*J. Soil Sci. and Agric. Eng., Mansoura Univ., Vol. 7 (4): 317 - 324, 2016*

# Toward A New Generation of Organic Manures: Enriched-Compressed Organic Manure As A Substitution of Ordinary Compost in Organic Farming Systems

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## ABSTRACT

There is an urgent need to maximize crop productivity of organic farming systems. For this purpose, a field experiment was carried out to evaluate the efficacy of modern enriched organic manures as compared with absolute organic manure and organic-based mineral manures application. Significant improvement in the quality of enriched manure (i.e. C/N ratio and nutrients content) was recorded following the application of mineral additives (rock phosphate and feldspar) and bio-inoculants (nitrogen fixing and phosphorus and potassium dissolving bacteria). Crop productivity was enhanced by modern enriched organic manures as compared with absolute organic manures (125.8 *vs.* 82.4 g/plant). Meanwhile, the organic-based mineral manure produced the highest yield (132.7 g/plant). Significant increase in N, P and K concentrations were recorded in fruits of plants grown in the modern enriched organic manures as compared with those grown in the absolute organic manure. Likewise, the organic-based mineral manure was the superior treatment on maximizing NPK utilization by cucumber plants. A pronounced reduction in nitrate accumulation was obvious in cucumber fruits grown in the modern enriched organic manure as compared with the organic-based mineral manure (33.1 *vs.* 66.3 mg $kg^{-1}$). Increasing the combination level of raw rice straw in organic manures (from 0 up to 75%) was associated with increasing C/N ratio, minimizing nutritive value of compost, reduction in cucumber productivity and alleviation of nitrate accumulation in fruits. Finding from this research is opening new prospective for the mass production on the commercial level of the modern enriched organic manures in organic farming systems.
**Keywords:** Compost; rice straw; rock phosphate; feldspar; bio inoculants; cucumber.

## INTRODUCTION

In Egypt, The imbalance between fast growing population and limited natural resources has led to a shortage in food supplies. Accordingly, several management practices should be undertaken in order to maximize the crop productivity and expand the total cultivated area; taking into consideration the continuous decline in the cultivated soil in the Nile Delta and Valley due to of fast urbanization. Agronomic production in sandy soil of Egypt is limited by low precipitation, high evaporation rates, low water holding capacities, high infiltration rates, low fertility levels and very low organic matter content, all of which may induce low water use efficiency (Mosa, 2012). The mega projects of land reclamation in Egypt will not only depend on delivering water canals to the desert, but several soil management practices should be undertaken during the implementation of these projects to improve the fertility of these virgin soils, and these practices should be in a sustainable manner.

There is a debate among scientists concerning the most efficient approach for sandy soil management. Some of them support the absolute organic farming system to manage the fertility of sandy soils. Others support the conventional farming system (mineral fertilization) as the most efficient approach; given the low productivity of organic farming. Consequently, there is an urgent need to capitalize a modern approach for sandy soil reclamation. This modern approach should combine the properties of sustainability of organic farming system and the high productivity of conventional (mineral) farming system.

The traditional approach of organic farming system depends on incorporating organic manures (e.g. farmyard manure, compost or green manure) into the rhizosphere (the plow layer). However, this traditional technique requires huge amounts of organic manures to achieve a significant effect; this is beside the extra cost of manpower and labor (Selim and Mosa, 2012). Therefore, it is necessarily to manufacture a modern eco-friendly organic manure source marked with high nutrients content to be able to compete with mineral sources, with a low volume to minimize the extra cost of manpower and transportation (El-Ghamry et al., 2009).

Most of research undertaken to maximize the productivity of organic manures is only focused on the combined application of sub-doses of mineral fertilizers to organic manures. However, the literature is in sufficient concerning manufacturing of modern enriched organic manures. In our research, we are introducing a new generation of organic compressed manures contains balanced constitutions of organic sources (rice straw and compost), eco-friendly mineral additives (rock phosphate and feldspars) and bio-inoculations (nitrogen fixing and phosphorus and potassium dissolving bacteria). This new generation of organic manures could maximize the low productivity of organic manures, which will encourage the investment in organic farming systems for exportation. Besides, a new type of industries (e.g. from seed to seed organic manures) could be generated, which will provide new job opportunities.

itionally, the most common approach to improve water-holding capacity and nutrient retention of sandy soils is to incorporate organic residues (e.g., green manure, farmyard manure, crop resi-dues) into the plow layer. However, this requires application of large amounts of organic residues to achieve a significant effect. In addition, application of some organic residues could be considered as a source of pathogens and weed seeds.

