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Research Article

Use of Nano Technology (Nano Gro) To Boost Productivity and Increase Pest Resistance in Okra Crop for Export in Southern Honduras

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The present study reports the effect of the nanotechnology molecule "Nano Gro" on a number of agronomical variables of okra, *Abelmoschusesculentus,* as well as its effect on leaf miner, white fly, *Bemisiatabaci,* and *Spodoptera* larvae attacking the crop. Most initial data was taken in a trial used for the registration of Nano Gro as an agricultural amendment in Honduras, carried in a plot worked by Juan Benito Guevara, a local okra producer farming in Las Bazas, very near the city of Choluteca, next to the Choluteca river, in Southern Honduras. However, other important data was taken on plots from different local okra companies and producers in the Choluteca area.

The stimulant Nano Gro is a mixture of sulfates and elements such as Fe, Co, Al, Mg, Mn, Ni and Ag, produced at a concentration of 10^{-9}mol, available in the form of an oligosacharid pellet. It has OMRI certification and can be used in organic and regular agriculture. According to the Honduran distributor (Núcleo Agro), Nano Gro stimulates the plant´s natural resistance to abiotic stress, which in turn makes the plant produce growth hormones like auxins, gibberellines and cytokinines. This hormone productionmakes the use of nutrients and water more efficient, resulting in greater plant resistance, greater performance and greater quality of fruit harvested.

Nano Gro had never been used in Southern Honduras, and the distributor recommended seed treatment and foliar applications every 21 days in crops with continuous harvest like okra, peppers, tomatoes, etc. The hypothesis for the present study was that Nano Gro would increase productivity and quality of treated okra, and that pests and diseases would not be as damaging in Nano Gro treated plants.

Figure 1

Figure 2

Figures 1 & 2: Overall view of the first trial block, with older planting next to it; and detail of immediate neighborhood of the first trial planting row, with an older okra crop and weeds next to it.

For seed treatment the recommendation of the distributor was to use any water volume between 0.5 and 5 liters per Nano Gro pellet, and to immerse seeds for 5 to 10 minutes in the Nano Gro solution. For foliar treatments the recommended rate was 1 pellet in 10 liters of water. Spraying had to be at a fast walking rate and with low water discharge because only a few droplets per plant were enough to produce the chemical signal sent to the plant by Nano Gro. Ideally, the spraying should target growing tips.

Mr. Guevara´s plot was planted by direct sowing, placing 1 or 2 seeds per planting hole, with a distance of 20 cm between plants and one planting row per bed. The sowing date was February 28th, 2020. The Nano Gro treatment had seed immersion for 5 minutes in a solution of one pellet of Nano Gro per 5 liters of water. The control treatment had no Nano Gro seed treatment. In addition, the entire trial had soil disinfection using Aquacitrox disinfectant at a rate of 5 cc per liter of water, applying 50 cc per planting hole, 3 days before planting. This treatment was tested for nematode and *Fusarium* control because previous plantings had suffered very serious plant damage and were terminated one month after their first harvest.

The field used for the trial had been previously planted with okra, had sandy soils and was irrigated with surface water from the Choluteca River. Under these crop conditions and with lack of crop rotation, premature plant death by soil fungi, such as *Fusarium* and *Rhizoctonia*, was considered the most limiting factor due to nematode damage that allowed these soil infecting fungi to enter the roots **(Figures 3 and 4).**

Figure 3

Figure 4

Figures 3 & 4: Nano Gro untreated okra plants planted in soil without Aquacitrox treatment against nematodes and fungi, and root of young plant of the neighboring okra plot with only 2 harvests, discarded due to severe damage by nematodes and serious attack by *Fusarium* and *Rhizoctonia*.

Seedling germination and survival data were not taken because there was considerable plant mortality due to wind. The plastic cover was loose in some beds, planting holes were deep and in some cases they had stubble, and this caused elongation of the plant and rubbing of it against the plastic, causing mortality **(Figure 5)**. In addition, due to the quarantine imposed in Choluteca by Covid 19, visits to the trial were occasional and data collection was initiated when evident differences between treatments were observed for the first time.

On the other hand, the whitefly population in the trial was extremely high due to the immediate neighborhood (older okra plantations, see **Figures 1 and 2**), to the amount of weeds present in the adjoining plot that also served as a white fly reproduction site, and to the amount of weeds within the Nano Gro plots **(see Figure 6)**. The population was so high **(see Figures 6,and 7)** that three insecticide applications were made to reduce the population and no white fly sampling was done until the population lowered considerably.

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Figure 5

Figure 6

Figures 5 and 6: Planting holes lost due to depth of the hole and to the presence of abundant stubble in them; and presence of viroticmalvaceous weeds between beds within the trials (circled in red), which contributed to the reproduction of whiteflies and to the infection of okra by virus.

