# Application of nano-chitosan NPK fertilizer on growth and productivity of potato plant

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## Abstract

Nanofertilizers improved technology for controlling release and target delivery of agrochemicals to achieve greater improvement in plant crop with lower environmental impacts. The effect of foliar application of chitosan (CS) nanoparticles loaded with nitrogen, phosphorus and potassium (NPK) on growth and yield parameters, chemical constituents and nutrients content of potato plants (spunta) grown in sandy loam soil were studied. It was applied to leaf surfaces, avoiding direct interaction with soil systems. The uptake and translocation of nanoparticles inside potato plants was investigated by transmission electron microscopy. The results revealed that nanoparticles were taken up and transported through phloem tissues. The obtained results could be summarized as follows: Foliar application with Nano CS-NPK levels (Nano 10, 50 and 100%) significantly increased all the growth and yield parameters, photosynthetic pigments, chemical constituents of potato tuber at harvest, and macronutrients in potato leaves and tubers as compared with the control treatment. The highest effective treatment in this respect was 10% Nano CS-NPK as compered with the other two levels. Thus, accelerating plant growth and productivity by application of nanofertilizers can open new perspectives in agricultural practice.

**Key words:** Nanofertilizers; CS-PMAA; Chitosan polymethacrylic acid; NPK: Nitrogen (N), Phosphorus (P) and Potassium (K); Transmission electron microscopy.

## 1.Introduction

Potato (*Solanum tuberosum* L.) is one of the major crops in the world, after rice, wheat and maize. Potato plant belongs to *Solanaceae* family  It is planted in 160 countries and regions worldwide **(Silver, 2013)**. In Egypt, total production of potato 5,029,022 tons  on area harvested of 184,592 ha **(FAO, 2017).** Potato tubers are a good source of starch, protein rich in amino acids several vitamins, and minerals **(Zaheer and Akhtar, 2016)**.

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The biggest goal of modern agriculture is effective management of production and protection of food crop with good quality and in sufficient quantity to meet the rise in world population for an additional 2.3 billon people by 2050 worldwide **(Silver, 2013).** Agriculture production is severely affected by many pests and diseases that can cause considerable losses. During the past 100 years, pesticides and chemical fertilizers were used to overcome these problems and increased yield. The huge utilization of these products raised productivity, but it also led to problem for human **(Adisa *et al.,* 2019)**.

In recent years, Nanotechnology has important application in plant science and agriculture. Nanotechnology refers to science of manipulating and control of matter at the nanoscale at range 1-100 nm, where a unique phenomenon enables novel applications **(Bhushan, 2017)**. Nanotechnology-derived devices are employed as delivery systems to combat crop pathogens, to minimize nutrient losses during fertilization, and to improve yield. The encapsulation of different chemicals in slow release particles can be very important for sustainable agriculture and food safety **(Adisa *et al.,* 2019)**. Recently, chitosan-based materials have been used to produce nanoparticles able to efficiently supply plants with chemicals and nutrients **(Malerba and Cerana, 2016)**. Chitosan is a natural cationic polysaccharide containing D-glucosamine and N-acetyl-D-glucosamine obtained by deacetylation of chitin. In fact, chitosan has a wide range of applications due to its non-toxic, biocompatible, biodegradable, exhibits diverse biological activities and chemical stability **(Malerba and Cerana, 2016).**

Many applications have been reported for chitosan nanoparticles (CNM) due to a positive surface charge increases affinity towards biological membranes, resulting in enhanced reactivity with biological systems **(Malerba and Cerana, 2016)**. Several studies were tried to use chitosan nanoparticles as a controlled release agent for nitrogen, phosphorus, and potassium fertilizers and evaluate the effect of application on wheat plants **(Abdel-Aziz *et al.*, 2016)**, French bean plant **(Hasaneen and Abdel-aziz, 2016a)** and red bean **(Biosci *et al.*, 2014).** A study conducted by **Chemistry (2017)** evaluated the potential use of Cu-Chitosan nanoparticle to enhance seedling growth in maize. These studies open new dimensions for chitosan nanoparticles to be used in various application of agriculture**.** Therefore, the aim of this study was to evaluate the effect of foliar application of Nano-chitosan in NPK fertilizer to improve growth and productivity of potato plants.

## 2.Materials and Methods

### 2.1.Preparation of nano-chitosan NPK fertilizers

The chitosan (CS) nanoparticles were prepared by polymerization of methacrylic acid (MAA) in two step process according to **(De Moura *et al.*, 2008; Corradini, *et al.*, 2010)**. The incorporation of NPK fertilizers in CS nanoparticles was obtained by dissolving suitable amounts of NPK in the following concentrations: 400 ppm, 60 ppm and 400 ppm respectively (100% concentration stands for 400 ppm of N, 60 ppm of P and 400 ppm of K and other concentrations were made from these stock solutions).

### 2.2.Plant material and growth conditions

A field experiment was conducted in Botany Department, Faculty of Women's for Arts, Science and Education, Ain Shams University Cairo, Egypt. Potato tuber seeds (spunta) were supplied by Egyptian potato rot Project, Agriculture Research Center, Ministry of Agriculture, Giza, Egypt. The experiment was laid out on pots (50 cm in diameter and 70 cm in depth) were filled with 150 Kg soil. The physical and chemical properties of soil are measured before planting (Table 2.1) according to **(Page *et al.*, 1982)**.

