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IMPROVING SANDY SOIL PROPERTIES BY USING FERTILIZER PELLETS MADE FROM AGRICULTURE WASTES

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ABSTRACT

Five products for fertilizer pellets made from the olive pomace (OP), biochar (Bp), bonechar (Bb) and some additives like zinc oxide nanoparticles (ZnONPs) with pellets diameters 5mm and 10 mm have been studied. Samples have been manufactured and tested on sandy soils. Results showed that pellets with 10 mm disintegrate after 24 hours while the pellets with of 5 mm were more stable for longer time. According to the SEM test, the chemical composition of tested OP pellets of diameter 5 mm for C, N and O contents were 47.5%, 16.3% and 33.1% and 49.8%, 17.0% and 32.6% for outer and inner sphere, respectively. At the column experiment, increasing pH after addition of pellets mixed with biochar due to the low buffering capacity of the sandy soil used. No salt accumulation was observed in any treatments after pellets application, and EC values remained in the appropriate range for some plant growth. Measuring the bulk density after pellets addition to the soil column at the end of the incubation, the average values of bulk density were 1.49 (control), 1.48 (OP), 1.45 (OP+Bp), 1.44 (OP+Bb), 1.46 (OP+ Bp+ Bb), and 1.43 (OP_Bp+Bb+ZnONP) g cm^{-3}. The benefit of converting the amended organic fertilizers to be pellets is to prevent the immigration of organic pellets through the soil column.

INTRODUCTION

The large quantities of agricultural waste could cause catastrophic environmental problems directly facing the farms and the government in general, if left without the proper treatment. Egypt is producing a lot of million tons of cotton and maize stalks as well as rice straw every year however the farmer burns most of it to get rid of them and to save time to prepare the cultivated area for agriculture**.** This act carries a bad impact on the environment and public health, although it can be used directly or almost directly without any techniques on them. However, some agricultural waste must be carried out operations for reuse as a useful application. The helping of applications on agricultural wastes maximizes their utilization and creates employment opportunities and increases the economic growth of the country.

On the other hand, there is a shortage in the production of fertilizers and animal feed and also researches that is concerned with the production of fertilizers from agricultural waste, which leads to increased prices of those products. One of the most important applications and most famous at all that are concerned with the work on agricultural waste for reuse in ease is the process of palletization that process in which the raw material component changes into pellets or cubes, under the influence of pressure and temperature. Many models work on it like the screw press, the piston

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press, the roller press mill, the pellet mill, and the others designs **(Shankar *et al.*, 2011)**. The palletization advantage for this application is not just the ease of storing, handling and transporting the material but also to maximize the using of agricultural wastes**(Tabil, 1996)**.

One of the most important agricultural wastes found in North Sinai is olive pomace wastes, due to the interest of farmers in planting olive trees and the occurrence of this place in the Mediterranean countries that are interested in that agriculture. About 50-60% of these huge quantities of the olive pomace are found around the olive oil production factory and it is difficult to use in the process of fertilizing directly **(Kavdır *et al.*, 2009)**. In addition to the National Project of the State, cultivation of 100 million olive trees. Hence, this huge number of olive trees would produce a lot of wastes and olive pomace wastes.

In sandy soils, the fertilization of plants faces a significant problem, the unstable fertilizer in the soil around the roots of plants because of the high porosity of sandy soil. It is also overcome the salinity of the soil at times gives excessive amounts of irrigation water. These massive amounts of water cause washing of the soil with all its components with the remaining fertilizer elements as well. The objective of the current work is to examine different mixtures of organic residuals pelletized with zinc oxide nanoparticles to produce novel fertilizer pellets on soil physicochemical properties.

MATERIALS AND METHODS

Biochar and Bonechar Preparation

Biochar was prepared from olive pomace (OP) collected from an extra-virgin olive oil extractor located in the Faculty of Environmental Agricultural Sciences, Arish University, Arish City, Egypt. In the extractor disposal area, the olive mill wastes were sun-dried in the field for several months. The as-received material was broken in a jaw crusher and sieved to obtain a particle size in the range of 1.0 – 3.0 mm cm. A known quantity of dried material of olive pomace (OP) wastes was taken in the closed perforated crucible and heated in a muffle furnace **(Sadaka *et al.*, 2014)** at 400°C for 75 min, the crucibles were carefully closed using a sealing mud to avoid oxygen interaction with organic materials. The pyrolysis process in the current study is classified as a slow pyrolysis process where the required temperatures were reached their peaks after approximately 20 mins. Bonechar was manufactured in the same way as biochar was manufactured as mentioned above with exception of pyrolysis time and temperature (600° C for 90 minutes).

Synthesis of Zinc Oxide Nanoparticles

Zinc oxide nanoparticles (ZnONPs) were synthesized according to the modified method described by **Gnanasangeetha and Thambavani (2013)**. Briefly, 0.02 M aq. Zn acetate dihydrate was dissolved in 50 mL distilled water under vigorous stirring. Then aqueous 2.0 M NaOH was added drop by drop to reach pH 12 at room temperature; then the whole solution was placed in a magnetic stirrer for 2 hours. After the reaction was completed, the obtained white precipitate was washed thoroughly with distilled water followed by ethanol to remove the impurities if present. Then the precipitate was dried in an oven overnight at 60°C and during drying the complete conversion of $Zn(OH)_2$ into ZnONPs takes place. The sample was sonicated and prepared by placing a drop of ZnONPs solution on glass coated gold grid using sputtering coater (JEOL JFC-1100E) and subsequently drying in air, before transferring it into a scanning electron microscope (SEM, with a high energy beam of electrons) operated at an accelerated voltage of 130 kV (Hitachi-S 3400N). The gained results confirmed that the produced ZnO nanoparticles showed a diameter of 15-40 nm as shown in Fig. 1.

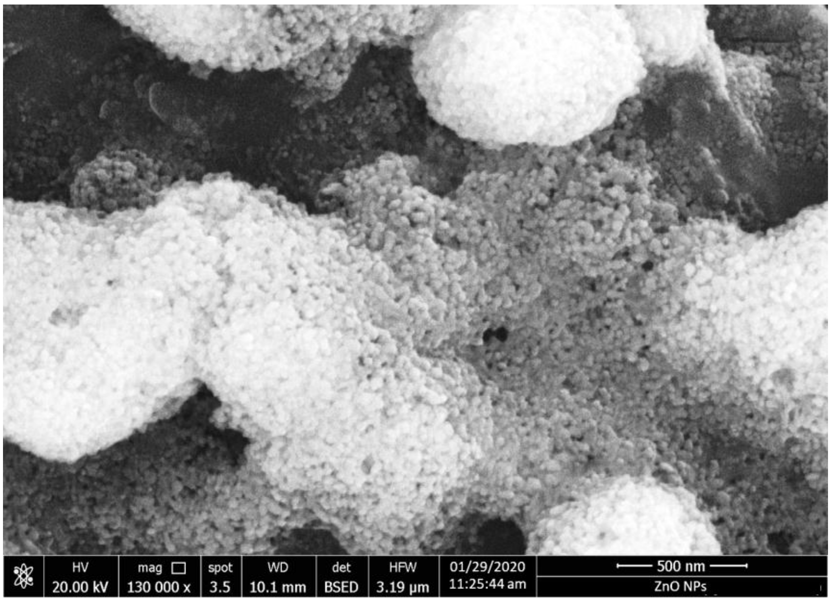

Fig. 1. SEM for Zn oxide nanoparticles

Fertilizer Pelletizing

In-house-made mixer, two different die sizes with diameters of 5 mm and 10 mm were used to produce pellets. Five types of pellets were produced: OP (as raw materials), OP + Bp (OP-derived biochar), OP + Bp + Bb (animal-derived bonechar) and OP + Bp + Bb + ZnONPs. Glycerol and molasses in a 1: 1 **(Portilla *et al.*, 2009)** with desirable amount were used as blinding materials that improve pellets productions. The mixing ratio of different organic materials was consistent with the unity with 6% of ZnO NPs. The scanning electronic microscopy (SEM) and energy-dispersive X-ray spectroscopy (EDX) (TESCAN XEIA FEG SEM, TESCAN, Ltd., Brno, Czech Republic) were undertaken at University of Maryland, United Stat to characterize the raw materials of OP.

Soil Column Experiment

Manufactured pellets were used in soil column experiments for the long term. The soil incubation was carried out in PVC columns of 30 cm height and 6 cm external diameter. A PVC end cap on the bottom of each column had a drain hole (3 mm) with an attached tube (4.3 mm) for collecting water draining out the bottom of the columns. The concave portion of the end cap was filled with approximately 200 g of coarse sand (4-7 mm). The total mass of oven dry soil in each column was 1000 g. There were two rates of pellets application, 0% (control), 3%, of each pellet components (*W/W*). The pellets were completely mixed with the top layer of soil in all treatments (10 cm). All columns were packed to approximately similar bulk densities. Bulk densities values ranged from 1.32 gcm^{-3} to 1.46 gcm^{-3}, depending primarily on the pellet application rates. The columns were incubated for seven leaching events. Every event lasting for a week. The 12 columns (duplicates) were randomly distributed in two square tables (Fig. 2).