Table No. 1 summarizes what was found during the first sampling, on March 25, 2020, 26 days after crop planting. The trial had two blocks with 2 replicates per treatment per block. Each replicate was 5 beds wide and 20 m long and had one meter separation between them. Data was taken from 10 plants per replicate, thus numbers presented correspond to 40 total observations per treatment.

Variable	Nano Gro	Control	Probability t- Test*
Plantheight (cm)	15.95 $\pm$ 1.85 A	14.000 + 1.92 B	P = 5.04 E-5
No. of leaves	18.23 + 4.42 ns	16.78 + 3.37 ns	P = 0.15
No. of flowerbuds	5.35 + 1.17 A	4.10 + 1.48 B	P = 0.0003
No.secondarybranches	5.00 + 1.48 ns	4.93 + 1.07 ns	P = 0.77
* P < 0.05 is statistically significant. P expressed with E - 5 is equal to 0.00000.			

Table 1: Average plant height in centimeters, average number of leaves, flower buds formed and number of secondary branches per okra plant treated with Nano Gro only to the seed and its respective control, 21 days after germination (n = 40). Las Bazas, Choluteca, March 25th, 2020.

Plants treated with Nano Gro (seed treatment only, for this sample) were taller, had more leaves, more flower buds, and a slightly higher number of secondary branches per plant **(Table 1)**, although not all these differences were statistically significant. On average, Nano Gro treated plants were 1.95 cm taller than control plants, and this difference was highly significant (P = 0.00005). In addition, Nano Gro treated plants had on average 1.25 more flower buds than control plants with a P = 0.0003. Although the data do not reflect bud size, larger and well-formed buds were commonly observed on the main stem and on secondary branches in the Nano Gro treatment and smaller buds were always observed on secondary branches of control plants. The number of secondary branches of Nano Gro treated plants was slightly higher than that of untreated plants, but these differences were not statistically significant.

One day after the first sampling, the first foliar application of Nano Gro was made. A motor-driven backpack pump sprayer was used and one pellet of Nano Gro was diluted in 10 liters of water for the application on the 2 blocks of the trial. From then on, Nano Gro was applied to the plants every 21 days using the same rate and the same amount of water.

Figure 7

Figure 8

Figures 7 and 8: High density of white flies in okra leaves thanks to availability of numerous alternate hosts in near by abandoned crop, and actual color and size of a pellet of Nano Gro.

Variable	Nano Gro	Control	P of t- Test*
Plantheight (cm)	33.73 + 5.06 A	30.05 + 4.52 B	P = 0.001
No. largeleaves	6.53 + 1.04 n.s.	6.23 + 0.83 n.s.	P = 0.10
No. buds in main stem	12.08 + 1.64 A	10.83 + 1.69 B	P = 0.0005
No. secondarybranches	4.65 + 1.10 n.s.	4.38 + 1.25 n.s.	P = 0.25
No. budsonbranches	13.45 + 4.45 A	8.68 + 4.50 B	P = 8.8 E – 07
No. open flowers	0.23 + 0.42 n.s.	0.15 + 0.36 n.s	P = 0.41
No. fruitsformed	0.18 + 0.38 A	0.00 + 0.00 B	P = 0.006
No. leaves with leafminer damage	3.05 + 0.78 A	3.73 + 0.75 B	P = 0.0007
* P < 0.05 is statistically significant. P expressed with E - 5 is equal to 0.00000.			

Table No. 2._ Average plant height in centimeters, average number of large leaves, of buds formed on the main stem, of secondary branches, of buds formed on secondary branches, of flowers, of fruits, and of leaves damaged by leaf miner/plant in Nano Gro treated okra and control, 10 days after the first foliar application of Nano Gro. Las Bazas, Choluteca, April 3, 2020.

In this sampling, due to the disparity in plant age and size as a result of plant loss due to wind damage, ten of the largest plants in each plot of the trial were selected and marked for sampling. These plants were marked with an orange ribbon, so that from this date on, they would be used for data collection in subsequent samplings. In this way, the productive behavior of the selected plants was accurately known and it was possible to see, over time, whether the differences between treatments were persistent.

In all the variables evaluated, without exception, the Nano Gro treatment had better results than the control; there were significant differences between treatments in the following variables: plant height, average number of buds per plant on the main stem, number of buds per plant on secondary stems, number of fruits per plant and number of large leaves affected by leaf miner.

Figure 9

Figure 10

Figures No. 9 and 10: View of the first block of the trial after weeding between beds, and *Cleome viscosa,* host of root nematode, one of the several weeds hosts of nematodes in the area, one of the reasons why *Fusarium* and *Rhizoctonia*, infections were so common.

