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The Combined Effect of Organic and Chemical Fertilizers under Water Stress on Nutrient Uptake of Corn and Bean Plants

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ABSTRACT

A field experiment was carried out at El Nubaria (North of the Nile Delta). The experiment included the following treatments: A) water regime treatments: I_1 = 100% of WR (water requirement), I_2 = 80% of WR and I_3 = 60% of WR; B) fertilizer treatments included: F_0 (control), F_1 (150% compost), F_2 (100% compost ≈10 ton/fed; 1 fed = 4200 m^2), F_3 (75% compost + 25% NPK), F_4 (50% compost + 50% NPK) and F_5 (full recommended NPK). Corn plants (*Zea mays* L. Single cross 129 white) were grown under these treatments and followed by bean (*Vicia faba* L. Nubaria 1) to evaluate the residual effect of such treatments. I_2 was considered to be best as it produced high corn grain yield. About 20% of irrigation water could be saved when only 80% of calculated WR of corn plants was applied. Also, corn grain yield increased with increasing mineral fertilizer rate. Reducing the water application rate from 100 to 80% ETc reduced bean seed yield by 35.38 and 5.32% compared with I_1 in first and second season, respectively. Seed yield was significantly increased at all rates of compost compared with the control in two consecutive seasons. Phosphorus (P) concentration in green and ear leaves and corn grain increased as the amount of water increased in the following order $F_5 < F_4 < F_3 < F_2 < F_1$, irrespective of the control treatment. Residual effect of compost alone or in combination with mineral fertilizer produced a more remarkable uptake of P by bean seeds than 100% chemical fertilizer treatment (F_5). Potassium concentration in new leaves, ear leaf and corn grain increased in the order $F_2 > F_1 > F_3 > F_4 > F_5$, irrespective of the control treatment, although K% in bean seeds increased in the order $F_5 > F_4 > F_3 > F_2 > F_1$. A high amount of irrigation (I_1) enhanced P and K availability more than I_2 and I_3. The combination of 50 or 25% mineral P fertilizer with compost increased available P more than applying 100% mineral fertilizers.

Keywords: banana compost, phosphorus, potassium, water management

INTRODUCTION

Fertilizers and agrochemicals play a very important role in increasing land productivity and fertility. Although mineral fertilizers can be used to replenish soil nutrients removed in crop harvests, they are too costly to be used in large quantities for profitable production in developing countries.

Because of growing demand for fresh water supply with increasing energy prices and depletion of water sources, farmers are forced to use efficient irrigation systems and/or to consider water stress practices or deficit irrigation. Therefore, researchers have been studying possible effects of reduced irrigation practices, especially on crop yield parameters. Oktem *et al.* (2003) concluded that the yield of sweet corn (*Zea mays saccharata* Sturt) was reduced with deficit irrigation in two years; furthermore, a 2-day irrigation frequency, with 100% ET (evapotranspiration) water application by a drip system would be optimal for semi-arid regions. El-Hendawy and Schmidhalter (2010) showed that yield variables (weight of ears per plant, number of grains per ear, weight of grains per plant, total grain yield per ha) increased with increasing irrigation rate.

Crop residue management is thus a promising alternative for nutrient recycling. It is a critical factor not only for increasing crop yields but also for sustaining long-term productivity, through the use of renewable resources easily and cheaply available on a farm. Patra *et al.* (2000) indicated that recycling crop residues reduces the need for fossil fuel-based fertilizer, and helps to sustain and restore soil fertility in terms of available nutrients and major physical and chemical characteristics of the soil. Abdel Moez (2001a) showed that application of banana composts significantly increased the dry matter, grain yield, protein, P and K contents in corn (*Zea mays* L.) grains compared to the control.

Abdel Moez (2001b) showed that application of banana compost (chicken manure: banana wastes at a 1: 3 ratio) at rate of 20 ton fed^{-1} (1 feddan = 4200 m^2) + 50% of recommended chemical fertilizers increased the dry weight, yield and protein % of soybean (*Vicia faba* L.) compared with 100% chemical fertilizers. Abdel-Maksoud *et al.* (2002) noted a significant increase in grain yield, straw yield, plant height and whole plant dry weight as well as N and P contents of wheat (*Triticum aestivum*) when fertilized by compost. Medina *et al.* (2004) indicated that the use of organic amendments to improve symbiotic development is of great importance for legume growth in poor and desertified soils. Lobo *et al.* (2006) found that compost treatments produced comparable above-ground biomass in green pepper (*Capsicum annum*) more than mineral fertilizers and the control.

Khalil *et al.* (2004) noticed that the highest N, P and K-uptake of wheat plants were obtained in case of 100% chicken manure application. Tawfik (2006) indicated that increasing the input of either organic or inorganic fertilization significantly enhanced various growth and yield characteristics as well as protein content in seeds of barley plants (*Hordeum vulgare*). Rasool *et al.* (2007) reported that the grain yield and uptake of N, P and K by both rice (*Oryza sativa* L.) and wheat were higher with the application of farm yard manure (FYM) and inorganic fertilizers than in control plots. Bhattacharyya *et al.* (2008) reported that yield of soybean followed by wheat in plots under unfertilized and inorganic fertilizer treatments decreased over time, but

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Table 1 Water requirements for drip irrigated corn grown on a sandy calcareous soil at El-Nubaria, Beheira governorate.

