THE RESPONSE OF ORCHARDGRASS-LADINO CLOVER TO THE APPLICATION OF HIGH-RISE POULTRY MANURE IN THE LOWER FRASER VALLEY

by

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ABSTRACT

Approximately 86% of the poultry population of British Columbia is concentrated in the lower Fraser Valley. Because many of these operations are located on small land areas adjacent to suburban developments, the management of the poultry manure is a major problem. Landspreading is still the most widely practised way of handling poultry manure. The objectives of this study were to determine maximum disposal rates and optimum fertilizer rates of high-rise poultry manure on orchardgrass and orchardgrass-clover forage. Experimentation with poultry manure rates of 1.25 to 40 tonnes per hectare applied to orchardgrass and orchardgrass-clover forage was carried out in the Chilliwhack district of the lower Fraser Valley over a 2-year period. The poultry manure contained 5.1, 2.5 and 2.0% N, P and K respectively in 1975, and 3.5, 1.6 and 1.4% N, P and K respectively in 1976, with coefficients of variation from 5 to 40%. The N:P:K ratio in the manure indicated that K and P (in some cases) would be limiting if the manure was applied to meet the N requirements of the crop.

The recommended rate of poultry manure determined for disposal was 20 t/ha/year on orchardgrass forage. A poultry manure rate of 10 t/ha/year on orchardgrass forage is recommended to efficiently utilize the N resource of the manure as a fertilizer. A poultry layer operation of 2500 hens would require 3.6 ha of orchardgrass forage to dispose of the poultry manure produced in one year and 7.3 ha of orchardgrass forage to utilize the manure efficiently as a fertilizer.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

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I. INTRODUCTION

Poultry manure management has become a major problem in the lower Fraser Valley of British Columbia. Confinement poultry houses located on small land areas (usually less than five hectares) combined with the spread of suburban developments into traditional agricultural areas and the high cost of transporting fresh poultry manure, has led to the stockpiling of the manure. As a result, environmental problems, mainly nitrate runoff into surface streams, nitrate leaching into the groundwater, odor and insect proliferation and the elimination of plant cover have occurred.

About 86% of the poultry population of B.C. is concentrated in the lower Fraser Valley. In 1975, the poultry population of B.C. was 26,640,000 birds consisting of 21,000,000 broiler chickens, 4,100,000 layer hens and pullets, and 1,500,000 turkeys, geese and ducks (Anon., 1974; Anon., 1976; Anon., 1977). The main egg producing area is centered in the Matsqui Municipality around Abbotsford. High-rise poultry houses with electric fans circulating air over the fresh droppings under the cages is one of the most common systems utilized by poultry producers in the lower Fraser Valley. This system is economical to run with low energy and labor costs. It allows the manure to be dried down to less than 30% moisture and conserves high quantities of N. The poultry manure is easy to remove from the house and odor and insect proliferation - a major problem when cleaning out poultry houses in populated areas - is virtually eliminated. Also, transporting the poultry manure is less costly when the moisture content is lower. With rising costs of N fertilizers and increasing difficulty in obtaining inorganic N, poultry manure from the high-rise poultry houses could be an easily accessible, economic source of plant nutrients, particularly N for the lower Fraser Valley.

The objectives of this study were:

(a) To determine the rates of poultry manure which provide sufficient N for optimum yield of orchardgrass-clover and orchardgrass forage;

(b) To determine the maximum disposal rates of the poultry manure with minimum nitrate leaching losses and no decrease in yield.

The maximum disposal rates were studied only as a short-term alternative to alleviate a possibly serious pollution problem. Utilizing the poultry manure effectively in crop production must be considered as the major long-term objective.

II. LITERATURE REVIEW

A. Poultry Manure Characterization

1. Production and Composition

Several workers (Yushok and Bear, 1943; White *et al*., 1944; Papanos and Brown, 1950) have reported a consistent rate of manure produced by laying hens of 63.6 kg of manure per bird per year. This would mean in a layer operation of 10,000 hens that greater than 600,000 kg of manure would be produced annually.

The nutrient composition of poultry manure is extremely variable and any general statements on the nutrient status of poultry manure can be misleading. The use of mean percentages for the major nutrients from several unrelated sources of manure produced under different conditions can give false values for the major nutrients. This can make disposal or fertilizer rates subject to large error (Wallingford *et al*., 1975).

There are many factors which contribute to the variability found in poultry manure. Three of the more important factors are feed rations and the type of poultry house and the manure handling system used (Perkins *et al*., 1964; Ostrander, 1975). Feed rations are the source of plant nutrients found in the manure so consequently the composition of the manure is directly related to the feed ration. Working with white leghorn hens over a two year period, Yushok and Bear (1943) found that 81% of the N, 88% of the P and 95% of the K in the feed was voided in the manure. Only 19%, 12% and 5% of the N, P and K respectively went into the production of the hen itself and the eggs. Of the dry matter contained in the feed, 56% is digested by the hen and the remaining 44% is voided in the manure (White et al., 1944). Therefore, in fresh hen droppings, with no litter, the concentration of N, P and K on a dry weight basis is actually increased from the initial feed consumed by the hen.

Ostrander (1975) indicates moisture content and nutrient content, particularly N, are affected by poultry house type and the handling system used. The high-rise poultry house is one of the least costly systems and most efficient in the use of labor. The house is built above ground with a concrete floor. Drying of the manure underneath the cages can be enhanced by using electric fans to circulate air over the manure cones formed or by using the slat system to increase the surface area of the manure exposed for drying (Ostrander, 1975; Elson and King, 1975). The moisture content should be below 30%, reducing odor and insect germination and making for easier handling. Other dry systems include in-house drying or dehydration. There are also several liquid systems which will affect manure composition.

Other factors which affect poultry manure composition include species of bird, bird density, age and physiological status of the bird, kind, amount and depth of litter (if any), climate, poultry house conditions, and age of the manure (Eno, 1962; Moore et al., 1964; Perkins et al., 1964; Hileman, 1967; El-Sabben et al., 1969). Hileman (1967) and El-Sabben et al. (1969) conclude that because of these factors and the interaction of many of these factors, it is very difficult to predict the composition of manure or litter. An indication of the general range and the variability of the N, P and K content in poultry manure is shown in Table I. The values are expressed as percent dry matter and range

Table I: Poultry manure or litter composition from data in the literature.

Description	Moisture	N	P	K	Source
	------% Dry Weight --------				
laying hens, fresh manure	77.8	1.05	0.36	0.42	Yushok and Bear, 1943
laying hens, 1-2 wks. old	66.8	1.41	0.45	0.47	Yushok and Bear, 1943
laying hens, old litter	47.2	1.83	0.62	0.63	Yushok and Bear, 1943
hen manure, 6 mo. accum.	15.8	2.79	1.24	1.23	White *et al.*, 1944
fresh undiluted hen droppings	-	1.13-1.75	0.36-0.71	0.31-0.65	Papanos and Brown, 1950
fresh droppings, laying hens	20-27	3.5-6.0	1.5-2.0	1.3-2.1	Tinsley and Nowakowski, 1959
fresh manure	76	6.73	1.98	1.68	Eno, 1962
10 wk. manure	68	3.64	2.64	2.29	Eno, 1962
laying hens, fresh manure	-	3.70	1.66	1.66	Moore *et al.*, 1964
broiler litter (after 1 brood)	-	3.37	1.47	1.42	Moore *et al.*, 1964
broiler litter (197 samples)	11.0-68.0	1.10-6.74	1.37-6.25	1.37-4.80	Hileman, 1967
Average	29.0	4.11	1.45	2.18	
broiler manure (82 samples)	24.9	2.27	1.07	1.10	Perkins and Parker, 1971
hen manure (31 samples)	36.9	2.00	1.91	1.88	Perkins and Parker, 1971
deep litter	6-71	0.3-3.5	.04-2.3	0.17-2.1	G.W. Cooke, 1972
broiler litter	9-75	0.4-3.6	.09-1.7	0.25-2.0	G.W. Cooke, 1972
batter	12-88	0.5-4.5	.13-2.1	0.17-3.3	G.W. Cooke, 1972
poultry manure, slat dried	15.0	4.9	2.1	2.3	Elson and King, 1975
poultry manure, deep pit I (Avg. 0-90 cm)	67.2	3.12	3.49	2.2	Bomke and Lavkulich, 1975

Continued ....

Description	% Dry Weight: Moisture	N	P	K	Source
deep pit II (Avg. 0-75 cm)	69.1	5.34	3.17	1.5	Bomke and Lavkulich, 1975
Stored, high-rise poultry manure 1975	22.5	5.08	2.51	2.02	Maynard, 1978[1]
1976	23.1	3.53	1.60	1.44	Maynard, 1978

[1]Mean values of the manure used in this study.

from six to 77.8% moisture; 1.05 to 6.74% N; 0.04 to 6.75% P; and 0.17 to 4.80% K.

2. Forms of Nitrogen

The forms of N in fresh manure include a range of 40 to 70% of the total N as uric acid and 5 to 10% as ammonia. The remainder of the N is as complex nitrogenous compounds of varied composition. In accumulated droppings, investigators found ammonia accounted for 42 to 43% of the total N (Papanos and Brown, 1950). In one-month-old droppings, 40 to 45% total N was in the ammoniacal form (Eno, 1962). Under warm, moist conditions, uric acid is readily converted to ammonia. Burnett and Dondero (1969) found extended storage of poultry manure resulted in a rapid decrease in uric acid accompanied by ammonia and aliphatic amine production. Ammonia evolution peaked after only five days and amine content after 14 days. In both cases, uric acid content decreased rapidly over the first seven days. A variety of aerobic and anaerobic bacteria associated with manure are capable of decomposing uric acid contained in freshly excreted poultry manure.

Phillips et al. (1978) found that 23 to 24% of the total N in stored high-rise poultry manure was in the ammoniacal form. The manure had been stored for at least one year and had probably composted during this time. This accounts for the higher ammonium content than is generally found in fresh hen manure. Lower ammonium values in the one-year-old manure compared to one-month-old hen manure could be the result of additional composting, tying up the ammonium N in complex compounds.

3. Nitrogen Mineralization from Poultry Manure

Manure-N mineralization in the soil is similar to N mineralization from soil organic matter. The environmental factors (pH, temperature, microbial populations, etc.) all affect N mineralization from manure. Mineralization of manure N is also influenced by the decomposition status of the manure and the form of the manure N.

As mentioned previously, between 40 and 70% of the total N in fresh hen manure is in the form of uric acid and it is readily converted to ammonia. Thus, in fresh hen manure it would be expected that a large portion of the total N is readily mineralized upon contact with the soil.

Pratt et al. (1973) suggested that 90% of total N is available in the first year of application, assuming the N is largely in the form of urea or uric acid. After five years only an additional two percent of the total N was mineralized. It should be noted that these values were not field-tested and are assumptions based on the author's experience with decomposition studies. Turner (1975) suggested that 75% of the total N is available in the first year and 93% after five years. Again there is no reference of these values being field-tested.

The first year mineralization value of 90% is based on California conditions where the soil temperature seldom is low enough to inhibit microbial decomposition of the manure (Pratt et al., 1975). Turner's mineralization rates are applied to the climatic conditions of the Pacific Northwest. Soil temperatures in the Pacific Northwest often remain between 0 and 10^{o}C through much of the winter. Mineralization will still proceed at temperatures above 0^{o}C but at a much slower rate. Therefore, Turner (1975) indicates a lower initial mineralization rate than the

California workers suggest.

Pratt et al. (1973) and Turner (1975) indicate by their decay series that little of the remaining portion of the total N in the manure becomes available. This is probably based on the assumption that the remaining N is in complex compounds which are very stable to further rapid decomposition.

Ageing or composting fresh manure alters the N forms usually resulting in decreased mineralization. Partly decomposed material tends to be resistant to further decomposition as the more readily available sources of energy have been removed (Barrow, 1961). The decay series for aged, covered poultry manure suggested for the Pacific Northwest indicated 60% of the total N as available in the first year with 87% available after five years (Turner, 1975). Eno (1962) indicated that 30 to 60% of the total N becomes available during the first six weeks of the growing season depending upon the N content and form of N in the manure.

In controlled incubation studies, Phillips et al. (1978) studied the mineralization of N from poultry manure stored for at least one year in a high-rise poultry house. The manure was incorporated into two acid soils of the lower Fraser Valley and incubated at two temperatures, 10 and 20^{o}C. Between 53 and 65% of the total N was mineralized. Twenty-four percent of the total N was already in ammonium form, so approximately one quarter to one half of the organic N was released. Temperature, liming and soil type had little effect on the overall ammonium-N production. Most of the N was mineralized within the first week of incubation.

In stored poultry manure, usually very little nitrification occurs unless the accumulating manure is aerated. In both fresh and stored manure there is little or no nitrate present. Once poultry manure is applied to the soil, nitrification becomes important. Olsen et al. (1970) suggested that in the incubation of dairy cattle manure incorporated in an aerobic soil, the conversion of ammonium to nitrate is at least as rapid as the conversion of organic N to ammonium.

In an earlier study, it was found that very little of the total N in poultry manure added to a soil had been nitrified after one week (Papanos and Brown, 1950). The greatest percentage of total N was nitrified between the first and second week with 50% of the total N nitrifying by the end of four weeks incubation at 28^{o}C. A similar pattern for nitrification in "warm, moist" soils was suggested by Eno (1962). Nitrate production is slow during the first week increasing to a maximum by four weeks.

In the mineralization study of stored poultry manure it was found that nitrification was affected by both temperature and liming (Phillips et al., 1978). While mineralization was unchanged by the two temperatures, 10 and 20^{o}C, nitrification was adversely affected by the lower temperature. The authors felt that 10^{o}C could have an inhibitory effect on nitrification for up to two months. Tyler et al. (1959) reported similar observations while studying the effects of low temperatures in four California soils and suggested it could be due to nitrification being retarded by the lower temperatures to a greater extent than ammonification. Floate (1970b), studying the mineralization of N from sheep faeces, found that mineralization of N did not show a temperature dependence at 5, 10 or 30^{o}C.

Giddens and Rao (1975) found nitrate production was greater at lower rates of poultry manure application and when applied as one complete treatment rather than as split applications. With cattle feedlot manure, a delay in nitrification occurred with increasing manure rates (Mathers and Stewart, 1970). Giddens and Rao (1975) attributed this to ammonia inhibition of the nitrifying organisms, particularly Nitrobacter. Olsen et al. (1970) found large amounts of nitrite in the surface soil four weeks after cattle manure application to an aerobic soil. They indicated that excessive amounts of ammonia at high levels of manure could inhibit the Nitrobacter and permit nitrite accumulation. Gidden and Rao (1975) also found a decrease in nitrate production when poultry manure was surface applied rather than incorporated into the soil. This is due more to a loss of N by ammonia volatilization rather than ammonia inhibition of the nitrifying bacteria.

4. Phosphorus Mineralization from Poultry Manure

The major portion of P in poultry manure is in the organic form except for small quantities in the urates (Eno, 1962). Availability and mineralization of the organic P is variable. Eno (1962) feels that P availability is directly related to the rate of manure decomposition and that P becomes available much slower than N. Working with sheep faeces, Bromfield (1961) similarly observed that organic P was not readily available and was slow to mineralize. Floate (1970a) also using sheep faeces, found that between 3 and 34% of the original total P in the faeces had been mineralized after 12 weeks at 30^{o}C. These samples had been inoculated with a soil extract rather than incorporated in a soil. Bromfield (1961) used only distilled water to wet the manure samples, so this may account for the differences in mineralization and availability.

In incubation studies using stored poultry manure from high-rise poultry houses, it was found that between 41 and 44% of added manure P was mineralized (Phillips et al., 1978). Since 32% of the manure P was Bray P_1 extractable less than 15% of the organic P in the manure was mineralized. Parker et al. (1959), using citrate soluble P as an index of availability, found 94.1% of P available in broiler manure and 88.4% of P available in hen manure. These values are averages determined from a wide range of fresh material collected in Georgia.

The variability in P mineralization reported here may be due to the age of manure used (fresh versus stored) and the methods involved in incubation and available P determinations. In general, though, P availability and mineralization is less than N and some index of net release other than total P is needed when looking at P from either a disposal or agronomic viewpoint.

5. Potassium Availability in Poultry Manure

As in the soil, K is found mainly in the inorganic form in poultry manure, usually in inorganic salts in the excretions from kidneys and in living and dead cellular material in faeces (Eno, 1962). All forms of K salts are readily available. Parker et al. (1959) found between 86 and 88% of the total K is water soluble.

B. Landspreading of Poultry Manure

1. Introduction

Most animal wastes have been and will continue to be disposed of on land (Stewart, 1968; Loehr, 1972; Wallingford et al., 1975). In the past, most farms were integrated farms (combined livestock and crop production) and were self-sufficient operations. They could spread all their manure on their own land and insufficient manure was a greater problem than oversupply (McIntosh and Varney, 1973). This was previous to the advent of inexpensive, easily available and easy to handle inorganic fertilizers, particularly N fertilizers (Pratt et al., 1973).

By the mid-fifties, inexpensive inorganic fertilizers were easy to obtain and manures were considered low value fertilizers and regarded as liabilities rather than assets (McCalla, 1974). The value per unit of manure was too low to warrant transporting the manure to areas where it could be used (Turner, 1975).

Confined animal production operations were developed during this time to meet the demands for increased efficiency and animal production. Between 1941 and 1966 the number of farms in Ontario was drastically reduced by 57, 65 and 50% for swine, poultry and dairy cattle, respectively, while the number of animals was increased (number of dairy cattle decreased slightly) (Townshend et al., 1969). Similarly, in the United States there was one half the number of farms in 1969 as in 1940 supplying their agricultural needs (Loehr, 1972). By 1972 nearly 100% of the United States commercial egg production was from confinement poultry houses (Loehr, 1972). Because of this, large amounts of manure have accumulated in small areas with no place to dispose of it. The problem has been accentuated by the expansion of urban and suburban developments into former agricultural areas (Zindel and Flegal, 1970).

During the 60's and the early 70's, most researchers considered animal manures waste and only the technological and economical problems of disposal were considered. Little work was done with regard to the conservation of the nutrients in manures. Moore et al. (1964) stated that "the greatest loss from manure is in the N content but since N is one of the cheaper of the fertilizer elements it's loss appears of minor importance when weighed against manure handling problems".

In recent years, the high cost and short supply of commercial fertilizers particularly N has stimulated a new interest in manures as a nutrient source. Furthermore, the increased awareness of the short supply of the fossil fuels, from which many N fertilizers are derived, has led to a change in attitudes. Jackson et al. (1977) state that "in view of environmental concern and high costs of fertilizers, the disposal of broiler litter is to be discouraged. However, the utilization of litter at recommended rates for its nutrient value is encouraged".

Landspreading is one of the most widely used systems of manure handling and is possibly the most practical at this time with regard to poultry manure. Landspreading of manure (to dispose of it) is "the incorporation of wastes to the land in a controlled land management program so that the applied wastes do not contribute to additional environmental quality problems such as contamination of groundwater, pollution caused by excessive runoff, odor or insect germination" (Loehr, 1972). Utilization of poultry manure as a fertilizer involves the landspreading of manure, coupled with crop production to maximize crop yields with the optimum nutrient supply. It is the conservation of the nutrient resources derived from the manure. Normally, N is the limiting factor from either a disposal or utilization viewpoint (Jones, 1969).

2. Land Disposal of Poultry Manure

a) Introduction

The problems that must be considered when determining land disposal rates are: runoff pollution, salinity, groundwater pollution, odor, insect germination, metal toxicities and pathogen hazards (Hileman, 1967; McCalla, 1974). Nutrient imbalances and animal health problems are sometimes considered in determining land disposal rates but are usually only included when looking at the agronomic value of poultry manure. Soil nitrate and soluble salts are the two soil chemical properties which have received the most attention (Wallingford *et al*., 1975). For the purposes of this review, the discussion on land disposal will be limited to these two problems.

b) Soluble Salts

Mathers and Stewart (1970) suggest that the disposal rate of manures should not impair yield, since that would eliminate a way of removing N from the soil system. It has been suggested that soil salinity due to excess soluble salts in poultry manure is the main cause of yield reduction. Shortall and Liebhardt (1975) indicated that there was a good correlation between soil salinity and tonnes of poultry manure. They suggest that excessive soluble salts are the primary cause of the yield reduction when high rates of poultry manure are applied to soil. K is considered the primary soluble salt responsible for salinity in heavy applications of poultry manure (Liebhardt and Shortall, 1974; Wallingford *et al*., 1975). Liebhardt and Shortall (1974) found a very significant correlation between K extractable with water and electrical conductivity of a manured soil.

Jackson et al. (1975) applied excessive rates of poultry litter on established fescue stands. They found depressed yields at 45 t/ha/year, and indicated that the mechanism for yield reduction was probably due to the smothering effect on the fescue from the heavy manure applications. The healthy appearance of the surviving species indicated very little evidence of direct salt damage. Vandepopuliere et al. (1975), also indicated that yield reductions of fescue stands occurred at poultry manure rates in excess of 44.8 t/ha/year. They suggested that the reduction was due to the killing or stunting of the plant growth but gave no indication of the mechanism.

