Effect of Organic Fertilizations and EM Applications on Growth Pattern, Nutrient Uptake and Grain Yield of Sweet Corn

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Abstract

Effective microorganisms (EM) containing lactic bacteria, Actinomyces and various other bacteria and fungi have been introduced to nature farming. In this study, effects of EM applications and organic fertilizations on growth and plant-soil nutrition of potted sweet corn were examined. An organic fertilizer, fermented with EM added using oil sludge, rice husk and bran anguish processing by-product, was used in comparison with chemical fertilizers, At the early stage, growth and dry matter production were lower for organic fertilized plants than for chemical fertilized ones because of lower nutrient availability from organic materials. However, organic fertilized plants showed higher growth rate from the middle stage and the final biomass and grain yield reached a level similar to or higher than chemical fertilized plants. Notwithstanding the problem of low nutrient availability at the early growth stage, the organic material fermented with added EM could be used as an organic fertilizer comparable to chemical fertilizers.

Introduction

Many problems of environmental pollution have resulted from excessive applications of pesticides, herbicides, and chemical fertilizers in the traditional farming system. This is endangering the existence of human beings on earth. Therefore, nature farming or organic farming has become more and more important. The concept and principles of nature farming were proposed by Okapi in Japan more than 50 years ago. One of the strict principles of nature farming is the prohibition of using both chemical and undreamed manure fertilizers (Okapi, 1987). Therefore, nature farming practitioners and researchers have to find some kind of organic materials to substitute for chemical fertilizers. Farmers in Japan have used an organic fertilizer fermented using organic materials such as oil mill sludge, rice husk and bran and fish processing by-products. Compared to the undreamed manure fertilizers that are used in organic farming, this kind of organic fertilizer does not involve the problems of pathogenic, heavy metals, antibiotics and animal growth-promoting hormones. Recently, application of effective microorganisms (EM) is introduced to the nature farming system (High, 1994). EM applications have been proved effective in many aspects and played important roles in promoting crop production and purifying the environment. However, detailed examinations are still not sufficient in researches on effect of EM. Practical usage has gone ahead before fundamental research on both nature farming and EM applications. Moreover, with organic fertilizations, it is difficult to have a yield reaching a level higher than or similar to that with chemical fertilizations because soil physical and chemical properties have been changed by chemical practices and the soil and the land environment have become dependent on chemicals. Therefore, in the present work, we examined the effects of organic fertilization effects and EM applications on plant growth, grain yield and the soil-plant nutrition.

Materials and Methods

Plant Materials and Treatments

Exp. I. Sweet corn (Zea mays L. cv. Honey-Bantam) with a growth period of about 80 days was used in this study. Plants were grown in June 1996 in Wagner's pots each with a 0.02 m^2 of surface area. The pots, each with one plant remaining after thinning, were placed in a Latin Square design in a glasshouse. A fine textured Andosol was used and the total soil nitrogen, available phosphorus, and potassium were 3.4, 0.025 and 0.44 g kg^-1, respectively, with a C/N ratio of 13. The field capacity of the soil was 80 percent on gravimetric basis. Each pot was filled with 3 kg fresh soil with a water content of 38 percent of the field capacity.

Exp. II. Seeds of the same sweet corn plants were sown in August 1996. The management of the plants was the same as in Exp. I.

Fertilizers. For both experiments, ammonia sulfate, superphospate and potassium sulfate were used for chemical fertilization treatments and the quantities of N, P and K were equivalent to the total content in organic fertilization treatments as described below. Organic materials such as oilseed sludge, rice husk and fish-processing by-product were fermented

anaerobically or aerobically with or without effective microorganisms (EM). The total nitrogen, available phosphorus, and potassium concentrations were 58, 30 and 2 g $kg^{-}1$ respectively, for both anaerobic and aerobic organic fertilizers. For Exp. I, only anaerobic organic fertilizer was used with the chemical fertilizers as control. Both anaerobic

and aerobic organic fertilizers were used in Exp. II.

