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ORIGINAL ARTICLE / ORIGINALBEITRAG

Effect of Sources of Nutrients and Nematicide Application on Fruit Yield, Quality and Nematode Density in Polyhouse Grown Banana (*Musa* AAA var. 'Azman')

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Abstract

This research was completed on the 'Azman' banana variety grown in productive greenhouses in Limonlu village, Erdemli county in Mersin province of Türkiye in the 2018–2019 and 2019–2020 growing seasons. Banana cultivation removes high amounts of plant nutrient elements from the soil and, as a result, conventional fertilizers are used excessively during plant development. Additionally, the uncontrolled use of conventional fertilizer may involve many risks in terms of health, such as increases in residue (nitrate, nitrite) content in fruit. Also, very high increases were observed for production costs to producers with the increasing fertilizer prices in recent times. Producers want to maintain quality, high-yield and lower cost production. In this research, the target was to reduce production costs to producers and to increase yield and quality of fruit with soil amelioration using natural fertilizers. In the study, the effects of banana waste, organic fertilizer, farm fertilizer, nematicide with ethoprophos active agent and conventional fertilizer applications on yield, impact on nitrate and nitrite accumulation in fruit and effects on nematode density, the main pest of the banana plant, in roots and soil were determined. According to the research results, in both growing seasons the highest yield for bunch weight (kg), finger weight (g), finger diameter (mm), and finger length (cm) was obtained from the sixth application using the combination of Novatec + Mocap + farm fertilizer. Plants with ethoprophos and farm fertilizer applied provided the best results for the lowest density of nematodes during measurements in September in both growing seasons. The best results were obtained from the second application (Novatec + ethoprophos) and sixth application (Novatec + ethoprophos + farm fertilizer). Residue content in fruit (nitrate, nitrite) were lowest in both growing seasons for plants administered the third application of Novatec + farm fertilizer.

Keywords Azman variety · Mersin · Residue · Ethoprophos · Novatec

Highlights

1. The aim of this study was to reduce the nitrate and nitrite accumulation in fruit caused by excessive chemical fertilizer use and to determine the nematode density in soil and roots after different fertilizer applications.
2. In this study, the effects of different combinations of natural and artificial fertilizers on nitrate and nitrite accumulation were determined with the HPLC technique.
3. The best results were obtained from the second application (Novatec + ethoprophos) and sixth application (Novatec + ethoprophos + burnt farm fertilizer).
4. In this research, the target was to reduce production costs to producers and to increase yield and quality of fruit with soil amelioration using natural fertilizers.

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Introduction

The banana plant belongs to the Musaceae family in the order Scitamineae. Banana (*Musa* × *paradisiaca*) derives from the Arabic word meaning finger (banana) (Boning 2006). More than half of global banana production comes from Asian countries. According to FAO data for 2020, India, China, Brazil and Ecuador are among the world's most important banana-producing countries (FAO 2020). In 2019, 128,778,738 tons of bananas were produced globally, with 30,460,000 tons of total production from India. In Türkiye, banana cultivation and cultivation areas are preferred by producers due to the continuously high banana price and the effect of yield in the year after planting. According to TUIK (Turkish Statistical Institute) 2020 data, banana production was 210,178 tons in 4.428 hectares area in 2010, while 2019 values show 548,323 tons of banana production in 8.488 hectares area (TUIK 2020). According to this data, a 36.2% increase in banana cultivation area occurred in Türkiye over 9 years. With cultivation in subtropical conditions, the highest banana production of 333,998 tons is obtained from the Mersin region in the country.

During banana cultivation, many factors like planting time, planting interval, soil needs, temperature, humidity, water, fertilization and selection of offspring plants significantly affect yield. The application times and amounts of organic and inorganic fertilizers are at least as important as the environmental conditions. Appropriate fertilization of bananas is very important in terms of high return on investment for growers as it leads to increases in bunch weight and increased fruit yield, reductions in the duration for maturation of banana bunches, increases in the number of marketable, quality bunches, and improvements in quality in terms of physical and chemical properties (Haifa 2017; Bodur et al. 2022; Kumar et al. 2020).

In this study, the effects of different combinations of natural and artificial fertilizers on nitrate and nitrite accumulation in fruit were determined with the high pressure liquid chromatography (HPLC) technique. Additionally, nematodes appear to be the most important problem in areas where bananas are cultivated. In addition to organic matter improving soil structure, it prevents proliferation of plant parasites called nematodes, which live freely in soil, and lowers their population. A previous study determined that the use of compost fertilizers against nematode occurrence was determined to provide increases in yield and quality by preserving the physical structure of the plant through the protective effect of the organic fertilizer on the plant. In this study, the aim was to reduce the nitrate and nitrite accumulation in fruit caused by excessive chemical fertilizer use and to determine the nematode density in soil and roots after different fertilizer applications. In Türkiye, since it is economical to use nematode pesticides in banana fields, it is used by producers in an integrated struggle. In this study, the nematode drug was used as a positive control. The effectiveness of the applications was determined according to the drug.

Materials and Methods

The material in this study comprised 'Azman' variety banana plants produced in *in vitro* conditions by Toros Nursery Corporation. The 'Azman' banana variety is a tall, strong and productive banana variety. The trial was completed in Limonlu town, Erdemli county, Mersin province (Fig. 1).

Tissue cultured banana plants were planted in a plastic greenhouse 7 m high, at 2 m distance between rows and plants in September 2018. The trial began in February 2019 and used 108 banana plants. This research was set up with six different applications, with six replications of each application and three plants in each replication according to the random block design. In the research, Novatec commer-



Fig. 1 Greenhouses where the trial was completed and general appearance of the Limonlu region and appearance of trial plants

cial fertilizer (Bursa, Türkiye) (commonly chosen and used in the region), Mocap 20 EC (ethoprophos; nematicide), banana waste, farm fertilizer and organic-derived AKC (fertilizer brand) fertilizers and their combinations were compared. Novatec fertilizer (18N-18P-18K) is a conventional fertilizer, in granule form given from tree crown projection in February and liquid form given weekly in the drip irrigation system. Organic Plus Solid Farm Fertilizer contained 45% organic matter, 1.5% total nitrogen, 1% nitrogen, 1% water-soluble K_2O, and 15% total humic and fulvic acid. The solid form of Organic Plus Solid Farm Fertilizer was applied at the rate of 25 kg/plant in February and the liquid form (2 L/decare) was given regularly each month from February to October. In the trial, banana waste (unprocessed) was obtained from banana pseudostem, leaves and rhizomes disintegrated in a banana chipper machine, and administered into soil at the rate of 25 kg/plant at the start of the trial (Fig. 2).

