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Effect of Crop Sequence, Compost and Plant Residues on Maize Yield Production, Sandy Soil Fertility and Reduce N-Mineral Fertilizer

***Mona M. Abou El-Nour[1] and Soad Y. Serry[2]**

[1] Botany Department, Women's College, Ain Shams University, Cairo, Egypt.
*Monamn2003@yahoo.com
[2] Soils, Water and Env. Res. Inst.; Agric. Res. Center, Giza, Egypt

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Abstract

Continuous population growth gives rise to food problems in developing countries, which requires enhancement in quantity and quality of agricultural products as well as reduce fertilizer use. Therefore a cropping system study was carried out to establish good agricultural practices that decrease soil degradation and building up fertility of desert soils in Egypt. Accordingly, two rotation cycles were established to investigate the effect of inclusion legume crop (pea) in the rotation compared to heavy feeder crop (potato), on yield and its components of the subsequent crop (maize) as well as soil organic matter level and microbial activity. Addition of biofertilizers, organic fertilizer and different levels of inorganic N were also applied to study their integrated effect on improving nutrients availability for maize crop and the investigated sandy soil as well. Results have been shown that the co-application of organic and inorganic fertilizers in the pea/corn rotation improved yield responses and NPK accumulation in maize crop relative to potato/corn rotation. Since the quality of soil is strongly related to several interactions between chemical and biological factors, significant variation was detected in chemical properties (organic C, total N and available P and K) and biological properties (total microbial count, CO_2 evolution and dehydrogenases activity) for soil of organically treated plots compared to inorganically treated one under different sequence practices. It was concluded that balanced fertilization using both bio- and organic as well as chemical fertilizers under pea/maize sequence was reported to improve crop productivity and reduce inorganic N fertilizer requirement.

Keywords: *Legume crop rotation, Compost, Biofertilizer, Desert soil.*

Introduction

Requirement for food is rising as the human population increases, without good concern through modification of the present practices or the discovery of new options, food production will continue to decrease per capita and per unit area. Unbalanced use of chemical fertilizers reduces soil fertility and quality of crops (Malakooti and Gheybi, 2003). Enhancement of current agriculture production system is required to correct this bad situation. On the other hand, the use of organic fertilizers (e.g., animal manure, crop residues and green manure) as alternative source of chemicals holds promise. Nitrogen is the most yield-limiting nutrient in crop production worldwide and mainly the most important factor needed for improving crop productivity and profitability (Guo *et al.*, 2016 and Amanullah *et al.*, 2016). Rotation is one of the valuable tools for nutrient recycling, which accelerate the microbial activity of the soil, permits better nutrient accessibility and higher crop yield (Pokhrel and Pokhrel 2013). Preissel *et al.* (2015) evaluated the net input of fixed N in cropping systems and noticed that legume-fixed N might improve the productivity of the subsequent crops, and increase farm- economic values comparable to cereal rotations. Xing *et al*. (2017) illustrated that including grain legumes in cereal-based crop rotations was more profitable than non-legume crop rotations. They studied the effect of including *Pisum sativum* and *Lupinus angustifolius* in cereal-based (wheat/canola) cropping systems; they concluded that this significantly increased the yields and profitability of wheat/canola in the following two years. The results showed that field pea and lupin could supply 30–65 kg N ha^{-1} to the next crop and 60–110 kg N ha^{-1} to following crops (wheat/canola) for two years. Low soil moisture accessibility, low soil fertility are causes for low crop productivity in semiarid climate (Amanullah *et al.*, 2012), beside the random use of chemical fertilizers by smallholders (Amanullah *et al*., 2015a). Further supply of nitrogen by enclosing legume crop in the cropping sequence involves no extra input and risk but may be a better replacement partly for chemical nitrogen. Incorporation of crop residues into the soil as a source of nutrients and management has been increasing in many parts of the world (Fischer *et al.*, 2002). To reduce the application of fertilizers, soil incorporation of crop residues has been proposed as a method of ameliorate soil physical, chemical, and biological characters (Ercoli *et al.,* 2008). In addition to the major nutrients (N, P and K), crop residues have also considerable amounts of secondary nutrients and micronutrients, then returning back these residues into the soil may be one of the best alternative for improving the physical, chemical and biological properties of the deprived soils (Hiel *et al.,* 2016). Dicotyledonous break crops are reported to enhance subsequent cereal yields by 15% to 25% because they decrease the possible impacts of pests, diseases and weeds, and enhance soil fertility "break-crop effect" (Kirkegaard *et al.,* 2008). The nitrogen profit and break crop effects indicate that legume crops are an important factor in crop sequences and are recommended for inclusion into cereal-based cropping systems (Preissel *et al.,* 2015). Organic applications increased nutrient status, microbial activity and productive possibility of soil (Kang *et al.,* 2005). The microbial biomass control nutrient mineralization and is a small but labile source of the main plant nutrients (C, N, P and S) (Dick, 1992). Jastrow *et al.* (2007) suggested that the process of soil aggregation, which is a vital controller of soil organic matter dynamics and soil fertility, is expected to be strongly associated with changes in microbial communities. Microbial community roles, for example extracellular enzyme production, decomposition and production of aggregate binding agents, have before been linked to aggregate formation and soil organic matter accumulation (Tiemann and Grandy, 2015). Rhizosphere micro-organisms such as plant growth promoting rhizobacteria (PGPR) are known to enhance the process of biological nitrogen fixation by improving the number of nodules and biomass and promote nitrogenase activity by colonizing root system and inhibit growth of harmful organisms. Das and Singh (2014) studied the effects of PGPR and some types of organic manures (Farm yard manure, Cereal compost, Legume compost) on the nutrient content of plant and grain of mungbean in a field experiment. The maximum protein and total N, P and K content of the stover were established in the plots receiving all the manures beside with co-inoculation of PGPR. In another study Amanullah *et al.* (2015b) observed that the integrated application of nitrogen (120 or 150 kg N ha^{-1}) along with compost (2 t ha^{-1}) enhanced yield and it's components in maize. Therefore the current research work was performed to study the profitability of insertion legume crops (pea) in cereal-based cropping system, compared to incorporated heavy feeder crops (potato) with integrated nutrient management (bio, organic and inorganic fertilizers) on yield and it's components of the succeeding crop (maize). Moreover, the effect on soil organic matter level, microbial biomass, soil enzymes and microbial activities of the soil were studied in order to introduce a proper crop rotation system for higher maize productivity in the study area.

