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Thomas J. Akin
University of Massachusetts Amherst

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THE LAND APPLICATION OF CRANBERRY PRESSCAKE

A Thesis Presented

by

THOMAS J. AKIN

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THOMAS J. AKIN

Approved as to style and content by:

Stephen Herbert
Stephen Herbert, Chair

Douglas Cox
Douglas Cox, Member

Duane W. Greene
Duane Greene, Member

William J Bramlage
William Bramlage, Department Head
Plant and Soil Science

ABSTRACT

THE LAND APPLICATION OF CRANBERRY PRESSCAKE

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THOMAS J. AKIN, B.A., UNIVERSITY OF ST. THOMAS
M.S., UNIVERSITY OF MASSACHUSETTS AMHERST
Directed by: Professor Stephen Herbert

From 1991 through 1994, research was conducted with the assistance and cooperation of Ocean Spray Inc. on the land application of cranberry presscake. Cranberry presscake is a food processing residual from the juice extraction process with a low pH (3.0-4.0) and a medium carbon:nitrogen ratio (30-40:1). Cranberry presscake has a dry matter content of approximately 50%, and is low in nitrogen (1.25% dry weight).

Experiments were conducted at the University of Massachusetts Agronomy Research Farm in South Deerfield, MA. Two field experiments (1 field corn study and 1 alfalfa study) were initiated in 1991. In 1992, the weed suppression effect of presscake was investigated in two further field corn studies, and the alfalfa study was continued. Most studies finished in 1993, but some observations were made in 1994.

In 1991, alfalfa establishment was investigated in cranberry presscake-amended soils. Incorporation of 76 Mg ha-1 of presscake delayed alfalfa and weed seedling establishment and reduced first cutting alfalfa yield. However, after the first cutting, there were no yield differences between treatments. Results from this and a second alfalfa study indicated that alfalfa could be planted in the fall after a spring presscake application or planted in the spring after presscake application in fall the previous year without any detrimental effects on yield.

Five rates of cranberry presscake (0, 22, 56, 90, and 112 Mg ha-1) were applied prior to planting corn and corn yields were determined. The five rates were applied in each of three years for a total of 0 to 336 Mg ha-1. Corn yields remained fairly constant, even with high cumulative rates of presscake application. Although large quantities of acidic material were added to the soil, there was no decrease in soil pH attributable to the presscake. Soil pH levels rose slightly with higher rates of presscake, probably due to the increased buffering capacity from the added organic matter.

Land application of cranberry presscake for field corn is justified both economically and environmentally. Farmers concerned with soil nitrogen immobilization resulting from a spring application of presscake, should apply the soil amendment in the fall after corn silage harvest.

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CHAPTER 1

INTRODUCTION

The purpose of this study was to examine the feasibility of utilizing cranberry presscake as a soil amendment in annually tilled agricultural soils in Massachusetts. Cranberry presscake is the residual produced from the extraction of juice from cranberries. Ocean Spray Inc., Massachusetts' largest cranberry grower cooperative and processor of cranberries, was interested in land application of the cranberry presscake as a cost-efficient, disposal alternative to landfilling or composting. Research on the land application of cranberry presscake was done in New Jersey at Rutgers University; however, in Massachusetts there have been no controlled field studies examining the impacts of land application of this food processing residual. Before Massachusetts farmers accept land application of cranberry presscake, they will need assurance that the practice is justified economically and is environmentally sound.

Farmers have recycled organic wastes through land application for millennia (Parr and Hornick, 1992). This recycling has been predominantly done on-farm, on relatively small scales. In the 20th-century, large-scale, industrial processing of wood and food products became more commonplace. The generation of large quantities of industrial organic wastes necessitated disposal contingencies. Many by-products found their way to landfills, but as landfills approached maximum capacity, the cost of landfilling also increased (Terman et al., 1973). The need grew for another inexpensive means of disposal, and land application was industry's preferred choice. Thus, land application of organic wastes shifted from a farmer's small-scale activity to a large-scale enterprise.

In the 1970s, land application, from the perspective of the processing industries, was an inexpensive, short-term solution to a waste disposal problem compared to the costs of landfilling the wastes (Terman et al., 1973). Much research has been carried out on the effects of land application of industrial organic waste products and sewage sludge products on soil quality and crop production (Dolar et al., 1972; Khaleel et al., 1981; Mays et al., 1973; Tester, 1989; and Tester et al., 1982). Research on the land application of food processing residuals in the 1970s concentrated on liquid wastes with high sodium concentrations from fruit and vegetable cannery operations (Dennis, 1953; Gambrell and Peele, 1973; and Hunt and Peele, 1968). Grape pomace, which has a nutrient and dry matter content similar to cranberry presscake, was evaluated as a fertilizer source in 1947 on California agricultural crops, and much of the grape post-harvest residuals are now returned to vineyards (Chaney et al., 1992). In Massachusetts, research on the disposal of apple pomace residuals focused on two possibilities: composting or land application (van de Kaamp, 1986). Due to high-population densities near the apple processing facility, composting was determined to be the best long-term disposal alternative. Currently, Ocean Spray Inc. does not have high-population densities near its processing facilities so land application may be the best viable disposal option if local farmers are willing to accept the cranberry presscake for land application. Ocean Spray Inc. also must assure that the presscake will be free of contaminants such as glass and plastic.

Soil Organic Matter and its Benefits

Bohn et al. (1985) define soil organic matter as "...an accumulation of dead plant matter, partially decayed and partially resynthesized plant and animal residues." It is a small (typically 2-10% by weight) but complex fraction of the soil that is a mixture of living and dead organisms; these organisms include bacteria, fungi, actinomycetes, earthworms, crop residues, weeds, fallen leaves, decaying roots as well as the exudates of living roots.

The benefits and importance of soil organic matter have long been recognized. Allison (1973) reported that increased soil organic matter levels increased soil aggregation and aggregate stability, decreased soil bulk density, increased cation exchange capacity, and increased soil biological diversity. Keeney and Corey (1963) found that increased soil organic matter levels increased buffering capacities of acid soils. Similar results were found in Vermont soils where the organic matter content of soils played a significant role in buffering soil pH (Magdoff and Bartlett, 1985). Helling et al., (1964) stated that increased soil organic matter levels contributed to higher cation exchange capacity due to the large number of negatively charged exchange sites, similar to those of clay particles, contained on the organic matter complex. Similarly, Tate (1987) refers to soil organic matter as both a reservoir and a source of plant nutrients (Figure 1.1). Plant nutrients mineralized from soil organic matter can be absorbed by plant roots. Plant nutrients also can be immobilized or sequestered into the soil organic matter complex (Figure 1.2). In addition to holding and storing plant nutrients, soil organic matter is also responsible for improved soil moisture retentiveness. Stevenson (1982) reported that humus could hold up to 20 times its weight in water. All of these beneficial effects of soil organic matter improves the fertility and productivity of the soil.

Soil organic matter can also be depleted quickly with modern agricultural practices. Following World War II, technological advances in machinery and chemical fertilizers made large-scale monoculture cropping systems possible. In the 1950s, university researchers in the Corn Belt region worried that the intense agricultural practices would strip productive soils of their soil organic matter and natural fertility (Larson et al., 1972). After the loss of soil organic matter, researchers feared that heavily cultivated soils would lose productivity and would be prone to severe compaction and erosion (Larson et al., 1972). Larson et al. (1972) reported that in conventionally tilled, continuous corn, approximately 6 Mg ha^{-1} $year^{-1}$ of residue returned to the soil was required to maintain soil organic matter levels. Dick (1983) found that long-term conventional tillage practices with no organic amendments reduced soil organic carbon levels by as much as 12% annually. The importance of maintaining soil organic matter levels for the health and productivity of agricultural soils is well understood, and the importance of soil organic matter cannot be overstated.

Tillage practices and fertilization heavily influence the flux of soil organic matter; however, other factors such as soil temperature, soil moisture, soil texture, and soil parent material also influence the dynamics of soil organic matter. These factors are relatively constant for a given locality; however, the nature (type of carbonaceous material and the carbon:nitrogen ratio of the material), and the quantity of the organic material added to the soil can have wide variations and can be manipulated in a number of ways.

The Decay Process and the Synthesis of Soil Organic Matter

The decay process of organic wastes is highly dependent on the nature of the carbonaceous material added to the soil. Carbonaceous wastes applied to soil are oxidized by heterotrophic organisms that utilize the energy for their metabolic processes (Bohn et al, 1985). Earthworms, arthropods, and many other soil microorganisms (primarily bacteria and fungi) quickly consume easily degradable organic materials that are added to the soil. Organic materials containing sugars, starches, and simple proteins, because of their relatively simple chemical make up, are decomposed quickly in the soil by soil-dwelling organisms. Conversely, organic materials consisting of cellulose, hemicellulose, fats, waxes, and lignin are decomposed much more slowly by soil microorganisms due to their high degree of polymerization and chemical complexity (Tate, 1987).

Jenkinson and Ayanaba (1970) found that the rate of decomposition of fresh organic matter fell off sharply after a short period of time (Figure 1.3). This sharp reduction in decomposition rate presumably coincides with the disappearance of easily degradable carbonaceous materials for soil microorganisms. Similarly, Stevenson (1982) theorized that decay of carbonaceous materials was very rapid until decay resistant plant carbon and microbial products dominated (Figure 1.4).

The end products of this oxidation process are carbon dioxide, water, energy (for the metabolism of bacteria and fungi), and degradation-resistant humus (Figure 1.5). Humus is an extremely complex and variable organic compound comprised of two organic acids, humic and fulvic acids (Tate, 1987). Humic acid is an extremely complex molecule with a formula weight of approximately 10,000 (Figure 1.6). Humus molecules contain many chemically reactive groups, e.g., carboxyl, phenolic hydroxl, and amine groups which play an important role in attracting and storing plant nutrients (Troeh and Thompson, 1993).

Nitrogen, phosphorous, and sulfur are the catalysts required by soil microorganisms to carry out the oxidation of soil-applied carbonaceous materials (Tate, 1987). Soil nitrogen is usually the limiting factor in the decay process because the soil microorganisms require nitrogen and the other catalysts to produce the proteins necessary to complete their life cycles. This incorporation of elements into the microbial biomass is known as assimilation (Stevenson, 1986). Soil nitrogen that is assimilated into the soil microorganism biomass is unavailable for plant uptake. This is also known as soil nitrogen immobilization.

The lack of soil nitrogen is one of the most important limiting factors in the decomposition slowdown of carbonaceous materials by soil bacteria and fungi (Waksman, 1942). Waksman (1942) found that when the carbon:nitrogen ratio of decomposing rye plants rose above 30:1, additional nitrogen was required to continue the production of carbon dioxide (Table 1.1). Allison and Klein (1962) and Allison et al., (1963) also reported that the carbon:nitrogen ratio of organic materials applied to the soil largely determines the rate and extent of soil organic matter synthesis and nitrogen release by microorganisms. Materials with a carbon:nitrogen ratio of less than 30:1 did not contribute significant quantities of soil nitrogen available for crop production; materials with carbon:nitrogen ratios greater than 30:1 caused soil nitrogen to be immobilized and reduced the pool of available soil nitrogen needed for plant growth.

Broadbent (1986) stated that the carbon:nitrogen ratio of soil amendments must be substantially lower than the threshold of 30:1 before a sufficient release of nitrogen could be of importance in crop production. In cases where excess soil nitrogen is present after crop harvest (fields receiving annual or heavy applications of manure or fields close to barns, etc.), additions of high carbon organic wastes may improve water quality by immobilizing soil NO_3^--N that otherwise would leach into groundwater. Large scale dairy farms with confined-housing have a high potential for groundwater pollution from excess soil NO_3^--N (Brinton, 1985 and Young et al., 1985). This potential hazard is further exacerbated by reduced acreage for manure application due to encroaching suburban communities. Applications of cranberry presscake may prevent the pollution of groundwater by immobilizing soil nitrate nitrogen.

The American Cranberry

The American Cranberry (*Vaccinium macrocarpon*) has been a high-value agricultural commodity for Massachusetts growers for almost two centuries. The first attempt to cultivate the wild cranberry was made in 1810 by Henry Hall, a Revolutionary War veteran, in the town of Dennis, Massachusetts (Hall, 1941). For most of the 19th- and 20th-centuries, Massachusetts has led the US in production of cranberries (Eck, 1990). Annual fruit production and sales in US Dollars for 1991 were 2 million pounds and 6 million US dollars respectively (USDA, 1991).

The ripe cranberry fruit is primarily water (88% moisture). The fruit dry matter contains fruit sugars (4.2%), organic acids (2.4%), and pectin (1.2%) (Fellers and Esselen, 1955). Cranberry juice contains approximately 1.32% quinic acid, 0.92% malic acid, 1.08% citric acid and 0.06% benzoic acid (Eck, 1990). After processing, one hundred pounds of cranberries yields approximately 7 gallons of juice. The juice is then clarified with a pectinase enzyme preparation and is then filtered with diatomaceous earth (Eck, 1990).

Cranberry Presscake Composition and Chemical Analysis

Cranberry presscake is the food processing residual from the juice extraction process; three types of cranberry presscake are generated at the Lakeville, MA Ocean Spray plant: Cranberry presscake with a diatomaceous filtering agent (celite), cranberry presscake with rice hulls (rice hulls are added to improve pressing efficiency), and cranberry presscake with no added products.

Cranberry presscake has a pH of 3.0-4.0, a carbon/nitrogen ratio of 30:1, and a nitrogen content of 1.25% on a dry weight basis (Table 1.2). Cranberry presscake has a variable dry matter content (50-66%) when it leaves the processing plant.

Field Experiments and Rationale

Massachusetts dairy farmers grow significant quantities of field corn and alfalfa for feed. These two agronomic crops, field corn (*Zea mays*) and alfalfa (*Medicago sativa*) account for a large portion of the tilled acreage that would be available for the land application of cranberry presscake. Field corn in particular is grown on more annually tilled acres than any other crop in Massachusetts (USDA, 1991).

The objective was to determine if cranberry presscake could be land-applied without any deleterious effect on soil quality and on corn and alfalfa yields. Field studies were initiated to examine the decomposition of cranberry presscake in field soils, to measure the effects of cranberry presscake application on the yield of field corn and alfalfa, and to examine the interactions and impact of cranberry presscake with limestone and nitrogen fertilizer on soil properties.

The cranberry presscake field studies were conducted at the University of Massachusetts Agronomy Research Farm in South Deerfield, MA. The soil at this experimental site was an Occum fine, sandy loam (Fluventic Dystrocrept), relatively low in organic matter (2%). The initial soil pH of the experimental area was 6.6 and the buffer pH was 6.9.

Harvest Data, Soil Tests and Statistical Analysis

Experimental field soils were prepared for planting using standard agronomic methods. The field crops grown for the cranberry presscake studies were harvested at the level of maximum economic value. Soil samples for the studies were collected from the experimental plots at a depth of 5 cm to determine soil pH and soil buffer pH. To determine soil NO_3^--N and soil organic matter, soil samples were collected at a depth of 30 cm. For all soil samples, approximately 12 cores were collected from each experimental plot and were composited. A subsample of the composite was used for all analyses. After collection, soil samples were air-dried and ground to pass through a 2-mm sieve. Soil samples tested for NO_3^--N were extracted with 0.01 *M* $CaSO_4$ (Bremner, 1965) using 5:1 solution/soil ratio, and were analyzed for NO_3^--N by a cadmium-reduction method using a Technicon Auto Analyzer (Technicon, 1977). Soil pH was measured 1:1 v (soil:distilled water), and soil buffer pH or lime requirement was measured according to the SMP method (McClean, 1982). Soil organic matter was determined by the Walkley-Black procedure (Walkley and Black, 1934).

For the alfalfa studies and two of the three field corn studies, analyses of variance for all main factors, and means separations were conducted by using the SAS statistical software (SAS Institute, 1988). For the central composite field corn study, a UNIX-based software package was used to process the data.

Table 1.1 Influence of C:N ratio of rye plants as controlled by age upon their decomposition during a 27 day period.

C:N ratio of Rye plants	C liberated as CO_2 (mg)	N liberated as NH_3 (mg)	N consumed from added N (mg)
20:1	287	22.2	0
28:1	280	3.0	0
50:1	200	0	7.5
200:1	188	0	8.9

Source: Waksman, 1942. *In:* Soils and Soil Fertility. 1993. Troeh and Thompson. 5th edition.

Table 1.2 Chemical analysis for the three presscake types are listed below. Chemical analyses were conducted by the University of Massachusetts Soil and Tissue Testing Laboratory in Amherst, MA.

Element	Presscake w/ Celite	Presscake w/Ricehulls	Presscake
Nitrogen	1.25%	1.26%	1.25%
Phosphorus	0.20%	0.15%	0.16%
Potassium	0.20%	*	0.21%
Calcium	0.06%	0.06%	0.07%
Magnesium	0.07%	0.05%	0.07%
Carbon	48.7%	49.0%	54.9%
pH	4.0	3.6	3.9
Carbon:nitrogen	38:1	39:1	44:1
Moisture	67%	60%	55%

* value for potassium from lab result was in question.

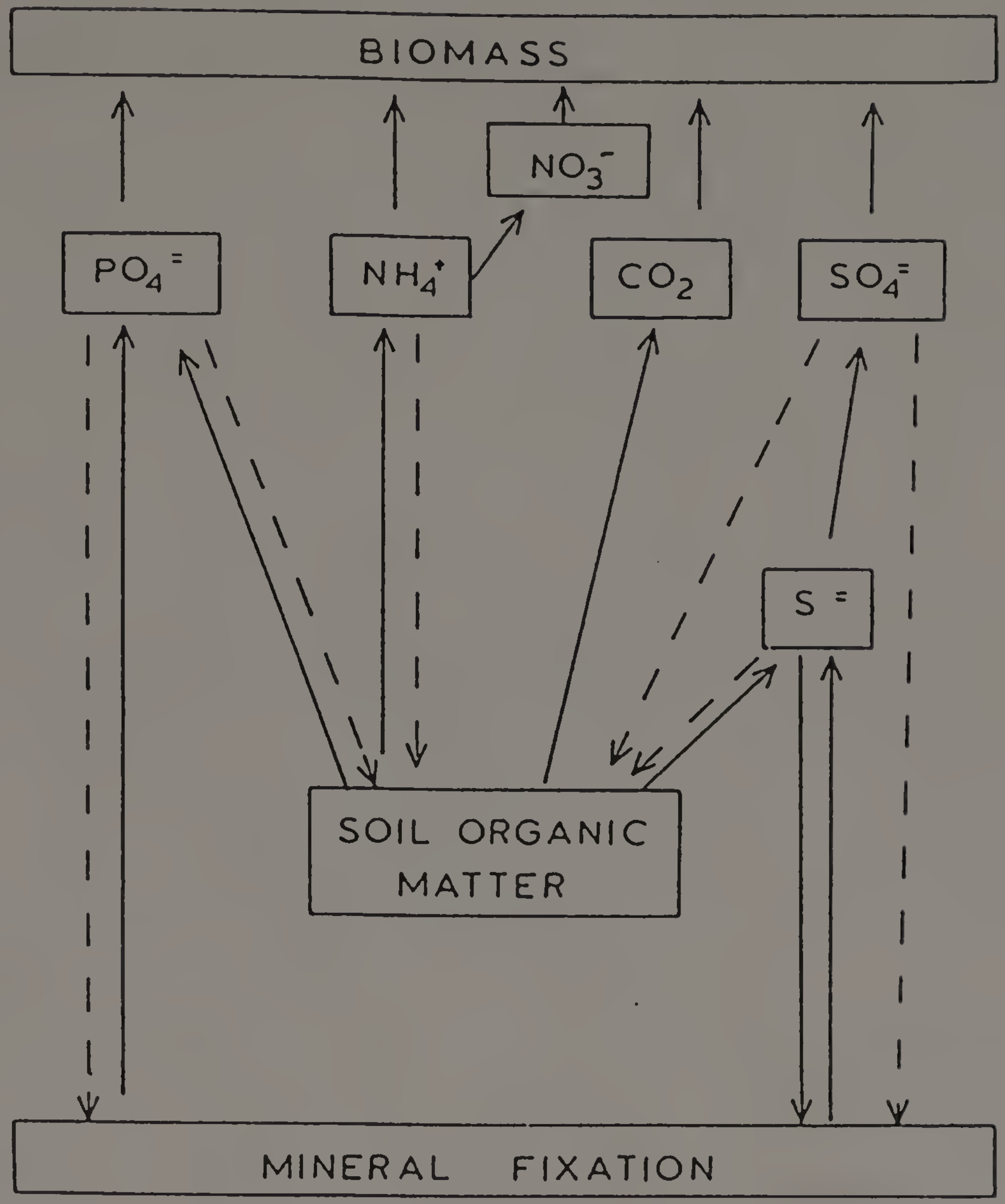

Figure 1.1 Soil organic matter as a source of plant nutrients. Solid arrow=nutrient production; dashed arrow=nutrient immobilization. From: Tate, 1987.