Figure 11

Figure 12

Figures 11 and 12: Okra plant with leaf minor damage on lower leaf plus numerous dead white flies on the silver plastic after insecticide application, and hundreds of *Bemisiatabaci* nymphs on a leaf of a Compositae weed of the immediate surroundings.

The plants, at the time of the second sampling, had already had 2 Nano Gro applications, 1 to the seed and 1 foliar application 22 days after germination. Nano Gro treated plants were on average 3.68 centimeters taller than control plants. This variable was highly significant with P = 0.001 **(Table 2)**. Nano Gro plots had more uniform plants compared to untreated replicates, as shown in figures 13 and 14. Additionally, the average number of buds formed on the main stem and on secondary branches was statistically higher in the Nano Gro treatment than in the control. The Nano Gro treatment had on average 1.25 and 4.77 more buds formed on the main stem and on secondary branches, respectively, than the control treatment. In summary, the Nano Gro treatment had on average 6.02 more buds formed per plant than the control at this early point in production.

Additionally, the vast majority of buds formed on secondary branches of Nano Gro treated plants were much larger than those of the control, i.e., the Nano Gro treatment exhibited a marked precocity in production compared to the control. This characteristic is also reflected in the fact that the Nano Gro treatment had, during this sampling, an average of 0.18 fruits already formed per plant, while the control had none. The difference in fruit formation between treatments was also highly significant (P = 0.006).

Figure 13

Figure 14

Figures 13 and 14: Nano Gro treatment with uniform and taller plants compared to the uneven and smaller control plants**.**

All the variables listed above correspond to agronomic characteristics of the plant; interestingly, the Nano Gro treatment also exhibited significant differences in pest damage. Table No. 2 shows highly significant differences in the number of large leaves affected by leaf miner, with the Nano Gro treatment having, on average, 0.68 leaves affected less than the control treatment, with P = 0.0007.

For leaf miner sampling, only large leaf miner-affected leaves were taken into account because of the total number of leaves affected, many of them were small and not comparable with the new and bigger upper leaves. Leaf miner affected leaves in Nano Gro treated plants had normally fewer mines than control plants but due to the large number of affected leaves, percent damage per leaf per treatment was not taken into account, even so, differences in leaf miner attack between treatments was highly significant (p = 0.0007).

The tendency of Nano Gro treated plants to be more uniform in size and productivity was also noted in several other okra trials around the Choluteca area, as can be seen on figures 15 and 16. A marked effect of tolerance of Nano Gro treated plants to nematodes was also consistent. The combination of soil disinfectant before planting, use of microbiological control agents like *Paecelomyces*, *Trichoderma*, etc and seed treatment with Nano Gro allowed the crop to be harvested for at least 4 months when irrigated with river water. Treated plants would only have some minor nematode infection on secondary roots while continuing to grow and produce for a long time.

Figure 15

Figure 16

Figure 17

Figures 15, 16 and 17: Okra untreated beds with uneven plant sizes and uniform, bigger Nano Gro treated plants. Nematode infection of secondary roots in Nano Gro treated plants 2 months old.

One day after the second sampling, Lepidoptera larvae were sampled. Larvae found were *Spodopteraexigua* and *S. sunia*, being *exigua* the most common species present. Because egg laying of *Spodoptera* genus is in masses, it is common to find consecutive planting holes with several affected plants, in contrast to single-laying species, which show damage in a scattered distribution. For this reason, instead of taking a number of plants per plot, the decision was made to observe 2 of the 3 central beds of the first block of plots, which had 2 replicates of each treatment. No more plots were taken for sampling because the incidence of Lepidoptera larvae was so high that it provided sufficient data for analysis. Data evaluated were: number of contiguous planting holes affected, number of plants affected in those holes, average number of leaves affected per plant and percentage damage of leaves affected by larvae.

Curiously, the number of observations in both treatments was the same, suggesting that both treatments had fairly similar adult *Spodoptera* egg laying. However, the number of observations of the percentage of leaf damage in the control was much higher than that of the Nano Gro treatment because data taken was per individual leaf, and the number of affected leaves in the control was much higher than that of the Nano Gro treatment. The Nano Gro treatment had a total of 41 observations of percentage of leaf damage while the control had 89 data of percentage of damage which corresponded to the total number of damaged leaves per treatment, that is, a little more than twice as many in the control. Table 3 summarizes the data corresponding to *Spodoptera* infestation and damage per treatment. In addition, the Nano Gro treatment showed a range of 1% to 20% damage per leaf, while the control had a wider damage range from 2 to 30%.

Figure 18 **Figure 19**

Figures 18 and 19: Large larva of *Spodopteraexigua* on okra shoot and large larva of *Spodopterasunia* causing damage on o kra leaf.

