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(Original Article)

Effect of Foliar Fertilization by Certain Microelements on Disease Severity of Pokkah Boeng on Sugarcane, Yield Cane and Juice Quality Under Field Conditions

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Abstract

A Field experiment was performed using artificial infection with a highly pathogenic isolate of *Fusarium subglutinans* the causal agent of sugarcane pokkah boeng (PB) disease. The effects of foliar spray of plants by certain microelements on PB disease severity (DS), cane yield and juice quality of sugarcane at two consecutive seasons were studied. The foliar spray sugarcane variety G.T. 54-9 with each of zinc (Zn), manganese (Mn) and iron (Fe) individually or in mixture (Zn + Mn + Fe) significantly reduced the DS compared to the control plants. Applying each microelement individually was less effective in the reduction of the DS compared to microelements mixture application. The incidence of the disease decreased with increasing the spray frequency. Three foliar sprays gave the highest reduction of DS compared to one or two sprays. Spraying with the tested microelements either individually or in mixture significantly increased the net cane yield, the sugar yield and recovery percentage in sugarcane juice, as well as raised the values of reducing sugar percentage. The greatest increase of reducing sugar percentage was obtained by mixture applications followed by single application in both seasons. According to our results, microelements spray holds a great promise to enhance resistance in sugarcane plants against PB disease and to increase both cane yield and quality of sugarcane juice.

Keywords: *Pokkah boeng disease, Fusarium subglutinans, Microelements, Sugarcane juice.*

Introduction

Sugarcane (*Saccharum officinarum* L.) is an economically important cash crop of many tropical and subtropical countries that is used to produce sugar and biofuels (Singh *et al.,* 2014). Moreover, it is used in the industrial fermentation of alcohol, active yeast (Bread yeast), citric acid, acetic acid, and dextrin production. In addition, it provides many industries with the required raw materials (Edye *et al.,* 2005). Sugarcane production is affected by different biotic or abiotic stresses. There are many diseases that infect the crop such as wilt, smut, red rot, pineapple,

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grassy shoot and PB diseases. The PB disease is caused by *Fusarium subglutinans* (Wollew & Reinking) and becomes one of the major diseases that infects sugarcane plants (Srivastava *et al.,* 2019). The causal fungal is airborne and it has a major role in sugarcane cultivation as it causes significant agricultural and economic losses in sugarcane. The disease is caused by *Fusarium* spp. complex. Consequently, it causes markedly reduction in yield and quality parameters by reducing cane height, length of internodes, cane girth and sucrose percentage. The yield losses reach to 80% due to the disease (Tiwari *et al.,* 2021 and 2022). Recent surveys showed an increasing trend of disease occurrence and affects most of the commercial cultivars. It comes under minor concern but in recent years it is going to be major on basis of their rising epidemiology during last few days. The pathogen can survive for year in the plant debris. Spraying infected plants with different fungicides like Bavistin or Copper oxychloride or Dithane M-45 is an effective way to control the disease (Vishwakarma *et al.,* 2013). The occurrence of the disease has been recorded in almost all the cane growing countries in the world (Tiwari *et al.,* 2022). This disease is an air-borne disease and first infection and secondary transmission is through the infected soil, irrigation water and splashed rains (Viswanathan, 2020). The plant diseases control using the fungicides raises serious concerns about the food, life safety, environmental quality and fungicides resistance pathogens isolates. Therefore, it is important to suggest alternative measures to control many plant diseases which do not harmful the environment and the other benefit increase yield and improve product quality (Camprubí *et al.*, 2007). Macro and micro-nutrients are basic for development of plants growth, plant healthy and disease control (Dordas, 2008). In addition, it dominates an important role in enhancing crop yield (Safyan *et al.,* 2012). Cane yield and yield parameters such as cane length, and weight were significantly affected with the foliar spray of macro and micronutrients (Roohi *et al*., 2021).