Microbe inoculant. The microbial inoculant used in this study was a group of beneficial microogranisrns containing about 80 species. The main species included in EM are as follows:-

1) Lactic acid bacteria :*Lactobacillus plantarum* (ACTCC8014), *Lactobacillus casei* (ACTCC7469), *Streptococcus lactis* (IF012007);
2) photosynthetic bacteria: *Rhodopseudomonas palustris* (ACTCC 17001), *Rhodobacter sphaeroides* (ACTCC17023);
3) Yeasts : *Saccharomyces cerevisiae* (IF00203), *Candida utilis* (IF00619);
4) ray fungi *Streptomyces albus* (ATCC3004), *Streptomyces griseus* (IF0358);
5) fungi : *Aspergillus oryzae* (IF05770), *Mucor hiemalis* (IF08567);
6) Others : Some microorganisms that are naturally existing and having combined into EM in the manufacturing process and can survive in the EM liquid of pH under 3.5. The density of most of the above mentioned microbes were in the range of 06 to l08 per ml. The same effective microorganisms were used for both Exp. I and II with the same quantity.

Treatments. Four treatments were made for Exp. I without Treatment 3) and 4) of the following six treatments, and six treatments for Exp. II as follows: 1) EM - Organic 1 Alanaerobically fermented organic materials 80 g, in which EM was added to the materials before fermented; 2) Organic 1 Alanaerobically fermented organic materials 80 g; in which EM was added before fermented; 4) Organic 2 Alaerobically fermented organic materials 80 g; 5) EM-Fertilizer Alchemical fertilizers (ammonia sulfate 5.3 g, long-period coated urea (LP coat - 70) 2.8 g, superphosphate 13 g and potassium sulfate 4.95 g), with EM, 80 ml, applied into soil the same time before sowing; the total amounts of nitrogen, phosphorus and potassium were the same as in the above mentioned organic materials; and 6) Fertilizer Althe same fertilizers as in 5). In exp. I, the applied amount of chemical fertilizers was half of that in Exp. II.

Growth and Yield Analysis

Relative growth rate. Samples of the total plant were taken l0, 20, 40, 60 and 80 days after sowing for Exp. I and 8, 25, 50 and 120 after sowing for Exp. II Relative Growth Rate (RGR) was calculated according to Nakaseko (1985) as follows;

RGR = (In M2-In MI)/(t_2-t_1) l),

Where M2 and M1 are dry mass at time t_2 and t_1.

Net assimilation rate. The net assimilation rate (NAR) was calculated as follows;

NAR = {(M2-Ml)/ (t2-tl)} x (In A_2 –InA_1)/ (A_2 –A_1) Ap 2),

Where A_2 and A_1 are leafarea at time t_2 and t_1.

Measurements of Mineral Nitrogen and Available Phosphorus in the Soil

After the plants sample was taken, the soil was collected. The concentrations of mineral nitrate-nitrogen and ammonium nitrogen as well as the concentration of available phosphorus in the soil and in the plant were measured using colorimetric method. (Ishitsuka, 1985).

Results

Growth and Productivity

Dry mass and leaf area at different stages. The upper part of Fig. 1 shows the absolute levels of plant dry mass for four different treatments in Exp.I. The lower part of this figure shows relative dry mass levels with the non-EM chemical treatment as 100 percent. Fig. 2 shows the results of dry mass for six treatments in Exp. II with the same style as in Fig. 1. Chemical fertilizers were applied with an N-P-K amount half of that in organic fertilizer for Exp. I, but with the same amount as in organic fertilizers for Exp. II. In both experiments, plants in EM plots showed slightly higher dry mass under all fertilizations at almost all growth stages. At the early stages, dry mass of organic fertilized plants was significantly lower than that of chemical fertilized plants. However, as growth stages developed, dry mass of organic fertilized plants reached a similar level to that of chemical fertilized plants. Figs. 3 and 4 show the results of leaf area in Exp. I and Exp. II, respectively. Except for the anaerobic organic fertilizer plot in Exp. II, leaf area increased in EM addition treatments. In Exp. II leaf area of organic fertilized plants could not reach a level close to that of chemical fertilized plants although the dry mass reached a level close to that of chemical fertilized plants at the harvesting stage. This suggested that less leaf area of organic fertilized plants produced a similar dry mass compared to the chemical fertilized plants.