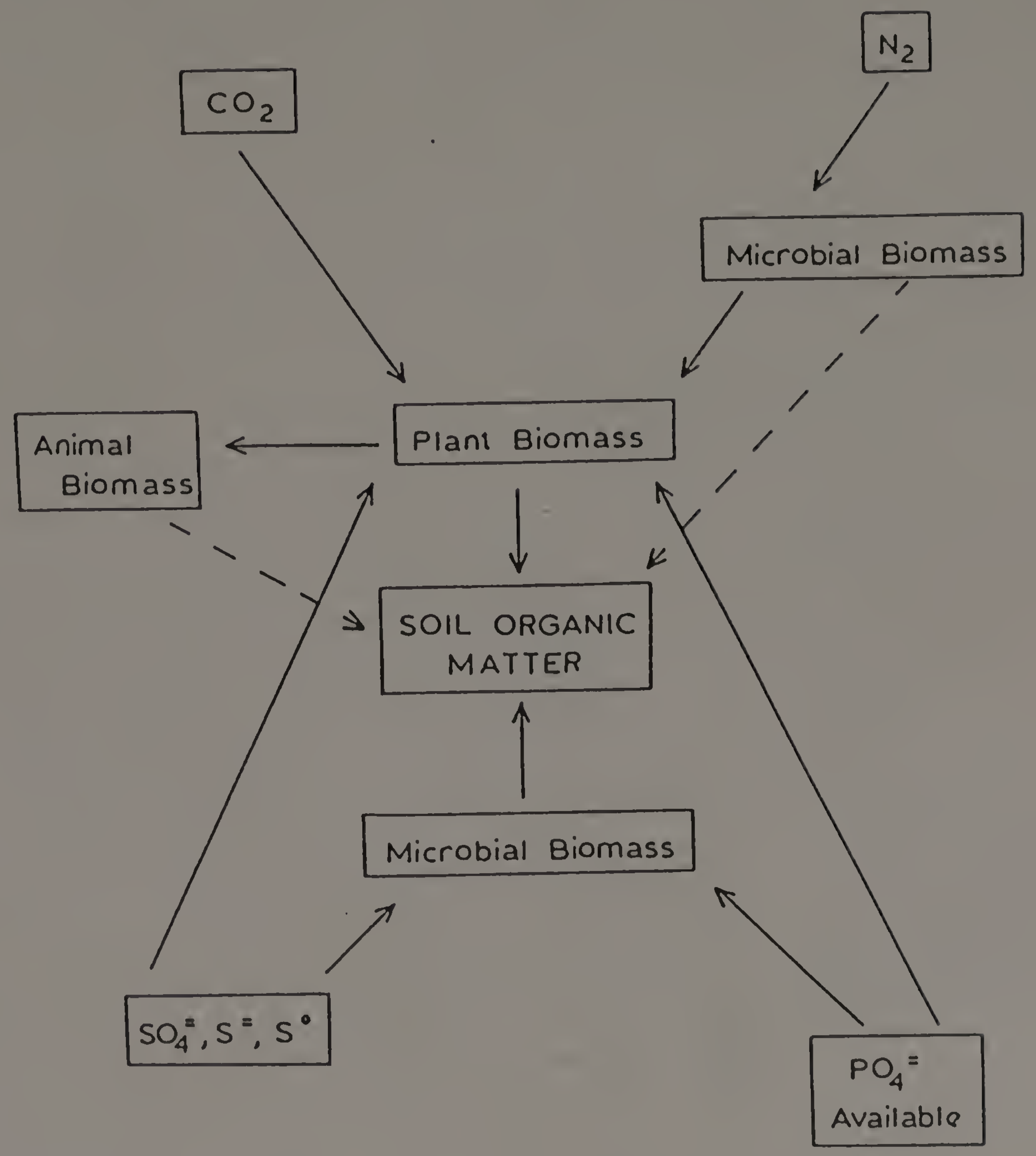

Figure 1.2 Plant nutrient sequestering into soil organic matter. A system receiving no external inputs. *In:* Tate, 1987.

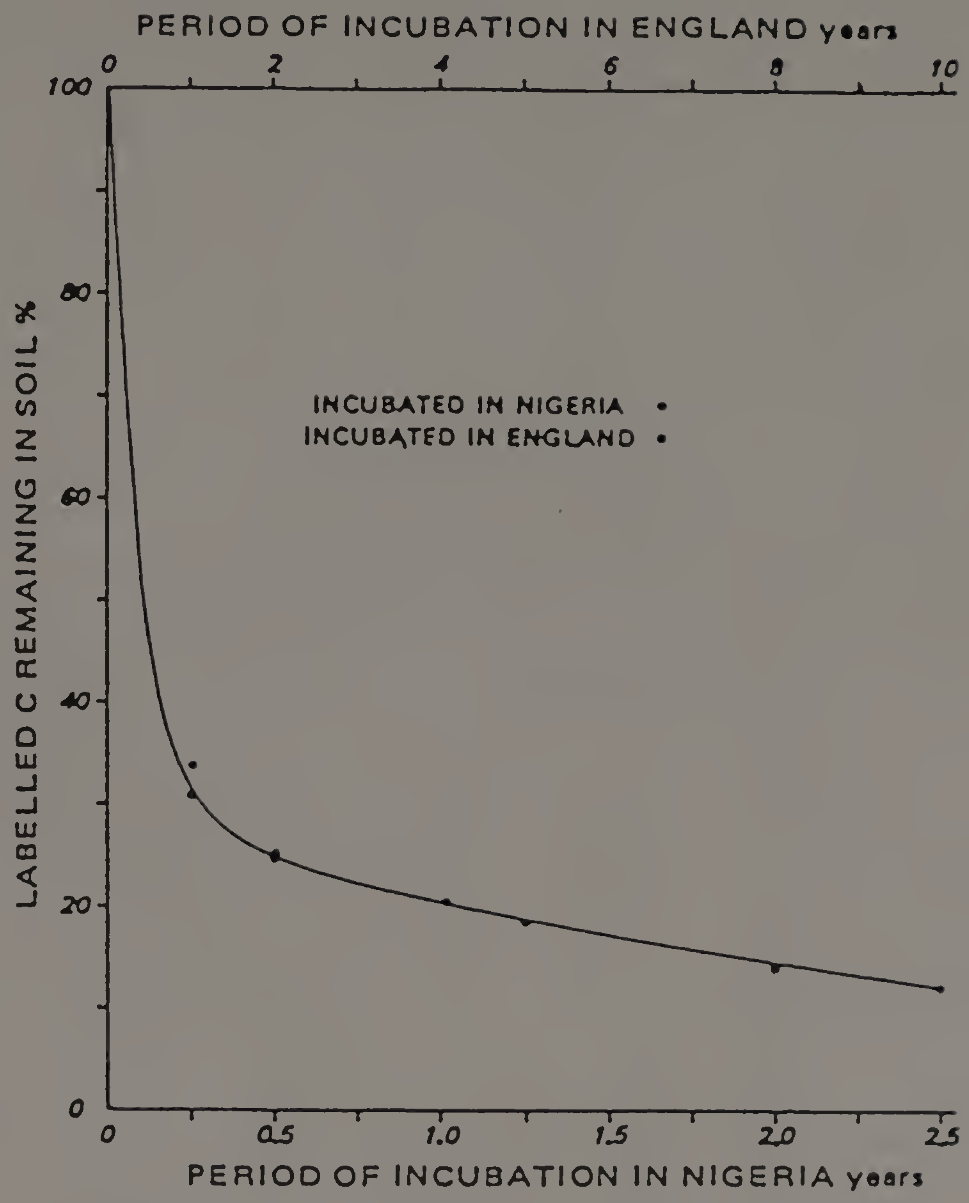

Figure 1.3 Decomposition of fresh organic matter added to soils in Great Britain and Nigeria. *From:* Jenkinson and Ayanaba, 1970 *In*: Soil Chemistry. Bohn et al., 1985.

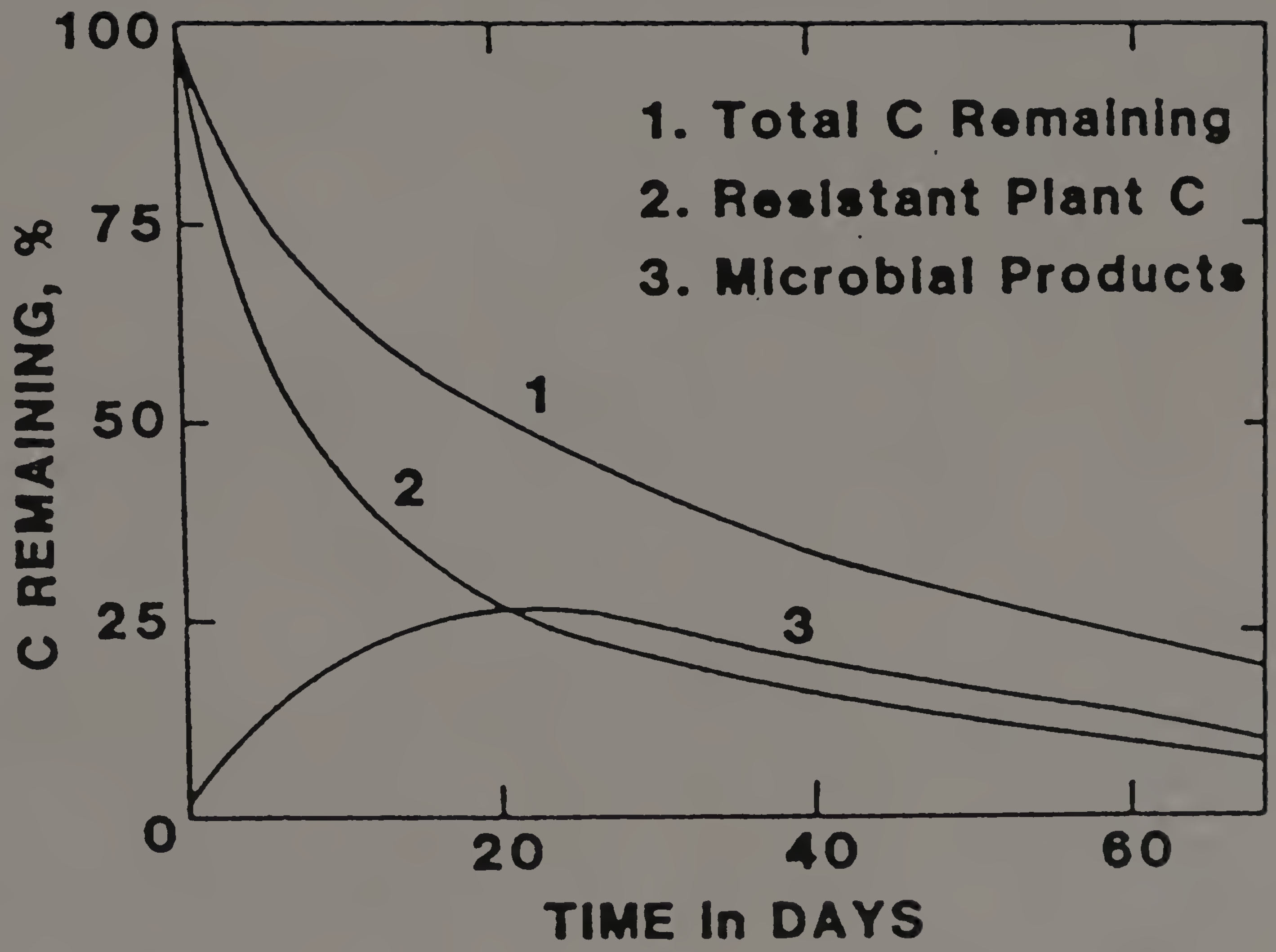

Figure 1.4 Idealized diagram for the decay of crop residues in soil under conditions optimal for microbial activity. *In:* F.J. Stevenson. Humus Chemistry. 1982.

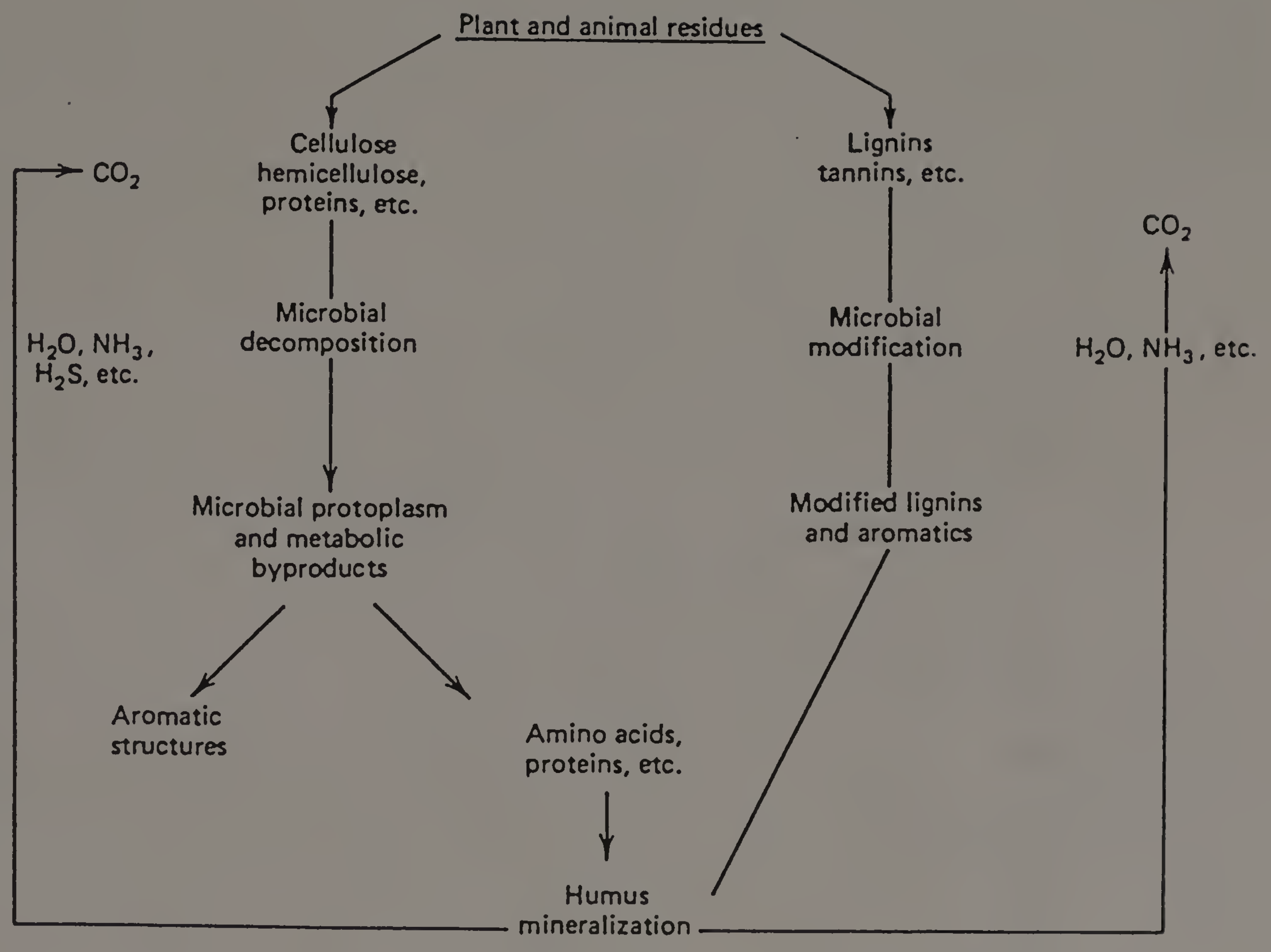

Figure 1.5 Organic matter decomposition and formation of humic substances. *From:* F.E. Bear, Ed. Chemistry of the soil. ACS Monograph Series No. 160. 1964. P. 258.

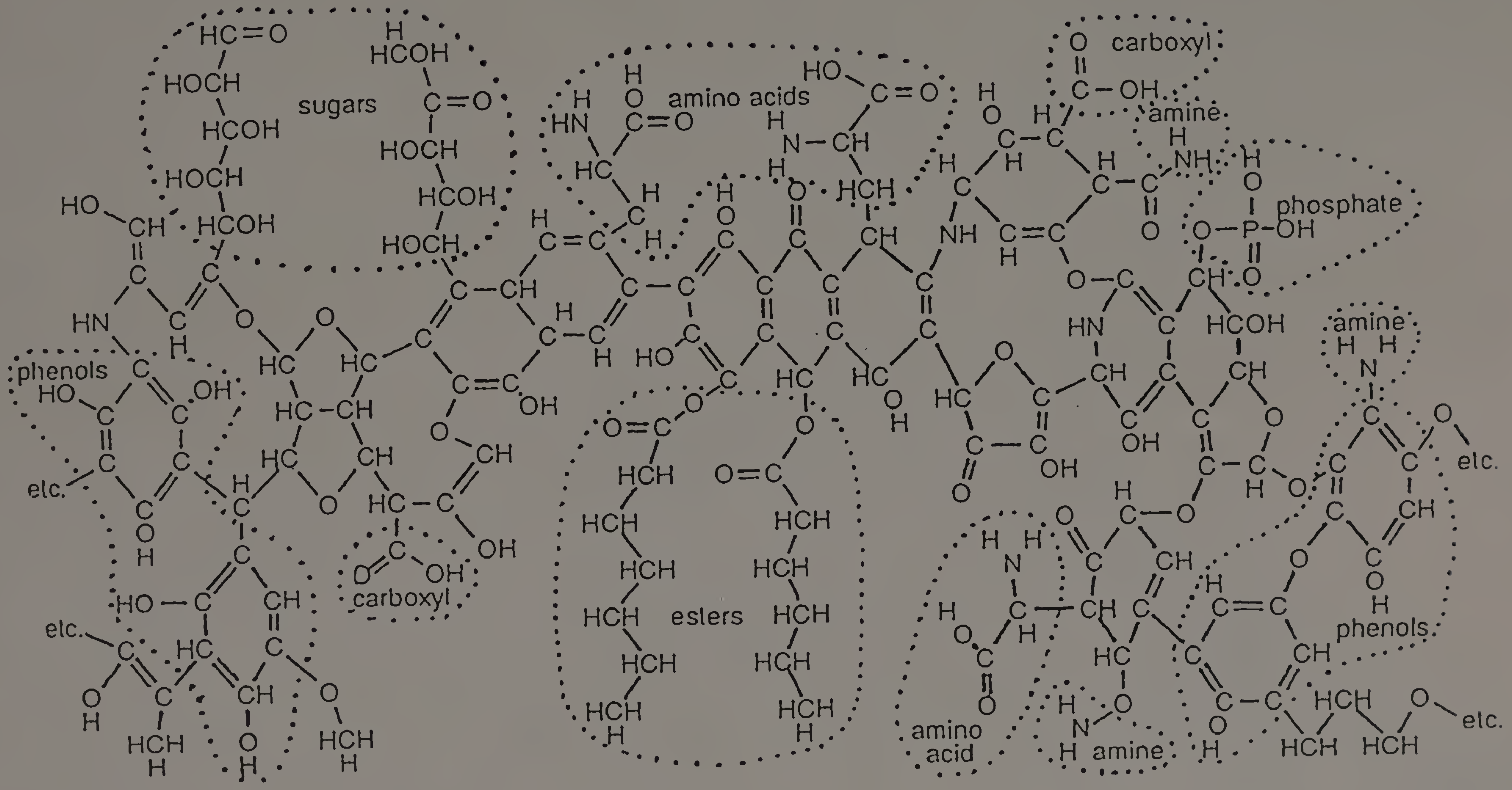

Figure 1.6 Hypothetical structure of a humic acid segment. *Source:* Jeff Novak, University of Georgia: *In* Soils and Soil Fertility. Troeh and Thompson, 1993.