The effect of foliar fertilization with microelements on disease incidence and mycotoxin concentrations in the wheat plants was determined by Cwalina-Ambroziak *et al.,* (2021). They found that the influence of foliar fertilization with micronutrients on fusarium infection and the content of mycotoxins in wheat grain were positive. Soil or plants treatment with micronutrients is recommended for control of certain sugarcane diseases (Rajakumar and Narayanaswamy, 2004), however, the effect of micronutrients on incidence of PB disease is still unknown. Although the PB disease has been a minor problem, the epidemiological threats during last few years indicated the growing concern for this disease. Nowadays, the disease incidence of PB has been reported from Aswan, Louxor and Sohag of Upper Egypt the major sugarcane growing governorates in Egypt and many other sugarcane-growing countries (Osman, 2021). Therefore, the present study was planned to investigate the effect of foliar spray with microelements (iron, zinc, manganese and their mixture) on incidence of the disease, cane yield and juice quality of sugarcane under field conditions.

Materials and Methods

Source of pathogen isolate and inoculum preparation

The fungal pathogen isolate F2 of *Fusarium subglutinans* was obtained from Plant Pathology Department, Faculty of Agriculture, Assiut University, Assiut, Egypt. Inoculum of the pathogen isolate was prepared and adjusted to reach 10^6 CFU/ml as the method by Osman (2021) using a hemocytometer slide.

Field experiment

The effect of different sprays of three microelements (Zn, 10 mg/100 ml), manganese (Mn, 15 mg/100 ml) and iron (Fe, 15 mg/100 ml), individually or in mixture on PB disease severity, as well as cane and sugar yield were tested at two growing seasons of 2020/2021 and 2021/2022 under field conditions and artificial inoculation with *F. subglutinans* F2 isolate. The G.T. 54-9 sugarcane variety was used.

The experimental unit or plot area was 10.5 m^2 containing 3-ridges; 3.5 m long and 3 m wide (1/400 feddan). Each treatment contained 3 plots and each plot included 3 rows, and one m between rows and 1m was apart between each plot. Each row of plot cultivated by duple cutting which consisted of three buds of stalk cane. The plants were irrigated every two weeks. The agricultural practices in sugarcane field were done (Rehman *et al.*, 2013). The recommended doses of NPK (230 kg N, 60 kg P_2O_5 and 48 kg K_2O/feddan) were used.

One hundred fifty mg/L of iron in forms of Fe chelate (Fe-EDTA 13.50%), 15 mg/ 100 ml manganese in forms of Mn chelate (Mn-EDTA 13.00%) and 10 mg/ 100 ml zinc in forms of Zn chelate (Zn-EDTA 14.00%) were prepared in distilled water and freshly used for application.

Two weeks before first spray of each treatment, the plants were inoculated with F2 isolate of *Fusarium subglutinans.* Sugarcane seedlings of G.T. 54-9 variety (three months old) were sprayed individually with each of Fe, Mn and Zn microelements solutions as well as their mixture. Plants sprayed with water only were used as control. Plants were sprayed once, twice and three times with the tested solutions of microelements at two weeks intervals.

Artificial inoculation and disease assessment

Leaf spindles of sugarcane plants were sprayed fully with fungal spores suspension of isolate F2. The control plants were sprayed with distilled water. The inoculated plants were covered with clear polyethylene pages overnight. Six months after inoculation, PB DS was recorded. The plants were irrigated every two weeks without adding fertilizers. The DS on artificially infected sugarcane plants was evaluated using a rating system from 0-5 according to the modified scale designed by Ramirez and Nass (2005) in which: 0 = healthy plant; 1 = Leaves showing chlorosis, narrowing and deformation; 2 = Spindle showing leaf crinkling and not completely folding; 3 = Stalk showing top rot and apical bud and side shoot development; 4 = Stalk showing ladder-like lesions; 5 = Stalk showing terminal knife cut and side shoot development.

(DS%) was calculated by the following equation:

$$\text{DSI }(\%) = [\ \Sigma\,(\text{S x N}) \ / \ \Sigma\text{T} \times \text{Maximum score}\ ] \text{ x } 100$$

Where: S = disease scale (0, 1, 2, 3, 4 or 5), N = number of stalks for each disease scale and T = total number of stalks.

Determination of cane, sugar yield and quality of sugarcane juice

The cane yield (tons/fed) and sugar yield (tons/fed) and quality of sugarcane juice were determined at the end of the growth season (eleven months after planting). Cane yield (tons/fed) was determined from the weight of the plants of each plot and calculated and transformed into ton/feddan (4200 m^2).