Month	May		June		July		August	September	Total
Period	15-31		1-30		1-31		1-31	1-12	
ET_0 mm day^{-1}	5.9		6.4		7.0		6.2	5.4	
No. of days	16	9	21	10	21	10	21	12	120
Kc		0.53		0.88		1.09		0.72	
Kr		0.7		0.85	0.91	0.95	1.0		
ETc/loc. mm day^{-1}	2.190	2.374	4.787	5.236	6.943	6.420	4.464	3.888	
Ks	1.15 (87%)								
Eu	1.11 (90%)								
Lr	10%								
IRg mm day^{-1}	3.075	3.333	6.722	7.352	9.749	9.015	6.268	5.462	
IRg L day^{-1} plant^{-1}	0.769	0.833	1.681	1.838	2.437	2.254	1.567	1.366	
IRg L season^{-1} plant^{-1}	12.304	7.502	35.301	18.38	51.18	22.54	32.907	16.392	= 200 L plant^{-1}
IRg m^3 season^{-1} fed^{-1}	206.71	126.03	593.06	308.78	859.90	378.62	552.84	275.39	
(I1)		332.7		901.8		1238.5		828.2	= 3300 m^3 fed^{-1}

ET_0 = reference evapotranspiration, **Kc** = crop coefficient, **Kr** = reduction factor for the influence of ground cover, **Ks** = a coefficient for the water storage efficiency of the soil, **Eu** = application uniformity, **Lr** = leaching requirements, **IRg** = gross irrigation requirements, **I_1** = 100% of water requirements.

Table 2 Water requirements for drip irrigated bean grown on a sandy calcareous soil at El-Nubaria, Beheira governorate.

Month	November	December	January			February	March	Total
Period	23-30	1-31		1-31		1-28	1-22	
ET_0 mm day^{-1}	2.7	2.7		2.0		2.4	3.0	
No. of days	8	31	1	30	10	18	22	
Kc		0.5			1.15		0.3	
Kr		0.8			0.9		1.0	
ETc/loc. mm day^{-1}	1.08	1.08	0.8	2.07	2.484	0.72	0.9	
Ks	1.15 (87%)							
Eu	1.11 (90%)							
Lr	10%							
IRg mm day^{-1}	1.516	1.516	1.123	2.91	3.488	1.011	1.264	
IRg L day^{-1} plant^{-1}	0.190	0.190	0.140	0.364	0.436	0.126	0.158	
IRg L season^{-1} plant^{-1}	1.52	5.89	0.14	10.92	4.36	2.27	3.48	= 28.6 L plant^{-1}
IRg m^3 season^{-1} fed^{-1}	51.072	197.904	4.704	366.91	146.50	76.20	116.79	
(I1)		253.68			513.41		193.0	= 960 m^3 fed^{-1}

ET_0 = reference evapotranspiration, **Kc** = crop coefficient, **Kr** = reduction factor for the influence of ground cover, **Ks** = a coefficient for the water storage efficiency of the soil, **Eu** = application uniformity, **Lr** = leaching requirements, **IRg** = gross irrigation requirements, **I_1** = 100% of water requirements.

increased in plots under N + FYM and NPK + FYM treatments for both crops. Subhadip *et al.* (2008) concluded that manure-amended plots showed higher available P. Mandal *et al.* (2009) showed that grain yield of soybean increased by 72.5 and 98.5%, and straw yield by 56.0 and 94.8% in NPK and NPK + FYM treatments, respectively more than the control.

Ginting *et al.* (2003) reported that the residual effects of compost application can maintain the level of a continuous corn yield for several years. In addition, the residual effects of compost applications significantly increased soil plant-available P (Eghball *et al.* 2004).

Taalab and Aziz (2004) reported that available K in field plots that received organic materials was higher than those treated with chemical fertilizers. Fan *et al.* (2005) demonstrated that inputs of K with organic materials resulted in a build-up of soil-available K because manure or straw generally contains high amounts of K. So far, the information on the effect of banana compost is a new practice.

The aim of this study was to evaluate the application of banana compost, mineral fertilizers and amount of water irrigation on corn production, their residual effect on bean production, and their effect on improving P and K concentration in soil and plants. Optimizing water and fertilizer inputs under given environmental conditions remains a major challenge for improving crop productivity.

MATERIALS AND METHODS

A field experiment was carried out at El Nubaria (North of the Nile Delta) Agricultural Research Station during four successive seasons by using a single corn cultivar (Single cross 129 white) and a bean cultivar (Nubaria 1) in a corn-bean-corn-bean rotation. The experiment included the following treatments:

A) Water regime treatments

Water regime treatments	Corn (m^3 fed^{-1})	Bean (m^3 fed^{-1})
I_1 (100% of WR)	3300.4	960.9
I_2 (80% of WR)	2640.3	768.8
I_3 (60% of WR)	1980.2	573.5

Crop evapotranspiration (ETc) was calculated according to the following formula:

$$ETc = Kc \times ET_0$$

where ETc = crop evapotranspiration in mm day^{-1}; ET_0 = reference evapotranspiration in mm day^{-1}; Kc = crop coefficient.