CHAPTER 2

EFFECT OF CRANBERRY PRESSCAKE ON ESTABLISHMENT AND YIELD OF ALFALFA

Introduction

Alfalfa (*Medicago sativa*) and alfalfa/grass mixtures are widely grown as haycrops in rotation with corn for silage on dairy farms in Massachusetts and represent significant land area available for presscake application. However, alfalfa establishment and economic yield are sensitive to soil acidity when soil pH drops below pH 6.0. Munns (1970) found that soil pH below 6.0 caused inactivity of nitrogenase, a soil enzyme required in the nitrogen fixation process. Alfalfa grown in soil pH less than 5.0 had no root nodulation due to the inhibition of the enzyme that normally breaks down the cell wall of roots so that infection by *Rhizobia* bacteria can occur (Munns, 1969). Current recommendations suggest a soil pH between 6.5 and 6.8 for optimal growth and production.

Although surface applications of agricultural limestone have found to benefit the growth and establishment of alfalfa (Rechcigl et al., 1985 and Koch and Estes, 1986), an acidic soil amendment such as cranberry presscake may be of great concern to farmers planting alfalfa crops.

Materials and Methods

A field experiment with alfalfa studied the effect of acidity from cranberry presscake on the establishment and yield of alfalfa. The experimental design was a factorial randomized complete block design with three replicates; individual plots measured 1.5 m X 3.6 m. Cranberry presscake and limestone were the two main factors for this experiment. The two cranberry presscake treatments were 0 and 76 Mg ha^{-1} (a one-time application made prior to planting of alfalfa). The calcium carbonate agricultural limestone treatment levels were applied annually at 0, 1.1 and 2.2 Mg ha^{-1}. The experiment was laid out at the University of Massachusetts Agronomy Research Farm in South Deerfield, MA. The soil at this experimental site was an Occum fine, sandy loam (Fluventic Dystrocrept), relatively low in organic matter (2%). The initial soil pH of the experimental area was 6.6 and the buffer pH was 6.9. Field oat (*Avena sativa*) was grown on the experimental site the preceding year and was harvested at maturity; no chemical fertilizers were applied to the oat crop.

Cranberry presscake was applied at the rate of 76 Mg ha^{-1} (wet weight) by surface spreading on May 2, 1991; the presscake had a dry matter content of 45%. The presscake was incorporated on May 3, 1991 with a disc harrow. The limestone treatment was applied on May 6, 1991 and was incorporated with a disc harrow on the same day. Alfalfa was sown at the rate of 9.1 kg ha^{-1} on May 9, 1991 with a Brillion seeder.

The harvest management of alfalfa was a three-cut system during each of the two years of the study with the first cut taken at full budding of flowers and the next two harvests at 10% bloom. At each cutting, random subsamples were collected, weighed, oven-dried at 60°C., and weighed again to determine dry matter content of the alfalfa. Harvest results were adjusted to 12% moisture by weight.

Soil samples were collected one month following incorporation of presscake, after each cutting, and after the final harvest of the growing season. Soil samples were collected at a depth of 5 cm to determine soil pH and soil buffer pH. To determine soil NO_3^--N, soil samples were collected at a depth of 30 cm. For all soil samples, approximately 12 cores were collected from each experimental plot and were composited; a subsample of the composite was used for all analyses. After collection, soil samples were air-dried and ground to pass through a 2-mm sieve. Soil samples tested for NO_3^--N were extracted with 0.01 *M* $CaSO_4$ (Bremner, 1965) using 5:1 solution/soil ratio, and were analyzed for NO_3^--N by a cadmium-reduction method using a Technicon Auto Analyzer (Technicon, 1977). Soil pH was measured 1:1 v (soil:distilled water), and soil buffer pH or lime requirement was measured according to the SMP method (McClean, 1982). An analysis of variance for all main factors, and means separations were conducted by using the SAS statistical software (SAS Institute, 1988).

Results and Discussion

On June 4, 1991, approximately one month following incorporation of cranberry presscake, soil samples were collected and analyzed for soil pH, soil buffer pH, soil NO_3^--N and soil organic matter changes. Soil pH, soil buffer pH, and soil organic matter measurements were non-significant for all treatments at the $P>0.05$ level. Experimental plots receiving cranberry presscake had highly significant ($P>0.0001$) reductions in soil NO_3^--N concentrations ($R^2=0.52$). Cranberry presscake-amended plots had mean soil NO_3^--N concentrations of 2.4 mg kg^{-1} whereas the unamended plots had mean soil NO_3^--N concentrations of 7.4 mg kg^{-1}. There were neither significant soil NO_3^--N changes among varying rates of limestone nor significant interactions between cranberry presscake and limestone.

In addition to the soil analyses, the cranberry presscake amended plots visually appeared much drier than plots not receiving the soil amendment. Plots not receiving the soil amendment appeared to have moisture levels at field capacity whereas the amended plots seemed much drier than the presscake plots. Two possible explanations are that an osmotic effect from the cranberry presscake application may have caused the immobilization of soil moisture, or an increase in soil microorganism respiration from the immediate decomposition of the presscake soil amendment may have also consumed a significant quantity of soil moisture. Pal and Broadbent (1975) conducted field respirometry studies with soil amended with feedlot manure. A linear relationship between reaction velocity and moisture content was observed; biological activity decreased 50% at 30% Water Holding Capacity (WHC) as compared to 60% WHC.

In plots receiving the cranberry presscake applications, both alfalfa seedling and annual weed seedling emergence were delayed (Figure 2.1). Biomass sample data collected on June 27, 1991 showed highly significant ($P>0.0001$) reductions in alfalfa seedlings and weed seedlings in the presscake amended plots. This may have been due to the moisture deficit observed in the presscake plots, or due to the reduced nitrogen levels measured earlier in the month.

The first harvest of alfalfa after establishment was taken on July 11, 1991. The second harvest was taken on September 3, 1991. Both harvests showed significantly lower ($P<0.0001$) plant growth in presscake plots; however, there was more recovery of alfalfa in the second harvest (Figure 2.2). In the first harvest, cranberry presscake-amended plots yielded approximately 2.0 Mg ha^{-1} alfalfa forage at 12% moisture whereas the control plots yielded approximately 4.1 Mg ha^{-1}. Due to severe infestation of annual crabgrass seedlings (particularly in plots not amended with presscake) and potato leafhopper (a serious insect pest to alfalfa), the entire experimental area was sprayed with Poast, Malathion, and crop oil, all at the rate of 1.7 liter ha^{-1} on July 31, 1991.

As evidenced by the first cutting of 1992 (third cutting overall) taken on June 9, there was complete recovery of the alfalfa (Figure 2.2). Approximately one year following presscake incorporation, there were no significant differences in alfalfa yields between presscake-amended and control plots. Also, there was no interaction between cranberry presscake treatments and limestone application rates, nor did the increasing rates of limestone application effect alfalfa yield (data not shown).

Due to the near complete recovery of alfalfa in June 1992, it was decided to accelerate the experimental design to observe potential carryover effects of presscake application. On June 10, 1992, the experimental area of alfalfa was plowed under and on June 12 was planted with field oat (*Avena sativa*) at the rate of 41 kg ha^{-1}. The germination and establishment of oat was not influenced by application of cranberry presscake the previous year. The oat stand was uniformly dense across all plots. Oat grain and straw were harvested on August 19, 1992; growth and forage yields of the oats were similar across all treatments (data not shown). Following the oat harvest, the entire experimental area was rototilled and disk-harrowed twice, and then planted again with alfalfa with a Brillion seeder at 9.1 kg ha^{-1} on August 24, 1992.

The second sowing of alfalfa was not effected by the application of presscake that had been applied 15 months earlier; alfalfa seedling populations were uniform in both presscake and check plots. Soil samples were collected and tested for soil pH, soil buffer pH, soil NO_3^--N concentrations, and soil organic matter; measurements were non-significant for all treatments.

Alfalfa Sown on Varying Dates after Presscake/Ricehull Incorporation

Due to the delayed germination of alfalfa observed in the 1991 cranberry presscake-amended plots, it was decided that further research was needed. Because most dairy farms in Massachusetts rotate back into alfalfa or alfalfa/grass mixtures following field corn, it was necessary to study further the possible carryover effects of presscake on the seeding of forage crops. An additional experiment on presscake/ricehull application and time of seeding of alfalfa was initiated on May 9, 1992 at the University of Massachusetts Research Farm in Deerfield, MA.

Presscake with ricehulls was applied at the high rate of 112 Mg ha^{-1} (fresh weight) and was incorporated with a disk harrow. Alfalfa was seeded into check plots (0 presscake), and plots with presscake, at intervals of 1 (May 10), 3, 9, 17, 38, and 69 days after presscake incorporation.

Establishment in 1992, was delayed in cranberry presscake plots seeded 1, 3 and 9 days after presscake incorporation, a result similar to that seen in the first alfalfa study in 1991. No forage harvests were taken this establishment year in 1992. In 1993 the first cutting was taken on June 9. Results from the first cutting indicated that cranberry presscake application had no significant ($P<0.05$) effect on alfalfa yield; however, planting date was significant at the $P<0.03$ level (Figure 2.3).

Alfalfa yield was greatest for the seeding date of May 26 (17 days after incorporation of presscake). Due to the severity of the drought experienced in July and August of 1993, a second cutting of the alfalfa was not taken until September 14, 1993.

Results from the second cutting indicated that planting date was significant, with the highest alfalfa yields resulting from plots sown on day 1 and again on 17; however, there seemed to be no direct correlation between time of presscake incorporation and the rest period before sowing alfalfa with respect to alfalfa growth and yield in the year after establishment.

Conclusion

Suppression of weed seedlings and suppression of small seeded forage crop establishment following presscake application first became evident in the alfalfa studies in 1991. No direct cause was evident except for the moisture levels apparent in cranberry presscake amended plots. Nitrate-nitrogen levels were also reduced in cranberry presscake amended plots, but it is unclear if this was a contributing effect. While this seedling suppression may be an impediment to alfalfa production, it was easily overcome by scheduling planting several weeks after presscake application. Applying supplemental nitrogen, if planting of alfalfa is to occur immediately, may also counteract the effects of cranberry presscake application. However, this and soil moisture deficits following cranberry presscake applications need further investigation.

Cranberry presscake application delayed alfalfa establishment but did not prevent establishment, nor did the cranberry presscake adversely effect soil quality. Therefore, based on these field studies, it appears that alfalfa can be safely planted in the fall after application of presscake in the spring, or following presscake application in a previous year.

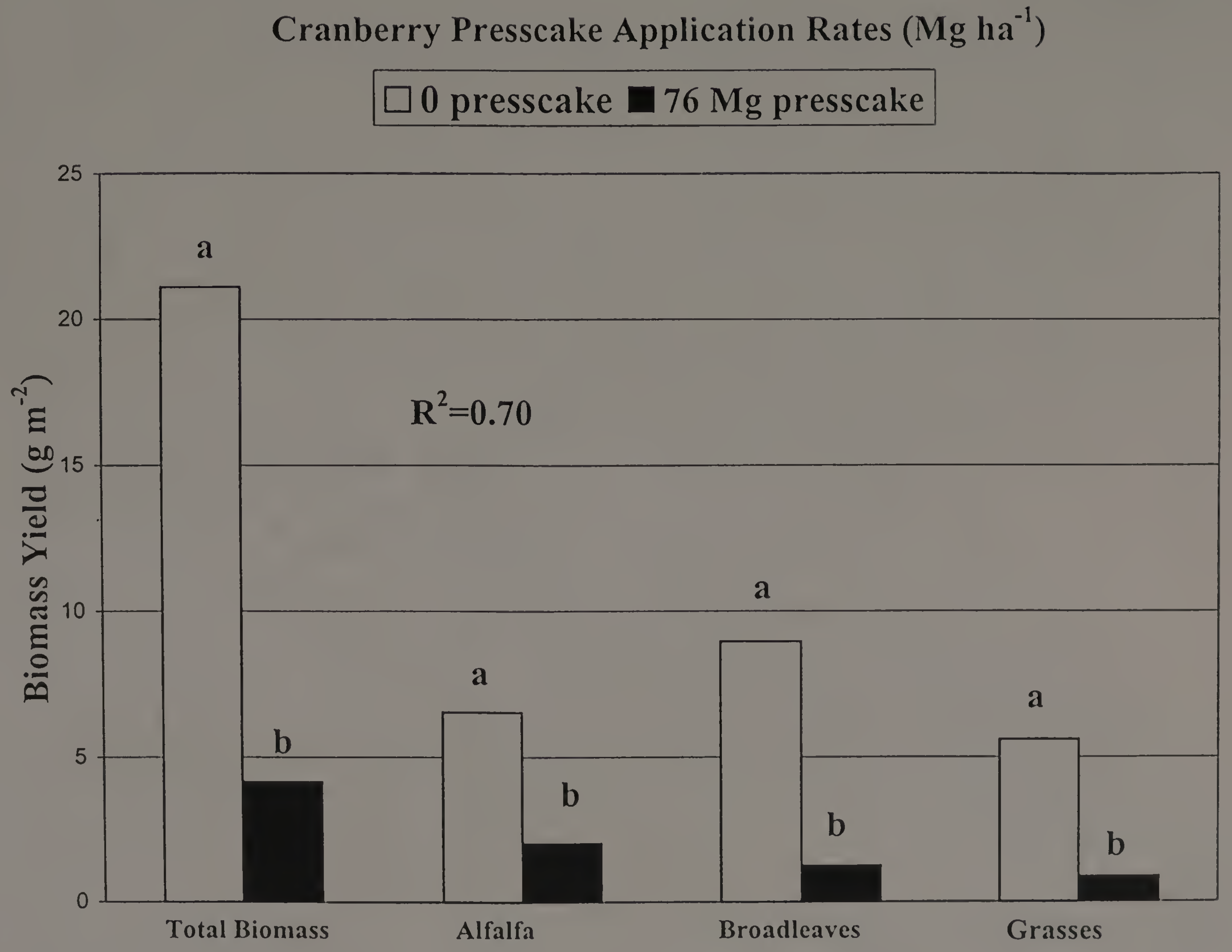

Figure 2.1 Alfalfa experiment biomass yields 55 days after incorporation of cranberry presscake.

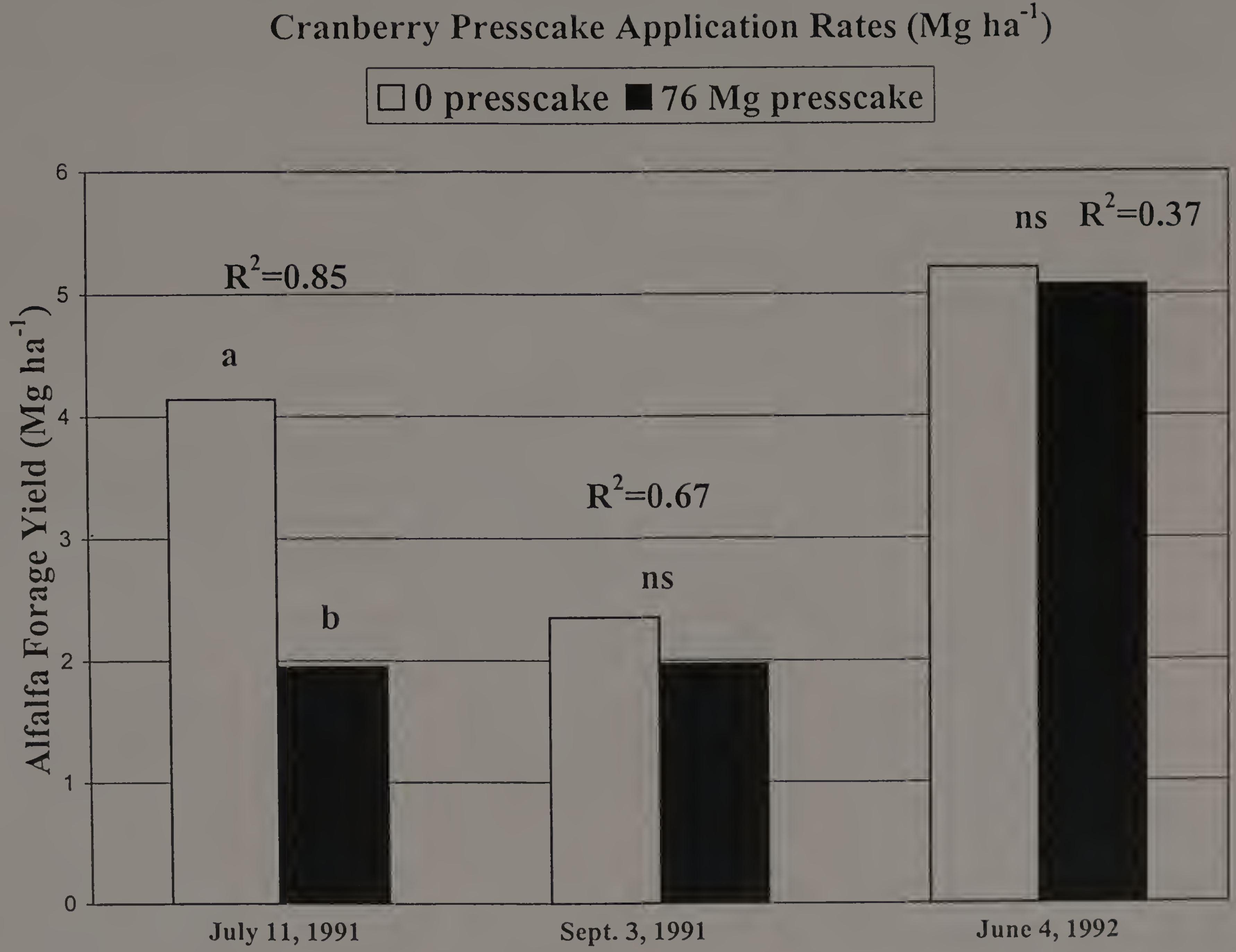

Figure 2.2 1991 and 1992 alfalfa forage yields.