Every seven days, 150 ml of 0.001M $CaCl_2$ solution was added to each column to produce a leaching event. Dilute $CaCl_2$ was used to reduce soil dispersion. The solution was introduced on the top of each column at approximately 4 ml/min, using a dropper system. The fiberglass filter paper was placed at the soil surface of each column to help disperse solution drops as they impacted the soil.

Fig. 2. The process of simulating irrigation in sandy soils and making some measurements on soil solution, leachate and percentage of organic matter.

At the end of the column experiment, a vertical section was made in all soil columns to see the shape of the fertilizer after the irrigation process, and whether it still took its shape or not. Also, the vertical sections were divided into horizontal sections to measure the percentage of organic matter **(Walkley and Black, 1934**) within each of the soil sections and measure the pH and EC of the soil solution during 3 sections above, middle, and bottom column soil at 0-10, 10-20 and 20-30 cm, respectively. Collected soil samples were oven-dried at 75° C for 24 hours, and EC and pH were measured in a soil solution ratio of 1:5 and 1:2.5, respectively. Sample pH was determined using a pH Meter (HANNA Instruments, Ann Arbor Michigan). The EC was determined using a conductivity meter (HANNA Instruments, Ann Arbor Michigan). All analyses were performed in triplicate. The concentration of DOC in leachate was evaluated by spectrophotometer (Model; CE1011, Cecil Instruments Limited) at 360 nm. Samples were diluted where necessary to obtain absorbance values in the range 0.0- 1.2. The DOC concentrations were calculated using the following formula:

$$DOC\ (gm^{-3}) = 160.1A + 6.9$$

Where, DOC is the dissolved organic carbon concentration (gm^{-3}), A is the measured absorbance in 1 cm cell.

Water Retention and Bulk Density of Treated Soil

This experiment consists of measuring the water retention of the treated soil and measuring the bulk density of the fertilized soil. The total weight of the soil column is 100 g, including 2 g of the pellet which is distributed in the top half of the soil column (4 cm). Water partitioning was assessed for every leaching event during the incubation by measuring the mass of water draining out the bottom of the column, water retained within the column, and water evaporated out the top of the column. The weight of each column was determined before the start of a leaching event and the mass of water retained within the column was determined by subtracting the initial dry column weight. Drainage was collected for approximately 24 hr., after the beginning of the leaching event in plastic bottles placed below each column and connected with the drainage tube. The collection bottles had a cap with a small hole that allowed the drain tube to be fitted into the bottle to minimize evaporation loss. The weight of each bottle was subtracted from the weight of the bottle without solution and weekly drainage was determined. Evaporation was assessed by computing the difference between water added and drainage plus any change in water content. Evaporative Demand Temperature in the room where the columns were incubated was kept constant during the incubation. Nevertheless, there were differences in temperature across the room and evaporative demand was also influenced by proximity to overhead air circulation fans. In order to consider these differences, evaporative demand was determined. For this, PVC cups were filled with an equal amount of water and placed above each column. Several times during the period of two or three days, the PVC cups were weighed to determine the average water loss per hour for each column. This measure of evaporative demand was used as a covariate in the statistical analysis.

Bulk density was determined before and after every leaching event. The distance from the top surface soil to the top of the column was recorded and the volume of soil was determined. Bulk density was calculated by dividing the mass of soil by the soil volume. This approach assumes no changes in soil mass during the incubation and the value obtained was the average bulk density of the column.

Statistical Analysis

Statistical analysis including Pearson correlation coefficients were determined using Minitab ® 15.1.3.0.; the default level of confidence was 95.0% ($P < 0.05$) unless stated otherwise in the discussion.

RESULTS AND DISCUSSION

Olive Pomace Characterization

Sample SEM micrographs with EDX spectrum of olive pomace pellets as a basic component of manufactured fertilizer are shown in Figs. 3, 4, 5 and 6. SEM images were taken at several magnifications ranging from 5000X to 10000X. Only one representative image was selected from the outer surface (Figs. 3 and 4) and the inner cross-section (Figs. 5 and 6) of manufactured pellets at die 10mm. Visual inspection of these images illustrates the differences in microstructure between the inner and outer surface, with distinct micropores observable, especially in the inner structure (Fig. 5).

Overall, the picture from the outer surface shows a rough surface while from the inner cross-section some pores are generally more developed although both materials had a significant number of visible pores. No doubt that the porous structures of comparable olive pomace-derived biochar would show a variety of shapes and sizes that cover the ranges of micropores, mesopores, and macropores. **Claoston *et al.* (2014)** reported that with converting raw material to biochar, the structure would become more ordered because the number of micropores decreased while the number of macropores increased **(Yunqiang *et al.*, 2020)** (SEM of biochar is not included in this study).

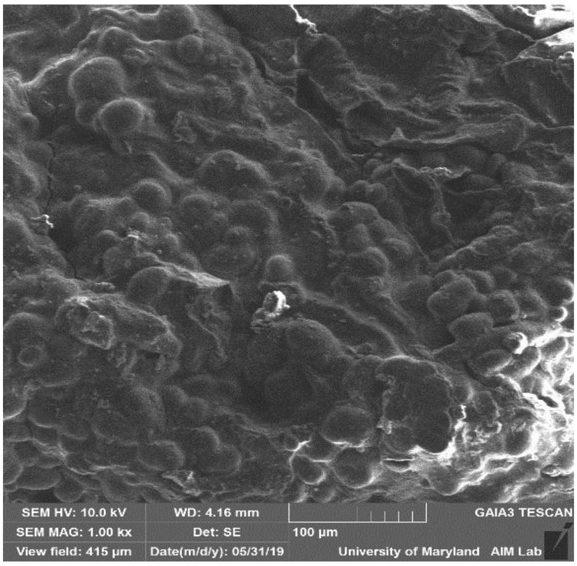

Fig. 3. SEM images of olive pomace pellets at 5000X magnification from outer sphere

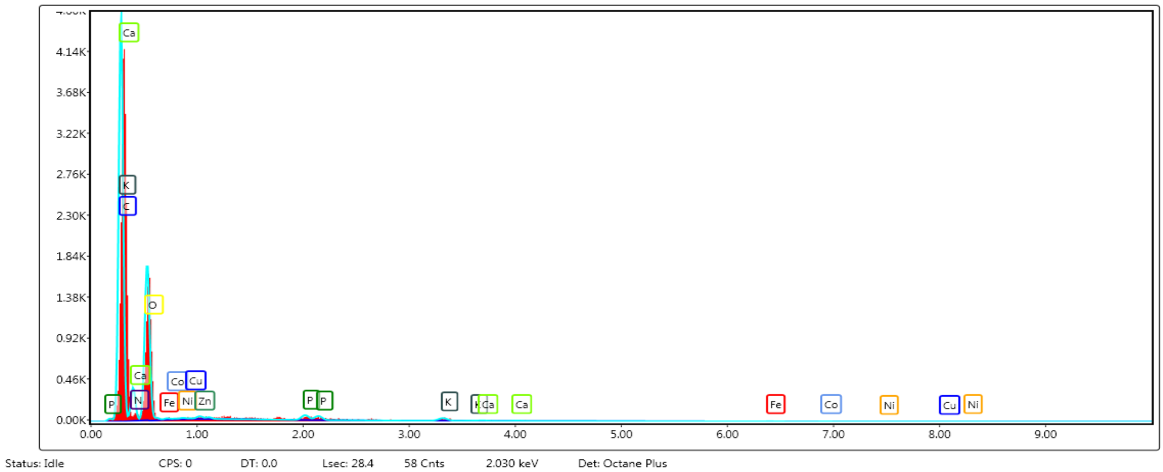

Fig. 4. EDX spectrum results of the outer sphere of olive pomace pellets

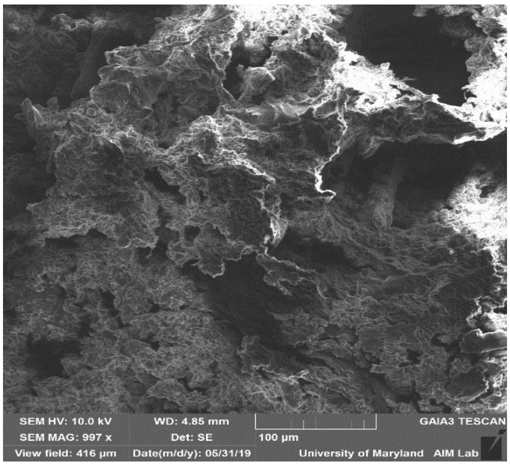

Fig. 5. SEM images of olive pomace pellets at 5000X magnification from inner sphere cross section