Materials and Method

Bacterial strains

Two local rhizobial strains ARC-201 and 202 representing one species (*Rhizobium leguminosarum*) were used as rhizobial inoculum and three locally isolates of plant growth promoting rhizobacteria (PGPR) species (*Serratia sp., Pseudomonas fluoresence and Paenibacillus polymyxa*) were used as biofertilizer as recommended by El Sayed (2007). All strains were provided from the Microbiology Dep. Soils, Water and Environment Res. Inst., Agriculture Research Center (ARC), Giza, Egypt.

Media used

The following media were used for sub-culturing and maintenance of the investigated bacterial strains also determination and counting of the soil microbial biomass.

1- Yeast Extract Mannitol media (YEM) (Vincent, 1970), for rhizobial strains

2- Congo-red yeast extract mannitol agar medium, for counting rhizobia using the plate count technique. It was prepared by adding 15 g/L agar and 10 ml of 1/400 aqueous solution of Congo-red to the YEM medium previously described. (Vincent, 1970)

3- Nutrient Agar (Atlas, 2004), for *Paenibacillus polymexa*,

4- Peptone glycerol medium (Grimont and Grimont, 1984), for *Serratia sp*.

5- Kings-agar B medium (Alef, 1995), for *Pseudomonas fluorescence***.**

6- Rose Bengal agar media (Martin, 1950) for total count of fungi.

7- Jensen media (Allen, 1957) for total count of actinomycetes.

Seeds

One variety (master pea) of *Pesium sativum* seeds and one variety (single hybrid 10) of *Zea maize* were obtained from Vegetables Research Dep., Horticultural Research Institute and Corn Research Dep., Field Crops

Research Institute, ARC, Giza, Egypt, respectively.

Compost used

Compost used is prepared from rice straw, farmyard manure, elemental sulfur, rock phosphate, bentonite and finally bio-enriched with *Tricoderma, Azotobacter* and *Bacillus*. The main characteristics of the prepared bio-enriched compost are illustrated in Table 1.

Table 1. Some physical, chemical and microbiological properties of the prepared compost.

Compost characteristic	Value
Physical characters:	
Bulk density (Kg/m^3)	568
Water holding capacity (%)	172.5
Chemical analysis :	
pH	7.24
E.C (dS m^{-1} 25^{o}C)	3.38
Total P (%)	0.67
Total K (%)	1.46
Available P (ppm)	1.32
Available K (ppm)	450.0
DTPA_ extractable Fe (ppm)	264.3
DTPA_ extractable Zn (ppm)	58.9
DTPA_ extractable Mn (ppm)	49.6
DTPA_ extractable Cu (ppm)	5.9
Organic matter (%)	19.92
Total nitrogen (%)	1.61
C/N ratio	12.37
Soluble nitrogen(ppm):	
NH_4^+	189.4
NO_3^-	211.3
Total	400.7
Biological analysis :	
Total bacteria (log No)	7.54
Total fungi (log No)	6.07
Total actinomycetes (log No)	6.99
*Dehydrogenase activity	164.7
**CO_2-evaluation rate	2.11

*µg TPF/100g dry soil/24hr. **mg CO_2/100g soil/24 hr.

Inoculum preparation

To prepare inoculum of the bacterial strains under investigation, vermiculite provided with 10% Irish peat was packed in polyethylene bags, then sealed and sterilized by gamma irradiation (5.0×106 rads). 120 ml of the tested bacterial culture (1×109 CFU/ml) of each bacterial strain was injected into the sterilized carrier bags to satisfy 60% of their water holding capacity (107 cells/g carrier).

Crop rotation experiment

Legumes are a great crop alternate with heavier feeding plants and or N-demanding crops such as corn or potato. Moreover, bio and organic fertilizers were suggested to reduce the used N-mineral fertilizer quantities, as well as their effects on improving of nutrients availability, chemical and biological activity of the studied soil. Therefore, *Rhizobium* and PGPR were added as biofertilizers, compost and plant residues were used as organic fertilizer.

Experimental design

The experiments were conducted at Ismailia Experimental and Research Station, Ismailia Governorate, Egypt, during two successive seasons, winter (November) for pea and potato and summer (June) for corn. The experimental field was divided into two equal halves 600 m^2 (12mx50m) to accommodate two rotation cycles. The experimental design was a split-split plot in the second phase of each rotation cycle. The main plot was the rotation system, compost represents the sub-plot and sub-sub plot was the different levels of nitrogen fertilizer (30, 60, 90 and 120 Kg/fed ammonium sulphate). In the first phase of the two cycles, pea (*Pisum sativum*) (first plot) and potato (*Solanum tuberosum* vr. *sponta*) which was cultivated in other private experiment (second plot) were planted as the first crop. The two plots were amended with organic farm yard manure (FYM) and compost as organic matter, PGPR as biofertilizer and the recommended dose of mineral fertilizers. In the second phase of each rotation cycle, only corn (*Zea maize*) was planted on the two halves, soon after pea and potato harvest.

The first phase of rotation cycle

In the first plot, seeds of *Pisum sativum* (master pea variety) were inoculated with mixture of the two strains of *Rhizobium leguminosarum* (ARC-201 and 202) as a commercial inoculum. Seeds were further inoculated with the investigated PGPR strains (*Serratia sp*., *Pseudomonas fluorescence* and *Paenibacillus polymyxa*). The inoculation was done by mixing the gamma irradiated vermiculite based inoculum at rate of 600 g/40 Kg seeds before sowing. Recommended dose of mineral fertilization (NPK) was applied at the rate of 20Kg/fed ammonium sulphate (20.6% N), 150 Kg/fed super phosphate (15.5% P_2O_5) and 50 Kg/fed potassium sulphate (48% K_2O) before sowing. Plot treated with traditional fertilization dose (100 Kg N/fed, FYM and rhizobial inoculant) was used as control. Seeds were sown on one side of ridges, ridges was 60 cm width and 4m length and 25 cm apart. Each plot included 4 ridges and the plot size was 600 m^2, sprinkler irrigation was applied.