Nematode medication with ethoprophos active agent was carried out at the point of emergence of new leaf at the rate of volume 2 L/decare in April, May and August (Fig. 2). Goat fertilizer was used as burnt farm fertilizer. Farm fertilizer was applied to soil in February at the start of the trial in both growing seasons at the rate of 25 kg/plant. Applications included: 1st application Novatec (control); 2nd application Novatec + Mocap; 3rd application Novatec + farm fertilizer; 4th application Novatec + banana waste; 5th application Novatec + Organic Plus Solid Farm Fertilizer; and 6th application Novatec + Mocap + farm fertilizer.

Yield Properties

Number of Fingers in Bunch (Number) Total number of fingers in each bunch were determined by counting before cutting the bunch from the plants.

Weight of Bunch (kg) Weight of each bunch was determined by weighing after cutting from the plant.

Yield per Hectare (ton) Determined by multiplying the yield value obtained from one plant by the number of plants per hectare.

Finger Weight (g) Immediately after being skinned and ripened, five fruits taken from the first, middle and last hand, and lower and upper rows of a hand were weighed on a sensitive scale. Fruits started to ripen in the 2nd eating



Fig. 2 The trial area with greenhouse cleaning, tillage, banana shredding machine, banana waste, and nematode medication and base fertilizer (Novatec) application stage

stage and measurements were performed in the 6th eating stage.

Finger Diameter (mm) Immediately after being skinned and ripened, the diameter of five fruits taken from the first, middle and last hand, and lower and upper rows of a hand were measured with a compass.

Finger Length (cm) Immediately after being skinned and ripened, lengths of five fruits taken from the first, middle and last hand, and lower and upper rows of a hand were measured with a compass. Fruits started to ripen in the 2nd eating stage and measurements were performed in the 6th eating stage.

Nitrate and Nitrite Amount (Residue Content) (ppm) Nitrate and nitrite analyses were performed with the HPLC technique according to a method developed by Chou et al. (2003). Samples prepared with methanol extract were qualitatively and quantitatively determined using a Phenomenex Luna C18 HPLC column (5 µm, 250 × 4.6 mm i.d.) at 213 nm wavelength in 0.8 mL/min flow.

Nematode Count per Plant Five plants were chosen for soil sampling and soil samples were taken from five different points where roots were located 0–30 cm from the pseudostem of the tree. Soil samples were blended and placed in 2 kg plastic bags. Root samples from the same locations were placed in plastic bags (Wang and Hooks 2009; Mant and Hinai 1996). With the aim of obtaining the nematodes in 100 g of soil, the Petri method, a modified form of the Baermann funnel method, was used and nematodes present in 50 cc (100 g) soil were obtained (Barker 1985; Southey 1986). Root samples were washed in water, cut to small pieces with 0.5–2.5 cm length and nematodes were obtained using the modified Baermann funnel (Barker 1985; Southey 1986) method. In this way, the amount of nematodes in 100 g of fresh root was calculated.

Experimental Design and Statistical Analyses The experiment was performed in a randomized block design. Data obtained from the trial were analyzed with variance analysis using the JMP version 5.0.1 (SAS Institute Inc., Cary, NC, USA) and compared with the mean LSD test.

Results and Discussion

Data related to yield, residue and nematode density in different growing seasons and with different applications to the material in the study were analyzed statistically.

Table 1 Finger count values for bananas with six different fertilizer applications for 2018–2019 and 2019–2020 growing seasons

Application number	Years		Mean application
	2018–2019 Growing period	2019–2020 Growing period	
1	240.8	221.5	231.1 b
2	291.1	263.6	277.4 a
3	295.0	256.8	275.9 a
4	263.8	243.5	253.6 ab
5	234.1	235.5	234.8 b
6	276.0	268.1	272.0 a
Annual mean	266.8 a	248.1 b	
$LSD_{5\%}$ year: 15.37*	$LSD_{5\%}$ year × application: NS	$LSD_{5\%}$ application: 26.62*	

NS not significant, *LSD* Least Significant Difference between the means at the required level of probability.
Statistical significance levels are listed in alphabetical order.

The effects of six different applications to the 'Azman' banana variety in two different growing seasons on the number of fingers are given in Table 1.

Finger Values for 2018–2019 and 2019–2020

When Table 1 is investigated, the effect of the year × application interaction on the number of fingers was statistically insignificant, while the effects of the year and application mean were statistically significant. The second (277.4), third (275.9) and sixth (272) applications were within the same group in statistical terms for the mean applications between 2018 and 2020. The highest values were obtained from the second application. The variation in finger numbers according to year was between 248.1 and 266.8, with the highest value obtained from plants in the first growing season. According to year × application, the finger values varied in the range from 221.5 to 295.

The study by Basavalıngaıah et al. (2010) reported the number of fingers in a bunch were between 78 and 139. In the 2019–2020 growing season, Basavalingaiah et al. (2010) identified higher finger numbers. Differences between some results obtained may be due to the banana varieties used in the research being different, in addition to cultural practices and cultivation in different ecologies. The values obtained for the 2018–2019 season were identified to be slightly higher than values for the 2019–2020 season. This difference may be due to a flooding event in the greenhouse that occurred in the second growing season.