The water requirements of corn and bean plants grown at El Nubaria station are presented in **Tables 1** and **2**, respectively.

B) Fertilizer treatments

1) F_0 (control)
2) F_1 (150% compost)
3) F_2 (100% compost ≈ 9.76 and 10.90 ton fed^{-1} for first and second season, respectively)
4) F_3 (75% compost + 25% NPK as ammonium sulfate, super phosphate and potassium sulfate)
5) F_4 (50% compost + 50% NPK)
6) F_5 (full recommended NPK = 120 kg N fed^{-1} as ammonium sulfate + 30 kg P_2O_5 fed^{-1} as super phosphate + 24 kg K_2O fed^{-1} as potassium sulfate).

Three main plots were separated by 2 m, each of which contained 18 subplots, each with an area of 10.5 m^2. The fertilization treatments were added before sowing corn. Under the same treatments and without any new additions, bean was planted to eval-

Table 3 Some physical and chemical properties of the studied soil.

Characteristics	Value
pH (1 : 2.5 soil : water ratio)	8.11
EC (Soil paste extraction) dSm^{-1}	1.32
Available nutrients (mg kg^{-1})	
Nitrogen	93.15
Phosphorus	7.90
Potassium	186.63
Nickel	0.37
Cadmium	0.156
Lead	0.592
Organic matter (%)	0.47
Calcium carbonate (%)	24.9
Sand (%)	68.91
Silt (%)	16.57
Clay (%)	14.52
Textural class	Sandy loam

uate the residual effect of the previous additions of organic and chemical fertilizers. Some physical and chemical properties of the used soil and compost are provided in **Tables 3** and **4**.

Compost preparation

Residues of banana were ground in a pile and mixed with rabbit manure at a rate of 3: 1 to obtain a compost rich in nutrient content and a low C/N ratio. Each layer of the pile was slightly moistened to reach about 60% of its water holding capacity. The pile was turned every week to enhance aeration. Effective microorganisms (EM) were applied to the compost during preparation. A mixed culture of beneficial microorganisms including predominant population strains of *Bacillus subtilis* (F.50, F.30), *Trichoderma reesei* (F.418) and yeast (*Sacchromyces cerevisiae* F N.10) was used. EM was brought from the Biotechnology Unit, Microbial Chemistry Department, National Research Center.

Preparation of soil samples

In each plot, four random soil cores were taken and mixed (approximately 0.5 kg of soil) from a depth of 0-15 cm at different times:
1) after corn harvest in first season (first sample);
2) after bean harvest in first season (second sample);
3) after corn harvest in second season (third sample);
4) after bean harvest in second season (fourth sample).

Available P was estimated colourmetrically in 0.5 M $NaHCO_3$ extract at pH 8.5, according to Watanabe and Olsen (1965). Available K was extracted with NH_4HCO_3-DTPA according to Soltanpour (1985) and measured by flame-photometry (Jenway PFP7).

Statistical analyses

Analysis of variance (ANOVA) was used to separate means and significant differences at P = 0.05 were determined by the least significant difference (LSD) test (Gomez and Gomez 1984).

RESULTS AND DISCUSSION

Corn grain and bean seed yields

From the results in **Tables 5** and **6** it is clear that irrigation treatments had a considerable effect on grain yield over the two growth seasons. The I_2 treatment was considered to be best. About 20% of irrigation water could be saved if only 80% of calculated water requirements of corn plants were applied. The enhanced grain yield in I_2 may be interpreted by: 1) greater efficiency of nutrients in soil treated with I_2 compared with the other treatments; 2) this amount of water was more suitable to export dry matter content to grains resulting in more grain filling, fresh weight and grain yield; 3) improving soil chemical and biological properties; 4) decreasing nutrient losses by leaching; 5) good aeration associated with the relatively low application of irrigation water. These results and hypotheses are in close agreement with those of Afifi *et al.* (1989), who found a decrease in

Table 4 Some physical and chemical properties of the compost in two seasons.

Season	Nutrient content			OM%	C/N ratio	EC dS/m 1:5	pH 1:2.5	BD* Mg m^{-3}	WHC** %
	N%	P%	K%						
First season	1.23	0.79	2.042	25.21	11.9	5.63	7.47	0.35	110
Second season	1.10	0.82	2.201	37.69	17.8	5.50	7.44	0.34	160

*BD= bulk density
**WHC= water holding capacity

Table 5 Grain yield (ton fed^{-1}) of corn plants in two growing seasons as affected by irrigation and fertilization treatments.

Fertilization treatments	First season				Second season			
	Irrigation treatments			Mean	Irrigation treatments			Mean
	I_1	I_2	I_3		I_1	I_2	I_3	
F_0	0.472	0.580	0.279	0.444	0.809	0.853	0.325	0.662
F_1	1.017	1.167	1.025	1.070	1.805	1.990	1.170	1.655
F_2	0.714	1.002	0.695	0.803	1.619	1.659	0.981	1.420
F_3	1.203	1.414	1.405	1.340	2.130	2.221	1.452	1.934
F_4	1.507	1.908	1.247	1.554	2.371	2.512	1.448	2.110
F_5	1.872	2.136	1.622	1.877	3.094	2.936	2.366	2.799
Mean	1.131	1.368	1.045		1.971	2.029	1.290	
$LSD_{0.05}$	I=0.099	F=0.140	IxF=0.242		I=0.165	F=0.233	IxF=ns	

Table 6 Seeds yield (ton fed^{-1}) of bean plants in two growing seasons as affected by irrigation and the residual effect of fertilization treatments.