Variable	Nano Gro	Control	Probability t- Test*
No. plantingholesaffected	2.00 + 1.88 A	4.07 + 2.59 B	P = 0.03
No. damagedplants/span	2.43 + 2.14 A	6.50 + 5.95 B	P = 0.04
No. damagedleaves/span	10.36 + 11.22 A	27.00 + 23.06 B	P = 0.04
% leafdamage	6.05 + 4.26 A	8.80 + 6.82 B	P = 0.006
* P < 0.05 is statistically significant.			

Table No. 3: Number of consecutive okra planting holes affected by *Spodoptera* larvae, number of plants affected in those holes, total number of damaged leaves in affected plants and percent damage of affected leaves in those planting holes. Las Bazas, Choluteca, April 4, 2020.

The number of planting holes affected by *Spodoptera*, the number of contiguous plants damaged, the total number of leaves per plant damaged and the percent damage observed per leaf was always significantly smaller in Nano Gro treated plants than in control plants, and the differences were all statistically significant. The control treatment had twice the number of planting holes affected, had two and a half times de number of damaged plants, had 2.5 times more leaves damaged than the Nano Gro treated plants and had on average 2.75% more damage per affected leaf than the Nano Gro treated plants.

Differences in foliar damage caused by *Spodoptera* larvae were very obvious, as can be seen in figures 20 to 23. One thing fairly common in the trial during the *Spodoptera* larvae attack was to see one medium to large size larva surviving in Nano Gro treated plants causing very little damage and having little or no fecal material. Apparently few small larvae survived, in contrast with control plants were small larvae were present in large numbers and caused severe damage.

Figure 20

Figure 20: Control plants (black) with considerable worm damage in 5 contiguous planting holes. Each damaged plant has at least 3 affected leaves.

Figures 21: Nano Gro treated plants (yellow) with minimal damage in 2 consecutive planting holes.

It would be interesting to find out if Nano Gro treated plants exhibit certain toxicity to phytophagous Lepidoptera larvae that could reduce their survival at an early age, and if medium or large size larvae pupate and give birth to healthy adults, with normal reproduction parameters.

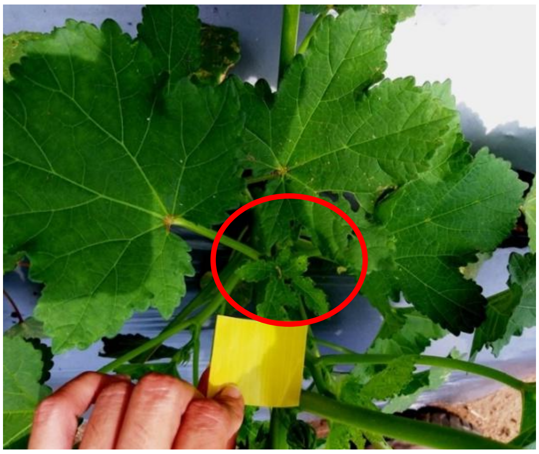

Figure 22 **Figure 23**

Figures 22 and 23: Medium-sized larva of *Spodopteraexigua*present in the shoot, slightly affecting 2 leaves per plant in the Nano Gro treatment (yellow), and widespread larval damage in a control plant (black), affecting at least 4 leaves, 2 of them severely.

Variable	Nano Gro	Control	Probability t-Test*
Plantheight (cm)	70.44 + 11.36 A	64.69 + 8.18 B	P = 0.015
No. harvestedfruits	2.33 + 1.15 n.s.	1.86 + 1.25 n.s.	P = 0.10
No. open flowers	0.67 + 0.48 n.s.	0.61 + 0.49 n.s.	P = 0.62
No. smallfruits	2.50 + 0.56 n.s.	2.42 + 0.77 n.s.	P = 0.61
No. mainstembuds	13.83 + 2.09 A	12.47 + 1.59 B	P = 0.004
No. secondarybranches	4.36 + 1.05 n.s.	4.69 + 1.37 n.s.	P = 0.29
No. open flowers	0.22 + 0.54 A	0.00 + 0.00 B	P = 0.02
No. formedfruits	0.39 + 1.40 n.s.	0.00 + 0.00 n.s	P = 0.10
No. budsonbranches	23.54 + 9.23 n.s.	21.47 + 7.77 n.s.	P = 0.10
Total productivestructures	44.47 + 10.77 A	38.83 + 8.72 B	P = 0.006
Adultwhiteflies	12.11 + 9.96 A	29.47 + 15.42 B	P = 8.64 E – 07

* P < 0.05 is statistically significant. P expressed with E - 7 is equal to 0.0000000.

