The Use of Municipal Waste Composts in Urban and Peri-Urban Vegetable Production Systems -Potentials and Constraints-

Trüggelmann, L., Holmer, R. J. and Schnitzler, W. H.

Lehrstuhl für Gemüsebau, Technische Universität München-Weihenstephan

ABSTRACT

In the fast growing cities of the developing world, the management of solid wastes is now an issue of vital importance to urban sustainability. Composting of the organic fraction in city waste and the use as soil amendment and plant nutrient source for Urban and Peri-urban Agriculture (UPA) has frequently been suggested as a development approach which can contribute simultaneously to tow different targets: to improve solid waste management and to promote UPA.

Despite this evidently advantageous and synergistic approach, the realization of composting potentials in southern countries is still relatively low. The communication tries to clarify some of the obstacles hindering the expansion of this waste management option. Experiences showed that the economically viable linkage between compost production and compost use is more difficult to establish. Development organizations usually stimulate the production and use of compost in UPA from an environmental perspective, rather than as a task of fertilizer production. Therefore, the marketing of compost as input in UPA remains difficult. Additionally, the compost use in UPA is under hard competition with mineral fertilizers and other organic nutrient sources, like for example chicken dung due to the high availability of these products in the proximity of cities.

Urban and Peri-urban farmers are confronted by a new product without clear recommendations and guidelines for its profitable application. There is still a lack of knowledge concerning the real value of compost for Urban and Peri-urban Vegetable Production Systems in tropical cities. Very little is still known about the comparative advantages for waste compost in horticulture under tropical lowland conditions for nutrient sourcing and soil improvement.

Under this condition, only fertilization trials can provide the necessary information about the marginal rate of substitution for compost in vegetable production. Therefore, a number of fertilization experiments combining different mineral and organic fertilizer (compost and chicken dung) input levels have been designed for Lycopersicon esculentum Mill. and, Brassica oleracea L.. First results for the mineral NP and organic fertilization of tomatoes are presented. The yield impacts of different fertilizer ratios are discussed.

Keywords: Philippines, Municipal Waste Compost, Urban Agriculture, Lycopersicon esculentum, Topical Lowland

RATIONALE

Municipal solid waste production continues worldwide to increase in both absolute and per capita terms (CSD, 1997). Particularly in developing countries, this is due to the continuing population growth and the dramatically increasing urbanization. By 2030, it is expected that nearly 5 billion (61 percent) of the world’s 8.1 billion people will live in cities, in contrast to 2.8 billion (47 percent) in 1999. The lion's share of this increase will take place in the developing world (UNFPA, 1996 and 1999). The development of the industrial and productive activities in the informal sector is leading to additional waste. Simultaneously, the increasing incomes in some areas due to the economic development are promoting the absolute consumption and are conducting to new pattern, associated with higher per capita waste generation rates (World Bank, 1999). A five-fold increase in global waste generation by the year 2025 is estimated (UNCED, 1992). In the fast growing cities of the developing world, the management of waste is an issue of vital importance for urban sustainability.

In general, the existing collecting systems in developing countries cannot provide the necessary volume to prevent efficiently the dumping of waste on streets and public areas, clogging of urban drainage systems, contamination of water resources and proliferation of insects and rodent vectors. Despite the fact, that local authorities in many developing country cities currently dedicate a large proportion of their budgets for the waste management services, less than 10 percent of urban waste receive some form of treatment and only a small proportion of treatment is in compliance with any acceptable quality standard (UNCED, 1992). In low-income countries more than 80 percent of waste management expenditures are usually absorbed by the collection costs and low cost landfilling still remains the most practicable waste disposal (World Bank, 1999). Furthermore, the future capacities for landfill sites in the proximity of urban centers are becoming more and more scarce. Material recovery and recycling becomes increasingly important to reduce the amount of solid waste for landfill (Zurbrugg, Ch. and Aristanti, Ch., 1999).

BENEFITS FROM MUNICIPAL WASTE COMPOSTING

The production of municipal waste compost (MWC) as an alternative to landfill or incineration is attractive, not only because it reduces the waste volume, but the resulting product can be used as an organic nutrient source or soil amendment to increase nutrient and organic matter content of agricultural soils. Considering the fact that between 40 to 85 % of the urban waste stream in developing countries is organic and therefore potentially compostable (World Bank, 1999), the quantities of solid waste necessarily destined for landfill could seriously be reduced. Composting could prolong the use of existing landfill sides, reduce public expenditures for waste collection and transport, and help to decrease pollution risks from landfills. Additionally, small scale decentralized composting units integrated with community-based primary collection schemes could offer additional income generating activities particularly for low-educated scavengers. Improved hygienic conditions for poor urban dwellers commonly not served by municipal services can be expected.