Bunch Weight for 2018–2019 and 2019–2020

The effects of six different applications to the 'Azman' banana variety in two different growing seasons on bunch

Table 2 Bunch weights of banana plants with six different fertilizer applications in the 2018–2019 and 2019–2020 growing seasons

Application number	Year		Mean application
	2018–2019 Growing season	2019–2020 Growing season	
1	39.0	39.6	39.3 c
2	48.0	46.5	47.2 a
3	45.5	47.1	46.3 ab
4	42.6	42.3	42.5 bc
5	38.3	40.3	39.3 c
6	49.3	48.3	48.8 a
Annual mean	43.8	44.0	
$LSD_{5\%}$ year: NS	$LSD_{5\%}$ year × application: NS	$LSD_{5\%}$ application: 6.25*	

NS not significant, *LSD* Least Significant Difference between the means at the required level of probability.
Statistical significance levels are listed in alphabetical order.

Table 3 Hectare yield values of banana plants with six different fertilizer applications in the 2018–2019 and 2019–2020 growing seasons

Application number	Year		Mean application
	2018–2019 Growing season	2019–2020 Growing season	
1	72.1	73.3	72.7 c
2	88.8	86.0	87.4 a
3	84.1	87.2	85.7 ab
4	78.9	78.3	78.6 bc
5	70.9	74.6	72.7 c
6	91.2	89.4	90.3 a
Annual mean	81.0	81.5	
$LSD_{5\%}$ year: NS	$LSD_{5\%}$ year × application: NS	$LSD_{5\%}$ application: 8.18*	

NS not significant, *LSD* Least Significant Difference between the means at the required level of probability.
Statistical significance levels are listed in alphabetical order.

weight are shown in Table 2. When the table is investigated, the year and year × application interaction effects were statistically insignificant for bunch weight, while the effect of mean application was statistically significant. The sixth (48.8 kg) and second (47.2 kg) applications were located within the same group in statistical terms, in relation to application mean values, and the highest values were obtained from the sixth application. The bunch weights were identified to vary between 43.8 and 44.0 kg according to year, with the highest values obtained from plants in the second growing season. The bunch weights varied between 38.3 and 49.3 kg according to year × application.

Devraj et al. (2019) applied different amounts of organic and chemical fertilizers, and their combinations to the 'Grand Naine' banana variety and identified bunch weight (29.23–32.87 kg). In the study by Basavalingaiah et al. (2010), the highest bunch weight was identified as 30.03 kg. The bunch weights in the studies by Devraj et al. (2019) and Basavalingaiah et al. (2010) were determined to be much lower than the results in our study. In both production seasons, the best results for bunch weight were obtained from plants in the sixth application group (Novatec + ethoprophos + farm fertilizer). The differences between these results are considered to be due to the different banana varieties used in research, in addition to cultural practices and cultivation in different ecologies.

Hectare Yields for 2018–2019 and 2019–2020

The effect on yield values per hectare for six different applications to the 'Azman' banana variety in two different growing seasons are given in Table 3. When this table is examined, the year and year × application interaction effects were statistically significant for hectare yield, while the mean application effect was identified to be significant in statistical terms. In terms of application mean, the highest hectare yield values were obtained for plants in the second (87.4 tons) and sixth (90.3 tons) applications. According to year, the yield per hectare values varied from 81 tons to 81.5 tons, with the highest values obtained from plants in the second growing season. The hectare yield values varied from 70.9 to 91.2 tons according to year × application.

Albadawy and Ali (2019) determined the hectare yield values to be 36.2–46.8 tons as a result of seven different fertilizer applications to the 'Grande Naine' banana variety. As a result, the values found by Albadawy and Ali (2019) were much lower than the values obtained in our study. The differences in some results may be due to different ba-

Table 4 Finger weight values of banana plants with six different fertilizer applications in the 2018–2019 and 2019–2020 growing seasons

Application number	Year		Mean application
	2018–2019 Growing season	2019–2020 Growing season	
1	164.0	154.8	159.4 bc
2	173.8	165.7	169.7 bc
3	175.1	170.3	172.7 b
4	166.4	164.7	165.5 bc
5	155.3	156.3	155.8 c
6	197.2	188.8	193.0 a
Annual mean	171.9	166.8	
$LSD_{5\%}$ year: NS	$LSD_{5\%}$ year × application: NS	$LSD_{5\%}$ application: 22.93*	

NS not significant, *LSD* Least Significant Difference between the means at the required level of probability.
Statistical significance levels are listed in alphabetical order.

Table 5 Finger diameter values of banana plants with six different fertilizer applications in the 2018–2019 and 2019–2020 growing seasons

Application number	Year		Mean application
	2018–2019 Growing season	2019–2020 Growing season	
1	36.8	35.9	36.3 b
2	38.8	37.7	38.3 a
3	37.9	37.8	37.9 a
4	36.6	36.0	36.3 b
5	36.4	36.2	36.3 b
6	39.5	39.2	39.3 a
Annual mean	37.7	37.1	
$LSD_{5\%}$ year: NS	$LSD_{5\%}$ year × application: NS	$LSD_{5\%}$ application: 2.19*	

NS not significant, *LSD* Least Significant Difference between the means at the required level of probability.
Statistical significance levels are listed in alphabetical order.

nana varieties being used in research, in addition to cultural practices and cultivation in different ecologies.

Finger Weights in 2018–2019 and 2019–2020

The effects of six different applications in two different growing seasons on the finger weight of the 'Azman' banana variety are given in Table 4. When this table is investigated, the effects of year and year × application interaction on finger weight were statistically insignificant, while the effect of mean application was statistically significant. In terms of application mean, the highest finger weight was obtained from plants in the sixth application (197.2 g). According to year, the finger weights varied from 166.8 to 171.9 g, with highest values obtained from plants in the first growing season. According to the year × application interaction, the finger weights varied in the range from 154.8 to 197.2 g.