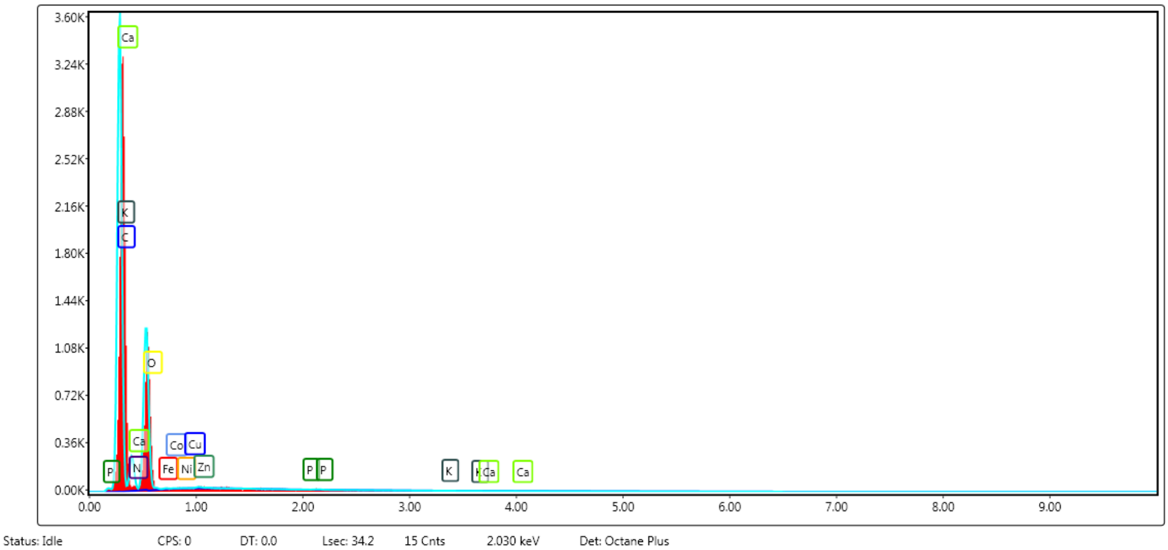

Fig. 6. EDX spectrum results of inner sphere cross-section of olive pomace pellets

Therefore, expected increase in network of pores in olive pomace -derived biochars suggest potential in soil amendment as the biochars porosity can play an important role in facilitating the movement of roots through the soil, serve as habitats for a variety of microorganism, and help in the storage for water in soil **(Downie *et al.*, 2009)**. For soil applications, the macropores in biochar affect the soil's hydrology and microbial environment. The larger the pores, the easier the penetration of water, plant roots and fungal hyphae in the soil particles **(Claoston *et al.*, 2014).**

The elemental composition of olive pomace pellets was assessed by measurement of C, H and N in the solid OP raw material as analysed by SEM-EDX; percentages by weight of different elements are given in Table 1. Overall, the chemical composition of tested OP for C, N and O contents were 47.5%, 16.3% and 33.1% and 49.8%, 17.0% and 32.6% for outer and inner sphere, respectively. Total metal content in the outer sphere was significantly greater than it in the inner sphere, suggesting much more nutrients were stuck in the surface area of OP compared with inner pores. These results reflect the nutrient enrichment in selected organic materials that could be favourable for improving soil fertility.

Stability of Manufactured Fertilizer Pellets

In an attempt to evaluate the stability of manufactured organic fertilizer pellets, each treatment was soaked in a sufficient amount of distilled water for different times (0, 4, 17 and 50 days). Inflation, shrinking, or deterioration was observed for each treatment during the incubation course. In the first attempt to evaluate the pellets obtained from die 10 mm, it was found that pellets were dissociated within 24 hrs and after 4 days were converted to water suspension (Fig. 7). Therefore, the stability experiment with organic pellets fertilizers synthesis using die 10 mm was terminated. This observation might be explained by low sticky material with the bigger diameter pellets **(Tumuluru *et al.*, 2010)**.

In the following part, the results obtained from all the treatments of organic fertilizers pellets manufactured from die 5mm will be presented and discussed. Figure 8 shows the behavior of OP (olive pomace as a raw material) as a function of incubation time. The results showed an increase in the length of pellets during the incubation course

Table 1. The elemental composition of solid olive pomace analysed by SEM-EDX; percentages by weight for both outer and inner-sphere surface

Element	Outer sphere	Inner sphere
C	47.5	49.8
N	16.3	17.0
O	33.1	32.6
Fe	0.45	0.30
Co	0.12	0.06
Ni	0.24	0.05
Cu	0.12	0.01
Zn	0.38	0.13
P	0.70	0.01
K	0.86	0.01

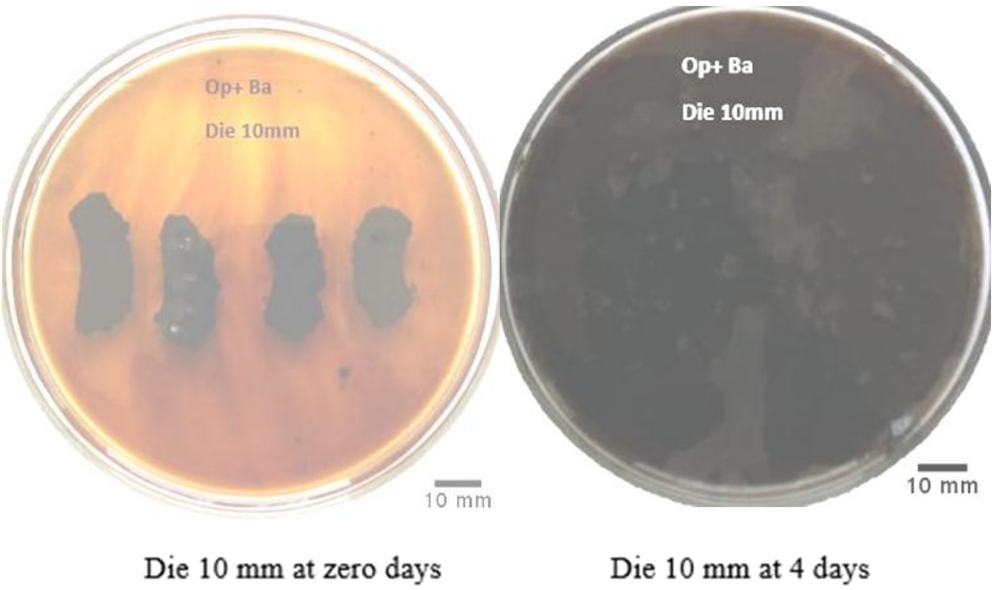

Fig. 7. Degradation of pellets manufactured using die 10 mm. This image is for demonstrates the instability of pellets at die 10 mm.

reflecting the inflation rate of fertilizers. A significant polynomial relationship was found between inflation rate and incubation time (R^2 = 0.98; Fig. 8). It seems the raw materials of OP are stable for long period. However, the existence of phenolic compounds in the olive pomace raw materials is not favorable for soil or plant growth. One major concern should be taken into our account is that toxic phenolic compound exists in olive pomace raw materials **(Cardoso *et al.*, 2005; Chanioti and Tzia, 2018; Manzanares *et al.*, 2020)**. Therefore, reducing the raw material of OP by charging it will decrease the phenolic compounds in the produced fertilizer. In a study undertaken by **Radwan *et al.* (2020)**, the author measured the phenolic compound in OP raw materials and its charing one. The author found that the total phenol compound in OP was reduced to half by carbonization OP raw materials suggesting that processing OP raw materials decrease the concentrations of total phenol compounds to its half concentrations; the concentration of total phenol of OP raw materials was 0.61 % while the same value was reduced to be 0.32% after processing to produce OP-derived biochar. This finding could highlight the importance of producing biochar from OP raw materials in terms of environmental protection.

An unexpected result was obtained when OP was mixed with OP-derived biochar (Bp) with a mixture ratio of 1 :1. Fig. 9 shows a decrease in pellets lengths as a function of the incubation course. The results suggested that plant-derived biochar (*i.e*. OP-derived biochar; Bp) is a little bit unstable due to the fast dissociation of such material under experiment conditions. The decline of pellets follows an exponential relationship during the incubation course.

In contrast, by replacing Bp with animal bone biochar (Bp) with the same mixture ratio (1:1) with OP, the belts were increased reflecting its stability and inflation rate (Fig. 10. These results suggest that Ca enriched Bp could be the main factor responsible for adhering effect of the pellets materials. It has well known that divalent cation (Ca^{2+}) can more effectively induce aggregation than monovalent cation (Na^+) **(Chen and Zhang, 2012**). The bonechar has a significant amount of Ca concentrations **(Afsharmanesh, 2021)**. The results showed a significant increase of PO+Bp during the incubation course followed by a polynomial relationship with a determination value of R^2 = 0.73 (Fig. 10).

Existence of Bb with the mixture of OP and Bp with a ratio of 1:1:1 improved the stability of the manufactured organic fertilizer pellets. As seen from Figure 11, the pellets were inflated during the incubation course up to 50 days. A significant polynomial relationship was observed at a determination value of R^2 = 0.96 between increase in the length of pellets and the incubation periods.

Finally, improving the organic fertilizer by adding ZnO nanoparticles (ZnNP) to increase the fertility effects of organic fertilizers shows a different trend. Figure 12. Shows an increase of pellets length of a mixture of OP+Bp+Bb+ZnNP with a ratio of 1:1:1 and 6%, respectively. This increase obtained up to 17 days then declined trend was observed but not less previous period point.