PROBLEMS MET BY LARGE OR SMALL-SCALED COMPOSTING FACILITIES

Despite these benefits, the realization of the composting potentials in developing countries is still low. A number of reasons can be enumerated for this: Activities in waste composting are predominantly conducted under an environmental goal, than rather as an operation to produce organic fertilizer for agricultural purposes, in order to meet the requirements of potential compost users (Mustin, M., 1987; Hart, D. and Pluijmers, J., 1996). In the past, large-scale centralized and highly mechanized composting plants were soon abandoned or scaled down due to high operational, transport and maintenance costs. Frequent mechanical problems together with a lack of operational know-how resulted in poor compost qualities. (Lardinois, I. and van de Klundert, A., 1993; Zurbrugg, Ch. and Aristanti, Ch., 1999). Despite their macro-economic benefits these plants are often not viable under micro-economic criteria (Sanders, S. and Oepen, M., 1999) and municipalities are unwilling to subsidize them. On the other hand, more appropriate small-scale composting facilities meet difficulties to provide a stable supply in quantity and quality. Due to possible negative impacts (odors, rodents, etc.) a low acceptance for composting plants in the proximity of human settlements can restrict their optimal location (SKAT, 1996). However, some positive examples for large and small-scale composting exist in developing countries.

MARKETING PROBLEMS FOR MWC

According to many authors, aside from the reduction of composting costs, compost marketing is the key issue for the success of MWC in developing countries. In many societies the low cultural acceptance for products derived from wastes (Diallo, M. and Vogel, J., 1996; Lardinois, I. and van de Klundert, A. 1993) can be an important handicap for MWC use. The low nutrient concentration and bulkiness of this organic fertilizer recommend only short transportation distances (Lardinois, I. and van de Klundert, A. 1993). Particularly with poorly developed infrastructure, the MWC use will be mostly limited to urban and peri-urban agriculture. On the other hand, mineral as well as other organic fertilizers (e.g. chicken dung from peri-urban poultry production) are currently highly available in the proximity of cities (Sanders, S. and Oepen, M., 1999). The capacity of MWC to compete with these organic fertilizers will depend on the specific local market conditions of their supply and the extent of urban and peri-urban agriculture. A massive promotion of urban and peri-urban horticulture could open a supply gap, where the use of MWC might become economically interesting. However, in order to promote the marketability of MWC the following issues require some considerations: dependable supply, product consistency, and product specification, proven performance and a reasonable pricing (Toffey, W. E., 1998). The undependable supply, because of important variations for municipal waste generations during the year, makes it difficult for users to integrate compost fertilization in their cropping systems. Due to the heterogeneity of garbage composition in time and space, the product consistency is difficult to obtain. Potential users are confronted with more or less unpredictable impacts of the organic fertilizer. Quality standards together with simple tests for quality and maturity need to be defined and developed. Different authors stressed the multiple purposes for MWC. However, the quality requirements are not identical if MWC should be used as mulch, organic nutrient source, soil amendment, in landscaping or in blends for potting and seedling media. Additional work on product specification could improve the marketability of MWC in developing countries. MWC is a new product with an unproven performance for urban and peri-urban farmers. Recommendations for MWC utilization for tropical horticulture especially under lowland conditions still need to be developed. In order to provide this kind of information, a program of plant nutrition experiments combining different mineral and organic fertilizer (compost and chicken dung) input levels have been designed for Lycopersicon esculentum Mill. and Brassica oleracea L.. An experiment of compost use in tomato production was recently conducted.