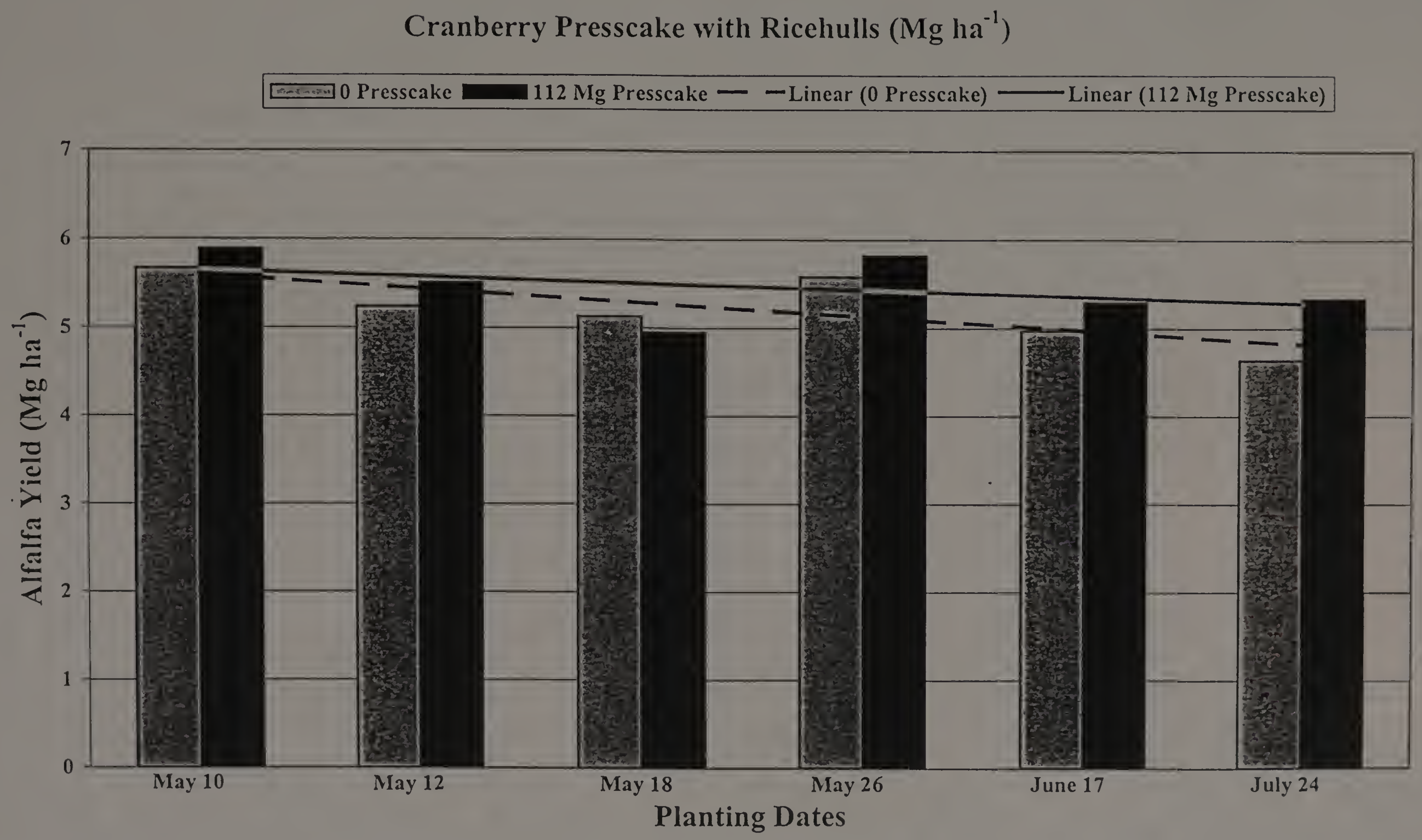

Figure 2.3 Alfalfa yields in Spring 1993, following differing planting dates into a presscake/ricehull-amended soil.

CHAPTER 3

THE "CENTRAL COMPOSITE" FIELD CORN STUDY

Introduction

Field corn is grown on more annually tilled acres than any other crop in Massachusetts, and represents potentially the greatest cropped area for applying cranberry presscake as a soil amendment. Current recommendations for nitrogen fertilization of field corn call for approximately 82 kg ha^{-1}; however, many Massachusetts dairy farmers apply much more nitrogen to field corn than is required (Herbert et al., 1991). Most dairy farmers believe the extra applications of nitrogen provide insurance against yield declines. Because of the possibility of soil nitrogen immobilization caused by cranberry presscake application, and because of the acidic nature of the cranberry presscake, it was necessary to study the interaction of cranberry presscake application with limestone, and nitrogen fertilizer. The effects of the three main factors on field corn establishment and yield were studied in a central composite design to uncover treatment trends and to improve field experiment efficiency.

Materials and Methods

Cochran and Cox (1957) described the three-factor response surface design as a central composite second order design in incomplete blocks (Plan 8A.4, page 373). The three factors for this field corn study were cranberry presscake/celite, calcium carbonate agricultural limestone, and nitrogen fertilizer. In the central composite design, the five levels of the three factors were predetermined in a ratio of –1.633, -1.00, 0, 1.00, and 1.633. The five levels of the cranberry presscake/celite factor were 0, 22, 56, 90, and 112 Mg ha^{-1}, respectively. The five levels for the limestone were 0, 182, 455, 728, and 910 kg ha^{-1}, respectively, and the nitrogen treatment levels were 23, 50, 91, 132, and 160 kg N ha^{-1}, respectively. In the central composite design, each block contains two plots at the central level or 0 level for each factor. Two blocks cover all combinations of the –1.00 and 1.00 levels; the third block compares the extreme levels (-1.633 and 1.633) of each factor with the other two main factors at the central level or 0 level.

One replicate of 20 plots measuring 2.3 m X 7.6 m was laid out at the University of Massachusetts Agronomy Research Farm in South Deerfield, MA. The soil at the experimental site was an Occum fine, sandy loam (Fluventic Dystrocrept), relatively low in organic matter (2%). The initial soil pH of the experimental area was 6.6 and the buffer pH was 6.9. Field oats (*Avena sativa*) were grown on the experimental site the preceding year and were harvested at maturity; no chemical fertilizers were applied to the oat crop. The central composite field experiment was repeated with the same treatments on the same experimental plots for three consecutive years at the University of Massachusetts Agronomy Research Farm.

In each year, the presscake/celite mixture (presscake alone was applied to the experimental area in year 3) was applied by surface spreading to the experimental plots after plowing. The limestone and one half of the nitrogen fertilizer (NH_4NO_3) treatments were also applied by surface spreading prior to planting; all of the amendments were incorporated by disk harrowing twice. The presscake/celite had a dry matter content of 45% and pH of 4.0, and the pH of the presscake component in the mixture was 3.6. Agway field corn (AG596) was planted on May 17, 1991, May 19, 1992, and June 8, 1993 at a population of approximately 66,666 plants ha^{-1} in 76 cm rows. Immediately after planting, the herbicides Dual (metolachlor) and Aatrex (atrazine) were applied at 0.5

liter active ingredient ha^{-1} and 0.6 liter active ingredient ha^{-1}, respectively, to control annual weeds.

In mid June of each year, when the corn plants were approximately 30 cm tall, soil samples were collected and soil pH, soil buffer pH, soil NO_3^--N, and soil organic matter levels were determined. Approximately 12 soil cores were collected from each plot at a depth of approximately 30 cm. Soil cores were composited and a subsample was air-dried and ground to pass through a 2-mm sieve. Soil pH was measured with a standard glass electrode and pH meter using a 1:1 v (soil:distilled water). Soil buffer pH was measured according to the SMP method (McClean, 1982). Soil samples tested for NO_3^--N were extracted with 0.01 *M* $CaSO_4$ (Bremner, 1965) using 5:1 solution/soil ratio, and were analyzed for NO_3^--N by a cadmium-reduction method using a Technicon Auto Analyzer (Technicon, 1977). Soil organic matter was determined by the Walkley-Black procedure (Walkley and Black, 1934). The second half of the nitrogen fertilizer treatment was applied immediately after the soil samples were collected in mid June. Soil samples were collected again after corn harvest and analyzed for pH, soil nitrate nitrogen, and soil organic matter.

Results and Discussion

The data from the three-factor central composite design was processed at the University of Massachusetts Office of Information Technologies laboratory on a UNIX-based operating system. Data were processed with a software package developed by B.G. Love at the Lincoln University Computer Center in New Zealand. The data presented in graphic form were compiled from the equations of the response surfaces. Corn harvest data are presented in Tables 3.1 and 3.2. The graphical results of the experiment are depicted such that when the levels of one main treatment vary, the other two treatments are evaluated at the central value. For example, presscake main effect data presented are for the central values for limestone and nitrogen 455 and 91 kg ha^{-1}, respectively. Similarly, for nitrogen, graphical presentation is for the central values of presscake and limestone 56 Mg ha^{-1}, and 455 kg ha^{-1}, respectively.

Field corn was harvested from the experimental site when grain approached the hard dough stage of maturity. Corn silage harvest data were adjusted to 70% moisture, and earcorn weights were adjusted to 25% moisture. Although trends were apparent in corn silage and earcorn yields, in all three years the yield differences did not change significantly (Statistical Probability, $P > 0.05$) with applications of cranberry, lime or nitrogen fertilizer (Figures 3.1, 3.2, and 3.3). This lack of a yield response indicates that no adverse effects on soil chemistry were caused by the application of cranberry presscake.

In the first year, the lack of a nitrogen fertilizer response was unexpected since the field corn crop followed a grain (*Avena sativa*) crop that had returned presumably little nitrogen to the soil. The contribution of organic nitrogen from the cranberry presscake (approximately 270 kg N ha^{-1} at the 112 Mg ha^{-1} application rate) may have been responsible for the lack of a nitrogen response throughout the study. As field corn requires less than 91 kg N ha^{-1} for optimal production, the nitrogen requirement may have been met by the amount of nitrogen mineralized from the cranberry presscake. The lack of a nitrogen response might be expected on many dairy farm soils where there has been a history of manure application and soil fertility is high. However, the experimental site was a sandy soil with little native organic matter (2%), and it had received no recent applications of manure. The lack of a nitrogen response may also indicate that the sandy texture/low bulk density of the soil provided for the near complete oxidation of the organic matter and mineralization of the organic nitrogen content of the presscake. Throughout the 3 years of the field corn study there was no evidence of immobilization of soil nitrogen. Any apparent depression in soil nitrogen levels following the incorporation and subsequent decomposition of cranberry presscake (Figures 3.4 and 3.5) were non-significant and did not effect the early growth stages of corn nor corn silage yields.

Mostly, trends in soil pH change were not evident, and all were non-significant ($P > 0.05$) except in the first year (1991) (Figures 3.6 and 3.7). The data presented in graphic form were compiled from the equations of the response surfaces for 1991 and 1992 soil pH data are presented in Table 3.3. The observed soil pH depression, with increasing rates of nitrogen fertilizer in 1991, was most likely due to the acidity generated by the nitrification of the NH_4NO_3 fertilizer. Increasing rates of presscake application caused soil pH values to increase slightly the first year. This was most likely due to the increased buffering capacity from the addition of organic matter although increases in soil organic matter were not detectable. In 1992, (Figure 3.8) as well as in 1993, soil pH values remained fairly constant across all treatments which may have also been a result of increased soil pH buffering capacity from the additional organic matter. Lack of a limestone response in all three years of the study, may reflect the growth tolerance of field corn to soil conditions with varying soil pH. The acidity generated by the cranberry presscake also may have been transitory; the organic acids in the cranberry presscake may have been neutralized or decomposed quickly by soil microorganisms. As was discussed in Chapter 1., researchers also have found that increasing rates of soil organic matter buffer soil pH and improve soil quality (improved soil fertility, biological activity and water holding capacity).

Conclusion

Cranberry presscake, with a moderate carbon:nitrogen ratio of 30:1, does not seem to effect soil properties or crop yields in a negative manner. In field experiments where much greater quantities of organic matter were added to the soil and organic materials had much wider carbon:nitrogen ratios than cranberry presscake, yields were much lower and soil chemical reactions were effected adversely. Edwards, et al. (1993) applied approximately 11 tons/acre of ground newsprint (moisture content not reported) to cotton (*Gossypium hirsurum*) and field corn (*Zea mays*). The newsprint, which had a carbon:nitrogen ratio of 100:1, caused severe stunting in the cotton and corn, and the crops also had higher incidences of soil borne diseases (*Rhizoctonia sp.* and *Sclerotium sp.*). When the carbon:nitrogen ratio of the newsprint was adjusted up to 30:1 with nitrogen fertilizer, stunting and incidence of disease were no longer evident, and there were no reductions in yield.

Morachan, et al. (1972) reported on a long-term study in the U.S. Corn Belt where field corn was crown continuously with high rates of corn stalk residue and sawdust applied as soil amendments with high rates of nitrogen. Over the 8 year study, soil pH drifted downward from 5.3 to 4.8, and yields were reduced markedly, presumably from induced calcium deficiencies due to low soil pH as calcium is much less soluble and much less available to plants as soil pH is lowered.

After three years of field experimentation at the University of Massachusetts Agronomy Research Farm, there appeared to be no negative long-term effects of land application of cranberry presscake to corn land. No evidence of detrimental immobilization of soil nitrogen was observed. Thus, the application of cranberry presscake to corn land should have no adverse effects at least as long as presscake application rates do not exceed the maximum annual rate of 112 Mg ha^{-1} (wet weight).

Table 3.1 Constants and coefficients of response surface for corn silage yields in 1991, 1992, and 1993; yields were adjusted to 70% moisture.

	1991	1992	1993
	Mg ha^{-1}	Mg ha^{-1}	Mg ha^{-1}
Constant	65.2	61.0	53.6
X_1 (Cranberry)	1.54	-0.78	0.96
X_2(Limestone)	1.75	-0.12	-0.21
X_3 (Nitrogen)	-0.61	-0.96	0.65
X_1^2	-0.26	1.37	0.19
X_2^2	0.67	-0.63	-0.48
X_3^2	-0.67	-0.43	-1.17
X_1X_2	1.84	-1.42	0.83
X_1X_3	-1.61	0.07	-0.92
X_2X_3	-0.71	0.10	1.34
SE:Linear	1.67	0.88	0.71
SE:Quadratic	1.17	0.88	0.71
SE:Interactive	1.51	1.13	0.92
R^2 (%)	0.50	0.47	0.55

Table 3.2 Constants and coefficients of response surface for earcorn 1991, 1992, and 1993; yields were adjusted to 25% moisture.

	1991	1992	1993
	Mg ha^{-1}	Mg ha^{-1}	Mg ha^{-1}
Constant	15.2	11.7	11.3
X_1 (Cranberry)	0.19	-0.05	0.16
X_2(Limestone)	0.28	-0.07	-0.05
X_3 (Nitrogen)	0.11	-0.14	0.23
X_1^2	-0.12	0.37	-0.03
X_2^2	0.19	-0.07	-0.06
X_3^2	-0.23	-0.10	-0.21
X_1X_2	0.19	-0.24	0.22
X_1X_3	0.11	-0.10	-0.23
X_2X_3	0.04	0.05	0.31
SE:Linear	0.22	0.19	0.19
SE:Quadratic	0.22	0.20	0.19
SE:Interactive	0.28	0.25	0.24
R^2 (%)	0.42	0.44	0.47

Table 3.3 Constants and coefficients of response surface for soil pH in June 1991, October 1991, and June 1992.

	June 1991	October 1991	June 1992
Constant	6.43	6.52	6.31
X_1 (Cranberry)	0.07	0.03	-0.02
X_2(Limestone)	-0.03	-0.04	0.00
X_3 (Nitrogen)	-0.12	-0.07	0.00
X_1^2	-0.06	0.01	0.00
X_2^2	-0.04	-0.01	0.00
X_3^2	0.04	0.02	0.01
X_1X_2	0.01	0.00	0.03
X_1X_3	-0.11	0.01	-0.03
X_2X_3	-0.04	-0.01	-0.01
SE:Linear	0.02	0.02	0.02
SE:Quadratic	0.02	0.02	0.02
SE:Interactive	0.03	0.02	0.03
R^2 (%)	0.88	0.76	0.30

Table 3.4 Constants and coefficients of response surface for soil N-NO_3^- July 1992, July 1993, November 1993.

	July 1992 mg kg^{-1}	July 1993 mg kg^{-1}	November 1993 mg kg^{-1}
Constant	20.72	34.00	6.15
X_1 (Cranberry)	-0.76	-1.54	-0.09
X_2(Limestone)	2.67	-0.81	1.06
X_3 (Nitrogen)	-3.00	4.62	0.93
X_1^2	1.21	-0.24	-0.19
X_2^2	2.13	-0.45	0.35
X_3^2	1.49	1.21	1.27
X_1X_2	1.18	5.35	0.32
X_1X_3	7.02	0.27	-1.07
X_2X_3	-2.17	-5.97	-0.42
SE:Linear	3.13	2.44	0.58
SE:Quadratic	3.14	2.46	0.58
SE:Interactive	4.04	3.16	0.75
R^2 (%)	0.42	0.58	0.63

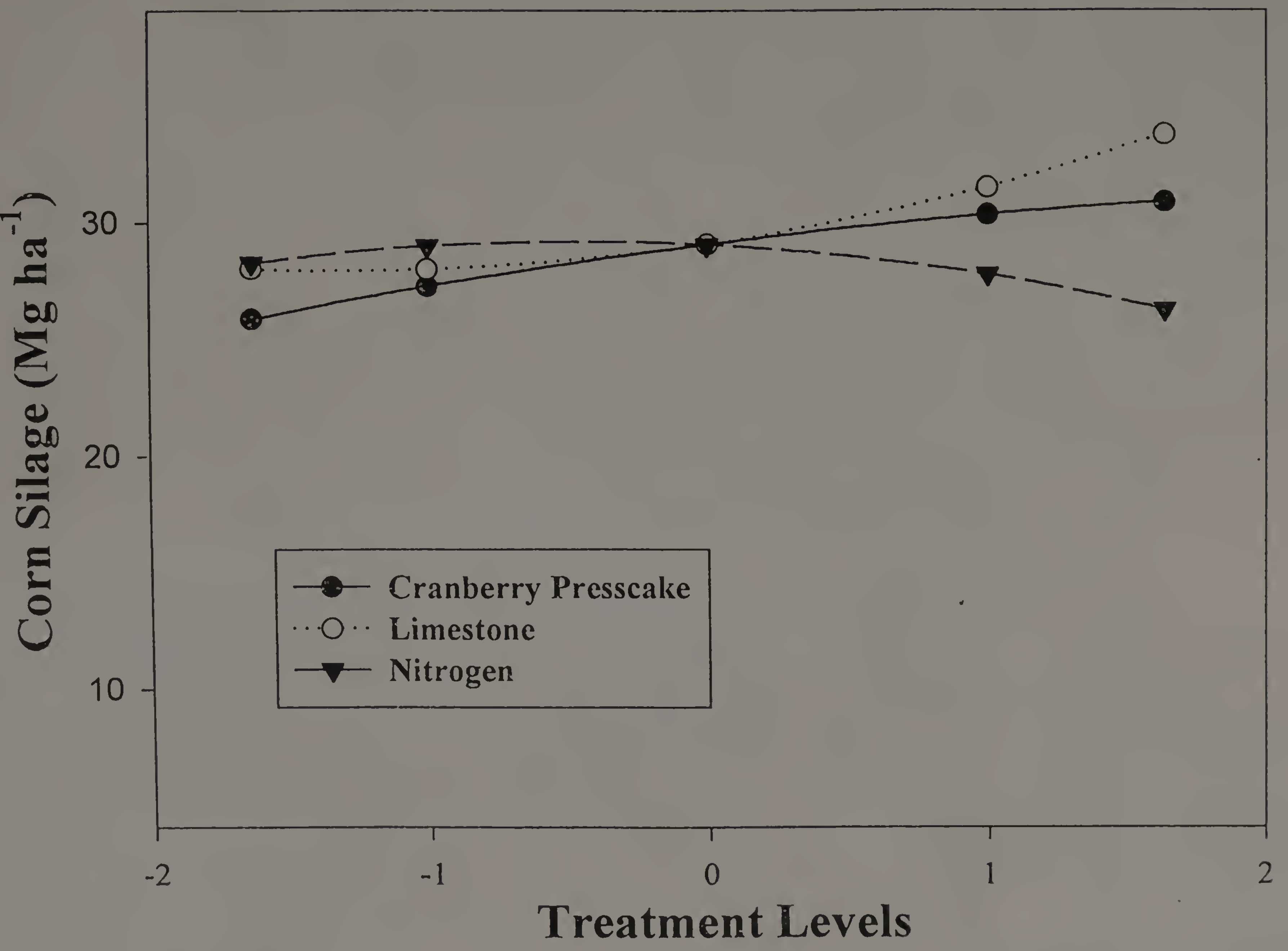

Figure 3.1 1991 corn silage yields after the first application of cranberry presscake/celite in May 1991.

