COVERING COMPOSTING WINDROWS:
EFFECTS ON THE PROCESS AND THE COMPOST

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ABSTRACT: Composting trials were undertaken to study the feasibility of using crucifer or carrot residues with sawdust or straw for composting. Geotextile covers were tested for their influence on different parameters. Two complete composting cycles were monitored. Measurements were taken for compost temperature, moisture, and leachate. Physico-chemical analyses were performed on compost samples. Phytotoxicity tests were done with compost leachate samples. The results showed that the temperature of the covered compost (CC) decreased more slowly during late fall and early winter than that of the non-covered compost (NC). In addition, CC did not freeze as deep over the winter, and it warmed up sooner and faster than NC in the spring. The moisture content of CC was significantly lower than in NC at the end of both composting cycles. CC had a higher mineral content than NC in both cycles, and nitrogen, phosphorus and potassium levels were significantly higher in CC of the second cycle. The carbon/nitrogen (C/N) ratio of CC showed a more important decrease earlier in the cycles observed. The quantity of leachate from CC was significantly reduced compared to NC in the second cycle. Compost leachate showed a high level of phytotoxicity in the first part of the composting cycle and this phytotoxicity disappeared sooner in CC of the first cycle. However the leachate in the second cycle became non-phytotoxic at the same sampling time in both CC and NC. The effects of geotextile covers included a favorable influence on compost temperature in late fall and in spring in a northern climate; a higher retention of mineral elements; an earlier maturation of the compost, and a reduction in the quantity of compost leachate generated. The use of these covers by agricultural producers or other composting operations could result in a better quality compost while releasing smaller amounts of leachate in the environment.

INTRODUCTION

Vegetable cropping systems yield large quantities of food material per surface area and generate considerable volumes of plant waste both in the field and as a result of processing. In order to minimize the environmental impact from improper waste disposal and to turn these plant residues into a valuable resource, some Quebec vegetable producers wanted to investigate the composting option. Several systems are available for composting: open systems with periodically turned piles or with static piles having forced ventilation; closed systems using vertical reactors which have continuous or discontinuous mass of materials, or horizontal reactors where materials are either static or periodically turned (de Bertoldi and Zucconi, 1987). In Quebec, open systems are most often used for farm residue composting (Sauvesty and Tabi, 1995).

Fruit and vegetable wastes are classified as a moderate to wet type of material with a moderate to low C/N ratio depending upon the nature of the waste (Rynk *et al.*, 1992). They are considered to have a poor to fair structure which means that standing piles of these wastes quickly collapse into a wet mess if nothing is done to process them. According to Rynk *et al.* (1992), the moisture content of a compost is particularly critical due to the risk of anaerobic conditions accompanied by odor problems and slow decomposition. In this project, it was expected that the carbonaceous material combined with the vegetable wastes would compensate for the high moisture in the vegetables. Due to a concern about groundwater contamination by compost leachate derived from precipitation water, the research project included the use of geotextile covers on compost windrows. Compost leachate initially results from the decomposition of the organic materials, then subsequently from percolation of precipitation and from runoff along the surface of the piles. There is little work which specifically addresses the phenomenon of leaching. Most of the work done has been concerned with nitrogen leaching (Ballestero and Douglas, 1996; Dewes, 1995; Ulen, 1993). Nitrogen leaching is very dependent on the form of waste being composted and its initial characteristics (Ballestero and Douglas, 1996). The application of plastic sheet covers on compost piles did not reduce total nitrogen losses since the covers enhanced NH_3 exhalation to such an extent that total nitrogen losses increased (Dewes, 1995). Fleece blankets placed over a compost windrow kept the level of nitrate-nitrogen in leachate consistently lower than when the blankets were removed and the site exposed to rainfall. (Lufkin *et al.*, 1995). Bidlingmaier (1992) noted an increase in the percentage of leachate relative to the rainfall as the compost matured and temperature decreased; this relative increase in leaching was attributed to a decrease in the rate of evaporation of the composting mass.