## MATERIALS AND METHODS

**1-Design of the experiment, and its layout.**

A Field experiment was carried out during the summer season of 2014 at a private farm located in Sherbeene District, Dakahlia Governorate aiming to evaluate the applicability of modern enriched organic manures as a substitution of the ordinary compost in organic farming systems. Cucumber (*Cucumis sativus,* L. cv. Reda) was selected to serve a tested plant based on its economic revenue. In a split plot design with three replicates, treatments were arranged to represent the possible combination between three types of substrate and four levels of combination. Main plots were assigned to the type of substrate (i.e. absolute organic manure, organic manure + mineral fertilizers and the modern enriched organic manure). In subplots the rate of organic forms combination were arranged as follows:

1- 100% compost.
2- 75% compost + 25% rice straw.
3- 50% compost + 50% rice straw.
4- 25% compost + 75% rice straw.

**2-Materials**

Mature compost (75% rice straw and 25% farmyard manure) was purchased from a private company (El-Khalil) located at Al Khattaba, Giza. Raw rice straw was obtained from Sherben District, Dakahlia Governorate. Rice straw was air dried, cut to small pieces (1-3 cm length) and preserved for the experiment. Peat moss was used as a growing media in the germination stage. Peat moss (type Shamrock) was imported from Ireland by the Ministry of Agriculture, Dokki, Giza, Cairo. The used mineral fertilizers were formaldehyde coated urea (46% N), phosphoric acid (85% $P_2O_5$) and potassium sulfate (48%K) at rates of 200, 180 and 100 Kg $Fed^{-1}$, respectively. In the modern enriched organic manures, natural mineral additives (natural ores) and microbial inoculations were added to the aforementioned organic substrates (compost and rice straw). Rock phosphate was purchased from the Fertilizers and Chemical Company at Abu-Zaabal District, Qalubia Governorate to serve as a source of phosphorus. Feldspar was obtained from Sinai Manganese Company to represent the potassium source. The chemical composition of the used organic substrates and the natural mineral additives is illustrated in Table 1. Nitrogen fixing and phosphorus and potassium dissolving bacteria were inoculated to fix nitrogen, and to accelerate the dissolution of rock phosphate and feldspar. These strains were kindly supplemented by Microbial Dept., Soil, Water and Environmental Research Institute, Giza.

**Table (1): Chemical characteristics of the organic substrates and mineral additives used in preparing compressed organic manures.**

| Chemical analysis | Organic substrates | | Mineral additives | |
|---|---|---|---|---|
| | Rice straw | Compost | Rock phosphate | Feldspar |
| Moisture content (%) | 8.35 | 27.4 | 1.2 | 0.88 |
| pH (1:10) | 6.37 | 7.42 | 7.8 | 9.22 |
| EC (1:10), $dSm^{-1}$ | 2.64 | 2.5 | 3.02 | 7.62 |
| OM (%) | 82.19 | 31.72 | N.D. | N.D. |
| Organic carbon (%) | 47.67 | 18.72 | N.D. | N.D. |
| Total nitrogen (%) | 0.61 | 1.25 | 0.03 | 0.02 |
| C/N ratio | 78.15 | 14.98 | -------- | -------- |
| Total Phosphorus (%) | 0.34 | 0.57 | 10.96 | 0.02 |
| Total potassium (%) | 0.51 | 0.62 | 0.53 | 11.22 |

**N.D. means not detected**

Chemical analysis of organic substrates and mineral additives was carried out according to the standard methods: moisture content using the gravimetric method (Richards, 1954), pH and EC in 1:10 suspension (Richards, 1954), organic matter using back titration method (Walkley and Black, 1954) and total NPK determination after the wet digestion using sulfuric ($H_2SO_4$) and perchloric ($HClO_4$) acids (1:1) as described by Peterburgski, (1968). Total nitrogen was determined using automatic Kjelahl equipment (Raypa DNP, 2000). Phosphorus was colorimetrically determined by spectrophotometer (UV-VIS Auto UV 2602) after treating with ammonium molybdate and stannous chloride. Potassium was determined using flame photometer (Jenway PFP7).

