Effects of organic stimulants and fertilization with Potassium Nitrate on the resistance to Black Sigatoka in Banano Ecuador

OBJECTIVES:

GENERAL OBJECTIVE

To establish the impact of using three organic stimulants and two fertilization programs based on Potassium Nitrate on the development, production and resistance to Black Sigatoka with relation to the number of leaves per plant in banana cultivation.

SPECIFIC OBJECTIVES

To determine the treatment that shows the lower occurrence of Black Sigatoka with relation to the number of leaves per plant.
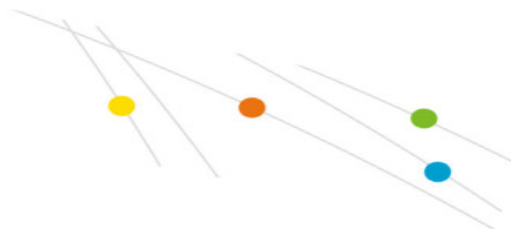
To identify the fertilization program that may significantly influence the bunch weight.

To establish the stimulant that allows obtaining a larger number of exportable fruit boxes per harvested bunch (ratio).

DESCRIPTION OF THE TRIAL

Location of the trial

This investigation was carried out between the months of January and August 2017, in the Yamile farm fields located 27 km from the Quevedo-Santo Domingo de los Tsáchilas route, Los Ríos province, coordinates 0° 50' 36.4" S 79° 29' 23.9" W, at 100 m.a.s.l.

Climate characteristics

The climate in the research area is tropical-monsoon, with maximum temperatures of 29°C and minimum of 23°C, and an annual average of 24.3°C, an annual rainfall of 1998 mm, evaporation of 1.67 mm/day, relative humidity of 84% and heliophany of approximately 840 hours.

Trial design and statistical analysis

To implement the trial, a completely random design was proposed that included 6 treatments in three repetitions. Data analysis was carried out by means of ANOVA and the comparison of averages was done through the Tukey test (p≤ 0,05), with the help of the Infostat statistical package.

The outline of the variance analysis is shown in Table 1:

Table 1. ANOVA outline used in the research

Variance source	Degrees of liberty
Treatments	5
Error	12
Total	17

The experimental unit consisted of banana suckers of recently flowering adult plants that measured between 1.30 m and 1.80 m, which were marked at the time of
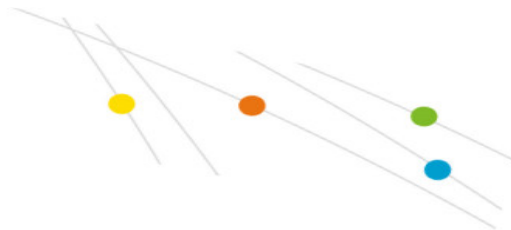
implementing the trial. In this way, uniform plants were available to observe and monitor the evolution of the bunch. The experimental field consisted of 7 plants in this condition distributed and selected in an area of approximately 30 m x 30 m that constituted the research field. Each treatment was applied to the whole field and the evolution of the plant´s response was obtained from the marked suckers.

Research instruments

Treatments under study	
T1	Potassium Nitrate at 150 %
T2	Potassium Nitrate at 100 %
T3	Kelpak
T4	Agrostemin
T5	NBO
T6	Control

The type and characterization of the fertilizers and biostimulants used in the trial are shown in Table 2:

Table 2.
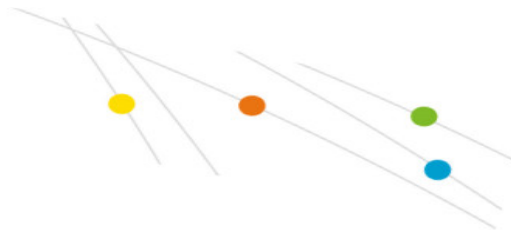
Type and characterization of the fertilizers and biostimulants used.

| Type | Product | | Dose | Commercial company |
	Commercial name	Chemical name		
Biostimulant	NBO Humidified rooting medium		1 l/ 100 l of water	Lombricorp
Biostimulant	Kelpak	Ecklonia maxima	1 to 2 l/ha	Daymsa
Biostimulant	Agrostemin	Ascophyllum nodosum	Drench (200 to 600 gr/ha)	QSI (Química Suiza Industrial)

The applications of the evaluated products were carried out following the recommendations of the product's distributor either as "drench" or as foliar application with a motorized pump.

