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EFFECTS OF NANOTECHNOLOGY LIQUID FERTILIZERS ON THE PLANT GROWTH AND YIELD OF CUCUMBER (*Cucumis sativus* L.)

Melek Ekinci, Atilla Dursun, Ertan Yıldırım, Fazilet Parlakova
Atatürk University

Abstract. Various fertilizers are used in order to increase the yield and quality of the cultivated vegetables. Therefore, products obtained from different sources can be used as fertilizer. Fertilizers produced with nanotechnology are one of them. Fertilizers derived from nanotechnology have started to attract attention in agriculture nowadays. This study was undertaken to determine the effects of nanotechnology liquid fertilizer on the plant growth and yield of cucumber (*Cucumis sativus* L.). The experiment was carried out in the Department of Horticulture at Ataturk University under unheated greenhouse conditions in Erzurum, Turkey, in 2011–2012. The doses of 2.0, 3.0 and 4.0 L ha^{-1} of Nanonat and Ferbanat were used as fertilizer source. The plant leaves were sprayed with Nanonat and Ferbanat suspension until becoming wet at ten day intervals for three times during plant growth. The results showed that the fertilizer treatments significantly improved the yield compared to control. According to the average of years the highest yield (149.17 t ha^{-1}) occurred in Ferbanat 4.0 L ha^{-1} application. As a result, this study suggested that the foliar applications of liquid fertilizer could improve the plant growth and yield of cucumbers.

Key words: fertilizer, cucumber, fruit, chlorophyll content, dry matter, yield

INTRODUCTION

The increasing world population has led to increases in food production. To increase food production it is necessary to use the different technologies in agriculture. Nanotechnology can be used as an alternative technology in a wide scientific area. Nanotechnology has been described as relating to materials, systems and processes which operate at a scale of 100 nanometres or less [Mousavi and Rezai 2011, Srilatha 2011, Ditta 2012]. Nanotechnology provides a lot of benefit in the area of pollution sensing and prevention, by exploiting novel properties of nanomaterials [Baruah and Dutta 2009, Srilatha 2011].

Corresponding author: Melek Ekinci, Atatürk University, Faculty of Agriculture, Department of Horticulture, 25240 Erzurum, Turkey, e-mail: ekincim@atauni.edu.tr

Nowadays, nanotechnology has been used in many agricultural fields such as production, processing, storing, packaging and transport of agricultural products [Mousavi and Rezai 2011, Ditta 2012]. Fertilizer derived from nanotechnology has started to attract attention in agriculture. Nanotechnology can have a profound impact on energy, the economy and environment, by improving fertilizer products [DeRosa et al. 2010]. Nanofertilizer can be encapsulated inside nanomaterials, coated with a thin protective polymer film, or delivered as particles or emulsions of nanoscale dimensions [DeRosa et al. 2010].

Ferbanat and nanonat liquid fertilizer have been obtained from nanotechnology. Ferbanat liquid fertilizer has natural elements as a new generation biostimulator against stress and soil microorganisms through obtained and produced in organic materials. Ferbanat contains micro humates, amino acids, vitamin, natural biological substances, micro elements and soil microfloras as agricultural useful values to increase vitality of products, activities of life and activities of the plant root zones [Ferbanat 2013]. Additionally, it has been described that nanonat is a vitamin and mineral source for agricultural products to induce chemical dressing using as 30–50% with biological nitrogen, phosphorus, potassium, calcium, magnesium and the elements in it [Nanonat 2013].

There are insufficient studies on fertilizers produced with nanotechnology, although we know it has significant impact in agricultural production. The aim of this study was to determine that the effects of nanotechnology liquid fertilizers on the plant growth and yield of cucumber (*Cucumis sativus* L.).

MATERIALS AND METHODS

Plant and fertilizer materials. Cucumber (*Cucumis sativus* L. cv. A-21F_1) was used as the plant material. Ferbanat and Nanonat liquid fertilizers were used in this study as fertilizer source. Ferbanat contains micro humates, amino acids, vitamin, natural biological substances, micro elements and soil microfloras [Ferbanat 2013]. Additionally, it has been described that nanonat is a vitamin and mineral store for agricultural products [Nanonat 2013].

0, 2.0, 3.0 and 4.0 L ha^{-1} doses of Nanonat and Ferbanat were made up with distilled water. Treatments used in the study are: Control (none treatment), F1: 2.0 L ha^{-1}, F2: 3.0 L ha^{-1}, F3: 4.0 L ha^{-}1, N1: 2.0 L ha^{-1}, N2: 3.0 L ha^{-1}, N3: 4.0 L ha^{-1}.