The parameters studied in relation to the use of the geotextile covers included compost temperature, compost moisture, physico-chemical characteristics of the compost, as well as the volumes and the quality of compost leachate. It is important to follow the temperature evolution in a compost windrow: a high temperature (55-60°C) is desirable for 2-3 days in the first stage, to sanitize the materials, but the rates of microbial activity and drying are greater at temperatures of 38-55°C (Hoitink and Fahy, 1986). In the case of vegetable residues, plant pathogens could be present in this material and should be exposed to adequate temperatures to destroy them.

The objectives of this research project were: to monitor the composting process of vegetable wastes in an intermittently-turned windrow system; to examine the effect of geotextile covers on compost temperature, compost leachate, and compost quality; and to assess the survival of important plant pathogens in a compost made from vegetable wastes (not discussed in this paper).

MATERIALS AND METHODS

The composting trials were run on the Macdonald Campus of McGill University (Ste-Anne-de-Bellevue, Quebec, Canada). This site is in a climatic zone where precipitation averages 940 mm (37 in.) annually, and the temperature ranges from -35°C (-31°F) to +35°C (95°F). Twelve composting platforms were built to provide conditions where leachate could be recovered and measured. Each platform measured 3.5 meters wide by 4.6 meters long; they were arranged in three rows 4 meters apart, with an in-row spacing of 2-2.5 meters between platforms. The randomized block design included 3 blocks of 4 platforms, with 2 replicates within each block. The design was a 2 x 2 factorial experiment (covered/non-covered and with/without pathogens). The organic material used included cauliflower wastes and sawdust (1:1 v/v) the first year; crucifer wastes and wheat straw (9:1(compressed) v/v) the second year. The compost material was mixed and partially shredded with a manure spreader before piling it onto each platform to a height of about 1.5 meters. Only 6 platforms were used in the first year of the project because of a shortage of vegetable residues due to the late start. Starting dates were November 15 in 1994, and October 12 in 1995. The complete cycle lasted 271 days the first year and 288 days the second year.

The geotextile covers (Compostex® by Texel Inc., St-Elzéar, Québec) applied in the covered treatment were made of non-woven fibers (polyester and/or polypropylene), 1.6 mm thick. This material was permeable to air and gas, but water-repellent. They were left on the compost throughout the cycle, being removed only for turning operations. Half of the compost windrows were inoculated with infected plant material representing three phytopathogens: there was a total of 28 samples per pathogen that were distributed in each inoculated windrow. The pathogens samples were either in a fixed determined position or placed at random in the compost windrow.

The temperature was read three times a week at two depths (30 and 60 cm) in two locations for each platform. Moisture was measured from composite samples taken at about 30 cm depth, every 1-2 weeks (except for winter time). The samples were weighed before and after oven-drying. Sampling for physico-chemical analyses was done at the beginning of the cycle (fall), before turning in spring time, and at the end of the cycle. Leachate was collected and measured after each precipitation. Samples of leachate were taken at six different times during the composting cycle for phytotoxicity tests. A germination index was calculated with a cress germination test (Zucconi *et al.*, 1981) performed with the collected leachate samples. Leachate from the first 10-12 days of composting was not included in comparing volumes for the two treatments, since most of this leachate was not a consequence of precipitation. Physico-chemical analyses were done for leachate samples taken at the beginning and at the end of the two cycles.

The temperature and moisture data were analyzed using a spatio-temporal or temporal repeated measures analysis of variance (ANOVAR) (Dutilleul, 1997) in order to check for interactions between time, depth and treatments. The second year data for leachate volume were submitted to an ANOVA after being log-transformed for normality requirements. Results from the cress germination tests were submitted to ANOVA, checking for treatment main effects at each dilution level within each sampling date.

RESULTS AND DISCUSSION

COMPOST TEMPERATURE

At the beginning of both cycles, temperatures above 55°C were recorded at 30 cm and 60 cm depths, in both CC and NC. CC stayed above 55°C slightly longer than NC (11-14 days vs. 8-10 days) in the two cycles. During the initial thermophilic period of the second cycle, temperatures above 70°C were recorded at the 60 cm depth for both CC and NC treatments. Such conditions are detrimental to the composting process. Microbial activity starts to decline at temperatures above 60°C because even thermophiles no longer have optimum conditions (Miller, 1993). The time required to perform the retrieval and insertion of pathogen samples (for the other aspect of the experiment) reduced the flexibility of the experiment in terms of timing the turning operations. That is why temperatures went above desirable levels before turning could be done.

