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Env. Biodiv. Soil Security **Vol. 2,** pp. 221 - 231 (2018)

Response of Cultivated Broccoli and Red Cabbage Crops to Mineral, Organic and Nano-fertilizers

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THE INTEGRATED application of different fertilizers including nano-fertilizers is a major area of interest within the modern agriculture. A field experiment was carried out aiming to investigate the effects of different types of fertilizers on growth development and productivity of red cabbage and broccoli under salinity and waterlogging stresses. The applied fertilizers included mineral fertilizer (i.e., recommended NPK fertilizers), organic fertilizer (i.e., compost tea) and nano-fertilizers (i.e., copper nanoparticles as nano-Cu) and selenium nanoparticles as nano-Se). The results verified that the vegetative growth of red cabbage and broccoli may depend on the kind of fertilizer. The recent results showed that treatments of nano-Se, nano-Cu and compost tea enhanced the plant growth, tolerance of plants to insects and induced the productivity. Our results revealed that integration of nano-fertilizers with organic fertilizers (compost tea) might be promising tool in modern and non-conventional agriculture. However, more investigations are still needed to clarify the effectiveness of these nanoparticles as well as the possible risks of using these nanomaterials if any.

Keywords: Copper nanoparticles, Selenium nanoparticles, Compost tea, Sustainable agriculture, Broccoli, Red cabbage.

Introduction

Agricultural sector faces nowadays great challenges in seeking for the sustainability. These challenges include the ability to provide safe and enough nutrition for the global population and at the same time the conserving or maintaining of the agroecosystem services (Alshaal and El-Ramady 2017; Agyin-Birikorang et al. 2018; Mupambwa and Mnkeni 2018). Therefore, several approaches have been adapted for conservation and management of biological diversity to sustain and increase crop productivity as well as to enhance agroecosystem services (Jarvis et al. 2013; Singh et al. 2017). Despite mineral fertilizers are essential for crop production, excess application of mineral fertilizers has detrimental consequences not only on quality of yield but also on agroecosystems. In addition, overdoses of mineral fertilizers are kind of energy wasting and it reduces nutrient use efficiency (Kaushik and Djiwanti 2017). The mineral N-fertilizers may get lost in due to many environmental processes such as runoff, leaching, emissions and volatilization. In general, about 50-70 % of the applied conventional chemical fertilizers get lost in the environment causing economic, agronomical, environmental concerns and health threats. Therefore, new alternatives should be used for eco-friendly, economic and organic or sustainable agriculture such as organic-, bio- and nano-fertilizers as well as slow or controlled release fertilizers (El-Ramady et al. 2018).

The new types of fertilizers based on nanotechnology are considered promising and non-traditional solution to upgrade the farming production worldwide. The common applications of nanotechnology in agriculture include nano-fertilizers, nano-pesticides and nano-carriers (Belal and El-Ramady 2016). The advancement and development of engineered nanoparticles is an imperative stage in agricultural field in particular using the biological methods. Although

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DOI: 10.21608/JENVBS.2019.6797.1046

these nano-fertilizers are important for the future agriculture, there are many potential risks on the agroecosystems (Khan and Rizvi 2017; Yata et al. 2018; Xu et al. 2018). Indeed, several investigations are needed to explore the efficacy of commercially available engineered nanomaterials on soil microbes, the proper application methods of nanofertilizers and the future of nanofertilizer market sector (Sanivada et al. 2017). Several studies have been published concerning the role of fertilizers in mineral form or nano-form using essential or beneficial nutrients such as selenium (e.g., El-Ramady et al. 2015a, b, c, d, e, f; Domokos-Szabolcsy et al. 2017; Shalaby et al. 2017) and silicon (e.g., Alsaeedi et al. 2017a, b; Alsaeedi et al. 2018). Surprisingly, nano-fertilizers have not yet been systematically and comprehensively investigated. Concerning the effects of nano-fertilizers on agroecosystems, several investigations should be conducted to follow and monitor the fate, behavior and biosafety of these nano-fertilizers on the ecosystems including plants, soils, water, microbes, etc.