Table No. 4._ Plant height in centimeters, number of fruits already harvested, open flowers, small fruits and buds on the main stem, secondary branches, flowers, fruits and buds on secondary branches, total number of reproductive structures and number of whitefly adults found on a shoot leaf of each sampled plant. Las Bazas, Choluteca, April 14, 2020.

During this third sampling, in all agronomic variables measured, the Nano Gro treatment had higher values than the control, with the exception of the variable number of secondary branches, in which the control had, on average, 0.33 more branches. Of all variables evaluated, plant height, number of buds present on the main stem, number of open flowers on secondary branches, total number of reproductive structures and number of whiteflies found on a leaf of the terminal shoot were statistically different between treatments.

The Nano Gro treated plants were on average 5.75 cm taller than control plants. In addition, they had, on average, 1.36 more buds on the main stem than the control plants. The control plants had no open flowers and no fruits formed on secondary branches, while the Nano Gro treated plants had, on average, 0.22 open flowers and 0.39 fruits formed on secondary branches per plant. The difference in the number of open flowers on secondary branches between treatments was statistically different at P = 0.02, but not the number of fruits formed, which had P = 0.10. The greater number of flowers and fruits on secondary branches in the Nano Gro treatment clearly indicate precocity and advanced growth.

The total number of reproductive structures shown in Table 4 reflects the sum of all reproductive structures of the plant: harvested fruits, flowers, small fruits and buds of the main stem and also of secondary branches. Although comparisons of numbers of individual structures between treatments do not always result in significant differences, the sum of structures shows a total average difference of 5.64 reproductive structures in favor of the Nano Gro treated plants with a highly significant probability of P = 0.0006.

Having 5.64 more reproductive structures per plant than the control plants implies a big difference in production and a good amount of extra income if these extra fruit translate into exportable fruit. Considering, and being pessimistic because it could be a much higher percentage, that 50% of these extra fruit of the first 2 months of harvest became exportable we would be talking about 120,856 to 141,000 more fruit in Nano Gro treated plants, with okra plant densities between 42,857 and 50,000 per Ha.

Table No. 5 shows another Nano Gro treatment characteristic: the consistent presence of heavier fruit. Data was collected under three different production settings, in places where one foliar application was made at different plant ages.

Producer/Company Nano Gro treatment and age of plant	Weight (g) Nano Gro	Weight (g) Control	Diference in weight (g)
Juan Benito Guevara Seed treatment and 1 foliar application, first month of harvest (n = 50)	12.03 + 0.91	10.94 + 0.98	1.09
AgrícolaAntar 21 days after foliar treatment, plants of medium age harvest (n = 30)	15.48 + 1.04	13.75 +1.12	1.73
AgrícolaAntar Young plantation treated 10 days after germination, starting harvest (n = 30)	14.61 + 1.01	13.55 + 1.11	1.06

Table No. 5: Average weight of individual fruit of Nano Gro treated and control plants, and weight difference in grams.

Having at least 1 gram more per fruit exported makes a big difference in productivity because the number of fruits required/box is reduced. It takes approximately 500 okra fruits of 14 grams to make a 7 Kg okra box for export, but it would only take 467 fruits to make the same box if fruit were 1 gram heavier (e.g. 15 grams/fruit). Big okra producing companies have a tendency to have better nutritional programs for the crop, and therefore fruit weight may vary between producers, nevertheless; the effect of Nano Gro on fruit weight gain is maintained, as seen on Table No.5.



Figure 24 **Figure 25** **Figure 26**

Figures 24, 25 and 26: Example of 3 growing tips of secondary branches of Nano Gro treated plants with strong and well formed buds, good quality fruit and evidence of harvested fruit (red circle) in trial carried at Cuasa Co.



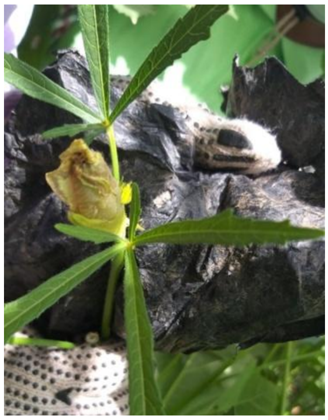

Figure 27 **Figure 28** **Figure 29**

Figures No.27, 28 and 29: Very weak bud, weak and poorly developed fruit, and recently faded flower with abortion symptoms in secondary branches of control treatment at Cuasa Co.

Of all the trials carried out in okra, in southern Honduras, to measure the effect of Nano Gro on crop productivity, only the trials with the companies Cuasa and Sinclair did not show significant increases in productivity, although they did show better postharvest quality and extended shelf life. Also, at Sinclair lower rejection of fruit by chinch bug damage, and lower incidence of *Botrytis* abortions in okra, were found.