Relative growth rate net assimilation rate. Figs 5 and 6 show the relative growth rate (RGR) for Exp, I and Exp. II respectively. The upper parts of the figures show the absolute values of RGR. Because there were large fluctuations of the values among growth stages, it is difficult to tell the differences from absolute values in these figures. The lower parts show the percentage values relative to the Non-EM-chemical treatment. For both experiments, at the early stage, RGR in organic fertilized plants was lower, but increased very fast and became much higher than that of chemical fertilized plants at middle and later stages. Compared with that for chemical fertilized plants with larger dry mass at the early stages, greater RGR for organic fertilized from the middle stages was because the RGR was calculated from the dry mass on an exponential basis. EM application showed positive effect on RGR at all stages under both organic and chemical fertilizations. Plants fertilized with aerobic organic materials grew better than plants with anaerobic organic materials. The results of net assimilation rate (NAR) were presented in Fig. 7 and 8 for Exp. I and Exp. II respectively. NAR showed similar tends to those of RGR

The final dry mass and grain yield. Table I show the final dry mass and grain yield for Exp. I and Exp. II. Although dry mass at early stages was low in organic sweet corn plants, the final dry mass was not low. Moreover, organic fertilized plants show a slightly higher grain yield and higher harvest index, EM treatment also increased grain yield and harvest index. Because the fertilizers were applied at the half rate of N-P.K of that in organic fertilizers and the soil was very poor, plants in chemical plot could not grow to produce normally ears. Therefore, the conclusion was limited from the data of Exp. I.

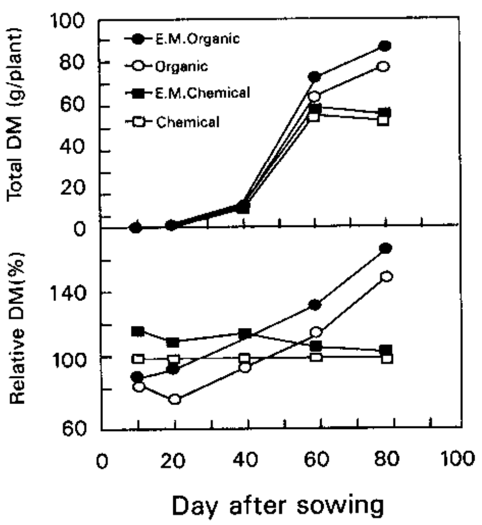

Fig. 1. Total dry mass of sweet corn plants fertilized with organic or chemical fertilizers with or without microbial inoculant application at different growth stages (Exp. I)

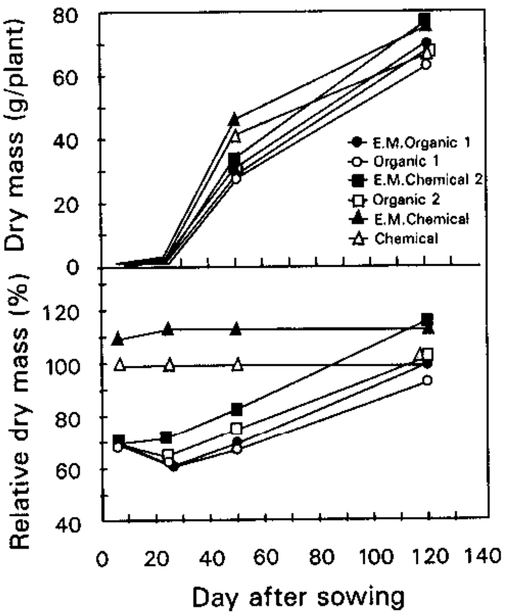

Fig 2. Leaf area of sweet corn grown with organic or chemical fertilizers with or without microbial inoculant application at different stages (Exp. I).