Using of mineral and organic fertilizers in crop production was fast becoming a key instrument in agriculture, whereas the using of nano-fertilizers still needs much effort to confirm. Mineral and organic fertilizers also are one of the most widely used groups of fertilizers and have been extensively used for food production. Therefore, the main subjects of this study were to (1) evaluate the response of cultivated broccoli and red cabbage crops to mineral, organic and nano-fertilizers under salt-affected soil; (2) identify the use of nano-fertilizers whether safe and economic for the agricultural environment or not and (3) to what extent, mineral and organic fertilizers can be replaced by nano-fertilizers?

Materials and Methods

To study the effects of different applied fertilizers on cultivated broccoli and red cabbage crops, a field experiment was carried out at the experimental farm of Faculty of Kafrelsheikh, Kafrelsheikh University. Broccoli (*Brassica oleracea* var. italica) and red cabbage (*Brassica oleracea* var. capitata) were cultivated on January 1st 2018in salt-affected soil. The cultivated crops received different types of fertilizers: a) mineral fertilizers (i.e., 70 kg N, 45 kg P2O5 and 50 kg K2O per acre as recommended doses)b) organic fertilizer (i.e., compost tea) c) nano-fertilizer (i.e., selenium nanoparticles (nano-Se) and copper nanoparticles (nano-Cu)). Organic fertilizer was supplied by the Department of Microbiology, Soils, Water and Environment Research Institute, Sakha. The complete randomized plots design was used to apply the following treatments for both vegetable crops:

1. Negative control (no fertilizers were added) (Control).
2. Recommended doses of NPK fertilizers (NPK-mineral control)
3. Nano-selenium at 100 ppm concentration (Nano-Se)
4. Nano-copper at 100 ppm concentration (Nano-Cu)
5. Organic fertilizer (Compost Tea).

The soil used is characterized as salt-affected soil having electrical conductivity of 4.49 dS m^{-1} and pH 8.65. The clay content is more than 53 % and the depth of soil water table was below 80 cm. Mineral, organic and nano-fertilizers were applied after about 75 days from transplanting of vegetable crops as foliar application. The applied amounts were repeated again after 4 weeks. Nano-Se and nano-Cu were biologically produced at Agricultural Microbiology Laboratory, Soil, Water and Environment Research Institute, Agricultural Research Center, Giza, Egypt. High resolution transmission electron microscope (HR-TEM, Tecnai G20, FEI; The Netherland) was used for the determining particle size of nanomaterials. Size of nano-Se ranged between 100-300 nm; while nano-Cu ranged between 350-500 nm.

Control soil samples were taken before starting the experiment. Chemical and physical properties of soils were assessed according to Page et al. (1982) and Klute (1986), respectively. The head weight of red cabbage and broccoli as well as some vegetative measurements including number of plants per plot and leaves per plant, stem length and diameter, leaf area, head weight and chlorophyll content were measured. Chlorophyll content and leaf area were measured at Horticulture Department, Faculty of Agriculture, Kafrelsheikh University. All vegetative parameters were recorded weekly.

Results and Discussion

Vegetative parameters of red cabbage and broccoli after first foliar application of mineral, organic and nano-fertilizers, applied separately, are presented in Fig. 1. Although no big differences of number of red cabbage plants per plot were noticed among treatments, but treatments of nano-

Se, nano-Cu and compost tea had higher values. Treatments of NPK and nano-Se as well as control recorded nearby the same number of leaves per red cabbage plant; while nano-Cu and compost tea possessed the lowest counted number of leaves per plant. Interestingly, treating red cabbage plants by nano-Se, nano-Cu and compost tea resulted in the same head diameter but these values were lower than those measured for NPK-treated plants and control. Plant height was almost the same among all treatments including control; however, the lowest number was related to control.