Hensler et al. (1970) found that excessive rates of dairy cattle manure on unlimed soils caused a marked reduction in the yield of the first crop but an enhancement in yield of the remaining two crops. They felt that the yield reduction was due to an ammonium induced Ca deficiency (malfunction of the terminal bud). In earlier work, Olsen et al. (1970) found 220 ppm and 440 ppm of exchangeable ammonium-N in the surface soil within four days after application of the two highest rates of dairy cattle manure. Hensler et al. (1970) assumed that these high levels of ammonium were the main cause of the low initial yields. In the following crops and in the limed soils, little or no reduction of crop yield at the same rates of manure was observed.

Soluble salts, particularly the K^+ ion, were a major cause of yield reduction in corn and cool season grasses fertilized with poultry manure. The smothering effect of heavy rates of poultry manure and ammonium toxicity may also be important in yield reductions.

c) Nitrate Leaching

The accumulation and downward movement of nitrate in the soil has been reported as a potential threat to groundwater quality and animal and human health (Wallingford et al., 1975). Excessive nitrate ingestion by mammals is undesirable for two reasons: (i) possible metabolic conversion to nitrite which can cause methaemoglobinaemia, especially in infants and in the presence of high amine diets or amine-derived drugs, and (ii) possible hepatoxic action and the formation of alkyl nitrosamines which have carcinogenic properties (Winteringham, 1974). Nitrate is also a factor in eutrophication of inland water bodies and hence is a possible threat to certain aquatic fish species (Winteringham, 1974). The World Health Organization (WHO) has established 10 ppm nitrate-N (45 ppm nitrate) as the maximum permissible concentration of nitrate in drinking water.

Active growing plants act as a "sink" for most nutrients by metabolizing them (Kläusner et al., 1971). The crop used should produce large amounts of vegetative growth, be tolerant of high fertility levels, and remove relatively large amounts of nutrients in the harvested portion (Hensler et al., 1970). Long season crops such as grasses present less opportunity for nitrate leaching than do annual crops such as corn and soyabean (Viets, 1974).

In some cases, nitrate will leach if the N applied in the manure is greater than that used by plants, and at other times no significant leaching occurs even after excess N is added to a crop. Wallingford et al. (1975) suggested that the varied results reported on nitrate leaching in soils after manure applications is due to different leaching volumes and variations in the complicated factors of ammonia volatilization, nitrification and denitrification.

Adriano et al. (1974) indicated that 50% of N from cattle feedlot manure applied to uncropped land can be lost through ammonia volatilization within a few weeks. Lauer et al. (1976) suggested that large quantities of ammonia may volatilize from manure in certain weather conditions. General evaporative conditions and precipitation appear to be the principle determinants of ammonia volatilization under field conditions. Therefore, with surface applied manures, a large percentage of the total N may be lost due to ammonia volatilization and will not be subject to leaching. In addition, the ammonia produced may inhibit the nitrite oxidizing bacteria preventing nitrification (Giddens and Rao, 1975). Other conditions affecting nitrification from poultry manure were discussed earlier.

Denitrification could also be responsible for a more significant portion of nitrate losses than leaching from manured soils during a growing season. Kimble et al. (1971), using dairy manure, found a decreasing NO_3/Cl ratio at all depths from spring to fall which suggests that something other than leaching was responsible for the loss of nitrate. They indicate that it probably was denitrification.

Ammonia volatilization, nitrification and denitrification are difficult to measure, especially when heavy rates of N are added in poultry manure. This makes land disposal rates difficult to predict. Thus, the best way to avoid nitrate leaching is to apply rates of poultry manure that do not provide N in excess of crop use.

3. Utilization of Poultry Manure as a Fertilizer

a) Introduction

Yield and quality of forage are the important considerations in the utilization of poultry manure as a fertilizer. Botanical and chemical composition are two quality components that may be adversely affected by manure application. Nitrate leaching and salinity problems, important in land disposal, should be of little concern if the manure is applied to optimize forage yields.

b) Yield

The effects of fertilizer applications (manure or inorganic) on the yield of orchardgrass and orchardgrass-clover mixtures are complicated by many management factors. Nitrogen rates, time of application, cutting frequency, K levels and botanical composition are the major factors involved (Gardner *et al.*, 1960).

(i) Effects of Nitrogen

Orchardgrass has a high N requirement and N fertilization is usually necessary to obtain high forage yields (Singh *et al.*, 1967; George *et al.*, 1973). Orchardgrass yields normally range from 6.5 to 13 t/ha/year in temperate climates of North America (Maas *et al.*, 1962; Alexander and McCloud, 1962; Schmidt and Tempas, 1965).

Several researchers have investigated the optimum N rates for maximum orchardgrass yields under various management and environmental conditions. Optimum N rates as inorganic fertilizers range from 224 kg N/ha/year to 672 kg N/ha/year (Mortensen *et al.*, 1964; George *et al.*, 1973). With the exception of a few studies, N fertilizer rates of between 225 and 340 kg

N/ha/year produced optimum orchardgrass yields. Donohue et al. (1973) indicated that 250 kg N/ha/year should be applied for optimum orchardgrass yields with minimal N losses on a Crosby silt loam soil.

Climatic conditions, inherent soil fertility and management practices may effect the optimum N rates required. Mortensen et al. (1964) found that increasing the frequency of cuts from three to five increased the elemental N required to produce the same amount of dry matter from 224 kg N/ha/year to 336 kg N/ha/year. Donohue et al. (1963) found that in drought conditions for one year, N rates up to 336 kg N/ha/year increased yields. The following year was cool during the normally hot dry months of July and August and yields increased only up to N rates of 168 kg N/ha/year.

Hileman (1967), using broiler litter as the N source, found 9 t/ha was the optimum rate of application for maximum fescue production. This rate of manure supplied 394 kg N/ha/year. At 18 t/ha, 790 kg N/ha was supplied to the fescue with no additional yield. In Georgia, 9 t/ha of poultry litter supplying between 180 and 336 kg N/ha was considered optimum to produce 10 to 12 t/ha of dry fescue forage or nearly 12 t/ha of hay/ha/year (Williams et al., 1972). Parker (1966) found that 9 t/ha of poultry manure gave optimum responses on orchardgrass-clover stands. This rate supplied 152 kg N/ha and produced 6.52 t/ha of dry forage. The average forage yield increase per tonne of manure decreased as the rate of manure increased. The average increase per tonne was 317, 232 and 192 kg of forage/ha, respectively, for 9, 18 and 26.9 tonnes of manure/ha. Vandepopuliere et al. (1975) applied poultry manure at rates of 22.5, 44.9, 67.4 and 89.8 t/ha to fescue pasture. This supplied 216, 431, 647 and 862 kg N/ha/year, respectively. The total forage yield for three harvests was

14.4 t/ha for the 22.5 tonnes manure/ha and 16.1 tonnes of dry matter/ha for the 44.9 t/ha rate.

Parker and Perkins (1971) found that broiler litter was only 55 to 65% as efficient as NH_4NO_3 when the manure was applied to coastal bermudagrass sod. Vandepopuliere _et al_. (1975) compared the amount of dry matter produced by manure treated plots to that produced by a chemical fertilizer. The chemical fertilizer supplied 339 kg N/ha and yielded 16.9 t/ha of dry forage. An equivalent amount of N/ha supplied by manure would yield approximately 15.3 t/ha of dry matter. Thus, the poultry manure N was about 90% as efficient as the chemical fertilizer in the production of dry matter.

Two-thirds or more of the total annual yield of dry matter in cool season grasses is produced during the cooler weather of May and June in temperate North America (Wedin, 1974). Heavy spring applications of N and favorable weather conditions at this time of year are the main reasons. Parker (1966) found that with medium to high rates of poultry manure (18 and 26.9 t/ha), almost one half of the total yield production was obtained in the first clipping. This represents less than one-third of the growing season. Burns _et al_. (1970) found that applications of 50% or more of the total N required early in the spring causes an early spring peak in yield followed by a marked reduction in midseason growth.

Several researchers (Gardner _et al_., 1960; Maas _et al_., 1962; Alexander and McCloud, 1962; Burns _et al_, 1970) have found that dividing the N among frequent applications gave greater uniformity of yield over the growing season but no net increase. Since the total production of dry matter is not affected by a single N application in the early spring, early applied N is utilized just as efficiently as later or split applications (Burns et al., 1970).

(ii) Effect of Botanical Composition

Clover or other legumes mixed with orchardgrass decreases the N requirement for the stand. Templeton Jr. (1975) indicated that forage productivity of perennial cool-season grass-legume mixtures was normally equivalent to that of the same grass receiving 150 to more than 200 kg N/ha/year. In Britain, all-grass swards require 157 kg N/ha/year to achieve the same herbage yields as unfertilized grass/clover swards (Whitehead, 1970).

The yield increase of an orchardgrass-clover mixture, due to an N application, is influenced by the amount of grass in the mixture. The greater the proportion of grass in a mixed stand, the greater the yield response per unit of N applied (Wolf and Smith, 1964). Whitehead (1970) suggests that the average annual response for an all-grass sward is 25 kg of dry matter per kg of N and 12 kg of dry matter per kg of N for grass/clover swards.

Increasing the N application to a grass-clover mixture, suppresses the clover content and any yield response to high rates of N is due to an increase in grass growth only (Gardner et al., 1960). N rates up to 101 kg N/ha increased the grass yield in a grass-clover mixture without decreasing the yield of the clover appreciably. Higher N rates decreased the clover yields by the same amount that the grass yields were increased (Maas et al., 1962).

Grass-clover mixtures are a complicated forage to evaluate, because of the varied proportions of grass and clover found at different rates of

N applied.

(iii) Effect of K

The principle nutritional factor controlling the yield of established herbage is N. If the forage is cut often, other nutrients may cause yield reductions. Potassium is the most likely element other than N to become limiting (Hemmingway, 1963; Duell, 1965; Nowakowski, 1970).

Dry matter yields of both pure orchardgrass and orchardgrass-clover mixtures were increased by the application of K fertilizers (Gardner et al., 1960). The increases were much greater for the mixed stand than orchardgrass alone. Hemmingway (1963) found over three years that N-only applications to established orchardgrass swards gave decreasing yields compared to NK treated swards. The N-only treatment maintained yields at 80 to 100% relative to the NK treatments in the first year. By the third year of continuous cropping, the N-only treatment yields had fallen to 60% of the NK treatment yields. Singh et al. (1967) noted similar results. Continuous cropping with orchardgrass gradually depleted the K reserve in the soil. This may be very important in poultry manure applications where the N:K ratio in the manure can be high (4:1). Reith et al. (1964) indicated that the amount of K supplied to orchardgrass depended on the N used as well as the soil reserves of K. No yield response from orchardgrass occurred when K content in the herbage exceeded 1.6% K (Hemmingway, 1963).

c) Botanical Composition

(i) Orchardgrass-Clover Mixtures

The advantages and disadvantages of a grass-clover mixture versus a pure stand of grass have been thoroughly investigated (Whitehead, 1970; Baylor, 1974; Jacobs and Stricker, 1975; Templeton Jr., 1975). The advantages include: higher dry matter yields, higher protein content and certain mineral nutrients in the herbage, more even forage production over the growing season, and diminished N requirements for the sward. The major disadvantage is the more intense management that is required to maintain the clover in the stand.

N often has an adverse effect on the clover content. Alexander and McCloud (1962) found that in the course of their study (2 years), applying various rates of N to an orchardgrass-clover sward, the clover content decreased from 17% to virtually nil (4%). Gardner et al. (1960) found that under the conditions of their experiment, ladino clover was tolerant to N applications. Frequency of N applications had no apparent effect on the percentage of clover in an orchardgrass-clover stand (Gardner et al., 1960; Maas et al., 1962).

Whitehead (1970) suggested that N applied in liquid manure or slurry appeared to cause less depression of clover than fertilizer N. Parker (1966) found similar results with solid poultry manure. The clover performance on a 9 tonnes of manure/ha treatment and the highest fertilizer rates were about equal, yet the manure treatment contained, on the average, four times as much N/ha/year. At the highest manure rate, 26.9 t/ha, virtually all the clover was eliminated by the first cut of the second year after manure application (Parker, 1966).

(ii) Weeds

Weed infestation may be an adverse effect of poultry manure application on agronomic crops. Many poultrymen and farmers, using poultry manure as a fertilizer, have expressed beliefs that the incidence of weeds increased where manure was spread. In laboratory studies using white leghorn hens, it was found that the viability of 25 weed species were destroyed in the intestinal tract of the hen (Cooper et al., 1960). Faecal matter collected showed no evidence of seeds nor was germination of any seed, if present, found in the faecal matter. This study suggests that any increase in weeds in the botanical composition of a crop, is the result of weeds entering the manure after it is excreted by the hen.

d) Chemical Composition of Forage

(i) Introduction

The concentration and balance of nutrients in forage is of great importance. In practice, ruminants are usually fed non-regulated or variable diets of forages. "Thus the concentrations of nutrients in the forage, as they affect voluntary intake of the forage, have a significant affect in the ultimate output of a useful animal product" (Raymond, 1969, according to Wedin, 1974). In addition, the composition of forage can indicate "luxury consumption" of an element which suggets the inefficient utilization of that nutrient.

(ii) Total N in Forage

Total N content in forage is closely associated with the amount of N applied (Dotzenko and Henderson, 1964). Extremes in % N in cool-season grass forage range from 1.5% in deficient mature grass to 6.0% in a well-fertilized lawn clipped weekly. Normally in tall growing cool-season grasses, slightly over 3% is considered average (Wedin, 1974).

Total N in orchardgrass and orchardgrass-clover mixtures have shown variable response to poultry manure applications. Parker (1966) found very little variation in the N content of orchardgrass-clover swards related to manure treatments. High clover content in the check and low manure plots may have accounted for this.

Vandepopuliere et al. (1975) and Papanos and Brown (1950), using grass stands, indicated that only slight increases in total N content of the forage occurred with increasing manure rates. Papanos and Brown (1950) found that the N content increased from 1.7% in the check plots to 2.2% in the 18 tonnes of poultry manure/ha plots. Vandepopuliere et al. (1975) found less than a 0.50% total N increase in the fescue tissue between the control and the 89.8 t/ha plot (supplied 862 kg N/ha). In a study using cattle manure on corn, the manure N did not significantly increase the total N in the leaves. In one year of the study, total N in the leaves decreased with increasing manure rates (McIntosh and Varney, 1972). The indication was that manures have only a minimal effect on the total N content in forage grasses.

Maturity of orchardgrass is another factor which affects total N content. Cutting frequency and time of application have very little effect on the protein production of orchardgrass (Mortensen et al., 1964). Percent N declines with maturity (Whitehead, 1970). George et al. (1973) indicates that lower total N values are expected for the first harvest of orchardgrass than the rest of the cuttings because the first cut is usually taken at the heading stage whereas other harvests are taken during the vegetative growth stage.

(iii) Total Phosphorus in Forage

Total P in forage grasses ranges from 0.14 to 0.50% (Wedin, 1974).

Approximately 0.30% is required for the maintenance of grazing animals (Baylor, 1974). The concentration of P in orchardgrass pasture was highest in early spring (0.40%), decreased slightly by late spring, and then remained fairly constant (0.25 to 0.30%) (Reynolds et al., 1971).

Several researchers found that %P decreased as the amount of N fertilization increased (Gardner et al., 1960; Mortensen et al., 1964; Dotzenko and Henderson, 1964; Reynolds et al., 1971). However, yield and uptake of P by orchardgrass increased (Gardner et al., 1960; Singh et al., 1967).

With manure applications, %P response is inconsistent. McIntosh and Varney (1972) found a small but significant decrease in %P of corn with increasing N from cattle manure. Papanos and Brown (1950) found that %P remained constant at 0.3% P regardless of manure treatment. In Georgia, the %P in fescue pastures fertilized with poultry litter increased 50% from 0.36% P with no poultry litter to 0.49% P where poultry litter was applied (Jones et al., 1973). Parker (1966) found that the poultry manure rates of 18 and 26.9 t/ha on orchardgrass-clover supplied P in excess of crop needs.

(iv) Total Potassium in Forage

Wedin (1974) indicates that a range of 1 to 4% K is normal for cool-season grasses. Concentrations above 1.6 to 1.7% K in orchardgrass represents luxury consumption of K (Hemmingway, 1963). The highest concentrations of K are found in the early spring in orchardgrass, decreasing to a low in the late spring and increasing again during the summer (Reynolds et al., 1971).

Potassium fertilization, N applications and Na all affect the percentage of K in orchardgrass and orchardgrass-clover mixtures. Potassium fertilization increased the K content in both pure stands and mixtures. Percent potassium was increased by K fertilization irrespective of N treatment (Griffith et al., 1964). Potassium in orchardgrass tissue decreased when N was the only fertilizer applied (Griffith et al., 1964; Duell, 1965; Hemmingway, 1963). Hemmingway (1963) found that in N-only treatments, the K content steadily declined with each cut of forage. In the first year, % K declined from 1.50% to 1.38% K. By the end of the three years, the percentage K in the N-only treated orchardgrass had decreased to 0.40% K. Griffith et al. (1965) suggested that there was a loose inverse relationship between Na and K content. Nitrogen fertilization raised the Na content while percentage K decreased. They indicate it may be due to an insufficient supply of K to cope with the increased yields associated with N applications.

Potassium in grass tissue increased due to manure applications (Vandepopuliere et al., 1975; Drysdale and Strachen, 1966; Jones et al., 1973a). Vandepopuliere et al. (1975) found that % K in fescue tissue increased from 1.86% K in the check to 4.50% K where 89.8 tonnes of poultry manure/ha rate. Drysdale and Strachen (1966) found increasing % K in grass with increasing manure rates. The liquid manure used had a N:K ratio of 1.0:1.7 and therefore supplied K in excess of that required for normal plant growth. If the N:K ratio was higher (e.g. 4:1 as it is in some poultry manure), the manure would not supply sufficient K for optimum plant growth when applied at rates to meet the N demand of the crop. When the available soil K was depleted, % K in the forage decreased similar to the results reported by Hemmingway (1963).

(v) Total Ca, Mg and Na in Forage

Ranges for Ca and Mg in cool-season grasses ranged from 0.28 to 2.50% and 0.06 to 0.73% respectively (Wedin, 1974). Both % Ca and % Mg in orchardgrass tend to increase in the spring and level off and remain constant through the rest of the growing season (Todd, 1961; Reynolds et al., 1971).

The responses of Ca and Mg to fertilization with N and K were inconsistent. Generally, K fertilization tended to depress Ca and Mg concentration in orchardgrass, particularly Mg (Todd, 1961; Gardner et al., 1960; Wedin, 1974). The response of Mg content in orchardgrass to N fertilization was variable from year to year and shows no consistent pattern (Todd, 1961).

Jones et al. (1973a) and Vandepopuliere et al. (1975), reported that slight increases of Ca and Mg content in tissue occurred with the application of poultry manure (litter) on fescue pastures. Jackson et al. (1975) observed that heavy rates of broiler litter resulted in large quantities of extractable K in acid soil profiles while extractable Ca and Mg were depleted. They felt this may contribute to the potential grass tetany hazard in cattle grazing fescue pastures heavily manured with poultry litter.

Grass tetany is a metabolic disorder of ruminants where intake of Mg is too low (Grunes et al., 1970; Grunes, 1973). It is often referred to as "hypomagnesmic" tetany. Spring or fall conditions when there is cool weather or when a period of cool weather is followed by warmer conditions is usually when the incidence of tetany is greatest (Grunes et al., 1970). Percent Mg, K/Ca Mg ratio (meq basis) and excessive % N in the forage have all been suggested as indicators of "tetany prone" forage (Grunes et al., 1970; Grunes, 1973; Jones et al., 1973b). Grass forage with a K/Ca + Mg ratio (meq basis) exceeding 2.2 is considered "tetany prone". High K/Ca + Mg ratios usually are more common in the spring and/or fall (Grunes, 1973). Broiler litter appears to enhance the K content without increasing the Ca or Mg content, particularly during the spring period when both cows and grass are "tetany prone" (Wilkinson et al., 1971). However, they found that when the ratio exceeded 3.0 no clinical symptoms of grass tetany occurred in the cattle.

Mg levels of 0.20% and greater are considered safe levels in forage. Grunes (1973) suggests that if Mg levels are maintained at high levels (in excess of 0.20%), ruminants should not suffer from Mg deficiency even though K and N in the forage may be high. Forages containing excessive N are considered "tetany prone". Jones et al. (1973b) found that 3.8% N or more in forage increased the likelihood of grass tetany.

Jones et al. (1973a) and Stuedeman et al. (1975) indicated that fescue pastures fertilized with poultry manure (litter) have a greater tendency for tetany than moderately fertilized forage. Mature cows grazing on these pastures could be susceptible to grass tetany if there was no other source of Mg in the diet.