At Cuasa, where a trial starting with seed treatment was done, results between Nano Gro and control treatment ended up with similar number of reproductive structures, but the size and quality of buds and fruit did not match, as can be noticed in **Figures No. 24 to 29**.

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Figure 30

Figure 31

Figure 31

Figures 30, 31 and 32: Control okra with no crunch, Nano Gro treated okra with much crunch, and difference in color between control (testigo, pale green) and Nano Gro treated fruit. Ginger Export Co., July 2020.

Results at Sinclair were the consequence of excellent nutritional management given by the company. Most trials carried out in okra in the region used Nano Gro only in foliar spraying and in most cases there was a tendency to get the same results: stronger and more uniform plants, with more production in secondary branches, less bud abortion, more reproductive structures, heavier fruit, better fruit quality and longer shelf life. For this reason, and to make sure improvements could be achieved even at Sinclair Co. using Nano Gro from the very beginning, a trial was set up between June and August 2020. Tables 6 to 10 show results obtained at Sinclair with seed treatment (which had not been done before) and consequent foliar treatments every 21 days.

The trial was planted by direct sowing, placing 1 seed per planting hole, with a distance of 20 cm between plants and one planting row per bed on June 24th 2020. Due to heavy rains during the post planting days plants were lost and resowing was necessary. The reseeding was treated with Nano Gro to maintain the experimental conditions. Initial data is presented in **Table No.6.**

Variable	Nano Gro	Control	P of t-Test
Plant height (cm)	95.25+5.09	89.25+5.73	0.1
Fruit harvested on main stem	0.63+1.41	2.13+3.18	0.28
Flowersonmainstem	0.50+0.53	0.38+0.52	0.60
Fruit formed on main stem	1.00+1.20	1.00+0.76	1.0
Budsonmainstem	18.88+4.42	16.75+2.25	0.36
Secondarybranches	7.50+2.83	6.13+1.96	0.20
Flower buds on secondary branches	30.75+14.47	24.38+12.69	0.14
Abortions per plant	0.88+0.64	1.63+1.19	0.20
Sum of reproductivestructures	51.75+12.94 A	44.63+13.31 B	0.04
Reproductivestructuresnotharvested	51.13+12.76	42.50+13.13	0.036

Table No. 6: Plant height in centimeters, number of fruits harvested, of flowers, fruit and buds of main stem, secondary branches, flowers on secondary branches, abortions, total reproductive structures, and number of reproductive structures not yet harvested per plant on Nano Gro treated and control okra plants. Sinclair Co., Guasaule, El Triunfo, Choluteca.. July 17th, 2020.

Notice that the Nano Gro treatment has the tendency to start harvest later on the main stem, but in contrast, although it has more buds on the main stem, it has more buds on secondary branches than the control treatment. In addition it has fewer abortions per plant. Although there are no significant differences between treatments in terms of specific structures (fruits, flowers, buds), there are significant differences in the sum of reproductive structures and in reproductive structures not yet harvested during the first sampling of the crop. There are 7 more reproductive structures and 8.5 more unharvested structures per plant in the Nano Grotreatment than in the control. Additionally, the control has twice as many aborted buds per plant as the Nano Gro treatment (1.63 vs. 0.88 abortions per plant, respectively).

Figure 33

Figure 34

Figures 33 and 34: Weight of 2 Nano Gro seed treated plants totaling 39 grams and weight of 2 control plants with much shorter root length and less root hair structure, weighing only 15 grams, 14 days after planting.

Table No. 7 resumes data taken on July 28th, eleven days after the first sampling.

Variable	Nano Gro	Control
Fruit harvested on main stem	10.60+2.50	6.1+2.23
Fruit formed on main stem	2.50+1.35	2.8+1.62
Flowersonmainstem	0.7+0.67	0.8+0.79
Budsonmainstem	16.6+2.46	13.9+2.08
Fruit harvested on secondary branches	1.6+1.78	0.2+0.42
Fruit formed on secondary branches	2.5+2.59	0.9+1.20
Flowersonsecondarybranches	0.3+0.67	0.2+0.42
Flower buds on secondary branches	26.2+11.54	28.5+9.10
Abortions per plant	1.1+0.99	4.1+1.29
Sum of reproductivestructures	61.0+14.24	53.4+11.39
Reproductive structures unharvested	48.8+12.82	47.1+11.73

Table No. 7: Average number of fruit harvested in main stem, of fruit, flowers and flower buds formed on the main stem, of fruit harvested on secondary branches, fruit, flowers, and flower buds formed in secondary branches, abortions per plant, total sum of reproductive structures and number of reproductive structures unharvest yet. Sinclair Co., Guasaule, El Triunfo, Choluteca, July 28th, 2020.