Regarding broccoli plants after first application of treatments, number of plants per plot showed the highest value (4.0) at treatments of nano-Se and compost tea compared to control (3.5). The highest value (21) of number of leaves per broccoli plant was denoted to treatment of nano-Se, whilst the lowest recorded value (16) was seen for compost tea treatment. Similarly, nano-Se treatment resulted in the highest head diameter (13 cm) compared to 7.2 cm as lowest measured value for control plants. The plant height of nano-Se treated broccoli plants was the highest among all treatments, while control plants possessed the

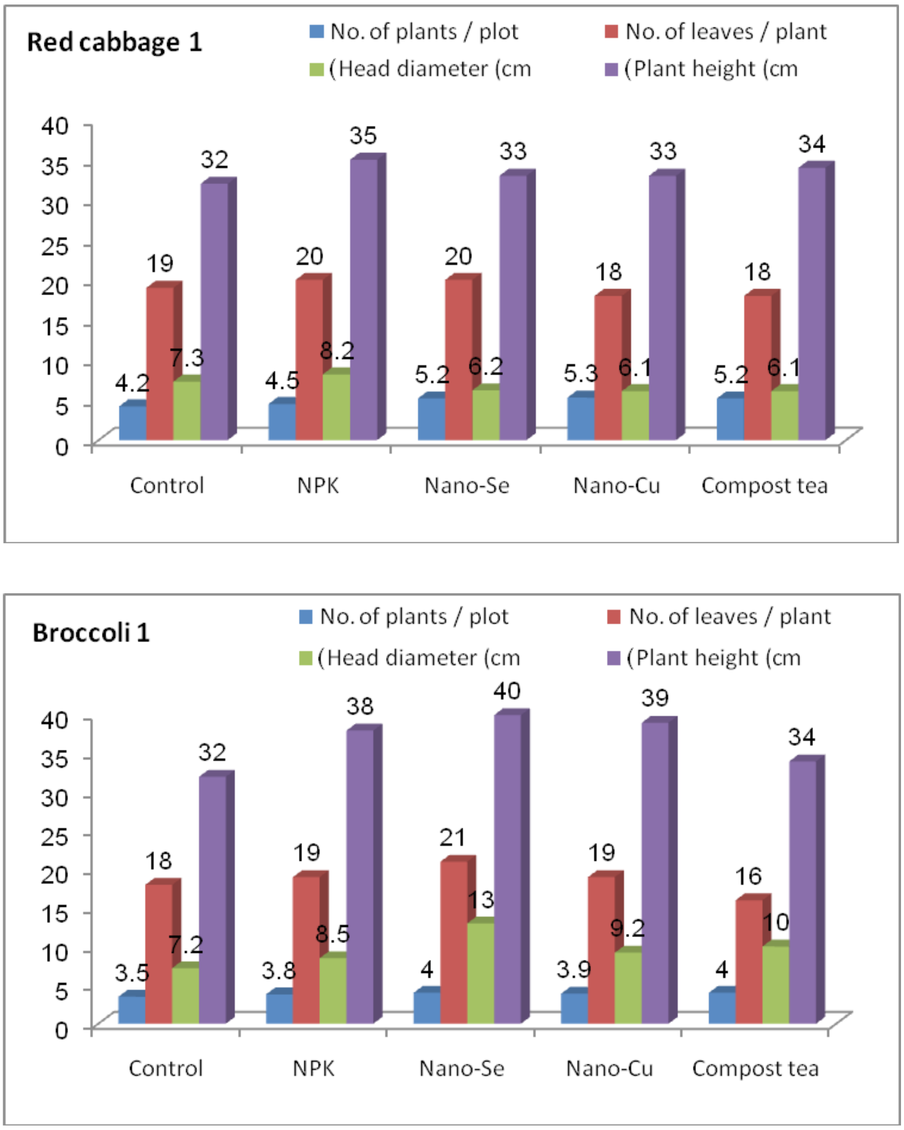
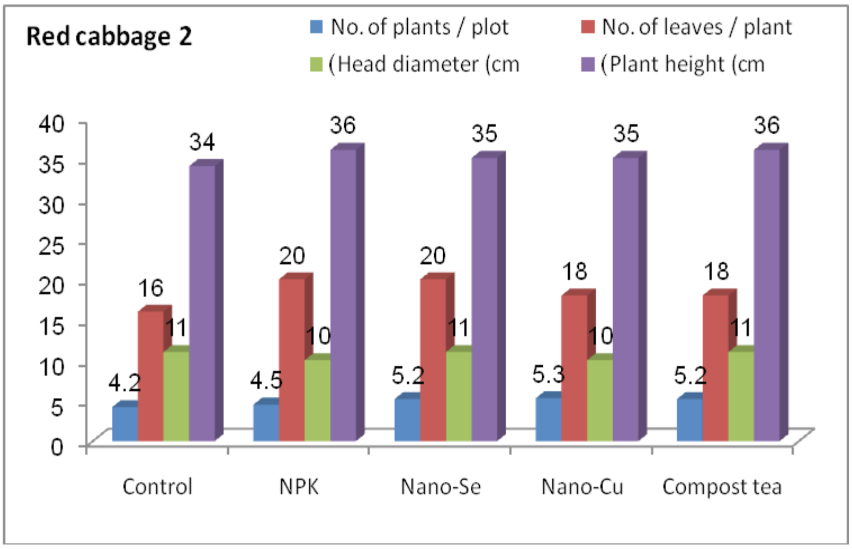