Orchardgrass has a high Na content relative to other grass species (Loehr, 1960; Griffith et al., 1960). Although no normal range is given, Loehr (1960) suggests that 0.16% Na in forage is the requirement for dairy cattle. Drysdale and Strachen (1966) found that the Na content of ryegrass and white clover was high at the first cut, decreased during midseason, and increased again by fall.

As mentioned above, there is a rough inverse relationship between Na and K content in orchardgrass. Butler (1963), according to Griffith et al. (1965), indicated that the low herbage Na was not always accompanied by a high K content.

(vi) Nitrate in Forage

As far as is known, nitrate accumulation is not injurious to the plant, but high levels of nitrate in forage are toxic to ruminants (Wright and Davison, 1964). Ingested nitrate is reduced to nitrite in the rumen and is readily absorbed through the gastrointestinal tract into the blood stream. Once in the blood, nitrite reacts with the oxyhemoglobin oxidizing Fe^{2+} to Fe^{3+} to form methemoglobin. When this occurs the oxyhemoglobin loses its ability to transport and release O_2 to the body and death can occur by asphyxiation (Williams et al., 1972; Wright and Davison, 1964).

Various levels of nitrate have been indicated as potentially toxic to ruminants. Murphy and Smith (1967) suggest that 0.07% (700 ppm) nitrate-N and above may be toxic to livestock if that forage is the only feed consumed. Ryan et al. (1972) set 0.15% nitrate-N as the safe level. Williams et al. (1972) indicate that ruminants may suffer from acute or chronic nitrate toxicity. Nitrate levels in excess of 0.2% nitrate-N can cause acute toxicity usually resulting in death. Chronic toxicity is associated with levels below 0.2% nitrate-N but greater than 0.07% nitrate-N. Wright and Davison (1964) felt that nitrate concentrations between 0.34 and 0.45% nitrate-N were potentially toxic.

Nitrate accumulates in pasture plants when the soil supplies nitrate faster than it can be assimilated into protein by the plant. Factors that affect this are: excess N fertilization, drought, cloudiness (shading), herbicides, soil nutrient imbalances, plant part, and kind and age of the plant (Wright and Davison, 1964; Williams et al., 1972). Excessive N, soil imbalances and kind and age of the plant are the main factors considered here. Deficiencies of K, P and S may inhibit protein synthesis in the plant and promote nitrate accumulation. This is unlikely to occur in pastures heavily fertilized with poultry manure or litter (Williams et al., 1972).

Excessive N fertilization has been associated with increased nitrate concentrations (Dotzenko and Henderson, 1964; George et al., 1973; Murphy and Smith, 1967; Crawford et al., 1961). Fertilizer rates of 448 and 672 kg N/ha produced maximum nitrate levels in excess of 0.40% nitrate-N (Reynolds et al., 1971). George et al. (1973) found 0.63% nitrate-N in orchardgrass fertilized with 1344 kg N/ha. They suggest that the risk of nitrate toxicity (using 0.15% nitrate-N as the potentially toxic level) may exist during the spring and midsummer with orchardgrass when top-dressed with at least 84 kg N/ha/cut.

Summer annuals, certain weeds and cool-season grasses are listed as nitrate accumulators (Wright and Davison, 1964). With the grasses, the age of the plant can be critical. Reid et al. (1966) reported lower nitrate levels in July regrowth than in May regrowth. Reynolds et al. (1971) found that nitrate concentrations were not as high in the second half of the growing season as in the first half. George et al. (1973) found that nitrate levels were significantly lower for orchardgrass harvested during periods of rapid growth and high yield. Concentrations reached a maximum during the July and August cutting dates when temperature and moisture stress reduced the yields. Wilkinson et al. (1971), using poultry litter on fescue pastures, found nitrate levels below 0.20% nitrate-N until August when concentrations of 0.33% nitrate-N were observed until November. Lund et al. (1975), working with cattle manure, reported that the organic N content in coastal bermudagrass increased until it was about 2.5% at which point nitrate accumulation proceeded very rapidly.

The above ranges of nitrate concentrations are considered as "potentially" toxic to ruminants. Health and type of ruminant and the percentage of the "potentially" toxic forage consumed in the animals diet are some of the conditions which affect the forage's toxicity to the ruminant. Wilkinson et al. (1971) found nitrate levels of 0.33% from August to November in manured fescue pastures, yet reported no clinical signs of nitrate toxicity in the cattle grazing it.

Gorden et al. (1962), according to George et al. (1973), suggested that economic considerations should be a greater concern than nitrate toxicity in setting upper limits to N fertilization for orchardgrass. Optimum yields usually occurred at concentrations equal to or less than 0.15% nitrate-N (George et al., 1973). Drought conditions and N applications after each harvest are possible exceptions.

e) Rate Comparisons

Some rates of poultry manure application in relation to certain aspects of yield and botanical composition have been mentioned. N appears to be the best constituent on which to base application rates of poultry manure. Generally, higher rates of poultry manure are applied to soil when disposal rather than efficient utilization is the objective. The land requirements for efficient use of poultry manure on corn is twice as much as for the maximum application of N which will not reduce yields or cause water pollution (Jones, 1969). Ten thousand laying hens in one year will produce approximately 5670 kg N and will require 40.5 ha for crop utilization and only 20.2 ha for pollution control (Jones, 1969). The same land requirements are necessary for 100,000 broilers over 10 weeks, excreting 7030 kg N.

Hileman (1965) suggested that 18 t of poultry manure/ha/year is the maximum disposal rate and 9 t/ha/year is the optimum rate for crop utilization. Parker (1966) found that 9 t of poultry manure/ha/year gave the biggest yield increase of orchardgrass-clover forage per tonne of manure applied. Increases in yield still occurred at 18 and 26.9 t/ha/year rates but the N was not used as efficiently. Perkins and Parker (1971) indicated that 6.7 to 9 t/ha/year of poultry manure maintained an adequate supply of the most important elements for crop growth. Nine t/ha of poultry litter on fescue pastures has been suggested as the rate which supplies adequate nutrients and minimizes grass tetany and nitrate toxicity (Williams *et al.*, 1972).

C. Nitrogen Balance

1. N Balance in Grassland and Grass/Clover Swards

The N balance of a grass/clover sward adapted from Whitehead (1970) is shown in Figure 1. Manure additions and symbiotic fixation of N by clover (if present) are the major N additions to the system. N fixation by non-symbiotic bacteria and additions to the soil by rainfall, etc., are of minor importance, especially if large amounts of manure N are applied.

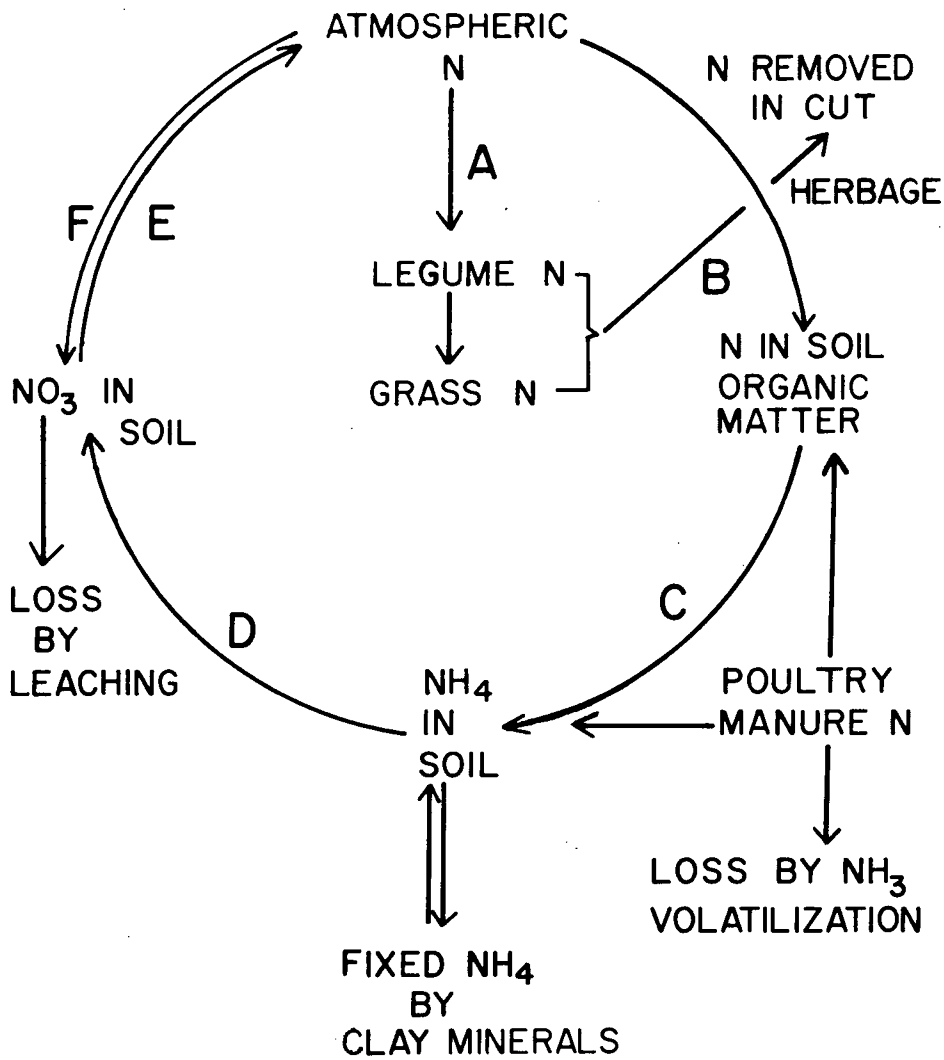

Figure 1. N balance in a Grass/Clover Sward Fertilized with Poultry Manure. A: N fixation by symbiotic Rhizobium; B: N fixation by free living bacteria; C: Ammonification; D: Nitrification; E: Dentrification; F: Additions of N from the atmosphere. Modified from Whitehead, 1970.

In soils deficient in N and where low rates of N are applied, these latter additions may be important (Allison, 1966).

Allison (1955) indicated that accurate values for fertilizer (manure) additions can be determined but legume fixation values are a problem. Whitehead (1970) feels that estimates of symbiotic N fixation in grass-legume mixes can be made. He suggests up to 252 kg N/ha/year can be fixed by clover in a clover/grass sward. Of this, 101 kg N/ha/year can be transferred to the grass. The transfer of N is usually by the decomposition of clover roots and nodule tissue. There is some evidence of the living roots exuding organic compounds containing N (Whitehead, 1972). Little transfer takes place in the establishment year of a grass/clover sward presumably because the clover is using all the N fixed and there is very little root decomposition (Whitehead, 1970).

The losses from the system (Figure 1) include crop removal, leaching, denitrification, ammonia volatilization and ammonium immobilization by certain clay minerals. Under normal field conditions, crop removal, leaching and denitrification are the major losses. Ammonia volatilization can be significant when manure is the source of N, particularly if it is surface applied and not incorporated (Allison, 1955; Adriano et al., 1974; Lauer et al., 1976). Although most mechanisms for losses are known, quantitative data relating to each type of loss are inadequate (Allison, 1955).

N recovery by the crop under average field conditions often is no greater than 50 to 60% of the applied N even if immobilization of N in the soil is taken into account (Allison, 1966). Wedin (1974) found that 69, 83 and 84% of the N applied to orchardgrass was recovered when applied at rates of 269, 90 and 180 kg N/ha/year, respectively.

2. Methods of Determining N Balance

N^{15} tracer techniques and the more common nontracer difference method are the two major techniques used in determining N balances in the field (Allison, 1966). The difference method considers only the N recovered in the crop or series of crops subtracting the values for the control from the treated plots. Soil gains may be included. Although not exactly comparable, the simpler difference method often yields results that agree favourably to the tracer method except when there is excessive biological or chemical tie-up of N in the soil (Allison, 1966). The difference method is actually preferred when practical applications not requiring extreme accuracy are needed.

Tests have shown that N recoveries in crops plus soil is rarely greater than 95% of the applied N and values of 70 to 95% are more common. It is not unusual for recovery values to be as low as 50 to 60% (Allison, 1955; Allison, 1966). Values of 5 to 25% N not recovered are so common they represent real soil losses and not experimental error (Allison, 1966). These losses are most likely to occur from leaching and denitrification, although ammonia volatilization may be significant in certain circumstances.

Olsen et al. (1970) determined the percent manure N recovered from an uncropped soil by subtracting the sum of nitrate, nitrite, ammonium, and organic N in the check from the sum of these values in the treated soils. Mathers and Stewart (1974) determined % N recovered from cattle feedlot manure applied to corn. The N recovered included the increase of the manured plots over the check in total N removed by the crop, nitrate accumulation in the profile, and total N changes in the surface 30 cm of the soil. At the lower manure rates (22 and 44 t/ha), the N added was accounted for but at the higher rates large amounts of N could not be accounted. Mathers and Stewart (1974) suggest that considerable losses of N occurred probably by ammonia volatilization and denitrification from the heavily manured plots.

Variations in manure composition and increased ammonia volatilization make N balance sheets of manure N under field conditions even more difficult than under normal fertilizer trials (Mathers and Stewart, 1974).

III MATERIALS AND METHODS

A. Site Description

The study site was established in April 1975, in the District Municipality of Chilliwhack on a gray gleysol of the Grigg series (silty clay loam). Grigg soil was derived from floodplain deposits of the Fraser River with good inherent fertility (Comar et al., 1962). Some chemical properties of the soil at the experimental site prior to the initial manure application are given in Table II. In general, Grigg soil is poorly drained, but the experimental site was adjacent to a drainage ditch on a slightly raised portion of the field which improved the drainage. In December of both years, the water table rose to within 90 cm of the surface but during the growing season the water table was well below this depth.

The climate of the area is inshore maritime (Comar et al., 1962). During the growing season (May to September), crop growth is often restricted due to a moisture deficit. During the two years of the study, precipitation data from the Chilliwack Gibson Road Climatological Station show that in one half of the growing season months of May through September (1975 and 1976), rainfall was less than 50 mm per month. All but one of these months (July 1976) occurred in 1975. In 1975, only August had more than 50 mm of rainfall. Mean temperatures over the period of May to September were approximately the same - 15.7^{o}C and 15.0^{o}C for 1975 and 1976, respectively. Precipitation and temperature data in detail are presented in Appendix Table A1.

Table II: Chemical properties of the Grigg soil at the experimental site.

Depth cm	pH in $CaCl_2$	Available P ppm	Total N %	CEC	K	Ca	Mg
				-------meq/100 g-------			
0-15	4.74	87.5	0.219	26.61	0.45	10.98	8.35
15-30	4.78	67.0	0.182	24.66	0.37	10.51	9.21
30-45	4.83	10.5	0.078	20.11	0.08	9.49	14.59
45-60	4.82	7.2	0.054	19.07	0.05	8.98	19.14
60-75	4.84	8.4	0.040	16.94	0.05	7.95	18.98
75-90	4.85	9.8	0.031	14.06	0.05	6.60	17.19

1. Average of the four blocks; 20 cores/block

B. Field Work

Plots measuring 3.05 m by 6.10 m were established on April 15, 1975 in a randomized complete block design with four blocks. Each replication contained poultry manure treatments of 1.25, 2.5, 5.0, 10, 20 and 40 t/ha, a fertilizer plot and a control plot. The manure rates were based on the manure as it came from the bag not on a dry weight basis. The poultry manure was applied before seeding and incorporated into the soil by raking. Seeding of the plots with orchardgrass (Dactylis glomerata L.) and Ladino (white) clover (Trifolium repens) mixture was done within three days of manure application. Problems with the percent clover in the fertilizer plots and an insufficient amount of N applied in 1976 made any comparisons between the manure rates and the fertilizer treatment invalid. Therefore, the results of the fertilizer treatment have been omitted from the discussion.

In 1976 (April 5), the manure plots were halved in width from 3.05 m to 1.525 m. The length remained at 6.10 m. On one half of the split plots a single application of poultry manure was surface applied onto the established forage stand at the same rate as in 1975. On the other half of the plots the application rate was the same, but was divided into three equal applications, once in the spring (April 5) and once after the first two harvests. In 1976 the manure was surface applied to the established sward.

In 1975, forage yields were obtained on July 2 and August 21. In 1976 there were four cutting dates - May 18, June 18, July 27 and September 9. The same harvest technique was applied to all cuts in both years. An 87 cm swath was cut lengthwise down the middle of each plot and the sample was removed and weighed immediately. A weighed subsample was taken for determination of dry matter yield and chemical analysis. The rest of the plot was then cut and the forage removed.

Following both growing seasons, soil samples were taken with an Oakfield probe to a depth of 90 cm (November 25, 1975 and December 15, 1976). Ten cores per sample were taken when the sampling depth was 15 cm (0-15 cm and 15-30 cm) and five cores per sample when the sampling depth was 30 cm (30-60 cm and 60-90 cm). Soil samples were similarly collected prior to the manure application in 1976 to check for residual nitrates.

C. Laboratory Procedures

1. Poultry Manure

Poultry manure was obtained from an egg producer near Aldergrove. The hens were housed in a high-rise poultry house with a concrete floor. The poultry droppings fall to the floor where they are partially dried by electric fans circulating air over the piles. Approximately once a year the manure was removed from the house, ground by hammer-mill and bagged for sale to home gardeners. The manure was dry enough to handle and spread easily with little or no odor problem.

A subsample from each bag of manure used was taken in the field before application and was frozen immediately upon return to the lab. The sample was kept frozen until the analysis was to be done, then it was thawed and analyzed wet. Moisture content was determined by drying a thawed sample for 24 hours at 80^{o}C in a forced air oven. All values recorded were on a dry weight basis. A modified dry ashing procedure for organic materials was used for the extraction of P, K, Ca, Mg and Na (Jackson, 1956; Isaac and Jones, 1972; Walsh and Beaton, 1973). The samples were ashed one hour at 300^{o}C and at least seven hours at 450 to 480^{o}C. Following the ashing, the elements were extracted with 3 ml of 1N HNO_3 followed by 5 ml of 2N HCl. Potassium, Ca, Mg and Na concentrations were determined with the Perkin-Elmer 330 atomic absorption unit. Phosphorus was determined colourimetrically using the Molybdenum Blue Method (Fisk and Subbarow, 1925, according to Chapman and Pratt, 1961). Total N was extracted by acid digestion at 420^{o}C and determined colourimetrically by a Technicon Autoanalyzer II (Technicon, 1975). Total N did not include nitrates.

2. Plant Material

Plant samples were brought in from the field in paper bags and dried at 70^{o}C in a forced air oven for 24 hours. The plant material was ground in a stainless steel Wiley mill to pass a 2 mm sieve and stored in plastic containers. In 1975 the clover and orchardgrass were analyzed together and a separate sample was taken for the determination of the percent clover (second cut only). In 1976, when there was clover present, the grass and clover components were hand separated prior to drying and chemical analysis. The percentage of each component was then determined on a dry weight basis and each component was analyzed separately.

The elements analyzed and procedures used for the plant material were identical to those used for the poultry manure, except that nitrate content was determined on the plant samples. Nitrate was extracted in a 10:1 water to plant sample ratio, shaken for 30 minutes and filtered. Nitrate was determined using the Cadmium reduction method with a Technicon Autoanalyzer II (Technicon, 1972).

3. Soil Samples

The soil samples were brought from the field in paper bags and immediately dried at 55^{o}C in a forced air oven for 24 hours. The samples were ground in a Hewitt soil grinder to pass a 2 mm sieve and stored in airtight plastic containers.

Nitrate and ammonium were extracted according to Bremner and Keeney (1963) using 2N KCl at a 10:1, KCl to dry weight of soil ratio. Nitrate was determined colorimetrically using the same procedure as for the plant samples. Ammonium was determined colorimetrically by the same procedure as for total N determinations of the poultry manure and plant material. Total soil N was determined similarly to the total N determinations of the poultry manure and plant material.

D. N Balance Determination

The % N recovered for the manured plots was determined by the difference method according to Allison (1966) and Mathers and Stewart (1974). It was calculated as follows:

$$\%\text{ N accounted for} = \frac{\left(\begin{array}{l}\text{N, removed by grass and clover}\\ \text{plus nitrate-N in 0-90 cm plus}\\ \text{total N 0-15 cm at a given}\\ \text{manure rate}\end{array}\right) - \left(\begin{array}{l}\text{N for the}\\ \text{same compon-}\\ \text{ents in the}\\ \text{control}\end{array}\right)}{\text{N added in the manure}}$$

For all but the 20 and 40 t/ha plots in 1975 and the 40 t/ha plots in 1976, the N removed by the crop is the only component used.

Total N and nitrate values recorded as kg/ha were determined using 0.95 g/cm^3 as the bulk density in the surface 30 cm and 1.25 g/cm^3 in the 30 to 90 cm zone. The surface bulk density was based on a leaching column study in the lab using the Grigg soil (Safo, personal communication, 1978) and values given in the literature (Adams et al., 1960; Soanes, 1970; Flocker et al., 1958). The value of 1.47 g/cm^3 (2 x 10^6 kg/hectare furrow slice) often used is far too high for surface agricultural soils as values of 1.20 to 1.50 g/cm^3 have been shown to inhibiting crop yields (Flocker et al., 1958).