At harvest time, ten millable cane stalks were collected randomly from each replicate (plot) and topped, stripped, cleaned then squeezed by an electric pilot mill. The extracted juice was mixed thoroughly and a sample of one liter was poured into a graduated cylinder and left to settle for 15-20 minutes to remove the foams and setting the sediments before starting chemical analysis. Then sugar recovery and reducing sugars percentage were determined. The sugar yield (tons/fed.) was calculated according to Yadav and Sharma (1980) as follows:

$$\text{Sugar yield (t/fed.)} = \text{net cane yield (t/fed.)} \times \text{sugar recovery percentage.}$$

Determination of sucrose percentage

Sucrose percentage in juice was determined according to the method described by Meade and Chen (1977) using a saccharometer (West Germany INSTRNO.139582 Dr. WONFGANG) tube and taking the reading, according to A. O. A. C. (1995).

Determination of sugar recovery percentage

Sugar recovery percentage was calculated according to the formula described by Yadav and Sharma (1980):

$$\text{Sugar recovery } \% = [\ \text{S - 0.4 (B} - \text{S)}] \times 0.73$$

Where: B = Brix reading, S = Sucrose percentage, 0.4 and 0.73 constants.

Determination of reducing sugars percentage

It was determined using Fehling solution according to Lane and Eynon method as mentioned in A. O. A. C (1995) as follows:

Reagents:

- Solution (A): Copper sulfate (35g) was dissolved in 400 ml of distilled water and completed to 500 ml, with distilled water.
- Solution (B): Sodium potassium tartrate (173g) and 50g of Sodium hydroxide were dissolved in distilled water.
- The two solutions (AB) were mixed and diluted to one liter directly before use.

Determination steps

Fifty ml of filtrate juice was transferred to a burette. Five ml of filtered juice from the burette was taken in a conical flask and 5 ml of mixing Fehling solution was added then, the flask was heated. The mixture is heated on a hot plate and exactly reaches the boiling point after 2 minutes. After boiling 2 ml methylene blue indicator was added; the colour turns to blue. Complete titration with boiling by the addition of filtrate juice until the liquid colour turns to red. Reading with ml of solution which was required for the titration was measured. Schmitz's table (Spancer and Meade, 1963) was used to calculate the reducing sugars percentage.

Statistical analysis

The field experiment was conducted in randomized complete block design (RCBD) with three replications (plots) and five treatments (Zn, Mn, Fe, Mixture and water) as well as three types sprinkle each microelement (once, twice and three times) in both seasons. All treatments were maintained in the same location each year of the study. Collected data were subjected to the proper of statistical analysis of variance (ANOVA) of RCBD. Microelements treatment of field experiment and determining means values of laboratory data were compared by using least significance difference (LSD) test at 5% probability level (Steel *et al.*, 1997). Finally, all statistical analyses were carried out using "MSTAT-C" computer software package (Freed *et al.*, 1989).

Results

Effect of Zn, Mn and Fe foliar fertilization on pokkah boeng disease severity

Under artificial inoculation with the pathogen, foliar spray with the three microelements (Zn, Mn and Fe) and their mixture significantly reduced PB DS on sugarcane plants compared with control plants in the first and second seasons (Table,1). However, when each microelement was applied individually the disease incidence was reduced less effectively compared to the mixed three microelements treatment. The highest severity of PB disease (68.00 and 72.00%) was recorded in untreated sugarcane plants (water treatment) in both seasons, respectively. The lowest DS (17.33 and 17.78 %) was recorded in plants treated with mixture of microelement fertilizer in the first and second seasons, respectively. Whereas the mixture of microelements treatment reduced the DS in sugarcane plants by 74.51 and 75.31 % in the first and second seasons, respectively. As separate treatment of microelements, the foliar spray with Zn and Fe reduced the PB DS of sugarcane plants more than the foliar spray with Mn microelement in both seasons. The foliar spray with Fe, Zn and Mn microelements reduced the PB DS on sugarcane plants by 66.01 and 67.90%, 66.34 and 65.43% and 61.76 and 65.13% in the first and second season, respectively.