Fertilization treatments	First season				Second season			
	Irrigation treatments			Mean	Irrigation treatments			Mean
	I_1	I_2	I_3		I_1	I_2	I_3	
F_0	0.545	0.318	0.219	0.361	0.699	0.526	0.239	0.488
F_1	4.270	2.869	2.132	3.090	4.270	3.411	2.956	3.546
F_2	2.642	1.753	1.218	1.871	3.136	2.985	1.388	2.503
F_3	2.378	1.229	1.041	1.549	2.687	2.679	1.123	2.164
F_4	1.413	1.030	0.879	1.107	1.828	1.809	0.924	1.520
F_5	1.183	0.835	0.769	0.929	0.904	1.393	0.806	1.034
Mean	2.072	1.339	1.043		2.254	2.134	1.240	
$LSD_{0.05}$	I=0.08	F=0.11	IxF=0.19		I=0.12	F=0.17	IxF=0.29	

corn grain yield from 2.8 to 2.6 ton fed^{-1} by increasing the amount of irrigation water from 800 to 1200 mm (water consumption use).

The low amount of nutrients mineralized in the composted plots may explain the low grain yield despite improved soil physical properties and increased availability of micronutrients. These results are consistent with the findings of Cox *et al.* (2001) where they measured yield of spring barley, spring pea and winter wheat in different years from 1995 though 1998 and they found low amount of N mineralized in the composted plots. Yang *et al.* (2005) studied that effect of fertilizers and manure on wheat and oilseed yields; Fan *et al.* (2005) showed that the addition of organic materials and inorganic fertilizers significantly enhanced grain yields of wheat and corn and soil chemical properties if compared with no additives or the addition of only inorganic fertilizers. Generally, grain yield in the second season was 1.5 times greater than that in the first season.

Reducing water application rate from 100% ETc (I_1 = 960.9 m^3 fed^{-1}) to 80% ETc (I_2 = 768.8 m^3 fed^{-1}) reduced bean seed yield by 35.38 and 5.32% compared with I_1, while the yield was reduced by 22.11 and 41.89% compared with I_2 when reducing the water application rate from 80% ETc to 60% ETc (I_3 = 573.5 m^3 fed^{-1}) in first and second season, respectively. This reverts to increasing soil moisture content and water absorption by plants in I_1 and I_2 plots compared to I_3.

Seed yield was significantly increased by using any rate of compost compared with the control in both seasons. The lowest value was that of the control followed by full recommended dose of mineral fertilizer. In the two seasons, the highest values of seed yield were: $F_1 \times I_1 > F_1 \times I_2 > F_2 \times I_1$. The lowest values were: $I_3 \times$ control > $I_2 \times$ control >s $I_1 \times$ control.

Phosphorus

Data in **Tables 7** and **8** show the effect of irrigation and fertilization treatments on P concentration and uptake of corn and bean samples. P concentration in green leaves, ear leaf and corn grain increased as the amount of water increased without a significant difference in the first year but with significant differences in the second year. This increment was perhaps attributed to the effect of water as a solvent liquid

Table 7 Phosphorous concentration (%) in green leaves, ear leaf, corn grain and grain uptake (kg fed^{-1}) in two growing seasons as affected by irrigation and fertilization treatments.

Fertilization treatments	Green leaves %				Ear leaf %				Corn grain Kg fed^{-1}				Uptake			
	Irrigation treatments			Mean	Irrigation treatments			Mean	Irrigation treatments			Mean	Irrigation treatments			Mean
	I_1	I_2	I_3		I_1	I_2	I_3		I_1	I_2	I_3		I_1	I_2	I_3	
First season																
F_0	0.064	0.067	0.072	0.068	0.052	0.050	0.047	0.050	0.120	0.105	0.127	0.118	0.557	0.612	0.362	0.510
F_1	0.078	0.071	0.071	0.073	0.060	0.050	0.048	0.053	0.123	0.137	0.123	0.128	1.251	1.599	1.261	1.370
F_2	0.072	0.067	0.071	0.070	0.056	0.050	0.047	0.051	0.117	0.116	0.119	0.117	0.764	1.166	0.823	0.917
F_3	0.071	0.066	0.061	0.066	0.053	0.043	0.048	0.048	0.102	0.109	0.099	0.103	1.230	1.540	1.390	1.387
F_4	0.069	0.066	0.069	0.068	0.045	0.043	0.046	0.045	0.099	0.099	0.109	0.102	1.507	1.888	1.353	1.582
F_5	0.068	0.064	0.058	0.063	0.041	0.038	0.033	0.037	0.091	0.085	0.069	0.082	1.551	1.812	1.121	1.495
Mean	0.070	0.067	0.067		0.051	0.046	0.045		0.109	0.108	0.108		1.143	1.436	1.051	
$LSD_{0.05}$	I=	F=	IxF=		I=	F=	IxF=		I=	F=	IxF=		I=	F=	IxF=	
	ns	0.005	ns		ns	0.006	ns		ns	0.011	ns		0.15	0.21	ns	
Second season																
F_0	0.210	0.180	0.204	0.198	0.178	0.157	0.193	0.176	0.236	0.184	0.222	0.214	1.910	1.548	0.722	1.393
F_1	0.209	0.178	0.193	0.193	0.218	0.172	0.172	0.187	0.254	0.245	0.217	0.239	4.579	4.900	2.511	3.997
F_2	0.192	0.174	0.175	0.180	0.171	0.151	0.149	0.157	0.244	0.233	0.213	0.230	3.958	3.868	2.069	3.298
F_3	0.184	0.165	0.171	0.173	0.160	0.134	0.140	0.145	0.236	0.229	0.192	0.219	5.041	5.084	2.776	4.210
F_4	0.176	0.150	0.165	0.164	0.145	0.112	0.101	0.119	0.229	0.222	0.189	0.214	5.444	5.580	2.736	4.587
F_5	0.158	0.144	0.144	0.149	0.123	0.092	0.067	0.094	0.219	0.158	0.156	0.178	6.767	4.661	3.672	5.033
Mean	0.188	0.165	0.175		0.166	0.136	0.137		0.236	0.212	0.198		4.616	4.274	2.414	
$LSD_{0.05}$	I=	F=	IxF=		I=	F=	IxF=		I=	F=	IxF=		I=	F=	IxF=	
	0.015	0.021	ns		0.021	0.030	ns		0.015	0.022	ns		0.47	0.67	ns	