**Table 2.1 Physical and chemical properties of soil**

| Soil texture | | | | pH | E.C (dSm$^{-1}$) | O.M (%) | $CaCO_3$ (%) | Available nutrients (mg Kg$^{-1}$) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Sand(%) | Silt(%) | Clay(%) | Texture | | | | | N | P | K |
| 62 | 16 | 22 | Sandy loam | 6.60 | 0.27 | 0.8 | 1.1 | 44 | 3.83 | 73 |

E.C: Electrical conduce, O.M: Organic matter.

The experiment included 35 pots and was divided in to five groups (7 pots/groups). Four tubers of equal size and weight of potatoes were planted in each pot. This was done on 24 January 2018. The groups were treated as follows:

The first group was sprayed with distilled water and represent as control.

The second group was sprayed with bulk NPK material (Biestersol 19-19-19) fertilizer.

The third, fourth and fifth group was sprayed at concentration 10, 50 and 100% of Nano CS-NPK fertilizer.

### 2.3.Data collection

Samples collected in each treatment, representing vegetative and yield stage (after 70 and 90 days respectively from emergency) were used for determination of growth parameters and physiological analysis.

### 2.4.Measurement of growth parameters and tuber yield

Vegetative growth as shoot and root length, fresh and dry weight, water content and dry mater percentage were determined after 70 days. While at harvest, number of tubers /plants, tuber yield /plant (g), average tuber wt. (g) and dry weight of tubes /plant (g) were measured.

## 2.5.Transmission electron microscope (TEM) analysis determination

Intracellular penetration of nanoparticles in potato plants was observed using TEM. After 10 days from applying CS-NPK Nano- fertilizer to verify the presence of Nano CS-NPK fertilizer inside potato plants. Small parts (~1mm$^2$) of freshly harvested leaves were fixated in 2.5 %(v/v) glutaraldehyde at 4$^o$C for 24 h. Following fixation, the specimens were embedded in gelatin capsules. Ultra-thin sections were cut on Reichert ultra-microtome and then stained by 2% uranyl acetate **(Juniper *et al.*, 1970).** Stained ultra-thin sections washed by steam distilled water and then were transferred to drops of lead citrate which were placed on a wax plate in a Petri dish for 10-20min and then were examined with TEM (Philips CM200, Mahwah, NJ, USA) at 80 KV **(Williams and Carter, 1996)**.

### 2.6.Estimation of photosynthetic pigment

Extraction of photosynthetic pigment according to **(Arnon, 1949)**. Concentrations of pigments were determined using equations published by **(Lichtenthaler and Buschmann, 2001):**

$$\text{Chlorophyll } a\ (\mu g\ ml^{-1}) = 12.25\ A_{663.2} - 2.79\ A_{646.8}$$

$$\text{Chlorophyll } b\ (\mu g\ ml^{-1})_b = 21.5\ A_{646.8} - 5.1\ A_{663.2}$$

$$\text{Carotenoids}_{(x+c)}\ (\mu g\ ml^{-1}) = (1000\ A_{470} - 1.82Chl_a - 85.02Chl_b)/198$$

### 2.7.Determination of carbohydrates

### 2.7.1.Total carbohydrate

Preliminary hydrolysis to convert polysaccharides into monosaccharaides was performed by using of 2.5N HCl. The total carbohydrate content was estimated by phenol-sulfuric acid method as **(Dubois *et al.*, 1956)**.

#### 2.7.1.1.Soluble and insoluble sugar

Extraction of both sugars and starch was done according to **(MoCREADY *et al.*, 1950)**. Dried sugar free pellet hydrolysis to convert starch into monosaccharaides by using 52% (v/v) perchloric acid.

Total soluble sugar and starch content was estimated by phenol-sulfuric acid method as **(Dubois *et al.*, 1956).** Starch content calculated by multiplying by 0.91. Reducing sugar was estimated according to **(Nelson, 1944)**. Non-reducing sugar were determined by subtracting the content of reducing sugars from the amount of total soluble sugars **(Shahidi *et al.*, 1999).**

### 2.7.2. Estimation of minerals

Plant tissue (0.1g) finely ground oven dry digested by mixture of concentrated $H_2SO_4$ and 30% $H_2O_2$ as the procedure described by **(NJOGU, 2012)**.

Total nitrogen was spectrophotometric determined according to **(Weatherburn, 1967)** method. The absorbance measured at 650 nm. Spectrophotometric determination of total Phosphorus content using 5% molybdenum blue procedure with 5% ascorbic acid (AA) as reducing agent according to **(Jastrzębska, 2009)**. The absorbance was measured at 825 nm**.**

Potassium were measured by flame emission photometry according to **(Okalebo *et al.*, 2002).**

### 2.7.3.Estimation of total soluble proteins

Quantitative estimation of protein was executed by **(Bradford, 1976)** method. Absorbance was measurement at 595 nm.