**3-Modern organic manures engineering.**

The aforementioned combinations between organic substrates and mineral fertilizers were calculated by dividing the recommendation dose of mineral fertilizers by the number of plants per Feddan. Each organic block received 5, 2.5 and 4.5 g of formaldehyde coated urea, phosphoric acid and potassium sulfate, respectively, which comprised half of the recommended dose for cucumber per Feddan. Concerning modern enriched manures, rock phosphate and feldspars were added at rates of 33 and 35 g, respectively per block. All mixtures were compressed to $2par/inch^2$ using a mechanical compressor at moisture of 40% for making compost blocks (Fig. 1). The compressed blocks of organic manures were air-dried until the weight constant (less than 5% difference between successive two weights).

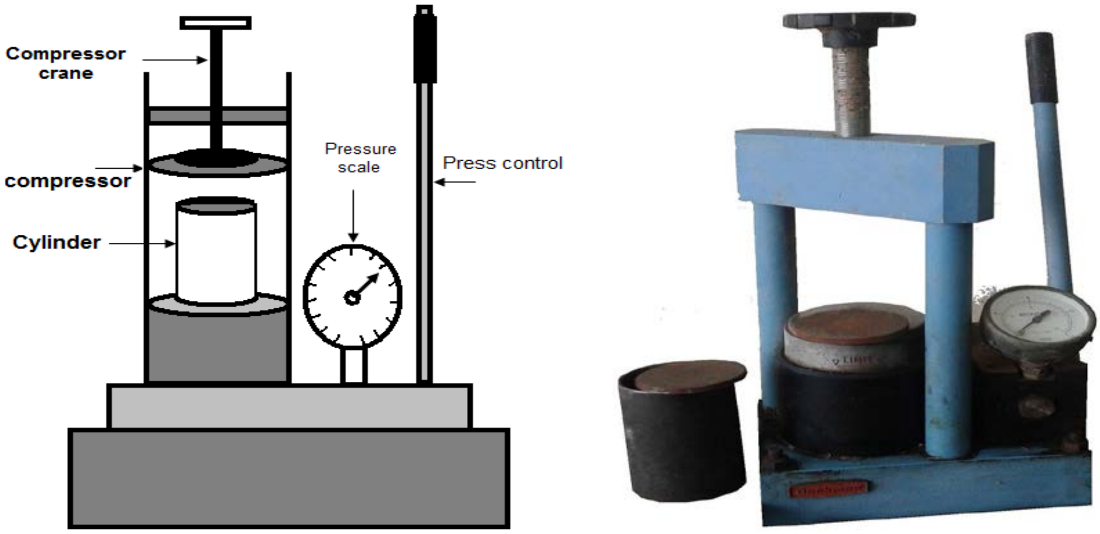


**Fig.(1): Schematic for the used mechanical compressor.**

**4- The Field experiment.**

The field experiment was conducted at a protected greenhouse located at a private farm in Sharbine District, Dakahlia Governorate. Seedlings were cultivated in a washed sandy soil obtained from Belkas District, Dakahlia Governorate to simulate the real cultivation in sandy soil. Seedlings were transplanted in soil on May 20, 2014 under drip irrigation system. Irrigation was performed using drip irrigation system with twin-wall drip tapes and outlets spacing every 0.5 m. The spacing between lateral lines was 0.5 m, and the discharge of drippers was 4 L $h^{-1}$. Irrigation was scheduled according to the plant growth stage, and soil moisture content. At flowering stage (30 days from sowing), representative manure and plant samples were taken for determination of NPK concentration (Fig. 2). At harvesting stage (40 days from sowing), vegetative growth and yield parameters were recorded. In addition, representative fruit samples were air and oven dried at 70 $^{\circ}$C until the weight constant. Subsamples (0.2 g) were digested with a 1 : 1 mixture of sulfuric ($H_2SO_4$) and per-chloric ($HClO_4$) acids according to Peterburgski, (1968) to determine total N, P and K concentrations.

**Fig. (2): Organic manures and plant sampling at flowering stage.**

**5-Statistical analysis**

Statistical analysis at a significance level of (0.05) was performed according to Duncan, (1955) using CoStat (Version 6.303, CoHort, USA, 1998–2004).

## RESULTS AND DISCUSSION

**1-C/N ratio of compost.**

Composting is the biological conversion of biodegradable organic materials into humus-like substances with lower volume, which converts nitrogen from the organic form to the mineral readily available form that satisfies the needs to mineral fertilizer use in intensive agriculture (Zhu et al., 2007). Carbon is the basic for building block and the source of energy of microorganisms. Besides, nitrogen is necessary for cell structure, protein and nucleic acids synthesis. If the C/N ratio of the organic manure is unbalanced, a risk associated with draw downs or tie-ups of plant nutrients could be occurred.

