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AGRONOMIC BENEFITS FROM APPLYING COMPOST AS AN ORGANIC FERTILIZER TO CLAY SOIL.

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Abstract: Two years greenhouse experiment developed to quantify and identify the agronomic benefits of applying compost as an organic fertilizer at different application amounts and methods to clay soil. The factors tested include the nutritional status and crop yield of tomato plants and the fate of nitrogen. The results of this study showed that, compost application had the capacity to stimulate vigorous growth, nutritional status, production levels of tomato, and to increase N recovery compared to control. All these improvements in growth quality parameters were not significantly different at the higher compost application rates of 240 and 360 t/ha. This finding indicates that the plant response due to the increasing of compost application rate is subject to diminishing returns.

Major considerations in recycling of such compost on clay soils are the anticipated groundwater contamination by nitrate leaching. High application rates of compost at high moisture status resulted in high levels of residual nitrate in the soil. From this study, it could be concluded that high loading rates of good quality compost to clay soils as organic fertilizer is agronomically valuable with limited potential environmental risk of nitrate leaching if managed properly. Under the conditions of this study, mixing compost into clay soil using drip irrigation system was the best management strategy practice to reach optimum agronomic benefits while minimizing environmental risks of nitrate leaching.

Key words: agronomic benefits, compost, nitrogen recovery, nitrate leaching, organic wastes.

Introduction

Egypt's population increase and increasing urbanisation have resulted in various negative effects on the society; in addition to the rising demand for food, the production of large amounts of animal and human wastes. These various organic residues include livestock wastes, industrial organic wastes, crop debris, sewage sludge, wood manufacturing wastes, and municipal refuse. The disposal of these residues has become an increasing problem and a growing expense for the country, farmers and municipalities.Organic wastes application to agricultural land in Egypt has become a vital issue. The application of organic wastes to the land surface or incorporation within the root zone of plants, not only provides significant agronomic and economical benefits, but also is one of the most readily available and generally cheap means of utilising animal, agricultural and human wastes (Awad *et al.*, 1993; Abdel-Sabour. 1997 and Smith, 1996).However, the agricultural use of such wastes can be harmful because of the addition of excess input of N (Van den Berg, 1993). Recently, composting has been recognised as a cost-effective and environmentally sound process for the treatment of animal, agricultural and human wastes. Composting is one method of stabilising organic wastes by removing compounds such as ammonia and leaving more stable organic forms of nitrogen that resist leaching and must be decomposed by soil micro-organisms before they are available to crops (Maynard, 1994; and Tambone, *et al.* 2007). Once applied to soils, the major biochemical processes which occur to compost are the transformation of N. These processes and the rates of macro and micronutrients release influence the potential environmental consequences, specifically that of soil and groundwater degradation (Maynard, 1993 and Stratton, *et al.*, 1995). Management of large scale addition of compost for beneficial use in the organic farming systems must take into account strategies to meet crop nutrient needs and protect the environment. Previous studies with compost have largely been designed to elucidate potential environmental concerns associated with nitrate leaching, rather than better understanding of management strategies to optimise crop yield and minimise environmental impacts associated with N leachability.

So, the aim of this crop trial was to make practical recommendations for appropriate compost application rates and methods that could be used to maximize agronomic benefits and minimize environmental consequences associated with N leaching. To achieve this aim the objectives of the crop trial were therefore: To determine the quality responses of growth and yield of tomato to different application rates (0.0, 120, 240, 360 t/ha) and methods (mulching and mixing) of compost under drip irrigation and greenhouse controlled conditions and to evaluate N recovery from compost by tomato crop under the above-mentioned conditions.

Materials and Methods

The crop trial was conducted in the greenhouse at village 8 located west El-Minia Governorate in the period from June, 2004 to October, 2006 . The experiment was performed with a compost to evaluate its suitability as an organic fertilizer for clay soil used in the organic farming of tomato.

Clay soil detailed in table (1) was collected from a stockpile at the faculty of agriculture farm. Prior to the initiation of the greenhouse study, the soil was air dried, sieved to < 2.0 mm, and the moisture content was adjusted at 15 % before the addition of compost. Sub-samples of the dried and sieved soil were used to determine the soil properties using standard methods (Page, *et al.* 1982; and MAFF, 1986). The compost detailed in table (2) was made from farmyard manure, sewage sludge and green wastes (include all types of green residuals, from grass cuttings to tree pruning and sugar beet wastes). Samples of the dried, ground, and sieved compost were used to determine some physical and chemical properties such as moisture, heavy metals and total nutrients. The compost was then added to the clay soil at rates of 0.0, 120, 240, 360 t/ha (dry weight basis) by two methods of application (surface and mix addition).

Table(1): Some physical and chemical properties of the experimental soil.

WHC, F.C and PWP (%)	23.54, 18.26 and 5.67, respectively.
A.V(F.C – PWP) (%)	12.59
A.V(WHC – PWP) (%)	17.87
Bulk Density (g/cm^3)	1.55
Particle Density(g/cm^3)	2.61
Porosity (%)	40.61
PH(1 : 2.5 suspension)	7.32
CEC (meq/100g soil)	22.6
O.M (%)	1.59
EC(dS/m at 25 ^{0}C and 1:5)	0.49
Total N, P and K (%)	0.091, 0.039and 0.55, respectively.
Particle size distribution (%)	Coarse and fine sand, 32.1, 23.4, silt, 8.5 and clay 36
Texture	Clay

- Each value represents the mean of three repllcation.

Table(2): Some physical and chemical properties of the studied compost.

PH(1 : 2.5 suspension)	8.25
EC(mS/cm at 25 ^{0}C and 1:5)	6.95
CEC (meq/100g soil)	52.5
Total organic carbon (D.M) (%)	36.1
Total NPK (D.M) (%)	2.25, 0.95 and 1.64 ,respectively
C/N Ratio	16.04
Ammonia (mg/kg)	454
Nitrate (mg/kg)	57

- Each value represents the mean of three repllcation.

Greenhouse plot preparation.

The trial was composed of 24 trenches; each trench was dug inside the greenhouse (length of 100 cm, width of 30 cm and depth of 30 cm) and covered with black polyethylene to maintain a high temperature environment. In June 2004, th e trenches were filled with 140 kg soil and the weights of air dried-compost corresponding to the equivalent application rates were added as surface or mix-applied by hand into the soil trenches to a depth of 20 cm (table 3).

