Pineapples Cultivated by Conventional and Organic Methods in a Soil from a Banana Plantation. A Comparative Study of Soil Fertility, Plant Nutrition and Yields

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ABSTRACT

A comparative study on conventional and organically grown pineapples cultivated in a soil from a banana plantation has been carried out in the Canary Islands.

Garden waste compost was used as fertilizer in the organic treatment and current NPK fertilization in the conventional one.

Soil pH, and available Ca and Mg were higher with the compost.

"D" leaf N, K, Ca and Mg levels of plants from the conventional treatment exceeded those from the organic one, but only N seemed to influence yields. Foliar Cu and Zn were higher in plants from the compost treatment, but apparently this did not affect pineapple production.

Fruits from both treatments had similar size and total weight, and free acids and sugar contents. The weight without crown of the fruits from the conventional treatment was significantly higher.

INTRODUCTION

Organic agriculture is a production system which avoids or excludes the use of compounded synthetic fertilizers, pesticides, growth regulators and livestock feed additives. It relies on crop rotation, crop residues, composting, legumes, green manure and aspects of biological control and use of natural insecticides, or fungicides to maintain soil productivity and tilth, supply plant nutrients and control insects, other pests and weeds (USDA, 1980).

Yields of conventionally grown foods are similar or slightly higher than

those from organic agriculture (USDA, 1980; Knorr & Vogtmann, 1983), while there is no agreement about differences in quality (Knorr & Vogtmann, 1983; Hodges, 1983).

Availability of nutrients from the soil remains more or less the same under both cultivation systems (Lockeretz *et al.*, 1984; Reinken, 1986; Alvarez *et al.*, 1988; Arden-Clarke & Hodges, 1988), but organic agriculture improves soil conservation, soil ecology and the environment (USDA, 1980; Lockeretz *et al.*, 1984; Arden-Clarke & Hodges, 1987 and 1988).

Though much research about yields, fruit quality, soil fertility and nutrition of pineapples has been done in recent years (Moreau *et al.*, 1991), there are no data relating to this fruit when organically grown. Interest in pineapples has increased in the Canarian Archipelago (Galán *et al.*, 1988), where it is mostly grown in soils formerly cultivated with bananas, and many of these soils have neutral or alkaline pH (Díaz, 1975). The pineapple cultivar 'Red Spanish' was shown to grow well in these pH conditions when it was conventionally cultivated (Alvarez *et al.*, 1987). To understand its behaviour when organically grown, a comparative study of its cultivation by conventional and organic methods has been carried out. This paper discusses its main results.

MATERIALS AND METHODS

The experiment was conducted in a glasshouse with pineapple plants (*Ananas comosus* L. Merr.), cultivar 'Red Spanish'. The plants were grown in a soil prepared with a mixture of soil and peat (10:1) in 300 l containers, four plants per container. The chemical characteristics of this mixture are given in Table 1.

Suckers uniform in appearance and total fresh weight (250 g) were chosen. Daily and nocturnal temperatures varied between $30 \pm 4^\circ\text{C}$ and $12 \pm 3^\circ\text{C}$, with a relative humidity of 55–75%. The glasshouse was shaded to avoid excessive temperature during late Spring, Summer and early Autumn.

The plants received ten litres of water per container each irrigation.

TABLE 1

Chemical characteristics of initial soil/peat mixture

pH	σ_p O.M.	ppm P	Available cations (meq/100g)		
			Ca	Mg	K
6.88	6.16	101	15.40	7.05	5.24

TABLE 2

Chemical characteristics (%) of the garden waste compost

N	P	K	Ca	Mg
1.93	0.31	1.02	3.20	0.76

following a schedule according to data obtained from irrometers placed in four containers chosen at random. Average water pH was 8.21 with a standard deviation of 0.177.

The experiment was a randomized complete block design (Little & Jackson, 1985) with five replications per treatment, four plants per replication.