Fig. 1. Vegetative growth parameters of red cabbage and broccoli after the first foliar application of fertilizers.

shortest height.

Vegetative parameters of red cabbage and broccoli after second foliar application of mineral, organic and nano-fertilizers, applied separately, are presented in Fig. 2. All treatments showed higher number of leaves or red cabbage compared to control; while head diameter of red cabbage was almost the same among all treatments. Control plants of red cabbage had the shortest plant height, but treated plants were taller regardless of treatment type. For broccoli plants, compost tea treatment had the lowest number of leaves (13), while control plant had the highest number of leaves (19). Head diameter of broccoli was the highest for plants treated by nano-Cu;



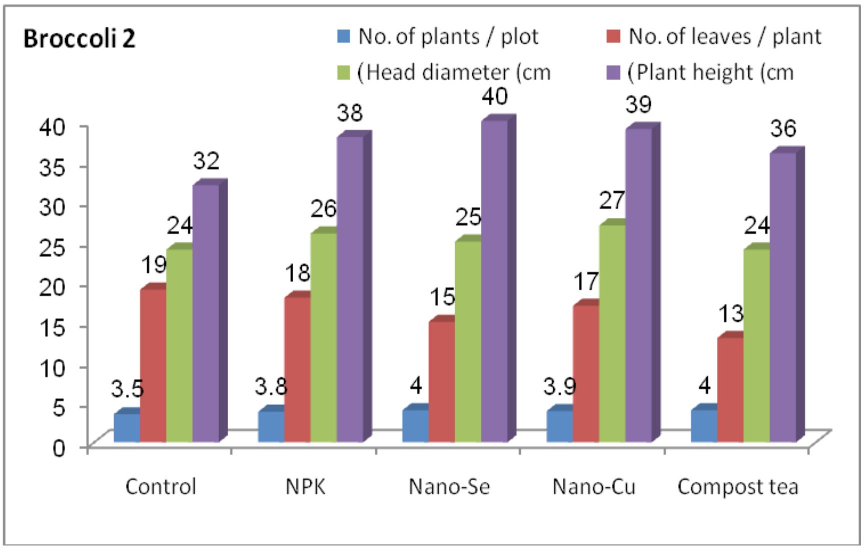


Fig. 2. Vegetative growth parameters of red cabbage and broccoli after the second foliar application of fertilizers.

whilst compost tea treatment and control had the lowest head diameter.

Data in Fig. 3 present chlorophyll content (SPAD), leaf area, infection rate and head weight of red cabbage and broccoli plants after treating by NPK, nano-Se, Nano-Cu and compost tea. Results showed that nano-Cu had the greatest influence on chl content among all treatments for red cabbage plant recording the highest chl content (160); while broccoli plants had the highest chl content when they were treated by compost tea (118). Largest leaf area of red cabbage (454 cm^2) and broccoli (250 cm^2) was linked to compost tea and nano-Se treatments, respectively. Red cabbage plants had the lowest infection rate by insects when they were treated by nano-Se. On the other hand, nano-Cu treatment resulted in the lowest infection rate of broccoli plants. Compost tea treatment resulted in the highest head weight of both red cabbage and broccoli plants. These results revealed that the integrated management is the best way for ensuring the sustainability. For example, compost tea treatment resulted in the highest biomass but in the same time plants were more susceptible for insect; therefore treating plants by both compost tea and nano-Se and nano-Cu would achieve the highest productivity and in the same time the greatest tolerance to insects (Fig. 4 and 5). This experiment was an attempt to evaluate: (1) The single effect of different kind of fertilizer on productivity of these vegetable crops under salt-affected soils; (2) Make a comparison between the conventional and nano-fertilizers;