Data in Fig. (3) illustrated that C/N ratio of different organic manures was comparable; however, an increase in this ratio was observed in the absolute organic manure (23.9). On the other hand, the mineral addition of formaldehyde coated urea in organic-based mineral manure led to decrease this ratio to 19.5. Meanwhile, nitrogen fixing bacteria in the modern enriched organic manures had a less contribution in lowering this ratio (22.2) as compared with formaldehyde coated urea.

Although the C/N ratio was 78.15 in the original rice straw (Table 1), a substantial reduction in this ratio was noticed at flowering stage. For example, the C/N ratio of organic manures in the form of 25% compost and 75% rice straw was 22.9. This is suggesting the decomposition of rice straw presented in organic manures after application to the rhizosphere. The organic-based mineral manure in the form of 100% compost recorded the lowest C/N ratio at flowering stage (18.64); however, the absolute organic manure in the form of 25% compost + 75% rice straw recorded the highest C/N ratio (25.44).

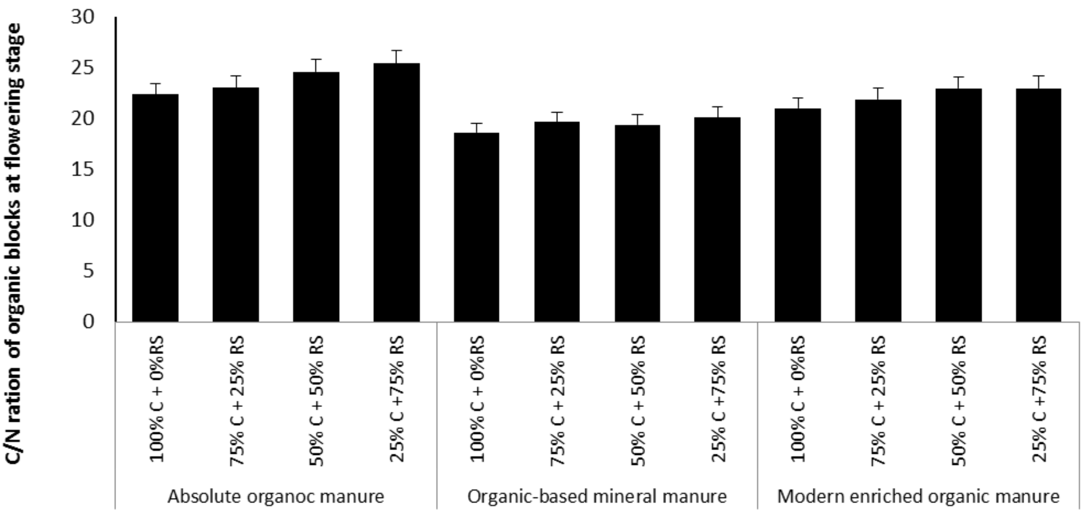


**Fig. (3): C/N ratio of organic manures at flowering stage.**

**2-Nitrogen, phosphorus and potassium concentrations in compost at flowering stage.**

Flowering stage is crucial for controlling growth and yield of cucumber. Consequently, there is an urgent need to optimize the nutrition of plant in this critical stage in order to maximize the produced yield. N, P and K concentrations were higher in the organic-based mineral manure with 0.49, 0.23 and 0.44%, respectively (Fig. 4). The modern enriched organic manure recoded the second ranking with 0.44, 0.23 and 0.39%, respectively. Meanwhile, the absolute organic manure was the worst treatment according to its low concentration of nutrients (0.36, 0.19 and 0.34% for N, P and K concentration, respectively).

The N content is one of the critical indices controlling compost quality (Goldstein and Steuteville, 1993). There are various studies pointed out the significant nitrogen losses during composting. According to Martins and Dewes, (1992), the severe reduction in nitrogen during composting (approximately 43-70%) is mainly attributed to ammonia evaporation and nitrate denitrification.