A significant interaction of time and treatment was identified for the fall (days 15-65) and spring (days 158-189) periods of the first cycle (Figures 1-A and 1-B). This interaction reflected the difference in rates of cooling in the fall and the rates of warming in the spring between the two treatments. The temperatures recorded for the first 47 days (fall period) of the second cycle consistently showed a significant difference between treatments (Figure 2-A). The early spring temperatures for that cycle (first 20 days) also showed that CC was significantly warmer than NC (Figure 2-B). As in the first cycle, there was again an interaction of time with treatment for these same periods. The added protection from the covers prevented the compost mass from freezing down to the center like the non-covered one did, particularly in the second winter. The frozen NC delayed the compost turning operations of the second spring (1996) by nearly 20 days. Although larger size windrows may not be subject to similar freezing problems, this observation underlines the protective effect of the covers against cold conditions. During the summer period when the composts were reaching the maturation phase, the geotextile covers had no significant influence on compost temperatures in both cycles.

The more limited number of replicates in the first cycle did not allow us to obtain statistically significant differences in compost temperatures, with a few exceptions. However, the results showed a definite trend in the effect of the covers on this parameter. The presence of covers not only kept the compost warmer, but it also affected the rate at which the compost cooled in the fall, and warmed in spring time.

COMPOST MOISTURE

Moisture levels were close to 70% at the beginning of each composting cycle. There were no significant differences between treatments for the fall period in either year. In both years, CC did not remain as moist as NC as the cycle advanced. In the first cycle, CC was significantly drier over the period starting on day 174 (May 9) until the end of the cycle (August 14) with one exception (Figure 3-A). A similar moisture pattern was obtained in the second cycle, where CC showed moisture levels significantly lower than NC for the period starting on day 223 (May 21) to the end of the cycle (July 25) with one exception (Figure 3-B).

The factors that could have contributed to better drying of CC include a more prolonged active period in the fall with warmer temperatures in the compost, and the water-repellent action of the covers preventing precipitation water from permeating the compost. As Finstein *et al.* (1992) observed, the heat generated by the decomposition of organic materials vaporizes water, and the vaporization causes drying of the compost. Water vaporization is not impeded by the porous material of the geotextile covers. Drying of the compost is not desirable in the earlier stages of composting, but the time at which lower moisture was observed corresponded more or less to the maturation phase where actinomycetes and fungi are more predominant and more tolerant of lower moisture levels (Zucconi and deBertoldi, 1987). However, moisture levels below 40% will slow down microbial activity and result in a reduction in terms of diversity and numbers of organisms in the compost. Therefore low moisture levels should only be targeted for the maturation phase of a compost, so that the moisture level does not become a limiting factor in the composting process. This research did not provide the opportunity to verify the influence of the geotextile covers on moisture levels of a compost that would be started at a different time of the year, e.g. early summer start. However, it seems that, given an adequate moisture level at the initial stage, a covered compost would remain moist enough for the active degradation of materials until the maturation phase.

PHYSICO-CHEMICAL ANALYSES OF THE COMPOST

Analyses of the finished composts indicated higher levels of nitrogen (N), phosphorus (P) and potassium (K) in CC for both cycles (Figure 4). The difference was statistically significant in the second cycle only. In both years, the micronutrient levels were all slightly higher in CC, with one exception (copper in the first cycle). The nitrate content of CC was higher than in NC at the end of both cycles and this difference was significant in the second year.

The apparent losses in N and K particularly, from NC demonstrated the influence of precipitation in affecting the nutrient content of a compost. Based on analyses done earlier (spring), it appears that a greater nutrient loss occurred earlier in the cycle before the compost material had reached a certain level of stabilization.