Specifications of the trial	
Number of treatments	6
Number of repetitions	3
Number of plants per experimental unit	7
Number of plants per repetition	42
Total number of plants at the trial	252

DATOS REGISTRADOS Y METODOLOGÍA DE EVALUACIÓN.

RECORDED DATA AND EVALUATION METHODOLOGY

Number of leaves at flowering
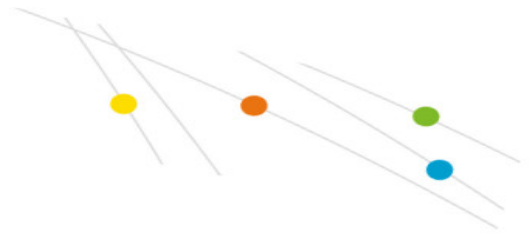
The number of leaves per plant in each treatment was recorded at the moment of flowering, and the average was subsequently determined.

Number of leaves at harvest

The number of leaves per plant at harvest was counted, to subsequently calculate the average.

Number of total leaves

The total number of leaves grown by the plant were recorded, from the sucker phase to the harvest, by plant in each experimental unit, to subsequently calculate the average.

Height of the pseudostem (m)

The plants were measured with a flexometer, from soil level to the intersection of the new, completely opened leaf. This was done on the 31st week of cultivation.

Pseudostem girth

To measure the pseudostem girth a reading was carried out at 30 cm from soil level up, using a metric measuring tape. This evaluation was done at the end of the plants' 31st week of age. Finally, the average was calculated and expressed in centimeters.

Number of hands per bunch

In each harvested bunch, the number of hands that made bunch up was counted, to subsequently calculate the average.

Bunch weight
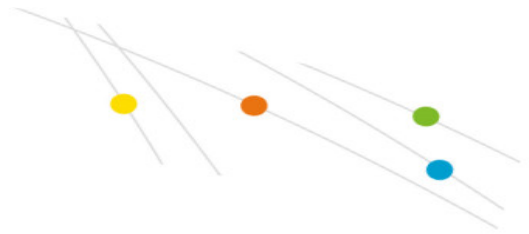
Once the bunch was harvested, the total weight (rachis and hands) was recorded in kilograms, this for the seven plants in the net field for each treatment.

Number of cases per bunch

The number of cases per bunch was established considering only the exportable fruit obtained from each bunch, for each one of the plants under study.

RESULTS

Number of leaves at flowering

The average number of leaves per plant at flowering are shown in Table 3. According to the variance analysis, the treatments presented a statistic significance at level 0.05, with a variation rate of 3.7%. After carrying out the Tukey test the treatment with Potassium Nitrate at 150% showed the higher number of leaves at flowering with 15.4, on an equal statistical level with the other treatments that recorded number of leaves between 14.2 and 15.3, except for the control, which showed the smaller average with 13.8 leaves per flowering.

Table 3. Average of number of leaves at flowering in the investigation about the effects of stimulants and Potassium Nitrate on the resistance to Black Sigatoka and
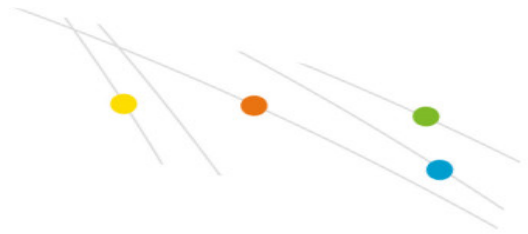
production in banana cultivation, in the Buena Fe area, 2017.

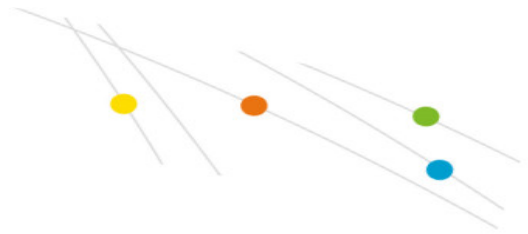| Stimulants and Potassium Nitrate	Number of leaves at flowering*	
T1: Potassium Nitrate at 150%	15.4	a
T2: Potassium Nitrate at 100%	15.3	a
T3: Kelpak	14.1	ab
T4: Agrostemin	15.0	ab
T5: NBO	14.2	ab
T6: Control	13.8	b
Average	14.6	
Variation rate (%)	3.7	

Averages with the same letter do not differ statistically according to the Tukey test at 95% probability.