Table(3): The equivalent application rates of compost (kg) and total N applied.

Applied compost		Total applied N kg/plot		
t/ha	kg/plot	From compost (kg/plot)	From Soil (kg/plot)	Total (kg/plot)
0.0	0.0	0.0	0.127	0.12
120	3.7	0.083	0.127	0.21
240	7.3	0.164	0.127	0.29
360	10.7	0.240	0.127	0.36

- Each value represents the mean of three repllcation.

In the case of compost mix applied, each trench was filled with soil to depth of 10 cm and the rest of 140 kg of compost treated soil mixture was added. In the case of compost as surface applied, the trenches were filled with 140 kg soil and compost was added at the above mentioned rates. The trenches were watered by drip irrigation and left bare and undisturbed for 30 days for the soil to settle down. In June 2004, the tomato trial commenced and ran for two seasons. In the first season, three seedlings of a greenhouse cultivar of tomato were planted 30 cm apart in each trench and thinned for two after vigorous growth.

The plant density was 5.6 (60 × 30 cm) plants / m^2. Plants were staked and the side shoots removed to increase the early yield of fruits and to support the upright growth. Each trench was watered every third day to compensate for losses of water using a drip irrigation system which maintained moisture content at field capacity during the period of the experiment. In each plot, soil moisture content was determined weekly at 10 cm depth by weighing soil samples dried in an oven for 24 h at 105°C. The tomato plants were not fertilised other than compost application during the growth cycle (120 days) and weed control was maintained by hand.

Tomato was first harvested on August and harvesting continued for two months. Leaf, fruit and soil samples were collected at the time of first harvest for nutrient analyses. In October at the last harvest, tomato plants were cut above the ground, washed with distilled water, weighed fresh, oven dried at 65°C for 96 h, and weighed again to determine dry weight. After the tomato experiment, plots were left for five months covered with black polyethylene and watered once a week for tomato roots to decompose before the second season. Tomato growth parameters were recorded throughout the entire growth cycle (i.e. after 60 and 120 days from planting out) included plant height, stem radius, fresh and dry weights of plants and fruit production.

The nutritional status of the tomato plants was checked by determine the content of nutritional elements (N, P, K and Fe, Mn, B) in tomato leaves taken from all experimental trenches during the productive phase (60 days after planting out). Plant leaves were analysed for N, P, K and Fe, Mn and B according to the procedures described by Page *et al.* (1982) and Avery and Bascombe (1982). Nitrogen recovery (NR%) was calculated as the percent of N applied for each treatment where: NR% = [(Plant N uptake for each treatment (kg/trench) - Plant N uptake for control (kg/ trench))/Total N applied for each treatment (kg/trench)] × 100.

Before the second year's compost application, soil samples were taken from each plot to determine the amounts of residual NO_3-N in soil plot (0-30 cm depth). The amounts of NO_3-N in 30 cm soil depth were calculated by multiplying their concentrations by bulk density and soil depth. Total N and NO_3-N were determined in soil and plant samples according to Rowell, 1994 and MAFF, 1986.

In late October 2005, compost was added for a second year at the same rates as in the first year to each plot as surface applied or mixed by hand into the soil to a depth of 20 cm. In January 2006, the second year crop experiment commenced with the same procedures as used in the first year.

All the crop experimental data for all parameters were analysed as a completely randomised block design, with three replicates. The experimental data was computed using the procedures available in the (6.11, SAS Institute, 1996) package. The averages of three samples of each treatment in the three experiment replicates were compared using Least Significant Difference (LSD) test at the 0.05 probability level.

Results and Discussion

- **The nutritional status, crop yield and the fate of nitrogen.**

This crop trial was conducted under controlled greenhouse conditions to evaluate compost suitability as organic fertilizer in terms of both agronomic benefits and environmental impacts. Leaf analyses for major nutrients (NPK) of the tomato variety for two seasons as affected by compost application rates and methods are shown in figures (1, 2 and 3), all the data is expressed on a dry matter basis. The concentrations of N, P, and K in tomato leaves taken from plants grown on compost amended plots were about twofold higher in the case of the lowest compost application amount (120 t/ha) than from the plants grown on untreated plots.

This increase was not proportional to the increase in application rate of compost in most cases, especially in the case of P and K. The highest N concentration (3.89%) was obtained by tomato plants grown on compost surface-applied plots with the application amount of 240 t/ha. The increase in either compost surface or mix applied plots was proportional to compost application rate.

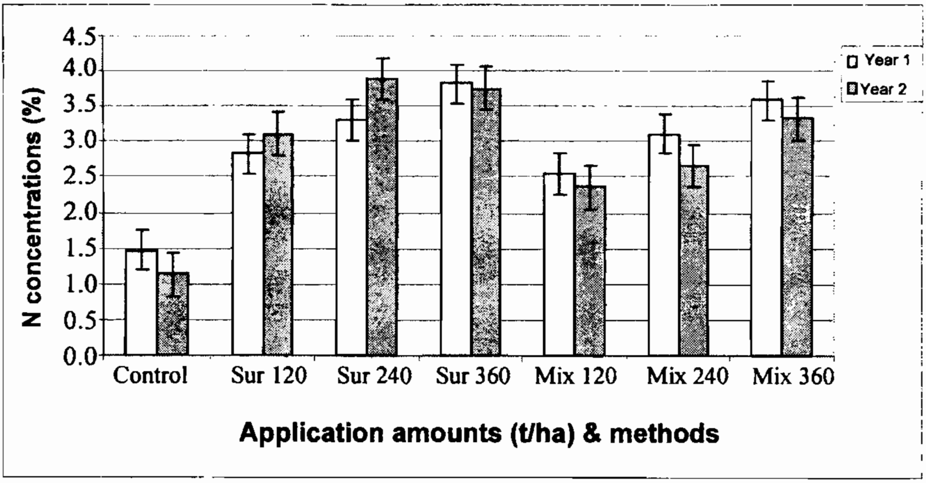

Fig.(1): Tomato N leaves as affected by compost addition. Vertical bars represent a fixed value (L.S.D value, $P < 0.05$).