### 2.8.Statistical analysis

All the obtained data were subjected to one way statically analysis of variance (ANOVA) according to **(Neter *et al.*, 1996)** using MSTAT-C program. Duncan's test was used for means separation.

### 3.Results and discussion

Figure 3.1 revealed that particles of Nano-CS-NPK fertilizer appeared in phloem tissue of potato leaves, especially in sieve tube. The diameter of nanoparticles presents inside sieve tubes showed a mean diameter varying 26.21±0.02 nm and more accumulation in leaves treated by Nano-CS-NPK 100%. When nanoparticles are applied on leaf surfaces, they enter through the stomata openings the substomatal chamber or through the bases of trichomes and then are translocated to phloem system **(Uzu *et al.*, 2010)**. **Du *et al.* (2011)** also found that nanoparticles induce formation of new larger pores in plant cell wall to allow the entrance of large nanoparticles. In the cytoplasm, the nanoparticles may bind with different organelles in it and interfere with the metabolic processes **(Abdel-Aziz *et al.*, 2016)**. The observed results indicate that phloem potato tissue is the main and unique pathway for translocation of nanoparticles and confirm the penetration of plant leaves. Similar results were obtained by **Wang *et al.* (2013)**. For successful foliar uptake, in addition particle size, other various factors should also be considered such as working environment (light, water and gas), plant species and nanoparticle application methods **(Abdel-Aziz *et al.*, 2016)**.

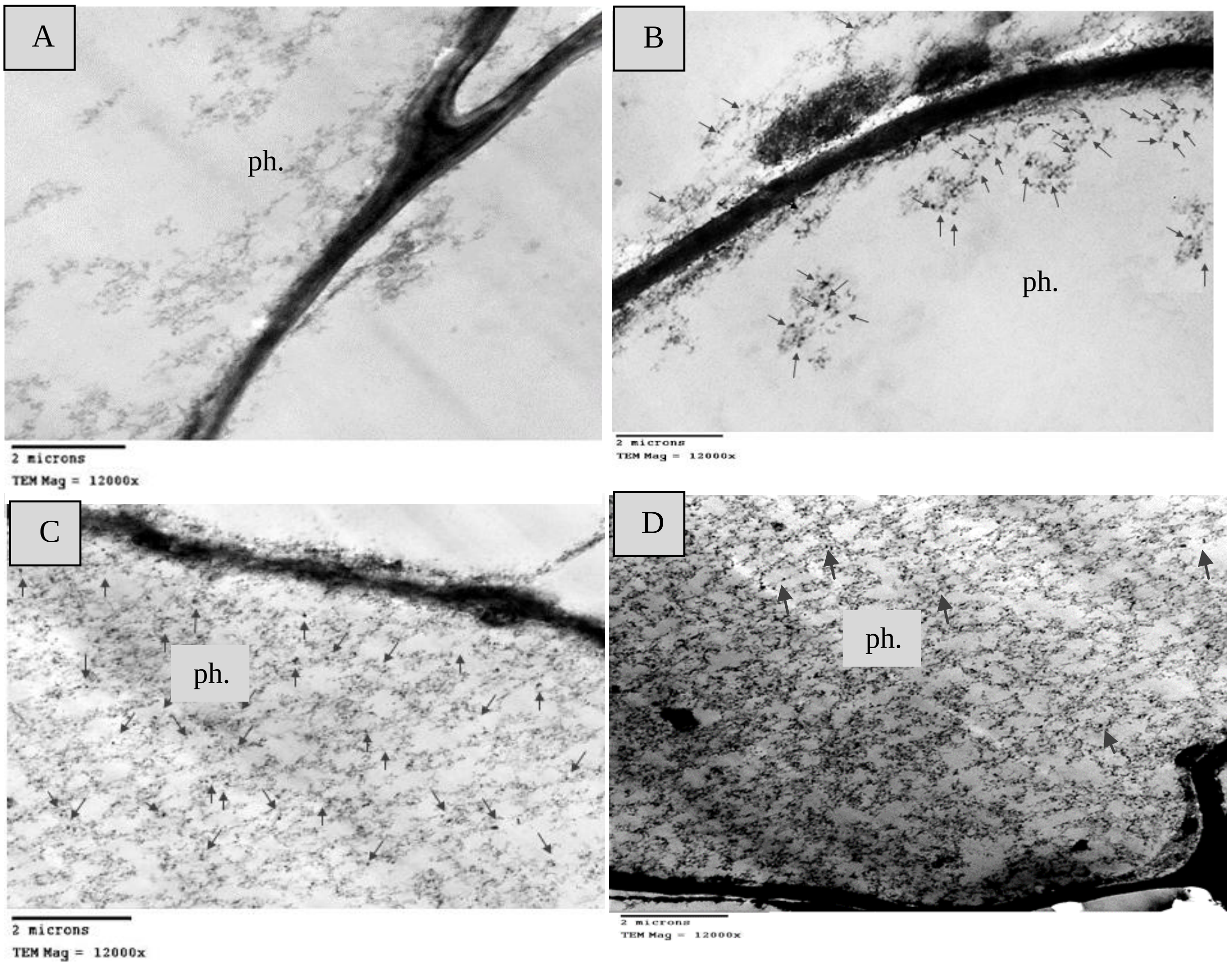


**Figure 3.1 TEM micrograph of phloem tissue of potato leaves treated with Nano-CS-NPK fertilizer. (A) Control, (B) Nano-CS-NPK 10%, (C) Nano-CS-NPK 50 %, (D) Nano-CS-NPK 100%. Bar: 2µl. Arrow indicates to nanoparticles**