In terms of percentage change of length of pellets, Fig. 13 shows that the treatment of OP+Bp and OP+Bb+Bp+ZnNP showed promising results. Although OP + Bp reached the highest change value with stability behavior, OP + Bb + Bp + ZnNP showed consistent increment with nanoparticle favourable addition.

In conclusion, the current simple experiment showed that both materials of OP with Bp and Bb with ZnO NPs are more stable for the incubation terms compared with the other treatments. Figure 14 shows the visual observation of pellets soaked in water in Petri dishes.

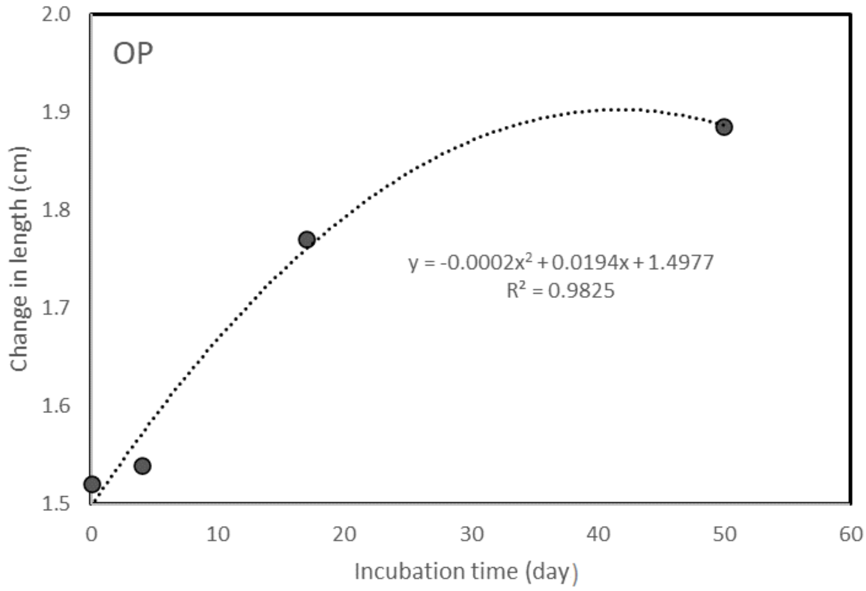

Fig. 8. Relationship between incubation time (day) and change of the length of olive pomace (OP) pellets (cm) as soaking in water. The dashed line represents the polynomial relationship

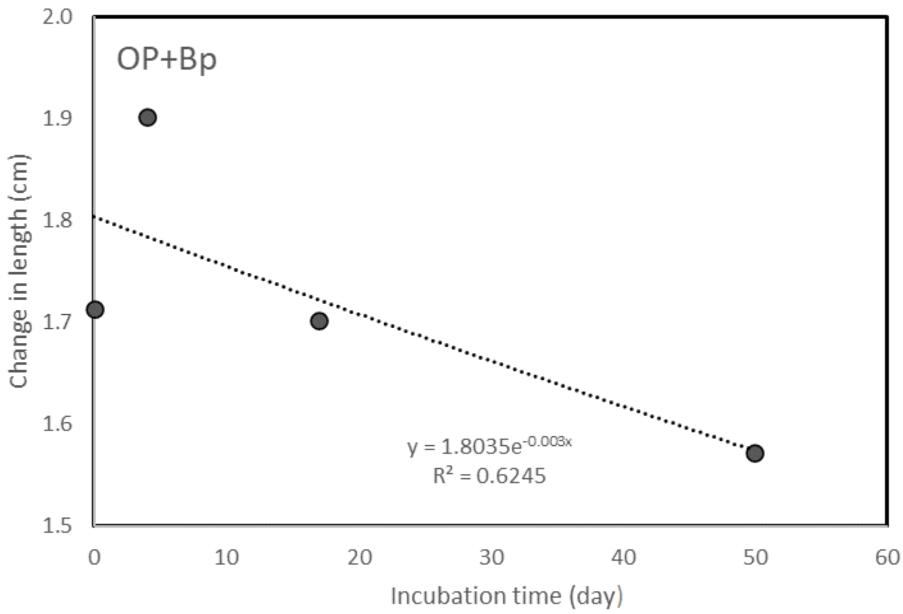

Fig. 9. Relationship between incubation time (day) and change of the length of olive pomace (OP) mixed with olive pomace-derived biochar (Bp) pellets (cm) (1:1 ratio) soaking in water. The dashed line represents the exponential relationship

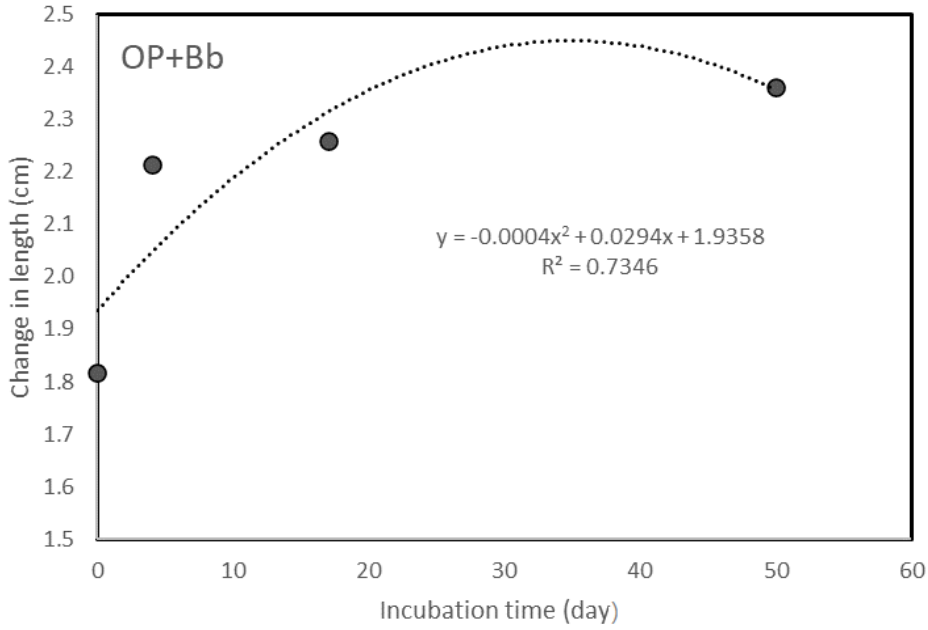

Fig. 10. Relationship between incubation time (day) and change of the length of olive pomace (OP) mixed with animal bone-derived biochar (Bb) pellets (cm) (1:1 ratio) soaking in water. The dashed line represents the polynomial relationship

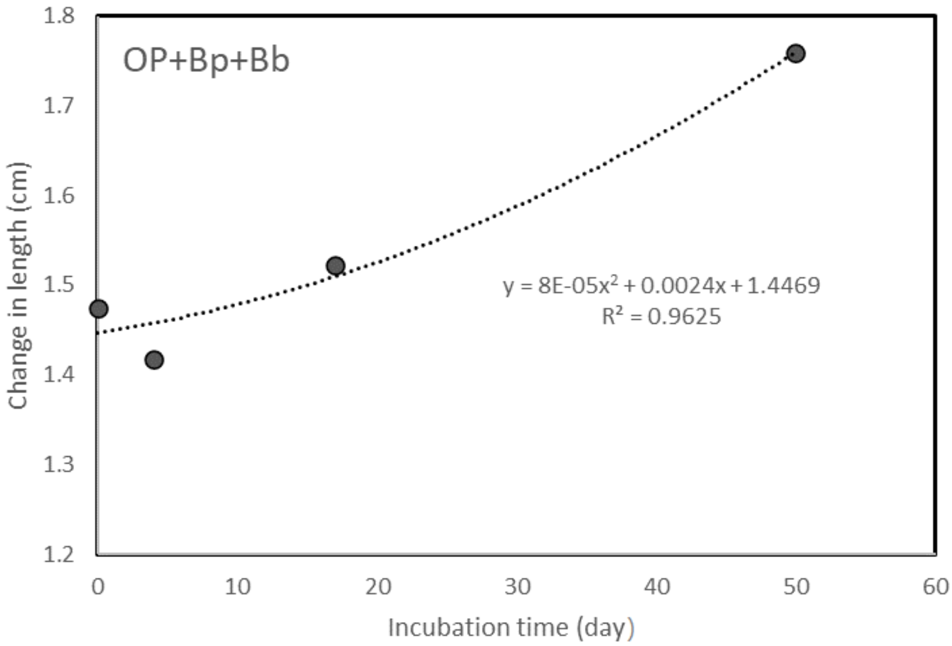

Fig. 11. Relationship between incubation time (day) and change of the length of olive pomace (OP) mixed with animal bone-derived biochar (Bb) and olive pomace-derived biochar (Bp) pellets (cm) (1:1:1 ratio) soaking in water. The dashed line represents the polynomial relationship