E. Statistics

Percentage nutrient values and yield were subjected to analysis of variance treatments and significant effects at the 0.05 level were graphed using curvilinear relationships (Little and Hills, 1975). Regression equations significant at the 0.05 and 0.01 level are reported. Soil nitrate levels were subjected to an analysis of variance treatment and LSD values were determined at the 0.05 level.

IV RESULTS AND DISCUSSION

A. Manure Composition

Mean values, rangesof concentrations and the coefficients of variation of the nutrient elements and moisture content of the poultry manure are given in Table III. The N supplied by the different rates of manure in 1975 and 1976 is listed in Table IV. Moisture content, % Ca, and % Na of the poultry manure were similar in both 1975 and 1976. The N, P, K and Mg percentages were all lower in 1976 than in 1975. In 1976 the variability of the manure composition among bags was between three and ten times greater than in 1975. Higher moisture content in several of the bags accounted for the greater variability in 1976. Nitrogen showed the greatest increase in variability and Ca the lowest.

Generally, aged manure from the high-rise poultry house produced a comparatively consistent source of nutrients (Table III). Within a given year (or batch of manure removed from the house), the nutrient variability was low, particularly in 1975. Nitrogen concentrations in the manure remained high even though the manure was dried and stored in the pit at least one year. The N:P:K ratio of the manure indicates that K may become limiting if the manure is applied at rates to meet the N requirements of most crops.

B. Yield

Analysis of variance for dry matter forage yields in 1975 and 1976

Table III: Manure composition

	% Moisture	%N	%P	%K	%Ca	%Mg	%Na
	----------------	Dry Weight Basis	----------------				
1975[1]							
Mean	22.50	5.08	2.51	2.02	5.92	0.72	0.51
Coefficient of Variation	7.4	3.7	5.4	6.1	10.1	4.1	3.6
Range	20.28-27.34	4.63-5.45	2.27-2.82	1.84-2.30	4.77-7.63	0.66-0.78	0.47-0.55
1976[2]							
Mean	23.10	3.53	1.60	1.44	5.60	0.58	0.45
Coefficient of Variation	30.0	39.11	35.0	30.4	30.6	28.5	28.9
Range	18.33-33.33	1.96-6.10	1.10-2.40	1.25-2.01	4.57-7.49	0.48-0.74	0.40-0.56

[1]Mean of 31 samples

[2]Mean of 29 samples

are given in Appendix Tables B1 and B2. Total yields and the individual yield totals for each harvest for both years are also listed (Appendix Tables C1 and C2). The control yields are listed in Appendix Tables C1 and C2 but are not included in the statistical analysis. In 1975, the control produced a mean forage yield per cut of 1.54 t/ha and a total dry matter yield of 3.08 t/ha. This high value is due to the legume component in the forage. In 1976 the total yield of the control was the same as the 1.25 t/ha treatments. Again, the reason for this was the contribution of the clover component in the stand.

In 1975, there was a significant mean yield response to manure treatment (Figure 2). Mean yield values increased from 1.91 to 3.53 tonnes of dry matter/ha for the 1.25 and 40 t/ha manure treatments, respectively. Although mean yield values increased with manure treatment, there was a ten-fold decrease in the forage yield increase per tonne of poultry manure as the rate of manure increased. The mean dry matter increase per tonne of manure was 200, 112, 64, 36 and 21 kg of dry matter forage per hectare, respectively, for 2.5, 5, 10, 20 and 40 t/ha of poultry manure. The yield increase per tonne of manure is approximately halved as the manure rate is doubled. Above the 2.5 t/ha treatment, the additional manure produced an increase in grass yield and a decrease in clover yield and content. The overall sward still showed an increase in yield above the 2.5 t/ha treatment because the dry matter yield of the clover decreased at a slower rate than the grass yields increased. The 2.5 t/ha rate of poultry manure supplied 98.5 kg N/ha in 1975 (Table IV). Manure rates of between five and ten t/ha/year would supply a range of N which would optimize the forage mixture yields without a complete removal of the clover component.

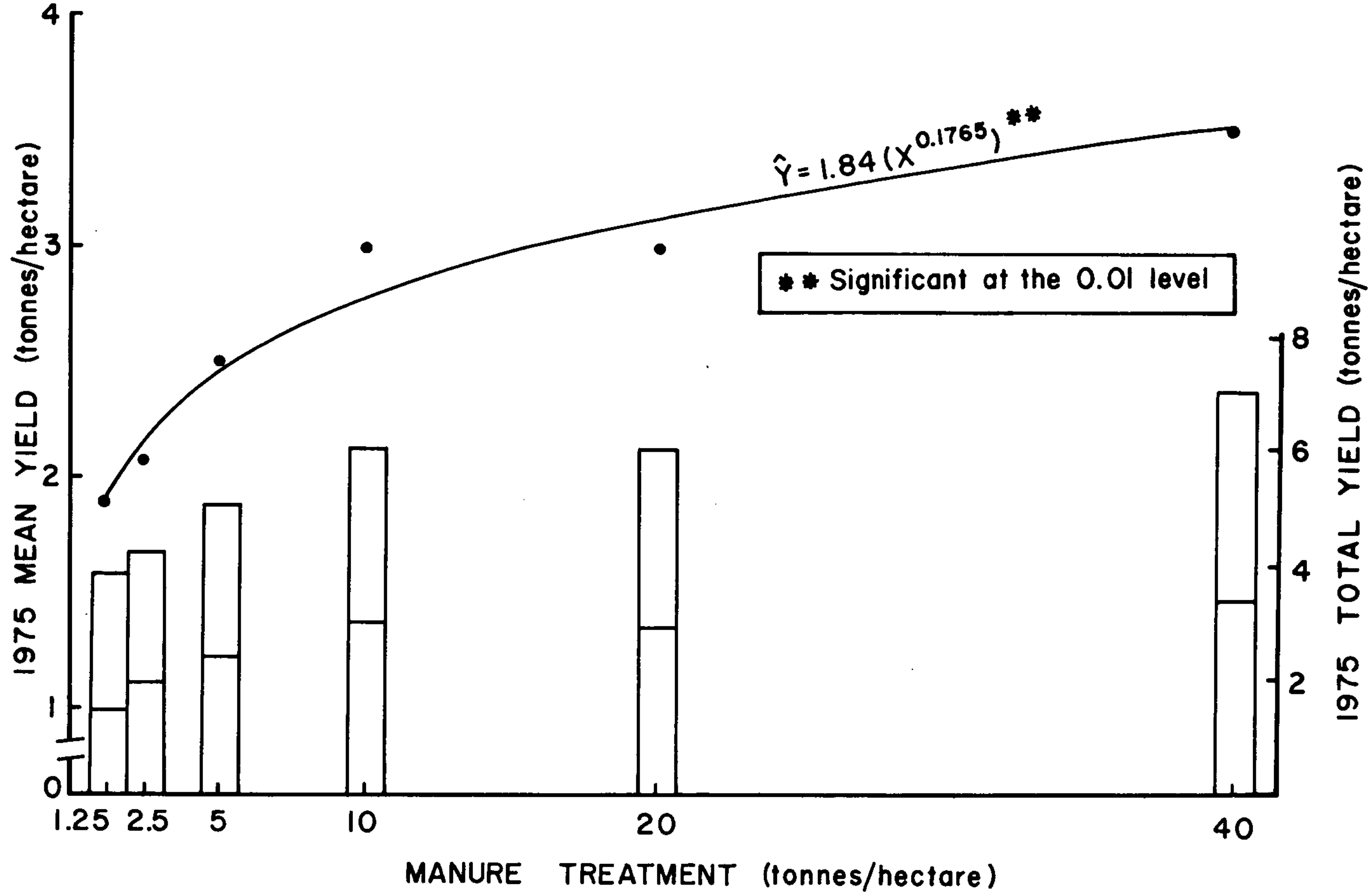

Figure 2. Mean Yields and Total Yield in 1975 as Affected by Manure Treatment

Table IV: N supplied by manure treatments in 1975 and 1976

Year	Manure Treatment t/ha	N Supplied by the Manure kg/ha
1975		
	1.25	49.0
	2.5	98.5
	5.0	197
	10	394
	20	787
	40	1575
1976		
	1.25	33.9
	2.5	67.8
	5.0	136
	10	272
	20	543
	40	1086

The 1976 total yields were considerably higher than in 1975. This would be expected as the sward was a new stand in 1975. In 1976 the poultry manure was surface applied rather than incorporated and there was no clover in the heavily manured plots. There was an additional factor of method of application (single versus split) in 1976. For all cuts and both methods, except the split application method on the second cut, there was a significant yield response to manure treatment.

The first cut produced the highest yields, between 30 and 50% of the total yield in less than one-fourth of the growing season. The single application of manure produced forage yields of 5.97 and 6.03 t/ha of dry matter at the 5 and 10 t/ha treatments, respectively. The dry matter produced at the 20 and 40 t/ha manure treatments was similar to the yields obtained at the 2.5 and 1.25 t/ha rates. Excessive soluble salts, free ammonia toxicity, smothering of the forage and/or ammonium induced cation deficiencies were all possible mechanisms which caused the yield reductions at the 10, 20 and 40 t/ha manure treatments. Soluble salts can reduce yields by up to 20% without any noticeable damage to the plants. Free ammonia affects the roots and possibly the crown of the grass, reducing yields. Ammonium can induce a cation deficiency such as Ca which causes terminal bud malfunction restricting the initial plant growth. Smothering of the forage can also reduce growth if the forage remains covered long enough. A similar decrease at the 20 and 40 t/ha treatments occurred at the second harvest, split application method. The split application did not cover the foliage sufficiently, particularly at the 20 t/ha rate, for smothering to be a cause of the yield reduction. There was no significant reduction in the cation concentration of the orchardgrass for any single treated plot at the first cut, so an ammonium induced deficiency was unlikely. The % P concentration was unaffected by manure application at the first harvest. Thus a reduction of P availability as a result of salt or ammonia increasing the pH was also unlikely to have been responsible for the yield decreases. Free ammonia toxicity or a general salt effect due to raising of the osmotic pressure of the solution around the roots of the grass or within the plant, was the most likely cause of the yield reduction.

Adverse effects of the manure at the high application rates were modified at the initial manure application date because of two intense rainfalls within two weeks of application, when 22.10 and 23.88 mm of rain fell. The high intensity of this rain could have been sufficient to prevent permanent damage. The orchardgrass at these high manure treatments was reduced in total yield only at the 40 t/ha treatment. The potential for crop damage or complete crop failure is high, particularly when applications of heavy rates of poultry manure are applied during dry periods or later in the growing season.

The 40 t/ha split manure application produced the highest yields at the first cut. This was a 47% increase over the dry matter produced at the 1.25 t/ha manure treatment. Diminishing increases in the dry matter produced per tonne of manure occurred at rates above 2.5 t/ha. However, a substantial increase in dry matter yield per tonne of manure was still obtained at the 5 t/ha treatment (Figure 3). Pure established orchardgrass stands have been found to require between 170 and 340 kg N/ha/year for optimum yield responses (Wedin, 1974). Only the 10 t/ha treatment supplied total N within that range (271 kg N/ha, Table IV). Cool, wet climatic

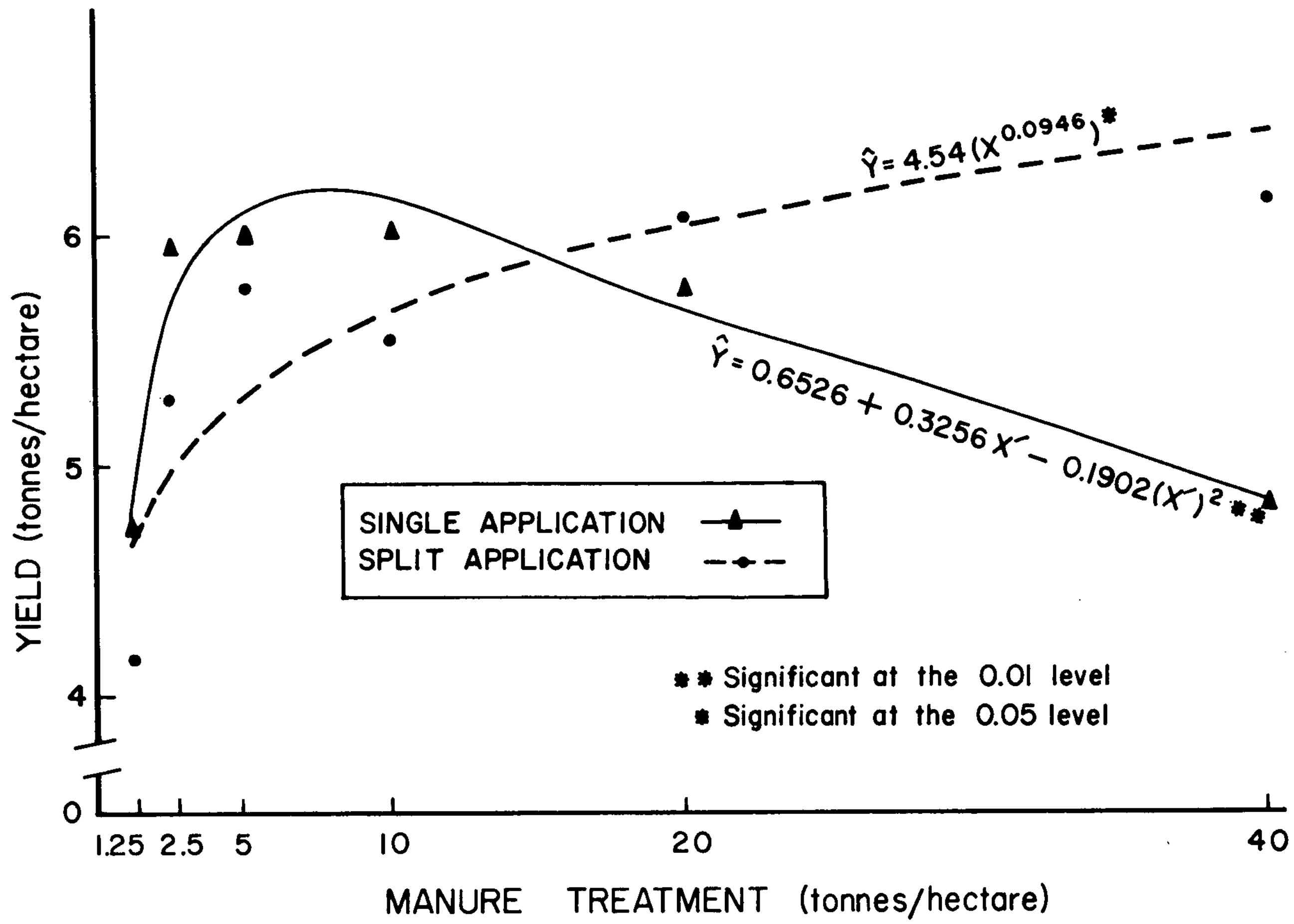

Figure 3. First Cut, 1976 - Total Yield as Affected by Poultry Manure Treatment and Method of Application

conditions and the clover present in the two lower manure treatment plots may have accounted for the optimum yield response at the lower manure treatments.

The second cut produced the lowest yield of any harvest for both application methods in 1976. There was a significant yield response to manure treatment for the single application method only (Figure 4). The response was similar to the split application of the first cut with diminishing yield returns per tonne of manure occurring above the 2.5 t/ha manure treatment. A good yield response to manure treatment was still observed up to the 10 t/ha treatment.

There was no significant yield response to the split application method at the second harvest. At rates above 10 t/ha, free ammonia damage or soluble salts resulted in yield reductions. The additional manure applied after the first harvest was beneficial at the lower manure rates. Yield values were greater for the split application treatments than for the single application treatments at manure rates below 10 t/ha.

For the third harvest, the effect of manure treatment on yields for both the single and split application yields produced significant responses (Figure 5). Generally, the split application treatments produced yields higher than the single application treatments. The single application treatments showed a yield increase of 89% over the range of manure treatments compared to 55% for the split application treatments. Good increases in yield per tonne of manure were found up to 10 t/ha although the maximum increase occurred at the 5 t/ha treatment for both methods.

At the fourth cut, both the split and single application methods showed similar significant yield responses to manure treatment (Figure 6). The

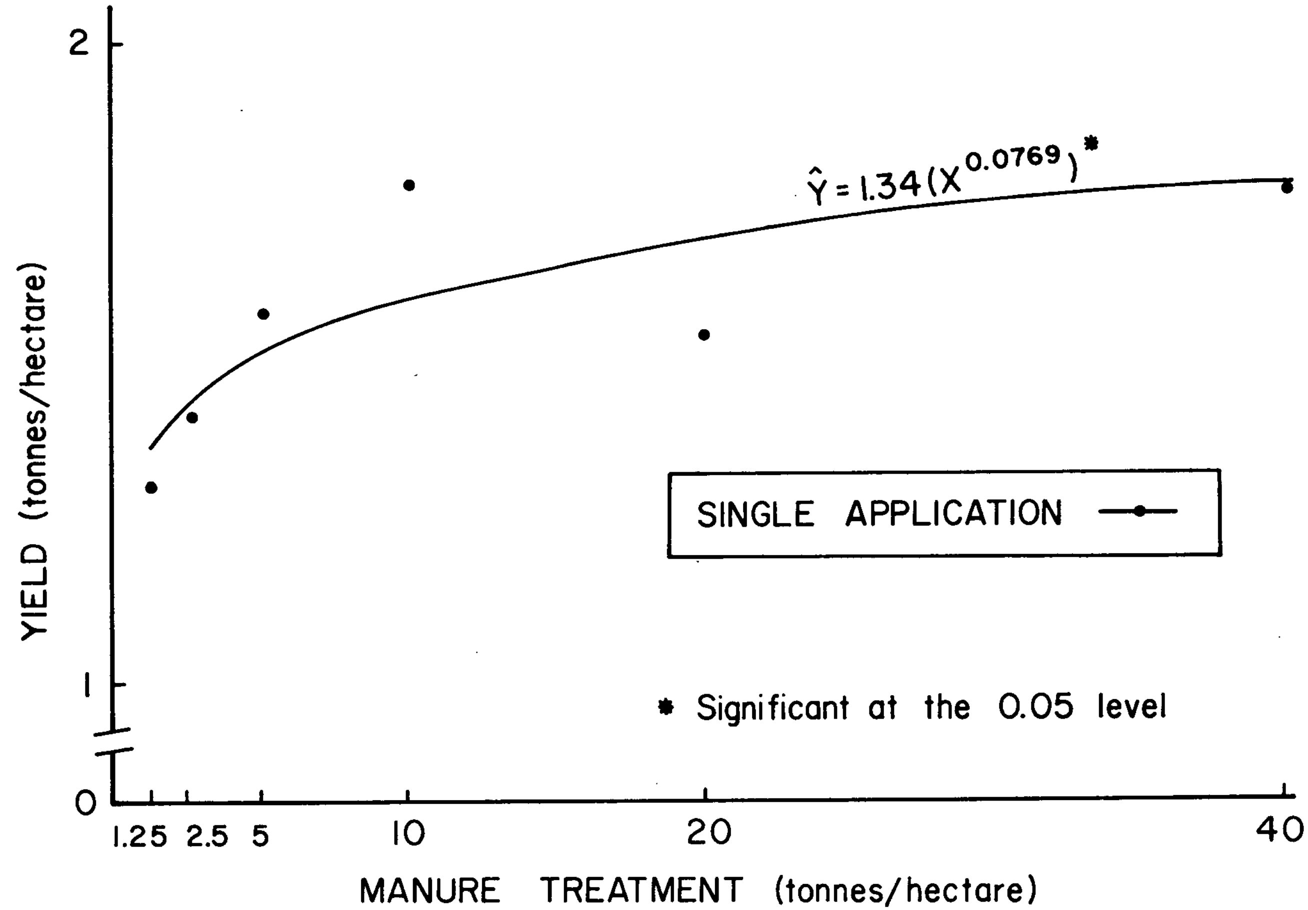

Figure 4. Second Cut, 1976 - Total Yield as Affected by Poultry Manure Treatment and Method of Application