Due to the enormous difference in harvested fruit found between the 17th and the 28th of July samplings, the following is an analysis of what has happened during this time in each treatment and how the reproductive structures have evolved over time. It is a fact that the Nano Gro treated plants are better nourished than the control, despite Sinclair's excellent nutritional plan, a fact that is irrefutably shown in the actual number of fruits harvested after 11 days, and in the enormous difference found in the number of abortions of each treatment. The Nano Gro treatment went from having a total of 0.63 fruits harvested **(Table No. 6)** to 10.60 in 11 days **(Table No. 7)**, while the control went from 2.13 fruits harvested to only 6.1 in the same period of time. On the other hand, the control had an average of 4.1 abortions per plant versus only 1.1 for the Nano Gro treatment.

In addition, the difference in the number of reproductive structures of each treatment is still large. During the July 17th sampling, the control had 44.63 total reproductive structures versus 51.75 of the Nano Gro treatment, a difference of 7.02 reproductive structures (Table No. 6). If we consider only unharvested structures, the Nano Gro treatment surpasses the control treatment even more, having 51.13 unharvested structures versus 42.50 of the control (8.63 more reproductive structures). Eleven days later, the differences are as follows: 61.0 total reproductive structures of the Nano Gro treatment versus 53.4 of the control **(Table No. 7)**. The number of unharvested reproductive structures in the July 28th sampling is practically the same for both treatments: 48.8 for the Nano Gro treatment versus 47.1 for the control. In other words, although the Nano Gro treatment has surpassed the control in having more structures harvested, it still has slightly more unharvested structures that will most likely reach harvest earlier than those of the control. This clearly demonstrates the enormous influence Nano Gro has on the formation and maturation of reproductive structures in the okra crop.

The control treatment fattened only 3.97 fruits that were harvested on the main stem in a period of 11 days, against 9.97 fruits fattened by the Nano Gro treatment **(Table No. 7)**. It is very evident that the Nano Gro treatment, although it initially took longer to fatten and bring fruit to harvest, once harvest began, has increased strength to fatten fruit, managing to do so in less time, and also fattening fruit on secondary branches.

The first 2 samples of the Sinclair trial were done taking 10 plants of each treatment randomly. Due to the enormous difference found in this last sampling, and to the intrinsic variability of plants in the crop thanks to replanting it was proposed to sample specific plants in order to reduce possible variability due to baised selection of plants for sampling. Table No.8 presents data taken during 2 sampling dates, 12 days apart using stationary sampling stations or marked plants.

Figure 35: Control plants, with bigger plant structure but smaller root system than Nano Gro treated plants with seed treatment using 1 Nano Gro pellet in 5 liters of water and immersion during 5 minutes.

Structure	August 6th	August 18th	August 6th	August 18th
	Nano Gro	Nano Gro	Control	Control
Plant height (cm)	152.7+12.75	187.9+11.12	144.10+9.04	169.7+16.26
Fruit harvested on main stem	9.80+6.80	19.4+9.55	8.60+4.95	13.7+4.76
Flowersonmainstem	0.50+0.53	1.3+0.82	1.30+1.42	0.9+0.57
Fruit formed on main stem	2.20+1.32	3.1+0.88	0.60+0.70	3.4+1.51
Budsonmainstem	14.30+1.70	12.7+1.77	12.0+2.70	11.0+2.26
Fruits harvested on 2dary branches	3.20+3.88	13.4+15.55	1.80+2.62	6.2+9.57
Fruits formed on 2dary branches	0.70+1.60	4.8+3.85	1.0+1.70	4.1+4.82
Flowerson 2dary branches	0.2+0.42	1.0+1.33	0.40+0.52	0.2+0.42
Flower buds on 2dary branches	23.90+13.76	31.7+13.94	18.8+16.79	21.50+17.80
Total reproductivestructures	54.80+24.73	87.4+39.78	47.20+27.37	58.3+35.93
Total not yet harvested structures	41.80+16.51	54.6+19.70	36.80+21.70	38.4+23.85
Abortions per plant	0.70+1.06	0.4+0.7	2.80+1.93	1.9+1.37

Table No. 8: Plant height, average number of fruit harvested, flowers, fruit, and flower buds formed in main stem, fruit harvested, fruit, flowers and flower buds formed in secondary branches, total number of reproductive structures, total structures yet unharvested, and number of abortions per plant in Nano Gro treated and control okra plants in two different sampling dates, 12 days apart. Sinclair Co., Guasaule, El Triunfo, Choluteca, August 2020.