Number of leaves at harvest

Table 4 shows the average number of leaves at harvest noticed with the treatments under study. The variance analysis showed at statistical significance at level 0.05 for the treatments under study, with a variation rate of 5.2%.

Fertilization with Potassium Nitrate at 100% and Agrostemin showed the highest number of leaves at harvest, with 7.5 each.

Table 4. Average number of leaves at harvest in the investigation about the effects of stimulants and Potassium Nitrate on the resistance to Black Sigatoka and

production in banana cultivation, in the Buena Fe area, 2017.

Stimulants and Potassium Nitrate	Number of leaves at harvest*	
T1: Potassium Nitrate at 150%	7.3	ab
T2: Potassium Nitrate at 100%	7.5	a
T3: Kelpak	6.5	abc
T4: Agrostemin	7.5	a
T5: NBO	7.5	abc
T6: Control	6.1	c
Average	6.9	
Variation rate (%)	5.2	

* Averages with the same letter do not differ statistically according to the Tukey test at 95% probability.

Number of total leaves

Table 5 shows the average number of total leaves. The variance analysis established that the treatments reached a statistical significance at level 0.05, with a variation rate of 3.3%.

Fertilization with Potassium Nitrate at 100% and Agrostemin recorded the highest number of leaves at harvest with 30.2 leaves each, without statistically differing from the other treatments, with averages from 28.3 to 29.2.

Table 5. Average of total number of leaves per plant in the investigation about the effects of stimulants and Potassium Nitrate on the resistance to Black Sigatoka and production in banana cultivation, in the Buena Fe area,
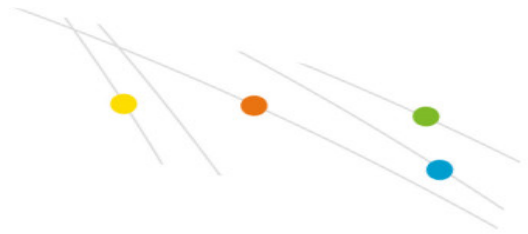
2017.

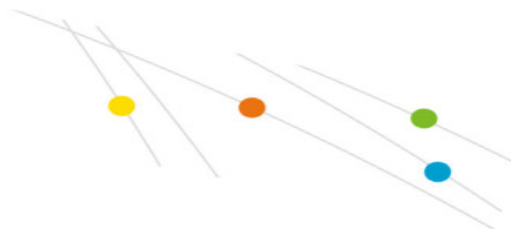| Stimulants and Potassium Nitrate	Total number of leaves*	
T1: Potassium Nitrate at 150%	29.2	ab
T2: Potassium Nitrate at 100%	30.3	a
T3: Kelpak	28.3	ab
T4: Agrostemin	30.2	a
T5: NBO	28.7	ab
T6: Control	27.1	b
Average	29.0	
Variation rate (%)	3.3	

* Averages with the same letter do not differ statistically according to the Tukey test at 95% probability.

Pseudostem height

The averages of plant height are shown in Table 6. The variance analysis did not register any statistical significance for the treatments under study, with a variation rate of 1.09%.

The greatest plant height was recorded with the Potassium Nitrate at 100% treatment with 4.27 m, statistically equal to the other treatments, which showed values between 4.19 and 4.26 each.

Table 6. Averages of plant height in the investigation about the effects of stimulants and Potassium Nitrate on the resistance to Black Sigatoka and production in banana

cultivation, in the Buena Fe area, 2017.

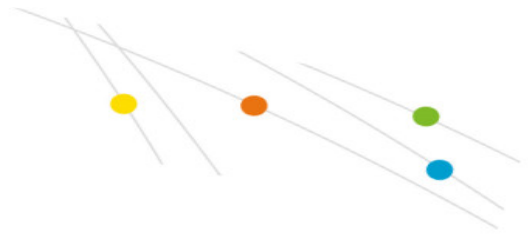| Stimulants and Potassium Nitrate	Plant height (m)*	
T1: Potassium Nitrate at 150%	4.16	a
T2: Potassium Nitrate at 100%	4.27	a
T3: Kelpak	4.26	a
T4: Agrostemin	4.26	a
T5: NBO	4.23	a
T6: Control	4.19	a
Average	4.23	
Variation rate (%)	1.09	

* Averages with the same letter do not differ statistically according to the Tukey test at 95% probability.