The suckers were planted in July 1986. During the whole period of growth and fruiting the plants of the conventionally grown controls each received 14 g of N as ammonium sulphate, 2 g of P as monoammonium phosphate and 7 g of K as potassium sulphate. The compost treatment consisted of three dressings of 1 kg each per container of garden waste compost, that is to say 14.45 g of N, 2.32 g of P and 7.65 g of K per plant. This compost was made on a biodynamic farm with garden wastes from La Orotava town. Its chemical characteristics are given in Table 2.

During seven months prior to artificial flower induction the heights of all the plants were measured at monthly intervals. Samples of soils and "D" leaf (Py & Pélegrin, 1958) from every replication of the control and the compost treatments were taken in May 1987, during artificial flower induction, fruiting (four months later) and harvesting (March to May, 1988).

Artificial flower induction was made in July 1987 with 25 ml per plant of 5% calcium carbide.

Techniques of soil analysis

The samples were dried in air, and passed through a 2mm mesh. pH was measured in water in a ratio 2:5, soil:water, shaken and allowed to settle for 10 minutes.

Organic matter (OM) was determined by the Walkley and Black method as modified by the Comisión de Métodos Analíticos del Instituto de Edafología y Agrobiología "José M. Albareda" (1973).

Available cations were extracted with a 1M ammonium acetate solution at pH 7, and determined by atomic absorption spectrophotometry.

Available phosphorus was extracted by the Olsen *et al.* method (1954), and determined by the Watanabe & Olsen method (1965).

Techniques of foliar analysis

"D" leaf samples (Py & Pêleguin, 1958) were washed in distilled water and their lengths, widths and fresh weights were measured. Their dry weights were determined after drying in an oven at 80°C until they reached constant weight. Then they were ground to powder. 0.2 g of this powder was used to determine N by the Kjeldahl method (Cottenie, 1980). A further 1 g of the powder was ashed in an oven at 480°C for 4 hr and then digested in 6 M hydrochloric acid (Chapman & Pratt, 1973). K, Ca, Mg, Fe, Mn, Zn and Cu were determined by atomic absorption spectrophotometry, and P by the vanadate-molybdate method (Chapman & Pratt, 1973).

Techniques of fruit analysis

Free acids content was determined by titrating 10 ml of fruit juice with 0.1 N NaOH. Sugar content of the juice was measured with a digital refractometer.

Statistical analysis

Data were subjected to Analysis of Variance (Little & Jackson, 1985).

RESULTS AND DISCUSSION

Table 3 shows the chemical characteristics of the soils at four times during the experiment.

The slight decrease with time of the pH values of the soils from the NPK treatment might be due to the acidifying action of the ammonium sulphate used as N fertilizer (Gros, 1981). As the pH levels of the soils receiving compost remained more or less unchanged, significant differences developed between treatments. The pH values of the soils from the control were generally slightly above the optimum range (4.5–5.5) for pineapples (Martin-Prével & Dugain, 1962; Samuels, 1962; Tay & Wee, 1972; Godefroy *et al.*, 1976), but those from the compost treatment were too high. This could be one of the factors that reduced the fruit yield in this treatment.

Except for the organic matter level of the soil from the compost treatment at fruiting time due to the third compost dressing, the OM content did not vary very much with time. Its values were similar to those found in commercial plantations of the Canary Islands (López, 1984; Galán *et al.*, 1988).

TABLE 3

Chemical characteristics of soils (pH, O.M., P and available cations) from the conventional (C) and organic (O) treatments at four different times of sampling.

Time of sampling	Treatment	pH	%	ppm	meq/100g		
			O.M.	P	Ca	Mg	K
May	C	6.39	4.96	119	20.00	7.07	5.65
	O	6.90	4.97	124	20.30	7.73	6.75
July	C	6.12	4.22	91	18.00	5.92	6.75
	O	7.02*	4.69	143	24.30*	9.37*	6.06
Fruiting	C	5.23	5.05	101	16.74	6.12	8.59
	O	7.12*	7.48*	99	26.66*	11.31*	8.23
Harvesting	C	5.80	4.99	149	20.90	7.14	8.15
	O	6.73*	5.41	142	22.18	9.14	6.85*

Pairs of values within the same column and sampling time followed by (*) are significantly different at the 0.001 level.

TABLE 4

Nutrient concentrations in leaves from the conventional (C) and organic (O) treatments at four different times of sampling.