Treatment of the soil with the lowest amount of compost (120 t/ha) as surface or mix applied increased the concentration of N in tomato leaves twofold compared with the control. In the first season, the difference in N% concentration between tomato's leaves taken from compost-surfaced and compost-mixed plots were insignificant at all application amount , illustrating that the N availability and release pattern were very similar.

In the second season, tomato leaves taken from compost-surfaced plots had higher N concentrations than those taken from the corresponding compost-mixed plots. This may be attributed to the initial immobilisation of N by the incorporated compost, followed by some slow mineralization by the time post-application.

Another possibility is the differences in the C/N ratio created by the method of application. Thus, surfaced compost resulted in greater soil inorganic N compared with the mixture of soil and compost. When such compost with a C/N ratio of 16 was applied to clay soil, compost N mineralization was greater in compost as mulch than in compost as incorporated, but additional N fertilizer is not required for either method of application. Although N concentration in tomato leaves was significantly higher from compost-surfaced plots compared with compost-mixed plots in the second season, tomato yielded more fruit in compost-mixed plots.

The average N concentrations were all within the optimum range (3.0-5.0 %) (Hochmuth, *et al.,* 1991) in all compost treatments except the lowest amount of compost, which were slightly below this range. In general, the N concentrations of tomato leaves from control plots were far below this optimum range and reported at deficiency level.

With regard to P, the results of tomato leaf analysis show different trends from the results of nitrogen. In the first year, phosphorus concentrations (%) in tomato plants were significantly increased due to compost application. In the second year, the most obvious improvement in P concentration resulted from the highest amount of compost as incorporated while the reverse happened with compost as surface applied (Fig. 2). Tomato leaves P concentrations increased slightly with increasing amount of compost, both with compost surface and mixed applied plots. This is probably due to a more intensive phosphorus adsorption and precipitation by organic matter with increased compost application amount.

The other possibility is inter-nutrients competition in the case of high availability of nitrogen. This effect, however, did not cause any P deficiency or harmful effect on tomato yield in any compost treatment. Generally, the average P concentrations in tomato leaves were all within the optimum range reported in the literature for tomato (0.3-0.6%) and were only below this range for the control (Hochmuth *et al.*, 1991).

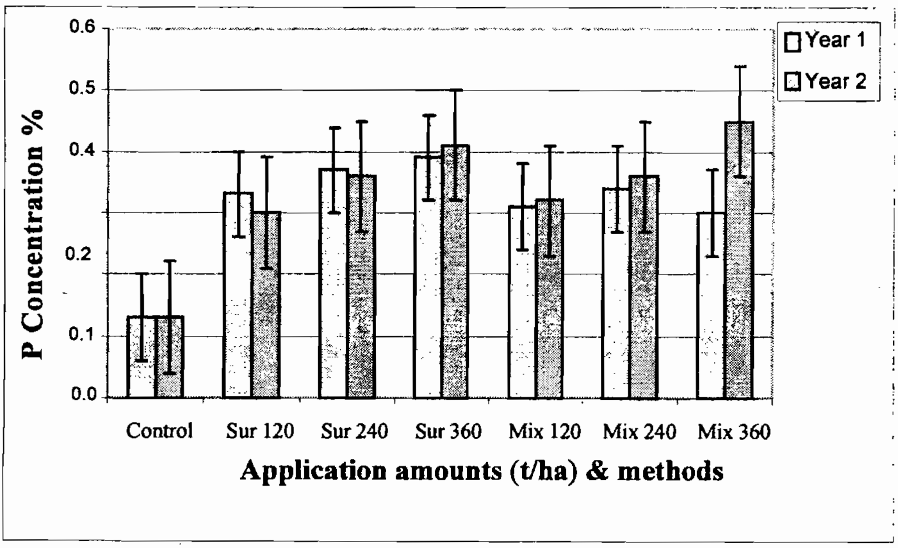

Fig.(2): Tomato P leaves as affected by compost addition. Vertical bars represent a fixed value (L.S.D value, $P < 0.05$).

Potassium concentrations (%) in leaves of tomato plants grown in compost-amended plots were significantly increased regardless of the method of application, in the first year, the increases being proportional to the application amounts (fig. 3). In the second year, there were no further significant responses of K concentration to higher application amounts or treatments. On the contrary, potassium concentration in tomato plants grown in compost-surfaced plots was significantly greater in the first year than in the second year. This phenomenon, however, did not cause the K concentrations in tomato leaves to be below the optimum average (2.0-5.0%) in all compost treatments (Hochmuth *et al.*, 1991).

In relation to micronutrients, adding compost significantly increased (*P* < *0.05*) tomato leaf concentration of Fe, Mn, and B when compared with the control. Tomato leaf concentrations of Fe, Mn, and B did not seem to correlate with high application amounts where as the application amount increased the tomato leaf concentration of Fe, Mn, and B decreased. In addition, it is worthy mentioning that, the data shows a decrease in tomato leaf concentrations of Fe, Mn, and B with increased application of compost regardless of the method of application (Fig. 4A, B and C). The decreases in trace elements concentrations between compost-amended plots were relatively small, and they were insignificant with increasing application amount.

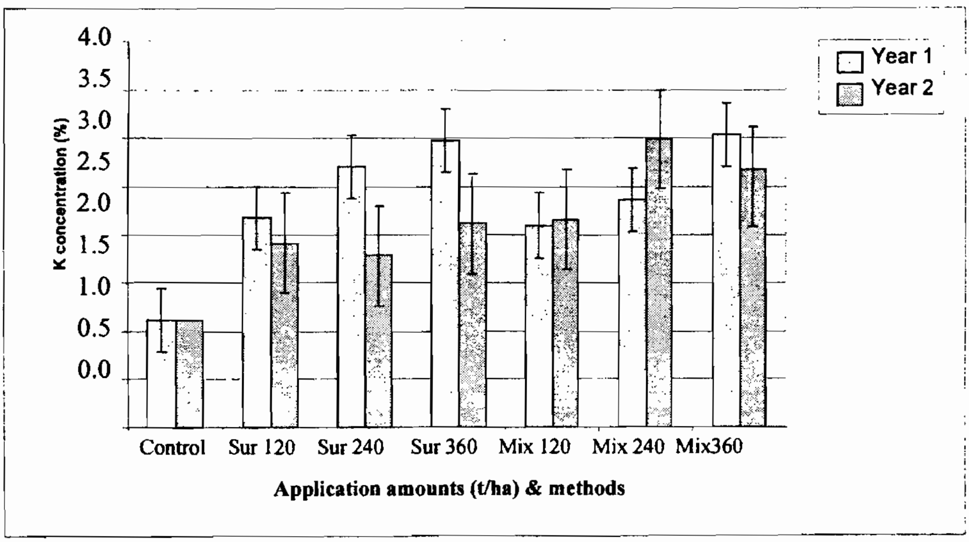

Fig.(3): Tomato K leaves as affected by compost addition. Vertical bars represent a fixed value (L.S.D value, P < 0.05).