Growth conditions and treatments. The study was carried out in the Department of Horticulture at Ataturk University under unheated greenhouse conditions in Erzurum (40º31'N; 40º54' E), Turkey, in 2011 and 2012. Cucumber (cv. A-21F_1) plants were grown under natural light conditions, approximate day/night temperatures of 27/14ºC and 75% relative humidity during the span of the experiment. The experiment was conducted based on a completely randomized design with three replicates. Seeds were sown in 45-celled seedling trays filled with peat.

The soil in the experimental area had 35.6% sand, 48.2% silt and 16.2% clay. Some of chemical properties of the soils were as follows: organic matter 8.0 g kg^{-1}, soil pH 7.15, plant available P 6.2 mg kg^{-1}, exchangeable K 0.78 g kg^{-1} and total N 0.5 g kg^{-1}. The basic fertilizers were applied in each plot at the rates 250 kg N ha^{-1} as ammonium nitrate, 110 kg P ha^{-1} as triple super phosphate and 180 kg K ha^{-1} as potassium sulphate before planting.

About 35 day-seedlings were transplanted to experimental areal at 50 × 50 cm row spacing distances in the second week of May in both years. Plants from each treatment were sprayed with each suspension of fertilizers until getting wet at ten days interval three times during plant growth, beginning two weeks after transplanting. The study was terminated in the second week of October in both years.

The effect of fertilizer treatments on the total yield and yield of per plant in cucumber was evaluated. Furthermore, the growth promoting effects of fertilizer treatments were determined for the average fruit weight, fruit weight per plant, plant length, fruit diameter and length, total soluble solid (TSS) and dry matter of cucumber fruits.

Chlorophyll reading value; a portable chlorophyll meter (SPAD-502; Konica Minolta Sensing, Inc., Japan) was used to measure leaf greenness. SPAD-502 chlorophyll meter estimates total chlorophyll amounts in leaves in a non-destructive method [Neufeld et al. 2006]. For each plant, measurements were taken at four locations on each leaf, two on each side of the midrib on all fully expanded leaves [Khan et al. 2003].

Data analysis. All data was subjected to Duncan's multiple range tests using SPSS statistical software.

RESULTS AND DISCUSSION

The effect of nanotechnology liquid fertilizer on total yield is shown in Fig. 1 and Table 1, yield per plant, average fruit weight, fruit diameter, fruit length, TSS, dry matter, plant length, and chlorophyll reading value cucumber are presented in Table 1.

Nanotechnology liquid fertilizers significantly ($p < 0.001$, $p < 0.01$ and $p < 0.05$) affected the total yield, yield of per plant, fruit weight, fruit length and dry matter statistically. While the highest yield (135.30 t ha^{-1}) and yield per plant (5.43 kg $plant^{-1}$) were obtained from Ferbanat 3.0 L ha^{-1} application in the first year, the highest yield (171.75 t ha^{-1}) and yield per plant (6.87 kg $plant^{-1}$) were determined in Ferbanat 4.0 L ha^{-1} in the second year. The lowest yield was obtained from the control in both years (tab. 1). According to the average of years the highest yield (149.17 t ha^{-1}) was occurred in Ferbanat 4.0 L ha^{-1} application (fig. 1).

The effect of nanotechnology liquid fertilizer on the average fruit weight, diameter, fruit length, TSS, plant length and chlorophyll reading value have changed by year, although the highest values of these parameters were obtained from plants applied with treatments. The lowest values of these parameters were recorded in the control (tab. 1). We observed the highest average fruit weight (149.01 g) and fruit length (16.87 cm) from Nanonat 4.0 L ha^{-1}, the highest fruit diameter (37.15 mm) from Ferbanat 3.0 L ha^{-1}, the highest TSS (4.11%) from Nanonat 3.0 L ha^{-1}, the highest dry matter (2.31%) and chlorophyll content (44.90) from Ferbanat 4.0 L ha^{-1} and the highest plant length (465.50 cm) from Ferbanat 2.0 L ha^{-1} applications. The result of this study showed that nanotechnology liquid fertilizer (Ferbanat and Nanonat) treatment increased the parameters of plant yield and growth compared to the control in cucumber.