The release of labile phosphorus from compost is affected by the organic feedstock. For example, the release of available phosphorus from composted green waste is approximately 60% of that of mineral superphosphate; whilst, the availability of phosphorus in composted poultry manure is the same of that of mineral superphosphate (Prasad, 2013). In addition, It is cleared that composting process might cause a disturbance in P fractions, which may affect phosphorus availability for plant nutrition. This might cause a nutritional risk in organic farming systems. Few studies have focused on the phosphorus fractions characterization during composting.

According to Wei et al. (2015), distinct differences in phosphorus concentration were recorded during composting of different manures with a significant decline with about 10% at the full maturity stage.

Potassium in the mature compost is much more available for plant nutrition than nitrogen and phosphorus, taking into consideration that potassium is not incorporated into an organic constitution of the organic feedstock (Marchner, 1992). Accordingly, substantial amounts of potassium could be leached from compost based on its high solubility. Sommer (2001) studied nutrient losses during composting, and he found that potassium leaching was about 8-16% of the amount present at the start of the experiment.

Rock phosphate and feldspar provides a slow released source for phosphorus and potassium utilization by plant. Accordingly, the modern enriched organic manure could reserve its nutritive value until reaching the flowering stage as compared with the absolute organic manure. Besides, the reproduction, and the continuous activation of the nitrogen fixing bacteria could provide a continuous source of available nitrogen to plant nutrition.

Increasing rice straw level in organic manures resulted in reducing N, P and K concentration in the compressed manures, taking into consideration the content of these elements in the original rice straw or compost (Table 1). Increasing level of rice straw application from 0 up to 100% resulted in N reduction by 28%, P by 27% and K by 51%. The modern enriched organic manure in the form of 100% compost is considered the most efficient treatment (after the organic based mineral manure), which could encourage its usage in organic farming systems.

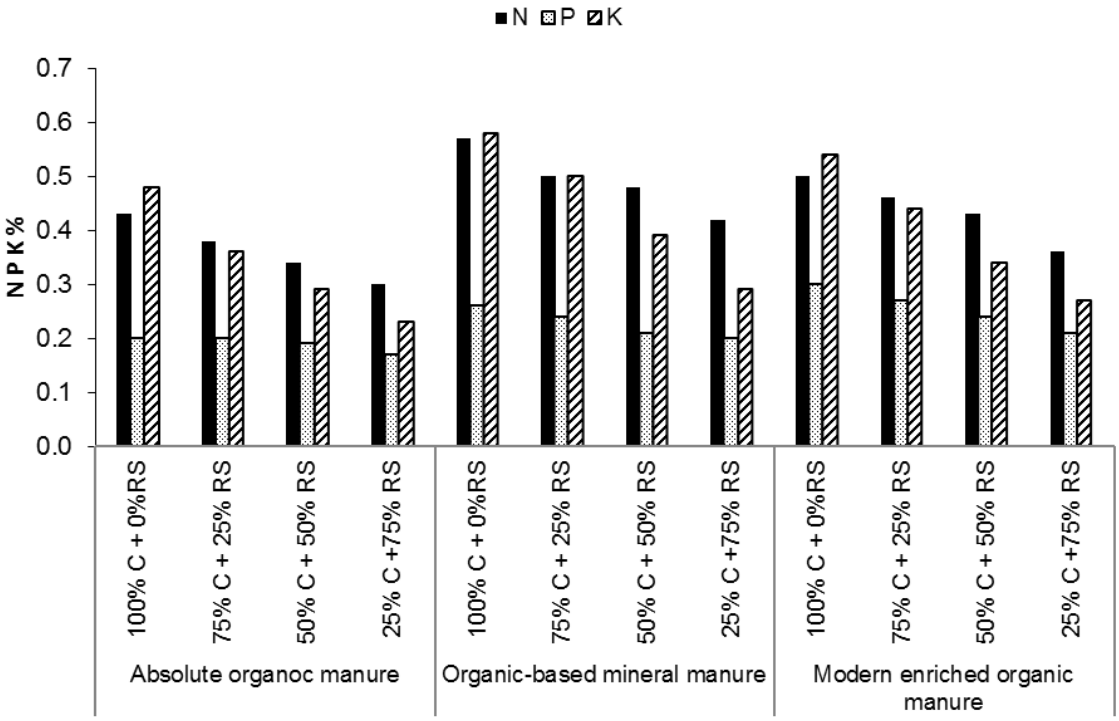


**Fig. (4): NPK concentration in organic manures at flowering stage.**

**3-Total fresh weight yield**

The total fresh weight yield of cucumber fruits was affected by the type of substrate, and the level of combination of organic feedstock. The organic-based mineral manure recorded the highest fruit yield (541.42 g plant$^{-1}$) with about 49.0 and 21.4% increment than those of absolute organic manure and modern enriched manure, respectively. On the other hand, increasing raw rice straw in the engineered manures resulted in reducing the net fresh weight yield. For example, increasing rice straw in organic manures up to 75% was associated with 45.3% yield reduction as compared with 100% compost.