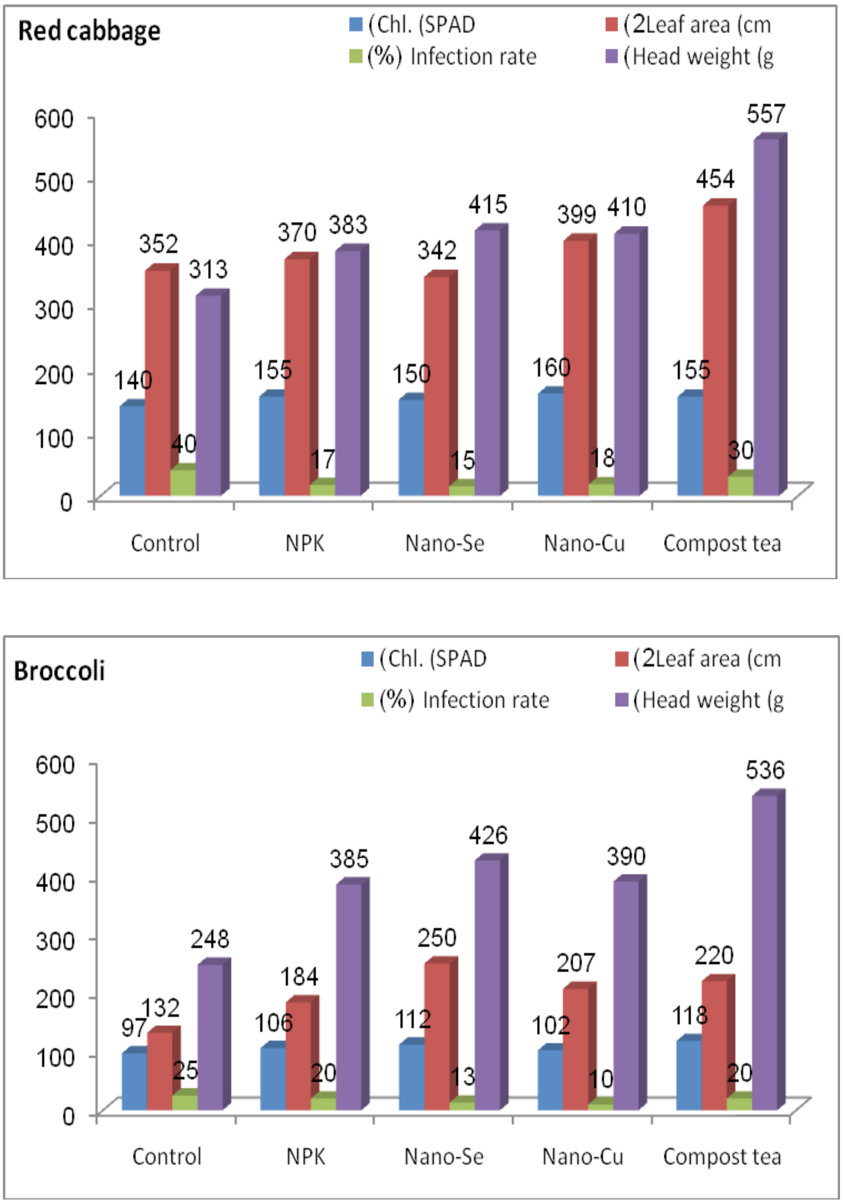


Fig. 3. Response of vegetative growth parameters of red cabbage and broccoli, head weight and infection rate to foliar application of fertilizers at harvest.