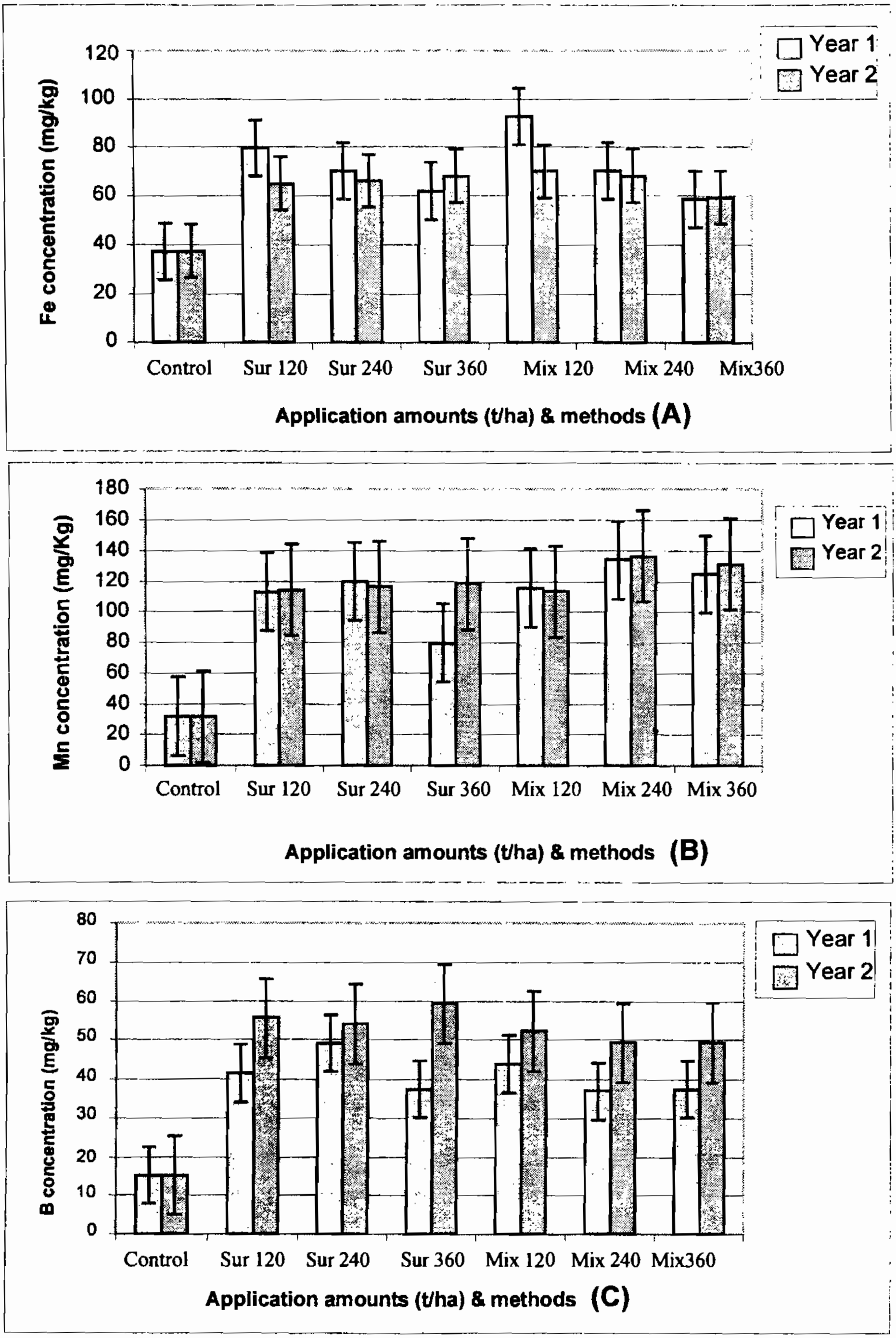

Fig.(4): Fe, Mn and B concentrations of tomato leaves. Vertical bars representa fixed value (L.S.D value, $P \leq 0.05$).

This decrease may be due to an increase in soil pH with increasing amounts of compost. In addition, the adsorptive effect of the compost organic matter at its lowest amount led to higher availability of micronutrients, but the reverse was observed where the amount were increased to 240 and 360 t/ha. There also appears to be a prohibitive effect by the increasing availability of NPK, since there was a significant decrease in the tomato leaves concentrations of micronutrients with high application amount of compost.

This indicated that the availability of micro-nutrients to tomato plants was not dependent only on the concentration of elements in compost or the method of application. Other affected soil edaphic conditions as a result of compost addition, such as pH, CEC, and organic matter, may also induce important effects.

The increased percentage concentrations of Fe and Mn in tomato leaves grown on compost-mixed plots were insignificantly higher than the concentrations in tomato leaves grown on compost-surfaced plots when equivalent amount of compost were applied for two years. The increase percentage concentration of B in tomato leaves grown on compost-surfaced plots was higher than the concentration in tomato leaves grown on compost-mixed plots when equivalent amount of compost were applied for two years.

These erratic results in the case of compost-surfaced plots suggest that the soluble forms of Fe and Mn are made less soluble in the soil once the pH is more than 8 in the compost-mulching layer. The other possibility may be due to the high amount of decomposition of organic complexes allowing the micronutrients to adsorb on soil particles making them less bio-available (McBride, 1995). However, the high concentration of B in tomato leaves in spite of the high pH reflects the higher total B concentration in this compost. On the other hand, mixed compost raised the final soil pH to 7.6, illustrated that the availability of Fe, Mn, and B to tomato plants was optimal. The average concentration of Fe in tomato leaves was marginally within the reported optimum range (60 - 240 mg/kg) in both seasons (Epstein, 1997; USEPA 2005).