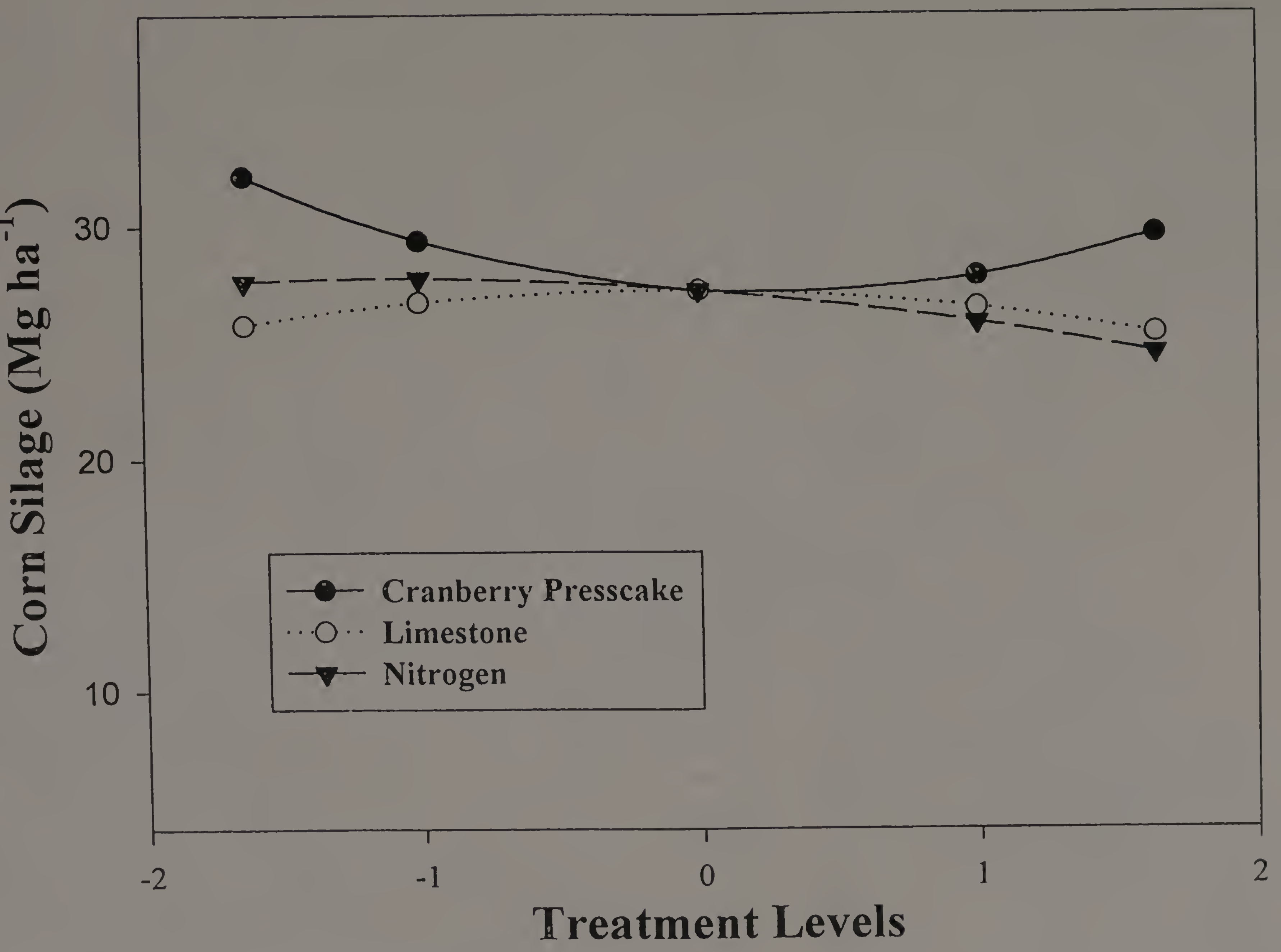

Figure 3.2 1992 corn silage yields after two years of cranberry presscake/celite application (May 1991 and May 1992).

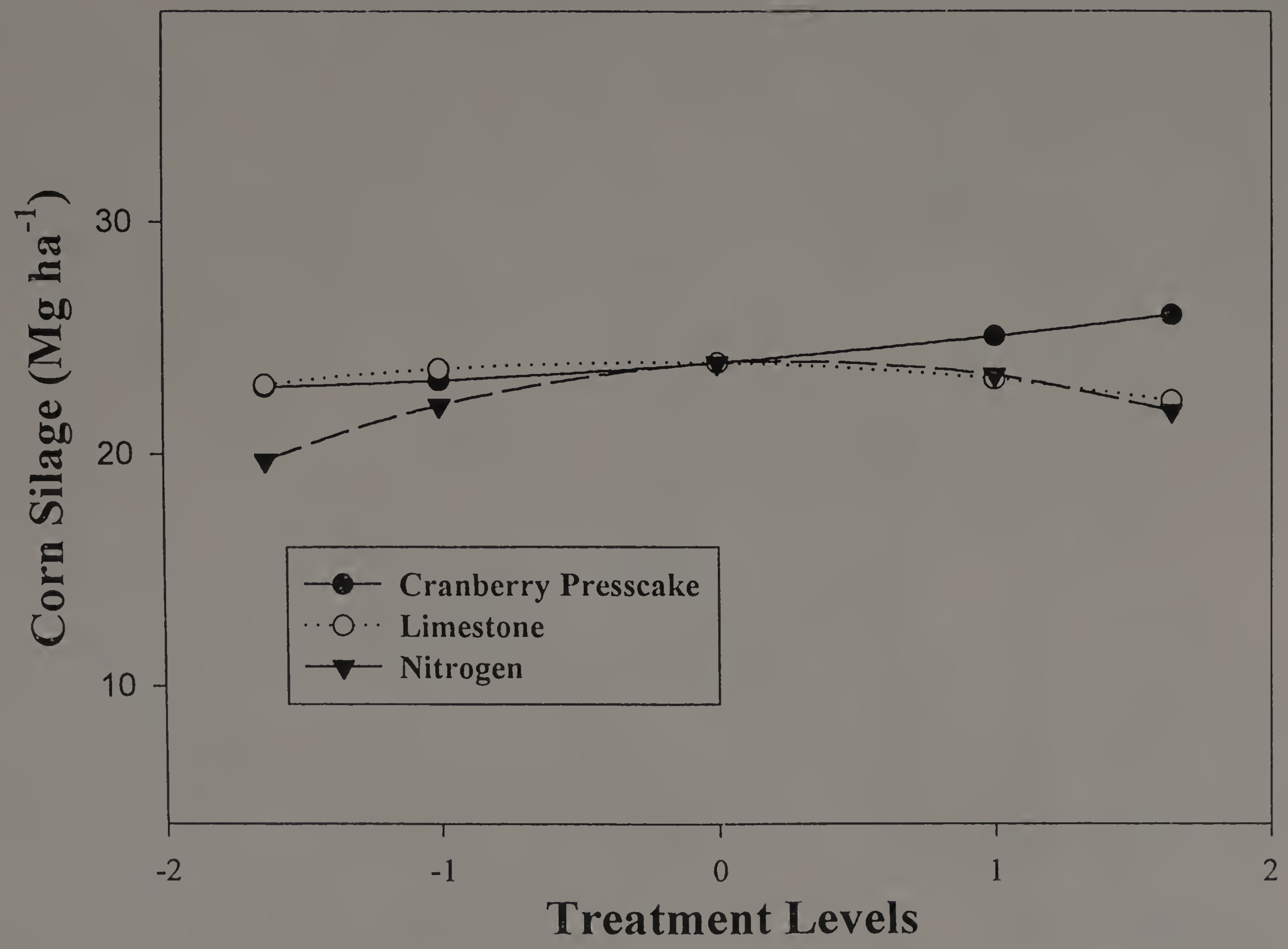

Figure 3.3 1993 corn silage yields after three years of cranberry presscake/celite application (1991, 1992 and 1993).

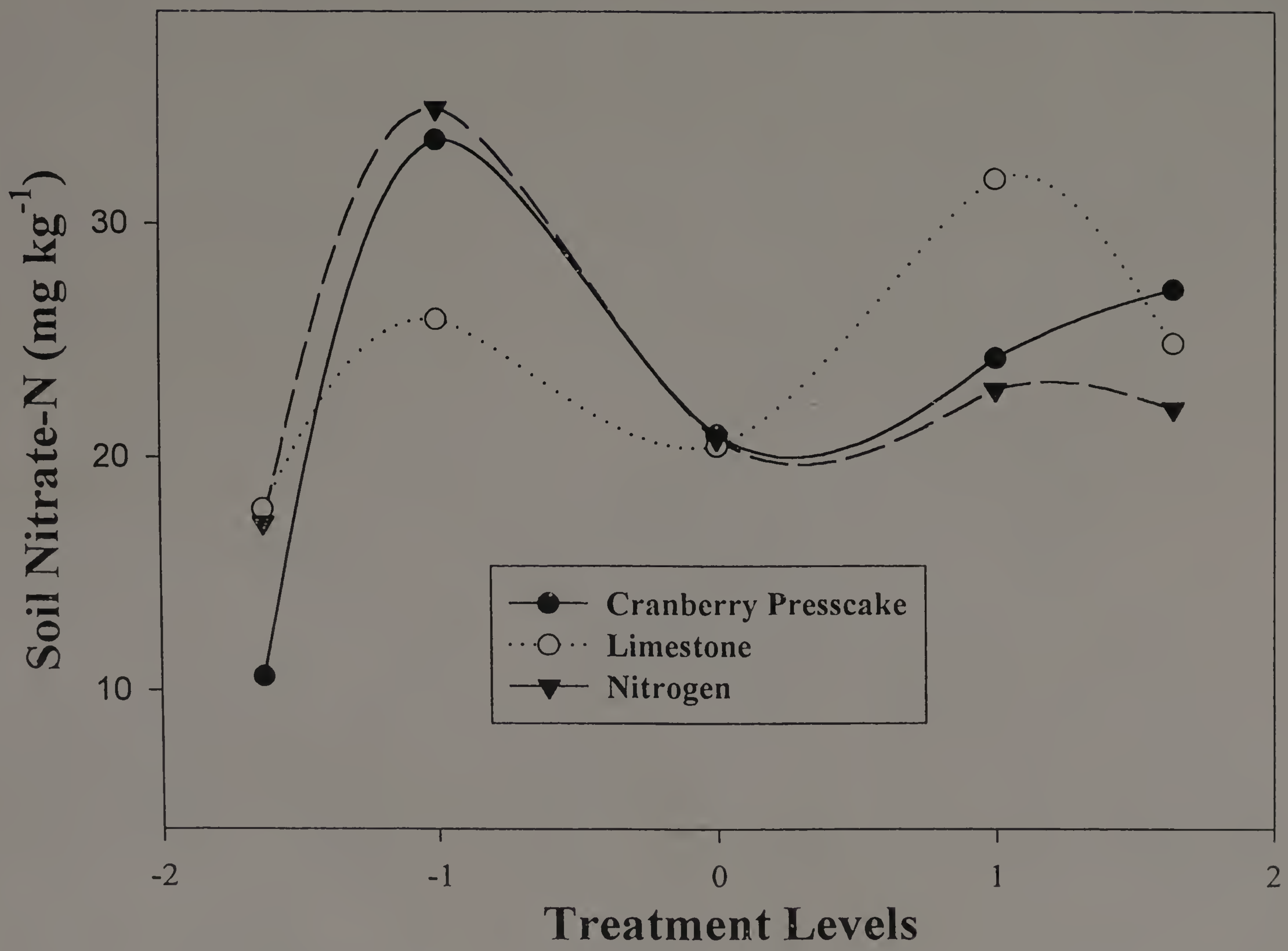

Figure 3.4 July 1992 soil nitrate-N concentrations after two years of cranberry presscake/celite application (1991 and 1992).

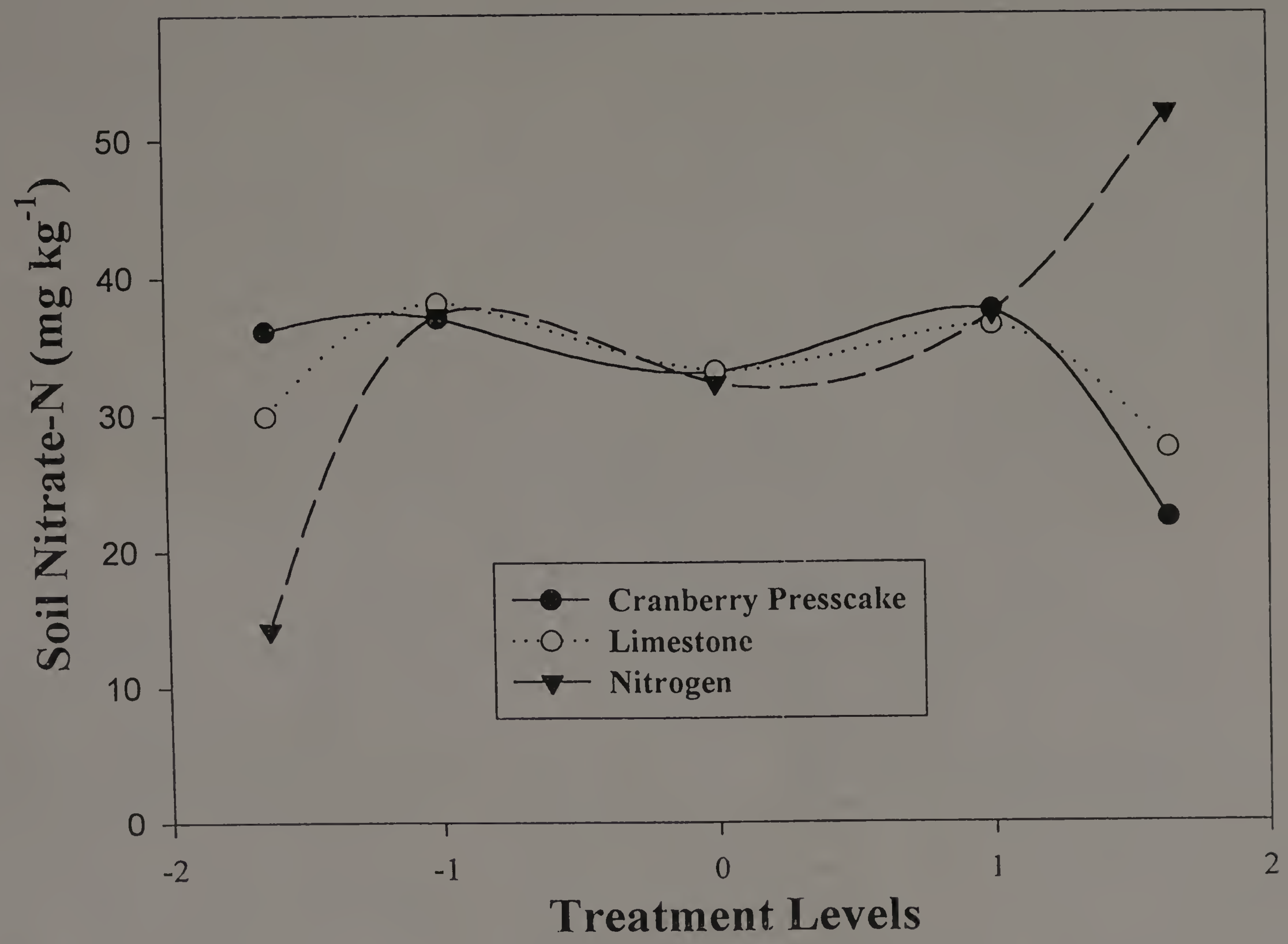

Figure 3.5 July 1993 soil nitrate-N concentrations after three years of cranberry presscake/celite application.

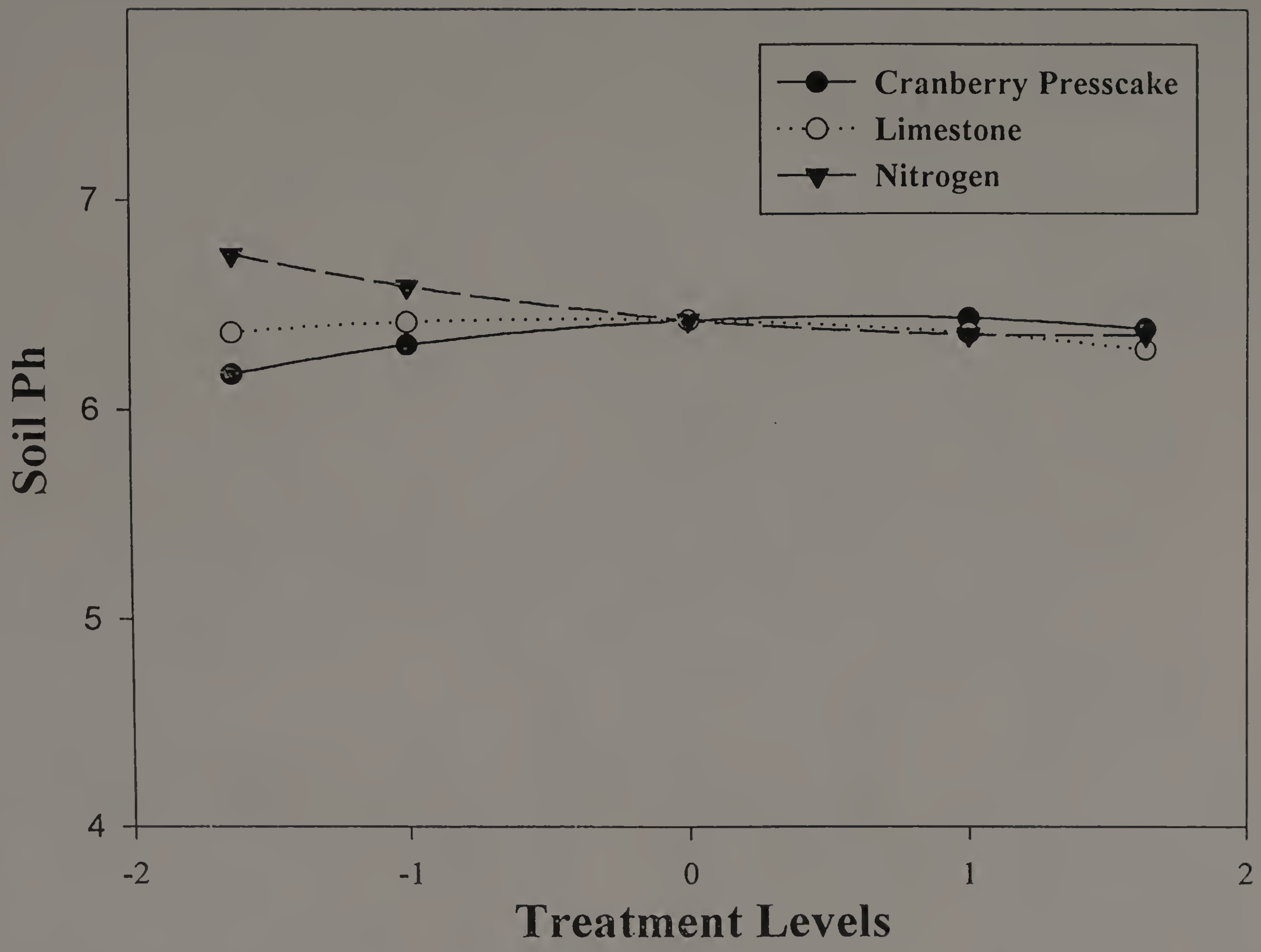

Figure 3.6 Soil pH readings in June 1991 after application of cranberry presscake/celite in May 1991.