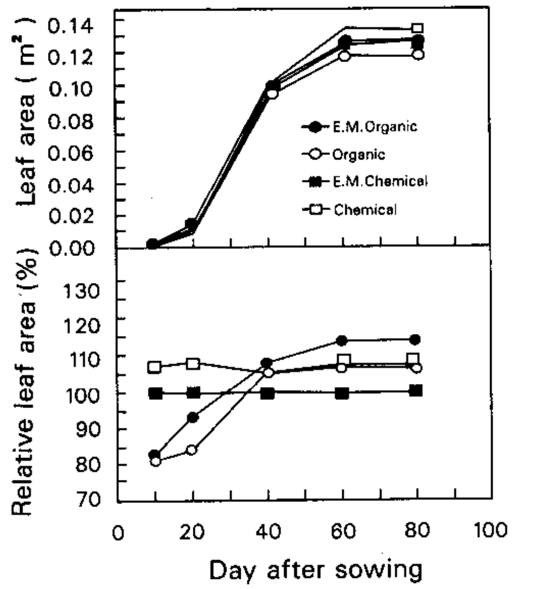

Fig. 3. Total dry mass of sweet corn plants ferlilized with organic or chemical fertilizers with of without microbial inoculant application at different growth stages (Exp. II)

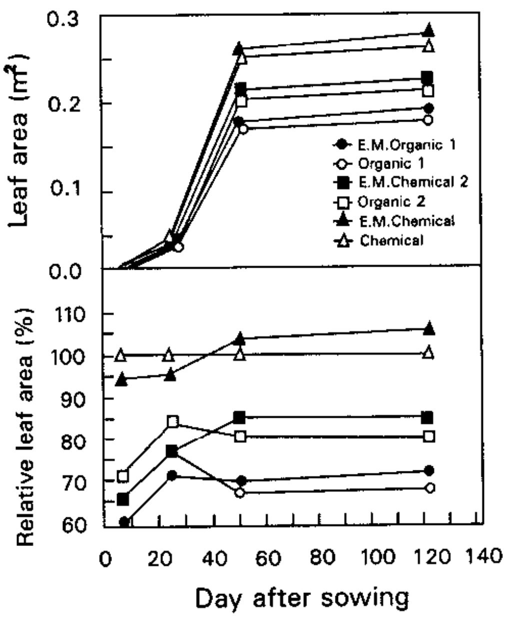

Fig. 4. Plant total leaf ares of sweet corn fertilized with organic or chemical fertilizers with of without microbial inoculant a pplication at different growth stages (Exp. II.).

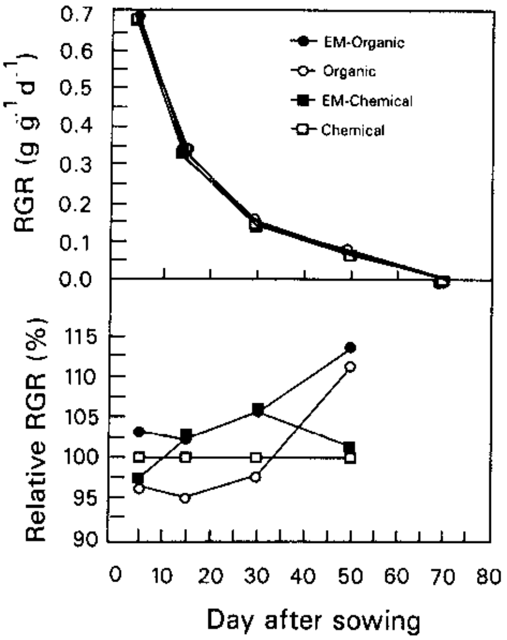

Fig. 5. Relative growth rate (RGR) sweet corn plants grown with organic or chemical fertilizers with or without microbial inoculant application at different growth stages (Exp. I).