Regarding the number of sprays, application of different number sprays with microelements (one, two and three sprays) significantly decreased DS of PB disease in sugarcane plants in both tested seasons. The DS decreased with increasing the number of sprays in the two tested seasons. Three foliar sprays of microelements showed the highest reduction of DS on sugarcane plants compared with two and one sprays in both seasons. On the other hand, the lowest reduction of DS was found when plants received one spray with microelements.

The interaction between foliar application of different microelements and number of sprays on sugarcane plants was significant. All tested sprays of the nutrients reduced DS of PB on sugarcane plants compared to control. Two and three sprays application of all tested microelements either individually or in mixture caused the highest reduction in DS followed by other treatments in the first season. Contrarily, in the second season only the three sprays of mixed microelement caused the highest reduction of DS.

Table 1. Effect of Zn, Mn and Fe foliar fertilization on pokkah boeng disease severity on sugarcane plants infected with *F. subglutinans* isolate F2 in two growing seasons

Treatments	Disease severity (DS %)							
	First season				Second season			
	Number of sprays			Mean	Number of sprays			Mean
	1	2	3		1	2	3	
Water (control)	70.00	68.00	66.00	68.00	74.00	72.00	70.00	72.00
Zn	32.00	21.33	15.33	22.89	30.67	26.67	17.33	24.89
Mn	33.33	28.67	16.00	26.00	30.00	26.00	19.33	25.11
Fe	29.33	23.33	16.67	23.11	25.33	26.67	17.33	23.11
Zn+Mn+Fe (Mixture)	23.33	16.00	12.67	17.33	21.33	18.00	14.00	17.78
Mean	37.60	31.47	25.33	31.47	36.27	33.87	27.60	32.58
L.S.D. at 5%								
Fertilizer (A)				2.32				1.81
Number of sprays (B)				1.80				1.40
Interaction (AxB)				4.02				3.14

Effect of Zn, Mn and Fe foliar fertilization on net cane yield (ton/fed.) of sugarcane

The results presented in Table No. 2 showed that foliar spraying of sugarcane plants with microelements, whether single or mixed, had a positive effect in increasing on total cane yield in tons per 0.42 acre (tons/fed) in both seasons. A description of the results found that the yield of sugarcane plants sprayed with mixture of microelements (Zn, Mn and Fe) was higher than in plants sprayed with each single microelement. As individually application, the foliar spray with Fe increased the yield higher than Mn and Zn treatments. The data in the same Table also showed that the more frequent of spraying on the cane plants with the elements exhibited the highest productivity than one application of each element alone or a mixture of the three tested elements in the two tested seasons. Net cane yield (tons/fed.) was significantly affected by the interactions between microelements application and spray frequency in both seasons. The lowest values of net cane yield were produced in untreated sugarcane plants. Also, foliar spray with Zn microelement once time had no effect on net cane yield compared to other microelements either alone or in mixture in the first season. In the second season all tested microelements either alone or in mixture increased the net cane yield compared to water treatment. The highest values of net cane yield (51.82 and 53.75

tons/fed.) were found in sugarcane plants sprayed three times with mixture of microelements in the first and second season, respectively.

Table 2. Effect of Zn, Mn and Fe foliar fertilization on net cane yield (ton/fed.) of sugarcane plants infected with F. *subglutinans* isolate F2 in two growing seasons

Treatments	Net cane yield ton/fed							
	First season				Second season			
	Number of sprays			Mean	Number of sprays			Mean
	1	2	3		1	2	3	
Water (control)	33.41	33.53	33.60	33.51	34.77	35.30	35.80	35.29
Zn	33.69	41.78	43.74	39.74	37.55	44.15	49.61	43.77
Mn	37.03	42.87	47.29	42.40	38.8	44.41	52.08	45.10
Fe	38.00	42.97	50.04	43.67	42.03	44.86	52.03	46.31
Zn+Mn+Fe (Mixture)	39.81	43.85	51.82	45.16	43.58	45.51	53.75	47.61
Mean	36.39	41.00	45.30	40.90	39.35	42.85	48.65	43.62
L.S.D. at 5%								
Fertilizer (A)				0.87				0.50
Number of sprays (B)				0.67				0.39
Interaction (AxB)				1.51				0.87

Effect of Zn, Mn and Fe foliar fertilization on sucrose percentage of juice of sugarcane

Data presented in Table (3) indicate that the sucrose percentage of sugarcane juice significantly affected by foliar fertilization with microelements in the two tested seasons. The data reveal that spray sugarcane plants with tested microelement alone or in mixture significantly increased the sucrose percentage in juice of sugarcane plants. The sucrose percentage of sugarcane plants treated with mixture of microelements was higher than that in plants treated with single microelements in both seasons. The foliar spray with Zn and Mn individually increased the sucrose percentage more than Fe in the first season. However, foliar spray with Zn increased the sucrose percentage of plants more than Fe and Mn in second season.