Devraj et al. (2019) applied different amounts of organic and chemical fertilizer and their combinations to the 'Grand Naine' banana variety and determined the finger weights varied from 164.8 to 186.53 g. Sandhya et al. (2018) identified finger weights to be 145–154.71 g for 'Grande Naine' banana variety administered different rates of nitrogen and potassium fertilizer. Ledo et al. (2018) determined the finger weights for 13 different banana varieties (87.09–193.96 g). Garasangi et al. (2018) applied organic and chemical fertilizers to the 'Rajapuri' banana variety and found finger weights varied from 46.56 to 141.50 g. Basavalingaiah et al. (2010) identified finger weights in their study (135.3–211.3 g). When results obtained in both growing seasons are compared with previous studies, values for the 2018–2019 season were similar to values obtained by Ledo et al. (2018). Values obtained by Devraj et al. (2019) were similar to the finger weights obtained in the 2019–2020 season. Values obtained by Sandhya et al. (2018) were lower than the values in this study. Differences in some results are thought to be due to different banana varieties being used in research, in addition to cultural practices and cultivation in different ecologies.

Finger Diameter in 2018–2019 and 2019–2020

The effects of six different applications in two different growing seasons on the finger diameter of 'Azman' banana variety are given in Table 5. When this table is investigated, the effects of year and year × application interaction on finger diameter were statistically insignificant, while the effect

Table 6 Finger length values of banana plants with six different fertilizer applications in the 2018–2019 and 2019–2020 growing seasons

Application number	Year		Mean application
	2018–2019 Growing season	2019–2020 Growing season	
1	154.5	147.4	150.9 c
2	166.8	161.5	164.1 ab
3	159.7	158.6	159.1 abc
4	157.9	152.1	155.0 bc
5	157.6	150.7	154.2 c
6	168.8	164.6	166.7 a
Annual mean	160.9	155.8	
$LSD_{5\%}$ year: NS	$LSD_{5\%}$ year × application: NS	$LSD_{5\%}$ application: 12.99*	

NS not significant, *LSD* Least Significant Difference between the means at the required level of probability.
Statistical significance levels are listed in alphabetical order.

of mean application was statistically significant. In terms of application mean, the sixth, second and third applications were in the same group statistically, with the highest finger diameter obtained from plants in the sixth application (39.3 mm). According to year, the finger diameters varied from 37.1 to 37.7 mm, with highest values obtained from plants in the first growing season. According to the year × application interaction, the finger diameters varied in the range from 35.9 to 39.5 mm.

Sarrwy et al. (2012) identified that finger diameter varied from 30.7 to 35.3 mm in a study using different planting intervals for 'Williams' banana varieties. Ledo et al. (2018) identified the finger diameter values for 13 different banana varieties (31.5–39.3 mm). When results obtained in both growing seasons are compared with these studies, values found by Sarrwy et al. (2012) were lower than the obtained data, while values obtained by Ledo et al. (2018) were similar to the values in both periods. Differences in some results may be due to different banana varieties being used in research, in addition to cultural practices and cultivation in different ecologies.

Finger Length in 2018–2019 and 2019–2020

The effects of six different applications in two different growing seasons on the finger length of 'Azman' banana variety are given in Table 6. When this table is investigated, the effects of year and year × application interaction on finger length were statistically insignificant, while the effect of mean application was statistically significant. In terms of application mean, the highest finger length was obtained from plants in the sixth application (166.7 mm). According to year, the finger length varied from 155.8 to 160.9 mm, with highest values obtained from plants in the first growing season. According to the year × application interaction, the finger lengths varied in the range from 147.4 to 168.8 mm.

Devraj et al. (2019) applied different amounts of organic and chemical fertilizers and their combinations to the 'Grand Naine' banana variety and determined that the finger lengths varied from 18.60 to 21.23 cm as a result. Sarrwy et al. (2012) determined that finger lengths varied from 18.57 to 19.93 cm in a study using different planting intervals for 'Williams' banana variety plants. Ledo et al. (2018) identified the finger lengths for 13 different banana varieties (13.42–21.57 cm). Garasangi et al. (2018) applied organic and chemical fertilizers to the 'Rajapuri' banana variety and found the finger lengths varied from 10.77 to 15.25 cm. A study by Basavalingaiah et al. (2010) identified fingers lengths as 12.40–22.27 cm. When results obtained from both periods are compared to these studies, the values for finger length in the studies by Devraj et al. (2019) and Sarrwy et al. (2012) were higher than values in our study, while values obtained by Ledo et al. (2018) are in the same range. Differences in some results are thought to be due to different banana varieties being used in research, in addition to cultural practices and cultivation in different ecologies.

Fruit Nitrate Content Identified in 2018–2019 and 2019–2020

The effects of six different applications in two different growing seasons on the nitrate content of 'Azman' banana variety are given in Table 7. When this table is investigated, the effects of year and year × application interaction were statistically significant for nitrate content. The effect of mean application was identified to be statistically insignificant. In terms of application mean, the nitrate content varied from 281.2 to 300.8 ppm, with highest values obtained from plants in the second application. According to the year × application interaction, the nitrate contents were from 148.1 to 425.0 ppm, with highest values obtained from plants in the first period. According to year, the ni-

Table 7 Nitrate content of banana plants with six different fertilizer applications in the 2018–2019 and 2019–2020 growing seasons

Application number	Year		Mean application
	2018–2019 Growing season	2019–2020 Growing season	
1	425.0 a	204.7 c	314.7
2	407.4 a	194.2 c	300.8
3	365.4 b	148.1 d	256.7
4	424.7 a	223.6 c	324.1
5	366.5 b	196.0 c	281.2
6	401.2 a	200.2 c	300.7
Annual mean	398.4 a	194.4 b	
$LSD_{5\%}$ year: 13.91*	$LSD_{5\%}$ year × application: 34.07*	$LSD_{5\%}$ application: NS	

NS not significant, *LSD* Least Significant Difference between the means at the required level of probability.
Statistical significance levels are listed in alphabetical order.