METHODS AND MATERIALS

The experiment was conducted during the rainy season at the Manresa Research Station of Xavier University located in Cagayan de Oro City, Philippines on a clay loam to clay soil (Tab. 1.). The area shows a humid tropical lowland climate, with an average yearly rainfall of 1700 mm and an average temperature of 27°C. Eight different levels of mineral N-P fertilization rates (Factor A, Tab. 3) were combined in a two factorial experiment with five different rates of organic fertilizer (Factor B). The N-P amounts in kg/ha for the treatments of factor A were 0 : 0, 115 : 0, 115 : 20, 115 : 40, 115 : 80, 58 : 40, 29 : 40 and 0 : 40. Three levels of market waste compost in rates of 2.1, 4.2 and 8.3 t/ha were compared to 2.1t/ha of chicken dung and a n untreated control. The compost was prepared at Manresa from organic vegetable market waste by heap composting. Each plot was 6.72m^2 (1.40m x 4.80m) without walking space, 11.52 m^2 including the walking space and replicated three times in a random block design. Tomatoes (cv. “Hybrid 7”, from BUSECORP) were seeded May 6, 1999 in rolled banana leafs containing a soil media made out of 6 parts of topsoil mixed together with 2 parts of chicken dung, rice hulls and coffee ground. “Marscap” was applied to the seedling bags before sowing in order to prevent damping-off. “Sevin” was sprayed twice during the study against ants and other insects. Highbeds with an elevation of 50 cm were prepared. Per plot one sack of rice hull (15-20 kg) was applied and incorporated. The organic fertilizers together with the full amount of mineral P and one third of the nitrogen fertilization were applied in the planting hole before transplanting. The seedlings were transplanted May 24 and May 25, 1999 in two rows per highbed at a distance 100 cm between rows and 0.40 m between within a single row (12 hills/row), yielding a total population of 48 plants per plot (20,833 hills per ha). During a first and second side dressing, one and four weeks after transplanting, the remaining amount of urea was applied together with 120 kg K/ha, 20 kg Mg/ha, 3 kg Zn/ha and 3 kg B/ha. Water requirement for the plants was met using drip irrigation. The spray program for pest and disease control followed the PUVeP standard operational practice (SOP).

Individual heights of 20 randomly chosen plants per plot at onset of flowering were recorded. The number of days from transplanting to the onset of flowering was identified. At the beginning of fruit setting, the number of flowers per plant and clusters per plant were counted for 10 randomly chosen plants per plot. The total stand of plants was identified at the beginning of the first harvest round. Each harvesting sequence, the weight and number of fruit were recorded for the 20 inner per plot. Marketable and non-marketable yield were distinguished. The experiment finished August 21, 1999 with the fourth harvest round of the last treatment.

RESULTS AND DISCUSSION

PLANT HEIGHT

The plant height was at every level of P significantly higher (5 % DMRT) as the 0-P treatment. The tallest plants were found with the low P rate of 20 kg P/ha. An observed reduction of plant height at higher P application was not significantly different from this treatment. A linear response of the plant height was observed for 28 and 56 kg N/ha. The medium N rate induced a significant bigger plant height at 5 % DMRT than 28 kg N/ha or 0 kg N/ha. The further doubling of the N rate did not improve the plant height significantly. Nevertheless, the compost and chicken dung applications had as well a significant (at the 5 %

level by LSD) influence on the plant height. All treatments with organic fertilization increased the plant height significantly in comparison to the zero treatment. The tallest plants were found with the application of 8.3 t compost per ha and were significantly taller than compared to lower rates of compost. The use of chicken dung at 2.1 t/ha proved a transitional performance between 8.3 t and 4.2 t compost per ha. However, at an equal rate of 2.1 t/ha, chicken dung was significantly more efficient to stimulate the plant growth than compost. This is certainly due to the higher amount of nutrients in the chicken dung (Tab. 2.). Particularly, nitrogen is known to enhance plant height (Adams, P., 1986).

HOMOGENEITY OF FIELD STAND

The impact of fertilization on the homogeneity of the field stand was analyzed with the coefficient of variation (CV) for the measured plant heights. The smaller the CV, the better is the homogeneity of the plant stand for the plant height. The mineral fertilization had a less strong impact on the homogeneity than the organic fertilization. Here, a significant (DMRT of 5 %) better homogeneity compared to the zero control was only found for a low P fertilization. Compost and chicken dung showed significant impacts on the homogeneity of the crop stand. The application of any quantity of chicken dung or compost reduced significantly (5 % LSD) the variations in the plant height between plants of the same treatment. The application of 2.1 t chicken dung per ha presented a corresponding effect than compost rates of about 4.2 and 8.3 t/ha. At the same application rate, chicken dung was more efficient than compost. This might be caused by the higher amounts of nutrients, which are provided by the chicken dung. In general, the positive effect of the organic nutrient sources on the plant height in this case of heavy clay or clay loam soil is due to improved physical properties. The increase of total porosity and the better pore size distribution favors water and air permeability (Gallardo-Lara, L. and Nogales, R., 1987). This enhances root growth and prevents anaerobic soil conditions during heavy rainfalls. Additionally, the application in the planting hole provides equal soil conditions for the seedlings and compensates the locally varying soil conditions. Therefore, the consequence is a more regular plant stand.