ISU†		May		July		Fruiting		Harvesting	
		C	O	C	O	C	O	C	O
%	N	1.54	1.34	1.56	1.41	1.90	1.30*	1.71	1.60
	P	0.17	0.24	0.22	0.20	0.26	0.23	0.22	0.20
	K	2.94	2.76	3.26	2.88	3.40	3.23	4.21	3.86*
	Ca	0.26	0.19	0.26	0.25	0.60	0.43*	0.82	0.59*
	Mg	0.17	0.14	0.19	0.18	0.24	0.20*	0.30	0.24*
ppm	Fe	104	98	98	99	105	85	110	145*
	Mn	32	25	36	47	68	66	83	68
	Zn	16	14	17	23	13	20*	16	25*
	Cu	6	5	3	6	4	7*	3	7*
	Fe/Mn	3.25	3.92	2.72	2.11	1.54	1.29	1.32	2.13

† International Standard Units.

Pairs of values within the same row and sampling time followed by (*) are significantly different at the 0.001 level.

Phosphorus levels of the soils were very high, considering the low requirements that pineapples have of this element (Godefroy *et al.*, 1971).

Available Ca, Mg and K contents were also high. Calcium levels from 4 up to 10 meq/100g are considered to be sufficient (Aubert, 1973; Guyot *et al.*, 1974; Giacomelli & Py, 1981), whereas a good range for Mg is 2.5–3.5 meq/100g (Godefroy *et al.*, 1977), and 0.32–0.52 meq/100g for K (Dalldorf & Langenegger, 1978). There were significant differences between the treat-

ments in available Ca and Mg contents in July and at fruiting time. However, they did not influence the absorption of these elements by the plant, because Ca and Mg levels from the organic treatment (Table 4) at fruiting time were significantly lower.

The significant decrease at harvesting time of available K from the compost treatment affected the K nutrition of the plant (Table 4), but its levels were within the normal range (Chapman, 1966).

Table 4 shows the nutrient concentrations in the leaves at the four sample times.

All the N levels exceeded the lower limit (1.29%) indicated by Chapman (1966), though accordingly to Dalldorf and Langenegger (1978) N values when the inflorescence is developing must be equal to or higher than 1.5%. At fruiting time the mean content of leaves from the compost treatment was significantly lower and did not reach the 1.5% level. It could be one of the factors that contributed to reduce fruit yield in this treatment. This lower leaf N concentration of pineapples from the organic treatment might be due to a decreased efficiency of the compost to supply this nutrient to the plants compared to that of mineral fertilizers. A similar trend has been reported by Terman *et al.* (1973) and Juste (1980).

All the P values exceeded the minimum level (0.1%) advised by Ramírez & González (1983).

Although the mean K content of the leaves from the compost treatment at harvesting time was significantly lower than that of the NPK, it had probably no effect on fruit yield, because its concentrations were higher than 2.2%, the value that Chapman (1966) considered acceptable. The same argument is applicable to the significant differences found with foliar Ca and Mg during fruit development and at harvesting time, as their values exceeded the lower levels indicated by Chapman (1966) [0.19% for Ca and 0.16% for Mg].

The significant difference in foliar Fe concentrations between the treatments at harvesting time is not important, since both Fe levels were within the normal range (80–150 ppm) (Marchal, 1971).

Iron and Mn nutrition are closely related in pineapples, and the Fe/Mn ratio may be more important than their separate levels. According to Marchal (1971) when ratios are less than 0.4 or more than 4 there is a nutrient imbalance and yields may be reduced. In our experiment all the Fe/Mn ratios were within that range.

The foliar zinc concentrations exceeded the minimum values (10 and 12 ppm) pointed out by Dalldorf and Langenegger (1978) and Marchal (1971), respectively. That means that though during fruit development and at harvesting times the levels of Zn of the leaves from the compost treatment were significantly higher, they did not appear to influence the yield or quality of the fruits.