The sucrose percentage of sugarcane plants increased with increase the number of sprays. Whereas, the foliar spray three times with each microelement either individually or in mixture was superior to two and one times sprays.

The interaction effect between microelements treatments and sprays frequency was found to be statistically similar in the two tested seasons. The best sucrose percentage (19.49 and 19.14%) was obtained when sugarcane plants were sprayed with mixture of microelements or Zn fertilizer three time in first season, respectively. On the other hand, the highest sucrose percentage of juice (18.96%) was found only in plants sprayed three times with mixture of microelements followed by in plants sprayed with Zn microelement alone and in plants sprayed two and one times with mixture of microelements.

Table 3. Effect of Zn, Mn and Fe foliar fertilization on sucrose percentage of juice of sugarcane plants infected with F. *subglutinans* isolate F2 in two growing seasons

Treatments	Sucrose percentage							
	First season				Second season			
	Number of sprays			Mean	Number of sprays			Mean
	1	2	3		1	2	3	
Water (control)	13.29	14.21	14.50	14.00	16.67	17.28	17.44	17.13
Zn	14.62	18.14	19.14	17.30	18.32	18.62	18.70	18.55
Mn	16.01	17.40	18.02	17.14	18.12	18.22	18.58	18.31
Fe	14.91	17.70	17.72	16.78	18.37	18.43	18.51	18.44
Zn+Mn+Fe (Mixture)	17.32	18.30	19.49	18.37	18.64	18.65	18.96	18.75
Mean	15.23	17.15	17.77	16.72	18.02	18.24	18.44	18.23
L.S.D. at 5%								
Fertilizer (A)				0.45				0.09
Number of sprays (B)				0.35				0.07
Interaction (AxB)				0.78				0.15

Effect of Zn, Mn and Fe foliar fertilization on sugar recovery percentage of sugarcane juice

The results expressed in Table (4) showed that the spray applications of each microelement either individually or in mixture markedly enhanced the sugar recovery percentage in juice compared to control plants in both experiment seasons. The plants treated with mixture of microelements exhibited the highest sugar recovery percentage of sugarcane plants (12.52 and 12.68%) in the first and second season, respectively. Sugar recovery percentage was higher in plants sprayed by mixture of microelements than in plants sprayed by microelement alone, while no significant effect differences between Zn, Mn and Fe microelements on sugar recovery percentage in the first season. However, in the second season, the sugar recovery percentage was higher in plants treated with both Zn and Fe microelements than in plants treated with Mn. Also, the data revealed that the highest sugar recovery percentage was recorded in plants of sugarcane sprayed three times with the microelements in both tested seasons.

Concerning to the interactions between the microelement's application and the number of sprays in both seasons, the highest sugar recovery percentage was recorded in plants sprayed two or three times with microelements mixture and three time with Zn microelement in the first season. The lowest sugar recovery percentage was recorded in untreated sugarcane plants in both seasons and in plants sprayed one time with single microelement in the first season.

Table 4. Effect of Zn, Mn and Fe foliar fertilization on sugar recovery percentage of juice of sugarcane plants infected with F. *subglutinans* isolate F2 in two growing seasons

