occurs in the late stages of the plant and is observed in the upper canopy leaves (Rosolem ve Mikkelsen, 1991). In addition, Oosterhuis et al. (1992) reported that the movement of potassium from the roots to the upper leaves was effective in the formation of bolls in cotton. The content of potassium thiosulfate was 25% K2O and 17% S and can be applied by different irrigation systems and foliar spray (Emam and Semida, 2020). The relationship between the K content of target tissue and quality parameters was found to be significant and positive in many crops (Behairy et al., 2015; Jifon and Lester, 2011).

It was found that the foliar fertilizers such as Nutri-leaf, Greenzit, Oomplesal and Multimicro increased the number of bolls and seed cotton yield, but other yield and quality characters were not affected (Yılmaz, 1986). Similarly, the effect of Fertilon Combi foliar fertilizer application on fiber uniformity and seed yield is significant however, plant height, number of monopodial and sympodial branches, number of bolls, boll weight, ginning out-turn, 100 seed weight, earliness rate, fiber length, fiber fineness and fiber strength were not affected compared to control (Temiz and Gencer, 1996).

There is little information about the combination of harpin protein and KTS in second crop cotton under field conditions. Therefore, the main objective of this study was to investigate the effect of harpin protein alone and in combination with KTS on cotton yield and quality characteristics under producer conditions.

MATERIALS AND METHODS

PG 2018 (Progen Company) cotton cultivar was planted as the second crop on 10 June 2016 after wheat harvest in a farmer's field (Söke/AYDIN 37°71' and N, 27° 38' E). The different combinations of harpin protein and potassium thiosulphate (KTS) with control were arranged in a Randomized Complete Block Design with three replications. The applications were control (non-treatment), harpin protein at peak squaring, harpin protein at first flowering, harpin protein at first flowering + after 21 days harpin protein, harpin protein at first flowering + after 21 days harpin protein + KTS, harpin protein at first flowering + after 21 days KTS (Bednarz et al., 2002).

The climate data of 2016 and long-term showed that the precipitation increased in May, September and October compared to the long-term averages and mean temperatures in the experimental year close to the long-term averages (Table 1). According to the results of soil analysis, the experiment area was defined as alkali, poor organic matter, non-saline, highly calcareous and insufficient in terms of nitrogen, phosphorus and potassium (Table 2).

The plot size was 4.2 m x 12.0 m (50.4 m^2) accommodating 7 rows spaced 0.73 m apart and five central rows were used to measure characteristics. Application doses for harpin protein and KTS were 60 g ha^{-1} and 250 cc/100 L. The harpin protein and KTS were sprayed with a portable hand-held field plot sprayer using a water carrier volume of 400 L ha^{-1}. The basal fertilizer recommended for second crop cotton growing in Aegean Region was applied using 300 kg ha^{-1} compound fertilizer (NPK 15:15:15). Urea of 100 kg ha^{-1} at the early seedling stage and 250 kg ha^{-1} of ammonium nitrate before the first irrigation were applied to supply the remaining dose of nitrogen. Insecticides controlled the leafhopper (Empoasca spp.) and aphid (*Aphis gossypii*). Hand hoe was applied one time and, the crops were irrigated three times with furrow irrigation. Seed cotton in each plot was harvested by hand two times.

Cotton bolls were harvested at 25.10.2016 (first harvest at the stage of 60% boll opening) and 08.11.2016 (second harvest). The first picking percentage (%) of the seed cotton yield obtained at the first harvest to the total yield in 15 plants randomly sampled from the central five rows of each plot was determined. After removing the edge effects, the seed cotton yield (kg ha-1) was determined by harvesting all the plants in the central rows. Seed cotton was ginned by laboratory-type roller gins and, fiber fineness (mic), fiber length (mm) and fiber strength (g tex^{-1}) were measured using HVI.

The recorded data were subjected to variance analysis using the TOTEM-STAT statistic packet program according to the randomized complete block design. The means for measured characteristics were compared by using the LSD test at a 5% probability level (Acikgoz et al., 2004).

Table 1. Meteorological data in the experimental year (2016) and long-term.

Months	2016 Mean Temp. (°C)	Mean Moisture (%)	Precipitation (mm)	Long-Term Mean Temp. (°C)	Mean Moisture (%)	Precipitation (mm)
May	20.3	58.1	56.1	20.9	48.9	36.5
June	26.9	50.3	8.8	25.9	49.6	13.5
July	28.5	46.0	1.2	28.4	54.3	3.9
August	27.2	52.8	14.2	27.6	56.6	2.3
September	22.8	53.7	82.5	23.5	52.8	13.1
October	18.6	57.4	292.0	18.4	68.9	44.2
Totally			440.6			113.5

Meteorological data were obtained from the Turkish State Meteorological Service.

Table 2. Soil characteristics of the experiment field.

pH	Lime (%)	Organic Matter (%)	Salinity (%)	N	P	K
8.2	12.01	0.75	0.01	0.04	0.95	17.75
Alkali	Very high	Very low	Non-saline	Very low	Very low	Very low

RESULTS AND DISCUSSION

The differences among combinations of harpin protein and KTS were non-significant for plant height, boll number, boll weight, seed index, number of sympodial and monopodial branches (Table 3). Plant height, boll number, seed index and the number of sympodial branches were slightly greater than that of control but boll weight reduced in harpin and KTS applications except for harpin protein at peak squaring compared with control. Although the effects of harpin protein and KTS on observed characters were non-significant, it was noticed that the application of harpin protein at peak squaring (B) performed favorably for boll number per plant, boll weight and sympodial branches per plant. In addition, the lowest seed index was recorded in the application of harpin protein at peak squaring (B).