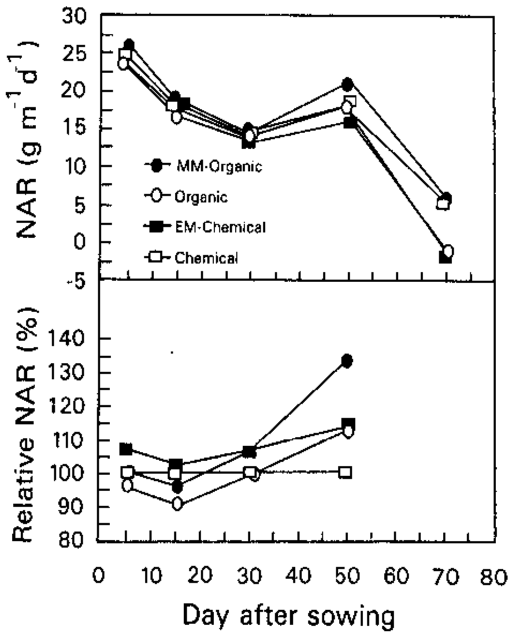

Fig. 7. Net assimilation rate of sweet corn plants grown with organic or chemical fertilizers with or without microbial inoculant application at different stages (Exp. I).

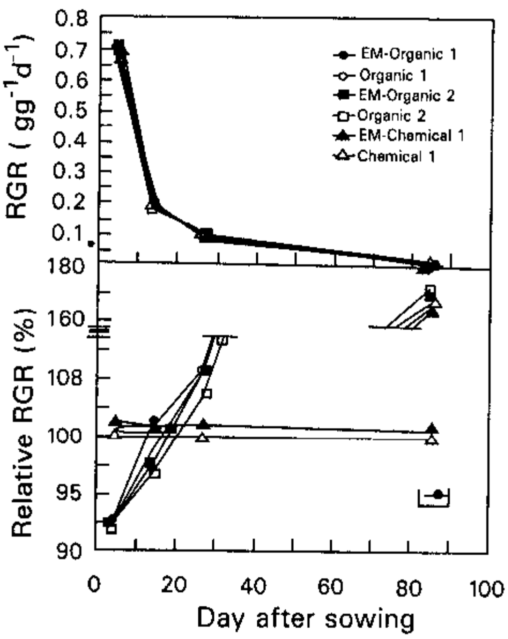

Fig. 6. Relative growth rate (RGR) of sweet corn plants grown with organic or chemical fertilizers with or without microbial inoculant application at different growth stages (Exp. II).

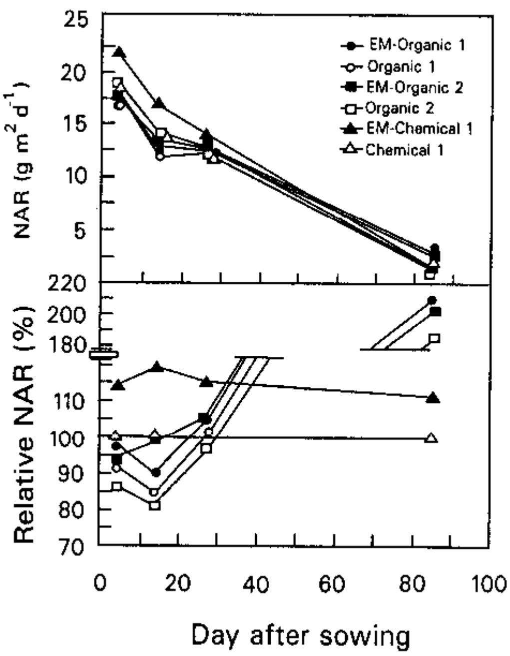

Fig. 8. Net assimilation rate of sweet corn plants grown with organic or chemical fertilizers with or without microbial inoculant application at differents stages (Exp. II).