The second phase of the rotation cycle

The two plots (previously occupied by pea and potato) of the experimental field were divided into two sub-plots, the two sub-plots were developed in such a manner that half of the legume and potato plots were given compost (recommended dose 5 ton/fed) (Abdel Wahab, 2008) seven days prior of sowing. Then after full dose of phosphate and one third of potassium were applied at final land preparation as a basal dose, the remaining two third dose of potassium was applied at 70 days after sowing. Phosphate was added in the form of super-phosphate (200Kg/fed 15.5% P2O5) potassium in the form of potassium sulphate (50 Kg/fed 48%K_2O). Nitrogen fertilization rates were full dose of nitrogen 120 Kg/fed (100%) as well as three reduced doses 90 Kg/fed (75%), 60 Kg/fed (50%) and 30 Kg/fed (25%). Nitrogen fertilizer was applied in four equal doses at 15, 30, 45 and 60 days after planting. The remaining plant residues of the previous crop (legume) were incorporated into the soil by rotovator before maize planting. To examine the effect of legume in rotation on maize plant productivity and soil status, plant samples were collected at harvest stage (120 days) for evaluation of different yield parameters (grain yield, stalk yield, length, diameter and weight of ear, 100 grains weight, N, P, K% and crude protein of stalk and grains). The improvement in nutrients availability and the enhancement in microbial activities of the soil were studied as well.

Soil analysis

Representative surface soil samples (20cm depth) were collected from the experimental sites before maize planting (after potato and pea harvest) for physical, chemical and microbiological assays (Table 2). Also, rhizosphere soil samples were chemically and biologically analyzed after maize harvest.

Table 2. Physical, chemical and microbiological analysis of the studied soil area.

Soil characteristic	Value
Particle size distribution:	
Sand (%)	90.51
Slit (%)	2.21
Clay (%)	7.28
Texture grade	Sandy
Chemical characters:	
Saturation percent (S.P %)	20.20
pH	7.70
E.C (dS m^{-1} 25 ^{o}C)	0.22
Soluble cations (meq/L)	
Ca^{++}	0.67
Mg^{++}	0.46
Na^{+}	1.32
K^{+}	0.45
Soluble anions (meq/L):	
$CO3^{-2}$	--
$HCO3^{-}$	1.69
Cl^{-}	0.62
$SO4^{-2}$	0.59
Organic matter (%)	0.21
Total nitrogen (ppm)	233.30
C/N ratio	10.36
Soluble nitrogen (ppm):	
$NH4^{+}$	12.23
$NO3^{-}$	6.76
Total	28.50
Available P (ppm)	9.82
Available K (ppm)	94.00
Biological characters:	
Total bacteria (log No.)	5.40
Total fungi (log No.)	3.21
Total actinomycetes (log No.)	4.20
*Dehydrogenase activity	35.33
**CO_2-evaluation rate	4.82

***µg TPF/100g dry soil/24hr. **mg CO_2/100g soil/24 hr.**

1-Soil chemical determinations

a) pH was measured in soil water suspension (1: 2.5) using glass electrode pH- meter and electrical conductivity as well as soluble ions in soil paste extracts (Jackson, 1973).

b) Organic carbon was determined by Walkly and Black method as described by Black *et al.* (1965).

c) Total nitrogen was determined using the macro Kjeldahl method. (Jackson, 1973).

d) Total soluble nitrogen was determined by steam distillation procedure using Mg- Deverda alloy (Black *et al.*, 1965).

e) Available phosphorus was determined using Spectrophotometer at wave length 640 nm. (Page *et al.*, 1982).

f) Available potassium was determined using Flame phtometer (Page *et al.*, 1982).

2-Evaluation of soil biological activity

The soil biological activity was taken as a biological tool for estimating the differences occurred in soil fertility between the two studied rotation cycles.

a) Microbial enumeration

Soil samples were microbiologically analyzed for densities of mesophilic bacteria, fungi and actinomycetes. Total count technique was employed to enumerate the groups of soil microorganisms (Page *et al.*, 1982).

b) Carbon dioxide evolution

Soil samples were estimated for carbon dioxide evolution by soil microorganisms according to Page *et al.* (1982).

c) Dehydrogenases activity

Activity was assayed according to Casida (1977).

Plant measurements

a) Nitrogen %

Nitrogen % of plant material was determined using wet digestion by mixture consist of perchloric ($HClO_4$) and sulfuric acid (H_2SO_4) at ratio 1:1 by volume as described by Jackson (1973). The N-concentration was measured in the digested solution using Macro-Kjeldahl method according to Page *et al.* (1982).

b) Phosphorus and Potassium %

P and K% in plant material were determined in the digested solution using stannus chloride reagent by spectrophotometer at 640 nm for phosphorus and using flame photometer for potassium according to Page *et al.* (1982).

d) Crude protein

Crude protein of seeds and straw was calculated by multiplying the nitrogen content (expressed in percentage) by 6.25.

e) Chlorophyll content

Fresh leaf sample (0.5 gm) was extracted by 20 ml 80% methanol after grinding. The sample was filtered through filter paper. The absorption of constant volume of filtered was measured at optical density 650 and 665 nm (Arnon, 1949). Total chlorophyll was calculated by the following equation:

Total chlorophyll (mg/L) = 25.5 D 650 + 4.0 D 665

f) Root surface area

It was measured by the titration method as described by Wilde and Voigt (1949). Air-dried root system was immersed in a solution of 3 N HCl for 15 seconds. Then the roots were drained for 5 minutes to remove excess acid then were transferred to a beaker containing 250 ml of distilled water. The contents of the beaker were stirred to wash the acid from the roots and then allowed to stand for at least 10 minute. 100 ml aliquot of the weak acid solution was tittered with 0.3 N NaOH and phenolphthalein indicator. The relative area of the root surface expressed in ml of NaOH that used in acid titration.

g) Nitrogenase enzyme activity

The nitrogenase activity of mature roots nodules was estimated using the acetylene reduction assay method according to Hardy *et al.* (1973).