This in addition to the above-mentioned may be due to Fe precipitating with added compost P as insoluble Fe phosphates, where a decrease in tomato leaves concentrations of P was observed in this experiment as the compost amount increased. Although, no nutrient deficiency or toxicity symptoms were observed, further research is needed to determine whether vegetable crops grown on such soils can accumulate much B from this type of compost to impose a food-chain toxic risk. However, all compost treatments had tomato leaf Mn and B concentrations within the reported optimum range (Epstein, 1997; USEPA 2005). In general, no nutrient deficiency or toxicity symptoms were observed in any compost treatment.

The results of this experiment clearly indicate that all compost treatments had the capacity to stimulate tomato leaf concentrations of macro- and micronutrients. The average nutrient concentrations were all within the optimum range reported in the literature for tomato in all compost treatments and were only below this range for the control. Results of a statistical analysis in all nutrient concentrations measured showed significant differences ($P = 0.05$) between control plots and compost-amended plots with a greater effect of compost high application amount than compost methods of application (surface and mix applied) in the first ye.. In the second year, signif-ant differences due to meth-ds of application were observ-d.

In general, t-mato plant nutritional eleme-t concentration did not respo-d significantly to increasing compost amount beyond 2-0 t/ha in the second year, r-gardless of the method of app-cation. This indicated that th- tomato plants may have reached the maximum nutrients uptake or excess nutrients may be enriching the soil organic matter and encouraging microbial activity.

In the first season, in the control plots tomato plants were yellow showing severe nutritional deficiency symptoms (corresponding to a depletion of nutrients from control plots) in comparison to the compost-amended plots. In the second season, plants in the control plots were severely stunted and dead plants were recorded. Thus, no yield was recorded indicating severe nutrient deficiency and depletion. Tables 5 and 6 list the results of stem radius, production level, and plant height, respectively.

Table(5): Plant stem radius (cm) for two seasons.

Application methods	Application amount (t/ha)	Stem radius (cm)			
		60 days		120 days	
		From planting out			
		Season 1	Season 2	Season 1	Season 2
Control	0.0	0.8	0.7	1.1	NA*
Surface-applied	120	1.2	1.5	1.8	1.9
Surface-applied	240	1.4	1.7	1.9	2.1
Surface-applied	360	1.5	1.9	2.1	2.8
Mix-applied	120	1.3	1.2	1.9	1.9
Mix-applied	240	1.5	1.6	1.9	2.1
Mix-applied	360	1.6	1.6	2.1	1.9
L.S.D 0.05	Application amount	0.26	0.21	0.22	0.31
	Application methods	0.35	0.26	0.41	0.46
	Seasons	0.30	0.30	0.32	0.32

* Not Applicable.

- Each value represents the mean of three repllcation.

Table(6): The effects of compost on some growth parameters.

Application methods	Application amount (t/ha)	Production level (kg/plot)		Plant height (cm)			
				After 60 days		After 120 days	
				From planting out			
		Season 1	Season 2	Season 1	Season 2	Season 1	Season 2
Control	0.0	1.91	NA*	107	59	161	NA*
Surface-applied	120	8.11	7.63	247	269	362	355
Surface-applied	240	10.3	10.6	257	291	358	388
Surface-applied	360	13.3	9.72	285	271	393	349
Mix-applied	120	7.72	10.4	192	246	287	371
Mix-applied	240	7.81	13.9	230	298	342	392
Mix-applied	360	11.5	13.9	249	281	338	390
$L.S.D_{0.05}$	Application amount	2.91	3.11	88	75	62	53
	Application methods	2.82	2.91	67	52	71	76

* Not Applicable.

- Each value represents the mean of three repllcation.

The results clearly indicate that all compost treatments had the capacity to stimulate vigorous growth of tomato plants by increasing stem radius and plant height. The stem radius of plants grown on the compost amended-plots were about twofold thicker in the case of the highest compost application amount (360 t/ha) than the plants from untreated-plots. The height of tomato plants was significantly affected by compost addition compared to control. However, in most cases, there were no significant differences between different application amount and methods of applications.

In general, plants vegetative growth in compost-surfaced plots was equal to or insignificantly better than the vegetative growth in compost-mixed plots. It is worthy mentioning that, vegetative growth and yield of tomato plants closely paralleled with the compost application amount of 240 t/ha and 360 t/ha, especially in the second year, indicating the highest quality plants were produced in plots receiving 240 or 360 t/ha. Vegetative growth observations and tomato yield were consistent in the first year with a greater effect of compost methods of application than compost high application amount. Tomato yields in compost-surfaced plots were higher than in compost-mixed plots. In the second year, although vegetative growth observations of tomato plants grown on compost-surfaced plots were better than the compost-mixed plots at all application amount, tomato yielded more fruit in compost-mixed plots.

One reasons is present to explain why tomato yield from compost-surfaced plots was higher than from the compost-mixed plots, in the first year. The greater yield under compost-surfaced plots was due to improved water retention characteristics that might have resulted in a soil environment more conductive to tomato growth.

Apparent significant effects of compost addition as surface or mix applied on soil moisture content at 10-cm depth was noted after each irrigation event. However, the soil moisture content was slightly higher in the case of compost-surfaced plots than in the case of compost-mixed. This suggests that the slightly lower moisture content in the case of compost-mixed plots was due to the deeper rooting system, which encouraged efficient soil water extraction and therefore increased evapotranspiration. The other possibility is that the thick mulching layer insulates the plots from greenhouse lights and thus reduces soil water evaporation.

In the second year, the reverse was noticed where tomato yield responded more to compost as mix-applied with the highest application amount (360 t/ha) than to compost as mulch with the same amount. On the contrary, the highest compost amount applied, as mulch in the second year was significant for tomato's green growth, but not for tomato yield. Furthermore, the onset of tomato flowering and date of first harvest was delayed in case of compost-surfaced plots compared with compost-mixed.

Table(7): The effect of compost on some growth parameters and N recovery.