Table 8 Nitrite content of banana plants with six different fertilizer applications in the 2018–2019 and 2019–2020 growing seasons

Application number	Year		Mean application
	2018–2019 Growing season	2019–2020 Growing season	
1	144.4 a	8.9 d	76.6 ab
2	128.9 ab	50.7 c	89.8 a
3	113.4 b	5.5 d	59.5 c
4	132.4 ab	8.2 d	70.3 bc
5	116.0 b	12.6 d	64.3 b
6	127.9 ab	10.1 d	69.0 bc
Annual mean	127.2 a	16.0 b	
$LSD_{5\%}$ year: 8.37*	$LSD_{5\%}$ year × application: 20.50*	$LSD_{5\%}$ application: 14.49*	

NS not significant, *LSD* Least Significant Difference between the means at the required level of probability.
Statistical significance levels are listed in alphabetical order.

trate content varied from 194.4 to 398.4 ppm, with highest values obtained from plants in the first growing season.

In a study, Klemo (2018) identified the standard nitrate limit values for many fruits and vegetables, and identified the nitrate limit value for banana as 200 ppm. Casanova et al. (2006) reported the nitrate amounts in bananas were in the range of 116–128 ppm. Jonvik et al. (2016) reported the nitrate values in banana fruits were 5.5 ppm. Barakat et al. (2011) administered different rats of fertilizer to 'Williams' banana varieties and identified the nitrate values in fruit as 15.80–18.65 ppm. Hosam El-Dein et al. (2009) identified lower nitrate amounts in banana from plants with compost applied compared to plants with chemical fertilizer applied. The obtained results were much lower than the values found by Hord et al. (2009), and values in the second growing season from the second, third and fifth applications were lower than the limit values identified by Klemo (2018). The nitrate values obtained by other researchers were identified to be lower. The nitrate content value in the harvest season is very important. The nitrate content was identified to be higher in plants harvested in seasons when the temperature is lower. Harvesting from plants in the first (Novatec) and fourth (Novatec + banana waste) applications were performed in the late period when temperatures had fallen. The high nitrate content values in both applications is thought to be related to the temperature values in the harvest season. Fruits harvested at low temperature have lower levels of nitrate accumulation.

Fruit Nitrite Content Identified in 2018–2019 and 2019–2020

The effects of six different applications in two different growing seasons on the nitrite content of 'Azman' banana variety are given in Table 8. When this table is investigated, the effects of year, mean application and year × application interaction were statistically significant for nitrite content. In terms of application mean, the nitrite content varied from 59.5 to 89.9 ppm, with highest values obtained from plants in the second application. According to the year × application interaction, the nitrite contents were from 5.5 to 144.4 ppm, with highest values obtained from plants in the first period. According to year, the nitrite content varied from 16.0 to 127.2 ppm, with highest values obtained from plants in the first growing season.

The study by Hord et al. (2009) determined the nitrite value in banana fruit to be 9 ppm. Sindelar and Milkowski (2012) reported the nitrite content in bananas to be 2.1 ppm. When the results are compared with previous studies, the nitrite values for first, third and fourth applications in the second season were lower than the values obtained by Hord et al. (2009). The values of Sindelar and Milkowski (2012) were identified to be lower than our results. The differences in the results are thought to be affected by different varietal traits of fruit and different care conditions.

Spiral Nematode (*Helicotylenchus multicinctus*) and Root-Knot Nematode (*Meloidogyne incognita*) in Roots During 2018–2019 (100 g)

The spiral nematode (*Helicotylenchus multicinctus*) and root-knot nematode (*Meloidogyne incognita*) values iden-

Table 9 Spiral nematode (*Helicotylenchus multicinctus*) and root-knot nematode (*Meloidogyne incognita*) in roots during the 2018–2019 growing season (100 g)

Application No.	February *Helicotylenchus multicinctus*	September *Helicotylenchus multicinctus*	February *Meloidogyne incognita*	September *Meloidogyne incognita*
1	16.66 ± 10.85	4400 ± 400 a	90 ± 82.25	800 ± 0
2	140 ± 105.57	133.33 ± 133.33 c	6.66 ± 6.66	0
3	33.33 ± 19.77	933.33 ± 133.33 c	10 ± 10	266.66 ± 266.66
4	346.66 ± 346.66	402.66 ± 228.63 c	13.33 ± 13.33	0
5	63.33 ± 52.26	3333.33 ± 581.18 ab	16.66 ± 9.54	0
6	140 ± 96.05	1733.33 ± 1139.2 bc	56.66 ± 38.09	400 ± 400
$D_{\%5}$	NS	1668.52*	NS	NS

NS not significant, *LSD* Least Significant Difference between the means at the required level of probability.
Statistical significance levels are listed in alphabetical order.
*$p < 0.05$

tified in the roots (100 g) according to month in the 2018–2019 growing season are given in Table 9.