NUMBER OF FLOWERS PER PLANT AT BEGINNING OF FRUIT SETTING

A systematic influence of the organic fertilization on the number of flowers per plant at beginning of fruit setting could not be statistically proven. On the other hand, the mineral N-P fertilization had a significant impact. The application of P increased the number of flowers per plant. However, only very high applications of phosphate (80kg P/ha) induced significantly higher amount of flowers compared to the zero treatment. The effect of nitrogen on the number of flowers was more pronounced. Low rates of nitrogen could not improve the number of flowers substantially. The highest number of flowers was found for a medium rate of N (56 kg/ha). The number of flowers decreased significantly at a higher N rate. A delay of flowering due to higher N rates was not observed.

YIELD, NUMBER OF HARVESTED FRUIT AND AVERAGE FRUIT WEIGHT

Without N-P and organic fertilization, a yield of only 17.2 t/ha for the total and 13.24 t/ha for the marketable yield were obtained. The highest yield in the experiment was found at 44.09 t/ha for the total yield and 37.20 t/ha for the marketable yield, respectively. This was achieved at combination of 112 kg N/ha and 20 kg P/ha together with 2.1 chicken dung.

Any amount of a P application increased the yield significantly over the control treatment without added mineral P. Rates over 20 kg P/ha appeared to induce slightly lower yields.

However, this difference was not significantly different at the 5 % level by DMRT. The nitrogen fertilization showed only at medium and higher application rates (56 and 112 kg N/ha) a significant yield increase. Nevertheless, demising yield increases occurred. The organic fertilization increased significantly (LSD 5 %) the total yield at medium and higher rates of compost. Particularly, a compost application of 4.2 t/ha provided the highest yield for the use of compost if P was added. However, in the average the chicken dung performed best but was not significantly better than compost at medium rate. At 2.1 t/ha of compost or chicken dung, the compost did not perform significantly better than the unamended control whereas the chicken dung did.

The yield increase seems to be rather caused by a higher number of fruit harvested per plant than by an increase in the average fruit weight. Indeed, the variances do not indicate a systematic influence of neither the mineral fertilization nor the organic fertilization on the average fruit weight. The correlation (Table 5) between different yield parameters showed strong and highly significant correlation between the yield (total and marketable) and the number of fruit harvested.

The average fruit weights correlated less with the yield and explained only around 25 % of the yield variations whereas the number of fruit explained 89 %. This observation underlines, that tomato yield in this experiment was mostly determined by the number of fruit. Additionally, the correlation between the yield and number of flowers at the beginning of fruit setting was higher than with the average fruit weight. Remarkable is the low but positive correlation, which was found between the number of fruit and the average fruit weight at harvest. This indicates that plants with more fruit had to some extent also heavier fruit.

The total number of harvested tomatoes was significantly influenced by the mineral and organic fertilization. A significant increase at the 5 % level by the DMRT for all phosphorous rates and for medium and higher nitrogen rates. The pattern of these curves follow in general the same pattern already observed for the total yield. An increasing nitrogen application increased, as well, the yield. Particularly, the amounts of 56 and 112 kg N/ha produced more fruit per plant. An increase of the number of tomatoes was stated for every organic fertilization treatment, if compared to the unamended control. However, a significant increase at the 5 % level of LSD was only identified for the use of chicken dung. At the same time, this treatment was not significantly different from compost applications rates of 4.2 and 8.3 t/ha.

The statement that higher yields for compost fertilized treatments compared to the unamended plots is mainly due to an increase for the number of fruit seems to be in contradiction to the findings of Maynard A.A. (1995), who found both an increase for the number of fruit and the average fruit weight. Nevertheless, in the case of tomato production under tropical lowland conditions the abortion and fertility of flowers seems to be one of the most important factors determining yield. Among other factors, the temperature and the nutritional state of the tomato plant influence the fertility and abortion of flowers (Atherton, J. G. and Harris, G.P., 1986).