Table 1. The effect of nanotechnology liquid fertilizers on growth, some fruit characters, chlorophyll reading value and yield of cucumber

Year	Application	Yield ($t\ ha^{-1}$)	Yield of per plant (kg)	Average fruit weight (g)	Fruit diameter (mm)	Fruit length (cm)	TSS (%)	Dry matter (%)	Plant length (cm)	Chlorophyll reading value
2011	control	113.06 c**	4.49 c **	141.67 ns	37.57 ns	17.67 ns	3.85 ns	1.82 d**	402.11 ns	35.45 ns
	F1	126.07 ab	5.04 b	146.50	38.88	17.80	3.84	1.83 cd	434.89	38.95
	F2	135.30 a	5.43 a	155.00	38.73	18.01	4.01	1.99 bcd	425.67	39.62
	F3	126.58 ab	5.06 ab	150.00	38.80	17.60	4.10	2.29 a	407.55	38.31
	N1	119.30 bc	4.77 bc	148.22	38.14	17.97	3.92	2.10 abc	418.67	34.68
	N2	115.24 c	4.61 c	152.89	38.56	18.15	4.21	2.18 ab	437.22	34.47
	N3	118.65 bc	4.75 bc	148.55	38.00	18.05	4.08	1.93 bcd	430.28	38.91
2012	control	140.25 c**	5.61 c**	122.60 ns	33.24 b*	14.06 b**	3.62 ns	1.99 ns	479.33 ns	39.87 ns
	F1	162.66 ab	6.51 ab	142.47	35.09 a	15.61 a	3.95	2.15	496.11	41.30
	F2	158.83 b	6.35 b	141.00	35.57 a	15.55 a	3.69	2.18	500.56	40.10
	F3	171.75 a	6.87 a	140.40	35.18 a	15.63 a	3.79	2.32	507.78	44.90
	N1	156.75 b	6.27 b	143.87	35.14 a	15.69 a	3.94	2.23	492.78	43.47
	N2	160.25 ab	6.41 ab	137.13	35.57 a	15.27 a	4.00	2.29	494.67	43.00
	N3	153.17 b	6.13 b	149.47	36.19 a	15.69 a	3.81	2.20	490.54	43.23
Average	control	126.66 d***	5.05 d***	132.13 b*	35.41 b*	15.86 b**	3.73 ns	1.91 d**	440.72 ns	37.66 ns
	F1	144.36 ab	5.77 ab	144.48 a	36.99 a	16.70 a	3.90	1.99 cd	465.50	41.30
	F2	147.07 a	5.89 a	147.99 a	37.15 a	16.78 a	3.84	2.09 abcd	463.11	40.10
	F3	149.17 a	5.97 a	145.20 a	36.99 a	16.61 a	3.94	2.31 a	457.67	44.90
	N1	138.03 bc	5.52 bc	146.05 a	36.64 a	16.83 a	3.93	2.16 abc	455.72	43.47
	N2	137.75 bc	5.51 bc	145.01 a	37.07 a	16.71 a	4.11	2.23 ab	465.95	43.00
	N3	135.91 c	5.44 c	149.01 a	37.09 a	16.87 a	3.94	2.07 bcd	460.41	43.23

*** – $p < 0.001$, ** – $p < 0.01$, * – $p < 0.05$, ns – non-significant at $p > 0.05$
Ferbanat: F1 – 2.0 $L\ ha^{-1}$, F2 – 3.0 $L\ ha^{-1}$, F3 – 4.0 $L\ ha^{-1}$,
Nanonat: N1 – 2.0 $L\ ha^{-1}$, N2 – 3.0 $L\ ha^{-1}$, N3 – 4.0 $L\ ha^{-1}$

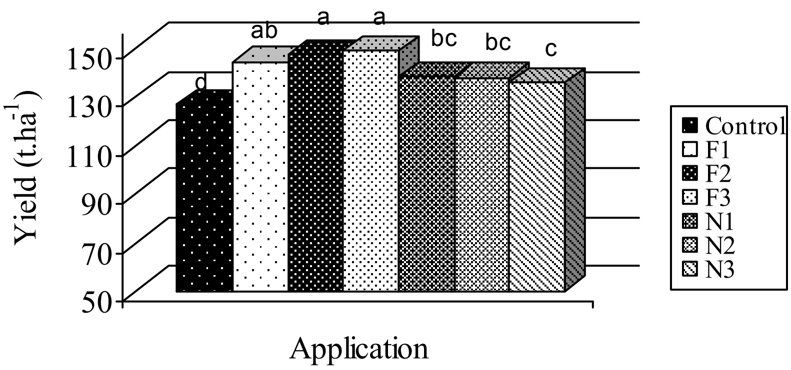

Fig. 1. The effect of nanotechnology liquid fertilizer on yield of cucumber. Mean values in bars followed by a different letters differ significantly at $p < 0.001$ for average years. (Ferbanat: F1 – 2.0 L ha^{-1}, F2 – 3.0 L ha^{-1}, F3 – 4.0 L ha^{-1}, Nanonat: N1 – 2.0 L ha^{-1}, N2 – 3.0 L ha^{-1}, N3 – 4.0 L ha^{-1})