I = irrigation; F = fertilization; ns = not significant

Table 8 Phosphorous concentration (%) and phosphorous uptake (kg fed^{-1}) in bean seeds during two growing seasons as affected by irrigation and fertilization treatments.

Fertilization treatments	P (%)				P uptake (kg fed^{-1})			
	Irrigation treatments			Mean	Irrigation treatments			Mean
	I_1	I_2	I_3		I_1	I_2	I_3	
First season								
F_0	0.247	0.230	0.219	0.232	1.339	0.733	0.468	0.847
F_1	0.295	0.248	0.236	0.260	12.599	7.106	5.038	8.248
F_2	0.291	0.232	0.229	0.251	7.676	4.056	2.758	4.830
F_3	0.278	0.223	0.227	0.243	6.620	2.744	2.354	3.906
F_4	0.276	0.222	0.216	0.238	3.931	2.270	1.904	2.702
F_5	0.269	0.222	0.213	0.235	3.203	1.854	1.639	2.232
Mean	0.276	0.230	0.223		5.895	3.127	2.360	
$LSD_{0.05}$	I=0.011	F=0.016	IxF=ns		I=0.274	F=0.388	IxF=1.326	
Second season								
F_0	0.393	0.379	0.342	0.371	2.742	2.012	0.818	1.858
F_1	0.598	0.501	0.501	0.533	25.749	17.153	14.982	19.295
F_2	0.527	0.475	0.455	0.486	16.528	14.191	6.309	12.343
F_3	0.436	0.469	0.433	0.446	11.725	12.512	4.918	9.718
F_4	0.418	0.419	0.434	0.424	7.559	7.680	4.010	6.417
F_5	0.396	0.347	0.434	0.392	3.573	4.826	3.526	3.975
Mean	0.461	0.432	0.433		11.313	9.729	5.761	
$LSD_{0.05}$	I=ns	F=0.080	IxF=ns		I=1.856	F=2.654	IxF=4.545	

on soil P, irrespective of its source. Thompson and Troeh (1982) stated that the soil solution can dissolve P compounds; P uptake by corn grain revealed a different trend: grain yield was highest with I_2 in the first year although there was no significant difference between I_1 and I_2 in the second season; in both seasons the water stress treatment (I_3) had lowest values. Gahoonia *et al.* (1994) concluded that reducing the soil water content decreased P uptake because: (1) It diminished the movement of P to roots by reducing the thickness of water films; (2) It reduces P absorption by the roots by reducing the number of root hairs, the elongation and turgidity of roots.

The effect of irrigation doses on P concentration in bean seeds decreased significantly in the order $I_1 > I_2 > I_3$ in the first season. No significant difference was observed among water doses in the second season. P-uptake by bean seeds followed the same latter trend in both seasons. With regard to the mixture of organic and mineral fertilizers and their effect on P concentration and P uptake in all plant tissues, data showed that P concentrations in green leaves, ear leaf, corn and bean yields increased in the order $F_5 < F_4 < F_3 < F_2 < F_1$ irrespective of control treatments. The values of P content in control plants fluctuated because 1) the P concentration in control plants increased since little growth raised the concentration, and 2) at other times P concentration decreased as a result of poor soil fertility in control plots. It is reasonable to expect that organic soil amendments may exert a positive influence on P concentration, presumably from the presence of humified organic material which enhances P availability by decreasing adsorption and fixation. Havlin *et al.* (1999) showed that organic anions can affect the P adsorption-desorption reactions in soil. The impact of organic anions on reduction of adsorption P is related to their molecular structure and pH. Also, compost can serve as a reservoir for P. Abou-Baker (2003) reported that organic manure induces the soil P supplying power through either a direct or indirect effect. The direct effect induces the continuous release of organic P, while the indirect effect is due to the role of organic acids and other acidic compounds which solubilize more P from insoluble potential P-bearing compounds.