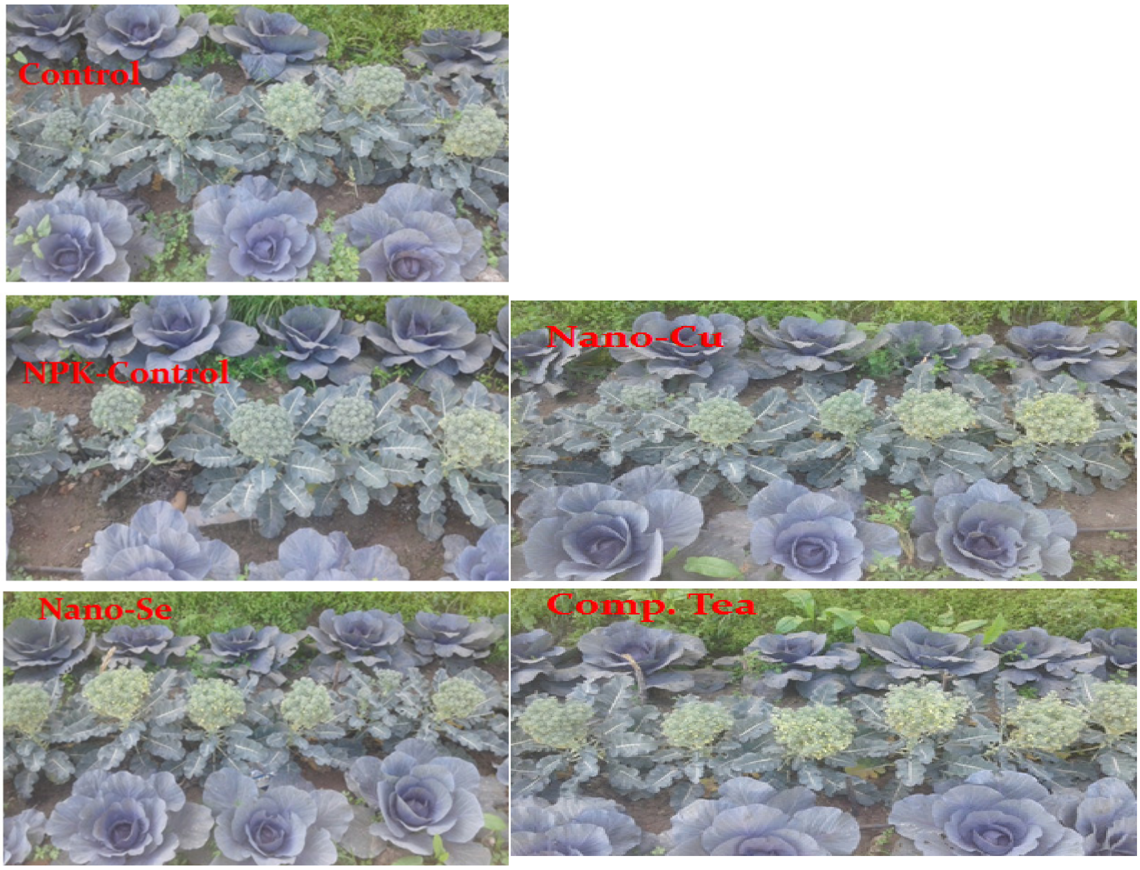


Fig. 4. An overview of the cultivated vegetable plants in the field after 2 weeks from foliar fertilizers application.

Fig. 5. An overview of some infected cultivated vegetable plants in the field after the application of foliar fertilizers.

and (3) Influence of different kind of fertilizers on plant resistance against pathogenic or infection.

Many remarks could be noticed from these results including: (1) Mineral fertilizers were and still one of the most important strategies in seeking for a high and enough yield from cultivated crops; (2) Organic fertilizer (i.e. compost tea) is NOT enough alone if we need to get the maximum production; (3) Nano-fertilizers need more investigations regarding their effects on soil biology, biofortified effects on human health, toxic effects on agroecosystem, etc.; (4) The biological method for preparing nano-fertilizers is the best and safe approach concerning the ecotoxicological effects on the environment; and (5) The integrated fertilization was and still one of the most important approaches in the sustainable agriculture.