The relative drop in C/N ratio for each treatment showed similar patterns in both cycles. In the first one, after starting with a C/N of 46.3, the compost analyses in spring showed a C/N of 24.7 and 34.9 for CC and NC respectively; these ratios were further reduced to 13.7 and 16.6 by the end of the cycle. This illustrates the effect of the covers in advancing the maturation process of the compost. This fact was confirmed by the higher nitrate content of CC. The presence of nitrates is also an indicator of maturity. As the compost matures, the form of mineral N shifts from ammonia to nitrate (Mustin, 1987).

COMPOST LEACHATE

The volumes of leachate recovered in the first cycle showed more noticeable differences between the two treatments in the first part of the cycle (up to day 163), where CC yielded lower volumes of leachate. In the second cycle, the fall period leachate volumes were not significantly different although NC yielded more leachate. The results for the spring and the summer periods indicate a significantly lower ($P<0.01$) leachate volume from CC (Figure 5). The geotextile covers contributed to a reduction of 79.6% and 63.1% of the compost leachate volume for the spring and summer periods, respectively. Physico-chemical analyses performed on leachate at the beginning and at the end of the cycle did not show any consistent trend in mineral content. More frequent analyses would be required to monitor the nature and concentration of elements that may be present at any particular stage.

The apparent lack of response to the covered treatment in the late spring/summer period of the first year could be explained by the experimental setup. The special platform setup for collecting the leachate included an impermeable membrane that covered a given surface area. While the mass of composting materials was reduced in volume as the composting process advanced, the platform area remained the same. This resulted in having part of the platforms area not being occupied by compost, leaving wide edges exposed. Unless the geotextile covers were pulled tight outside the complete platform area, precipitation water diverted by the covers could still end up being collected as leachate after reaching the ground within the platform area. In the second year, more attention was given to prevent non-leachate water from reaching the collection system in both CC and NC, as the compost mass diminished. The geotextile covers edges were also pulled outside the platform collecting area as much as possible. Therefore, the results of the second cycle are more representative of the effect of the geotextile covers in reducing the occurrence of leachate. The leachate collected in the first stages of composting are somewhat difficult to evaluate, since part of it may be attributed to the water derived from the initial decomposition of the fresh organic materials. Liquid collected in the first 10-12 days of the composting cycle were not included in the statistical analyses since no major precipitation had occurred during that time. Nevertheless, the difference between treatments may have been attenuated in the remainder of the fall period due to the potential contribution of the organic materials to the leachate collected.

The phytotoxicity tests performed with the compost leachate gave variable results. In the first year, leachate from NC resulted in a lower germination index than that from the covered composts. The differences between the two treatments tended to become more significant at higher concentrations. CC leachate at 100% concentration reached the safe threshold (germination index >60) in the samples of May 1995 (day 183), while the NC leachate had reached that stage only at the last sampling date. In the second year, no significant differences were found between treatments at any given concentration or date of sampling. The threshold for absence of phytotoxicity was reached by the third sampling date (day 107) for both treatments. The difference in characteristics of the compost leachate between the two cycles may reflect some of the modifications that were made after the first cycle. The platform base collecting the leachate was changed from a fine sand base to a two-layer base of gravel and coarse sand. This would have affected the flow and content of leachate going through. The nature of the carbonaceous material was also different: sawdust in the first cycle and wheat straw in the second cycle. However, the trends observed demonstrated that early leachate is highly phytotoxic unless diluted to 10-30%. It is likely that the substrates used and the rate of decomposition will play a role in determining the characteristics of leachate. It was not clear whether geotextile covers influenced the quality of leachate in that respect.

CONCLUSIONS

The application of geotextile covers on compost windrows presents several potential benefits. The protection offered by these covers can allow a producer to start a composting cycle in late summer or fall with the expectation that temperatures will be adequate in the windrows, despite cold air temperatures. The prolongation of warm temperatures within the compost in the fall and spring can result in an earlier maturation of the compost. A covered compost can present a lower moisture content as it nears maturation, making the handling of the material easier. However, the moisture content of a covered compost would have to be monitored to insure that it does not become too dry too soon in the composting cycle. The reduction in leachate volumes results in better retention of mineral elements in the compost, and at the same time, less risks of groundwater contamination. Even in situations where the leachate is recovered for treatment or disposal, the reduction in volumes to handle is also advantageous.