Application amount (t/ha) & Methods	Fresh weight (kg/plot)		Dry weight (kg/plot)		Nitrogen uptake (kg/plot)		N Recovery (NR %)	
	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2
Con. 00.0	4.85	3.3	0.22	0.1	0.004	0.001	3.7	0.8
Surface. 120	9.66	11.9	1.33	2.15	0.037	0.066	16.1	26.8
Surface. 240	10.5	13.2	2.20	2.81	0.072	0.11	24.1	30.1
Surface. 360	11.9	14.2	2.29	2.98	0.086	0.11	23.1	21.7
Mix. 120	9.3	11.3	1.15	1.69	0.028	0.04	11.7	15.8
Mix. 240	10.2	11.6	1.51	2.33	0.046	0.062	14.8	15.7
Mix. 360	10.9	13.1	1.97	2.66	0.071	0.085	18.6	16.2
$L.S.D_{0.05}$ Amount		3.88	4.31	0.41	0.65	0.023	0.03	2.3
$L.S.D_{0.05}$ Methods.		2.66	3.22	0.55	0.77	0.018	0.051	3.5

- Each value represents the mean of three repllcation.

Plausible reason was observed to explain why an inverse relationship between the increased amount of compost as mulch and tomato fruit production existed in the second season. Examination of root structure in compost-surfaced plots showed much more extensive tomato root development with many more root hairs into the thick compost-mulching layer than into the underlying clay soil. This pattern of root development allows for more luxurious N uptake at the expenses of other macro or microelements in circumstances of increased availability of nutrients. In contrast, the root development in plants grown on compost-mixed plots was evenly distributed in the entire compost amended plots.

Results of the effect of compost on fresh weight (kg/plot), dry weight (kg/plot), N uptake (kg/plot) and N recovery % of tomato plants grown on compost-amended plots for two seasons are presented in table (7). The results revealed that both fresh and dry weights of tomato plants were increased significantly due to compost addition. This increase was not proportional to the increase in compost application rates.

The statistical analysis illustrates that a significant difference existed only for dry weight of tomato plants depending on methods of application and application amount ($P \leq 0.05$; table 7). However, there was no significant effect for fresh weight of tomato plants between different application amounts or methods. The highest application amount (360 t/ha), however, had the greatest effect upon the fresh weight of tomato plants.

In the absence of artificial N fertiliser, total N uptake of tomato plants increased significantly with the addition of compost in both seasons compared to control (Table 7). The overall response of tomato plants N uptake is presented in figure (5). The figure displays the mean N uptake results for each application amount and method and the least significant difference intervals. Among the compost application methods, total N uptake in the first season was similar except for the 240 t/ha compost-surfaced treatment, which had significantly higher N uptake compared to the same amount of compost-mix applied treatment. However, in the second season, total N uptake by tomato plants grown on compost-surfaced plots was significantly higher compared to compost-mixed.

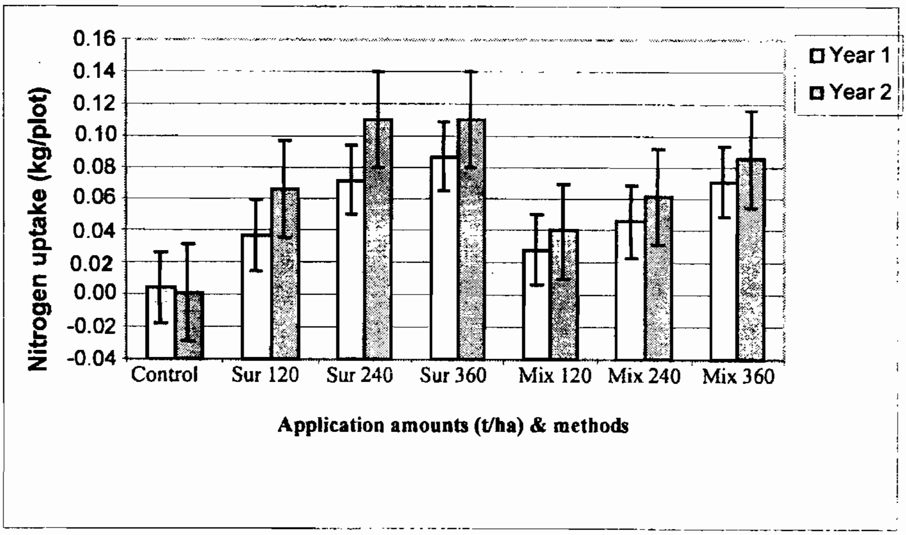

Fig.(5): Total N uptake as affected by compost addition. Vertical bars represent a fixed value (L.S.D value) for compost application amounts.

Total N uptake of tomato plants was significantly affected by compost application amount (120, 240 and 360 t/ha). However, in most cases, there were no significant differences between the compost application amount of 240 t/ha and 360 t/ha as mulch or incorporated.

In the first season, the total N uptake increase (94%) at the application amount of 240 t/ha as mulch was nearly double that achieved at 120 t/ha. However, the total N uptake increase at the application amount of 360 t/ha was not significant and only 20% more than that achieved at 240 t/ha. In the second season, the total N uptake increase at the application rate of 240 t/ha as mulch was significant and 66% higher than that achieved at 120 t/ha. However, there was no increase in the total N uptake increase at the application rate of 360 t/ha over that achieved at 240 t/ha.

These findings indicated that diminishing returns of nitrogen uptake are being measured for increases in application amounts over 240 t/ha, especially in the case of compost-surfaced plots. Also, these results showed that total N uptake was the same among compost-surfaced plots receiving 240 or 360 t/ha of compost. This finding suggests that tomato plants may have reached maximum N uptake and excess N will be likely to accumulate in the clay soil and leach into ground water or volatilise from the compost mulching layer under tomato cultivation.

In summery, the different effects observed in these two methods of application can be explained on the basis of variation in C/N ratio. In general, growth parameters (fresh and dry weights) and total N uptake of tomato plants closely paralleled at the compost application amounts of 240 and 360 t/ha, especially in the second year, indicating that the highest quality plants were produced in plots receiving 240 or 360 t/ha.

Compost addition significantly ($P \leq 0.05$) influenced tomato N recovery from all compost-treated plots compared to control (Table 7). The overall N recovered by tomato plants and the least significant difference intervals are presented in figure 6.

The graphic illustration and statistical analysis show that significant differences do exist in N recovery by tomato plants arising from both the compost application amounts and methods. The highest N recovery was achieved by tomato plants grown on compost-surfaced plots. At 240 and 360 t/ha surface-applied compost, N recovery by tomato plants were approximately the same. The results of N recovery by tomato plants grown on compost-surfaced plots were significantly higher than for the compost-mixed in both seasons. Tomato N recovery from compost-surfaced plots was very high and similar regardless of the application rate.