Statistical analyses

The mean values of triplicates data of different parameters were submitted to analysis of variance (ANOVA) the treatment means were compared according to the procedures outlined by Snedecor and Cochran (1980).

Results and Discussion

Maize was grown in plots had previously cultivated by pea and potato, the remaining legume residues were incorporated into the soil. Four N-rates (30, 60, 90 and 120 Kg /fed.) were compared; recommended phosphorus and potassium were applied to all plots. Half of each plot was given compost as recommended.

NPK accumulation and yield response of maize to nutrient management in different cropping systems.

A- Main effect

In respect to the main effect of either inorganic-N addition, organic manure or rotation system data present in Tables 3 and 4 reveal that they achieve positive effect on maize yield and its components as well as NPK grain accumulation when they applied solely. Many researchers have reported that N is a key factor in the response of cereals following legumes compared with cereals following non-legumes (Chalk *et al*., 1993 and Smiley *et al*., 1994). Currently a good response was detected for plots receiving a supply of manure or under legume rotation sequence. In accordance, Chen (1993) illustrated that legume can provide 15 T/ha biomass and quick decomposition of which is possible with easy releasing of the available nutrients responsible to create an increase of 810 kg/ha grain yield of wheat and maize in the next season.

Table 3. Main effect of inorganic N, compost and rotation system on yield and its attributes of maize plants.

Treatments \ Parameters		Stalk Yield (ton/ha)	Cob Yield (g/pl.)	Grain Yield (ardab/ha)	Cob Diameter (cm)	Cob Length (cm)	100 Grain Wt (g)
1- *Response to graded levels of nitrogen fertilizer*							
Kg N /Fed	30	8.17	460.00	41.68	4.05	17.66	19.41
	60	8.71	504.00	45.94	4.24	18.87	21.13
	90	9.99	591.10	50.39	4.46	19.78	22.98
	120	10.57	614.50	53.90	4.63	20.46	24.73
L.S.D 0.05		**1.749**	**36.62**	**3.482**	**0.095**	**0.531**	**1.345**
2- *Response to compost*							
Without Compost		8.59	538.30	45.60	4.19	18.32	20.83
With Compost		10.08	546.50	50.36	4.50	20.06	23.29
F value		**10.80****	**0.25**	**14.65****	**6.26***	**5.62***	**7.54****
3- *Response to rotation system*							
After Potato		8.90	508.30	46.81	4.28	18.70	21.60
After Pea		11.76	576.50	51.16	4.41	19.51	23.52
F value		**8.62****	**48.30*****	**54.65*****	**5.18***	**4.32***	**6.34***

NS=Non significant ***p<0.05, ** P<0.01 and *** P<0.001**

Table 4. Main effect of inorganic N, compost and rotation system on % NPK status of maize yield

Treatments \ Parameters		Stalk Crude Protein	Grain Crude Protein	Stalk P	Grain P	Stalk K	Grain K
1- *Response to graded levels of nitrogen fertilizer*							
Kg N / Fed	30	3.91	9.01	0.076	0.123	0.737	0.497
	60	4.28	10.60	0.091	0.145	0.844	0.942
	90	5.01	11.08	0.143	0.169	0.907	1.234
	120	5.61	11.69	0.248	0.207	0.980	1.460
L.S.D 0.05		**0.149**	**0.336**	***NS**	**0.0263**	**0.0263**	**0.0263**
2- *Response to compost*							
Without Compost		4.295	9.967	0.115	0.1604	0.728	0.967
With Compost		5.109	11.23	0.1633	0.1612	1.010	1.100
F value		**6.54***	**8.42****	**0.45**	**0.26**	**5.62***	**3.14***
3- *Response to rotation system*							
After Potato		4.561	10.220	0.113	0.145	0.812	0.708
After Pea		4.843	10.980	0.166	0.177	0.922	1.359
F value		**3.62***	**4.50***	**0.19**	**4.52****	**4.64***	**5.72***

NS=Non significant ***p<0.05, ** P<0.01 and *** P<0.001**

B- Interaction effect

1- Yield and yield components.