The percentage of tomatoes harvested on the flowers counted at the beginning of fruit setting was used to indicate the differences for the flower fertility. It was found that low nitrogen as well as low phosphorus nutrition increased flower abortion or reduced flower fertility (op cit.). At higher N application, the fruit setting rates were significantly higher at the 5 % level by DMRT. Therefore the number of harvested tomatoes at 112 kg N/ha were higher than for 56 kg N/ha despite the fact that more flowers were formed for this treatment at the beginning of fruit setting. A significant difference for fruit setting was not found for low and middle applications rates of N when compared to the unfertilized treatment. These N application rates did not provide enough nitrogen in order to guarantee a maximum fruit setting. Concerning the P fertilization, a similar statement can be done. Despite the fact that the number of flowers was the highest at 80 kg P/ha, the fruit setting did not perform significantly better than the 0 P treatment. On the other hand, fruit setting was significantly better for medium P rates. High P application rates are suspect to have negative interactions with some micro-nutrients like Mn, Zn and Boron (Mengel, K. and Kirby, E., 1982; Adams P., 1986). Particularly, Mn and Zn deficiencies have serious impacts on the number of fruit per plant (Adams P., 1986). This might explain to some extent the lower fruit setting rates at high P applications. Compost did not appear to have important impacts on the fruit setting. On the other hand, chicken dung showed a significantly higher fruit setting which is probably due to the higher total N and the positive effects on P availability.

CONCLUSION

The observed yield differences were mostly due to a higher number of fruit per plant rather than to a higher average fruit weight. In the average over all mineral fertilization rates, the use of market waste compost at rates of about 4.2 t/ha increased yield significantly, when compared to the unamended treatment. Other researchers confirmed this findings with broadcast compost applications at two to ten times higher rates (Maynard, A., 1993; Clark, G. A. et al., 1995; Ozores-Hampton, M. et al., 1994). For the average over all mineral fertilization treatments, higher applications rates of compost at 8.3 t/ha did not result in further yield improvements. Therefore, application rates should be limited to the range between 4.2 and 8.3 t/ha.

In general, the additional application of N and P increased significantly at the 5 % level by DMRT the yields (total and marketable) compared to the treatments where only compost or chicken dung was provided. This increase was not significant for the marketable yield at a compost rate of 8.3 t/ha. Compost alone did not provide the necessary amounts of N and P for an optimal production, in this case. The use of MWC needs to go hand in hand with a harmonic mineral plant nutrition.

However, in this experiment compost was not able to compete with chicken dung as organic nutrient source. The best yield was found at half of the SOP phosphate rate together with chicken dung. Very high rate for phosphorus showed negative but not significant impacts on the total and marketable yield and is therefore, not recommended. Despite the fact that visible specific deficiency symptoms were not observed, phosphorus induced deficiencies for micro-nutrients might be a valuable explanation for this effect.

Some limits for the validity of this experiment have to be considered. Mainly, the chemical soil fertility of the experimental area is relatively high and further increases in fertility are only to be expected due to an improvement of the physical properties of this kind of soil. Important improvements of chemical soil conditions, e.g. increase of pH and CEC, by compost application are more expected for sandy soils. Positive increases have been obtained with poor soils but not with fertile ones (Gallardo-Lara, L. and Nogales, R., 1987).

Cumulative effects especially regarding the physical properties may occur and improve the performance of the compost applications. This still needs to be evaluated.

REFERENCES

ADAMS, P., (1986). Mineral Nutrition. In: ATHERTON, J.G. and RUDICH, J., (Ed.): The Tomato Crop. A scientific basis for improvement. London, New York Chapman and Hall p. 281-334

ATHERTON, J.G. and HARRIS, G.P., (1986). Flowering. In: ATHERTON, J.G. and RUDICH, J. (Ed.): The Tomato Crop. A scientific basis for improvement. London, New York Chapman and Hall p. 167-200.

AVNIMELECH, Y., COHEN, A. and SHKEDY, D., (1993). Can We Expect A Consistent Efficiency Of Municipal Waste Compost Application? Compost Science and Utilization, 1 (4) p. 7-14.

CLARK, G.A.; STANLEY, C.D. and MAYNARD, D.N., (1995). Municipal solid waste compost in irrigated vegetable production. In: Proceedings of the Soil and Crop Science Society of Florida, 54 p. 49-53.