Pseudostem girth (cm)

The averages shown in Table 7 correspond to the pseudostem girth observed with the treatments under study. In accordance with the variance analysis, the treatments did not reach a statistical significance, the respective variation rate being 2.6%

The greatest pseudostem girth of 26.7 cm was obtained with Potassium Nitrate at 100%, statistically equal to the other treatments, which registered averages between 25.1 and 26.4 cm.

Table 7. Averages of the pseudostem girth (cm) in the investigation about the effects of stimulants and Potassium Nitrate on the resistance to Black Sigatoka and

production in banana cultivation, in the Buena Fe area, 2017.

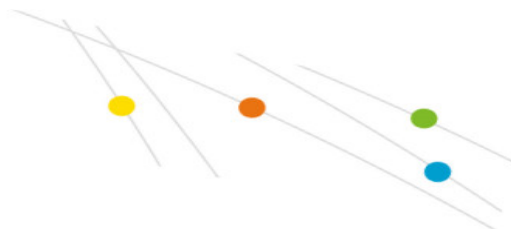| Stimulants and Potassium Nitrate	Pseudostem girth (cm)*	
T1: Potassium Nitrate at 150%	25.8	a
T2: Potassium Nitrate at 100%	26.7	a
T3: Kelpak	26.4	a
T4: Agrostemin	26.4	a
T5: NBO	26.4	a
T6: Control	25.1	a
Average	26.1	
Variation rate (%)	2.6	

* Averages with the same letter do not differ statistically according to the Tukey test at 95% probability.

Number of hands per bunch

Table 8 shows the averages of the number of hands per bunch of the treatments under study. The variance analysis did not show any statistical significance for the treatments, indicating a variance rate of 6.4%.

The largest number of hands, 8.5, was obtained when fertilization with Potassium Nitrate at 100% was applied, statistically equal to the treatments with Potassium Nitrate at 150%, Agrostemin and Kelpak, which produced 7.2 and 8.2 hands per bunch, respectively.

Table 8. Averages for the number of hands per bunch in the investigation about the effects of stimulants and Potassium Nitrate on the resistance to Black Sigatoka and

production in banana cultivation, in the Buena Fe area, 2017.

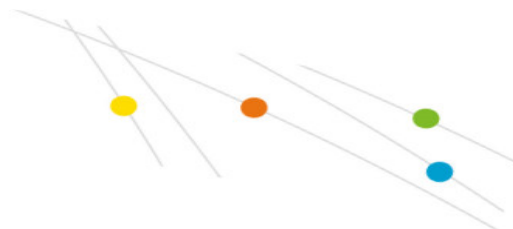| Stimulants and Potassium Nitrate	Number of hands per bunch*	
T1: Potassium Nitrate at 150%	8.0	ab
T2: Potassium Nitrate at 100%	8.5	a
T3: Kelpak	7.2	abc
T4: Agrostemin	8.2	ab
T5: NBO	7.0	bc
T6: Control	6.6	c
Average	7.6	
Variation rate (%)	6.4	

* Averages with the same letter do not differ statistically according to the Tukey test at 95% probability.

Bunch weight (kg)

Table 9 shows the averages of bunch weight (kg). According to the variance analysis, the treatments presented statistical significance at 0.05 level. The variation rate was 3.5%.

Bunches with an increased weight at 32.8 kg were obtained when fertilization with Potassium Nitrate at 100% was applied, showing statistic equality with Potassium Nitrate at 150% and Agrostemin with values of 32.2 and 31.2 kg, respectively. And all those mentioned, statistically higher than the other treatments under study.

Table 9. Averages for bunch weight (kg) in the investigation about the effects of stimulants and Potassium Nitrate on the resistance to Black Sigatoka and production

in banana cultivation, in the Buena Fe area, 2017.

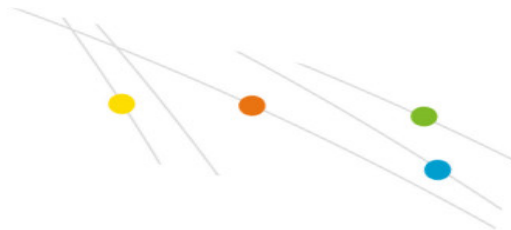| Stimulants and Potassium Nitrate	Bunch weight (kg)*	
T1: Potassium Nitrate at 150%	32.2	ab
T2: Potassium Nitrate at 100%	32.8	ab
T3: Kelpak	29.4	bcd
T4: Agrostemin	31.2	abc
T5: NBO	29.0	cd
T6: Control	27.3	d
Average	30.3	
Variation rate (%)	3.5	

* Averages with the same letter do not differ statistically according to the Tukey test at 95% probability.