When the spiral nematode values for February for the roots of banana plants with different fertilizer applications in the 2018–2019 growing season are investigated, the highest nematode value was 346.66 per 100 g for the fourth application (Novatec + banana waste). This was followed by 140/100 g for the second (Novotec + ethoprophos) and sixth (Novatec + ethoprophos + farm fertilizer) applications. The lowest value of 33.33/100 g was obtained for the third application (Novatec + farm fertilizer). There were no statistically significant differences identified between the groups for the spiral nematode values identified in September, with the highest value of 4400/100 g obtained from the first application. This was followed by the fifth application with the value of 3333.33/100 g (Novatec + AKC). The lowest value was 133.33/100 g for the second application (Novatec + ethoprophos). The root knot nematode values determined for the roots of banana plants with different fertilizer applications were found to be insignificant in statistical terms between February and September. In February, the highest root-knot nematode value was 90/100 g for the first application, followed by 56.66/100 g for the sixth application. The lowest value was 6.66/100 g for the second application (Novatec + ethoprophos). In September, the highest root-knot nematode value was 800/100 g obtained for the first application. This was followed by the sixth application with 400/100 g. Nematodes were not observed in the second, fourth and fifth applications. Chitamba et al. (2013) reported 2050/100 g for spiral nematodes and 16,775/100 g for root-knot nematodes in the roots of banana plants. Özarslandan et al. (2020) applied five different nematicide applications to banana plants in four different greenhouses and determined the root-knot nematode values to be 0–6900/100 g, with spiral nematode values for the roots of 0–5000/100 g. Jaramillo et al. (2019) identified the spiral nematode values to be 17,333–31,633/100 g as a result of different nematicide applications to the 'Williams' banana variety. The researchers stated they observed increases in yield with nematode control. Felde et al. (2005) identified values of 3200, 10,500, 12,600, and 22,900/100 g for spiral nematodes and 500, 600, 1000 and 2800/100 g for root-knot nematodes in the roots of banana plants grown in four different locations. Aguirre et al. (2016) identified the values as 1669–4240/100 g for spiral nematodes and 141–4094/100 g for root-knot nematodes in the roots of the *Musa* AAA variety. When the values for the 2018–2019 growing season are compared with other studies, the values obtained by Chitamba et al. (2013) were higher than the values in February. In September, the values for the first and fifth applications were identified to be higher than the results from the study by Chitamba et al. (2013). The values obtained by Özarslandan et al. (2020) were in a similar range to the values from our research. The values obtained by Felde et al. (2005) were higher than the values obtained in February in our study. The values for the first and fifth applications in September were identified to be within the range of values obtained by Felde et al. (2005). The other applications had lower values. The spiral nematode values obtained by Aguirre et al. (2016) were higher than the values for February. The values for the fifth and sixth application in September were in the range of values obtained by Aguirre et al. (2016). When the root-knot nematode values for the 2018–2019 season are compared with other studies, the values in our study are much lower than the values found by Chitamba et al. (2013). Apart from the values for the first application in September, other applications had root-knot nematode values much lower than values in the study by Felde et al. (2005).

Spiral Nematode (*Helicotylenchus multicinctus*) and Root-Knot Nematode (*Meloidogyne incognita*) in Soil During 2018–2019 (100 g)

The spiral nematode (*Helicotylenchus multicinctus*) and root-knot nematode (*Meloidogyne incognita*) values identi-

Table 10 Spiral nematode (*Helicotylenchus multicinctus*) and root-knot nematode (*Meloidogyne incognita*) in soil during 2018–2019

Application No.	February *Helicotylenchus multicinctus*	September *Helicotylenchus multicinctus*	February *Meloidogyne incognita*	September *Meloidogyne incognita*
1	146.66 ± 65.04	113.33 ± 94.04	83.33 ± 48.83	0
2	170.00 ± 69.42	13.33 ± 6.66	20.00 ± 13.66	0
3	106.67 ± 24.58	60.00 ± 20.00	26.66 ± 9.88	0
4	123.33 ± 72.92	13.33 ± 6.66	46.66 ± 27.64	40.00 ± 40.00
5	80.00 ± 52.91	106.66 ± 76.88	33.33 ± 16.05	26.66 ± 13.33
6	283.33 ± 152.26	60.00 ± 34.64	33.33 ± 19.77	13.33 ± 13.33
$D_{5\%}$	NS	NS	NS	NS

NS not significant

fied in the soil (100 g) according to month in the 2018–2019 growing season are given in Table 10. When the table is investigated, statistically significant differences were not identified for the spiral nematode values in soil. In February, the highest spiral nematode value in soil was 283.33/100 g for the sixth application. This was followed by the second application. The lowest value was 80/100 g identified for the fifth application. Plants with nematode medication administered were identified to have higher nematode values in February. This situation may be due to the increase in root volume for the plants with nematode medication administered and hence more nematode spread. For plants with less root volume or where roots rotted, fewer nematodes were identified. When the spiral nematode values are investigated in soil for September, the highest value was 113.33/100 g for the first application (Novatec). This was followed by 106.66/100 g for the fifth application. The lowest value was 13.33/100 g for the second (Novatec + ethoprophos) and fourth applications. For root-knot nematode values in soil, the highest value of 83.33/100 g was obtained with the first application in February. This was followed with 46.66/100 g for the fourth application. The lowest value was 20/100 g for the second application (Novatec + ethoprophos). In September, statistically significant differences were not identified for the root-knot nematode values in soil, with highest value of 40/100 g for the fourth application. This was followed by the fifth application (Novatec + AKC) with a value of 26.66/100 g. Root-knot nematodes were not encountered in soil for the first, second and third applications. Chitamba et al. (2013) identified the root-knot nematode values as 1675/100 g, with spiral nematode values of 469/100 g in soil of banana plants. Özarslandan et al. (2020) applied five different nematicides to banana plants in four different greenhouses, and identified the nematode values in roots and soil in two different periods. The root-knot nematode values in soil were 0–2970/100 g, while the spiral nematode values in soil were 0–12,034/100 g. When the spiral and root-knot nematode values in soil during the 2018–2019 growing period are compared with previous studies, the values in the first period were higher than the values identified by Chitamba et al. (2013). Values were identified to be in the range of values obtained by Özarslandan et al. (2020).

Spiral Nematode (*Helicotylenchus multicinctus*) and Root-Knot Nematode (*Meloidogyne incognita*) in Roots During 2019–2020 (100 g)

The spiral and root-knot nematode values identified in the roots according to month in the 2019–2020 growing season are given in Table 11. The values were identified to be statistically insignificant between the applications. Though insignificant, the highest spiral nematode value in roots from February of 233.33/100 g was obtained from the second application. The lowest value of 20/100 g was identified for the third application. In September, the highest spiral nematode value was 1466.66/100 g for the fourth application. The lowest value was 33.33/100 g from the sixth application. In February, the highest root-knot nematode value was 86.66/100 g obtained from the third application, while the lowest value was 6.66/100 g from plants in the first application. In September, the root-knot nematode values were highest at 100/100 g for the third application, while values were lowest at 6.66/100 g for the second and sixth applications. The results of the statistical analysis observed large differences between repetitions. This situation shows the density of nematodes on roots and in soil in some regions, while certain regions had lower density. As a result, large differences were present between the samples and the large differences in statistical analyses were due to this situation. When the root-knot and spiral nematode values for the 2019–2020 period are compared with other studies, values were much higher in the study by Chitamba et al. (2013). The results were in a similar range to the values obtained by Özarslandan et al. (2020). Values obtained by Aguirre et al. (2016) were identified to be higher than the values in this study. The effects of the different applications on the root-knot and spiral nematode values from the roots in the 2018–2019 and 2019–2020 growing seasons are given in Fig. 3.