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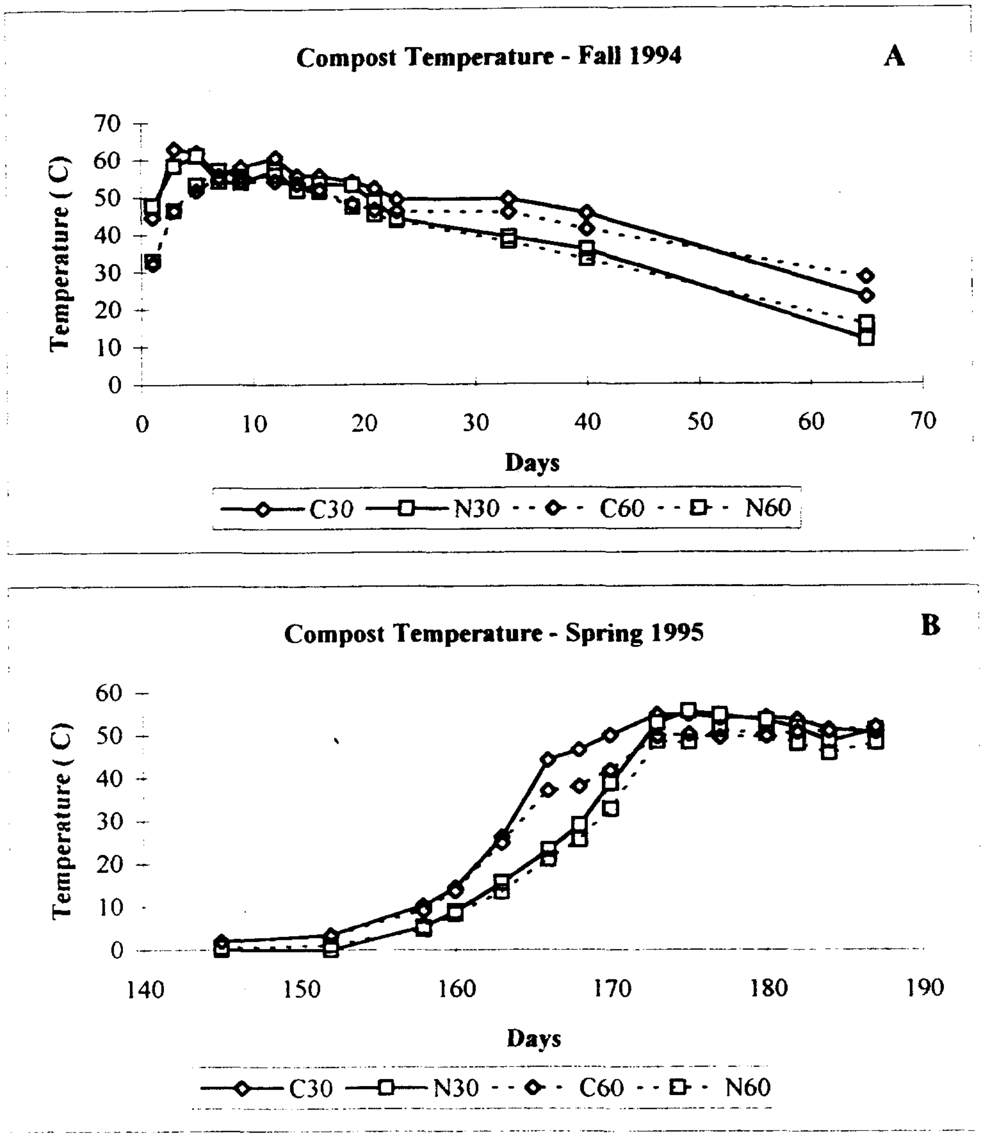

FIGURE 1 - 1994-1995 Effect of covering on the temperature of compost piles at depths of 30 and 60 cm. Each point represents the mean temperature of 3 windrows. Time intervals are as follows: (A) 17.11.94 to 25.01.95, (B) 05.04.95 to 25.05.95 (C30 and C60 are for covered compost at 30 cm and 60 cm depths, N30 and N60 are for non-covered compost at 30 cm and 60 cm depths).