Integrated Soil Fertility Management (ISFM)

It could be defined Integrated Soil Fertility Management (ISFM) as *"A set of soil fertility management practices that necessarily include the use of fertilizer, organic inputs and improved germplasm combined with the knowledge on how to adapt these practices to local conditions in aim of maximizing the agronomic use efficiency of the applied nutrients and improving crop productivity"*. Any of the interventions is required to increase the efficiency and profitability of food production as related to use of land, labor, fertilizer inputs and financial investments. Integrated Soil Fertility Management combines agronomic practices relating to crops, mineral fertilizers, organic inputs and other amendments that are tailored for different cropping systems, soil fertility status and socioeconomic profiles. The first entry point of ISFM is focusing on the agronomy of crops and inorganic fertilizers. Interventions on germplasm involve the selection of varieties, spacing and planting date. Interventions on fertilizer use respectively target the formulation, placement, rate and timing of inorganic nutrient inputs. The second entry point of ISFM targets interventions on organic resource management, including the return of crop residues, manure, compost and other types of organic wastes, next to rotation or intercropping with legumes and use of plant growth promoting micro-organisms. The third and last entry point of ISFM deals with any other amendments that may be needed to lift limitations to productivity such as soil acidity, micronutrient deficiency, erosion, soil compaction or pests and diseases (Bationo et al. 2018).

Therefore, the soil fertility is an important component in the sustainability of agriculture. This component should follow all management practices to protect, conserve and sustain it through a vital program. This program should include all kinds of fertilizers in harmony such as mineral, organic, biological and nano-fertilizers. More investigations are needed concerning nano-fertilizers and their effects on different compartments of the agroecosystem.

Evaluation of applied fertilizers

It is thought that, mineral fertilizers cannot dispense them but should reduce the global amount of these fertilizers to protect and conserve our environment. The using of mineral, organic and biological fertilizers should be managed to conserve the soil fertility and to get the maximum crop production. It is well known that, organic manure is a commendable organic fertilizer, as it contains nitrogen, phosphorus, potassium and other essential nutrients. The most important factors responsible for low yield are inappropriate crop nutrition management and poor soil fertility. The field experiment was performed to evaluate the impact of different fertilizer (organic and inorganic) on yield and yield components of some vegetable crops.

Day by day, a lot of fertilizers could find in the market. Some of these fertilizers are already investigated and accepted by the agricultural society. But some of these fertilizes (in particular nano-fertilizers) are still just patents and definitely need more and more studies and evaluation. The most important point is to produce nano-fertilizers through the biological methods, which more safer and active comparing with physical and chemical methods. So, it could be recommended that the "biological" nano-fertilizers are considered a promising tool in agricultural production. Furthermore, it should use mineral, organic, biological and nano-fertilizers in harmony without unfair use or over-use of anyone. Therefore, it is not important to investigate and evaluate different kinds of fertilizers but also calculate the economic evaluation. Then, a recommendation can be posted to help farmers or stalk holders in their production. Further studies about the ecotoxicological effects of different fertilizers on agroecosystem are needed.

Conclusion

Concerning nano-fertilizers, nano- copper (nano-Cu) and nano-selenium (nano-Se) have been used in this study. These nano-fertilizers were used in this investigation because of their role in enhancing the growth cultivated plants under both salinity and waterlogging stress. The effects of mineral and organic fertilizers on the crop productivity have been also discussed. The separate effects of these previous fertilizers (i.e. mineral, organic and biological nano-fertilizers) have been investigated. Further studies are needed to focus on the integrated application of these fertilizers. Therefore, soil fertility was and still and will be one of the most important strategies in the sustainable agriculture. This needs a comprehensive and an integrated program of fertilization. These fertilizers should include all kinds and should apply in right time, amount or dose, place and form as known with 4 R strategy. Biological nano-fertilizers might be promising tools in modern and non-conventional agriculture. Furthermore, urgent investigations are needed to highlight on the risks of these nanomaterials if any.Therefore, it should apply the right amounts of nutrients for cultivated crops in the right time, place, and form to get the optimal crop production. The applied fertilizers also should be integrated (i.e., mineral or chemical, organic, bio- and nano-fertilizers).

Acknowledgements

Authors acknowledge Dr. Hassan El-Ramady for his co-supervision on the students of the 4th year during their graduation project, Soil and Water Dept., and his encouragement. Authors also thank both Dr. Tamer Elsakhawy and Dr. Alaa El-DeinOmara for their supplying Nano-Se and nano-Cu (Agricultural Microbiology Lab., Soil, Water and Environment Research Institute, Agricultural Research Center, Giza, Egypt). Deep thanks for Horticulture Dept., for their help in measuring chlorophyll content and leaf area.

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(*Received* 21/12/2018;
accepted 12/2/2019)