Number of boxes per bunch (ratio).

The averages corresponding to the number of boxes obtained per harvested bunch are shown in Table 10. The variance analysis indicated a high statistical significance for the treatments under study, with a variation rate of 5.9%.

The highest number of boxes per bunch corresponded to the treatments with Potassium Nitrate at 100%, 150% and Agrostemin, with an average of 1.6 boxes per bunch, statistically higher to the other treatments, which recorded values between 1.2 and 1.3 boxes per bunch.

Table 10. Averages for the number of boxes per bunch in the investigation about the effects of stimulants and Potassium Nitrate on the resistance to Black Sigatoka and

production in banana cultivation, in the Buena Fe area, 2017.

Stimulants and Potassium Nitrate	Number of boxes Per bunch *	
T1: Potassium Nitrate at 150%	1.6	a
T2: Potassium Nitrate at 100%	1.6	a
T3: Kelpak	1.3	b
T4: Agrostemin	1.6	a
T5: NBO	1.3	b
T6: Control	1.2	b
Average	1.4	
Variation rate (%)	5.9	

* Averages with the same letter do not differ statistically according to the Tukey test at 95% probability.

ECONOMIC ANALYSIS OF THE POTASSIUM NITRATE 100% TREATMENT VS CONTROL (FARM).

The details of the total quantity of fertilizer applied in the treatment with Potassium Nitrate at 100% and the control treatment are set out in Table 1.

Table 1. Nutritional contribution to the trial.

Element	Control (kg/ha)	Qrop® mix 100% (kg/ha)	Qrop® mix 150% (kg/ha)
N	351	351	544
P_2O_5	0	0	0
K_2O	576	574	842

Table 2.
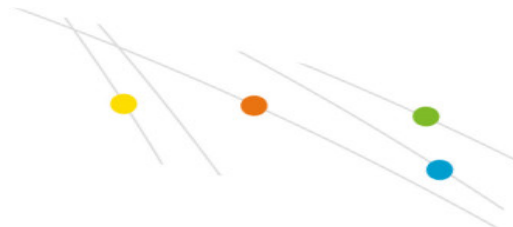
Description of the control treatment (customer's program).

CONTROL TREATMENT (FARM)						Nutritional contribution kg/ha/year							
MONTHS	Fertilizers	Bags/ aplic	Cycles	Bags/ year	Amount kg/ha	N	P_2O_5	K_2O	Cl	S	MgO	CaO	Zn
JAN, FEB, MAR, APR, MAY, JUN, JUL, AUG	Ammonium Nitrate	0,75	17	12,75	637,5	217							
	Nitromag	0,75	17	12,75	637,5	134					48	70	
	MOP	1,13	17	19,21	960,5			576	432				
	Magnesium Sulfate Gr	0,3	17	5,1	255					51	64		
Total						351		576	432	51	112	70	
Nutritional contribution/ ha						351		576	432	51	112	70	

COSTs Fertilizers	Bags	$/bag	$/ha
Ammonium Nitrate	12,75	16	204
Nitromag	12,75	24	306
MOP	19,21	16	307
Magnesium Sulfate Gr	5,1	14	71
			889

Table 4. Description of the treatment with Potassium Nitrate at 100%.

TREATMENT WITH POTASSIUM NITRATE AT 100%						Nutritional contribution kg/ha/year							
MONTHS	Fertilizers	Bags/ aplic	Cycles	Bags/ year	Amount kg/ha	N	P_2O_5	K_2O	Cl	S	MgO	CaO	Zn
JAN, FEB, MAR, APR, MAY, JUN, JUL, AUG	Ammonium Nitrate	0,64	17	10,88	544	185							
	Potassium Nitrate	1,5	17	25,5	1275	166		574					
	Magnesium Sulfate Gr	0,4	17	6,8	340					68	85		
Total						351		574		68	85		
Nutritional contribution/ ha						351		574	0	68	85	0	

COSTs Fertilizers	Bags	$/bag	$/ha
Ammonium Nitrate	10,88	16	174
Potassium Nitrate	25,5	44	1122
Magnesium Sulfate Gr	6,8	14	95
			1391

Table 5. Profit analysis of the Potassium Nitrate 100% vs Control trial.