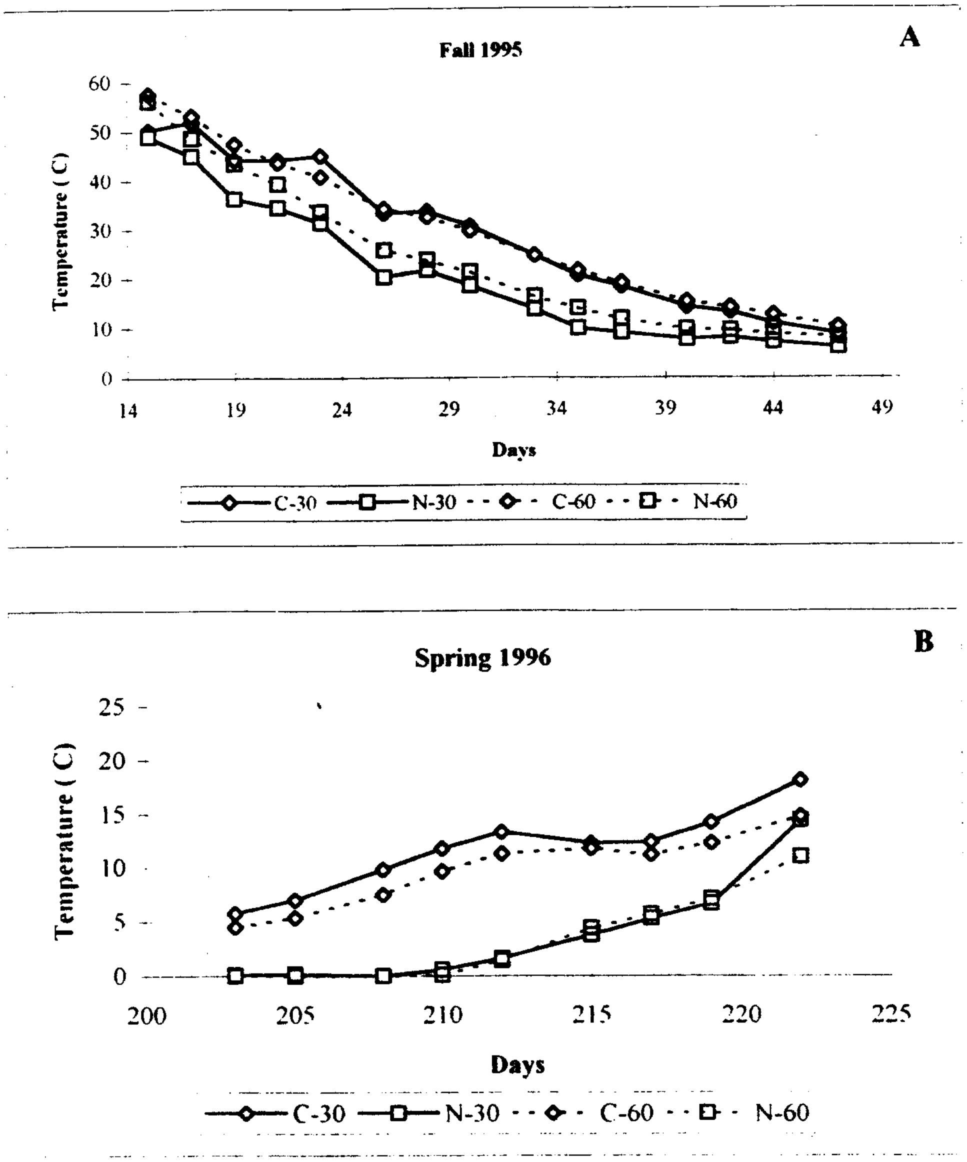

FIGURE 2 - 1995-1996 Effect of covering on the temperature of compost piles at depths of 30 and 60 cm. Each point represents the mean of six windrows. The time periods for each graph are as follows: (A) 25.10.95 to 29.11.95, (B) 28.04.96 to 23.05.96. (C30 and C60 are for the covered compost at depths of 30 and 60 cm; N30 and N60 are for the non-covered compost at 30 cm or 60 cm depths)