CSD, (1997). Overall Progress achieved since the United Nations Conference on Environment and Development: Environmentally sound management of solid wastes and sewage-related issues. Fifth session of the Commission on Sustainable Development, 7-25 April 1997, United Nations Distr. General E/CN.17/1997/2/Add.

DIALLO, M. and VOGEL, J., (1996). L'Afrique qui réussit. Vie et combats d'un leader paysan guinéen. Paris 222 p.

GALLARDO-LARA, L. and NOGALES, R., (1987). Effect of the application of town refuse compost on the soil-plant system: A Review. Biological Wastes 19, p. 35-62.

HART, D. and PLUIJMERS, J., (1996). Wasted Agriculture. The use of compost in urban agriculture. Urban Waste Expertise Programme, WASTE Consultants, Gouda, 100 p.

LARDINOIS, I. and VAN DE KLUNDERT, A., (eds.) (1993). Organic Waste. Options for small scale recovery. WASTE Consultants, Gouda, 132 p.

MAYNARD, A.A., (1993). Evaluating the suitability of MSW compost as a soil amendment in field-grown tomatoes. Compost Science and Utilization 1 (2) 34-36.

MENGEL, K. and KIRBY, E., (1982). Principles of plant nutrition. Third edition, Bern, 593 p.

MUSTIN, M., (1987). Le compost. Gestion de la Matière Organique, Paris 954 p.

OZORES-HAMPTON, M.; SCHAFFER, B.; BRYAN, H.H. and HANLON, E.A., (1994). Nutrient concentrations, growth, and yield of tomato and squash in municipal solid-waste-amended soil. HorScience 29 (7) p. 785-788.

SANDERS, S. and OEPEN, M., (1999). Gold in the Garbage. Jahresbericht der GFA.

SKAT, (1996). Valorisation des déchets organiques dans les quartier populaires des villes africaines. Centre de Coopération Suisse pour la Technologie et le Management, St. Gallen, Suisse 143 p.

TOFFEY, W. E., (1998). We're in the soils business, remember! BioCycle, December 1998, p. 57.

UNCED, (1992). Environmentally Sound Management of Solid Wastes and Sewage Related Issues (Chapter 21 of Agenda 21). In: Report of the United Nations Conference on Environment and Development (UNCED), Rio de Janeiro, 3-14 June 1992, A/CONF.151/26 (Vol. II) 14 August 1992.

UNFPA, (1999). The State of World Population 1999. 6Billion: A Time for choices. New York: UNFPA.

UNFPA, (1996). The State of World Population 1996: Changing Places: Population, Development and the Urban Future. New York: UNFPA.

WORLD BANK, (1999). What a Waste: Solid Waste Management in Asia.
Urban Development Sector Unit, East Asia and Pacific Region, May 1999, Washington, D.C., 43 p.

ZURBRUGG, CH. and ARISTANTI, CH., (1999). Resource Recovery in a Primary Collection Scheme in Indonesia. SANDEC News 4, January, p.8-9

Table 1. Soil characteristics and chemical analysis of the experimental area

Textural Class	Top Soil (0-20 cm)[f]	Clay loam
	Subsoil (20-30 cm)[f]	Clay
pH (H_2O, 1:1)		6.1
Organic Matter [%][a]	TS	1.82
	SS	1.14
Total N [ppm][b]		1000
Total P [ppm][c]		1004
Available P [ppm][d]		19
Total K [ppm][c]		583
Available K [ppm][e]		244
CEC [meq/100g of DM][g]		16.1
EC (H_2O, 1:1) [dS/m]		1.09

[a]Graham Colorimetric Method; [b]Modified Kjeldahl Method; [c]Spectrophotometric after digestion in aqua regia; [d]Olson Method; [e]Cold H_2SO_4-Flamephotometer; [f]Sedimentation Analysis-Hydrometer Method; [g]Ammonium Acetate Method

Table 2. Main characteristic of chicken dung and market waste compost

	Compost	Chicken Dung
pH (H_2O, 1:1)	6.4	7.41
Organic Matter [% of DM] [a]	10.9	
Organic Carbon [% of DM] [a]	6.3	
C/N ratio	7.5	
Total N [% of DM] [b]	0.85	2.44%
Total P [% of DM] [c]	0.63	1.87%
Total K [%of DM] [c]	0.30	3.75%
CEC [meq/100g of DM] [e]	32.41	
EC (H_2O, 1:1) [dS/m]	1.79	