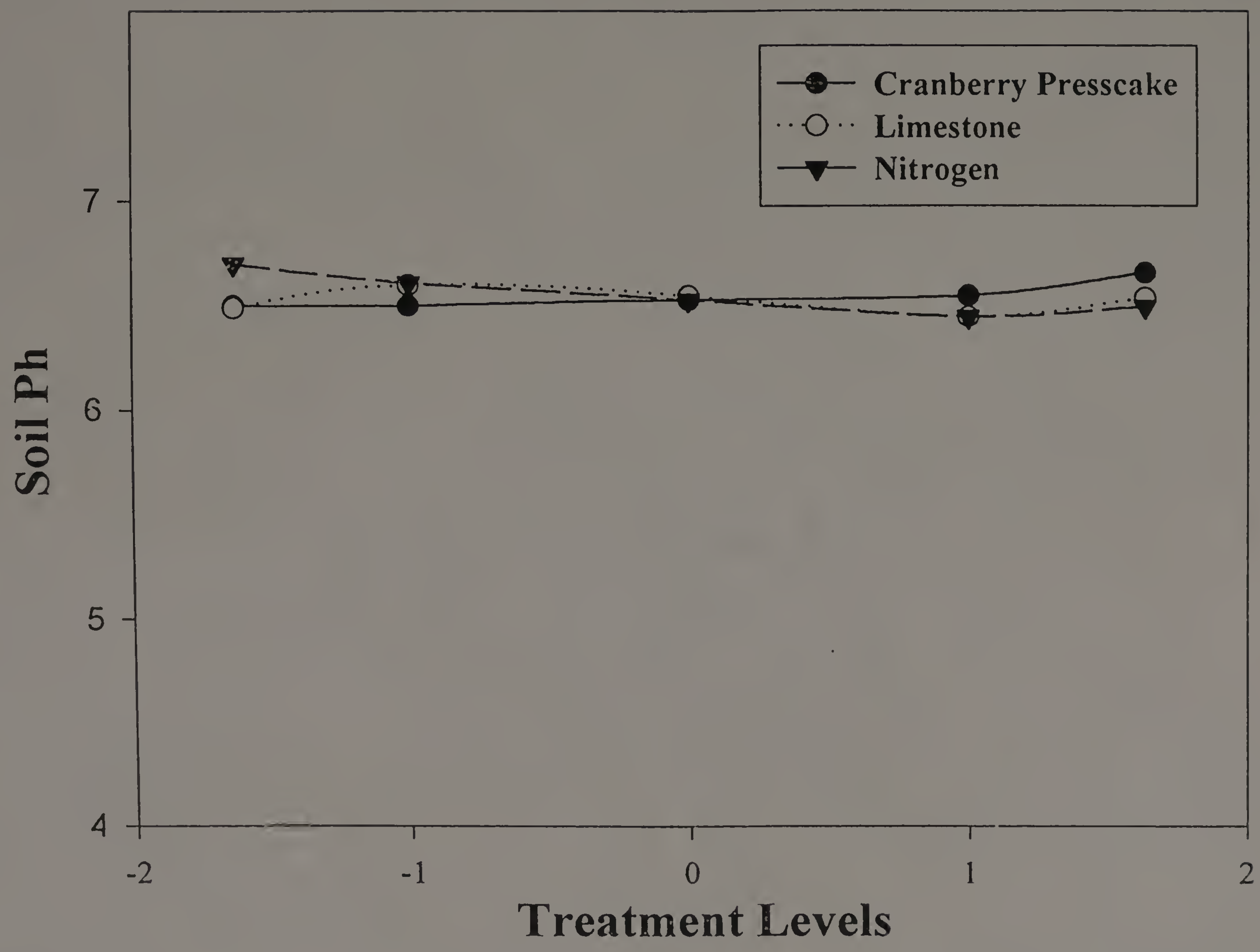

Figure 3.7 Soil pH readings in October 1991 after application of cranberry presscake/celite in May 1991.

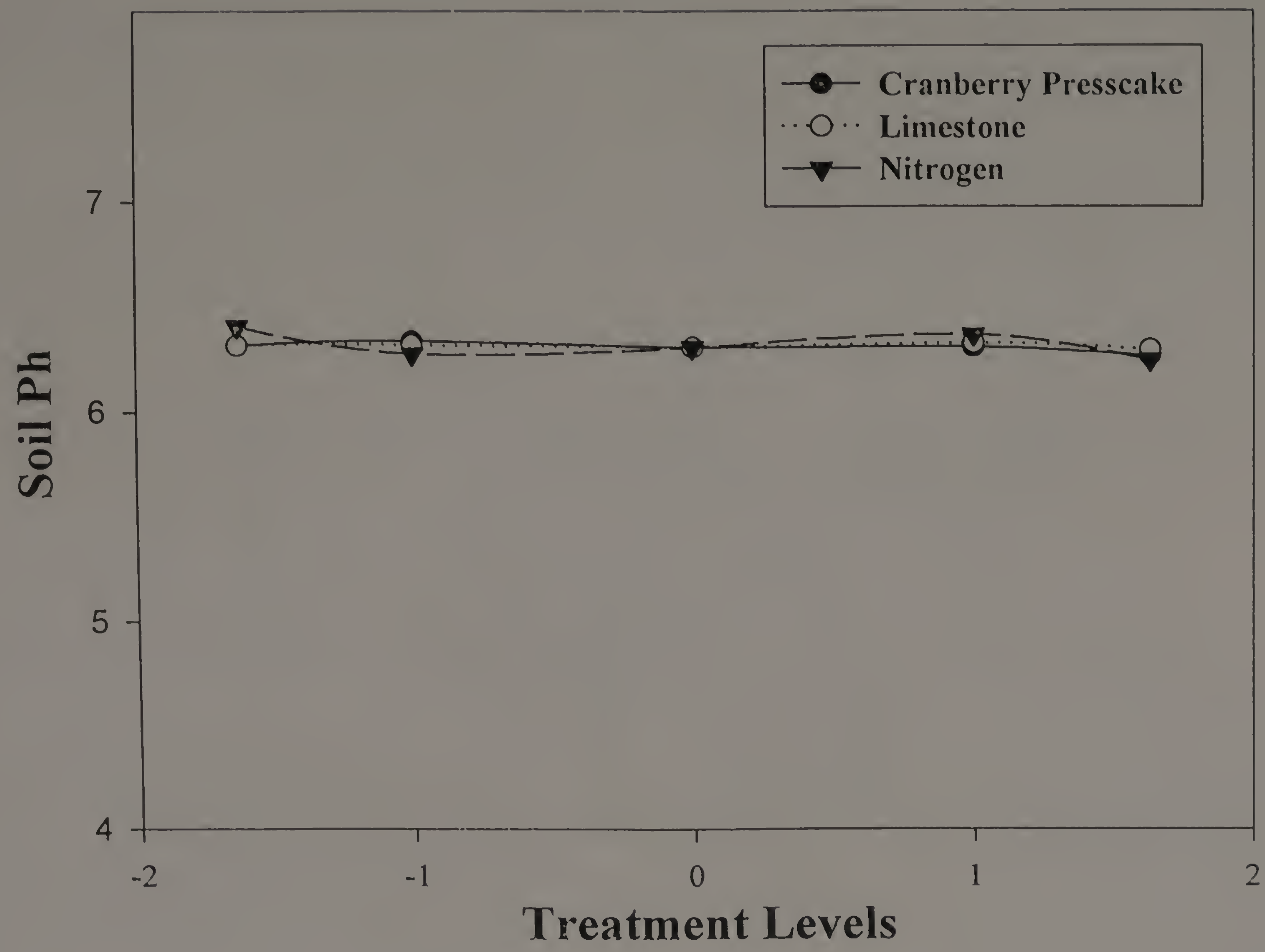

Figure 3.8 Soil pH readings in July 1992 after the second application of cranberry presscake/celite (May 1991 and May 1992).

CHAPTER 4

FIELD CORN PRODUCTION: EXPERIMENT I. CRANBERRY PRESSCAKE AND WEED SUPPRESSION AND EXPERIMENT II. VARIOUS RESIDUAL TYPES OF CRANBERRY PRESSCAKE

Introduction

Incorporating cranberry presscake prior to planting has been the recommended practice in New Jersey for row crops (personal correspondence with the Rutgers University Cooperative Extension). In this system, the roots of developing corn seedlings may come into direct contact with the cranberry presscake. However, it was thought that the effects of the cranberry presscake would be buffered by the soil after incorporation thus eliminating negative effects on crop establishment, if application rates did not exceed 76 Mg ha^{-1}. At 76 Mg ha^{-1}, it was thought that decomposition of the presscake might reduce soil nitrogen levels, however, the nitrogen immobilization would not be great enough to reduce crop yields since the C:N ratio of cranberry presscake is approximately 30:1 (Chapter 2).

In field experiments with soil-incorporated cranberry presscake at the University of Massachusetts, presscake-amended plots resulted in noticeable reductions in the germination and establishment of annual weed populations (Chapter 2).

In this experiment with cranberry presscake, there were no observed phytotoxic effects from the incorporation of the soil amendment; however, using presscake applied as a surface application of mulch had not been observed previously. Seeding corn 3 to 5 cm. into the soil would eliminate the possibility of corn seed coming into direct contact with the cranberry presscake applied to the surface. In previous experiments, spreading and incorporation of presscake prior to planting may have resulted in some presscake coming in direct contact with germinating corn seeds. Such incorporation of presscake resulted in the suppression of alfalfa and broadleaved and grassy weeds (Chapter 2). Thus, the roots of developing corn seedlings could come into direct contact with the cranberry presscake, and seedling development could be inhibited. Surface application of the presscake would eliminate similar adverse effects on the developing corn seedling roots. However, there would be the possibility of adverse effects as corn emerged through the cranberry presscake mulch.

Two experiments were designed to evaluate the effectiveness of cranberry presscake as a weed-suppressing soil amendment. Cranberry presscake was surface-applied as a mulch before and after planting to determine the effect of planting through a presscake mulch, and were compared to incorporation of cranberry presscake as a soil amendment for weed suppression in field corn (*Zea mays*).

Materials and Methods

The experiments were carried out at the University of Massachusetts Agronomy Research Farm in Deerfield, MA; the soil was an Occum (Fluventic Dystrocrept) fine, sandy loam. An experimental area was chosen that had been fallow for the previous two years and had been uniformly infested with annual weeds. The predominant annual weed species consisted of lambquarters (*Chenopodium album*), large crabgrass (*Digitaria sanguinalis*), fall panicum (*Panicum dichotomiflorum.* Michx.), redrooted-pigweed (*Amaranthus retroflexus*), and shepherd's-purse (*Capsella bursa-pastoris*). Both experimental designs were randomized factorial, complete block designs with four replicates. Experiment II. was a split plot design where half of each main treatment plot received herbicide application and half of the plot was left untreated with herbicides.

Main treatments for Experiment I. (Cranberry Presscake and Weed Suppression) consisted of the following:

1. Check (no cranberry presscake), herbicides used for weed control.
2. Check (no cranberry presscake), no herbicide application.
3. 90 Mg ha^{-1} presscake (4 cm depth), corn planted after incorporating presscake.
4. 45 Mg ha^{-1} presscake (2 cm depth), corn planted before spreading presscake.
5. 90 Mg ha^{-1} presscake (4 cm depth), corn planted before spreading presscake.
6. 90 Mg ha^{-1} presscake (4 cm depth), corn planted after spreading presscake.
7. 90 Mg ha^{-1} presscake (4 cm depth), corn planted into a cleared strip after spreading presscake, no herbicide application.
8. 90 Mg ha^{-1} presscake (4 cm depth), corn planted into a cleared strip after spreading presscake, band spray of herbicides over cleared strip.

The main plot treatments for Experiment II. (Various Residual Types of Cranberry Presscake) were:

1. Check (no presscake).
2. 90 Mg ha^{-1} cranberry presscake as a surface mulch.
3. 90 Mg ha^{-1} cranberry presscake, soil incorporated.
4. 90 Mg ha^{-1} cranberry presscake/rice hulls as a, surface mulch.
5. 90 Mg ha^{-1} cranberry presscake/rice hulls, soil incorporated.
6. 90 Mg ha^{-1} cranberry presscake/celite as a surface mulch.
7. 90 Mg ha^{-1} cranberry presscake/celite, soil incorporated.

The experimental areas were prepared by plowing the fallow soil. On April 27, 1992, 228 kg ha^{-1} of fertilizer (15% N-8%K-12%P) and 4.5 Mg ha^{-1} of limestone were applied to the experimental area. Then, the experimental areas were harrowed twice. Cranberry presscake was applied according to the experimental designs for both field experiments. Field corn was planted May 4, 1992. Surface applications for presscake mulch treatments were applied to plots on May 5, 1992.

Individual plots measured 2.3 m by 7.6 m long; corn rows were 76 cm wide. Corn seed was planted 4 cm. deep with approximately 16 cm between seeds in the rows; final plant density was approximately 66,000 plants ha^{-1}. Immediately after planting, the herbicides Dual (metolachlor) and Aatrex (atrazine) were applied at 0.5 liter active ingredient ha^{-1} and 0.6 liter active ingredient ha^{-1}, respectively, to Experiment I. and to treatments 1 and 7 as prescribed for the herbicide subplots of Experiment II. In all plots, weed populations were determined by collecting above ground weed biomass samples in mid June (immediately following pre-sidedress nitrate soil testing) and again after harvest. Weed populations were separated into grasses and broadleafed weed categories and oven dried to determine dry matter content.

An analysis of variance for all main factors and means separations were conducted by using the SAS statistical software (SAS Institute, 1988).

Results and Discussion

Experiment I. Cranberry Presscake and Weed Suppression

Nine weeks after planting corn, weed pressure in all plots not sprayed with herbicides was significant (Figure 4.1), however, there was no measurable weed biomass in the check plot receiving herbicides. In the cranberry presscake-mulched treatments, there was a reduction of weed biomass between rows of corn and more so at the 90 Mg ha^{-1} rate than the 45 Mg ha^{-1} rate.

Weed pressure in the strip not receiving mulch was severe in the treatments not receiving herbicides, but was less than 30% of the value for the whole plot when herbicides were applied to the strip. Weed growth was not well suppressed when presscake was incorporated. Applying cranberry presscake as a mulch before or after planting did not adversely effect corn establishment or corn growth.

The early weed complex consisted mostly of crabgrass although shepherd's-purse was abundant in the incorporated presscake treatment. This trend was evident after corn harvest as well; measurement of weed biomass after harvest (Figure 4.2.) showed a similar pattern of weeds pressure as was found early in the corn growth cycle. The low rate of presscake mulch (45 Mg ha^{-1}) and the incorporated presscake treatment both had similar weed biomass to the non-herbicided check plot. Other mulch treatments including the non-herbicide strip treatment had less than 50% of this weed biomass.

Corn silage yield was 80 Mg ha^{-1} in the herbicided check treatment, 68% more than the non-herbicided check treatment (Figure 4.3). Corn silage yields were reduced with presscake incorporation, and with the presscake mulch treatments (both 45 Mg ha^{-1} and 90 Mg ha^{-1}) where corn was planted first. However, in the 90 Mg ha^{-1} rate mulch treatment (corn planted after surface application), corn yield was similar to that of the herbicided check treatment. Silage yields tended to be lowest where weed biomass was greatest suggesting weed competition was more responsible for reducing yield than application (and incorporation) of presscake. Earcorn yields had responses to treatments similar to responses in silage yield (Figure 4.4).

Experiment II. Various Residual Types of Cranberry Presscake

All plots receiving herbicide treatments resulted in no measurable weeds at both the mid June and post harvest samplings. Weed pressure in control plots not sprayed with herbicides was severe (Figures 4.5 and 4.6). Weed pressure in the non-herbicided control treatment 4 weeks after seeding exceeded 800 g m^{-2} whereas mulch and incorporated treatments except for the cranberry ricehull incorporated treatment had less than 200 g m^{-2} of weed biomass (Figure 4.5). Weed biomass sampled after corn harvest decreased for the control treatment possibly due to die-off of smaller weeds due to shading from the corn canopy. Weed biomass after corn harvest in most non-herbicide treated mulched and incorporated treatments increased slightly compared to the earlier sampling date.

Corn silage yield was approximately 80 Mg ha^{-1} in the herbicided check treatment, slightly less than the Incorporated-Ricehull treatment (Figure 4.7). Corn silage yields were only slightly reduced with presscake/celite incorporation, and with the presscake/celite mulch treatments. Silage yields tended to be lowest where weed biomass was greatest suggesting weed competition was more responsible for reducing yield than application (and incorporation) of presscake. Earcorn yields had no significant responses to treatments (data not shown).

Soil pH levels for all treatments in both Experiment I. and Experiment II. did not vary across treatments and were all non-significant (data not shown). In Experiment II., soil nitrate-N levels measured in June 1992 were fairly stable across all treatments (Figure 4.8). The control and presscake/ricehull mulch treatments had the highest levels (between 20-25 mg kg^{-1}), however, there was no indication of soil nitrogen immobilization.

Conclusion

Overall, there appeared to be little difference in yield responses of corn silage and earcorn among cranberry presscake application methodologies and among cranberry presscake types. Weed pressures seemed to be the most severe, as was expected, in plots that did not receive any herbicide treatment. Weed suppressing abilities of cranberry presscake were evident; however, further study is required on the economic returns of presscake application versus herbicides for weed control.

Cranberry presscake does warrant consideration from farmers as a soil amendment as there have been observed no detrimental effects from its application to field soils. In soils of light, sandy texture (such as the sandy loam textured soil at the University of Massachusetts Agronomy Research Farm), medium to high rates of cranberry presscake may be applied. In soils with a heavier texture and a higher native organic matter level, there seems to be less rapid oxidation of freshly applied organic matter, and a more conservative application rate of presscake should be considered (Herbert et al., 1993). Farmers who do opt for accepting cranberry presscake should be well informed on their soil fertility status before applying the soil amendment. Farmers should also initiate a soil testing program so that nitrogen levels can be monitored and adjusted as necessary.