Table 11 Spiral nematode (*Helicotylenchus multicinctus*) and root-knot nematode (*Meloidogyne incognita*) in roots during 2019–2020 growing season (100 g)

Application No.	February *Helicotylenchus multicinctus*	September *Helicotylenchus multicinctus*	February *Meloidogyne incognita*	September *Meloidogyne incognita*
1	106.66 ± 58.11	1186.66 ± 909.30	6.66 ± 6.66	13.33 ± 13.33
2	233.33 ± 120.18	106.66 ± 58.11	13.33 ± 13.33	6.66 ± 6.66
3	20 ± 11.54	193.33 ± 103.49	86.66 ± 46.66	100 ± 57.73
4	146.66 ± 86.66	1466.66 ± 819.21	26.66 ± 26.66	40 ± 30.55
5	160 ± 87.17	733.33 ± 176.38	20 ± 20	33.33 ± 24.03
6	80 ± 40	33.33 ± 33.33	20 ± 11.54	6.66 ± 6.66
$D_{5\%}$	NS	NS	NS	NS

NS not significant

When results obtained from both growing seasons are compared (Fig. 3), the plants administered nematode medication and farm fertilizer were observed to have much reduced nematode density in September. The highest values for the 2019–2020 season were observed to have maximum values that were reduced compared to the previous year. Sequential regular application of nematode medications and farm fertilizer over 2 years significantly reduced nematode density.

Spiral Nematode (*Helicotylenchus multicinctus*) and Root-Knot Nematode (*Meloidogyne incognita*) in Soil During 2019–2020

The spiral nematode (*Helicotylenchus multicinctus*) and root-knot nematode (*Meloidogyne incognita*) values identified in soil according to month in the 2019–2020 growing season are given in Table 12. When the table is investigated, differences in statistical terms were not identified between the applications. In soil in February, the highest spiral nematode value of 186.66/100 g was obtained from the second application. The lowest value of 86.66/100 g was identified for the sixth application. In September, the highest value among spiral nematode values was 300/100 g

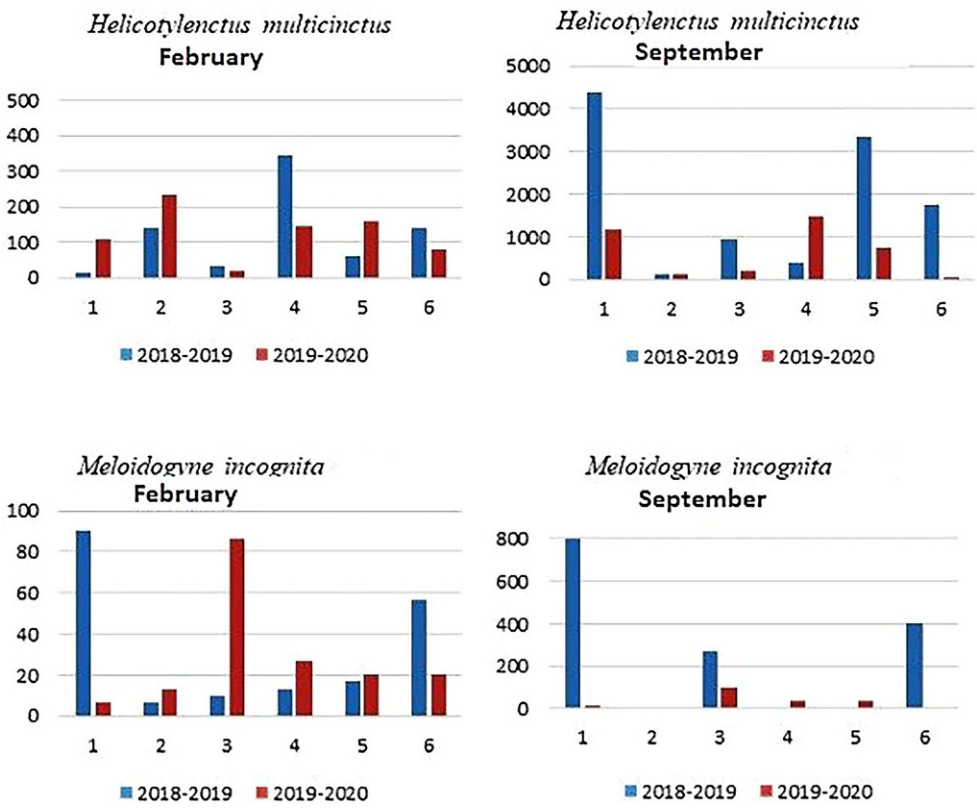


Fig. 3 Effects on *Helicotylenchus multicinctus* and *Meloidogyne incognita* in roots during the 2018–2019 and 2019–2020 growing seasons

Table 12 Spiral nematode (*Helicotylenchus multicinctus*) and root-knot nematode (*Meloidogyne incognita*) in soil during 2019–2020

Application No.	February *Helicotylenchus multicinctus*	September *Helicotylenchus multicinctus*	February *Meloidogyne incognita*	September *Meloidogyne incognita*
1	160 ± 34.64	153.33 ± 29.05 bc	46.66 ± 24.03	13.33
2	186.66 ± 131.31	26.66 ± 13.33 d	53.33 ± 17.63	0
3	120 ± 69.28	46.66 ± 37.11 cd	40 ± 30.55	13.33 ± 13.33
4	146.66 ± 86.66	300 ± 57.73 a	26.66 ± 17.63	26.66 ± 13.33
5	153.33 ± 63.59	233.33 ± 33.33 ab	60 ± 11.54	33.33 ± 6.66
6	86.66 ± 52.06	13.33 ± 13.33 d	26.66 ± 6.66	6.66 ± 6.66
$D_{5\%}$	NS	113.25	NS	NS

NS not significant

for the fourth application. The lowest value was 13.33/100 g from the sixth application. In February, the highest root-knot nematode value in soil was 60/100 g obtained from the fifth application. The lowest value was 26.66/100 g from plants in the fourth and sixth applications. In September, root-knot nematodes were not observed in soil from the second application. The highest root-knot nematode value was 26.66/100 g obtained with the fourth application. When the root-knot and spiral nematode values for the 2019–2020 period in soil are compared with other studies, values were higher in the study by Chitamba et al. (2013), and results were in the range of values obtained by Özarslandan et al. (2020). Differences between the studies may be due to different weather conditions (especially different temperature values), and different fertilizing programs. Apart from these, natural enemies found in soil are very effective on nematode density. The effects of the different applications on the root-knot and spiral nematode values in soil from the 2018–2019 and 2019–2020 growing seasons are given in Fig. 4.