Treatments	Sugar recovery percentage							
	First season				Second season			
	Number of sprays			Mean	Number of sprays			Mean
	1	2	3		1	2	3	
Water (control)	9.12	9.14	9.22	9.16	11.64	11.71	11.78	11.71
Zn	9.68	11.96	13.31	11.65	12.21	12.46	12.71	12.46
Mn	9.98	11.61	12.37	11.32	11.94	12.55	12.58	12.36
Fe	9.35	11.92	12.16	11.14	12.31	12.38	12.49	12.39
Zn+Mn+Fe (Mixture)	11.47	12.49	13.59	12.52	12.57	12.62	12.84	12.68
Mean	9.92	11.42	12.13	11.16	12.13	12.34	12.48	12.32
L.S.D. at 5%								
Fertilizer (A)				0.68				0.09
Number of sprays (B)				0.52				0.07
Interaction (AxB)				1.17				0.16

Effect of Zn, Mn and Fe foliar fertilization on sugar yield ton/fed. of juice of sugarcane

The data presented in Table (5) showed that foliar spray with any tested element (Zn, Mn or Fe) either individually or in mixture markedly produced high sugar yield compared to water treated plants in both seasons. Moreover, the sugar yield in sugarcane plants sprayed with mixture of microelements was higher than in plants treated by single each microelement. The foliar spray with mixture of microelements increased the sugar yield of sugarcane plants by 50.97 and 31.62 % compared to water treatment in the first and second seasons, respectively. As individually application of microelements, the foliar spray with each microelement increased the sugar yield (tons/fed.) of sugarcane plants compared to untreated plants without significant differences among them in the first season. The foliar spray with the tested microelements differed in their effect on the sugar yield, whereas, Fe application resulted the highest sugar yield followed by Mn treatment, then Zn treatment. Moreover, the foliar spray with single microelement of Fe, Mn and Zn increased the sugar yield (tons/fed.) by 43.41 and 28.17%, 42.83 and 25.99% and 42.24 and 24.36%, in the first and second season, respectively. In all tested case, the sugar yield increased with increasing the number of sprays of microelements. The foliar sprays three times with each microelement alone or in mixture increased the sugar yield higher than one- or two-times applications.

Concerning the interaction between foliar fertilizers application of microelements and number of sprays in both tested seasons, the highest sugar yield (7.04 and 6.9 tons/fed.) was recorded in sugarcane plants sprayed three times with mixture of microelements in the first and second season, respectively. The lowest sugar yield was recorded in untreated sugarcane plants in both tested seasons.

Table 5. Effect of Zn, Mn and Fe foliar fertilization on sugar yield ton/fed. of juice of sugarcane plants infected with F. *subglutinans* isolate F2 in two growing seasons

Treatments	Sugar yield ton/fed							
	First season				Second season			
	Number of sprays			Mean	Number of sprays			Mean
	1	2	3		1	2	3	
Water (control)	2.73	2.80	2.84	2.79	4.10	4.14	4.15	4.13
Zn	3.26	5.43	5.81	4.83	4.59	5.50	6.30	5.46
Mn	3.68	5.13	5.84	4.88	4.63	5.57	6.55	5.58
Fe	3.57	5.13	6.09	4.93	5.19	5.55	6.50	5.75
Zn+Mn+Fe (Mixture)	4.57	5.47	7.04	5.69	5.48	5.74	6.90	6.04
Mean	3.56	4.79	5.52	4.62	4.80	5.30	6.08	5.39
L.S.D. at 5%								
Fertilizer (A)				0.22				0.04
Number of sprays (B)				0.17				0.03
Interaction (AxB)				0.39				0.07

Effect of Zn, Mn and Fe foliar fertilization on reducing sugar percentage of juice of sugarcane

From the results in Table (6) noticed that reducing sugar was affected in plants that were sprayed with microelements. The amount of reducing sugar increased in plants that were sprayed with the microelements used in both experimental seasons. In the first season, the highest percentage of reducing sugar was recorded in plants that were sprayed with a mixture of the three elements, followed by reducing sugar in plants treated with Fe alone. On the other hand, in the second season, Fe was the least effective in increasing reducing sugar, while the mixture of microelements was the highest in increasing reducing sugar followed by Mn and zinc, respectively. The lowest reducing sugar content was recorded in sugarcane plants treated with water in both seasons.

Number of sprays with microelements was significantly increased reducing sugar percentage of sugarcane plants in the first and second seasons. The results cleared that increasing number of sprays with microelements from one to three sprays led to increasing reducing sugar percentage. The highest reduction of reducing sugar percentage was recorded when the microelements sprayed three times. The lowest reducing sugar percentage was obtained at application one spray of microelements on sugarcane plants.