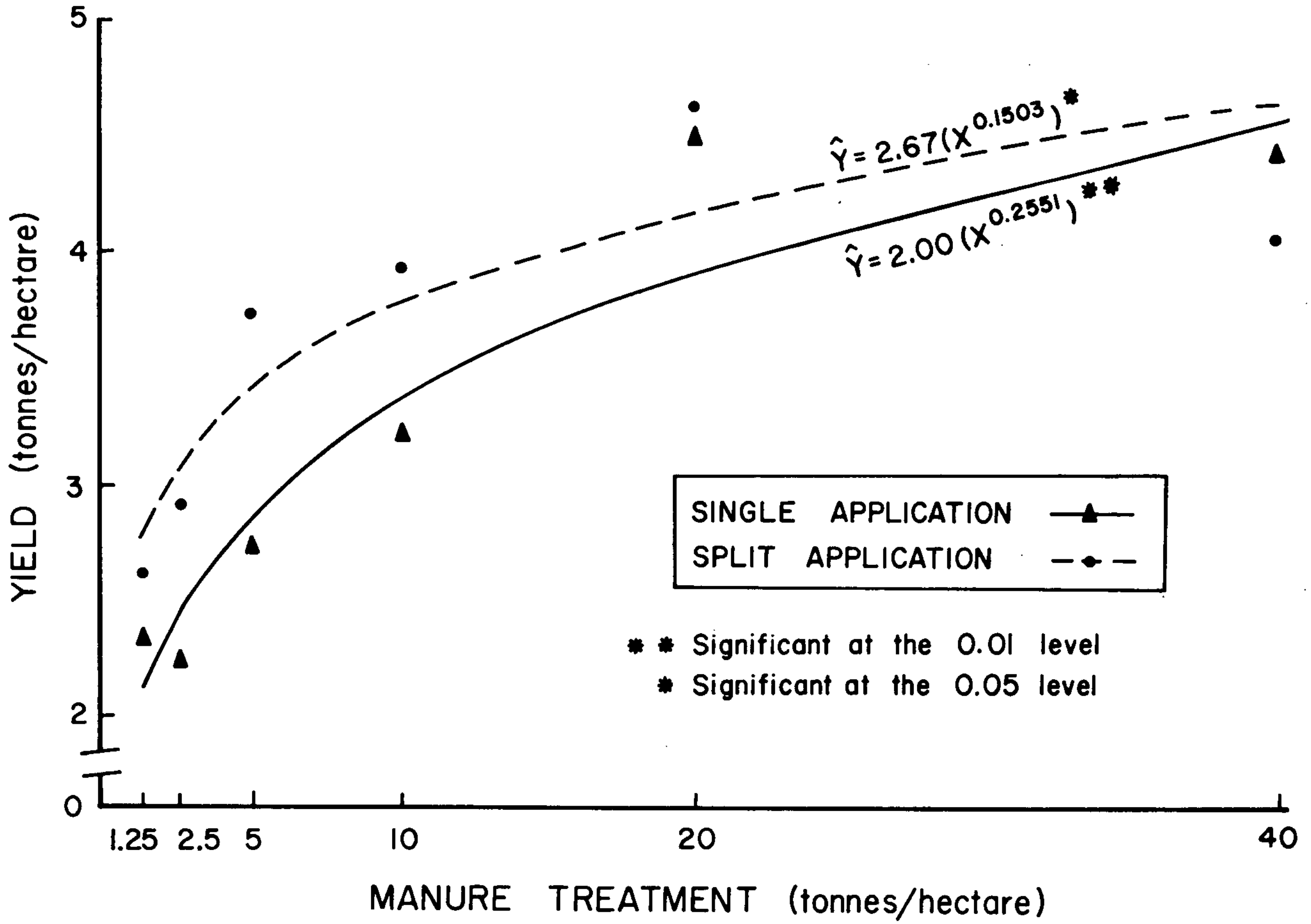

Figure 5. Third Cut, 1976 - Total Yield as Affected by Poultry Manure Treatment and Method of Application

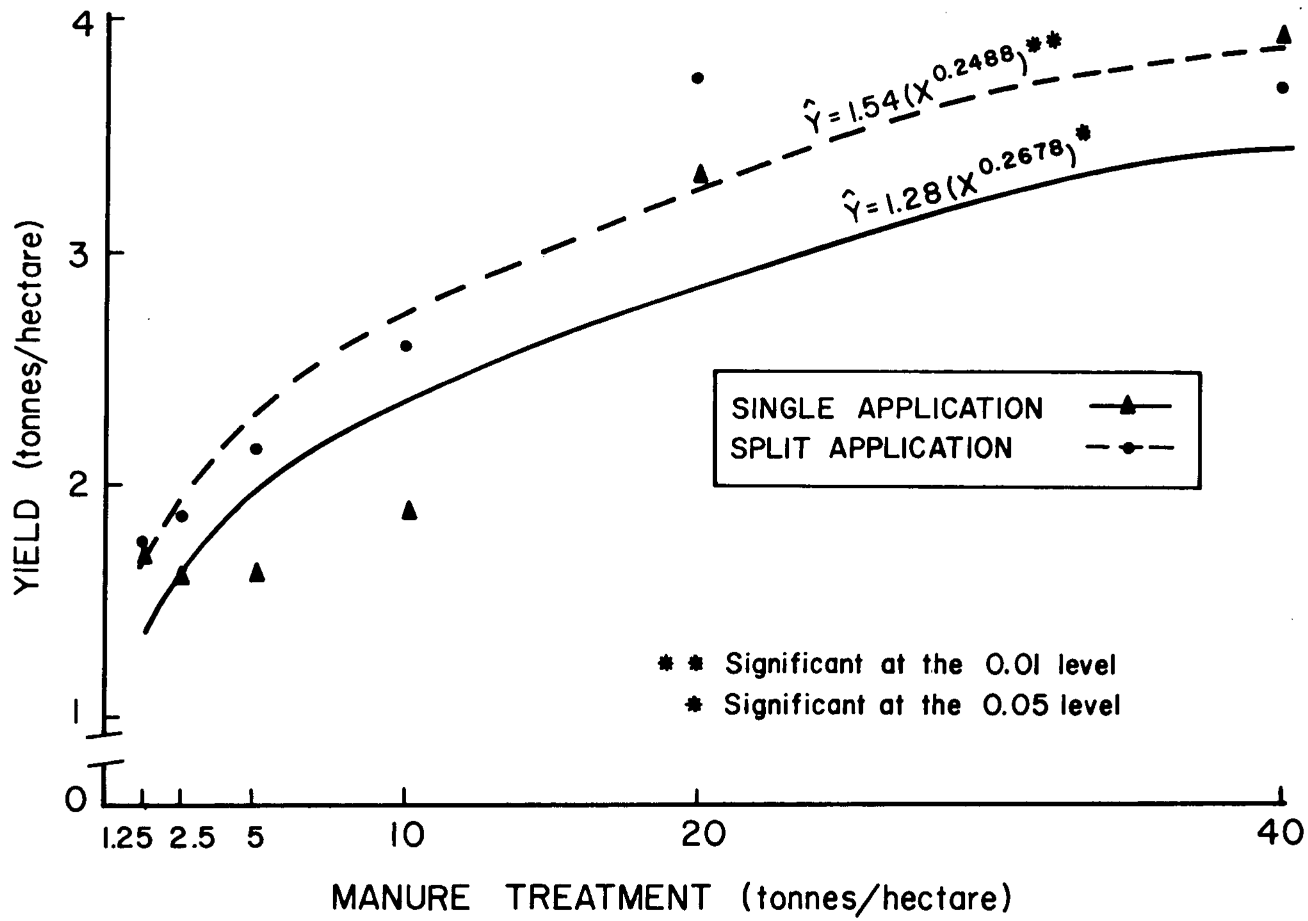

Figure 6. Fourth Cut, 1976 - Total Yield as Affected by Poultry Manure Treatment and Method of Application

split application method had yields 0.3 to 0.4 t/ha higher than the single application method. The single application led to a 131% yield increase compared to 113% for the split application between the 1.25 and 40 t/ha treatments. Residual N at the higher manure treatments is responsible for the higher percentage yield increase at the fourth cut.

Total yields ranged from 10.04 at the 1.25 t/ha manure rate to 16.08 t/ha at the 20 t/ha manure rate, split application (Figure 7). The 40 t/ha rates were slightly lower than either of the 20 t/ha treatments' total yields. At the 5, 10 and 20 t/ha manure treatments the split application method produced total yields about 1.2 t/ha higher than the single application method. The total yields of the mid-range manure treatments would indicate a more efficient utilization of the manure resources, particularly N, when the manure is surface applied in three equal applications rather than all at once. The lower total yields for the single application method might also be the result of damage due to free ammonia or soluble salts when the manure was applied in the spring.

The yield data were influenced by the clover present in the 1.25 and 2.5 t/ha manure treatments and the cool, wet weather during the summer. The clover increased the yields at the lower treatments above what would be expected if a pure stand of orchardgrass had received the same treatments. As well, the cooler weather increased the efficient utilization of the mineralized N. The cooler weather provided excellent growing conditions for the grass so there was a higher demand for N and thus less N was lost during the growing season. The combination of these two factors produced maximum increases in dry matter yields per tonne of manure at the 2.5 t/ha rate. Excellent yield increases still occurred up to the 10 t/ha rate but

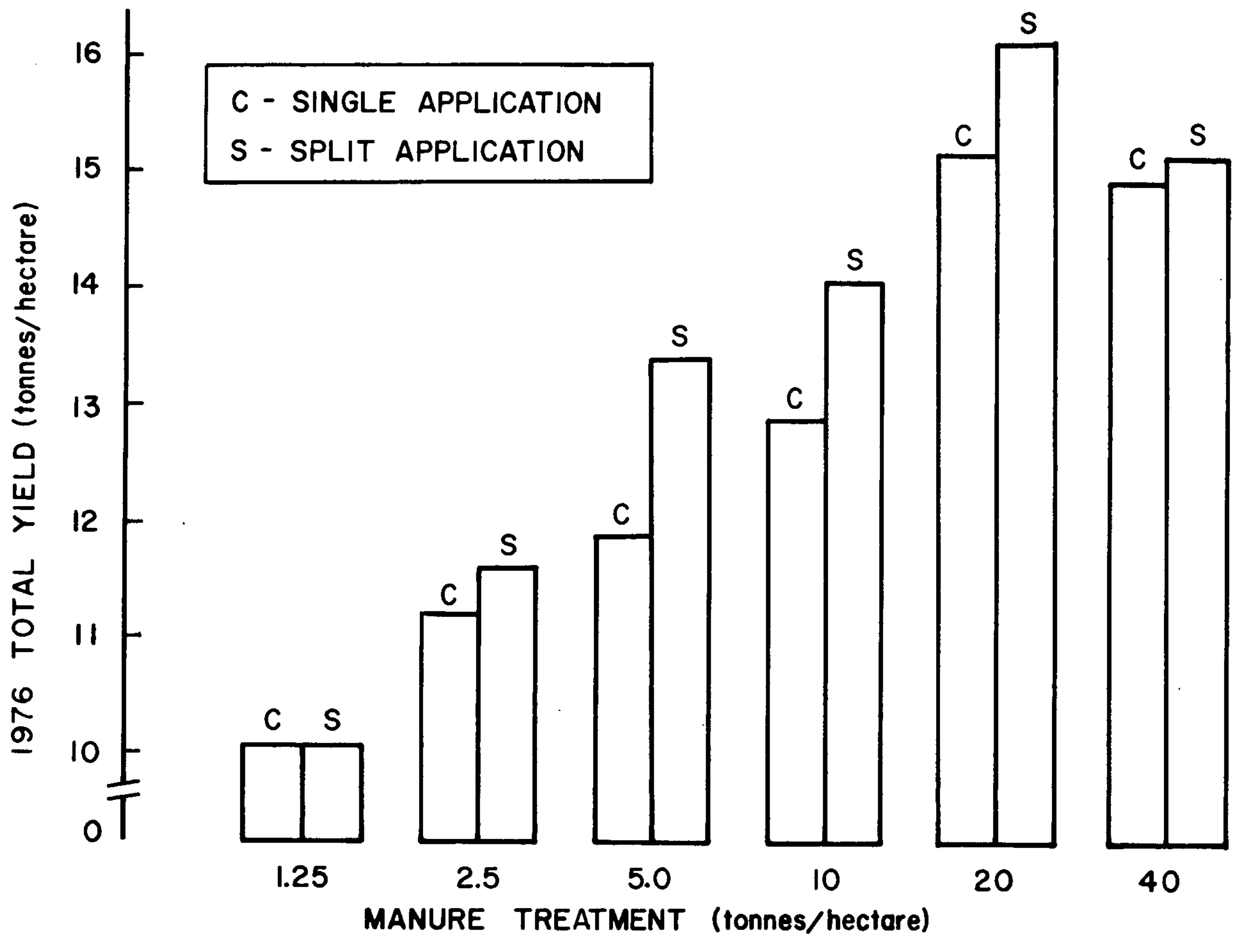

Figure 7. 1976 Total Yield as Affected by Poultry Manure Treatment and Method of Application

at a lower increase per tonne of manure than at the 2.5 t/ha treatment. The wet weather, particularly around the first and third manure application dates, possibly modified the adverse effect of the heavy manure rates. Had drier weather followed any one of the manure applications, more severe damage could have resulted at the single application rates of 10 t/ha and above and at the split application rates of 20 and 40 t/ha.

C. Botanical Composition

In 1975 increasing the manure rate decreased the clover content. The clover content from the 5 t/ha to the 40 t/ha manure treatment remained fairly constant (Table V). It has been suggested that N applied as manure causes less depression of clover content than if the same amount of N is applied as inorganic N fertilizers (Whitehead, 1970; Parker, 1966). The levelling off of the clover content at approximately 25% above the 5 t/ha rate could be an indicator of this.

Weeds were present in the new stand only. They were not a function of manure treatment but of the forage growth rate. The weeds were highest in the control and the 1.25 t/ha treatment, which had the lowest forage yields. Virtually no weeds were present at rates greater than 10 t/ha in 1975. In 1976 no appreciable weed component was observed.

The clover was eliminated at the 10 t/ha manure treatment and above from the first harvest date on in 1976 (Table VI). By the third cut, the clover disappeared completely from the 5 t/ha plots, both methods. Only in the control, 1.25 and 2.5 t/ha plots was clover a factor. The clover content decreased considerably from the last harvest date in August 1975

Table V: Botanical composition - second cut, 1975

	Control	1.25	2.5	5	10	20	40
		t/ha					
% Legume	46	47	33	22	28	26	25
% Weeds	15	20	9	8	2	1	2

Table VI: Percent legume - 1976

Cut	Control	1.25		2.5		5		10[1]	20	40
		t/ha								
		sin	spl	sin	spl	sin	spl			
		--- % Clover - Dry Weight Basis ---								
1st	11	14	16	7	9	2	3	0	0	0
2nd	26	24	27	13	18	3	5	0	0	0
3rd	27	34	32	22	12	1	1	0	0	0
4th	26	37	39	27	19	0	0	0	0	0

[1] For the manure treatments above 10 t/ha, the legume content was the same for both methods.

to the first harvest date in May 1976. By the first cut, the clover content in these plots was less than 20%. More frequent cuts in 1976 reduced the shading by the grass and the clover content improved by the fourth cut to at least double the initial percentage in 1976. The third manure application following the second harvest at the 2.5 t/ha manure treatment depressed clover yields at the third and fourth harvests compared to the single application. Otherwise the split application had no apparent effect on the clover percentage at the 1.24 and 2.5 t/ha rates.

Besides the obvious adverse effect of N on the clover, shading of the clover by the grass, particularly between the last cut in 1975 and the first cut in 1976, was a major cause of the clover disappearance. In 1976, the more frequent cutting dates allowed the clover percentage to increase in the manured plots where the clover was not irreversibly affected.

D. % Total Kjeldahl Nitrogen and % Nitrate-N in the Forage

Percent total kjeldahl nitrogen (% TKN) shows a significant response similar to the response of the mean yields in 1975 (Figure 8). The % TKN levels had the greatest increase per tonne of manure at the 2.5 t/ha treatment. Substantial gains in percentage increases per tonne of manure continued until the 10 t/ha rate. The second cut produced no significant response. Only the 20 and 40 t/ha treatments produced higher % TKN in the forage than the 1.25 t/ha rate. This is because the 1.25 t/ha treatment contained 50% clover in the stand while the remaining treatments had about 30% clover. There is very little transfer of N fixed by clover to the grass in the establishment year of a clover-grass sward (Whitehead, 1970).

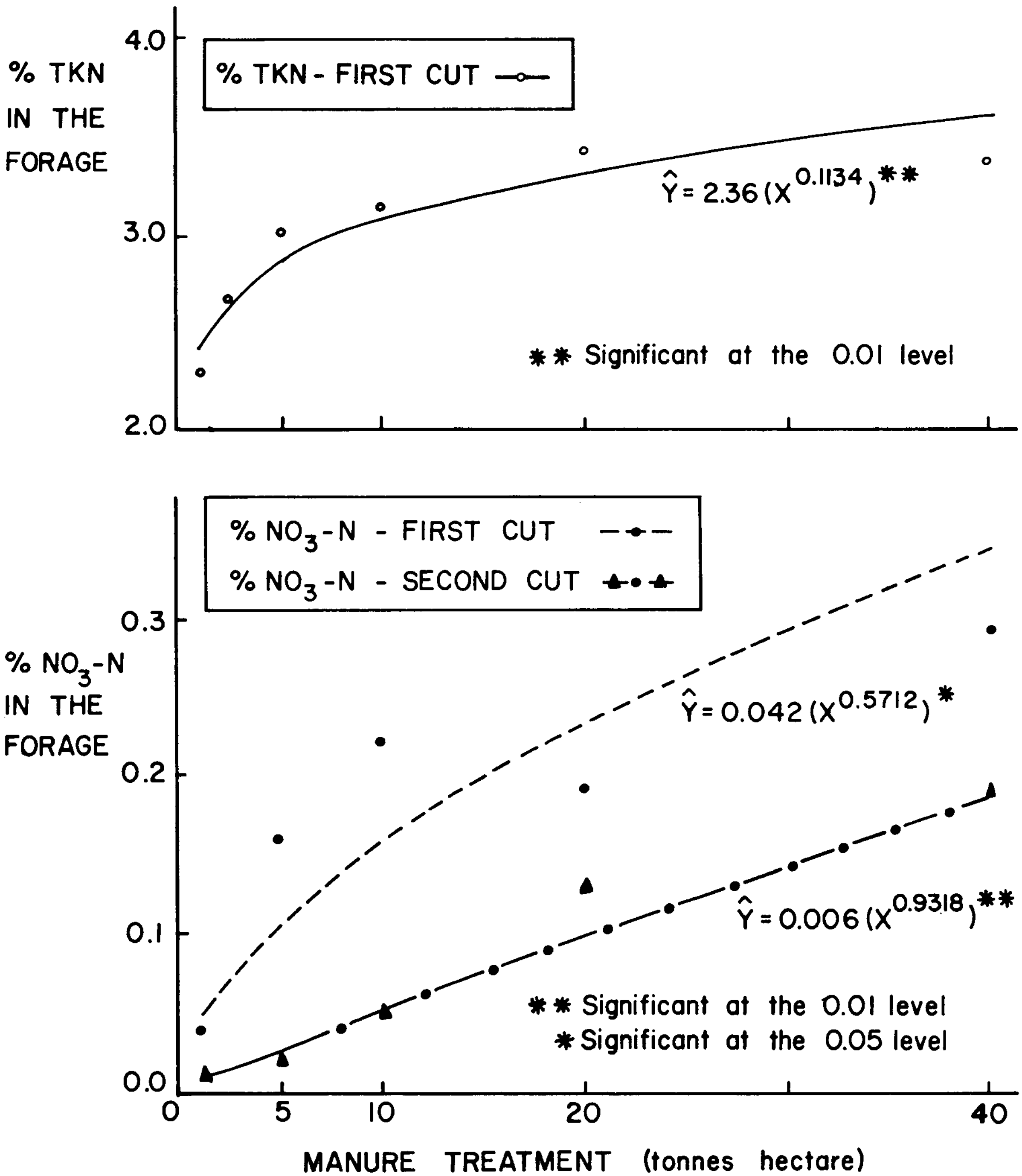

Figure 8. Percent Total Kjeldahl N and % Nitrate-N in the Forage by Cut in 1975 as Affected by Poultry Manure Treatment

Therefore, the high TKN percentage in the 1.25 t/ha treatment was simply a result of the higher clover content in the stand which contains a higher percentage of N than orchardgrass. The 20 and 40 t/ha treatments produced the highest % TKN values because of the high quantities of N supplied at these manure rates (787 and 1575 kg N/ha, respectively). The TKN levels were significantly higher at the first cut in 1975.

The first cut produced nitrate concentrations significantly higher than the second cut but the nitrate-N levels were still below the 0.34% nitrate-N considered potentially toxic by Wright and Davison (1964). Only the 10 and 40 t/ha treatments in the first cut produced nitrate-N percentages in the forage above 0.20% (critical nitrate-N level cited by Williams et al., 1972). No nitrate-N percentages in excess of 0.20% were found for any treatment at the second cut. The higher nitrate-N concentrations for the first cut are due to the high rates of N incorporated into the soil with the manure in the spring. The rate of increase of the % nitrate-N for both cuts is much higher than for any other element or for dry matter yield (Figure 8). The second cut produced the highest rate of increase, twice the rate increase of the first cut. It is the result of the residual N at the higher manure treatments.

Nitrate responses to manure applications were much greater than the % TKN yet in no case did the nitrate-N levels become alarmingly high. For manure rates which supplied the optimum N suggested for maximum orchardgrass-clover yields (5 or 10 t/ha treatment), nitrate-N concentrations were no cause for concern.