There are insufficient studies on fertilizers produced with nanotechnology, although nowadays it is known to have a significant impact in agricultural production. It was reported that Ferbanat applications as foliar can be increased 25–45% in the number of tomato fruit and flowers [Ferbanat 2013]. Previous studies reported that 3.0 L ha^{-1} doses of Nanonat and Ferbanat applications have improved the yield, plant growth and quality of tomatoes [Ekinci et al. 2012]. Ferbanat application with a sprinkler and drip irrigation system have increased development root of the plant and the number of buds and weight of cucumber plant [Ferbanat 2013]. It was determined that Ferbanat application increased yield in potatoes with 35–40% and in cabbages with 38–42% [Ferbanat 2013]. In another study it was shown that nano-preparation coated nitrogen fertilizer increased the yield of rice and nitrogen absorption amount of rice (35.2% and 42% respectively).

Moreover, previous studies reported that the effects of applications on leaf chlorophyll and dry weight of rice were not significant [Wang et al. 2001]. In a study that examined the effects of nanomaterials on pepper germination, it was determined that the activation time of a 1 hour treatment (water treated with nanomaterial) promoted pepper germination [Wu et al. 2012]. Nitrogen, which is one of the most important nutrients in agricultural production, might be given only very few parts to plant and soil need, although it has been reported that the use of very small nanofertilizer particles is more effective than this rate [DeRosa et al. 2010].

This effect is also provided with other plant nutrients. The nutrients which are available for the plant can be encapsulated in nanomaterials (nanotubes or nanoporous materials), coated with thin protective polymer film or added as particles or emulsions of nanoscale [DeRosa et al. 2010, Srilatha 2011, Ditta 2012]. As a result of this study it can be expressed that the fertilizer used in this study showed this effect and becomes available for cucumber plants.

CONCLUSSION

The changing climate, sustainable use of natural resources, environmental factors, urbanization, accumulation of pesticides and over use fertilizers are the most important problems of modern agriculture. New techniques and methods have been used in order to avoid the detrimental effects of these factors. The nanomaterial is one of the new technologies that into almost all areas of our lives and being to be used in agriculture production. The researchers indicate many of the potential benefits of nanotechnology. This study has identified that fertilizers can have important effective on the plant growth and yield of cucumber.

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WPŁYW PŁYNNYCH NAWOZÓW UZYSKANYCH ZA POMOCĄ NANOTECHNOLOGII NA WZROST I PLONOWANIE OGÓRKA (*Cucumis sativus* L.)

Streszczenie. W celu zwiększenia plonowania oraz jakości uprawianych warzyw używa się różnych nawozów. Jako nawozy mogą więc być stosowane produkty uzyskane z różnych źródeł, w tym również nawozy produkowane metodą nanotechnologii. Obecnie nawozy te zaczęły być zauważane w rolnictwie. Niniejsze badania podjęto w celu określenia wpływu płynnego nawozu uzyskanego dzięki nanotechnologii na wzrost oraz plonowanie ogórka (*Cucumis sativus* L.). Doświadczenie przeprowadzono w latach 2011–2012 na Wydziale Ogrodnictwa Uniwersytetu Ataturk w warunkach nieogrzewanej szklarni w Erzurum w Turcji. Jako źródła nawozu użyto dawek 2,0, 3,0 oraz 4,0 $L \cdot ha^{-1}$ Nanonatu i Ferbanatu. Podczas wzrostu liście roślin trzy razy spryskiwano zawiesiną Nanonatu i Ferbanatu do momentu, gdy stawały się mokre. Uzyskane wyniki dowiodły, że zabiegi z użyciem nawozów polepszyły plon w porównaniu z kontrolą. Według średniej z lat, największy plon (149,17 $t \cdot ha^{-1}$) otrzymano po zastosowaniu Ferbanatu w ilości 4,0 $L \cdot ha^{-1}$. Niniejsze badania sugerują, że dolistne zastosowanie płynnego nawozu może poprawić wzrost i plon ogórków.

Słowa kluczowe: nawóz, ogórek, owoce, zawartość chlorofilu, sucha masa, plon

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