**Table 3.1 Vegetative growth parameters in potato (70 day after emergency) sprayed with normal and different concentrations of nanofertilizers (Nano CS-NPK 100, 50 and 10%).**

| Treatments | Length (cm) | FW (g)/plant | DW (g)/plant | Dry matter (%) | Water content (%) |
|---|---|---|---|---|---|
| **Control** | 83.11±0.03 c | 85.06±0.49 d | 11.30±0.91 e | 13.3±0.63 c | 86.67±2.63 c |
| **Bulk NPK** | 97.51±0.14 b | 114.5±0.19 c | 21.75±0.78 d | 19.04±0.80 b | 80.96±0.70 c |
| **Nano CS-NPK 10%** | 112.0±0.25 a | 135.7±0.07 a | 32.39±0.92 a | 23.87±0.51 a | 76.13±0.51 a |
| **Nano CS-NPK 50%** | 100.1±0.75 b | 120.0±0.50 b | 26.13±0.85 b | 21.77±0.68 a | 78.23±0.68 b |
| **Nano CS-NPK 100%** | 96.41±0.01 b | 103.4±0.58 b | 19.12±0.81 c | 18.54±0.79 b | 81.46±0.79 b |
| **F-value** | 66.379** | 69.177*** | 142.867*** | 25.538*** | 25.538*** |

Means with the same litters not significant. **: P<0.01, ***<0.001.

**Table 3.2 Root growth parameters in potato (70 day after emergency) sprayed with normal and different concentrations of nanofertilizers (Nano CS-NPK 100, 50 and 10%).**

| Treatments | Length | FW | DW | Dry matter | Water content |
|---|---|---|---|---|---|
| **Control** | 12.95±0.4 c | 4.88±0.01d | 0.65±0.30 d | 13.70±0.11 b | 86.30±0.41 b |
| **Bulk NPK** | 20.21±0.61 d | 10.4±0.50 c | 2.46±0.06 c | 23.47±0.81 a | 76.53±0.81 b |
| **Nano CS-NPK** | 25.73±0.85 a | 14.2±0.58 a | 3.47±0.13 a | 24.77±0.68 a | 75.23±0.68 a |
| **Nano CS-NPK** | 24.01±0.46 b | 13.4±0.70 a | 3.26±0.18 a | 25.01±0.58 a | 75.00±0.06 b |
| **Nano CS-NPK** | 18.71±0.36 c | 8.81±0.60 b | 2.00±0.16 d | 22.67±0.58 a | 77.33±0.58 b |
| **F-value** | 226.143** | 74.939** | 112.157** | 17.976** | 17.976** |

Means with the same litters not significant. **: P<0.01, ***<0.001.

The results of growth parameters are presented in Table 3.1; 3.2 showed that application of potato plants with either normal NPK fertilizer or different concentrations of nanofertilizers led to significant increase in all growth variables were measured as length, fresh weight, dry weight and dry matter except water content for shoot (Table 3.1) and root (Table 3.2), at fully vegetative growth stage. The values of measuring growth variables were higher in nanofertilizers-treated plants than in normal fertilizer-treated plants except Nano CS-NPK100%. The following sequence of treatments (Nano 10 > Nano 50 > normal > Nano 100 > C) was displayed with potato plants grown on sandy loam soil for all the vegetative and yield variables throughout the entire period of the experiment. Fertilizer is one of major factors that effect on growth and yield of various crops and vegetables. They are supplied by three main nutrients: nitrogen, phosphorus, potassium and macro or/and micronutrient.

However, the applied normal fertilizers is lost to the environment and cannot be absorbed by plants, causing not only substantial economic and resource losses but also very serious environmental pollution **(Rai *et al.*, 2015).** Nanofertilizers harmonized the release of fertilizer N, P and K with their uptake by crops, so preventing undesirable nutrient losses to soil, water and air via direct entry by crops, and avoiding the interaction of nutrients with soil, microorganisms, water and air **(Adisa *et al.*, 2019)**. **Mahmoodzadeh *et al*. (2013)** and **Abdel-Aziz *et al.* (2016)**

reported that direct exposure of wheat plants to specific type of nanoparticles caused significant increase in all growth parameters determined at optimum concentrations of nanosolution.