P uptake by corn grains in the first season fluctuated. The highest value was recorded in F_4 (50% compost and 50% NPK) followed by F_5 (100% NPK) although a significant difference did not exist between them. The next highest value was obtained in F_3 (75% compost + 25%NPK) followed by F_1 (150% compost) also without a significant difference between them. The lowest value resulted from the control treatment. The difference in P concentration in the first season changed the trend of yield. In the second season, the trend of P concentration was unlike the P uptake trend in the first season, but followed the same trend as corn grain. This could be due to the small differences in P concentration in the second season which might have not been sufficient to change the trend in yield.

Fertilizers application treatments tended to increase P uptake by bean seeds more than untreated plots in both years. This trend supports the results of bean seed yield. These results suggest that the residual effect of compost alone or in combination with mineral fertilizer resulted in a more remarkable uptake of P by bean seeds grown in subsequent seasons after corn than by adding all the doses of nutrients as mineral fertilizers.

P concentration in the ear leaf was lower than in green leaves, not only due to a dilution effect since ear leaves have a larger area than green leaves, but also since most of absorbed P is directly translocated and stored in grains so that a greater P concentration was recorded in grains. This is an important feature from the viewpoint of plant nutrition because P is a vital and essential element for plant germination and plays an important role in energy storage and transfer. Moreover, P concentration of bean seeds is higher than corn grains (**Tables 7, 8**).

Generally, P concentration of corn samples in all stages is less than known limits for P in plants, but it improved in the second season.

Potassium

Potassium concentration and uptake as affected by the studied treatments in the two growth seasons are listed in **Tables 9** and **10**. The data indicates that water stress treatment (I_3) gave a high K concentration than I_1 and I_2 in green leaves of corn in the first season. This trend was also observed in ear leaves in both seasons and in corn grains in the first year. An opposite trend was seen in growth and yield of corn because the high growth dilutes K concentration, since K does not enter organic matter composition (Wallace 1943). Average values of K concentration in green leaves in the second season showed another trend: I_1 increase K concentration more than I_2 and I_3 (there was no significant difference between the last two treatments). This may reflect the effect of a huge amount of compost in soil after the second addition, therefore the supplying power of

Table 9 Potassium concentration (%) in green leaves, ear leaf, corn grain and grain uptake (kg fed^{-1}) in two growing seasons as affected by irrigation and fertilization treatments.

Fertilization treatments	Green leaves (%)				Ear leaf (%)				Corn grain (%)				Uptake (kg fed^{-1})			
	Irrigation treatments			Mean	Irrigation treatments			Mean	Irrigation treatments			Mean	Irrigation treatments			Mean
	I_1	I_2	I_3		I_1	I_2	I_3		I_1	I_2	I_3		I_1	I_2	I_3	
First season																
F_0	2.01	2.05	2.11	2.06	1.62	1.67	1.7	1.66	0.65	0.64	0.74	0.68	3.06	3.71	2.05	2.94
F_1	2.08	2.04	2.08	2.07	1.61	1.56	1.67	1.61	0.60	0.63	0.66	0.63	6.10	7.35	6.79	6.75
F_2	2.12	2.10	2.10	2.11	1.71	1.60	1.68	1.66	0.62	0.68	0.69	0.66	4.42	6.77	4.79	5.33
F_3	2.08	2.04	2.08	2.07	1.58	1.53	1.64	1.58	0.60	0.62	0.65	0.62	7.21	8.76	9.13	8.37
F_4	2.08	2.02	2.07	2.06	1.55	1.52	1.62	1.56	0.60	0.62	0.65	0.62	9.04	11.83	8.10	9.66
F_5	2.04	2.02	2.05	2.04	1.41	1.49	1.62	1.50	0.60	0.56	0.62	0.59	11.23	11.97	10.06	11.09
Mean	2.07	2.05	2.08		1.58	1.56	1.65		0.61	0.62	0.67		6.84	8.40	6.82	
$LSD_{0.05}$	I=0.03	F=0.04	IxF=ns		I=0.05	F=0.08	IxF=ns		I=0.03	F=0.04	IxF=ns		I=0.63	F=0.89	IxF= 1.55	
Second season																
F_0	2.60	2.29	2.21	2.37	1.85	1.68	2.28	1.97	0.68	0.62	0.67	0.66	5.59	5.60	2.26	4.48
F_1	3.25	2.13	2.45	2.60	1.85	1.52	1.74	1.70	0.65	0.67	0.63	0.65	11.63	13.32	7.39	10.78
F_2	3.51	2.36	2.69	2.85	2.07	1.57	1.79	1.81	0.79	0.76	0.65	0.73	12.75	12.61	6.35	10.57
F_3	2.96	2.10	2.32	2.46	1.41	1.48	1.61	1.50	0.59	0.61	0.56	0.59	12.47	13.59	7.92	11.33
F_4	2.65	2.02	2.20	2.29	1.24	1.37	1.63	1.41	0.55	0.59	0.55	0.56	12.90	14.87	7.90	11.89
F_5	1.95	1.91	2.10	1.99	1.19	1.29	1.59	1.36	0.51	0.39	0.39	0.43	15.63	11.43	9.35	12.13
Mean	2.82	2.13	2.33		1.62	1.48	1.77		0.63	0.61	0.57		11.83	11.90	6.86	
$LSD_{0.05}$	I=0.17	F=0.23	IxF= 0.40		I=0.14	F=0.20	IxF= 0.33		I=ns	F=0.10	IxF=ns		I=1.65	F=2.33	IxF=ns	

Table 10 Potassium concentration (%) and potassium uptake (kg fed^{-1}) in bean seeds during two growing seasons as affected by irrigation and fertilization treatments.