Taking into consideration nutrients content of organic manures, the total fresh weight yield was matched with these levels. The compressed organic-based mineral manure in the form of 100% compost was the most efficient treatment for maximizing the produced yield (678.3 g plant$^{-1}$). On the other hand, the compressed absolute organic manure in the form of 25% compost and 75% rice straw was the worst engineered manure (173.7 g plant$^{-1}$). Meanwhile, the modern enriched organic manure produced a high yield in its 100% compost form (573 g plant$^{-1}$) with only 15.5% yield reduction as compared with the superior treatment. This is support the applicability of modern enriched organic manures in organic farming systems keeping in mind the quality of the produced yield as compared with mineral fertilizer additives with organic manures.

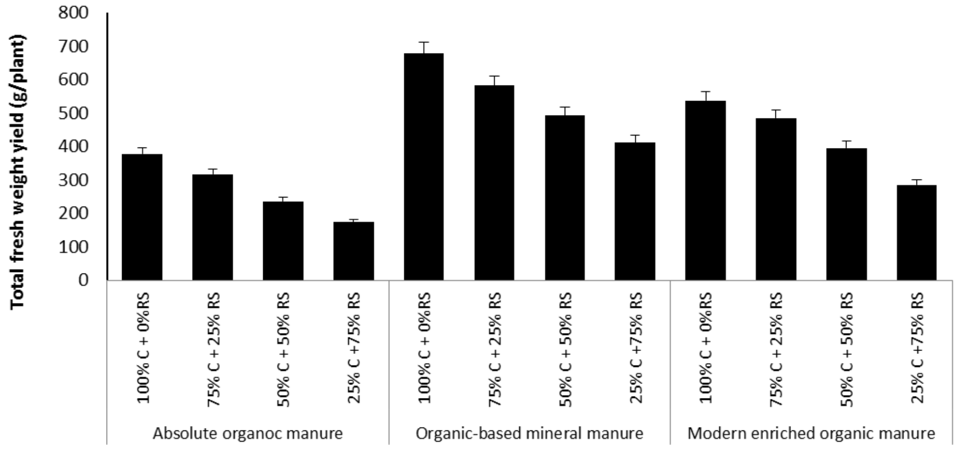


**Fig. (5): Total fresh weight yield (g plant$^{-1}$)**

The low content of nutrients in the absolute organic manures is the most important factor limiting the productivity of cucumber plant. Mineral fertilizer additives provide a readily available source of plant nutrients. However, the fast dissolution of these mineral fertilizers would be the major concern. Meanwhile, the modern enriched organic manures with their natural mineral additives and bio inoculations provide a slow released source for mineral nutrition in a sustainable manner.

**4-Nitrogen, phosphorus and potassium concentrations in cucumber fruits.**

The presences of mineral fertilizers in the organic-based mineral manure led to a significant increase in N, P and K concentrations as compared with absolute organic and modern enriched organic manures. The increment of N, P and K concentrations reached 8.6, 7.5 and 10.2%, respectively as compared with the absolute organic manure application. This substantial increment, however, was relatively lower with natural mineral additives and bio inoculants application in the modern enriched organic manure (5.43, 3.7 and 4.6% for N, P and K, respectively).The imbalance in matching between nutrients supply and the demand of plant could result in nutrients disorders in plant, which will cause imbalances in plant growth and yield (Zhang et al., 2007). Mineral NPK fertilizers in the organic-based mineral manure provides readily available source of NPK nutrients for plant uptake. This is supported by the data of mineral contents in different organic manures, which showed higher contents of NPK concentrations at flowering stage as compared with other organic manures. On the other hand, the natural mineral additives and bio inoculants presented in the modern enriched mineral fertilizers provides a slow-available source for nutrients influx. This slow available source supported plant nutrition in all growth stages without higher accumulation in plant tissues. Meanwhile, plants grown under absolute organic fertilizer application recorded the lowest concentrations of NPK. This is mainly attributed to the low content of these nutrients as illustrated in Fig. (4).The incorporation of organic manures in the intensive agricultural systems had been widely recognized. However, there are various reports suggested the insufficient/imbalanced contribution of these organic resources to meet plant growth stages (Salas et al., 2003). The wider C: nutrients (e.g. N, P and K) could be the reason for nutrients immobilization and unavailability for plant uptake (Singh and Brar, 2006).