**Table 3.3 Yield parameters in potato (90 day after emergency) sprayed with normal and different concentrations of nanofertilizers (Nano CS-NPK 100, 50 and 10%).**

| Treatments | No. of tubers /plant | Tuber yield/plant (g) | Average tuber weight (g) | DW of tubes/plant (g) | Tuber dry mater/plant (%) |
|---|---|---|---|---|---|
| **Control** | 4.33±0.58 d | 392.0±0.40 d | 74.17±0.85 d | 74.36±0.33 e | 18.97±0.25 c |
| **Bulk NPK** | 7.33±0.58 c | 583.3±0.51 c | 91.07±0.02 c | 132.8±0.04 d | 22.77±0.21 d |
| **Nano CS-NPK 10%** | 8.67±0.58 a | 684.7±0.60 a | 117.2±0.01 a | 171.2±0.22 a | 25.00±0.30 a |
| **Nano CS-NPK 50%** | 7.67±0.58 ab | 627.3±0.11 b | 99.73±0.62 b | 149.5±0.55 b | 23.84±0.29 d |
| **Nano CS-NPK 100%** | 6.43±0.57 bc | 552.1±0.08 c | 88.17±0.45 c | 128.4±0.06 c | 21.37±0.21 c |
| **F value** | 24.3*** | 108.414*** | 39.086*** | 156.011** | 167.403** |

Means with the same litters not significant. **: P<0.01, ***<0.001.

The data in Table 3.3 showed that the change in potato yield treated with normal and different concentration of nanofertilizers (Nano CS-NPK). The results indicated that treatment with nanofertilizers significantly increased in the number of tubers /plant, tuber yield /plant (g) average tuber weight (g), dry weight of tubers /plant (g) and tuber dry mater/plant (%) for tuber yield at harvest stage as compared with control. Highest values of N, P and K in shoots and tubers of potato plants were obtained by using Nano CS-NPK10% as compared with other treatments. The concentration of 10% recorded the highest potato yield parameter. The obtained results in this investigation are in good agreement with those obtained by **Hasaneen and Abdel-aziz (2016b)** who reported that the increased growth parameters of French bean plants as influenced by foliar application of either nanocomposite NPK nanoparticles or nano-engineered CNTs-NPK. The NPK effect on vegetative growth and yield of potato has been documented by **BĂRĂSCU *et al* (2015) and Mokrani *et al.* (2018b)**. Potato plant needs a high level of nitrogen fertilizer for a fast cycle, high growth rate and increased the number of tubers **(Mokrani *et al.*, 2018b)**. Low N rates not only lower yield but also reduce tuber size due to reduced early defoliation and leaf area **(Jin *et al.*, 2015)**. Nowadays, application of fertilizers containing NPK is vital for the development of crop production and plays important roles in food safety. The importance of these NPK fertilizers lies in their role to supply the necessary nutrients for plant growth **(Mokrani *et al.*, 2018**). When a nanoengineered composite which consists of N, P, K, micronutrients, mannose and amino acids was applied to grain crops, it appeared to enhance the uptake and use of nutrients (**Abdel-Aziz *et al.*, 2016; Biosci *et al.*, 2014; Mastronardi *et al.*,**

**2015)**. **Mokrani *et al.* (2018a**) showed also a lowest potato plant length, stem diameter and few numbers of potato tubers with low weight under excess NPK fertilization rates.

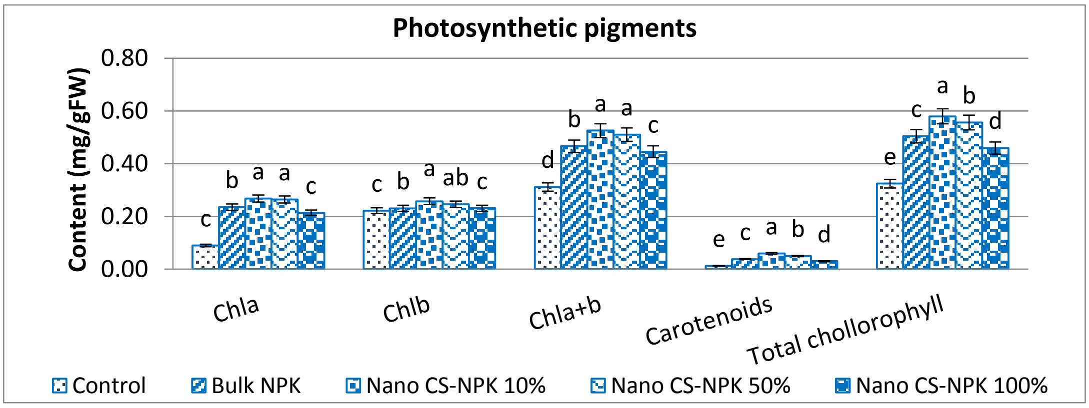


**Figure 3.2 Photosynthetic pigments content (mg/g FW) in potato leaves (70 day after emergency) sprayed with normal and different concentrations of nanofertilizers (Nano CS-NPK 100, 50 and 10%).** Vertical bars represent the standard division (±SD). Different letters above the bars indicate significant difference using Duncan's multiple range tests at $P < 0.05$, for samples.