Notethat the number of fruits harvested on the start date of the new study with marked plants does not correspond to that of the previous sampling. On July 28th, the plants of the Nano Gro treatment had an average of 10.6 fruits harvested and those of the control only 6.1 **(Table No. 7)**. The new plants selected to continue the study had, on August 6th, 9.8 fruits harvested for the Nano Gro treatment (vs. 10.6 on July 28th) and 8.6 fruits harvested for the control (vs. 6.1 on July 28th). Why these differences? The new plants for the study were chosen by the company's harvester, who favored their treatment with larger and more productive plants, and disfavored the Nano Gro treatment with less productive plants. Even so, the results presented below maintained the trends of higher productivity and greater fattening in less time in favor of the Nano Gro treatment, which shows, once again, the enormous usefulness of this nanotechnology molecule.

In twelve days, plants treated with Nano Gro had on average 19.8 harvested fruits (9.6 fruits on main stem and 10.2 on secondary branches), and also 12.8 unharvested structures on average, thus increasing in this period a total average of 32.6 reproductive structures per plant compared to the previous sampling. In addition, this treatment decreased the number of abortions per plant to 0.4, having had on average 0.7 abortions during the previous sampling. Also, plants grew an average of 35.2 cm compared to their previous average size, 12 days before.

In contrast, the control treatment had a total average of 9.5 fruits harvested per plant (5.1 fruits on the main stem and only 4.4 fruits on secondary stems), which is slightly less than half the number of fruits harvested in the Nano Gro treatment (19.8 fruits). Additionally, there is a much smaller number of unharvested structures in the control (1.6 structures) compared to the Nano Gro treatment (12.8 structures). In other words, the Nano Gro treatment is fattening its fruits much faster and is also demonstrating vigorous and abundant growth of new reproductive structures, something is not occurring in the control, despite the good nutritional management of the company. On the other hand, the average number of abortions of the control is 1.9 per plant, compared to only 0.4 abortions on average for the Nano Gro treatment, in other words, there are 4 times more abortions in the control than in the Nano Gro treatment.

At this state of things, the Nano Gro treatment has managed to fatten and harvest, on average, 12.9 more fruits per plant than the control treatment in less than a month and a half of harvesting, and this difference in numbers of fruit produced will continue to grow, as evidenced by the number of structures not yet harvested from both treatments. Considering this average number of fruits per plant (12.9) and an average density of 42,857 plants per Ha, 552,855 more fruits per Ha would be expected in the Nano Gro treatment at this age of the crop.

Being conservative, let's say that 50% of that fruit is packable, and having an average of 500 American okra fruit per 7 Kg box, we are talking about 553 additional okra boxes per Ha in 1.5 months of harvest, and that, at $5/box, is $ 2,765 additional just for the use of Nano Gro. So far, the total number of pellets used for the Nano Gro treatment is 34: 1 pellet for seed treatment, 6 pellets for the first foliar treatment, and 9 pellets for the following 3 foliar treatments (27 total pellets in 3 treatments). Pellet cost varies locally between $7 and $10 U.S. dollars, therefore the investment in Nano Gro is highly profitable.

The hypothesis that Nano Gro would increase productivity and quality of treated okra, and that pests and diseases would not be as damaging in Nano Gro treated plants turned out to be true. In all trials carried out, Nano Gro treated plants were more uniform, and produced more and heavier fruit of better quality than control plants. Statistical differences were also found in numbers of white flies, *Spodoptera* larvae and leaf miners present between treatments.

Additionally, Nano Gro treated plants had less nematode infection and maintained production for longer periods of time than untreated plants. This ability was enhanced by the use of integrated nematode management that included soil disinfection with Aquacitrox, the addition of the nematode biological control agent *Paecelomyces* and the use of *Trichoderma* for management of *Fusarium* and *Rhizoctonia*.

It is concluded that the use of Nano Gro in okra significantly increases plant productivity and uniformity. Nano Gro reduces fruit fattening time in okra when used for seed treatment and every 21 days, thereafter. Therefore, in times of high prices, Nano Gro can be used to take advantage of the market by increasing the number of exported boxes, thus highly increasing crop profitability in such cases. Nevertheless, its use is recommended at all times to improve profits through increased fruit weight, plant productivity, better fruit shelf life and increased postharvest quality of fruit. At present, with shipping costs rocketing after the Covid-19 crisis, Nano Gro offers, additionally, a tremendous advantage due to its small size: its shipping cost is minimal. One kilogram of Nano Gro contains 20,000 pellets.

For all the above mentioned attributes, the nanotechnology molecule Nano Gro promises to be a great tool for increased productivity at low cost in agricultural production systems. Additional studies have been conducted in other crops in Honduras with similar outstanding results. Nano Gro offers production sustainability and respect for the environment because it promotes less pesticide and chemical fertilizer use, while enhancing plant natural resistance to abiotic and biotic factors such as drought, and pests and diseases, respectively.

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