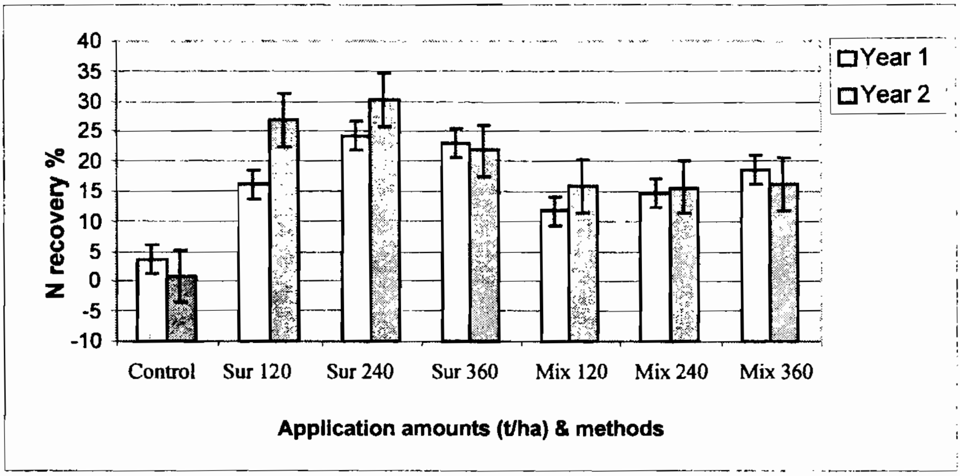

Fig.(6): Total N recovered as affected by compost addition. Vertical bars represent a fixed value (L.S.D value) for compost application amounts.

Two plausible reasons are present to explain why N uptake or recovered by tomato plants from compost-surfaced plots was significantly greater than from the compost-mixed. Firstly, surface application of compost with such a low C/N ratio, caused significant mineralization of organic N. Once mineralised, this N can probably be taken up by the plants, immobilised, denitrified and volatilised or leached. This leads to increased levels of available nitrogen within the soil crop system so causing greater increases in N uptake and recovery or loss. However, in the case of compost mix-applied plots, most of the compost N incorporated into organic substances contributes mainly to a stable clay soil structure and to a high C/N ratio resulting in a passive N pool where N remineralization will probably proceed slowly for several seasons. Second, even without compost organic N mineralization, mulch-applied compost rates of 120, 240, and 360 t/ha would supply immediate 60, 121, and 181 kg/ha inorganic N at the time of application (0.509 kg N per tone compost accounting for compost inorganic N), respectively. Whereas, the same incorporated-compost application rates may not supply the same amount of inorganic N at the time of application due to NH_4^+-N fixation on the surfaces of clay and organic matter in the soil-compost mixture and therefore this N is not available for nitrification or plant uptake.

After one compost application, residual nitrate at the end of the first season increased as the application rate of compost increased regardless of the method of application (Fig, 7). Residual nitrate-N was significantly greater with compost-surfaced plots than with compost-mixed at all application rates. These observations suggest that greater compost decomposition and a faster rate of N mineralization occurred with compost-surfaced plots than with compost-mixed. The compost intimately incorporated with clay soil would decompose less rapidly than the surface applied compost. Thus, mulched compost resulted in significantly greater N mineralization compared with incorporated compost.

As a result, greater amounts of nitrate will be likely to accumulate in clay soil and leach into the groundwater with surface applied than incorporated compost. Tester *et al.* (1977) stated that the N immobilization that was evident in the decomposition of compost alone may reduce mineralization levels when the compost is mixed with some soil.

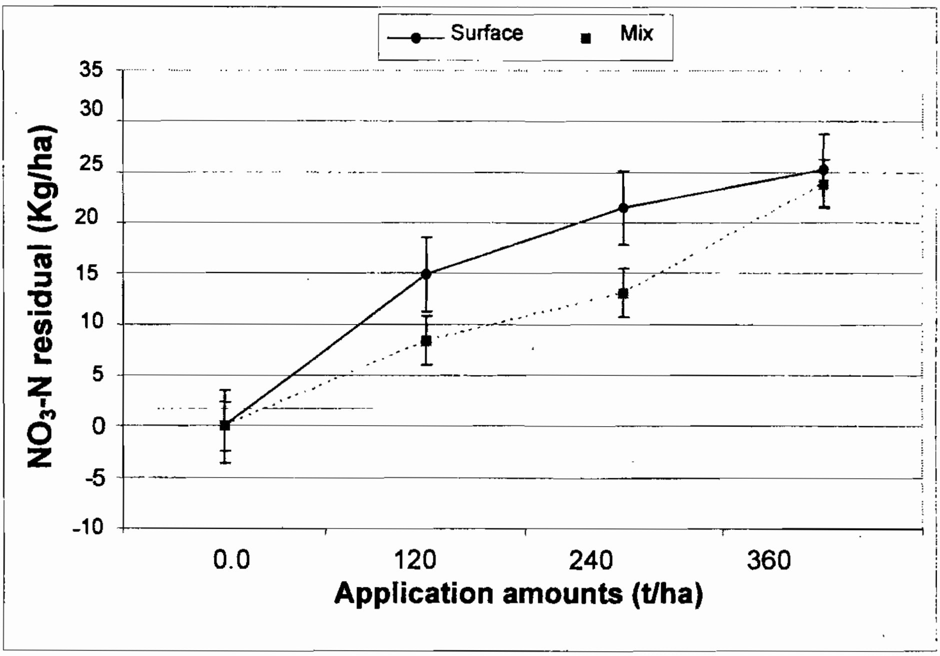

Fig.(7): Soil residual NO_3-N after first season harvest. Vertical bars represent a fixed value (L.S.D value) for compost application method ($P \leq 0.05$).

After two compost applications with different rates, residual nitrate followed a similar pattern except for the highest application rate (360 t/ha) where it was significantly greater with compost-mixed plots than with compost-surfaced (Fig. 8). Nitrate-N residual ranged from nil kg/ha with no compost added to 40.36 and 46.19 with 360 kg/ha of compost as mix-applied and 240 t/ha of compost as surface-applied, respectively.