When the soil nematode values in the first and second growing seasons are compared, the highest root-knot nematode values in the second period were identified to be lower than the highest values in the first period. The low-

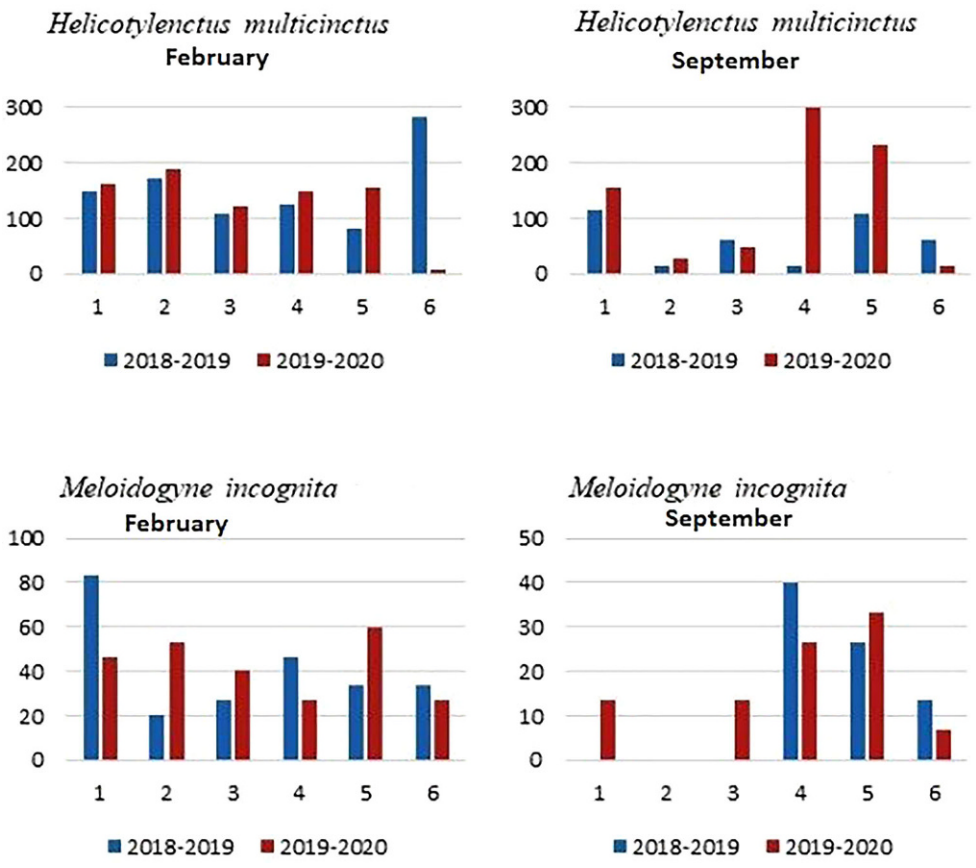


Fig. 4 Effects on *Helicotylenchus multicinctus* and *Meloidogyne incognita* in soil during the 2018–2019 and 2019–2020 growing seasons

est values in the first period were identified in soil from the second application, while the lowest nematode density in the second period was identified for soil from the sixth application.

Conclusion

This study used single, double and triple combinations of different fertilizer applications to examine the effect on fruit yield and quality and nitrite and nitrate accumulation for the 'Azman' banana clone grown under cover and produced the following results in two different periods. In the first period, the highest results for finger weight, finger diameter, finger length and bunch weight were obtained from plants in the sixth application (Novatec + Ethoprophos + farm fertilizer).

In the first period, the highest number of fingers was obtained from plants in the third application. The highest values for nitrate and nitrite contents were obtained from plants in the first application (Novatec), while the lowest values were obtained from plants in the third application (Novatec + farm fertilizer). In the second period, the highest results for finger number, finger weight, finger diameter, finger length and bunch weight were obtained from plants in the sixth application (Novatec + ethoprophos + farm fertilizer). The highest value for nitrite content was obtained from plants in the second application (Novatec + ethoprophos), while the lowest values were obtained from plants in the third application (Novatec + farm fertilizer). The highest values for nitrate content was obtained from the fourth application (Novatec + banana waste) with lowest values from the third application (Novatec + farm fertilizer).

When the results obtained are assessed, Mocap and farm fertilizer positively affected root development of plants and increased root volume. With the increase in root volume, intake of nutrients increased and best results were obtained in terms of yield. In addition to providing best results in terms of yield, the plants with earliest harvest were those with farm fertilizer and Mocap applied. The combination of Novatec + Mocap + farm fertilizer provided good results in terms of yield for cultivators, and it is recommended to try different doses of this combination. Additionally, the Novatec + farm fertilizer application providing the lowest levels of residue on fruit, which is very important for human health, is also recommended.

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Author Contribution *Nermin Kalay Sarı*: Writing-original draft, Formal analysis, Conceptualization; *Nesibe Ebru Kafkas*: Methodology, Supervision, Data Curation; *İlbilge Oğuz*: Writing-review & editing; *Adem Özarslandan*: Resources, Validation.

Conflict of interest N. Kalay Sarı, N.E. Kafkas, İ. Oğuz and A. Özarslandan declare that they have no competing interests.

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