Chlorophyll is the light harvesting pigment responsible for photosynthesis. Sufficient amount of chlorophyll means greater production of photosynthesis responsible for the growth and development. The obtained results in Figure 3.2 is the same of those obtained from the growth parameters and yield. The highest values of photosynthetic pigment were obtained by using Nano-CS-NPK 10% fertilizer comparing to the other treatments. The increases in the photosynthetic pigments in shoots may be attributed to the important role of (P) in the potential activity of photosynthesis. **Ibrahim and Mohamed (2012b**) found that photosynthetic pigments in potato leaves increased significantly by increasing NPK levels. **Fageria *et al.* (2009**) found that the favorable effect of NPK on photosynthetic pigments may be also due to N which is acting as structural compounds of the chloroplast. correspondingly, an enhancement chloroplast formation leads to an increase in chlorophyll. This study conducted by **Mansouri and Omidi (2018**) who found that treatment with 0.01% w/v Nano-CS and 0.5% w/v potassium nitrate enhance in the highest germination percentage, stem length, chlorophyll content and relative water content of Quinoa seedlings . It seems that NPK treatment significantly increased carotenoids in potato shoots. These results are in agreement with those obtained by **Bojović *et al.* (2005) and Tranavičienė *et al.* (2007)** who reported that photosynthetic pigments in potato leaves increased by increasing NPK levels**. Tranavičienė *et al.* (2007**) found that carotenoids in wheat leaves increased significantly by increasing N levels.

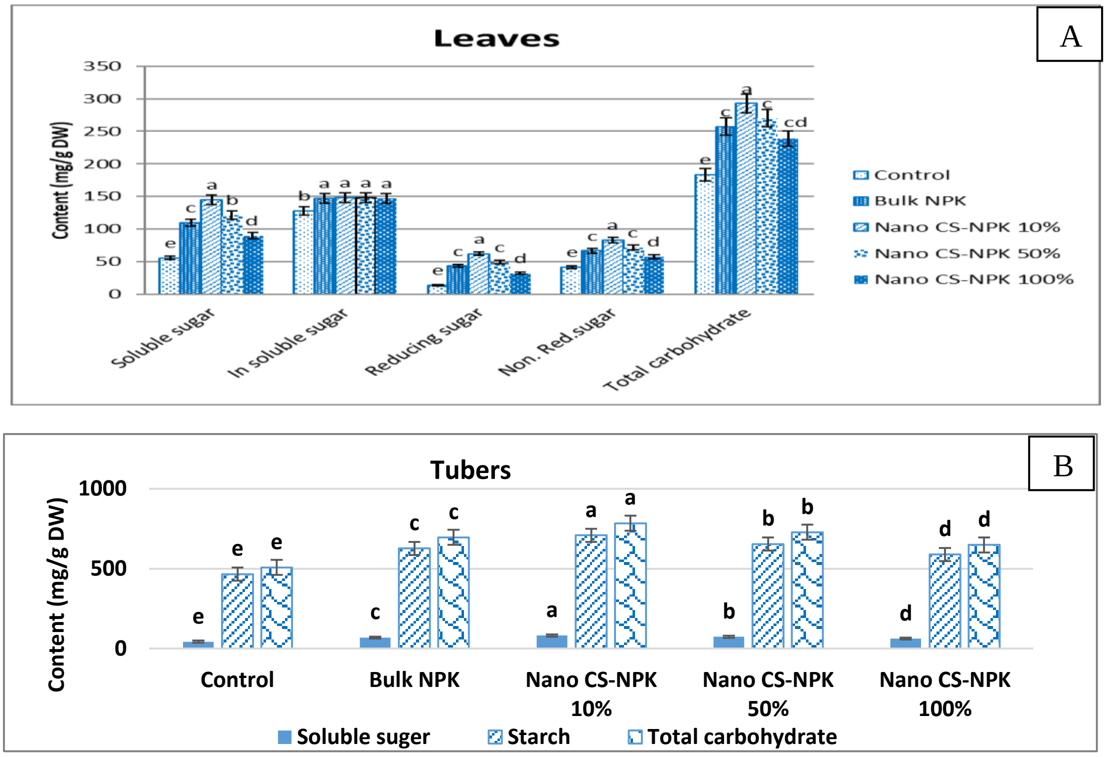


**Figure 3.3 Carbohydrates content (mg/g DW) in A; potato leaves (70 day after emergency), B; potato tubers (90 day after emergency sprayed with normal and different concentrations of nanofertilizers (Nano CS-NPK 100, 50 and 10%).** Vertical bars represent the standard division (±SD). Different letters above the bars indicate significant difference using Duncan's multiple range tests at $P < 0.05$, for samples.