Fertilization treatments	K (%)				K uptake (kg fed^{-1})			
	Irrigation treatments			Mean	Irrigation treatments			Mean
	I_1	I_2	I_3		I_1	I_2	I_3	
First season								
F_0	1.55	1.82	1.64	1.67	8.44	5.86	3.56	5.95
F_1	1.51	1.70	1.70	1.64	64.39	48.82	36.21	49.81
F_2	1.51	1.73	1.70	1.65	39.92	30.40	20.55	30.29
F_3	1.52	1.73	1.74	1.66	35.95	21.27	18.12	25.11
F_4	1.55	1.79	1.87	1.74	21.92	18.48	16.48	18.96
F_5	1.66	1.80	1.90	1.79	19.58	15.06	14.66	16.43
Mean	1.55	1.76	1.76		31.70	23.32	18.26	
$LSD_{0.05}$	I=0.07	F=0.1	IxF=ns		I=1.51	F=2.13	IxF=3.69	
Second season								
F_0	1.318	1.896	1.499	1.571	9.22	9.99	3.59	7.60
F_1	1.715	1.410	1.227	1.451	72.96	48.10	36.31	52.45
F_2	1.600	1.531	1.340	1.490	50.17	45.72	18.60	38.16
F_3	1.871	1.663	1.682	1.739	50.69	44.52	18.91	38.04
F_4	1.904	1.531	1.849	1.761	34.82	27.80	17.44	26.69
F_5	1.919	2.020	1.953	1.964	17.34	28.10	15.64	20.36
Mean	1.721	1.675	1.592		39.20	34.04	18.41	
$LSD_{0.05}$	I=ns	F=0.28	IxF=ns		I=5.52	F=7.80	IxF=13.52	

Table 11 Available phosphorous (mg kg^{-1}) in soil after harvesting corn and bean plants in first and second seasons as affected by irrigation and fertilization treatments.

Fertilization treatments	After corn				After bean			
	Irrigation treatments			Mean	Irrigation treatments			Mean
	I_1	I_2	I_3		I_1	I_2	I_3	
First season								
F_0	6.94	5.51	5.21	5.77	6.67	5.59	4.54	5.60
F_1	38.92	35.33	31.15	35.13	29.78	24.44	22.80	25.67
F_2	34.39	24.62	24.01	27.67	27.90	22.84	20.52	23.76
F_3	24.10	12.81	10.76	15.89	20.13	13.95	8.98	14.35
F_4	18.13	10.74	8.31	12.39	14.78	13.23	7.53	11.85
F_5	17.42	9.27	7.80	11.50	11.16	8.56	5.21	8.31
Mean	23.26	16.38	14.54		18.41	14.77	11.60	
$LSD_{0.05}$	I=1.15	F=1.62	IxF=2.81		I=1.97	F=2.79	IxF=ns	
Second season								
F_0	4.04	3.17	3.10	3.44	3.43	3.15	2.29	2.96
F_1	44.35	42.90	28.69	38.65	19.90	17.07	13.83	16.93
F_2	30.49	26.86	27.98	28.45	12.51	10.68	7.74	10.31
F_3	27.85	24.88	26.53	26.42	6.52	5.87	5.30	5.90
F_4	23.50	22.31	22.63	22.81	4.36	4.15	5.20	4.57
F_5	7.48	18.88	21.91	16.09	4.15	3.29	3.00	3.48
Mean	22.95	23.17	21.81		8.48	7.37	6.23	
$LSD_{0.05}$	I=ns	F=5.04	IxF=8.73		I=1.16	F=1.63	IxF=ns	

soil K increased when compost remained in the soil. Also it may be due to the K content of compost in the second season which is relatively higher than that in the first season, as shown in **Table 4**.

There was no significant difference between the effect of irrigation treatments on K concentration of corn grain and bean seeds in the second year. Increasing water level up to 100% of water requirement (I_1) resulted in low K concentration of bean seeds in the first season compared with the other two addition levels (I_2 and I_3) which recorded the same value (1.76%).

Unlike the trend in K concentration, the K uptake of corn grain increased significantly when I_2 was applied followed by I_1 then I_3 (**Table 9**).

When assessing the effect of fertilization treatments, K concentration in new leaves, ear leaves and corn grain in both growing seasons increased in the order $F_2 > F_1 > F_3 > F_4 > F_5$, irrespective of the control treatment. This trend was opposite to that observed for corn growth and yield. Furthermore, K% in bean seeds increased in the order $F_5 > F_4 > F_3 > F_2 > F_1$ in both seasons, while a reverse trend was true for yield of bean seeds. This discrepancy between K concentration and yield due to a dilution effect was discussed before for P.