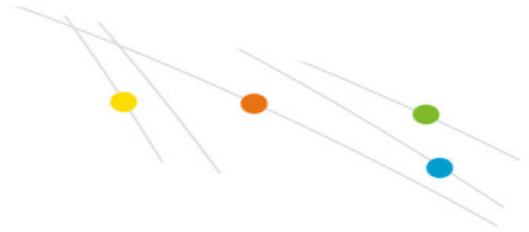| Control		Parameters	NP at 100%	
889	$/ha	Cost of Fertilizers	1391	$/ha
13050	$/ha	Total Costs	13552	$/ha
6,8	%	Cost of Fertilizers/ Total Costs	10,3	%
6,2	$/mt	Obtained Price	6,2	$/mt
2520	mt/ha	Yield	3360	mt/ha
15624	$/ha	Gross Income	20832	$/ha
2574	$/ha	Gross Margin	7280	$/ha
16,5	%		34,9	%
		Additional Gross Profit	4706	$
			18,5	%

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

The treatment with Potassium Nitrate at 150% produced more leaves at flowering with 15.4. The plants reached the highest number of leaves at harvest, with an average of 7.5 leaves each with the treatments with Potassium Nitrate at 100% and Agrostemin, confirming a decrease in foliage loss due to the attack of Black Sigatoka.

The treatment with Potassium Nitrate at 100% produced a higher number of total

leaves with 30.3 leaves per plant, exceeding the absolute control by 3.2 leaves.

The treatment with Potassium Nitrate at 100% produced a greater increase in height and girth of the pseudostem in such a way that it showed higher and thicker plants at flowering with a height of 4.27 m and 26.7 cm in girth.

When applying the treatment with Potassium Nitrate at 100%, the bunches showed a higher weight with 32.8 kg, with an average of 8 hands per bunch, reflecting a productivity of 1.6 boxes per bunch, the latter value being equal to those obtained with the Potassium Nitrate at 150% and Agrostemin treatments.


RECOMMENDATIONS

Investigate different application doses of the stimulants under study in order to identify the effect on the growth and production of banana plants.

Evaluate slow release fertilizers to establish an efficient fertilization plan for the banana crop.

Promote the use of stimulants for the crops, as they have proven to have several benefits in the development and production of plants.

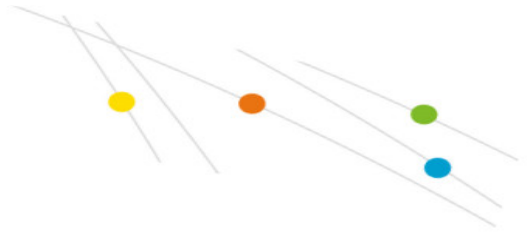Measure the foliar area in other similar trials as well as the incidence of the Black Sigatoka disease.
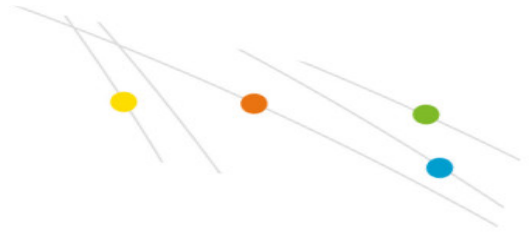
ANEXOS
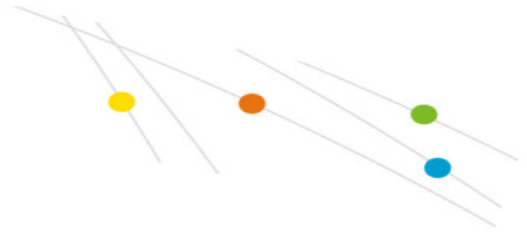
Annex 1. Sampling for soil analysis

Annex 2. Fencing
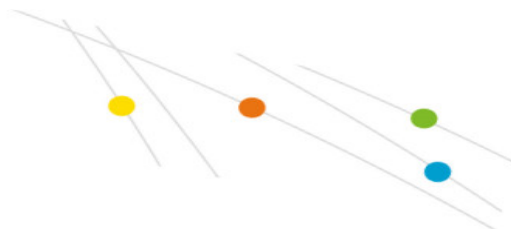
Annex 3. Identification of plants for the trial

Annex 4. Identification of number of leaves

Annex 5. Preparation of fertilization mix

Annex 6. Bunches with Potassium Nitrate 100% treatment

Anexo 7. Weight of exportable fruit per bunch