The interaction between foliar fertilizers of microelements and the number of sprays on sugarcane plants was markedly affected reducing sugar percentage in the first and second season. In the first season, the highest reducing sugar percentage (0.55 and 0.53%) was recorded in sugarcane plants treated with mixture of microelements at three and two times, respectively. Foliar spray three times with microelements mixture or Mn as single application caused the highest reducing sugar percentage followed by both mixture treatment and Mn and Zn microelements sprayed two times. The lowest reducing sugar percentage in juice of sugarcane plants were found in untreated sugarcane plants in the first and second season.

Table 6. Effect of Zn, Mn and Fe foliar fertilization on reducing sugar percentage of juice of sugarcane plants infected with F. *subglutinans* isolate F2 in two growing seasons

Treatments	Reducing sugar percentage							
	First season				Second season			
	Number of sprays			Mean	Number of sprays			Mean
	1	2	3		1	2	3	
Water (control)	0.41	0.43	0.45	0.43	0.29	0.30	0.31	0.30
Zn	0.47	0.49	0.51	0.49	0.33	0.35	0.37	0.35
Mn	0.46	0.50	0.52	0.49	0.35	0.37	0.39	0.37
Fe	0.49	0.52	0.52	0.51	0.34	0.35	0.36	0.35
Zn+Mn+Fe (Mixture)	0.51	0.53	0.55	0.53	0.36	0.38	0.40	0.38
Mean	0.47	0.49	0.51	0.49	0.33	0.35	0.37	0.35
L.S.D. at 5%								
Fertilizer (A)				0.01				0.01
Number of sprays (B)				0.01				0.01
Interaction (AxB)				0.02				0.02

Discussion

Pokkah boeng disease caused by *Fusarium moniliforme*, is consider one of the major diseases of sugarcane in different countries of the world (Mohammadi *et al*., 2012). In recent years, its occurrence has been recorded in greater part of cane growing areas in Egypt (Osman, 2021). The reduction of microelements such as zinc, iron and manganese was recorded in diseased stalks and leaves of sugarcane plants infected with the disease compared to healthy ones (Dohare *et al*., 2003; Singh *et al*., 2006). Zinc, manganese and iron content in plant tissues increased significantly with the foliar applications with each microelement (Zeidan *et al*., 2010). The present study was planned to investigate the effect of foliar spray with the microelements (Zn, Mn and Fe) either separately or in mixture on incidence of the disease as well as on quality of juice under field conditions. Our results showed that foliar spray with these microelements significantly reduced PB disease incidence on sugarcane plants compared to control plants. The reduction in DS was lower in plants received separate microelements applications than in plant treated with combined microelements. These results are in agreement with those obtained by several researches on different diseases and hosts (Dordas 2008). These microelements may play a role of the in closing the stomata, delaying the penetration and development of the pathogen or they have a toxic effect, causing reduction in the growth of the pathogen (Bakeer *et al*., 2014). Moreover, the application of microelements can enhance the formation of mechanical barriers (lignifications) as well as the synthesis of toxins (Phytoalexins) as mentioned by Marschner (1995). Microelements is affecting the phenolics and lignin content and membrane stability. Also, it affects resistance indirectly, such in deficient plants they will be more suitable feeding substrate (Bakeer *et al*., 2014).

Enhanced resistance in plants against PB disease may be due to the role of each microelement in control the disease. Zinc is important in starch and protein synthesis, and a little zinc concentration induces accumulation of amino acids and reducing sugars in tissue plants (Römheld and Marschner, 1991). Fe is a component of peroxidase and stimulates other enzymes involved in the biosynthetic pathway. Mn inhibits the induction of aminopeptidase, an enzyme which supplies essential amino acids for fungal growth and pectin methylesterase, a fungal enzyme that degrades host cell walls. Its controls lignin and suberin biosynthesis (Vidhyasekaran, 1997). Both lignin and suberin are important biochemical barriers to fungal pathogen invasion (Vidhyasekaran, 2004), since they are phenolic polymers resistant to enzymatic degradation (Agrios, 2005).