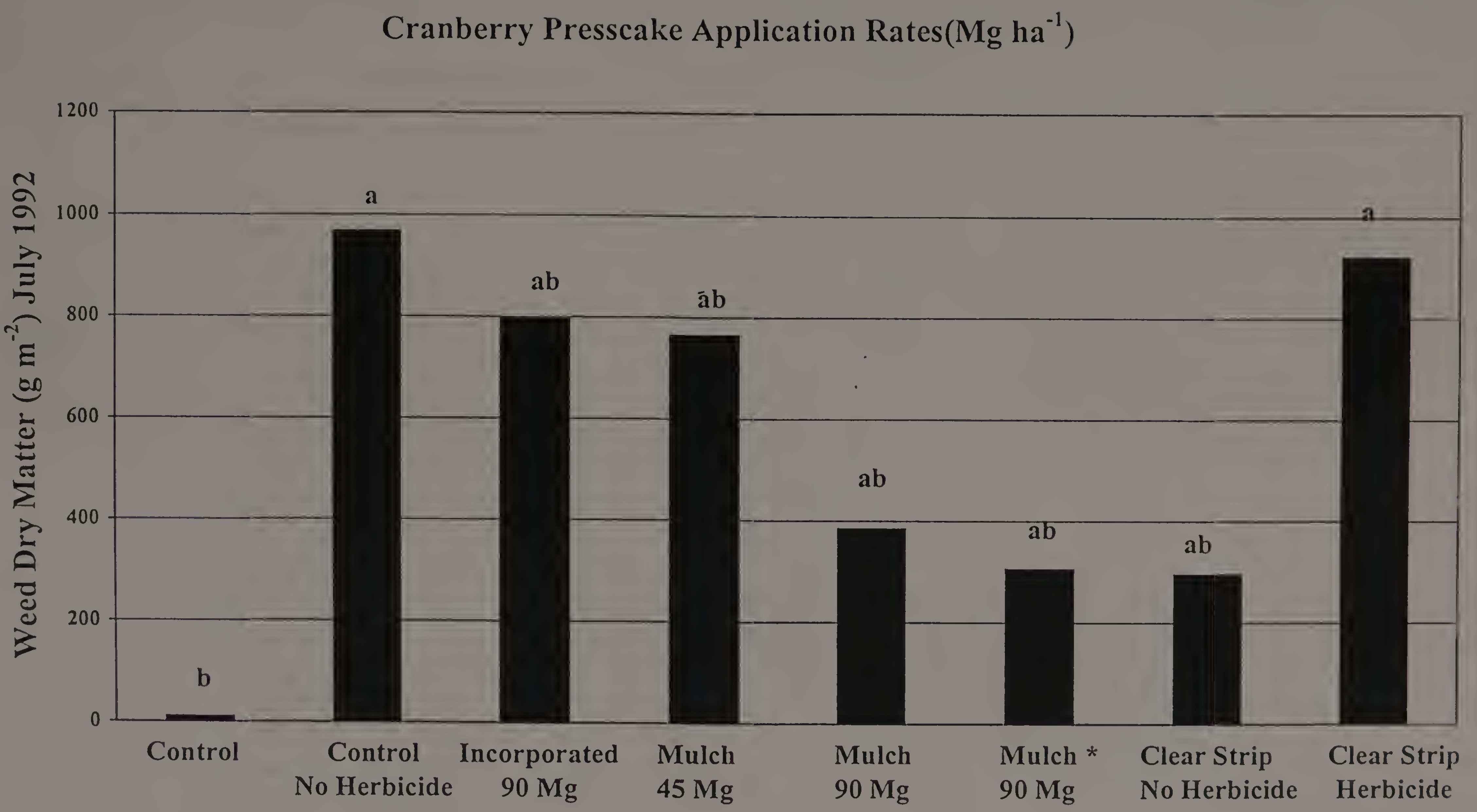

Figure 4.1 Weed biomass determined 9 weeks after corn seeding. The "Mulch * 90 Mg" refers to treatment where corn was planted after spreading the mulch. Treatments with the same letter were not significant at the LSD>0.05 level.

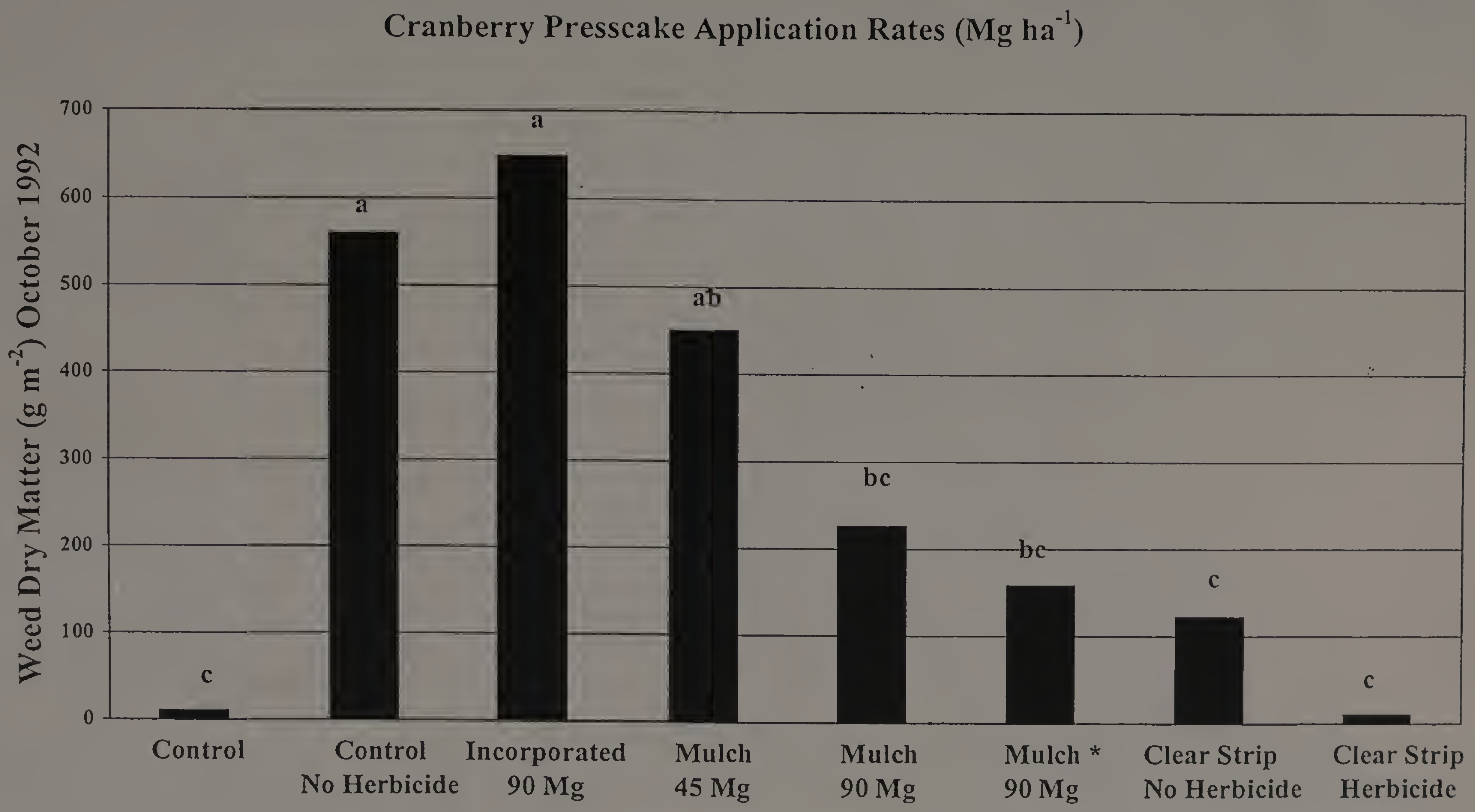

Figure 4.2 Weed biomass determined after corn harvest in October 1992. The "Mulch * 90 Mg" refers to treatment where corn was planted after spreading the mulch. Treatments with the same letter were not significant at the LSD>0.05 level.

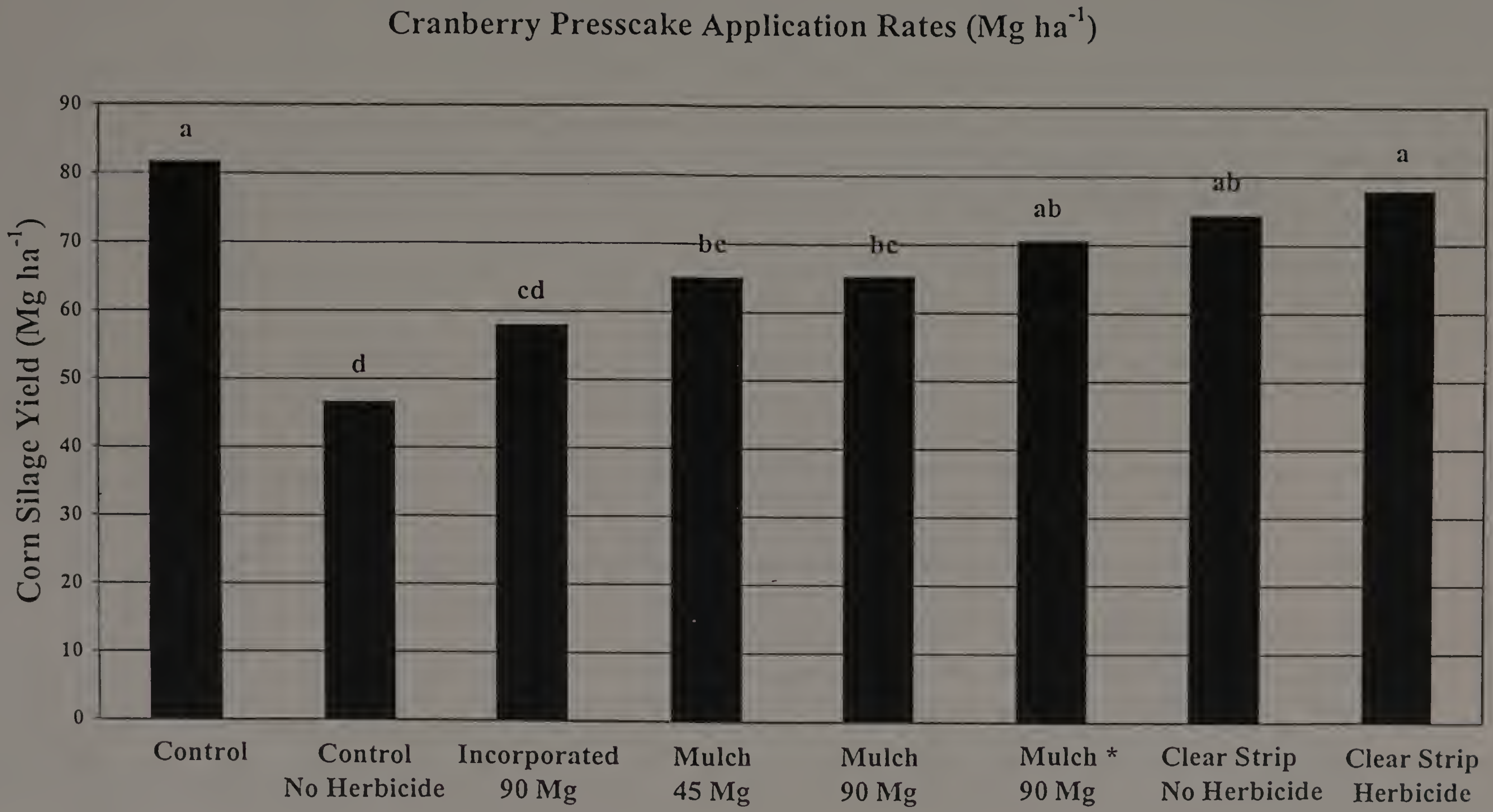

Figure 4.3 Silage yield (70% moisture). The "Mulch * 90 Mg" refers to treatment where corn was planted after spreading the mulch. Treatments with the same letter were not significant at the LSD>0.05 level.

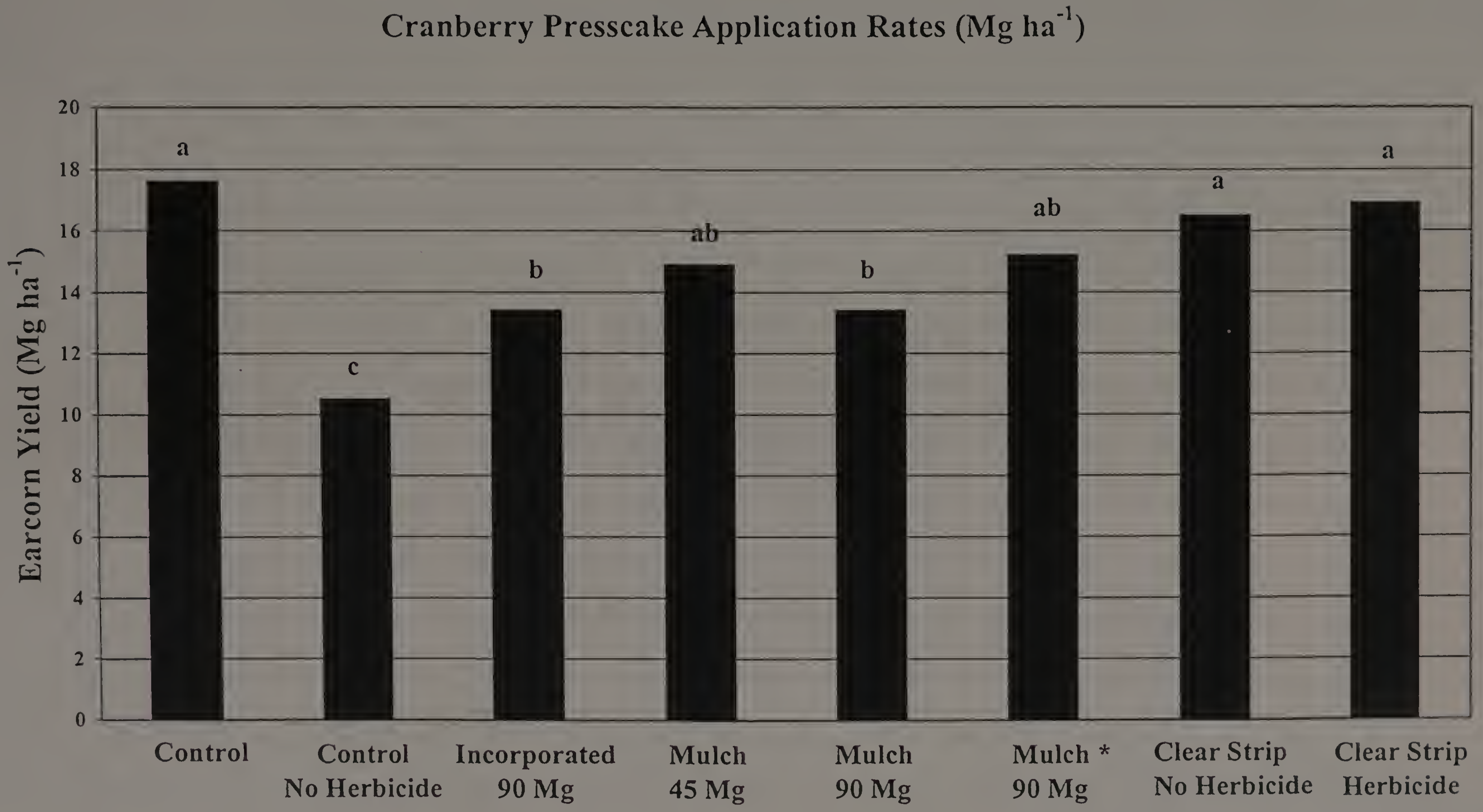

Figure 4.4 Earcorn yield (25% moisture). The "Mulch * 90 Mg" refers to treatment where corn was planted after spreading the mulch. Treatments with the same letter were not significant at the LSD>0.05 level.

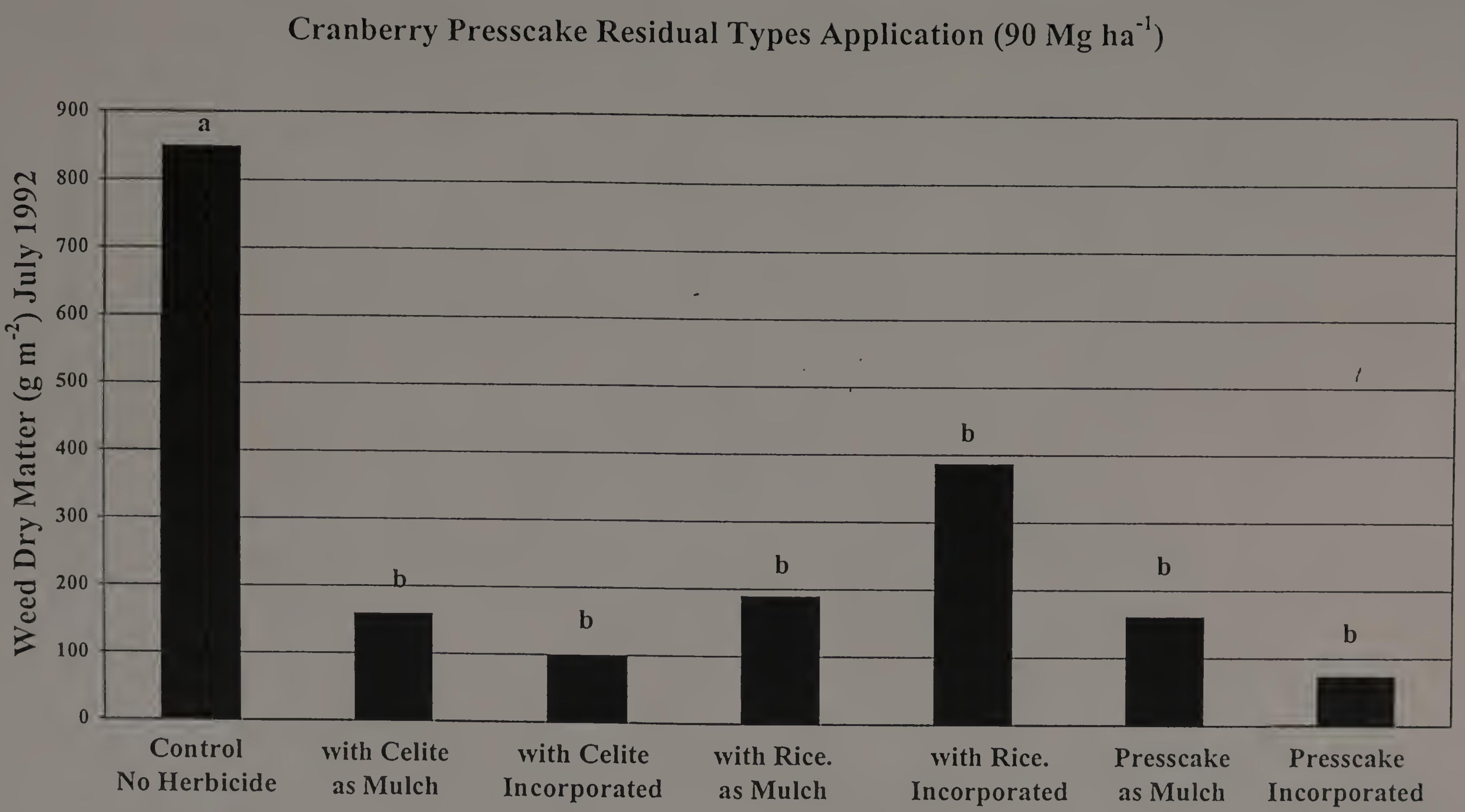

Figure 4.5 Weed biomass determined 9 weeks after corn seeding for check, mulch, and incorporated treatments. Treatments with the same letter were not significant at the LSD>0.05 level.