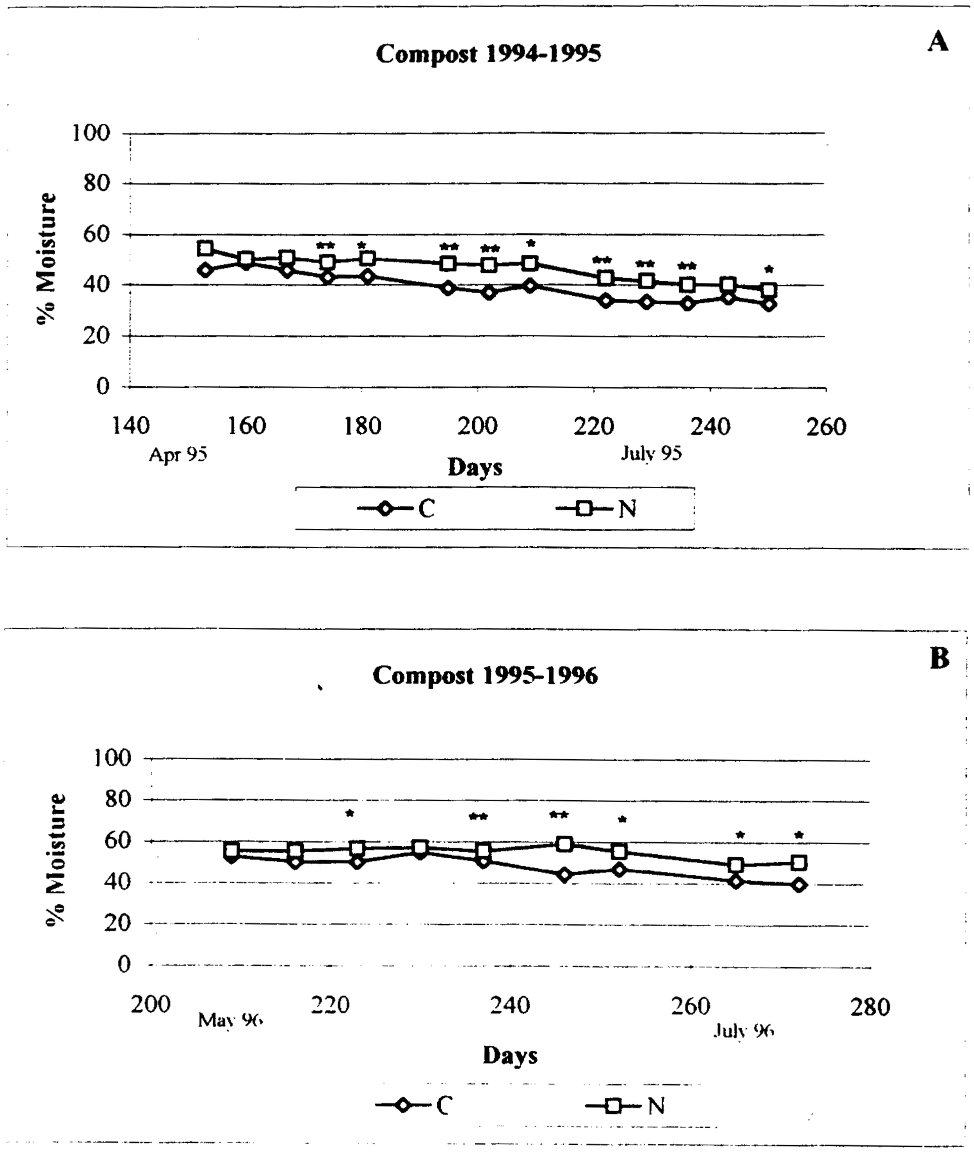

FIGURE 3 - Compost moisture content for the spring and summer seasons of (A) 1995 and (B) 1996. Data points represent the mean of 3 windrows in (A) and of 6 windrows in (B) for covered compost (C) and non-covered compost (N). Significant differences are indicated with * ($p < 0.05$) or with ** ($p < 0.01$) for each date where they occurred.