In 1976, the orchardgrass forage was analyzed separately from the clover when clover was present. Only in the control, 1.25 and 2.5 t/ha treatments was there sufficient clover in the samples for analysis. At these low rates, nitrate-N percentages in the clover were similar to the % nitrate-N in the orchardgrass (less than 200 ppm). The % TKN concentrations were approximately two to three times higher in the clover than the orchardgrass for all four cuts. A complete chemical analysis of the clover is presented in Appendix Table E1. The N concentrations are taken into account for the N balance sheet but the N values recorded for the clover have been omitted from the discussion of % TKN and % nitrate-N. The effects of the clover and N fixation by the clover on the chemical composition of the orchardgrass is important in explaining some of the responses observed in 1976.

At the first harvest the % TKN for the single and split application treatments produced significant responses to manure treatment (Figure 9). The maximum increase in % TKN per tonne of manure for the single application method occurred at the 2.5 t/ha manure treatment. The maximum increase in % TKN for the split application method occurred at the 5 t/ha manure rate. Substantial increases in the % TKN gain per tonne of manure for both methods were observed up to the 10 t/ha treatment. The single application treatments produced % TKN concentrations higher than the split application treatments at all rates of manure.

Percent nitrate-N increased approximately 25 times from the 1.25 to the 40 t/ha treatment. The single application treatments produced actual nitrate-N concentrations ranging from 0.01 to 0.50%. The split application treatments ranged from 0.01 to 0.30% nitrate-N (Figure 9; Appendix Table D3). Nitrate-N percentage in the orchardgrass at the 10, 20 and 40 t/ha single application treatments and the 20 and 40 t/ha split application

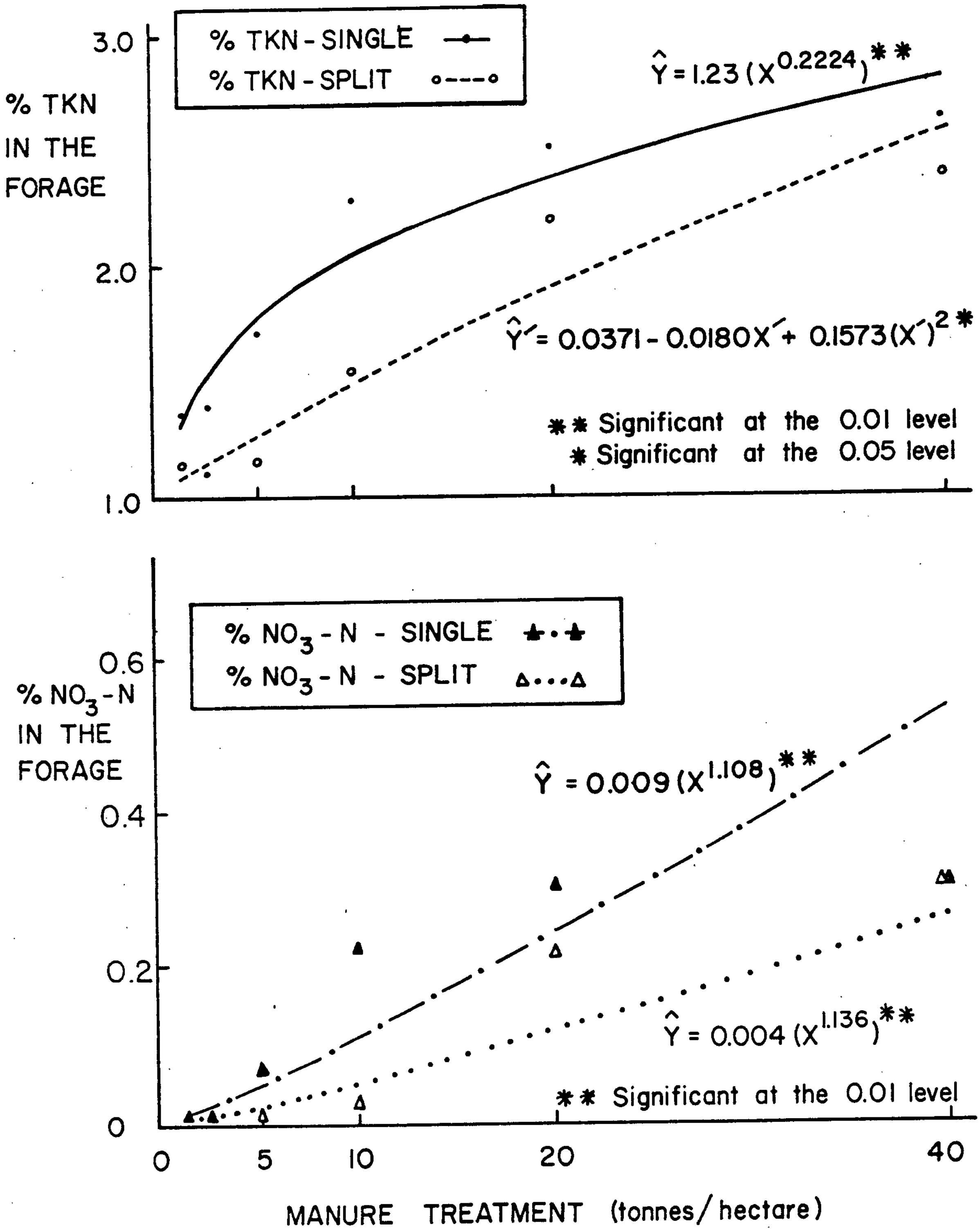

Figure 9. First Cut, 1976 - Percent TKN and % Nitrate-N in the Forage as Affected by Poultry Manure Treatment and Method of Application.

treatments were in excess of 0.20%. The rate of increase in % nitrate-N per tonne of manure was maximum at the higher manure treatments for both methods. This is the opposite response to that found for % TKN and dry matter yield. At the higher manure treatments, the manure was supplying N in excess and the orchardgrass is taking up nitrate faster than it can be assimilated into protein. Therefore the nitrate is accumulating in the orchardgrass on the heavily manured plots.

At the second % TKN and % nitrate-N responded significantly to both the single and split application methods (Table 10). The % TKN for the single and split application treatments followed a similar response. The additional manure added following the first harvest had no apparent effect on the % TKN. The maximum rate increase in % TKN was at the 2.5 t/ha treatment for both methods. Substantial increases in % TKN occurred up to the 20 t/ha rate. The % TKN for the second cut, both methods, was significantly higher than the first cut. At the second harvest lower yields coincide with higher quality forage in terms of crude protein (% TKN).

The 20 and 40 t/ha treatments for both methods produced the maximum increase in % nitrate-N per tonne of manure for the second cut. The excessive N applied at these manure rates caused the large increase in % nitrate-N above the 10 t/ha treatment. Nitrate-N concentrations in the orchardgrass at the 20 and 40 t/ha treatments for both methods were higher than the potentially toxic limits of 0.34 to 0.45% suggested by Wright and Davison (1964). Orchardgrass in the 10 t/ha split application treatment had 0.32% nitrate-N. Nitrate-N percentages for the above-mentioned treatments were considerably higher at the second harvest than at the first harvest.

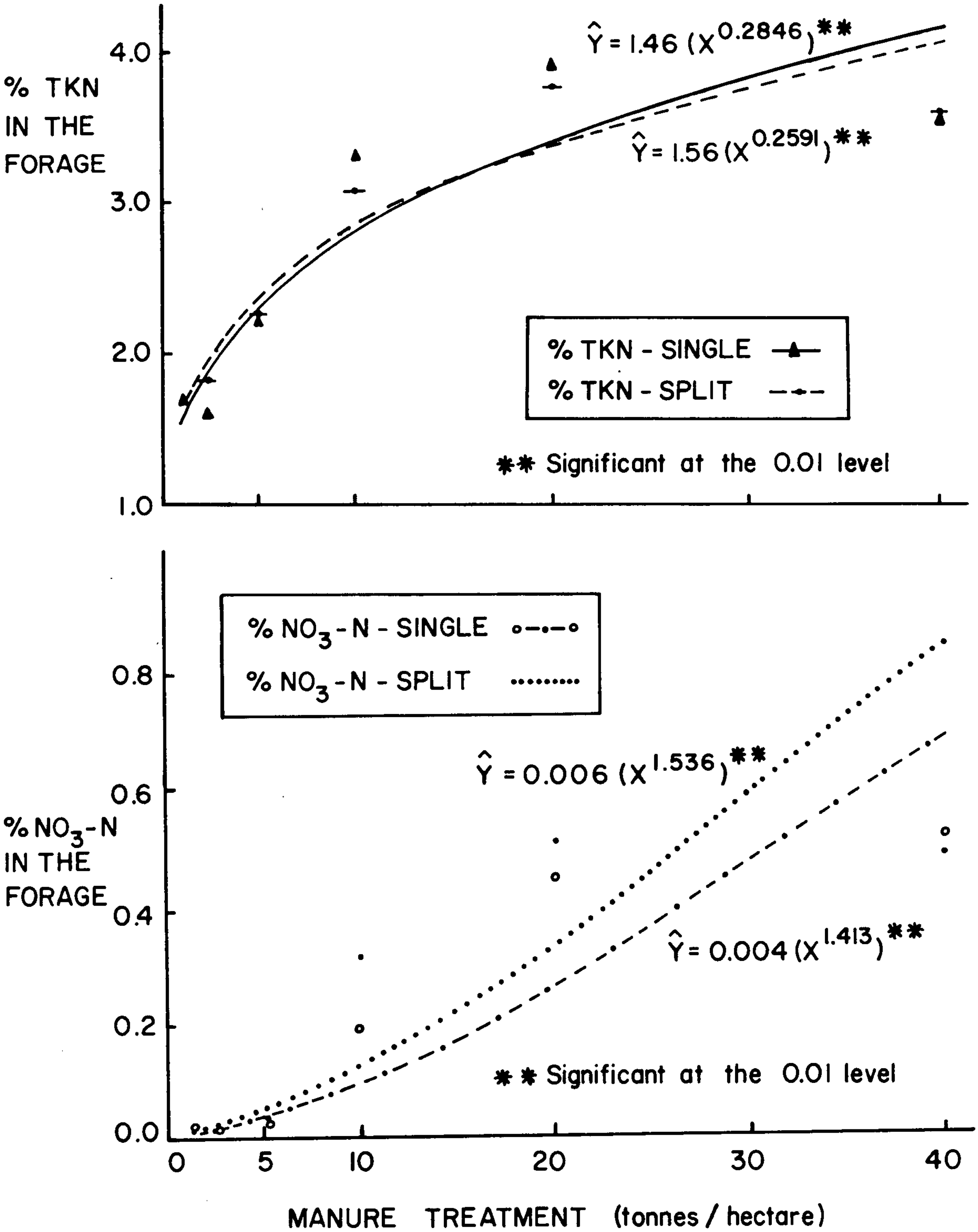

Figure 10. Second Cut, 1976 - Percent TKN and % Nitrate-N in the Forage as Affected by Poultry Manure Treatment and Method of Application

Higher % TKN values and increased nitrification of the manure N resulted in more rapid accumulation of nitrates. Above a certain total organic N level, nitrate assimilation into protein slows and nitrate accumulation proceeds very rapidly. Lund et al. (1975) indicated about 2.5% total organic N was the critical percentage. Nitrification of the manure N probably reached a maximum between the first and second harvest, thus large quantities of nitrate-N were present in the root zone. At the first harvest nitrification was limited to some degree by temperature. Production of nitrate from the mineralized manure N probably peaked between the first and second harvests.

For the third harvest, % TKN responded significantly to the split application treatments (Figure 11). The concentrations and response are similar to those observed in the first cut for the split application treatments. There was no significant response of the % TKN in the single applications. The clover present in the 1.25 and 2.5 t/ha manure treatments (34 and 22% clover, respectively) produced higher % TKN values in the orchardgrass than in the orchardgrass of the 5 and 10 t/ha manure treatments. Very little manure N was available at the single application rates below 20 t/ha by the third harvest.

Both methods produced similar nitrate concentrations until the 10 t/ha treatment for the third cut. The split application treatments increased at a greater rate than the single application treatments above the 10 t/ha treatment. The third manure application following the second harvest probably accounts for the greater rate of increase at the higher manure rates in the split application treatments. The rate of increase and the % nitrate-N were lower for both methods at the third cut than for the second cut. The 20 and 40 t/ha treatments for both methods produced % nitrate-N

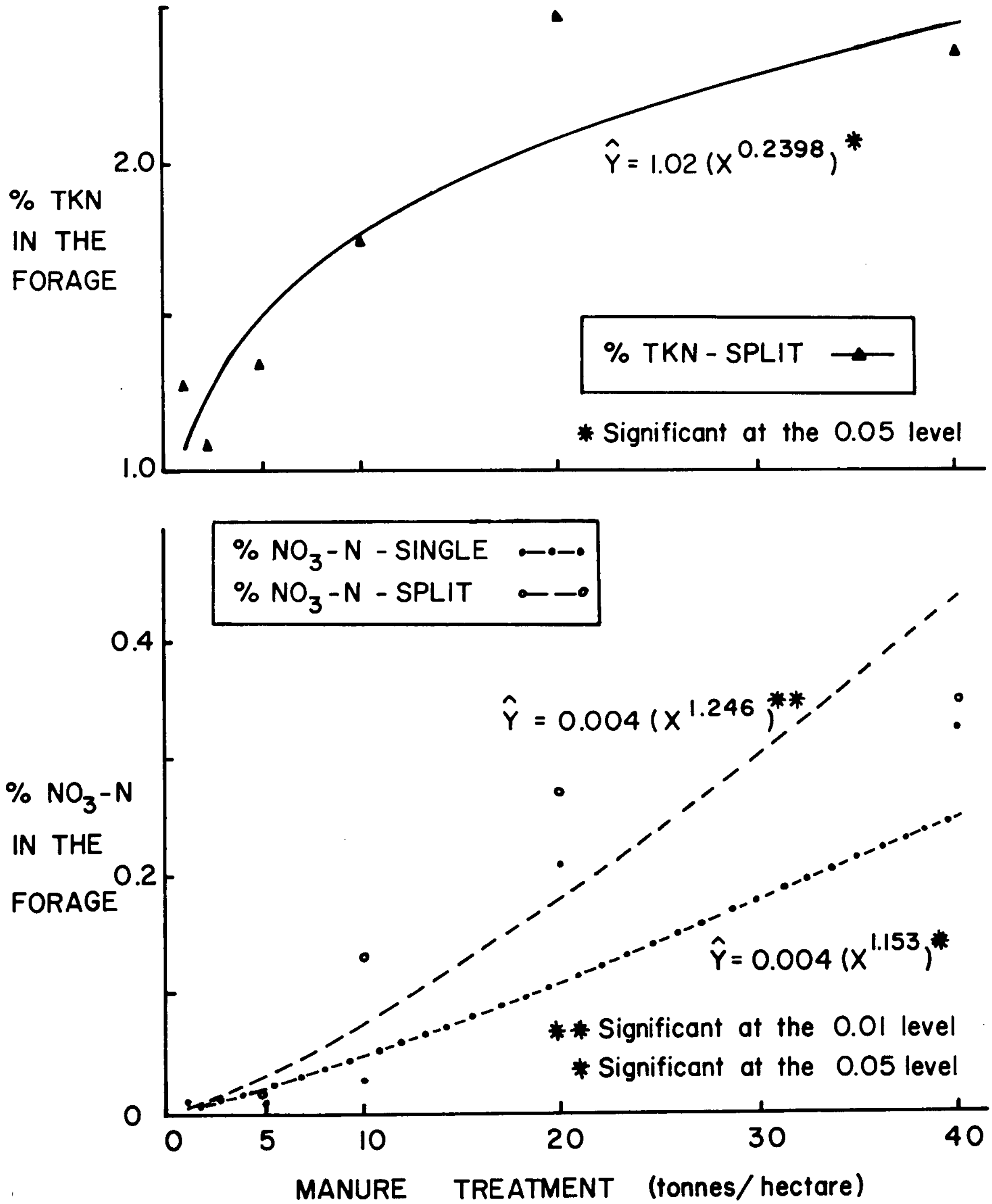

Figure 11. Third Cut, 1976 - Percent TKN and % Nitrate-N in the Forage as Affected by Poultry Manure Treatment and Method of Application

concentrations in the orchardgrass in excess of 0.20%. All other treatments had nitrate-N percentages below 0.15%.

The % TKN in the orchardgrass of the fourth cut responded sig-nificant response for the single application treatments (Figure 12). There was no significant response for the split application treatments. The % TKN concentrations for the single application treatment decreased initially then increased at the manure rates greater than 5 t/ha. A similar negative response at the lower manure treatments was observed for the split application method. The negative response for both methods at the low manure treatments is because of the clover present in the 1.25 and 2.5 t/ha treatments. A portion of the N fixed by the clover is transferred to the orchardgrass giving the 1.25 and 2.5 t/ha treatments an additional supply of N. By the fourth harvest, at the 5 and 10 t/ha rates, there is little residual available manure N to provide an increase in the N concentration of the orchardgrass. This is also reflected in the nitrate concentrations of the orchardgrass.

The % nitrate-N of the fourth cut produced significant responses for the single and split application treatments (Figure 12). Nitrate levels were similar for both methods except at the 40 t/ha treatment. The 40 t/ha split application treatment produced orchardgrass containing nitrate-N in excess of 0.50%. The large jump in the nitrate-N percentage between the 20 and 40 t/ha treatments indicates a significant amount of available soil N was still present at the fourth cut of the 40 t/ha treatment for both methods.

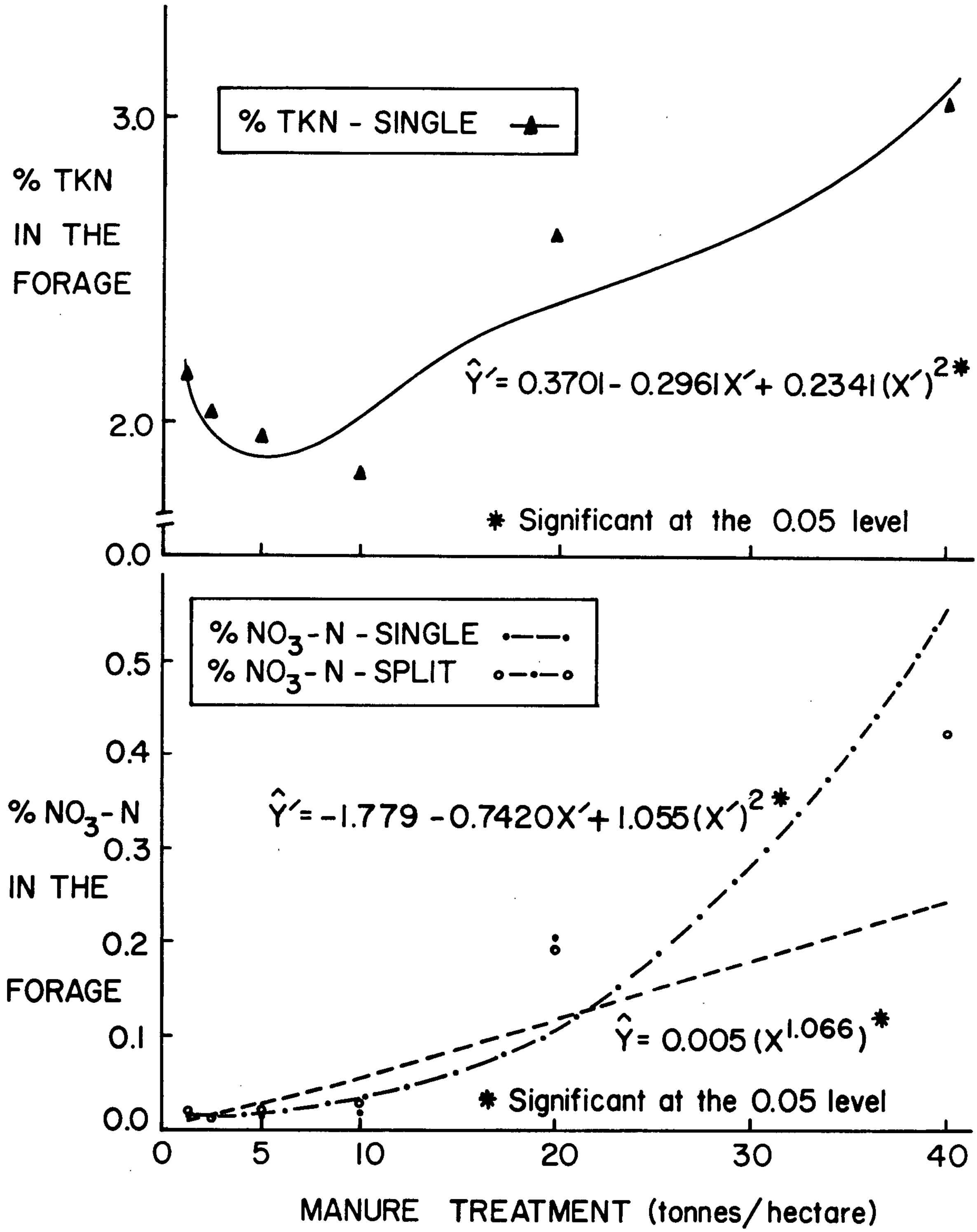

Figure 12. Fourth Cut, 1976 - Percent TKN and % Nitrate-N in the Forage as Affected by Poultry Manure Treatment and Method of Application

E. Percent P in the Forage

In 1975 there was a significant cut effect with % P (Appendix Table B7). The first cut produced concentrations significantly higher than the second cut. For both cuts, % P concentrations were independent of manure treatment. Percent P ranged from 0.25 to 0.28% P for the 2.5 and 20 t/ha treatments, respectively, at the first harvest. The second harvest produced a range of 0.18 to 0.22% P (Appendix Table D4). Phosphorus was supplied by the poultry manure in excess of the crops' needs. The P removed by the crop, the P added in the manure, and the estimated P available over the growing season are listed in Table VII. The available P from the poultry manure is 40% of the total P as suggested by Phillips et al. (1978). In all treatments in 1975, the total P supplied in the manure was in excess and the estimated P available exceeded the P removed by the herbage in all but the 1.25 t/ha treatment.