[a]Graham Colorimetric Method; [b]Modified Kjeldahl Method; [c]Spectrophotometric after digestion in aqua regia; [e]Ammonium Acetate Method

Table 3. Mean for Total Yield of Tomatoes (t/ha), (Average over three replications)

Mineral Fertilization kg N/ha : kg P/ha	Organic Fertilization 0 t/ha organic fertilization	2.1 t/ha compost	4.2 t/ha compost	8.3 t/ha compost	SOP 2.1 t/ha chicken dung	Mean Mineral Fert.
0 : 0	17.24 c	21.54 b	22.17 b	24.50 b	25.38 c	22.17 d
112 : 0	26.87 ab	29.88 ab	30.81 ab	34.41 a	37.05 ab	31.80 b
112 : 20	33.28 a	35.65 a	36.02 a	35.83 a	44.09 a	36.97 a
SOP 112 : 40	34.92 a	34.03 a	37.62 a	35.49 a	38.95 ab	36.21 a
112 : 80	35.00 a	34.28 a	37.37 a	34.28 a	41.33 a	36.45 a
56 : 40	35.19 a	36.62 a	36.33 a	35.12 a	35.12 ab	35.68 a
28 : 40	25.80 abc	28.81 ab	34.28 a	27.03 ab	30.27 bc	29.24 bc
0 : 40	21.69 bc	27.05 ab	30.50 ab	29.16 ab	23.92 c	26.47 c
Mean Organic Fert:	28.75	30.98	33.14	31.98	34.52	31.87

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT. To compare the organic fertilization means in a row LSD(5%)=3.037 t/ha; LSD(1%)=4.027 t/ha. To compare means for combinations of mineral and organic fertilization in a row LSD(5%)=8.590 t/ha; LSD(1%)= 11.391 t/ha.

Table 4. Mean for Marketable Yield of Tomatoes (t/ha), (Average over three replications)

Mineral Fertilization kg N/ha : kg P/ha	Organic Fertilization 0 t/ha organic fertilization	2.1 t/ha compost	4.2 t/ha compost	8.3 t/ha compost	SOP 2.1 t/ha chicken dung	Mean Mineral Fert.
0 : 0	13.24 d	16.62 b	18.41 b	21.09 a	22.24 cd	18.32 e
112 : 0	22.44 abc	23.11 ab	24.69 ab	27.77 a	31.14 abc	25.83 bc
112 : 20	27.43 ab	30.05 a	31.28 a	29.82 a	37.20 a	31.16 a
SOP 112 : 40	29.41 a	27.75 a	31.58 a	28.22 a	32.31 ab	29.85 ab
112 : 80	28.49 ab	27.32 a	29.34 a	28.18 a	35.26 a	29.72 ab
56 : 40	27.83 ab	29.47 a	31.49 a	29.34 a	28.48 a-d	29.32 ab
28 : 40	19.62 bcd	22.54 ab	28.06 a	21.95 a	25.56 bcd	23.55 cd
0 : 40	18.13 cd	23.03 ab	25.26 ab	23.36 a	19.57 d	21.87 de
Mean Organic Fert:	23.32	24.99	27.52	26.22	28.97	26.20

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT To compare the organic fertilization means in a row LSD(5%)=2.938; LSD(1%)=3.896. To compare means for combinations of mineral and organic fertilization in a row LSD(5%)=8.309; LSD(1%)=11.019.

Table 5. Correlation between Yield Parameters

	Total (including non marketable)			Marketable			Flowers/plant at begin of fruit setting
	Yield [t/ha]	Fruit Weight [g/fruit]	Number of Fruit	Yield [t/ha]	Fruit Weight [g/fruit]	Number of Fruit	
Total Yield [t/ha]	1.000	0.485**	0.947**	0.971**	0.476**	0.924**	0.592**
Average Fruit Weight of all Fruit [g/fruit]		1.000	0.186**	0.514**	0.949**	0.232*	0.231*
Number of all Fruit Harvested			1.000	0.903**	0.193*	0.957**	0.589**
Marketable Yield [t/ha]				1.000	0.497**	0.946**	0.592**
Average Fruit Weight of Market-able Fruit [g/fruit]					1.000	0.200*	0.256**
Number of Marketable Fruit						1.000	0.583**

** significant at 1% level * significant at 5% level