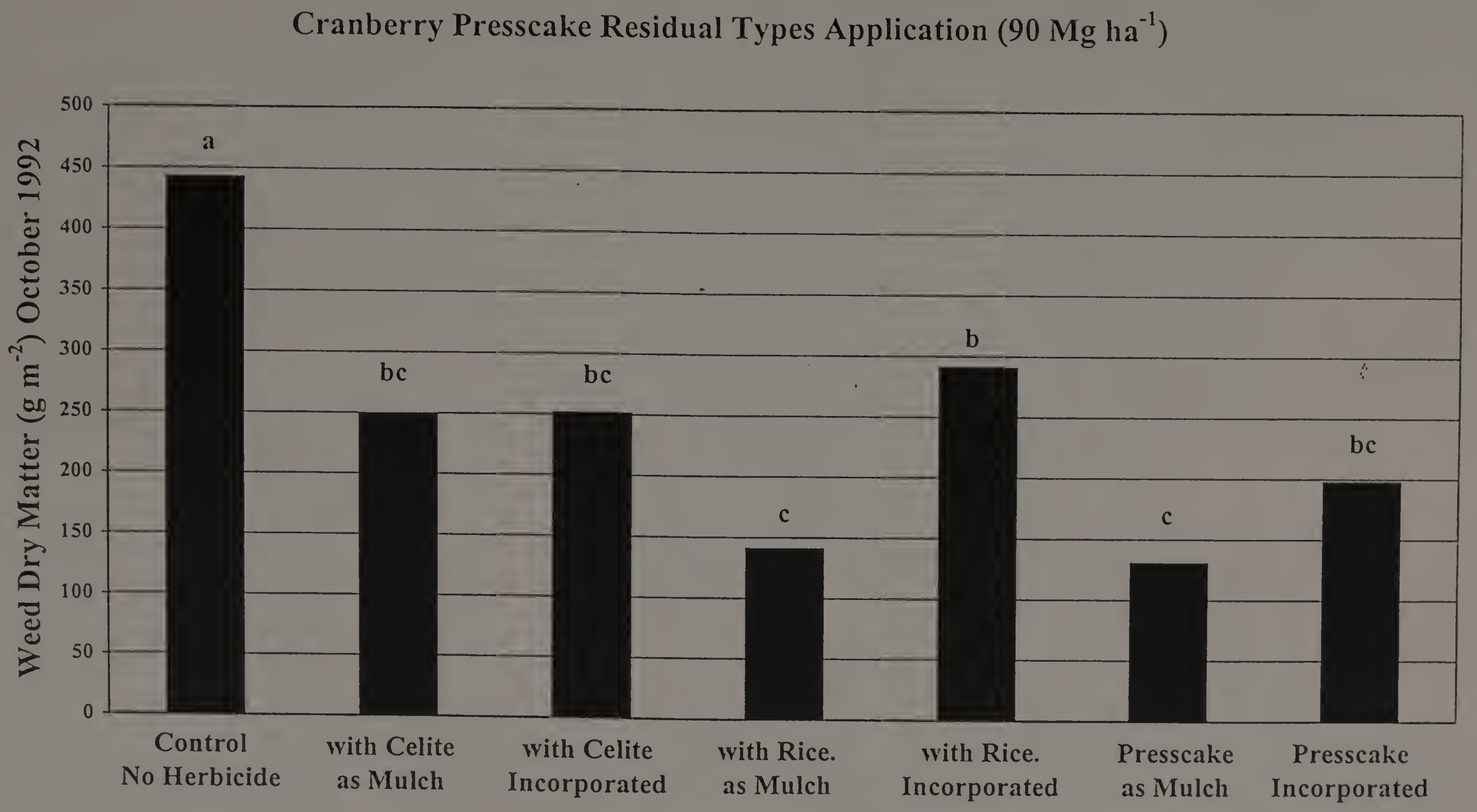

Figure 4.6 Weed biomass determined after corn harvest in early October 1992. Treatments with the same letter were not significant at the LSD>0.05 level.

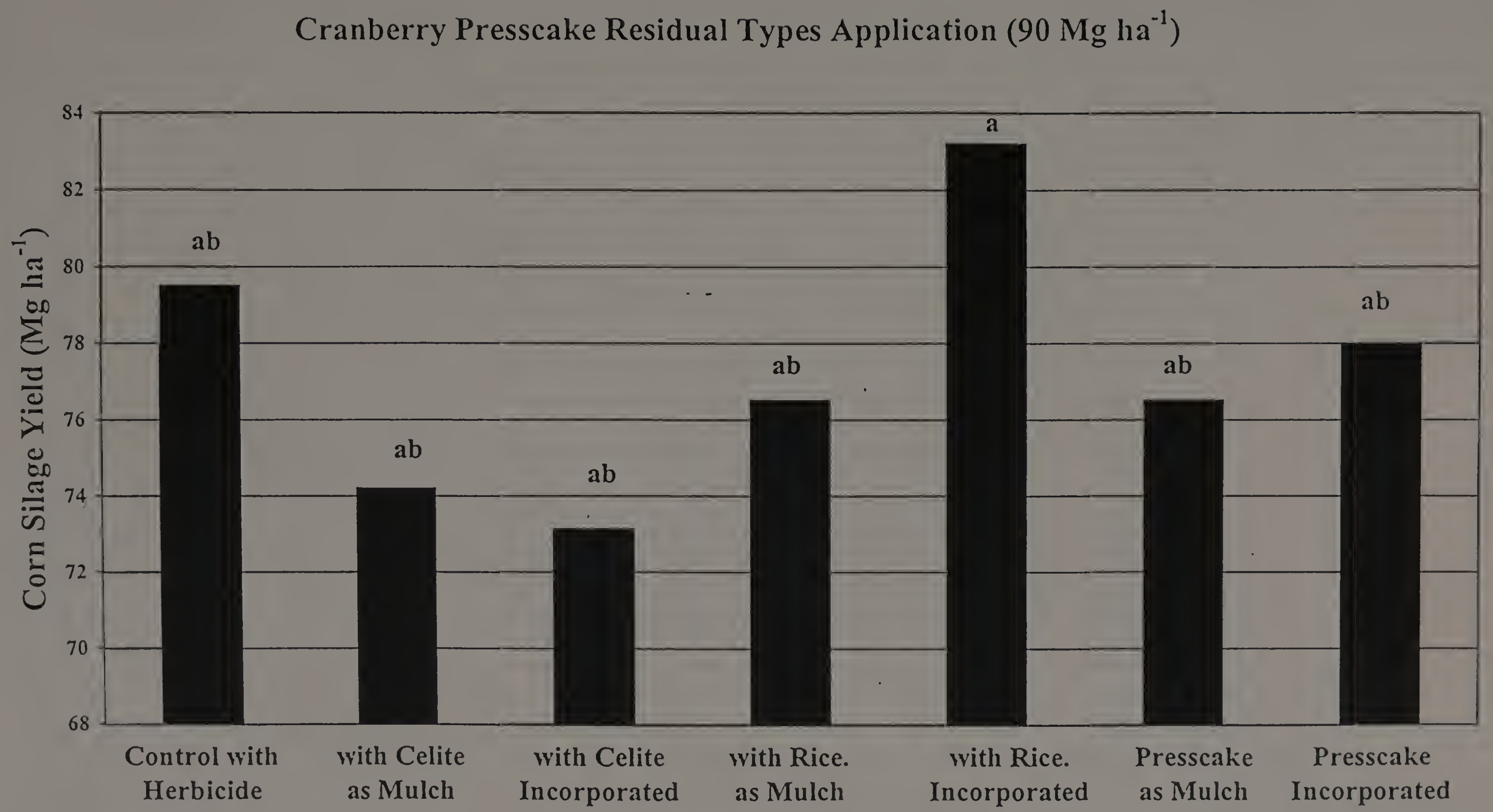

Figure 4.7 Silage yield (70% moisture). Treatments with the same letter were not significant at the LSD>0.05 level.

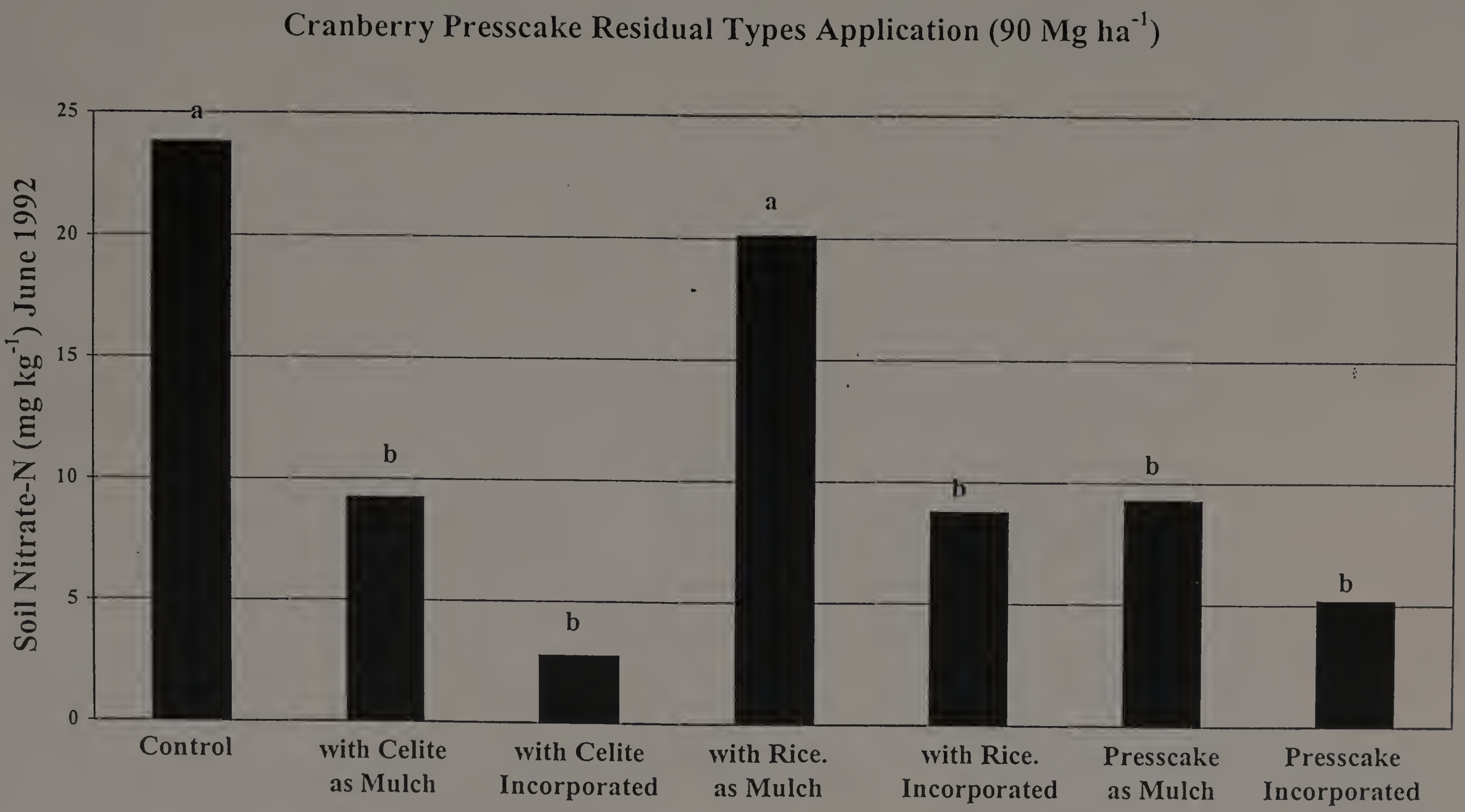

Figure 4.8 June 1992 pre-sidedress soil nitrogen test results for three types of cranberry presscake residuals in field corn. Treatments with the same letter were not significant at the LSD>0.05 level.

BIBLIOGRAPHY

Allison, F.E. 1973. Soil organic matter and its role in crop production. Elsevier Science Publishing Co., New York, NY.

Allison, F.E. and C.J. Klein. 1962. Rates of immobilization and release of nitrogen following additions of carbonaceous materials and nitrogen to soils. Soil Sci. 93:383-386.

Allison, F.E., R.M. Murphy and C.J. Klein. 1963. Nitrogen requirements for the decomposition of various kinds of finely ground woods in soil. Soil Sci. 96:187-190.

Bohn, H.L., B.L. McNeal, and G.A. O'Connor. 1985. Soil Chemistry. 2nd ed. Macmillan, New York, NY.

Brady, N.C. 1990. The Nature and Property of Soils. 10th ed. Macmillan, New York, NY.

Bremner, J.M. 1965. Inorganic forms of nitrogen. p. 1179-1237. *In* C.A. Black et al. (ed.) Methods of soil analysis. 1st. ed. Agronomy Monograph 9. American Society of Agronomists. Madison, WI.

Brinton, W.F., Jr. 1985. Nitrogen response of maize to fresh and composted manure. Biol. Agric. Hortic. 3:55-64.

Broadbent, F.E. 1986. Effects of organic matter on nitrogen and phosphorous supply to plants. *In:* The Role of Organic Matter in Modern Agriculture. Martinus Nijhoff Publishers. Dordrecht, Netherlands.

Chaney, D.E., L.E. Drinkwater and G.S. Pettygrove. 1992. Organic Soil Amendments and Fertilizers. Univ. Calif. Pub. #21505. Univ. Calif., Davis, CA.

Cochran, W.G. and G.M. Cox. 1957. Experimental Designs. 2nd Ed. John Wiley and Sons, Inc., N.Y.

Dennis, J.M. 1953. Spray irrigation of food processing wastes. Sewage and Indust. Wastes. 25:591-595.

Dick, W.A. 1983. Organic carbon, nitrogen and phosphorous concentrations and pH in soil profiles as affected by tillage intensity. Agron. J. 47:102-107.

Dolar, S.G., J.R. Boyle and D.R. Keeney. 1972. Paper mill sludge disposal on soils: effects on the yield and mineral nutrition of oats (*Avena sativa* L.). J. Environ. Qual. 1(4):405-409.

Eck, P. 1990. The American Cranberry. Rutgers University Press. New Brunswick, NJ. 420 pp.

Edwards, J.H., R.H. Walker, N. Lu, and J.S. Bannon. 1993. Applying organics to agricultural land. Biocycle. 34(5):48-50.

Fellers, C.R. and W.B. Esselen. 1955. Cranberries and cranberry products. Mass. Agr. Exp. Sta. Bull. No. 481.

Gambrell, R.P. and T.C. Peele. 1973. Disposal of peach cannery waste by application to soil. J. Environ. Qual. 2(1):100-104.

Hall, C.J. 1941. Cape Cod winds gave idea of cultivation of the cranberry. Cranberries—The Nat. Cranberry Mag. 6(1):4.

Helling, C.S., G. Chesters, and R.B. Corey. 1964. Contribution of organic matter and clay to soil cation exchange capacity as affected by pH of the saturating solution. Soil Sci. Soc. Am. Proc. 28:517-520.

Herbert, S.J., J. Daliparthy, G. Litchfield, F.X. Mangan, and B. Germond. 1991. Massachusetts Agronomy Report. University of Massachusetts Extension Bulletin.

Herbert, S.J., J. Daliparthy, G. Litchfield, F.X. Mangan, and T. Akin. 1993. Massachusetts Agronomy Report. University of Massachusetts Extension Bulletin.

Hunt, P.G. and T.C. Peele. 1968. Organic matter removal from liquid peach waste by percolation through soil and interrelations with plant growth and soil properties. Agron. J. 60:321-323.

Keeney, D.R. and R.B. Corey. 1963. Factors affecting the lime requirement of Wisconsin soils. Soil Sci. Soc. Am. Proc. 27:277-280.

Khaleel, R., K.R. Reddy, and M.R. Overcash. 1981. Changes in soil physical properties due to organic waste applications: a review. J. Environ. Qual. 10(2):133-141.

Koch, D.W. and G.O. Estes. 1986. Liming rate and method in relation to forage establishment. Crop and soil responses. Agron. J. 78:567-571.

Larson, W.E., C.E. Clapp, W.H. Pierre, and Y.B. Morachan. 1972. Effects of increasing amounts of organic residues on continuous corn: II. Organic carbon, nitrogen, phosphorous, and sulfur. Agron. J. 64:204-208.

Magdoff, F.R. and R.J. Bartlett. 1985. Soil pH buffering revisited. Soil Sci. Soc. Am. J. 49:145-148.

Mays, D.A., G.L. Terman, and J.C. Duggan. 1973. Municipal compost: effects on crop yields and soil properties. J. Environ. Qual. 2(1):89-92.

McClean, E.O. 1982. Soil pH and lime requirement. pp. 199-224. *In:* Agronomy Monograph no. 9 (2nd ed.) ASA-SSSA. Madison, WI.

Morachan, Y.B., W.C. Moldenhauer, and W.E. Larson. 1972. Effects of increasing amounts of organic residues on continuous corn: I. Yields and physical properties. Agron. J. 64:199-203.

Munns, D.N. 1969. Short communications. Enzyme breakdown of pectin and acid inhibition of the infection of *Medicago* roots by *Rhizobium*. Plant Soil 30:117-119.

Munns, D.N. 1970. Nodulation of *Medicago sativa* in solution culture. V. Calcium and pH requirements during infection. Plant Soil 32:90-102.

Pal, D., and F.E. Broadbent. 1975. Influence of moisture on rice straw decomposition in soils. Soil Sci. Soc. Am. Proc. 39:59-63.

Parr, J.F. and S.B. Hornick. 1992. Agricultural use of organic amendments: a historical perspective. Amer. J. Alternative Agric. 7(4):181-189.

Rechcigl, J.E., D.D. Wolf, R.B. Renau, Jr., and W. Kroontje. 1985. Influence of surface liming on yield and nutrient concentration of alfalfa established using no-tillage techniques. Agron. J. 77:956-959.

SAS Institute. 1988. SAS/STAT user's guide. Version 6.03. SAS Inst. Cary, NC.

Stevenson, F.J. 1982. Humus chemistry. John Wiley & Sons. New York. 443 pp.

Stevenson, F.J. 1986. Cycles of soil. John Wiley & Sons. New York. 380 pp.

Tate, R.L. III. 1987. Soil organic matter--Biological and ecological effects. John Wiley & Sons. New York.

Technicon Instruments Corp. 1977. Technicon AutoAnalyzer II Industrial Method no. 334-74W/B. Technicon Instruments Corp., Tarrytown, NY.

Terman, G.L., J.M. Soileau, and S.E. Allen. 1973. Municipal Waste Compost: Effects of crop yields and nutrient content in greenhouse pot experiments. J. Environ. Qual. 2(1):84-89.

Tester, C.F. 1990. Organic amendment effects on physical and chemical properties of a sandy soil. Soil Sci. Soc. Am. J. 54:827-831.

Tester, C.F., L.J. Sikora, J.M. Taylor and J.F. Parr. 1982. Nitrogen utilization of tall fescue from sewage sludge compost amended soils. Agron. J. 74:1013-1018.

Troeh, F.R., and Thompson, L.M. 1993. Soils and Soil Fertility. 5th ed. Oxford University Press, New York, NY.

United States Department of Agriculture (USDA). 1991. New England Agricultural Statistics. Pg. 36. USDA, Durham, NH.

van de Kaamp, M. 1986. Apple pomace can be productive. Biocycle. 27(3):39.

Walkley, A. and I.A. Black. 1934. An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Sci. 37:29-38.

Waksman, S.A. 1942. The microbiologist looks at soil organic matter. Soil Sci. Soc. Am. Proc. 7:16-21.

Young, C.E., B.M. Crowder, J.S. Shortle, and J.R. Alwang. 1985. Nutrient management on dairy farms in southeastern Pennsylvania. J. Soil Water Conserv. 40:443-445.