Table 1. Dry Mass and Yield of Sweet Corn Plants Grown Under Organic and Chemical Fertilizations with or without Microbe Applications.

Parameter	**Organic 1**		**Organic 2**		**Chemicals**	
	EM+	**EM-**	**EM+**	**EM-**	**EM+**	**EM-**
Exp. I						
Total dry mass	86a	77b			54c	52c
Ear dry mass 39a	39a	35b		12c	4c	
Harvest index (%)	45a	46a			22b	7c
Exp. II						
Total dry mass	67b	63c	77a	70b	75a	68b
Ear dry mass 29a	25b	28a	24b	26ab	21c	
Harvest index (%)	30a	28	27	25	26	23

Nutrient Availability and Uptake

Fig. 9 shows the dynamic changes of nitrate nitrogen. The lower left part of Figs.9 shows the available nitrogen concentration in the soil. The upper left part shows the dynamic changes of the total nitrogen in the soil and that absorbed by the plant. The right parts of the graphs show the percentage values of available nitrogen relative to the non-EM-chemical control. At the beginning, available nitrogen was much lower in the organic fertilized pots than in the chemical fertilized pots. This was the reason why plant growth and dry matter production were lower at early stage in organic fertilized pots than that in chemical fertilized pots. As growth stage developed, both available nitrogen in soil and the total nitrogen available and absorbed by plants reached a higher level than those for chemical fertilization treatment. This was why plant growth became higher in the organic fertilized plants at later stages. Fig. 10 shows the dynamic changes of available phosphorus in the same style as in Fig. 9. The available phosphorus in soil of chemical treatments decreased as growth stage developed. However, it showed almost no decreases up to the end in organic fertilization treatment. For the total of phosphorus absorbed by the plant plus that available in the soil reached a similar level for both organic and chemical fertilizations. The total available phosphorus was slightly higher in EM plots.

Discussion

At the early stage, growth and dry mass of plant was lower for organic fertilized plants than for chemical fertilized ones. This might be attributed to the low nutrient availability from the organic materials. However, organic fertilized plants showed a higher root/total dry mass ratio than the chemical fertilized plants. The physiological activity of root shown by the respiration rate was also higher in organic fertilized plants than chemical fertilized plants. The mechanisms might include both adaptation and nutrient balance. The condition of low available nutrients imposes a stress on the plants, which forces plants to develop more, longer and more active roots reaching to farther places to search nutrients. On the other hand, the organic fertilizer contains more kinds of nutrients which make the nutrients more balanced than the chemical fertilizer that contains only N-P-K. These are just speculative hypotheses and we do not have experimental data to support these suggestions. Because the organic fertilized plants developed a good root system with more and longer seminal and nodal roots, they possessed more potential to uptake the nutrients which became available at the middle and later growth stages. Therefore, the relative growth rate and net assimilation rate based on unit of leaf area was much higher in organic fertilized than chemical fertilized plants.