Data in Table 5 reveal that maize yield and its components responded positively to the proper crop rotation and fertilization management. The higher values of all investigated parameters were recorded for the composted legume/cereal cropping system in which residues were incorporated with nitrogen application at the rate of 120 Kg N/fed. The plots of potato/cereal cropping system in which no residues and compost were included responded poorly and resulted in least mean values of yield parameters. Kouyaté *et al.* (2000) suggested that yield increases may be due to the increased accessibility of mineral nitrogen provided by mineralization of legume residues. Result of the present investigation showed that at harvest the yield of composted maize significantly increased in pea rotation by 28.46% for stalk yield 15.48% for grain yield, 18.21% for cob yield, 4.89% for cob diameter, 1.74% for cob length and finally 12.40% for 100 grain weight at 120 Kg N/fed. over composted maize in potato rotation at the same N level. These results are in agreement with Horst and Hardter (1994) who recorded a significant increase in maize grain yields when maize was planted in rotation with cowpea than for maize monocropping, which was due to the incorporation of plant residues of cowpea, which returning high amounts of nitrogen to the soil. Results were also in line with that obtained by Muhammad *et al*. (2011), who reported that maize grain yield and yield components were mostly higher in legume-cereal (chickpea-maize) cropping system complemented with nitrogen. Meng *et al.* (2012) illustrated that legume rotation stimulate cereal growth and yield increases seemed to depend on the capability of the legume to enhance early N and P availability for the following cereal. Better management of high yielding crops with lower inorganic N was detected (Table 5), the parameters like cob diameter, 100 grain weight and grain yield in pea/corn rotation for the composted plants at 90 Kg N/fed., showed no significant differences compared to that obtained for the same treatment at 120 Kg N/fed. which indicated that legume (pea) inclusion in rotation supplied about 30 Kg /fed. less N to the subsequent crop. Thus, the probable reason for more grain yield could be the more number of grains /cob and more 100 grain weight since more cob diameter was recorded. This result reflects the noticed support of compost for the maize yield and its attributes particularly under desert soil conditions (Abdel-Wahab *et al.*, 2002). One of the most important earlier explanations observed by Herridge *et al.* (1995) is that nitrogen "sparing" is another way in which legume crops add N to intercrop or rotation crops. Since part of their N requirement is met by N_2 fixation, legumes utilize less of the available soil N than cereals, thereby save or preserve inorganic N for the following crop. Stanger and Lauer (2008) illustrated that if N is the only cause of yield differences between rotations, then these differences would be expected to disappear if more than sufficient N is applied, it is clear that N fertilizers do not substitute for crop rotation. The obtained results are also in good accordance with results achieved by Sharifi and Taghizadeh (2009) who observed an increased ear diameter and ear length with increasing N level. Rehman *et al.* (2010) explained that the increases in grains yield were probably due to the more number of rows per ear, or number of grain per row. Xing *et al.* (2017) reported that the direct N benefit of grain legumes to the succeeding crops would be invisible when N fertilizer was applied over the optimal level. Considering the beneficial impact of organic fertilizer (compost and plant residues), it can be concluded from the current results that composted maize in pea rotation at 120 Kg N/fed. achieved significantly higher stalk yield, grain yield, cob diameter and 100 grain weight by 52.84, 14.61, 7.17 and 11.78% respectively than the non-composted ones. At the same time, maize after potato grown without organic fertilizer produced considerably lower yield compared to that after pea with organic compost. Rhizosphere studies made by Gan *et al.* (2015) showed that the effects on soil pH and acid phosphatase activity were secondary causes for the observed growth difference between rotated cereals and continuous cereals. Recently, Ashworth *et al.* (2016) showed that including soybean twice within a 4-yr rotation increased corn yield by 6% compared to continuous corn across 12 year. Xing *et al.* (2017) concluded that field pea and lupin could contribute 30–65 kg N ha^{-1} to the next crop and 60–110 kg N ha^{-1} to subsequent crop for two years, corresponding to 30–55% and 60–86% of net N inputs of legume-fixed N, respectively.

Table 5. Interaction effect of inorganic N, compost and rotation system on yield and its attribute of maize plants grown in sandy soil

Parameters / Kg N/fed	Stalk Yield (ton/ha)		Grain Yield (ardab/ha)		Cob Yield (g/pl)		Cob Diameter (cm)		Cob Length (cm)		100 Grains Wt (g)	
	After Pea	After Potato	After Pea	After Potato	After Pea	After Potato	After Pea	After Potato	After Pea	After Potato	After Pea	After Potato
With Compost												
30	9.22	8.11	44.04	41.79	518.50	417.00	4.17	4.17	18.00	17.77	21.60	19.43
60	9.73	8.85	49.17	46.46	550.20	468.70	4.40	4.37	20.27	19.47	22.43	22.03
90	11.73	10.06	54.71	49.75	636.70	546.70	4.83	4.53	21.23	20.93	24.40	22.4
120	13.45	10.47	58.41	50.58	652.20	551.70	4.93	4.70	21.60	21.23	26.27	23.37
Without Compost												
30	7.90	7.45	41.25	39.66	471.20	433.30	3.967	3.900	17.33	17.53	18.90	17.70
60	8.19	8.06	45.12	43.04	527.00	470.00	4.133	4.067	18.10	17.63	20.80	18.90
90	8.30	8.39	48.62	46.50	622.90	558.30	4.33	4.23	19.00	17.97	22.27	21.53
120	8.80	8.64	50.96	48.67	632.50	590.90	4.60	4.30	20.57	18.43	23.50	23.07
L.S.D. 0.05	**3.45**		**7.44**		**68.41**		**0.19**		**1.08**		**2.69**	

2-NPK accumulation

Concentrations of some major nutrient elements in maize grain yield were evaluated; increasing N fertilizer rates promote significant increase in total nutrient uptake. Maximum NPK content were produced by the higher nitrogen application (120 Kg /fed.). Data in Table, 6 reveal that significant increases in nutrient accumulation can be observed for the composted maize yield (stalk and grains) at 120 Kg N/fed. in the pea rotation compared with the corresponding non-composted ones. The percentage increases are 13.42 and 16.55%, for stalk and grain crude protein, 94.17 and 15.66% for stalk and grain P% and 66.92 and 52.24% for stalk and grain K% in respective order. A possible reason suggested by Bakhtiar *et al.* (2005) and Yaseen *et al.* (2006) illustrated that application of organic fertilizer in combination with mineral fertilizer have been found to increase absorption of N, P and K in various crops as compared with chemical fertilizer alone. In accordance, Bokhtiar and Sakurai (2005) also illustrated that plant uptake of N, P and K was reported to be at maximum with application of farmyard manure accomplished with 120 kg N/ha. In addition, Abedi *et al.* (2010) recommended using combination of organic and inorganic fertilizer to realize highest yield without negative effect on seed quality, it is assumed that the compost application lead to grain protein content enhancement due its effect on soil structure and consequently increase in plant nutrients uptake. It is worthy mentioned that NPK accumulation in non-composted maize under investigation for potato rotation at 120 Kg N /fed. were highly significant lower when compared to the composted maize in pea rotation and receiving the same N dose. Stalk and grain crude protein, stalk and grain P% and stalk and grain K% were lower by 22.53, 17.99, 45, 21.51, 42.95 and 72.22 % in respective order. Obviously, it seems the crop sequences may suggested to effect macronutrients accumulation. Lupwayi *et al.* (2011) demonstrated that roots of non-legumes grown in rotation with legumes contain endophytic rhizobia which act as plant growth promoting rhizobacteria that lead to spread out the root of the crop, enhancing nutrients uptake which enabling those plants to accumulate more N, P, K, Ca, Mg and Na. This suggests that contribution of rhizobia to the rotational benefits of legumes in cropping systems is in more ways than just fixing N_2.