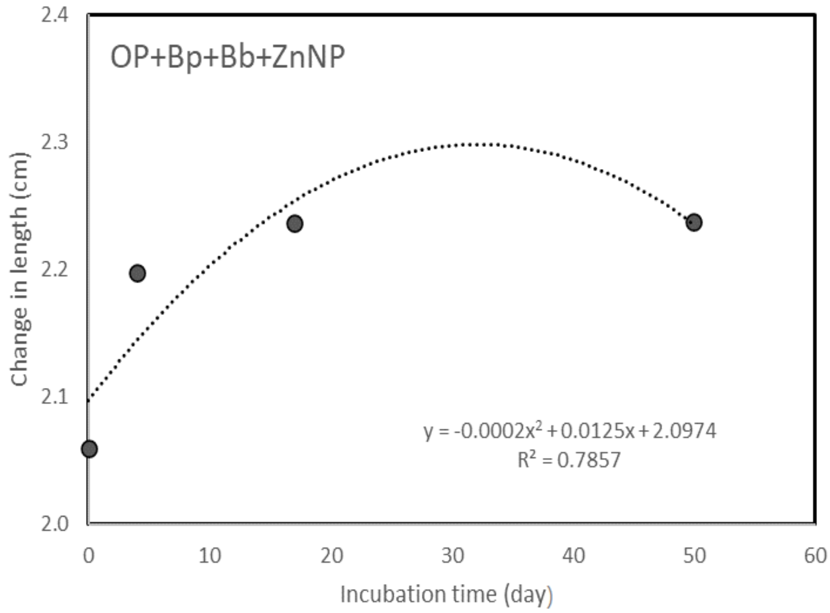

Fig. 12. Relationship between incubation time (day) and change of the length of olive pomace (OP) mixed with animal bone-derived biochar (Bb), olive pomace-derived biochar (Bp) and ZnO nanoparticles (ZnNP) pellets (cm) (1:1:1 ratio and 6%, respectively) soaking in water. The dashed line represents the polynomial relationship

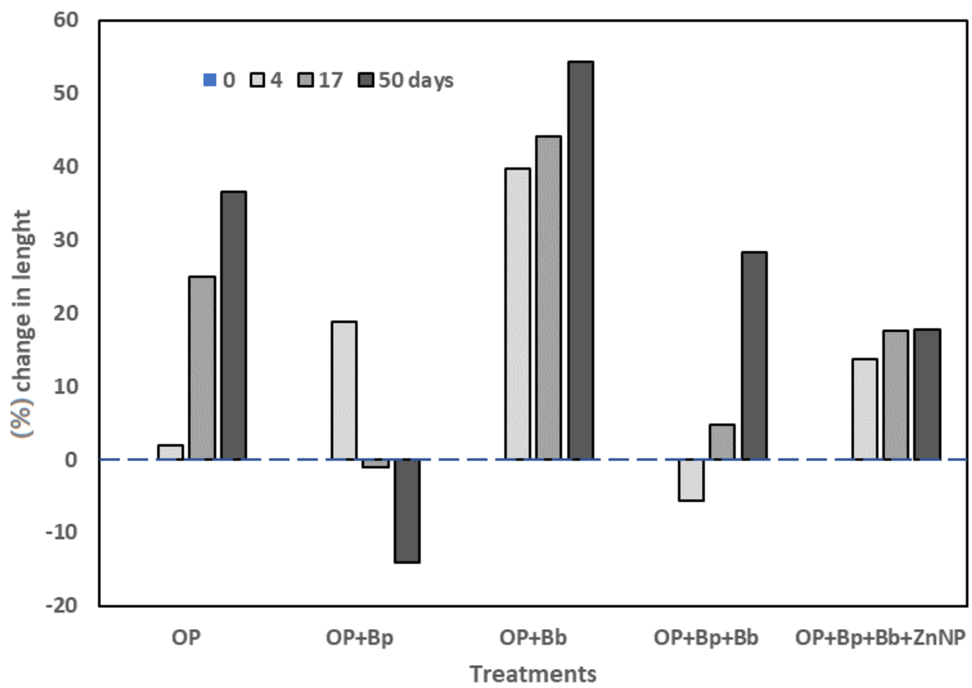

Fig. 13. Change (%) from initial measurement (at zero time) as a function of incubation time (0, 4, 17 and 50 days) of all tested treatments. The dashed horizontal line represents the baseline as zero-day time

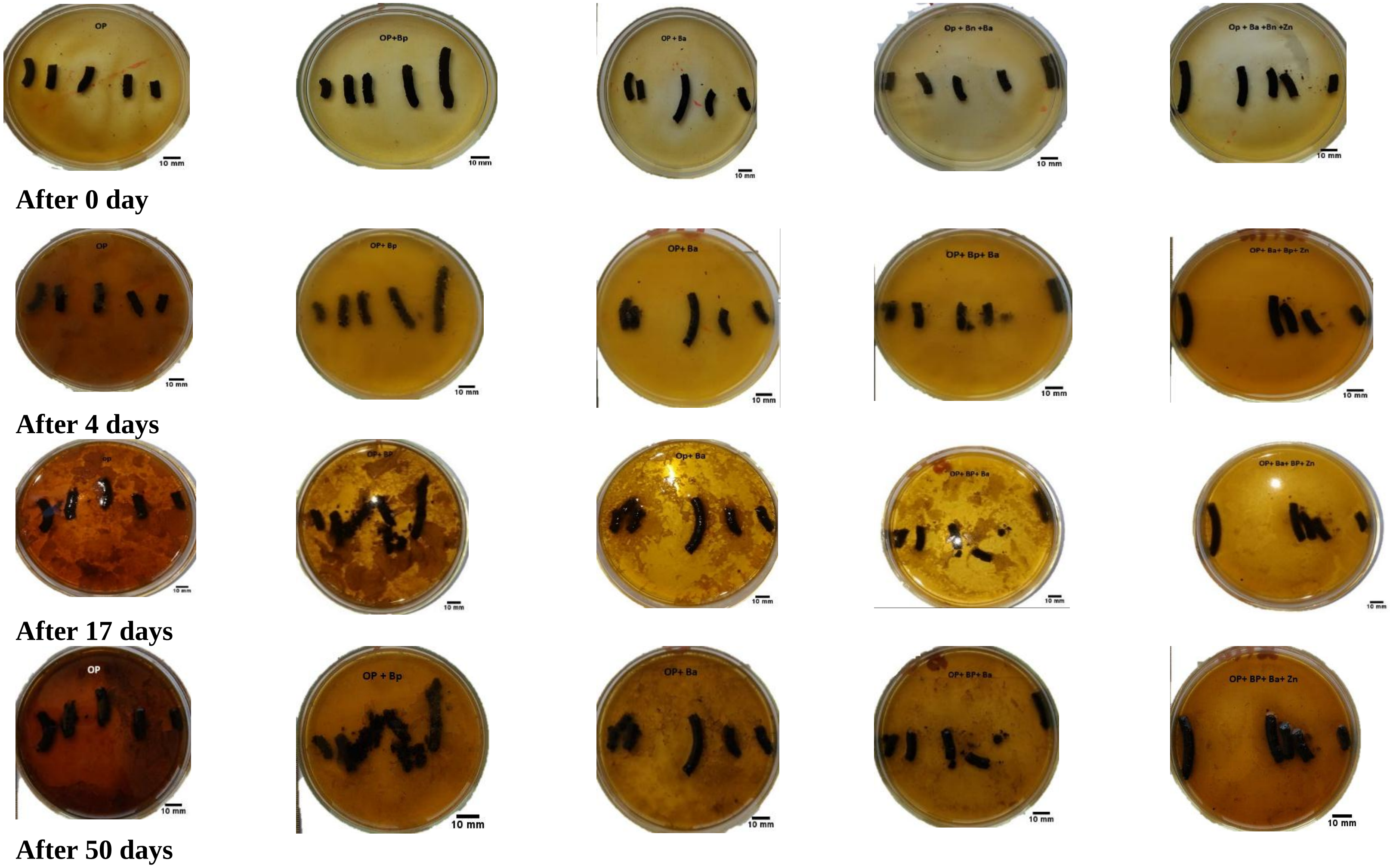

Fig.14. Images representing change in length (inflation or degradation) of tested manufactured pellets soaked in water for different times

Leachate pH, EC and DOC

Figs. 15, 16 and 17show the effect of different types of pellets added to sandy soil on pH, EC and DOC of soil pore water, respectively. Significant increase has been observed in soil water leachate pH (as general average values) with increasing the incubation course ($r>0.90$; $p < 0.01$; Fig. 18). All pH values were near to neutral value and with approximately one pH unit. The maximum pH value was corresponding to OP+Bp (pH = 7.64) after 336 hrs of incubation (Figure 15). However, it is interesting to note that all pH values were lower than that of the control (without any addition). A significant difference (< 0.01) has been found between the pH values measured at initial addition time and those measured at incubation time higher than 96 hrs.

EC values (Fig. 16) showed a decrease with increasing incubation time to the sandy soil. A negative significant relationship has been observed between EC values and incubation time as the interaction could be reached equilibrium ($r = -0.88$; $p < 0.01$) (Fig. 19). The maximum EC value was corresponding with 2.26 ± 0.66 dSm^{-1} at zero time. Regarding the impact of added biochar on soil pore water dissolved organic matter (DOC), Fig. 17 shows that a significant increase of DOC measured in soil pore water collected from sandy soil was amended with different types of added pellets compared to the control.