It has been known that long-term fertilizations with organic materials improve soil physical, chemical and biological properties (Hillel, 1980). Growth and activity of the root system are promoted by the improved soil properties (Jones, 1983). Up to now, there have been many researchers on organic fertilization (U.S.D.A., 1980; Lockeretz and Kohl, 1981; Harwood, 1984; Vogtmann, 1984). However, the mechanism of the effect of the EM used in this study has not been clear in many aspects. Therefore, the effects of EM applications on plant growth and physiology were examined in a detailed way. The effective microorganisms used in the present study contained a group of beneficial microbes. EM applications with both organic and chemical fertilizers promoted plant growth at all growth stages and increased grain yield as. a consequence. Many observations of growth promotion, yield increases, and quality improvements are reported by the farmers without strict scientific controls. However, researches on the individual species of microbes included in the effective microorganisms used in the present study have been well conducted from long ago. Some phytohormones and the derivatives are synthesized by soil microbes including some species contained in the EM used in this study (Arshad and Frankenberger Jr, 1992). Barea et al. (1976) have found that among 50 bacteria isolated from the rhizosphere of various plants, 86, 58 and 90 percent produce auxins, gibberellins, and kinetin-like substances, respectively. Kampert et al. (1975) has reported that 55 percent of bacteria and 86 percent of fungi isolated from the rhizosphere of *Pinus silvestris* can produce gibberellins and the derivatives. *Actinomyces* and *Streptomyces* produce auixins and similar substances (*Purushothaman* et al., 1974; Mahmoud et al., 1984), gibberellins (Arshad and Frankenberger Jr, 1992), and cytokinins (Bermudeze de Castro et al., 1977; Henson and Wheeler, 1977). Some fungi like *Aspergillus niger* produce. gibberellins (El-Bahrawy, 1983). The promotion of root development and activity by EM applications might be due to the effects of plant growth regulators produced by inoculated microbes. However, we do not have available data to support this hypothesis. Further studies are necessary to examine the mechanistic basis for the effects of EM on plant growth. EM has been used in agriculture, especially in organic farming systems in advance of fundamental researches. Therefore, we need to elucidate the problems remaining in the technology of EM applications.