Table 6. Interaction effect of inorganic N, compost and rotation system on % NPK status of maize yield

Parameters / Kg N/fed	Stalk Crude Protein		Grain crude Protein		Stalk P		Grain P		Stalk K		Grain K	
	After Pea	After potato	After Pea	After Potato	After Pea	After Potato	After Pea	After Potato	After Pea	After Potato	After Pea	After Potato
With Compost												
30	4.27	3.94	10.00	10.13	0.132	0.063	0.172	0.100	0.790	0.790	0.509	0.487
60	4.68	4.31	11.13	10.97	0.140	0.080	0.182	0.120	1.100	0.820	1.687	0.69
90	5.80	5.68	11.80	11.10	0.144	0.090	0.248	0.130	1.157	0.993	2.083	1.00
120	6.17	6.03	13.17	11.50	0.200	0.157	0.251	0.187	1.297	1.110	2.340	1.315
Without Compost												
30	3.93	3.50	8.77	7.13	0.052	0.054	0.117	0.098	0.740	0.633	0.505	0.49
60	4.13	4.01	10.50	9.80	0.062	0.082	0.138	0.139	0.753	0.703	0.890	0.503
90	4.33	4.24	11.13	10.30	0.065	0.090	0.183	0.178	0.767	0.713	1.317	0.537
120	5.44	4.78	11.30	10.80	0.103	0.110	0.217	0.197	0.777	0.740	1.537	0.65
L.S.D 0.05	**0.2881**		**0.8722**		**0.05259**		**0.05259**		**0.05259**		**0.05259**	

3- Impact of rotation program on soil chemical and biological properties of soil corn rhizosphere.

Most of the horizontal extension in Egypt for plant production is carried out in newly reclaimed soils particularly in sandy ones which suffer from structure, nutritional problems and alkaline pH. Soils will not be appropriate for crop production if they lack main nutrients. Soil fertility management is an essential part of successful crop production, nutrients must be available in adequate and balanced quantities. Data recorded in (Table 7) illustrate that cultivation of legumes in sandy soil resulted in an increase of soil organic carbon (SOC) content as well as essential nutrients (NPK) after harvest as compared to the initial situation (Table 8). Differences in pH as well as EC values among investigated treatments were not statistically significant (Table 7). Furthermore, no significant differences were also detected for soil pH after pea or potato harvest (Table 8) and pH values of soil corn rhizosphere for all investigated treatments. However, the numerical values of the pH were a bit lower for composted plots. While a remarkable decrease was noticed when compared with the initial soil pH (7.7) before cultivation (Table 8). Sarwar *et al.* (2008a) illustrated that soil pH is the single soil characteristic, which point out an overall picture of the medium for plant growth including nutrient supply trend, salinity, sodicity status and soil mineralogy. Yaduvanshi (2001) concluded a decrease in soil pH after the use of organic materials he suggested that the production of organic acids during mineralization of organic materials would have caused the decrease in soil pH value. Similarly, Sarwar *et al.* (2008a) concluded that application of compost alone and in combination with chemical fertilizer reduced the soil pH significantly as compared to control. In general, Electrical conductivity is a soil parameter that indicates indirectly the total concentration of soluble salts and is a direct measurement of salinity. The recorded EC of the experimental soil tend to increase in the composted plots. In accordance, a study conducted by Sarwar *et al.* (2008b) illustrated that the decomposition of organic materials released acids or acid forming compounds that react with the soluble salts already present in the soil and either converted them into soluble salts or at least increased their solubility therefore, the EC of soil was increased. Results also illustrated that legume/cereal cropping system and combined application of compost with inorganic N fertilizer maintained the higher soil nutrients content. Data present in (Table 7) illustrate significant difference in residual SOC left, total nitrogen (TN) and available NPK compared to soil before cultivation (Table 8). Treatments receiving compost in combination with 120 or 90 Kg N/fed. after pea cultivation recorded the maximum values. Results were in good accordance with Senigagliesi and Ferrari (1993) who found that the crop/pasture with legume rotation increased the organic matter in soil by 46.7%, N by 48.3% and P by 76.0% with respect to original contents. Soil organic carbon and TN values for the investigated experimental soil before cultivation were