In 1976 a similar pattern was observed. There was no significant method effect so % P concentrations presented are an average for both methods. Percent P increased from the first cut to the second cut. The third and fourth cuts produced % P levels that fluctuated between the concentrations obtained at the first two harvests. There was no significant response of % P to manure treatment. The results were inconsistent and varied with each cut. The first cut showed very little fluctuation in % P. At the second cut the % P in the orchardgrass increased 25% over the range of manure rates applied. The third and fourth harvests produced % P concentrations which decreased 15 to 25% from 1.25 to the 40 t/ha treatments (Appendix Table D5). Available P in the surface 15 cm of the soil was high so no immediate effect of the added P in the manure

Table VII: Total P and estimated P available from high-rise poultry manure and P removed in the forage, 1975

Manure Treatment t/ha	Total P Added By Manure	Estimated P Available[1]	P Removed in The Forage
	kg/ha		
1.25	24.3	9.7	9.0
2.5	48.6	19.4	8.9
5.0	97.3	38.9	11.4
10	194.5	77.8	13.3
20	389.0	155.6	13.8
40	778.1	311.2	17.2

[1]Forty percent of the total manure P as determined by Phillips *et al.*, (1978).

on the % P concentration in the orchardgrass would be observed at the first cut. The negative response of % P to manure treatment at the third and fourth harvests was most likely a dilution effect of the increased yield response to the manure treatment.

The P removed by the orchardgrass, the P added by the manure, and the estimated P available in 1976, are given in Table VIII. The estimated P available for the 20 and 40 t/ha treatments was well in excess of the P removed by the crop. The 10 t/ha treatment had a similar amount of P removed in the harvest as was estimated to be available from the manure. The lower manure rates did not supply an adequate amount of available P to equal the P removed by the crop. The high level of available P in the surface soil would more than compensate for the differences.

At all but the two lowest manure rates of 1976, total P was added in excess of P removed by the crop. Assuming 40% is available over the growing season, the 2.5 t/ha treatment in 1975 and the 10 t/ha treatment in 1976 supply sufficient P to meet the P demand of the forage. For orchardgrass swards, the high-rise poultry manure will supply P in adequate amounts when the manure is applied to optimize N utilization.

F. Percent K in the Forage

In 1975, significant cut and treatment effects for % K were observed (Appendix Table B9). Percent K decreased in the second harvest. The treatment response was the same for both cuts and the mean % K values produced a significant response, similar to the mean yield response in

Table VIII: Total P and estimated P available from high-rise poultry manure and the P removed in the forage, 1976

Manure Treatment t/ha	Total P Added By Manure	Estimated P Available[1]	P Removed in The Forage
	kg/ha		
1.25	15.4	6.2	36.7
2.5	30.8	12.3	41.9
5.0	61.5	24.6	46.4
10	123.0	49.2	49.5
20	246.1	98.4	55.0
40	492.2	196.9	54.9

[1]Forty percent of the total manure P as determined by Phillips *et al.*, (1978).

1975. The K concentrations in the forage were above 2.0% for all treatments of both cuts indicating "luxury consumption". The total K removed in the herbage, the K added in the manure, and the total K available in 1975, are indicated in Table IX. The latter estimate is the sum of the available soil K in the surface 15 cm (prior to the initial manure application) and the total K in the manure (assuming 100% becomes available over the growing season). The total K available in 1975 was well in excess of that removed by the crop and most of the excess would remain in the rooting zone for use in 1976.

In 1976 the second cut produced the highest percentage of K with the other three harvests having a similar range of concentrations. All the values were in excess of the 1.6 to 1.7% K that Hemmingway (1963) suggested as indicating luxury consumption. Percent K values were averaged for both methods as there was no significant method effect. The first three harvests produced three different significant responses. At the first harvest the % K remained approximately at the 3.0% level and then increased to 3.5% at the 40 t/ha treatment (Appendix Table D7). Percent K for the second harvest ranged from 3.20 to 4.50%. At the third harvest, % K ranged from 2.64 to 2.90% K for the 1.25 and 10 t/ha manure treatments, respectively. The 20 and 40 t/ha treatments had % K concentrations in the orchardgrass of 3.41 and 4.59% K. The % K at the fourth cut had no significant response. Concentrations of 2.72 to 3.04 were observed up to the 20 t/ha treatment. The 40 t/ha treatment yielded a % K value of 4.15%.

The K removed by the crop in 1976, the residual K from 1975 and the K added by the manure in 1976 are given in Table X. All the manure rates supplied less K than was removed by the crop. Most of the K available

Table IX: K added in the manure, total K available to the forage and the K removed in the herbage, 1975

Manure Treatment t/ha	Total K Added By The Manure	K Available To The Forage[1]	K Removed in the Herbage
	----------	kg/ha	----------
1.25	19.6	371.5	91.5
2.5	39.1	391.1	117.8
5.0	78.3	430.3	145.3
10	156.6	508.6	195.9
20	313.1	665.1	216.9
40	626.2	978.2	262.4

[1]K added by the manure plus available soil K (352 kg K/ha).

Table X: Residual K from 1975, K added in the manure, total K available to the forage and the K removed in the herbage, 1976

Manure Treatment t/ha	Residual K from 1975	Total K Added By the Manure	K Available to the Forage	K Removed in the Herbage
	-----	----- k/ha	-----	-----
1.25	280.0	13.8	293.8	288
2.5	273.3	27.7	301.0	340
5.0	285.0	55.4	340.4	358
10	312.7	110.7	423.4	396
20	448.2	221.5	669.7	519
40	715.8	442.9	1158.7	604

for the crop, particularly below the 20 t/ha treatment, was from the K in the soil and residual K from the manure applications in 1975. In 1976, the total K available at the 20 and 40 t/ha treatments (manure plus residual K) was still higher than the K removed in the herbage. This could explain the sharp increase in % K between the lower manure rates and the 20 and 40 t/ha treatments (particularly the 40 t/ha rate), in all but the second cut. Up to the 20 t/ha treatment, the available K is approximately equivalent to the K removed in the forage. Thus, in a less fertile soil with low available soil K, the application of these poultry manure rates would not meet the orchardgrass needs for K. This would be especially so at manure rates applied to meet the N requirements of the crop. Had this study continued and the only source of K available was that supplied by the poultry manure, % K concentrations in the orchardgrass would have decreased and K would probably have become limiting for plant growth.

G. Percent Ca, Mg and Na in the Forage

In 1975, % Ca and % Mg were significantly different between cuts (Appendix Tables B11 and B12). For both elements, the concentrations increased from the first to the second cut. Percent Ca in 1975 decreased slightly as the manure rate increased (0.71 to 0.64% at the first cut and 1.11 to 0.86 at the second cut). Magnesium concentrations showed no pattern and were inconsistent in relation to manure treatment. In 1975, significant cut and treatment effects were observed for % Na (Appendix Table B13). As with % Ca and % Mg, Na concentrations increased from the first to the second cut. The response of mean % Na to manure treatment was similar to the mean forage yield in 1975. Approximately 79 and 158 kg Na/ha were added by the 20 and 40 t/ha treatments, respectively, so an increase in % Na in the forage was expected.

In 1976, the % Ca and Mg increased in the spring from the first to the second cut then levelled off and remained constant throughout the rest of the growing season. Percent Na showed a gradual increase in concentration as the growing season progressed.

The Ca concentrations were low in 1976 compared to 1975. The first cut produced no significant response to manure treatment. A significant response was observed at the second cut. In the third and fourth cuts, % Ca in the orchardgrass decreased significantly with increasing manure treatments. A simple dilution effect and the high K concentration at the 20 and 40 t/ha treatment could have caused the % Ca depression at the third and fourth cuts.

Percent Mg was not consistent with manure treatment. There was no significant response at the first and third harvests. The second and fourth cuts produced significant responses. The inconsistent pattern of the Mg concentrations in response to manure treatment or N is not unexpected. Results from earlier work (Todd, 1961) indicated that the Mg content in orchardgrass as a function of N fertilization is variable from year to year and shows no consistent pattern.

In 1976 the rate of response of % Na to manure treatment was the highest except for the nitrate-N response. The single application treatments had no significant responses at the second and fourth harvests. The split application treatments also had two non-significant responses at the second and third cuts. In all cuts, for both methods except the split application treatment, first cut, there was a consistent increase in % Na up to the 40 t/ha treatment. At the 40 t/ha rate the Na concentration dropped. At the cuts where the % Na response to manure treatment produced no significant response, the depression of % Na at the 40 t/ha treatment was significant. The increase in % Na was expected due to the large quantities of Na added by the manure. The decrease in the % Na at the 40 t/ha treatment could be a competition effect with K. The concentrations for all cuts increased considerably at the 40 t/ha treatment. Griffith et al. (1965) have suggested that a rather loose inverse relationship between Na and K content does occur.

In 1976, K/Ca + Mg meq ratios were determined for both methods for all cuts. With the exception of one or two treatments, all manure rates produced K/Ca + Mg ratios in excess of 2.2. The highest ratios were found in the forage of the first harvest and decreased with each successive cut. There was an inconsistent response of the K/Ca + Mg ratio to manure treatment. The high ratios were partially the result of the low Ca concentrations in the orchardgrass in 1976 and the general environmental conditions in the lower Fraser Valley. Although forage containing a K/Ca + Mg ratio in excess of 2.2 is considered potentially tetany prone, this is by no means the only indicator. Mg concentrations below 0.20% are also used to indicate Mg deficiencies and tetany prone forage. Grunes (1973) suggested that if Mg levels are above 0.20%, ruminants should not suffer Mg deficiency even though K and N in the forage may be high. The data indicate that the forage of the first cut would have the potential to cause grass tetany. The K/Ca + Mg ratio exceeds 4.0 and %

Mg levels are all below 0.20% (0.13% Mg average for all treatments. If no other Mg was supplemented in the diet, mature cows might be susceptible to grass tetany. Tests with ruminants consuming the forage are required before any positive statements can be made.

H. Nitrate-N Levels in the Soil

The analysis of variance tables for nitrate-N concentrations in the soil for 1975 and 1976 are in Appendix Tables B17 and B18. In 1975 the treatment x depth interaction was significant at the 0.01 level. The treatment means for nitrate-N in 1975 are in Table XI. Only the 20 and 40 t/ha treatments produced significant differences in nitrate-N at any depth. Significant differences were found at the 30 to 60 cm depth for the 20 t/ha manure treatment and at the 15 to 30, 30 to 60 and 60 to 90 cm depths for the 40 t/ha treatment. By the end of November in 1975, at the time of sampling, the bulk of the nitrate-N was concentrated at the 30 to 60 cm depth. The nitrate-N concentrations at the 20 and 40 t/ha treatments also indicated nitrate-N had leached to the 60 to 90 cm depth. The water table at the time of sampling was at the 90 cm depth in most parts of the plot so nitrate was beginning to enter the groundwater. By the spring less than 8.0 ppm nitrate-N was found at the 20 and 40 t/ha rates for all depths. Thus, the high levels of nitrate found at the 20 and 40 t/ha rates had leached into the groundwater over winter.

In 1976, there was a highly significant treatment x depth interaction with respect to nitrate-N concentrations in the soil. The method of manure application had no significant effect on the soil nitrate-N concentrations.

Table XI: Mean nitrate-N levels in the soil (ppm) and the effect of manure treatment and depth, November 25, 1975.

Manure Treatment t/ha	Depths			
	0-15cm	15-30cm	30-60cm	60-90 cm
	------------------ ppm	---------------------		
Control	3.4	3.2	3.2	3.4
5	3.1	3.0	3.4	3.1
10	3.5	3.2	3.2	3.3
20	4.2	4.4	10.6	6.5
40	6.6	17.9	33.8	26.2

$LSD_{.05}$ - 4.6 ppm.

The mean nitrate-N levels for 1976 are given in Table XII. Only the 40 t/ha treatment produced significantly higher nitrate-N concentrations. The levels of nitrate were much less than in 1975. The maximum concentration in 1976 was 18.8 ppm nitrate-N compared to 33.8 ppm in 1975. The bulk of the nitrate was concentrated at the 30 to 60 cm depth for the 40 t/ha treatment with a significant proportion at the 60 to 90 cm depth. A significantly higher concentration was found at the 15 to 30 cm depth as well. At the 0 to 15 cm depth, the 40 t/ha treatment had a nitrate-N concentration significantly different from the other manure treatments except the 20 t/ha rate.

The lower nitrate concentrations in the soil in 1976 were possibly the result of the following: less N was added by the manure in 1976, the poultry manure was surface applied rather than incorporated, and the manure was applied to an established stand. Considerable N (up to 50%) can be lost by ammonia volatilization when manure is surface applied depending on the weather conditions. Some N that otherwise would have been lost to leaching could have been volatilized as ammonia in 1976. Applying the manure to an established forage stand also limits leaching losses as the growing stand can utilize the immediately available N. In 1975 it was several weeks before the forage was growing vigorously and most of the N nitrified during this period would have been subject to leaching. There was also 450 kg N/ha less applied at the 40 t/ha treatment in 1976 because of a lower concentration in the manure.

Table XII: Mean nitrate-N levels in the soil (ppm) and the effect of manure treatment and depth, December 15, 1976.

Manure Treatment t/ha	Depths			
	0-15cm	15-30cm	30-60cm	60-90 cm
	ppm			
Control	3.1	3.2	2.9	2.8
5	2.8	2.7	2.7	2.7
10	3.1	3.0	2.8	3.1
20	4.3	3.6	3.3	3.4
40	7.2	9.6	18.2	10.9

$LSD_{.05}$ - 3.7 ppm.

I. N Balance

The % N accounted for was determined as outlined in the "Materials and Methods". The N balance in 1975, including the N recovered in the crop, total N in the top 15 cm and nitrate-N at the 30 to 90 cm soil depth, is presented in Table XIII. In 1975, significant differences in total N in the surface soils (0-15 cm) and nitrate-N concentrations in the soil (15-90 cm) were observed only at the 20 and 40 t/ha treatments. At the lower manure rates, the only N accounted for was in the crop. Total N and nitrate-N concentrations in the soil were not significantly different from the control at these manure treatments. At the 20 and 40 t/ha manure treatments, 51.3 and 86.6% N was accounted for. In the remaining four manure treatments, between 25 and 33% N was recovered, all in the orchard-grass-clover forage. The most N accounted for was at the 20 and 40 t/ha treatments, yet only 15 and 10%, respectively, of the N was recovered in the forage. Total recovery of the N from the manure by the orchardgrass decreased with increasing manure application probably because mineral N was available in excess of the grass's ability to take it from the soil. Leaching losses were significant at the 20 and 40 t/ha treatments and total N in the surface 15 cm was increased. Approximately 1000 kg N or about 63% of the added manure N at the 40 t/ha treatment was accounted for in the total N of the surface 15 cm. The 20 t/ha treatment had an increase of 250 kg N/ha in the surface 15 cm accounting for 31% of the manure N added. No increases occurred below 15 cm. Ammonium determinations were made on the samples at all depths but no appreciable differences for any treatment at any depth were observed. At the 20 and 40 t/ha treatment, between 30 and 60% of the added manure N remained in an organic form in the top 15 cm.

Table XIII: N balance sheet, 1975 - N removed by the crop, difference in total N of the top 15 cm of soil, nitrate-N in the 0-90 cm depth of soil, N added by the manure and the % N accounted for.

Manure Treatment t/ha	N Removed 2 Cuts	Total N in Soil 0-15cm	NO_3-N 30-90 cm	Total N Measured	Increase over Control[1]	N Added in the Manure	Percent N Accounted for
	kg/ha						
Control	74	3098	25	3197	-	-	-
1.25	90	-	-	-	16	49	32.6
2.5	100	-	-	-	26	98	26.5
5.0	130	-	-	-	56	197	28.4
10	172	-	-	-	98	394	24.9
20	192	3344	65	3601	404	787	51.3
40	236	4097	228	4561	1364	1575	86.6

[1]Increase over the control for all but the 20 and 40 t/ha treatments is based on the N removed by the crop only.

This indicates that between 40 and 70% of the added poultry manure N was mineralized over the growing season. No increases in total N were found at the lower manure treatments, where experimental error, variations in manure composition and any minor losses can account for a significant portion of the N added. Decomposition rates for manure have been found to be similar over a wide range of manure application treatments (Mather and Stewart, 1974). Thus, the manure N likely was mineralized at a similar rate for all the treatments, but only at the two highest manure treatments was there sufficient N added for an accurate assessment of the N balance sheet.

In 1976, the % N accounted for was generally lower than in 1975 (Table XIV). The exceptions were the 10 t/ha treatment where the % N accounted for was higher in 1976 and the 20 t/ha treatment which had a similar recovery percentage. The general trend for lower recovery values is the result of three factors. Ammonia volatilization losses would increase because the poultry manure was not incorporated. There was greater variability in the manure N composition which may also account for the increase in the % N recovered at the 10 t/ha treatment. The N fixed by the clover in the control decreased % N recovered by increasing the N removed by the orchardgrass in the control.

In 1976 only the 40 t/ha treatment supplied sufficient N for a partial assessment of the N balance sheet. Below the 40 t/ha rate an accurate determination of the N balance is impossible. The residual total N from 1975 makes an estimate of mineralization for 1976 invalid. A decay series is required whereby the mineralization of the residual manure N from the previous year could be determined.

Table XIV: N balance sheet, 1976 - N removed by the crop, difference in total N of the top 15 cm of soil, nitrate-N in the 0-90 cm depth of soil, N added by the manure and the % N accounted for

Manure[1] Treatment t/ha	N Removed 4 cuts[2]	Total N in soil 0-15 cm[3]	NO_3-N 0-90 cm	Total N Measured	Increase over Control[4]	N Added in the Manure	Percent N Accounted for
	----------	----------	----------	kg/ha	----------	----------	----------
Control	176	-	29	205	-	-	-
1.25	184	-	-	-	8	34	24.0
2.5	181	-	-	-	5	68	7.4
5.0	202	-	-	-	26	136	19.0
10	281	-	-	-	105	272	38.7
20	445	-	-	-	269	543	49.4
40	453	251	126	830	625	1086	57.5

[1]Average of both methods.

[2]Includes the N removed in the clover at the control, 1.25 and 2.5 t/ha rates.

[3]Increase in total N from the residual total N determined in April, 1976 for all the treatments.

[4]Increase over the control is based on the N removed in the crop only, except for the 40 t/ha treatment.

The two year balance produced differences only at the 40 t/ha treatment for the total soil N and soil nitrate-N concentrations. Between 20 and 30% of the N added in the manure was recovered in the crop over the two years at manure rates below 40 t/ha. At the 40 t/ha treatment, only 16% of the total manure N added was recovered by the crop. However, 52% of the total N added was accounted for at this rate. Approximately one-third of the total N added was accounted for in the surface total soil N. This would indicate that two-thirds of the poultry manure added over the two years was mineralized. It is important to note that approximately 30% of the total N added was recovered in the harvested orchardgrass at the 10 t/ha rate over the two years. Losses usually result in only 50 to 70% of the total added N from inorganic fertilizers being recovered in the crop. Often this value is lower (Allison, 1966). Thus, the N added in the manure at the 10 t/ha treatment over the two years is at least 45 to 60% as efficient as an inorganic N source.

J. Rate Recommendations

The high-rise poultry manure used in this study was easy to handle, virtually odorless and, when applied at rates to meet the N crop requirement, only K was limiting. Before using a similar poultry manure product, an analysis for chemical composition and moisture content is recommended to determine the nutrient value of the manure. Although within a given batch the manure's variability is usually low, the chemical composition can vary considerably between poultry houses or batches within one house. An N input/output scheme could possibly work well for poultry manure.

Knowing the N in the feed and the N used by the bird, an estimate of the N voided in the manure could be determined without chemical analysis. In either case, an accurate estimate of the nutrient content, particularly N, is necessary before applying poultry manure to the land.