In our study, the application of Zn, Mn and Fe either separately or in mixture not only increased cane yield but also increased the sugar yield, sugar recovery and reducing sugar percentage in juice of sugarcane plants compared to control. Such results are in accordance with those reported by Ghaffar *et al*. (2011) and Rehman *et al*. (2013). These positive effects of foliar application with micronutrients on yield and yield component improvement of sugarcane might be attributed to their critical role in crop growth, involving photosynthesis processes, respiration, biochemical and physiological activities (Behrouznajhad and Zehtab-Salmasi 2011 and Bameri *et al*., 2012). The growth parameters and yield of sugarcane treated with mixture of microelements three times was higher than in plants treated with each single microelement one time. Also, it exhibited the best growth and net cane followed by two and one sprays. The present results are in trend with the results obtained by Singh *et al*. (2002), who found that application of zinc either alone or with Mn improved the production of cane, and maximum cane yield was recorded when mixed Zn + Mn was used. The increasing of sugar recovery percent in juice was clear after foliar application of iron and zinc (Ghaffar *et al*., 2011). Increase in the sugar recovery percentage might be due to the additional application of microelements and based upon the previous results of sucrose and purity percentage, it could be concluded that there is a positive and close relationship between sugar recovery and both purity and sucrose percentage. Zinc is a component of carbonic anhydrase, several dehydrogenases and auxin production which in turn enhance plant growth (Potarzycki and Grzebisz, 2009). Mn is required for biological redo system, enzyme activation and oxygen carrier in nitrogen fixation (Romheld and Marachner, 1995). Manganese is required for enzyme activation, in electron transport and disease resistance. However, iron is necessary for the biosynthesis of chlorophyll and cytochrome, leading to an increase in the biosynthesis of materials and growth (Behrouznajhad and Zehtab-Salmasi, 2011). In conclusion, it can be concluded that foliar application of microelements is more efficient in reducing occurrence PB disease and enhancing resistance in sugarcane plants as well as increasing the growth and quality of juice when soil conditions are not suitable for nutrients availability.

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تأثير التسميد الورقي ببعض العناصر الصغرى في شدة الاصابه بمرض بوكا بوينج على قصب السكر ومحصول القصب وجودة العصير تحت الظروف الحقلية

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الملخص

أجريت تجربة حقليه وذلك بالعدوى الصناعيه للنباتات القصب بعزله شديده القدره المرضيه من الفطر *Fusarium subglutinan* المسبب لمرض بوكا بوينج لمدة عامين متتاليين لمعرفة تأثير الرش الورقي لنباتات قصب السكر بواسطة بعض العناصر الصغرى على شدة مرض بوكا بوينج وإنتاجية القصب والسكر وجودة عصير قصب السكر. فلقد وجد أن الرش الورقي لنباتات قصب السكر صنف G.T. 54-9 بكل من الزنك والمنجنيز والحديد بشكل منفصل أو خليط منهم قلل بشكل كبير من شدة مرض البوكا بوينج مقارنة مع النباتات الغير معامله (الرش بالماء). ومع ذلك، فإن تطبيق العناصر الصغرى بشكل منفصل كان أقل فعالية في الحد من شدة المرض مقارنة بمخلوط بالعناصر الصغرى الثلاثه مجتمعة. علاوة على ذلك، انخفضت شدة المرض مع زيادة عدد مرات الرش. حيث أعطت الرش الورقي ثلاث مرات أعلى خفض في شدة المرض مقارنة برشة واحدة أو رشتين. وقد أدى رش نباتات قصب السكر بالعناصر الدقيقة التي تم اختبارها إما بشكل منفصل أو في خليط إلى زيادة معنوية في صافي إنتاج القصب، وإنتاجية السكر، ونسبة استرداد السكر في عصير النباتات المعالجة مقارنة بالنباتات غير المعالجة. كما سجلت أكبر زيادة في خفض نسبة السكر المختزل فى معاملات خليط العناصر الصغرى يليها الرش بلعنصر منفردا في كلا الموسمين. وفقًا للنتائج التي توصلنا إليها، فإن رش نباتات القصب بالعناصر الصغرى يعتبر واعدًا في تعزيز مقاومة نباتات قصب السكر ضد مرض بوكا بوينج وزيادة إنتاجية القصب وجودة عصير قصب السكر.