The obtained results, showed that treatments of potato plants with bulk material and chitosan NPK nanoparticles, induced significant increases in total carbohydrate, soluble and insoluble sugar, reduced and non-reduced sugar at fully vegetative growth stage (Figure 3.3a) and led to significant affected the tuber yield at harvest stage as total carbohydrate, soluble sugar and starch content (Figure 3.3b). Results clearly indicate an increase and build-up of stored starch during nanofertilizers and a dramatic depletion at Nano CS-NPK100%. These results are in agreement with those obtained by **Mokrani *et al.*, (2018b**) who reported that potato accumulated low amount of sucrose and starch under the excess regime in tubers, the levels of reducing sugars and starch in spunta leaves decreased by increasing NPK levels**.**

In this concern, **Lindhauer and De Fekete (1990)** reported that starch synthesis in potato tubers grown at varied (k) nutrition activated some selected enzymes (sucrose synthase, UDP-D, glucose pyrophosphatase, starch phosphorylase, amylases). Comparing our results in (Figure 3.3), it is obvious that the positive correlations between the rates of K uptake and starch production indicate that the dynamic phase of K supply to the tubers has greater importance for starch synthesizing processes, than the influence of total K content. The obtained results agree with those obtained by **(Mona *et al*. (2012)** who mentioned that increasing NPK levels significantly increased the growth parameters, yield and its components as well as nutrient uptake of sugar beet and sweet sorghum plants. **Ibrahim and Mohamed (2012b**) and **Mokrani *et al.* (2018b**) proved that NPK application significantly increased reducing, non-reducing and total sugar as well as carbohydrates, starch, and protein contents in wheat grains and potato respectively.

Carbohydrate supply is essential for the high energy demanding process of nitrogen fixation. As well, a carbon skeleton for assimilation and transport of fixed nitrogen is provided by the same metabolic pathway intermediates (**Chinnasamy and Bal, 2003**). The potassium (K) applications is decreased reducing sugar **(Zörb, *et al.*, 2014)**, K application activates also a number of enzymes involved in photosynthesis, carbohydrate metabolism, proteins and assists in the translocation of carbohydrates from leaves to tubers, which increases the size of tubers but not their number **(Hawkesford *et al.*, 2012).** Biomass and bulking rate of potato tubers are positively affected by synthesis and accumulation of starch. K plays a key role in stimulating the activity of the starch synthase enzyme, catalyzing the incorporation of simple glucose molecules into complex molecules of starch **(Hawkesford *et al.*, 2012)**.

**Table 3.4. Nitrogen fractions content (mg/g DW) in potato leaves (70 day after emergency) sprayed with normal and different concentrations of nanofertilizers (Nano CS-NPK 100, 50 and 10%).**

| Treatments | N | P | K |
|---|---|---|---|
| **Control** | 16.76±0.07 d | 0.20±0.01 e | 1.07±0.05 d |
| **Bulk NPK** | 21.64±0.12b | 0.37±0.00 c | 3.53±0.02 b |
| **Nano CS-NPK 10%** | 23.44±0.12 a | 0.44±.00 a | 3.77±0.01 a |
| **Nano CS-NPK 50%** | 22.11±0.04 b | 0.41±0.02 b | 3.67±0.01 b |
| **Nano CS-NPK 100%** | 20.74±0.12 c | 0.34±0.00 d | 3.20±0.09 c |
| **F value** | 219.8*** | 1705.4*** | 626.2*** |

**Table 3.5. Nitrogen fractions content (mg/g DW) in potato tubers (90 day after emergency) sprayed with normal and different concentrations of nanofertilizers (Nano CS-NPK 100, 50 and 10%).**

| Treatments | N | P | K |
|---|---|---|---|
| **Control** | 14.92±0.07 e | 0.19±0.00 d | 0.77±0.10 d |
| **Bulk NPK** | 20.24±0.10 c | 0.37±0.00 b | 3.49±0.02 b |
| **Nano CS-NPK 10%** | 22.38±0.05 a | 0.43±0.00 a | 3.67±0.06 a |
| **Nano CS-NPK 50%** | 21.38±.05 ba | 0.38±0.03 b | 3.55±0.01 b |
| **Nano CS-NPK 100%** | 19.38±0.03 d | 0.33±0.01 d | 2.41±0.01 c |
| **F value** | 442.7*** | 154.2*** | 1037.3*** |

Means with the same litters not significant. **: P<0.01, ***<0.001.

Data presented in Table 3.3; 3.4 revealed that macronutrients (N, P and K) in both leaves and tubers of potato plants were higher by applying different NPK fertilizers than that of control treatment. Highest values of N, P and K in shoots and tubers of potato plants were obtained by using Nano-CS-NPK10% as compared with other treatments. This finding is in agreement with results reported previously by **(Abdel-Aziz *et al.*, 2016; Biosci *et al.*, 2014; Mastronardi *et al.*, 2015)** suggesting that when a nano-engineered composite which consists of N, P, K, micronutrients, mannose and amino acids was applied to grain crops, it appeared to enhance the uptake and use of nutrients. In this concern, **Ibrahim and Mohamed (2012a**) reported that foliar spray of micronutrients enhanced growth and increased the dry matter accumulation in potato and nutrients significantly increased the leaf content of the sprayed element. These effects may also due to the presence of macronutrients in the foliar fertilizers that may be mediated via the enzymatic systems responsible for biosynthetic apparatus, and thus rising sugars and nitrogen in intact plants. This means that foliar application of fertilizers induced increases in mineral status of plants.