In general, the increasing pH after the addition of pellets mixed with biochar due to the low buffering capacity of the sandy soil used **(Alburquerque *et al.*, 2014)**. This limiting effect is considered positive in acidic soils, especially if they are limited by metal toxicity or nutrient deficiencies, but it can lead to negative effects associated with excessively high soil pH values. In our case, the pH of the soil pore water reached values lower than 7.6 after the application of all types of organic pellets, which may or may not have negative effects on crop production. Similar to pH, soil EC values increased with biochar addition to a greater extent for those biochars richer in ashes **(Alburquerque *et al.*, 2014).**

No salt accumulation was observed in any treatments after pellets application, and EC values remained in the appropriate range for some plant growth. Soil pore water EC results varied with a greater influence of the type of different added pellets, and this shows a significant difference among pH and DOC. The decomposition of pellets containing biochar and raw materials of OP could be expressed as C loss by dissolving in soil pore water. Only a small portion of biochar C moved as DOC. These findings are consistent with previous studies that reported minimal DOC leaching from biochar-amended field plots **(Major *et al.*, 2010; Bell and Worrall, 2011)**. Most of the DOC was lost during the first flush (lower than 72 hrs, see Fig. 17), suggesting that the majority of leachable C may be removed during the first rain event after the pellet's amendment. Once in the field, pellets can be microbially decomposed **(Baldock and Smernik, 2002)** and physically broken down **(Spokas *et al.*, 2014**) but this depends on the stability values of pellets themselves and the field condition.

In general, the benefit of converting the amended organic fertilizers to be pellets is to prevent the immigration of organic pellets through the soil column. This could be observed from the measurements of organic matter in different soil column sections. Figure 20 shows that total organic matter measured in the soil column after finishing the column experiments at 0-10, 10-20 and 20-30 cm.

The results indicated that the highest OM content was observed in the top 10 cm of the soil column for all pellet types compare to the control which confirms our expectation.

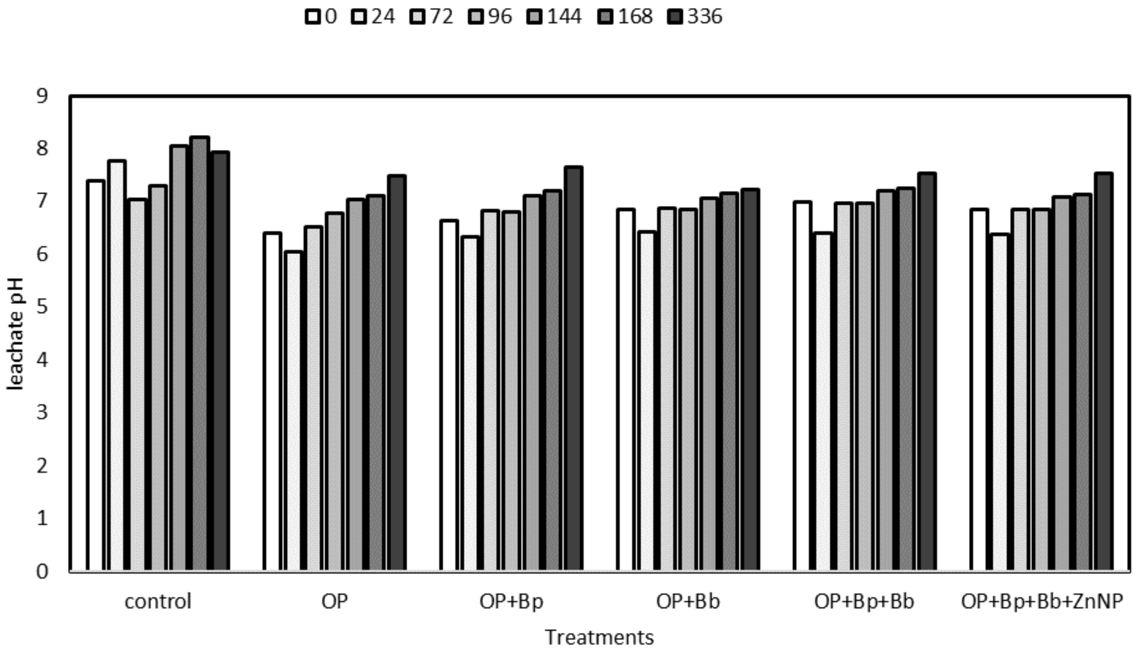

Fig. 15. pH values of soil leachate resulting from adding different types of organic pellets as a function of incubation time (0, 24, 72, 96, 144, 168 and 336 hrs)

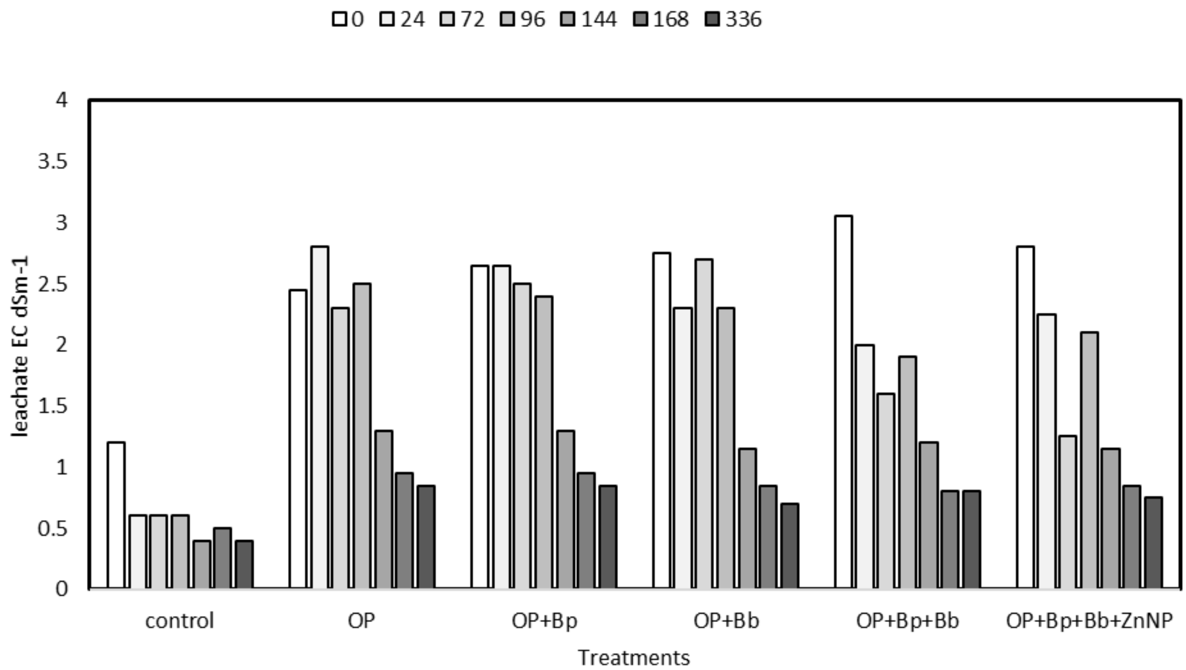

Fig. 16. EC values of soil leachate resulting from adding different types of organic pellets as a function of incubation time (0, 24, 72, 96, 144, 168 and 336 hrs)

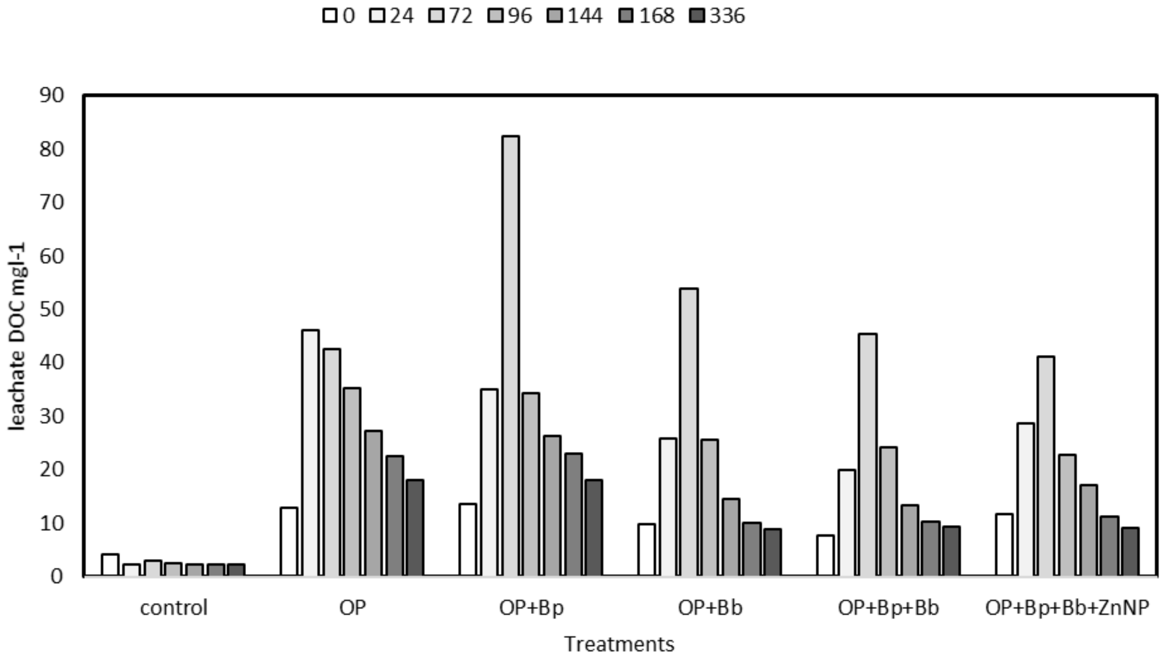

Fig. 17. DOC values of soil leachate resulting from adding different types of organic pellets as a function of incubation time (0, 24, 72, 96, 144, 168 and 336 hrs)