K uptake by corn grains in both seasons was significantly affected by fertilization treatment. It increased in the order $F_5 > F_4 > F_3 > F_1 > F_2 > F_0$. These results are consistent with the records of corn yield. K uptake by beans seeds increased in the order $F_1 > F_2 > F_3 > F_4 > F_5 > F_0$. These trends are compatible with the values of bean yield.

In general, K concentration and uptake was higher for samples in the second season than those in the first. The reason may be that the soil became more fertile after the second addition. Moreover, K concentration in different parts of corn increased in the order green leaves > ear leaf > grains in both seasons.

Available phosphorus

Available P in the first and second soil samples varied significantly by applying different irrigation levels (**Table 11**). High irrigation amount (I_1) enhanced P availability more than I_2 and I_3 by 42.00 and 59.97% for the first sample and 24.64 and 58.71% for the second sample, respectively. Insignificant differences were noted in the third sample after water doses were added. In the fourth sample, the variation between (I_1 and I_2) and (I_2 and I_3) did show a significant effect although the application of I_1 raised available P significantly to 1.36 times that of water stress treatment (I_3). This may be ascribed to a rapid initial release of P from P

Table 12 Available potassium (mg kg^{-1}) in soil after harvesting corn and bean plants in first and second seasons as affected by irrigation and fertilization treatments.

Fertilization treatments	After corn				After bean			
	Irrigation treatments			Mean	Irrigation treatments			Mean
	I_1	I_2	I_3		I_1	I_2	I_3	
First season								
F_0	155.7	154.8	146.9	152.5	150.9	125.2	115.1	130.4
F_1	281.2	262.0	222.8	255.3	236.7	227.0	202.4	222.0
F_2	276.2	229.7	204.0	236.6	227.4	217.8	198.9	214.7
F_3	220.9	224.3	179.4	208.2	222.1	209.8	171.6	201.2
F_4	219.7	168.8	178.8	189.1	194.8	166.8	171.7	177.8
F_5	172.4	156.0	158.2	162.2	168.5	149.3	151.6	156.5
Mean	221.0	199.3	181.7		200.1	182.6	168.5	
$LSD_{0.05}$	I=25.76	F=36.43	IxF=ns		I=18.33	F=25.92	IxF=ns	
Second season								
F_0	135.4	123.8	100.4	119.9	125.4	104.7	94.5	108.2
F_1	348.1	329.4	290.6	322.7	213.3	185.5	152.8	183.9
F_2	311.8	302.7	231.8	282.1	166.8	162.5	130.6	153.3
F_3	288.1	276.7	225.6	263.5	157.7	158.0	130.5	148.7
F_4	282.9	257.5	220.4	253.6	145.5	141.3	128.9	138.6
F_5	230.9	220.5	169.2	206.9	126.8	135.0	124.8	128.9
Mean	266.2	251.8	206.3		155.9	147.8	127.0	
$LSD_{0.05}$	I=35.75	F=50.56	IxF=ns		I=19.70	F=27.85	IxF=ns	

minerals by adding a high amount of water in the presence or absence of a fertilizer (Thompson and Troeh 1982).

Regardless of the effect by irrigation, all fertilizer applications increased extractable P significantly more than the control in four soil samples in the order: $F_1 > F_2 > F_3 > F_4 > F_5 > F_0$. These results are in close association with finding by Bowman and Halvorson (1997) and Chiu *et al.* (2006) who reported that organic amendment can provide a large amount of soil P.

The combination of 50 or 25% of mineral P fertilizer with compost increased available P more than applying 100% mineral fertilizers. This may be due to the role of compost in enhancing the release of mineral fertilizers.

The increase in P availability by increasing the amount of compost materials could possibly be due to: 1) the solubility effect of organic agencies upon native and applied P; 2) the biodegradation of organic materials which produce several organic acids and HCO_3^- ions which release P in the soil system; 3) reduction of P adsorption by the competition of organic anions for adsorption sites, oxalate, citrate, tartrate and malate that can be adsorbed on soil surfaces similarly to $H_2PO_4^-$; 4) organic acids are also able to reduce soil pH and reduce the concentration of free Ca which precipitates phosphate ions, especially in calcareous soils which contain a high amount of $CaCO_3$ and possess the ability to transformation of available P to di and tri calcium phosphates; 5) in addition to organic P content in compost which is gradually released over time.

Available potassium

Mean values of available K content in the soil after harvesting four yields in two years under different water levels are shown in **Table 12**. Available K increased gradually as the rate of irrigation water in all soil samples increased. Application of I_1 was superior while I_3 was inferior. With respect to fertilization treatments, data showed a positive response due to compost application, irrespective of irrigation treatments. The extractable K in plots which received a mixture of mineral and compost gave higher values than those in the 100% mineral fertilizer treatment. A similar trend was reported by Khadr *et al.* (2004) who showed that application of organic manure + NPK fertilizers gave higher values than NPK alone.

The superiority of organic treatments may be attributed to: 1) soil content of initial clay minerals and organic material is low and consequently low content of K ions; 2) competition between Ca^{++} and K^+ in calcareous soil; 3) application of organic matter resulted in a build-up of soil K; 4) application of organic material is able to block the K fixation sites.

Based on these results, it could be concluded that banana compost, which is plentiful, might be combined with certain chemical fertilizers and irrigation to saved water and improve soil fertility. This leads to increase plant production, particularly in newly reclaimed soil.

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