Regarding the effect of organic substrates combination, it is cleared that increasing the rate of rice straw application resulted in a significant reduction in NPK concentration. With increasing rice straw application in organic manures from 0 to 75%, NPK concentrations decreased by 14.5, 9.56 and 19.5%, respectively. Rice straw has a low nutritive value, not only because of its low nutrients content, but also because of the low availability of its nutrients in the original form. These results are matched with the data of C:N ratio and NPK concentration in organic manures. The most efficient treatment for maximizing NPK concentrations was the compressed organic based-mineral manure in the form of 100% compost; however, the worst combined treatment was the compressed absolute organic manure in the form of 25% compost and 75% rice straw.

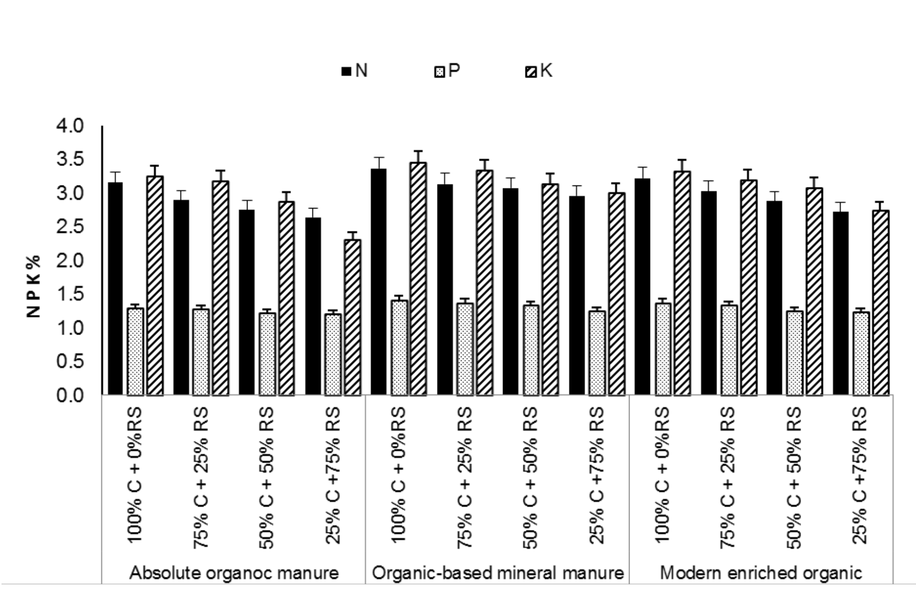


**Fig. (6): Nitrogen, phosphorus and potassium concentrations in cucumber fruits.**

**5-Nitrate concentration in cucumber fruits**

Significant increase in $NO_3$ concentration was recorded in cucumber fruits grown in organic-based mineral manure (66.3 mg $kg^{-1}$) as compared with absolute organic manure (15 mg $kg^{-1}$) and modern enriched organic manure (32.1 mg $kg^{-1}$). The presence of formaldehyde coated urea in compressed manures (5 g $block^{-1}$), was associated with higher accumulation of $NO_3$ in cucumber fruits. The major part of urea in the compressed blocks converted to $NO_3$ by nitrifying micro-organisms (Kumar et al., 1989). The activity and propagation of these nitrifying micro-organisms are significantly improved with organic matter (e.g. compost) application (Vallini et al., 1997). Plants amended with modern enriched organic manures recorded the second ranking after organic-based mineral manures with 32.1 mg $kg^{-1}$. Meanwhile, the plants amended with absolute organic manures recorded the lowest concentration in $NO_3$ accumulation in cucumber fruits (15 mg $kg^{-1}$).

Organic substrates combination led to a significant effect on $NO_3$ concentration in cucumber fruits. There was a big difference between compressed organic manures in the form of 100% compost and those in the form of (25% compost + 75% rice straw) (74.1 *vs.* 8.6 mg $kg^{-1}$, respectively). This could be attributed to the fast leaching of nitrate under raw rice straw media as compared with compost media, which contain substantial amounts in active adsorption in the relatively decayed organic matter. The compressed organic based mineral manure in the form of 100% compost recorded the highest concentration of $NO_3$ in cucumber fruits. However, modern enriched and absolute organic manures were below the limit of detection (LOD) for nitrate determination with raising rice straw to 50 and 75% in the compressed blocks.