0.21% and 233.3ppm respectively. An increase reached 161.9 % for SOC and 120.01% for TN were detected for treatment of 120 Kg N/fed. with compost in pea rotation. While comparable with composted plots in potato rotation at 120 kg N/fed. SOC and TN increased by 100% and 29.87% only. Cazzato *et al.* (2012) illustrated that soil N loss may be minimized by using valuable legume crops which can supply sufficient BNF input to enhance soil N by improved recycling of N through plant residues. Furthermore, results obtained by Rutkowska and Pikula (2013) pointed that the most important factor which stabilizes organic carbon content in agricultural soils was crop rotation with legumes. On the other hand, a detected positive impact was observed in soil organic built up status and soil total N for soil under investigation while using the proper rotation cycle (legume /cereal) especially with organic matter addition (taking in consideration that pea plant residues were incorporated into soil after pea harvest). May the present results demonstrated only little improvement in soil C and N content for the composted plots at pea rotation. It is however, expected that the improvement of soil organic matter and N content will be more obvious in long term experiments. It is believed that organic matter in soil is typically slow to respond to management changes and treatment effects and may not be easily estimated within a short period of time. Foley and Cooperband (2002) suggested that the greatest improvement in water retention resulted soon after application of different organic composts. Brady and Weil (2005) explained that soil organic matter encourages granulation, increases cation exchange capacity and responsible for adsorbing power of the soils up to 90%. Concerning soil available nutrients changes, data recorded indicated that the higher soil available nitrogen values were obtained for the plots received 120 Kg N/fed. after pea cultivation either composted (55.10 ppm) or non-composted (53.90 ppm).This increase reached about two-fold when compared to initial available soil N before cultivation (28.56) (Table 8). Moreover, the percentage increase of P over the initial value (soil before cultivation) was found to be 31.36% at 120 Kg N/fed. and 30.34% at 90 Kg N/fed. While the percentage increase of K was 29.14% at 120 Kg N/fed. and 25.21% at 90 of Kg N/fed., which is in consistent with results obtained for yield parameters. In accordance Jayathilake *et al.* (2006) demonstrated that the available P and K were highest when organic matter and chemical fertilizer were applied to the soil, than in soil with chemical fertilizer only. They suggested that the built up of available P and K in soil could be due to the organic acids which were released during microbial decomposition of organic matter, and increasing the available P and K. These agreed with Sarwar *et al.* (2008b) who reported that phosphorus status of the soil was found to be improved significantly as well as water soluble potassium, when chemical fertilizer and compost were added to the soil after wheat harvest in rice /wheat rotation. They assumed that the hydrogen ions released from organic materials are exchanged with K on exchange site or set free from the fixed site of soil particles, thus the overall status of soil available K is improved. The living fraction of organic matter (the microbial biomass) responds much more quickly to changes in crop management or environmental conditions than soil organic matter (Doran *et al.*, 1996). In this context, the biological activity of the current experimental soil as expressed through number of microorganisms, production of CO_2 and enzymatic activity were generally higher in the pea rotation system and co-application of enriched compost with inorganic N fertilizer treatment (Table 7). This was in line with Tilman *et al.* (2006) who noticed that belowground benefits of rotational plant diversity have been linked to changes in microbial communities. Further, McDaniel *et al.* (2014) illustrated that crop rotations increase microbial biomass by an average 21%. The current result showed also that the highest CO_2 evolution was observed at 120 and 90 Kg N/fed. this was in parallel with microbial biomass and dehydrogenase activity. It is obviously shown that dehydrogenase in rhizosphere soil with organic matter treatment was on average three times higher than that of chemical fertilizer treatment. The percent increases in CO_2 evolution, and dehydrogenase activity, for composted soil in pea rotation at 120 Kg N/fed. were 34.1 and 185.87%, respectively over the non-composted at 120 Kg N/fed. in potato rotation. The abovementioned results were in good accordance with the early explanation of Bolton *et al.* (1985) who illustrated that dehydrogenase is very useful for the estimation of soil microbial responses to organic manure because it is known to be associated primarily with microbial activities that are linked with the initial breakdown of organic material. Consistently, stronger dehydrogenase activity in soil treated with compost and FYM or compost-applied plots compared to soil treated with mineral fertilizer have been observed by many studies (Marinari *et al.*, 2000; Wlodarczyk *et al.*, 2002 and Khosro *et al.*, 2011) which have been linked to higher organic matter content. The recorded data illustrated good co-relation between soil biological activity and organic matter content, as the lowest values were obtained from plots with no compost application. This result was in harmony with the total fungal and bacterial count as the organically treated plots recorded the maximum microbial population count (significant variation) compared with inorganically treated plots. In accordance Khosro *et al.* (2011) illustrated that the higher organic matter levels in the compost treatments may provide a more favorable situation for the accumulation of enzymes in the soil environment, as soil organic constituents are considered to be important to make up stable complexes with free enzymes. Tiemann and Grandy (2015) demonstrated also that microbial community functions, such as extracellular enzyme production and production of aggregate binding agents, have been linked to aggregate formation and soil organic matter increase. Many studies concluded that fungal-dominated communities have been associated with both qualitative and quantitative enhancement of soil organic matter accumulation with crop rotation (Six *et al.*, 2006; Hungria *et al.*, 2009 and McDaniel *et al.*, 2014). Consistently, the current results showed maximum fungal population with significant improvement of SOC and total N in the organically treated plots. The results were in agreement with that reported by Nakhro and Dkhar (2010) who illustrated that a significant variation in fungal population was found between organic and inorganic treated plots, they suggested that the application of organic fertilizers increased the organic carbon content of the soil and thereby increasing the microbial counts of the soil.

Table 7. Effect of compost manuring and N-fertilization on chemical and biological characteristics of soil after maize harvest.

Parameters / Kg N/Fed		pH	EC dS/m2	Organic carbon (%)	Total nitrogen (ppm)	Total soluble N (ppm)	Available P (ppm)	Available K (ppm)	*CO2 evolution	**Dehydrogenase activity	Total count of bacteria (LogNo.)	Total count of fungi (LogNo.)	Total count of action. (Log No.)
After Pea													
30	With Compost	7.29	0.23	0.36	293.30	50.93	12.23	113.80	8.60	82.40	5.92	3.63	4.70
60	With Compost	7.30	0.24	0.38	297.30	52.40	12.40	115.50	9.56	94.83	5.93	3.69	4.70
90	With Compost	7.31	0.24	0.46	304.00	53.60	12.80	117.70	10.90	99.67	5.93	3.79	4.71
120	With Compost	7.31	0.25	0.55	513.30	55.10	12.90	121.40	12.87	125.50	6.00	3.86	4.74
30	Without Compost	7.75	0.21	0.28	260.00	48.9	8.80	105.3 O	7.56	40.20	5.46	3.56	4.62
60	Without Compost	7.81	0.22	0.34	273.30	51.0	9.20	106.90	7.76	42.67	5.53	3.59	4.63
90	Without Compost	7.58	0.23	0.37	283.00	52.5	9.26	107.20	8.46	43.93	5.49	3.63	4.66
120	Without Compost	7.72	0.21	0.40	293.40	53.9	9.70	108.10	9.60	44.80	5.53	3.65	4.66
After Potato													
30	With Compost	7.33	0.20	0.34	256.00	46.73	11.20	114.2 N	7.16	81.27	5.85	3.52	4.55
60	With Compost	7.42	0.22	0.36	270.70	48.30	11.30	115.90	8.21	89.30	5.89-	3.55	4.59
90	With Compost	7.40	0.22	0.38	290.00	49.00	11.70	117.30	9.53	90.23	5.98	3.57	4.40
120	With Compost	7.41	0.21	0.42	303.00	51.20	11.80	119.40	10.50	101.40	5.99	3.40	4.62
30	Without Compost	7.19	0.23	0.26	240.40	35.50	8.10	99.5	6.80	36.27	5.30	3.51	4.44
60	Without Compost	7.83	0.23	0.31	252.20	38.80	8.30	100.1	7.46	41.73	5.39	3.53	4.46
90	Without Compost	7.81	0.23	0.36	263.30	40.50	8.50	101.3	8.53	42.77	5.49	3.54	4.48
120	Without Compost	7.56	0.22	0.36	268.70	45.60	8.40	102.2	9.33	43.90	5.55	3.55	4.52
L.S.D.0.05		**N.S.**	**N.S.**	**0.05**	**0.94**	**6.39**	**1.51**	**25.21**	**0.44**	**2.41**	**0.27**	**0.23**	**0.14**