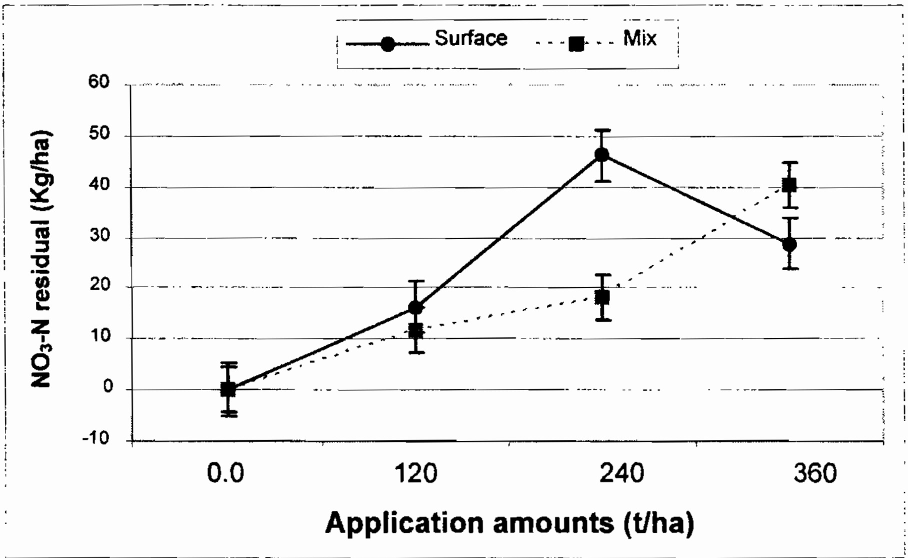

Fig.(8): Soil residual NO_3-N after second season harvest. Vertical bars represent a fixed value (L.S.D value) for compost application method ($P \leq 0.05$).

It was speculated that the greater residual N in the compost-mixed plots at the highest rate of 360 t/ha after two compost applications was due to a more constant value of the C/N ratio that might be accompanied by a net mineralization of N. In addition, there was greater water availability and more constant soil structure that might have resulted in more optimum soil workability and more conducive soil environment to microbial decomposition, N release and balanced utilization of nitrate by crops. On the other hand, in the case of compost-surfaced plots at the same rate, there was a large pool of nitrate that would be available for crop luxurious uptake and therefore did not accumulate in the soil plots.

There is also a possibility that some of N might have been lost through NH_3 volatilization. Nitrogen recovered by tomato crop and residual nitrate with compost-surfaced plots exceeded 20% of the total applied N after one and two compost applications. Similarly, N recovered in compost-mixed plots exceeded 15% after one and two compost applications. These values were higher than the 10% value reported for compost in the literature (Tester *et al*, 1977).

Conclusion and Recommend-ations

In this study, surfaced or mixed application of compost with 2.25% of total N tended to result in consistent and more than adequate N availability for tomato plants, especially, with 240 or 360 t/ha compost application amounts in the first and second years with no fertiliser. Thus, the absolute concentration of total N must be considered when using compost as mulch or incorporating in an organic farming project of clay soil. The results of this study indicate that compost can be used as the only source of nutrients in the organic farming systems at amounts high enough to supply most of the nutrients without excessively contaminating the groundwater with nitrate. The results also indicate a cumulative effect in the soil plot with yearly application of compost with substantial increases in residual nitrate in the soil profile. The substantial residual nitrate concentration in the soil indicates that rapid nitrification can occur in clay soils, thus increasing its potential to leach into groundwater. Less nitrate leaching would be expected on compost-mixed plots due to more stable soil structure that might have resulted in less infiltration. In the organic farming systems, to lessen nitrate leaching and to increase the effective utilization of the nitrogen-rich compost, a drip irrigation system that decreases and restricts the volume of water delivered to each root zone, thereby minimizing leaching losses is required.

Over the two years of this study, surface-applied was similar to mixed-applied compost in their ability to supply adequate nutrients to tomato plants at both 240 and 360 t/ha application amounts. Where the diminished yield per unit of compost addition was clearly seen, beyond which further additions will not improve the yield. Increasing compost application amounts increase the overall agronomic benefits and might raise the environmental impacts associated with nitrate leaching in the case of repeated application. But, the overall agronomic benefits need to be calculated in combination with other soil chemical and physical properties that are provided by compost addition (in press).

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الفوائد المحصوليه من استعمال كومبوست كسماد عضوى لأرض طينيه.

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تجربة محصولية أجريت لمدة سنتين تحت ظروف الصوبة للتعرف علي الفوائد المحصولية لإضافة الكومبوست كسماد عضوي بكميات وطرق مختلفة إلي ارض طينية. العوامل المختبرة تشمل الحالة الغذائية وإنتاجية نبات الطماطم وكذلك حركة النيتروجين. نتائج هذه الدراسة بينت أن إضافة الكومبوست حفزت النمو والحالة الغذائية ومستوي الإنتاجية للطماطم وكذلك إزدادت نسبة امتصاص النيتروجين بالمقارنة بالكنترول.

كل هذه التحسينات في مقاييس جودة النمو كانت غير معنوية عند إضافة ٢٤٠ طن كومبوست للهكتار أو ٣٦٠ طن كومبوست للهكتار. هذا يدل أن استجابة النبات نتيجة لزيادة نسبة الكومبوست يخضع إلي النقص في العائد من وحدة الإضافة. اعتبارات كبيرة يجب أن تؤخذ في الاعتبار عند تدوير هذه النوعية من الكومبوست في الأرض الطينية وهى تلوث المياه الجوفية بالنترات . عند استعمال كميه عالية من الكومبوست في حالة ارتفاع نسبة الرطوبة أدي إلي زيادة نسبة النترات المتبقية في التربة.

من هذه الدراسة يمكن استخلاص أن إضافة كميات كبيرة وتدار بشكل جيد من الكومبوست العالى الجوده كسماد عضوي إلي الأراضي الطينية أعطي نتائج محصولية جيدة مع وجود تأثير بيئي محدود فيما يتعلق بالنترات المتبقيه عرضة للغسيل. تحت ظروف هذه الدراسة خلط الكومبوست في الأرض الطينية مع إستعمال نظام الري بالتنقيط أحسن استراتيجيه أداريه للوصول إلي الفوائد المحصولية المرجوة مع تقليل المخاطر البيئية.