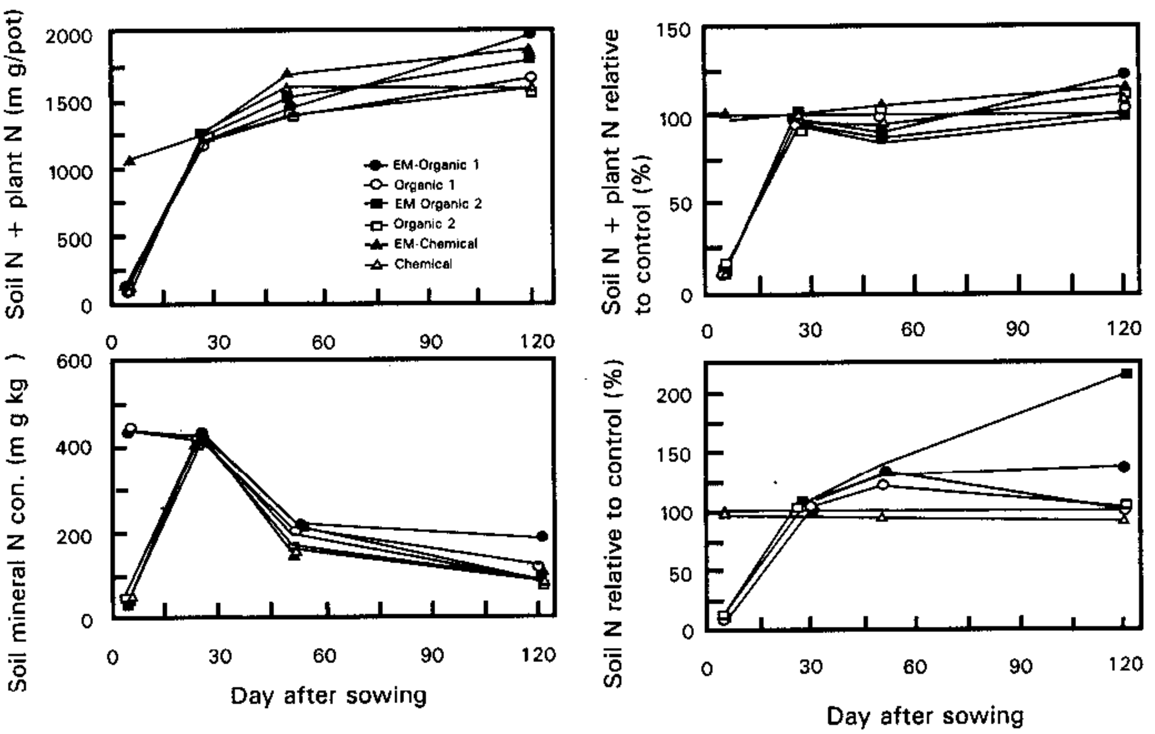

Fig. 9. Dynamic changes in nitrogen in the soils and the total in the soil and plant of sweet corn fertilized with organic materials and chemicals

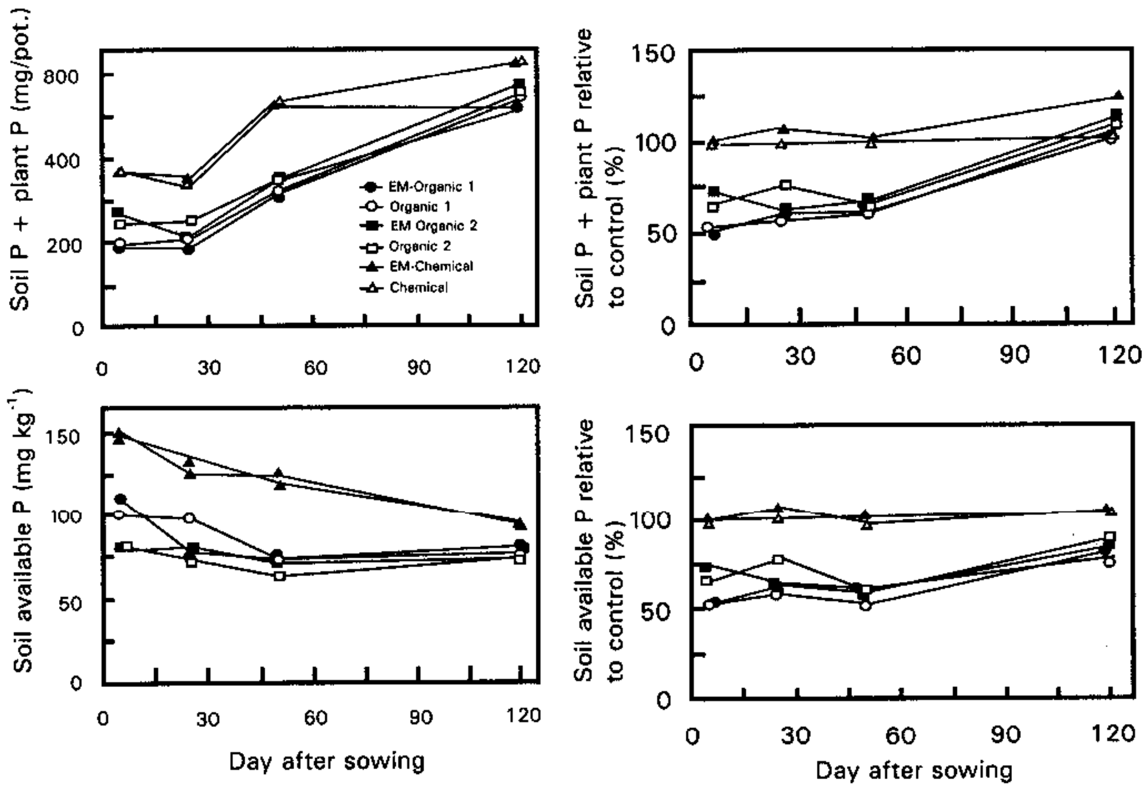

Fig. 10. Dynamic changes in available phosphorus in the soils and the total in the soil and plant of sweet corn fertilized with organic materials and chemicals.

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