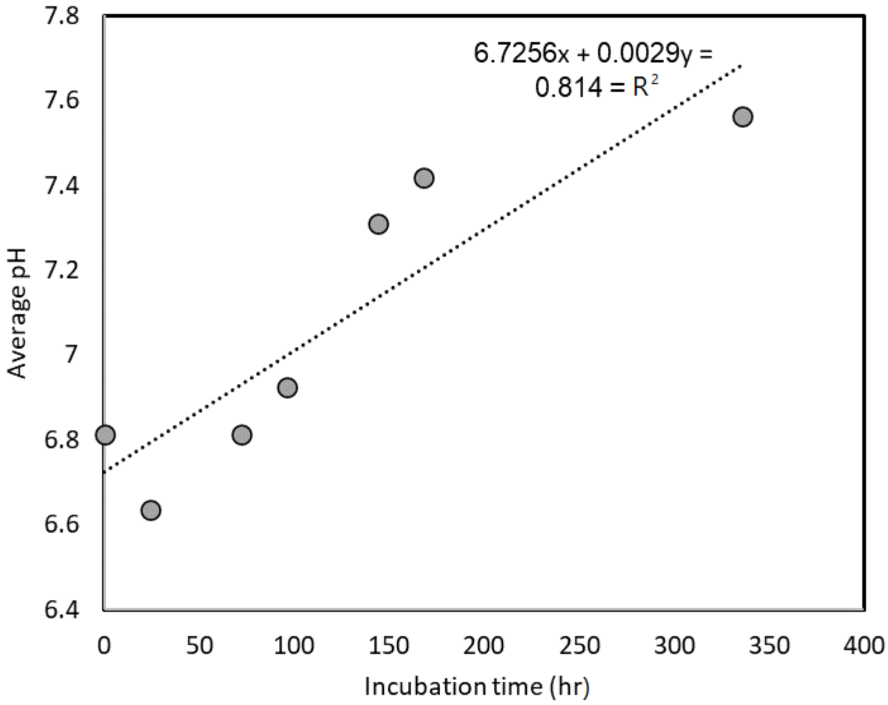

Fig. 18. Liner relationship between general average values of pH measured in the leachate and incubation time in the whole column experiment dataset. Dashed line represents a liner relationship

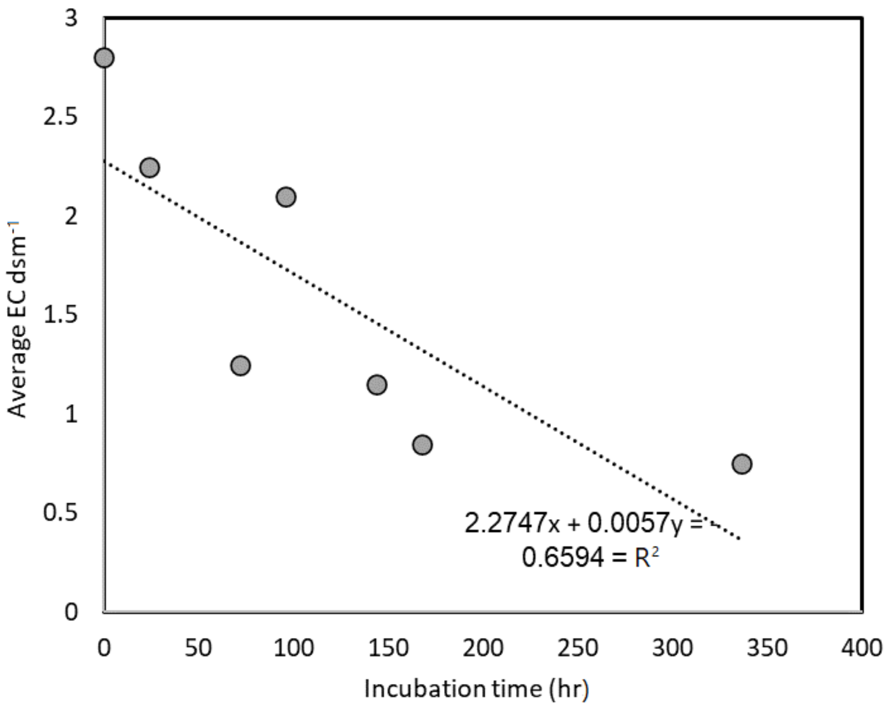

Fig. 19. Liner relationship between general average values of EC measured in the leachate and incubation time in the whole column experiment dataset. Dashed line represents a linear relationship

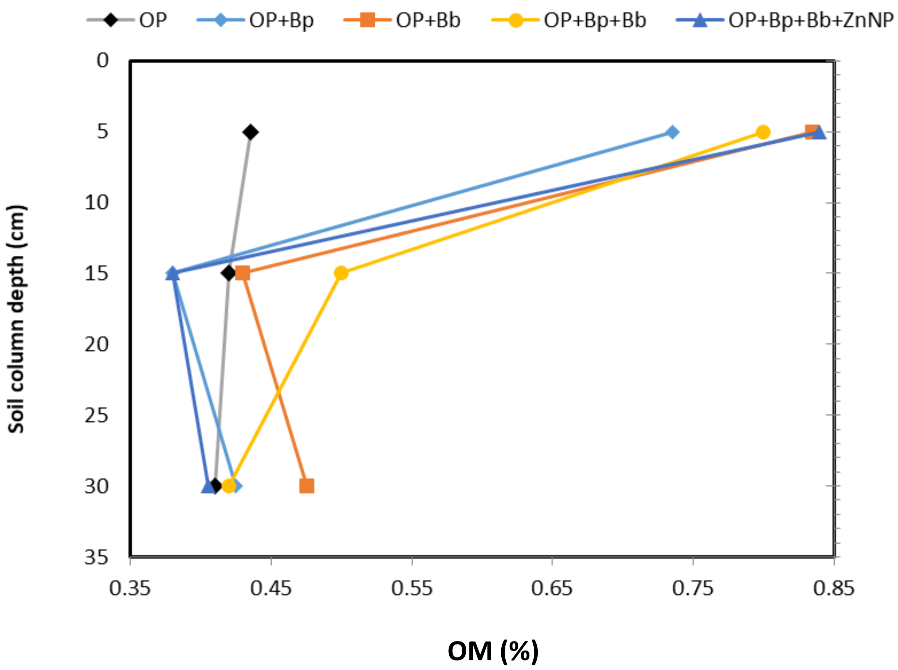

Fig. 20. Distribution of total soil OM (%) in the soil column at the end of the incubation course

Moreover, soil EC and pH measured at the three different sections of the soil column after incubation course was presented in Figs. 21 and 22, respectively. Although both values were increased at the middle section of the soil column then decreased at the bottom of the column, they all are in the safe range for plant growth and good soil characteristics.

Determine Changes in Bulk Density after Pellets Addition to the Soil Column

The bulk density of the control columns increased significantly during the incubation from 1.46 to 1.49 g cm^{-3} for 0 and 96 days of incubation course, respectively (Fig. 23). At the end of the incubation, the average values of bulk density were 1.49 (control), 1.48 (OP), 1.45 (OP+Bp), 1.44 (OP+Bb), 1.46 (OP_Bp+Bb), 1.43 and (OP_Bp + Bb+ ZnNP) g cm^{-3}. Other researchers have also found a decrease in soil bulk density after organic fertilizer including biochar additions **(Laird *et al.*, 2010; Githinji, 2014; De Jesus Duarte *et al.*, 2019)**, probably due to the low bulk density of the biochar itself **(Downie *et al.*, 2009**). A decrease in bulk densities may promote plant root elongation **(Voorhees *et al.*, 1975)** and root density **(Thompson *et al.*, 1987**). In addition, reduction of bulk density by 12% has been shown to improve water infiltration by 27% **(Franzluebbers, 2002)**.