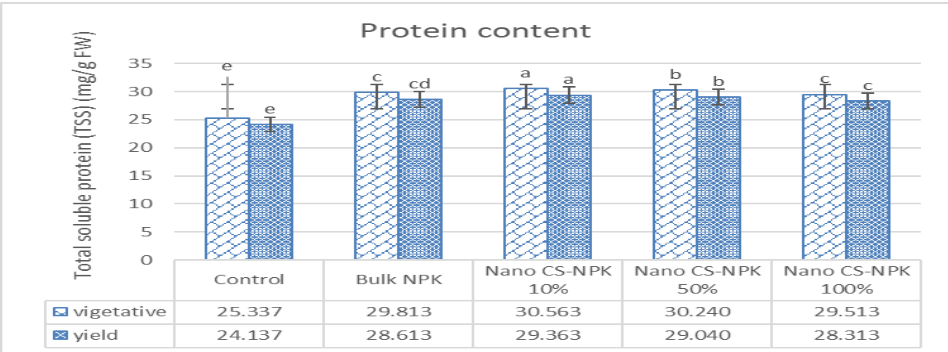


**Figure 3.4 Total soluble protein (TSS) content (mg/g FW) in potato leaves (70 day after emergency) sprayed with normal and different concentrations of nanofertilizers (Nano CS-NPK 100, 50 and 10%).** Vertical bars represent the standard division (±SD). Different letters above the bars indicate significant difference using Duncan's multiple range tests at $P < 0.05$, for samples.

Data presented in Figure 3.4 revealed that total soluble protein content in both leaves and tubers of potato plants were significantly higher by applying different NPK fertilizers than that of control treatment, which is in contrast to the conclusion of **Abdel-Aziz *et al.* (2018)** who reported that the effect of foliar application of Nano CS-NPK fertilizer on the chemical composition of wheat grains showed increasing levels of either normal or nanofertilizers induced significant decrease in protein content of the wheat grains, but how this works is not yet clear. It is supposed that nanofertilizers alter gene expression for protein synthesis during plant development similar to those observed in rice under drought conditions **(Mushtaq *et al.*, 2008)**. Some research suggested that the application of nanofertilizers decreased the protein content and increased the fat content of wheat plants (**Abdel-Aziz *et al.*, 2018**). It seems that when foliar nutritionals were used, the photosynthetic activity was stimulated, leading to enhancement of chemical constituents as crude protein, starch, carbohydrate, L-ascorbic acid and T.S.S in shoots **(Ibrahim and Mohamed, 2012b)**.

## 4.Conclusion

It can be concluded that foliar application of either normal or nanofertilizer (Nano CS-NPK) at different concentrations to potato plants, induced marked significant variable significantly increases in all growth variables of potato plant. Foliar application Nano-CS-NPK 10% fertilizer shows the best nanofertilizers used and enhancing growth, productivity and chemical constituents of potato plants. Excessive use of fertilizer to enhance the crops productivity does not necessarily contribute to yield enhancement rather is mostly poses threat to human health and causes serious environmental problems. Our research would be beneficial for other studies involving the application of nanotechnology in the field of agriculture. Nevertheless, further field studies are needed to study the effect of different agrochemicals incorporation on growth and metabolism of different plants and to ensure the safety of the nanotreated plants for the use of animals and humans. Studies on the mechanism of uptake and formation of nanoparticles within plants have also need to more investigations. The importance of these NPK fertilizers lies in their role to supply the necessary nutrients for plant growth.

## 5.References

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## الملخص باللغة العربية

# تخليق النانوكيتوزان وتطبيقاته كسماد ومضاد للفطريات على البطاطس

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الأسمدة النانوية من التقنيات المطورة لتحكم أكبر في تحررالكيماويات الزراعية لتحقيق أفضل تحسن في المحاصيل النباتية مع تقليل التأثيرات السلبية على البيئية. تم دراسة تطبيق الإستخدام الورقي لجسيمات الكيتوزان (CS) النانوية المحمل عليها عناصرالنيتروجين والفوسفور والبوتاسيوم (NPK) على معايير النمو والإنتاج, المكونات الكيميائية ومحتوى المواد الغذائية لنباتات البطاطس (صنف سبونتا) المزروعة في التربة الرملية . مع مراعاة تجنب التفاعل المباشر مع أنظمة التربة. تم دراسة إمتصاص ونقل الجسيمات النانوية داخل نباتات البطاطس عن طريق المجهر الإلكتروني . أظهرت النتائج أن الجسيمات النانوية أخترقت أنسجة النبات وقد تم نقلها عبر أنسجة اللحاء. وقد أظهرت النتائج أن التطبيق الورقي للتركيزات المختلفة للنانوكيتوزان المحمل بالعناصر الغذائية (١٠ ,٥٠ و ١٠٠ ٪) على نبات البطاطس أدي الى زيادة كبيرة في النمو والإنتاج ، أصباغ التمثيل الضوئي، المكونات الكيميائية من درنات البطاطس، والمغذيات الكبرى في أوراق ودرنات البطاطس بالمقارنة مع النبات غير المعامل. تم الحصول على أعلى قيم من المعاملات المذكورة باستخدام النانوكيتوزان تركيز ١٠% بالمقارنه بالتركيزين الأخرين. وقد خلصت النتائج أنه يمكن تسريع نمو النبات وإنتاجية عن طريق إستخدام الأسمدة النانوية التي تفتح آفاقًا جديدة في الممارسات الزراعية.