NS=Not significant

Table 8. Some chemical and biological characteristics of soil before cultivation and after pea and potato harvest

Soil / Parameters	Control (soil before cultivation)	Soil after pea harvest	Soil after potato harvest	L.S.D.0.05
Chemical Feature				
pH	7.70±0.320	7.40±0.210	7.50±0.245	**0.24**
EC(dS/m2)	0.22±0.014	0.23±0.045	0.22±0.045	**0.06**
Organic carbon (%)	0.21±0.011	0.38±0.108	0.26±0.061	**0.06**
Total –N (ppm)	233.3±12.350	800.0±42.560	666.7±35.480	**3.49**
Total soluble-N ppm	28.56±1.540	58.85±2.452	40.39±2.346	**0.09**
Available phosphorus (ppm)	9.82±0.340	16.00±1.330	11.3±0.250	**1.20**
Available potassium (ppm)	94.00±2.372	115.00±3.45	101.00±5.620	**3.33**
Biological Feature				
Dehydrogenase activity(µg TPF/100g dry soil/24h)	35.33±1.850	91.46±3.280	85.73±3.452	**12.18**
CO_2 evolution rate (mg CO_2/100g soil/24 h)	4.82±0.242	8.01±0.322	7.87±0.220	**0.06**
total bacteria log No.	5.40±0.324	6.10±0.178	5.56±0.174	**0.46**
Total fungi log No.	3.21±0.110	3.92±0.0682	3.30±0.0624	**0.06**
Total actinomycetes log No.	4.20±0.242	4.80±0.0845	4.53±0.172	**0.13**

Conclusion

Crop rotation with legumes can be considered one of the most excellent alternatives for plant nutrient management by improving soil chemical and biological properties. Incorporation of grain legumes offer an effective N benefit to succeeding crops which efficiently reduce the N-fertilizer consumption and provide an economic benefit for yield production and farmers. In general, the co-application of inorganic and organic manure through a crop rotation system including legumes, in newly reclaimed sandy soils, believed to be a good way for increasing yield and yield components of maize. The natural plant protection by crop rotation is another point should be taken in consideration.

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تأثير التعاقب المحصولي والكمبوست والبقايا النباتيه علي إنتاج الذره الشاميه وخصوبة الأراضي الرمليه و تقليل أستخدام السماد العضوي

مني محمد أبو النور[1] و سعاد يوسف سري[2]

[1] قسم النبات – كلية البنات للآداب و العلوم و التربيه – جامعة عين شمس – القاهره
[2] قسم الميكروبيولوجي – معهد بحوث الأراضي و المياه – مركز البحوث الزراعيه – الجيزه

الملخص

تم إجراء تجربه حقليه لدراسة تأثير نظام التعاقب المحصولي وأستخدام محاصيل مختلفه للوصول إلي نظام زراعي يؤدي إلي تحسين خصوبة التربه الزراعيه الرمليه في مصر. وعلي ذلك تم تصميم دورتين زراعيتين لأختبار تأثير إدخال نبات بقولي (البسله) بالمقارنه بنبات مستهلك للعناصر الغذائيه من الأرض (البطاطس) علي إنتاجية محصول النبات التالي(الذره) وكذلك مستوي المواد العضويه والنشاط الميكروبي في التربه. كما تم دراسة تأثير إضافة أسمده حيويه و عضويه مع مستويات مختلفه من التسميد النيتروجيني المعدني علي تحسين الخصائص الكيميائيه للتربه الرمليه وكذلك مدي أستجابة محصول الذره لهذا التسميد. وقد بينت النتائج أن الأستخدام المزدوج للسماد العضوي والغير عضوي في الدوره الزراعيه بسله/ذره أدي إلي تحسين إنتاجية محصول الذره وكذلك رفع مستوي العناصر الأساسيه (NPK) المتراكمه فيه مقارنتاً بدورة بطاطس/ذره. بم أن كفاءة التربه مرتبطه إرتباط وثيق بتداخل عوامل عديده من التفاعلات الكيميائيه والبيولوجيه فقط لوحظ تغير معنوي في الخصائص الكيميائيه (الكربون العضوي، النيتروجين الكلي والفوسفور والبوتاسيوم المتاح) والخصائص البيولوجيه (العدد الكلي للكائنات الدقيقه، ثاني أكسيد الكربون في التربه ونشاط أنزيم الديهيدروجيناز) للتربه المعامله بالسماد العضوي بالمقارنه بالمعامله بالسماد النيتروجيني المعدني لمختلف الدورات تحت الدراسه. وعلي ذلك فقد لوحظ ان توازن أستخدام الأسمده البيولوجيه والعضويه مع الأسمده المعدنيه في دوره زراعيه تحتوي علي نبات بقولي يؤدي إلي تحسين إنتاجية المحاصيل و تخفيض إستخدام الأسمده النيتروجينيه المعدنيه في الزراعه.