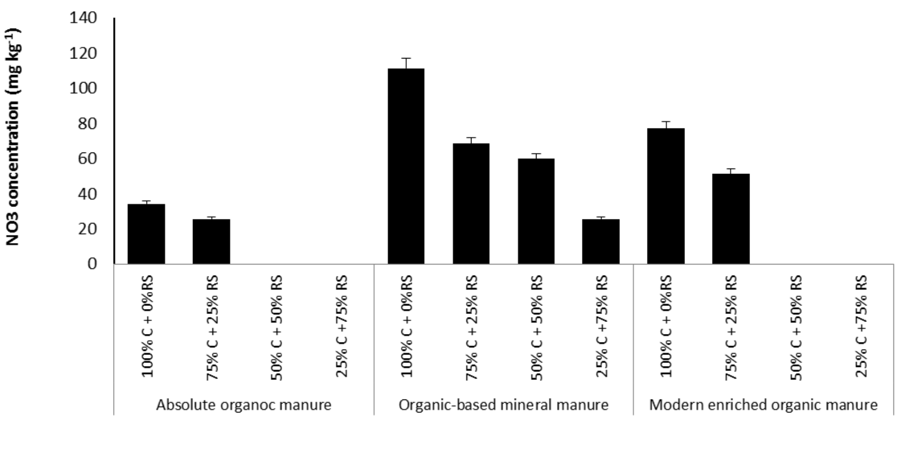


**Fig (7): Nitrate concentration (mg $kg^{-1}$) in cucumber fruits.**

## CONCLUSION

In conclusion, compressed enriched organic manure could be used efficiently as a growing media in modern organic farming systems based on its high nutritive value, high productivity and nutrient supply potential of plant nutrients.

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## نحو جيل جديد من الأسمدة العضوية: سماد عضوي محسن مضغوط كبديل للكمبوست العادي في نظم الزراعة العضوية


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هناك ضرورة ملحة لتعظيم انتاجية نظم الزراعة العضوية. لهذا الغرض أجريت تجربة حقلية لتقييم فعالية الأسمدة العضوية المحسنة مقارنة بالأسمدة العضوية المطلقة أو الأسمدة العضوية المعدنية. حدث تحسن معنوي في جودة الأسمدة العضوية المحسنة (نسبة الكربون: النيتروجين و المحتوي العنصري) بعد إضافة المواد الخام المعدنية (صخر الفوسفات والفلسبار) واللقاحات الميكروبية (البكتريا المثبتة للنيتروجين والبكتريا المذيبة للفوسفات والبوتاسيوم). حدث تحسن في انتاجية المحصول بواسطة الأسمدة العضوية المحسنة مقارنة بالأسمدة العضوية المطلقة (١٢٥.٨ مقابل ٨٢.٤ جرام/نبات). في هذه الأثناء انتجت الأسمدة العضوية المعدنية أعلي محصول (١٣٢.٧ جرام/نبات). سجلت زيادة معدنية في تركيز النيتروجين و الفسفور والبوتاسيوم بثمار الخيار النامية في الأسمدة العضوية المحسنة مقارنة بتلك النامية في الأسمدة العضوية المطلقة. وبالمثل، كانت الأسمدة العضوية المعدنية هي المعاملة المتفوقة في تعظيم استخدام النيتروجين والفسفور والبوتاسيوم بواسطة نباتات الخيار. حدث انخفاض ملحوظ في تراكم النترات في ثمار الخيار النامية في الأسمدة العضوية المحسنة مقارنة بالأسمدة العضوية المعدنية (٣٣.١ مقابل ٦٦.٣ ملليجرام/كيلوجرام). زيادة نسبة ادماج قش الأرز الخام في الأسمدة العضوية (من صفر إلي ٧٥%) كان متبوعا زيادة نسبة الكربون: النيتروجين، تقليل القيمة الغذائية للكمبوست، تخفيض انتاجية الخيار وتقليل تراكم النترات في الثمار. نتائج هذا البحث تفتح آفاقا جديدة نحو الإنتاج علي المستوي التجاري للأسمدة العضوية المحسنة في نظم الزراعة العضوية.