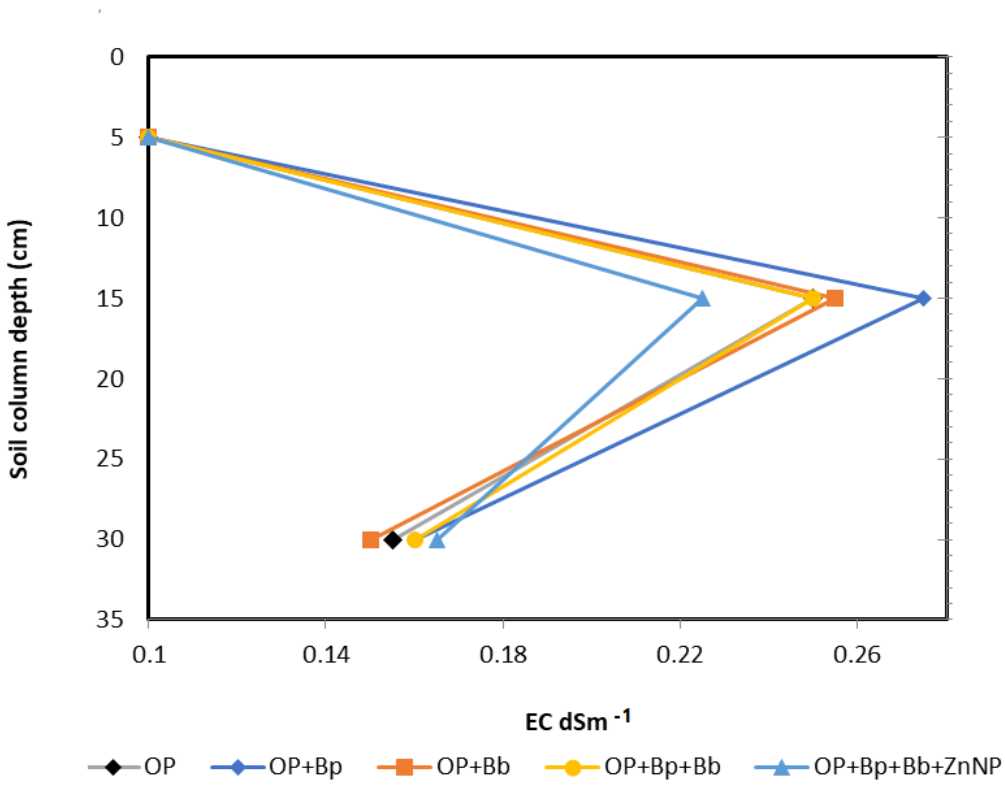

Fig. 21. Distribution of soil EC (dsm^{-1}) in the soil column at the end of the incubation course

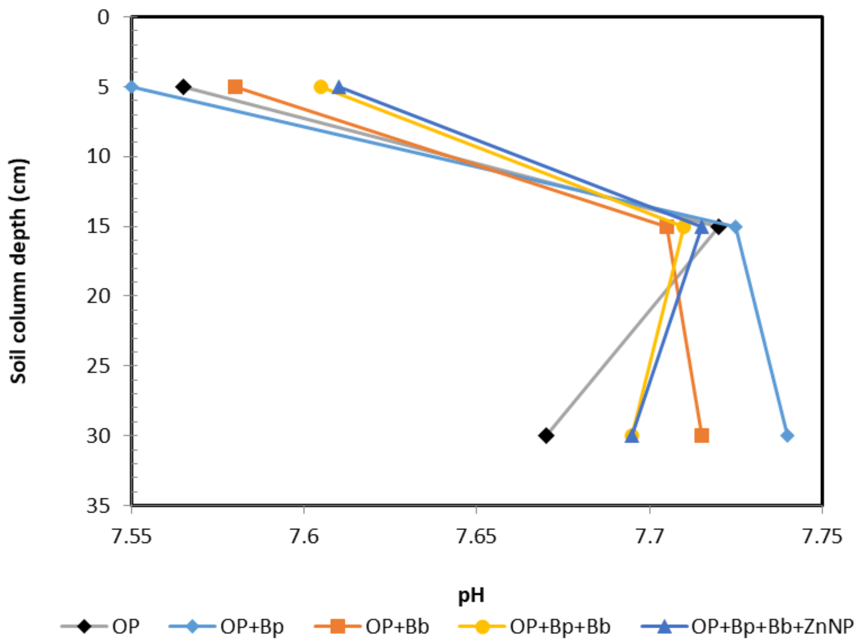

Fig. 22. Distribution of soil pH in the soil column at the end of incubation course.

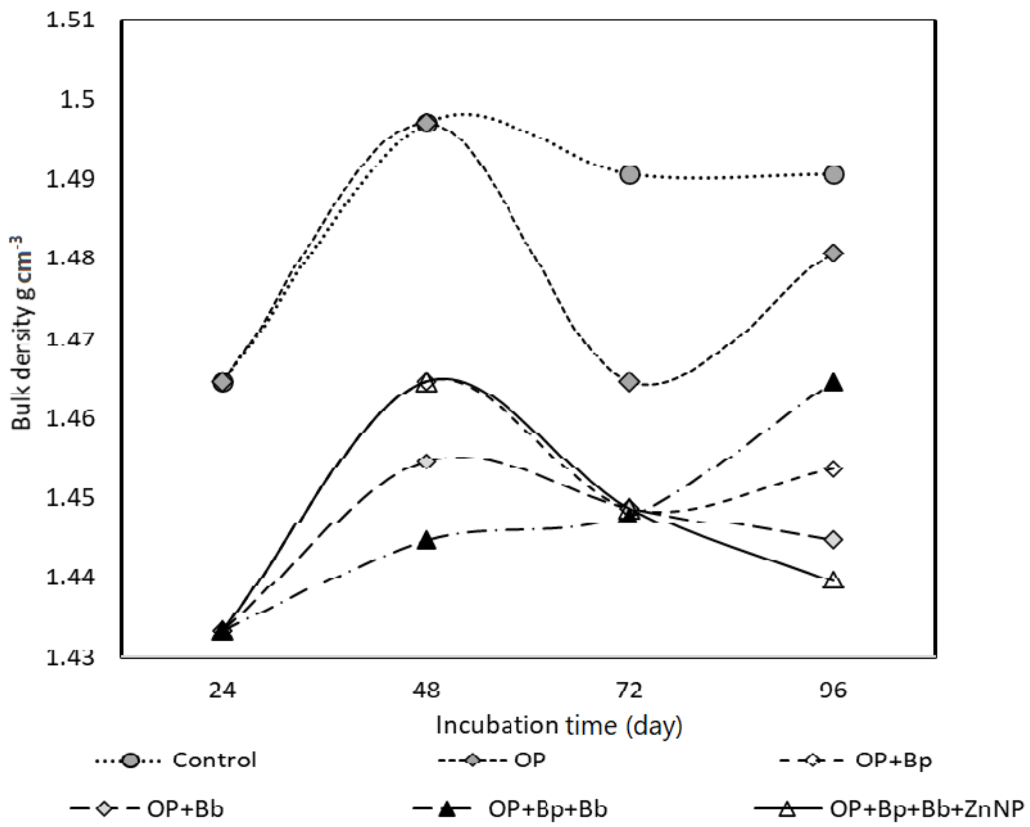

Fig. 23. Temporal dynamic of bulk density for each treatment during the 96 days of incubation. Error bare were removed for clarity

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الملخص العربي

تحسين خواص التربة الرملية باستخدام حبيبات سماد مصنوعة من المخلفات الزراعية

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إن قدرة الأرض الرملية على الاحتفاظ بالماء والعناصر الغذائية اللازمة للنبات اقل منها في الأراضي الطينية. قد تم انتاج خمسة أنواع من الحبيات من مخلف تفل الزيتون (OP)، والفحم النباتي (Bp)، فحم العظام (Bb) وبعض الإضافات الأخرى مثل جزيئات النانو لأوكسيد الزنك (ZnO NPs) بقطر 5مم وأخرى بقطر10 مم. تم عمل التجربة بمعمل كلية العلوم الزراعية البيئية جامعة العريش، مدينة العريش. تم قياس ثبات حبيبات السماد المغمورة في الماء لفترات زمنية مختلفة، أظهرت النتائج انحلال وتفكك الحبيبات بقطر 10 مم خلال 24 ساعة فقط من بداية التجربة بينما الحبيبات ب بقطر5 مم اظهرت ثباتيه اعلي اختلفت فيما بينها طبقا لمكونات الحبيبات تم العمل على الخمس منتجات لحبيات السماد وعمل SEM وبالتحليل الكيميائي أظهرت النتائج عناصر C وN وO كالتالي 47.5%، 16.3% و33.1% وذلك للطبقة الخارجية وكان 49.8%، 17.0% و32.6% من الداخل على التوالي. تم قياس الرقم الهيدروجيني (pH) والتوصيل الكهربائى (EC) لمحلول وطبقات التربة بعد ريها لفترات مختلفة وكانت قيم كلا منهما في الحدود الأمنية لنمو النباتات وخصائص التربة الجيدة وانخفضت الكثافة الظاهرية للتربة بشكل عام عند التسميد بالحبيبات، كما ان وجود حبيبات السماد تعمل على تقليل فقد الماء الي الطبقات السفلية في الأراضي الرملية حيث يدخل في بعض مكوناتها الفحم النباتي. يجب اجراء تجارب لتعميم استخدام هذه الأسمدة على النباتات بشكل مباشر في المستقبل.

الكلمات الاسترشادية: الفحم النباتي، الفحم الحيواني، التربة الرملية، الكثافة الظاهرية والمخلفات الزراعية.

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