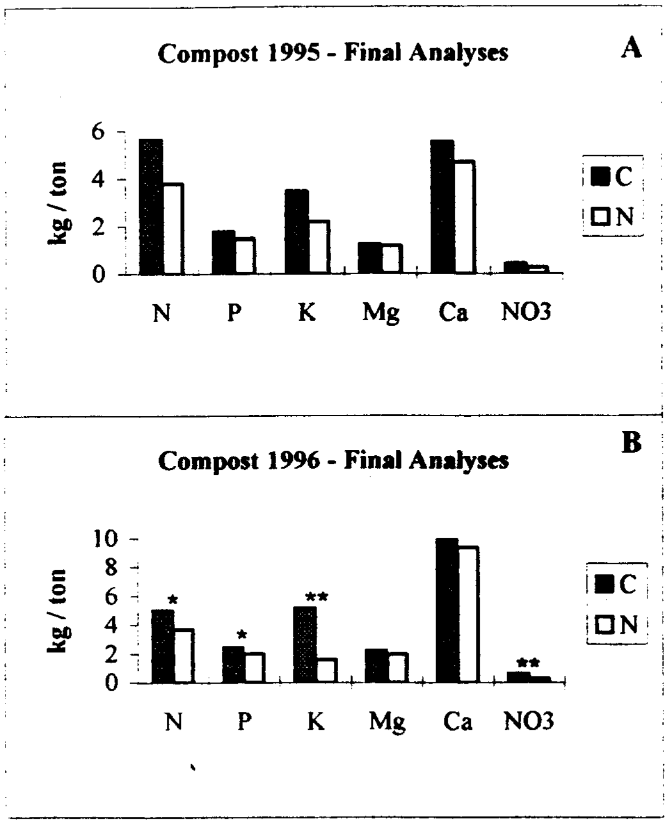

FIGURE 4 - Final physico-chemical analyses results for composts in covered windrows (C) and non-covered windrows (N) in 1995 (A) and 1996 (B). Data represent the mean of three windrows in (A) and of six windrows in (B). Significant differences are indicated with * ($P < 0.05$) or ** ($P < 0.01$).

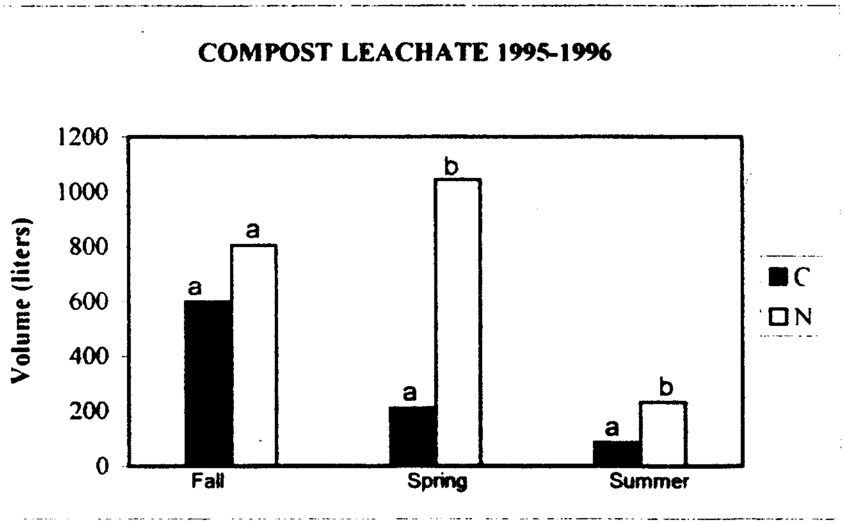

FIGURE 5 - Compost leachate volumes for the year 1995-1996 from covered compost (C) and non-covered compost (N). Data represent the mean of cumulative volumes per platform for each treatment in each of three seasons. Treatments with a different letter differed significantly ($P < 0.01$) within a given season.