The combinations of harpin protein and KTS significantly affected first picking percentage, seed cotton yield and fiber fineness (Table 4). The effect of harpin protein at the first flowering stage on the first picking percentage (60.23%) was positive and followed by harpin protein at peak squaring (B) and harpin protein at first flowering + after 21 days harpin protein (D). This result indicated that the early maturity of cotton could be induced by different applications of harpin protein. The highest seed cotton yield was significantly recorded in harpin protein at peak squaring (B) with 4231.6 kg ha^{-1} and followed by harpin protein at first flowering + after 21 days harpin protein (4108.3 kg ha^{-1}) and harpin protein at first flowering + after 21 days harpin protein + KTS (4098.0 kg ha^{-1}).

Table 3. Mean performances of foliar applications in plant height, boll number, boll weight, seed index, number of sympodial and monopodial branches.

Treatments	Plant Height (cm)	Boll Number ($plant^{-1}$)	Boll Weight (g)	Seed Index (g)	Sympodial Branches ($plant^{-1}$)	Monopodial Branches ($plant^{-1}$)
A	113.3	7.27	4.6	9.1	9.50	1.30
B	114.2	7.60	4.7	9.2	9.83	1.23
C	114.1	7.37	4.3	9.9	9.56	1.31
D	115.3	7.33	4.4	9.8	9.66	1.06
E	114.2	7.37	4.1	9.7	9.76	1.16
F	116.2	7.30	4.0	9.6	9.56	1.10
Mean	114.6	7.37	4.4	9.6	9.65	1.19
CV (%)	1.17	1.55	1.25	0.33	2.38	11.58
$LSD_{(0.05)}$	ns	ns	ns	ns	ns	ns

A; Control, B; harpin protein at peak squaring, C; harpin protein at First Flowering, D; harpin protein at First Flowering + after 21 days harpin protein, E; harpin protein at First Flowering + after 21 days harpin protein + KTS, F; harpin protein at First Flowering + after 21 days KTS, ns; non-significant.

Table 4. Mean performances of foliar applications in first picking percentage, seed cotton yield, fiber fineness, fiber length and fiber strength.

Treatments	First Picking (%)	Seed Cotton Yield (kg ha^{-1})	Fiber Fineness (mic.)	Fiber Length (mm)	Fiber Strength (g tex^{-1})
A	59.03 c	4036.0 bc	4.81 c	29.73	29.56
B	59.98 ab	4231.6 a	5.14 a	29.62	30.50
C	60.23 a	4058.0 bc	4.91 bc	29.89	30.33
D	59.76 ab	4108.3 ab	4.86 c	30.27	31.06
E	59.53 bc	4094.0 ab	5.09 ab	29.45	29.50
F	59.03 c	3931.6 c	4.88 bc	29.62	31.10
Mean	59.59	4076.58	4.95	29.76	30.34
CV (%)	1.29	3.64	3.89	0.64	2.00
$LSD_{(0.05)}$	0.685	152.4	0.219	ns	ns

A; Control, B; harpin protein at peak squaring, C; harpin protein at First Flowering, D; harpin protein at First Flowering + after 21 days harpin protein, E; harpin protein at First Flowering + after 21 days harpin protein + KTS, F; harpin protein at First Flowering + after 21 days KTS, ns; non-significant.

The favorable values obtained from harpin protein at the early stage (squaring) and harpin protein at flowering and repeated doses and KTS addition indicated that firstly harpin combinations, secondly harpin, and KTS combinations could be used to improve the seed cotton yield depending on the increase in boll number, boll weight and the number of sympodial branches. Similarly, French (2001) and Bednarz et al. (2002) revealed the positive effect of harpin protein on seed cotton yield although insufficient soil moisture and low availability of potassium restricted beneficial effects. It was reported that foliar application of KTS enhanced growth and boll development (Clapp, 1998) and increased seed cotton yield (Hons and Sanders, 1993). Unlike, Husman and Doerge (1993) stated that the response of yield and fiber quality to potassium applications was not clear in Arizona cotton growing.

Treatments compared with control significantly increased fiber fineness value, and the applications of harpin protein at peak squaring and harpin protein at first flowering + after 21 days harpin protein + KTS had the higher coarse fiber than that of control and other treatments. This result is in contradiction with finding reported by Bednarz et al. (2002) who found the non-significant effect of harpin protein on fiber quality.

CONCLUSION

This study revealed that harpin protein and KTS could positively affect seed cotton yield and earliness in cotton, whereas the effects of harpin protein and KTS on yield components and fiber quality except fiber fineness may be limited. It is highlighted that especially harpin protein should be evaluated under biotic and abiotic stress conditions depending on its induced effect on resistance. There is a need to conduct studies with plant growth regulators and foliar fertilizers that can be used in addition to both applications.

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