Some values of foliar Cu were below the minimum level (5 ppm) recommended by Marchal (1971), but we did not observe any symptoms of Cu deficiency as described by Marchal (1971) and Jorgensen (1978). In other treatments made at the same time as those discussed in this paper (Carracedo, 1992), the plants received foliar applications of micronutrients. Their levels of foliar Cu ranged from 7.8 up to 14.2 ppm, but no significant difference in yields were noted. It is unlikely therefore that these low Cu concentrations had any influence on the fruit weights. During fruiting and at harvesting times Cu values were significantly higher in leaves from the organic treatment. Apparently, the compost had a positive influence on Cu and Zn absorption by the plant.

The development of the height of the plants during seven months prior to artificial flower induction is represented in Figure 1. The height of the plants in the compost treatment increased steadily during the seven months, whilst in the NPK plants, heights decreased during May and June and increased in July. Both kinds of trends were observed by Py & Lossois (1962) for the same variable. The decrease of height may be explained by the very nature of the way that this variable is evaluated. The height of pineapples is obtained measuring their longest leaf, that most of the time coincides with one of the older leaves that are physiologically mature. When senescence of this leaf occurs, the next longest leaf may be shorter, causing a decrease in the measure of the height. There were no significant differences between the plant heights of the two treatments.

FIGURE 1. Evolution of the height of the plants during seven months prior to artificial flower induction.

TABLE 5

Length, width, fresh weight (FW) and dry weight (DW) of leaves from the conventional (C) and organic (O) treatments at four different times of sampling.

Time of sampling	Treatment	Length cm	Width cm	FW g	DW g
May	C	79.0	2.32	23.62	3.95
	O	69.6	2.40	20.17	3.30
July	C	67.8	2.32	17.61	2.93
	O	72.5	2.52	21.13	3.53
Fruiting	C	61.8	3.21	18.19	3.43
	O	62.7	2.87	17.76	3.22
Harvesting	C	68.5	2.96	17.63	3.47
	O	63.8	3.00	16.13	3.17

TABLE 6

Means of total weight (TW), weight without crown (WWC), length, perimeter (P), free acids (FA) and sugar content (SC) of the fruits from the conventional (C) and organic (O) treatments.

Treatment	TW g	WWC g	Length cm	P cm	FA meq%	SC %
C	596.0	533	8.65	32.74	21.25	16.18
O	507.8	430*	8.17	31.25	16.99	15.39

Pairs of values within the same column followed by (*) are significantly different at the 0.05 level.

No influence of the compost treatment was noted on length, width, fresh weight and dry weight of the leaves (Table 5). Even though there was a progressive increase in width of the leaves from plants in the compost treatment, the values were not significantly different from those of the controls.

Whereas the total weight, length and perimeter of the fruits were similar in both treatments (Table 6), there were significant differences between them in the weight without crown. The lower fruit weight from the compost treatment might be due to the high pH levels of the soils and the low foliar N concentration during fruit development. Unfavourable effects of high pH on fruit yield of pineapples have been widely reported (Samuels, 1962; Godefroy *et al.*, 1976; Marchal, 1980), as well as the negative effect of low nitrogen (Sideris & Young, 1950; Py *et al.*, 1956; Lacoëuilhe, 1984).

The free acid contents were very high (Table 6), normal values being less than 10 meq% in Red Spanish pineapples (Antoni & Leal, 1981). This could be due to the low temperature and shading of the glasshouse. Pineapples grown during cool periods or reduced available light tend to be more sour (Green, 1963; Py *et al.*, 1987).

CONCLUSIONS

The most outstanding effect of the compost on the soil chemical characteristics was to maintain the pH near neutral values, a factor that could adversely affect the fruit yield.

The low N content in compost treatment samples at fruiting time might reduce fruit production, whereas no conclusive effects could be deduced from the differences in other nutrients between the two treatments.

No differences between the treatments were observed in the growth rate of the plants, measurements of the leaves, and fruit characteristics, except in the weight without crown which was significantly lower from compost treated plants.

Organic fertilization of pineapples with compost based on current N doses used in conventional agriculture may produce a shortage of this nutrient and reduce yields. More research is needed to settle the fertilizer supply suitable for pineapples when organically grown in the Canary Islands.

Canarian organic farmers should take care of soil pH when cultivating 'Red Spanish' pineapples in former banana plantations.

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