A disposal rate of 20 t/ha/year on orchardgrass forage would ensure maximum loading without nitrate leaching problems. Incorporation of the poultry manure into the soil is not possible if the manure is applied to an established stand. Odor control could be a problem but the poultry manure from the high-rise house was dried to less than 25% moisture and the odor was minimal. Whether the manure was applied in a single application or in three equal applications did not make any significant difference for disposal. If manure rates in excess of 20 t/ha/year are applied in a single application under dry or drought conditions, crop yield reductions may result. Caution is advised if applying this rate all at once. Split applications would decrease the chances of plant damage in the spring. Although not the case in this study, drought conditions following the application of one-third of the 20 t/ha/year rate could possibly result in plant damage and yield reduction. The application of manure merely for disposal is not recommended unless there is a serious pollution hazard and there is no feasible alternative. Whenever possible the poultry manure should be stored, handled and utilized to conserve the nutrient resources of the poultry manure, particularly N.

Based on the data obtained in this study, a poultry manure application of 10 t/ha/year would supply sufficient N most efficiently to maximize orchardgrass forage yields without seriously affecting the forage quality. Rates below 10 t/ha/year did not supply enough N to maximize yields. Above

10 t/ha/year there was a very low return in dry matter yield and % TKN of the forage per tonne of manure applied. Also, potentially nitrate-N toxic forage was common for all the harvests at poultry manure rates above the 10 t/ha/year rate.

Manure incorporation into the soil where possible would increase the efficiency of the N utilization. In established forage stands, incorporation is not possible. Split applications if feasible would result in a more uniform yield, possibly a higher dry matter yield and a reduction of nitrate-N in the grass in the spring forage. Drought conditions following a split application of 10 t/ha/year could possibly cause nitrate accumulations in the forage and caution should be taken if split applications are applied during the summer months. Irrigation will reduce the volatilization losses, the nitrate accumulating in the plant, and hence will increase the efficiency of the manure N.

When the manure is applied at rates to utilize the N resource, the K and possibly the P added in the manure is low relative to the N component. Potassium would have to be supplemented for orchardgrass forage and most other crops. Phosphorus, depending on the inherent soil fertility, may or may not have to be supplemented to forage. For most row crops, P would need to be supplemented to the crop if only manure was used.

The land requirements for the utilization and disposal of high-rise poultry manure on an orchardgrass sward are shown in Table XV. An integrated farm system where poultry manure can be efficiently utilized as a fertilizer is most desirable. The land areas determined are based on previous work, the data collected in this study and the assumption that N is the limiting factor in the application of manure to the land. A poultry layer operation

Table XV: Land requirements for the utilization and disposal of high-rise poultry manure on a pure orchardgrass sward in the Lower Fraser Valley.

Size of Operation	Fresh Manure Excreted[1]	Stored[2] Manure Dried to 25% Moisture	N Excreted[3] -Dry wt. Basis	Crop Utilization[4]	Disposal[5]
	kg/year			ha.	ha.
1000 layers 365 days	64,600	29,070	772	2.9	1.4
2500 layers 365 days	161,500	72,675	1930	7.3	3.6
5000 layers 365 days	323,000	145,350	3859	14.6	7.3
10,000 layers 365 days	646,000	290,700	7718	29.1	14.6

1. Assuming 64.6 kg manure/bird/year at 80% moisture.

2. One year in a high-rise poultry house with drying fans.

3. Moisture - 25% and N - 3.54%, dry weight basis.

4. Land requirement as orchardgrass forage, equivalent to 10 t/ha/year.

5. Maximum application of manure which will not reduce yields or cause nitrate-N leaching, equivalent to 20 t/ha/year.

of 2500 hens would require 7.3 ha of orchardgrass forage to efficiently utilize the N resource in the poultry manure.

V SUMMARY AND CONCLUSIONS

1. The poultry manure contained 5.1% N, 2.5% P and 2.0% K on a dry weight basis in 1975 with coefficients of variation less than 10%. Concentrations of 3.5% N, 1.6% P and 1.4% K with an average coefficient of variation of 35% were found in 1976. The N:P:K ratio indicates K and P for some crops would be limiting if the poultry manure is applied at rates to meet the N requirements of most crops.

2. In 1975, the highest total yield of 7.0 t/ha was produced at the 40 t/ha treatment. The maximum yield increase per tonne of manure occurred at the 2.5 t/ha treatment. Above the 2.5 t/ha manure treatment, the yield increase per tonne of manure decreased with each successive manure treatment. In 1976, total yields ranged from 10 to 16 t/ha. Yield reductions at the first and second cuts were probably the result of soluble salts or free ammonia. Smothering of the forage and/or ammonium induced cation deficiencies could also have been a factor. Clover in the 1.25 and 2.5 t/ha treatments and the cool, wet weather of 1976, could have modified the effects of manure treatment on dry matter yields.

3. Clover was eliminated at all rates above 2.5 t/ha by the spring of 1976. More frequent cuttings in 1976 increased the clover percentages in plots receiving manure rates up to 2.5 t/ha. Weeds in the stand were a function of forage growth rather than manure treatments.

4. Percent TKN ranged from 2.41 to 3.58% for the first cut in 1975. The varying clover percentages at the different manure treatments produced variable % TKN concentrations for the second harvest. Nitrate-N

concentrations were higher in the first cut, but no percentages exceeded 0.34% nitrate-N.

5. Percent TKN differences among cuts in 1976 are due to the maturity of the orchardgrass at harvesting. Percent TKN showed a diminishing response to manure treatment. The clover present in the lower manure treatments modified the response of % TKN to manure treatments at the third and fourth harvests particularly. Generally, % TKN showed substantial increase up to the 10 t/ha/year manure treatments. Percent TKN concentrations for the 10 t/ha treatment (split and single method) ranged from 1.24 to 3.30% TKN. At manure rates below 20 t/ha, nitrate-N concentrations did not exceed 0.34% nitrate-N. Only at the 20 and 40 t/ha treatment, both methods, did % nitrate-N reach alarmingly high concentrations, potentially toxic to ruminants.

6. Levels of P, K, Ca and Mg in the forage were adequate. High soil concentrations of these elements did not allow for any responses to manure treatments. Poultry manure applied at the 10 t/ha rate supplied available P similar to that removed in the harvested orchardgrass. At this rate, manure K would not meet the crop's needs if the manure was the only source of K.

7. Significant differences in soil nitrate concentrations were found at the 20 and 40 t/ha treatments in 1975 and the 40 t/ha treatment in 1976. The nitrate-N concentrations were lower in 1976 at these rates. It may have been because of increased ammonia volatilization due to surface applying the manure, a lower N content in the manure used in 1976 and the manure being applied to an established orchardgrass sward.

8. In 1975, the increases in total N content in the surface 15 cm

indicate between 40 and 70% of the N added in the manure mineralized. Of the total N added in the manure over the two years between 16 and 30% was recovered in the crop. At the 10 t/ha manure treatment, 30% of the total N added in the manure was recovered in the harvested orchardgrass for both years. This is at least 45 to 60% as efficient as an inorganic N source.

9. High-rise poultry manure of the same approximate composition used in this study could be disposed of at rates of 20 t/ha-year on orchardgrass forage. A layer operation of 2500 hens would require 3.6 ha to dispose of the poultry manure produced in one year. Variations in composition and environmental conditions could affect the maximum disposal rate and how it is applied.

10. A poultry manure rate of 10 t/ha/year on orchardgrass forage is recommended to efficiently utilize the N resource of the manure as a fertilizer. K supplements would be required on a soil low in available K. An orchardgrass stand of 7.3 ha would produce maximum dry matter yields of good quality if fertilized with the poultry manure produced in one year from a high-rise poultry house containing 2500 layers.

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APPENDICES

APPENDIX TABLE A1: Precipitation and Temperature Data for 1975 and 1976 from the Chilliwack Gibson Road Climatological Station.

Year	Month	Day	Temperature-^{o}C Min.	Max.	Mean	Precipitation-mm. Total	No. of Days
1975	April	-	-4.4	20.6	7.3	51.10	8
	May	-	1.7	29.4	12.4	49.78	10
	June	-	2.8	31.1	14.7	38.86	10
	July	-	8.3	32.8	18.7	43.94	5
	Aug.	-	4.4	30.6	16.2	94.23	12
	Sept.	-	4.4	29.4	15.9	10.92	4
	Oct.	-	-1.1	24.4	9.4	336.04	25
	Nov.	-	-5.0	21.7	5.4	255.27	19
	Dec.	-	-6.7	14.4	3.3	413.77	17
1976	Jan.	-	-2.2	12.2	3.8	230.12	18
	Feb.	-	-5.0	10.6	3.2	167.13	17
	March	-	-10.0	12.8	4.2	125.22	15
	April	-	-1.1	25.6	9.6	87.38	12
		5	2.8	21.7	-	4.57	1
		6	7.2	15.0	-	-	1
		7	5.6	16.1	-	1.78	1
		8	7.8	10.6	-	4.57	1
		9	5.6	17.8	-	-	1
		10	7.2	22.2	-	2.03	1
		11	6.1	9.4	-	5.59	1
		12	1.7	15.0	-	-	1
		13	1.7	15.0	-	-	1
		14	2.8	8.9	-	22.10	1
		15	1.1	8.9	-	-	1
		16	-1.1	12.2	-	TR	1
		17	4.4	9.4	-	1.27	1
		18	5.0	11.1	-	1.27	1
		19	4.4	14.4	-	23.88	1
		20	5.0	10.6	-	6.35	1
		21	1.7	12.8	-	-	1
		22	3.9	13.3	-	-	1
		23	2.2	12.2	-	6.10	1
		24	6.1	10.6		7.87	1
	May	-	1.7	27.8	12.1	79.50	14
		18	1.7	18.9	-	-	1
		19	2.8	17.7	-	-	1
		20	7.8	15.6	-	-	1
		21	3.3	21.7	-	-	1
		22	6.1	13.9	-	0.51	1
		23	8.9	17.7	-	0.51	1

Continued ....

Year	Month	Day	Temperature-°C Min.	Max.	Mean	Precipitation-mm. Total	No. of days
1976							
		24	8.9	13.3	-	10.67	1
		25	7.2	15.0	-	16.76	1
		26	7.8	13.3	-	11.18	1
		27	8.3	12.2	-	TR	1
		28	4.4	13.9	-	2.29	1
		29	5.6	13.9	-	5.59	1
		30	2.8	15.0	-	-	1
		31	2.8	14.4	-	5.08	1
	June	-	1.7	27.2	14.2	102.11	10
		1	5.6	13.3	-	2.03	1
		15	12.2	15.0	-	39.37	1
		16	12.8	18.9	-	TR	1
		17	11.1	26.1	-	-	1
		18	10.0	27.2	-	2.29	1
		19	14.4	19.4	-	-	1
		20	7.8	27.2	-	-	1
		21	8.3	21.1	-	-	1
		22	11.1	16.7	-	4.32	1
		23	10.6	16.1	-	2.79	1
		24	10.0	15.6	-	16.00	1
		25	7.8	16.7	-	-	1
		26	10.0	18.3	-	-	1
		27	5.6	24.4	-	-	1
		28	9.4	26.1	-	-	1
		29	13.3	21.1	-	-	1
		30	8.9	20.0	-	9.65	1
	July	-	4.4	28.8	16.7	40.39	10
		1	10.0	17.8	-	5.59	1
		2	9.4	22.2	-	-	1
		3	4.4	15.6	-	3.05	1
		4	5.0	21.7	-	10.16	1
	Aug.	-	8.3	26.1	16.3	115.82	15
	Sept.	-	5.6	27.8	15.6	86.36	8

APPENDIX TABLE B1: Analysis of Variance-Yield, 1975.

Source	DF	MS	F-Value
Block	3	0.0757	0.3703
Treatment	5	2.9359	13.818 **
T x B (A)	15	0.2125	1.0391
Cut	1	1.6476	8.1068*
T x C	5	0.1854	0.9067
Error	18	0.2045	-
Total	47	-	-

**, * - Significant at the 0.01 and 0.05 level, respectively.

APPENDIX TABLE B2: Analysis of Variance-Yield, 1976.

Source	DF	MS	F-Value
Block	3	0.0329	0.2383
Treatment	5	8.9450	64.779 **
B x T (A)	15	0.2394	1.7340
Method	1	1.5337	11.106 **
T x M	5	0.1790	1.2960
MB/T = B	18	0.0961	0.6958
Cut	3	137.25	993.87 **
C x T	15	2.1704	15.717 **
C x M	3	0.5631	4.0778**
C x TM	15	0.5952	4.3098**
Error	108	0.1381	-
Total	191	0 --	-

** - Significant at the 0.01 level.

APPENDIX TABLE B3: Analysis of variance - % TKN, 1975.

Source	DF	MS	F-Value
Block	3	0.0500	1.1493
Treatment	5	0.8820	23.210 **
T x B(A)	15	0.0380	0.8734
Cut	1	3.1982	75.511 **
T x C	5	0.2226	5.1164**
Error	18	0.0435	-
Total	47	-	-

** - Significant at the 0.01 level.

APPENDIX TABLE B4: Analysis of variance - % nitrate-N, 1975.

Source	DF	MS	F-Value
Block	3	0.0022	1.2008
Treatment	4	0.0535	28.118 **
T xB(A)	12	0.0019	1.0190
Cut	1	0.0990	53.013 **
T x C	4	0.0066	3.5388*
Error	15	0.0019	-
Total	39	-	-

**, * - Significant at the 0.01 and 0.05 level, respectively.

APPENDIX TABLE B5: Analysis of variance - % TKN, 1976.

Source	DF	MS	F-Value
Block	3	0.1160	2.8957*
Treatment	5	11.715	292.59 **
B x T(A)	15	0.0595	1.4868
Method	1	0.1403	3.5038
T x M	5	0.0140	0.3493
MB/T = B	18	0.0222	0.5533
Cut	3	11.768	293.90 **
C x T	15	0.7601	18.983 **
C x M	3	0.6929	17.305 **
C x TM	15	0.0967	2.4141**
Error	108	0.0400	-
Total	191	-	-

**, * - Significant at the 0.01 and 0.05 levels, repsectively.

APPENDIX TABLE B6: Analysis of variance - % Nitrate-N, 1976.

Source	DF	MS	F-Value
Block	3	0.0016	0.5840
Treatment	5	0.8861	326.37 **
B x T(A)	15	0.0015	0.5394
Method	1	0.0001	0.0516
T x M	5	0.0014	0.5154
MB/T = B	18	0.0019	0.7021
Cut	3	0.1054	38.808 **
C x T	15	0.0360	13.274 **
C x M	3	0.0218	8.0140**
C x TM	15	0.0078	2.8735**
Error	106	0.0027	-
Total	189	-	-

** - Significant at the 0.01 level.

APPENDIX TABLE B7: Analysis of variance - % P, 1975.

Source	DF	MS	F-Value
Block	3	0.0031	3.6721*
Treatment	5	0.0009	1.8634
T x B(A)	15	0.0005	0.5954
Cut	1	0.0588	69.403 **
T x C	5	0.0010	1.1685
Error	18	0.0009	-
Total	47	-	-

**, * - Significant at the 0.01 and 0.05 levels, respectively.

APPENDIX TABLE B8: Analysis of variance - % P, 1976.

Source	DF	MS	F-Value
Block	3	0.0023	1.5341
Treatment	5	0.0012	0.7704
B x T(A)	15	0.0012	0.7993
Method	1	0.0003	0.1825
T x M	5	0.0010	0.6313
MB/T = B	18	0.0005	0.3458
Cut	3	0.1838	121.76 **
C x T	15	0.0100	6.6304**
C x M	3	0.0011	0.7465
C x TM	15	0.0012	0.8012
Error	108	0.0015	-
Total	191	-	-

** - Significant at the 0.01 level.

APPENDIX TABLE B9: Analysis of variance - % K, 1975.

Source	DF	MS	F-Value
Block	3	0.1664	4.2556*
Treatment	5	2.1400	41.511 **
T x B(A)	15	0.0516	1.3183
Cut	1	5.1026	130.48 **
T x C	5	0.0698	1.7840
Error	18	0.0391	-
Total	47	-	-

**, * - Significant at the 0.01 and 0.05 levels, respectively.

APPENDIX TABLE B10: Analysis of variance - % K, 1976.

Source	DF	MS	F-Value
Block	3	1.0535	9.0365**
Treatment	5	8.0764	69.276 **
B x T(A)	15	0.1463	1.2550
Method	1	0.0501	0.4293
T x M	5	0.2668	2.2882
MB/T = B	18	0.1119	0.9596
Cut	3	5.0797	43.572 **
C x T	15	0.6146	5.2720**
C x M	3	0.3622	3.1069*
C x TM	15	0.1345	1.1537
Error	108	0.1166	-
Total	191	-	-

**, * - Significant at the 0.01 and 0.05 levels, respectively.

APPENDIX TABLE B11: Analysis of variance - % Ca, 1975.

Source	DF	MS	F-Value
Block	3	0.0291	0.6071
Treatment	5	0.0485	1.6752
T x B(A)	15	0.0290	0.6046
Cut	1	0.9718	20.282 **
T x C	5	0.0322	0.6720
Error	18	0.0479	-
Total	47	-	-

** - Significant at the 0.01 level.

APPENDIX TABLE B12: Analysis of variance - % Mg, 1975.

Source	DF	MS	F-Value
Block	3	0.0021	3.2657*
Treatment	5	0.0017	2.3613
T x B(A)	15	0.0007	1.1119
Cut	1	0.0320	49.814 **
T x C	5	0.0021	3.1387*
Error	18	0.0006	-
Total	47	-	-

**, * - Significant at the 0.01 and 0.05 levels, respectively.

APPENDIX TABLE B13: Analysis of variance - % Na, 1975.

Source	DF	MS	F-Value
Block	3	0.0004	1.6687
Treatment	5	0.0031	4.5454*
T x B(A)	15	0.0007	3.0012*
Cut	1	0.0096	42.552 **
T x C	5	0.0005	2.1129
Error	18	0.0002	-
Total	47	-	-

**, * - Significant at the 0.01 and 0.05 levels, respectively.

APPENDIX TABLE B14: Analysis of variance - % Ca, 1976.

Source	DF	MS	F-Value
Block	3	0.0037	2.2338
Treatment	5	0.0030	1.8134
B x T(A)	15	0.0017	1.0410
Method	1	0.0001	0.0314
T x M	5	0.0023	1.3981
MB/T = B	18	0.0008	0.4776
Cut	3	0.0786	47.396 **
C x T	15	0.0077	4.6285**
C x M	3	0.0003	0.1780
C x TM	15	0.0011	0.6823
Error	108	0.0016	-
Total	191	-	-

** - Significant at the 0.01 level.

APPENDIX TABLE B15: Analysis of variance - % Mg, 1976.

Source	DF	MS	F-Value
Block	3	0.0012	4.2405**
Treatment	5	0.0058	20.580 **
B x T(A)	15	0.0004	1.2455
Method	1	0.0001	0.2669
T x M	5	0.0010	3.3984**
MB/T = B	18	0.0002	0.6277
Cut	3	0.1015	361.23 **
C x T	15	0.0021	7.6418**
C x M	3	0.0008	3.0494*
C x TM	15	0.0003	1.0507
Error	108	0.0003	-
Total	191	-	-

**, * - Significant at the 0.01 and 0.05 levels, respectively.

APPENDIX TABLE B16: Analysis of variance - % Na, 1976.

Source	DF	MS	F-Value
Block	3	0.0177	8.8551**
Treatment	5	0.2391	119.74 **
B x T(A)	15	0.0046	2.2923**
Method	1	0.0075	3.7567
T x M	5	0.0113	5.6420**
MB/T = B	18	0.0056	2.7927**
Cut	3	0.0257	12.871 **
C x T	15	0.0301	15.065 **
C x M	3	0.0212	10.604 **
C x TM	15	0.0047	2.3624**
Error	108	0.0020	-
Total	191	-	-

** - Significant at the 0.01 level.

APPENDIX TABLE B17: Analysis of variance - Nitrate-N in the soil, 1975.

Source	DF	MS	F-Value
Block	3	5.1969	0.2580
Treatment	4	960.21	47.672 **
Error (A)	12	20.142	-
Depth	3	163.89	25.862 **
T x D	12	103.98	16.409 **
Error (B)	45	6.3370	-
Total	79	-	-

** - Significant at the 0.01 level.

APPENDIX TABLE B18: Analysis of variance - Nitrate-N in the soil, 1976.

Source	DF	MS	F-Value
Block	2	18.956	1.4710
Treatment	4	340.03	26.387 **
Error (A)	8	12.886	-
Method	1	6.1291	0.2324
T x M	4	6.6542	0.2523
Error (B)	10	26.373	-
Depth	3	20.526	17.969 **
T x D	12	29.210	25.572 **
M x D	3	2.2830	1.9986
T x MD	12	1.2168	1.0653
Error (C)	60	1.1423	-
Total	119	-	-

** - Significant at the 0.01 level.

APPENDIX TABLE C1: Forage yield by cut, 1975.

Manure Treatment t/ha	Yield		
	First Cut	Second Cut	Total
	----------------	t/ha	----------------
1.25	1.44	2.38	3.82
2.5	1.92	2.24	4.16
5.0	2.32	2.63	4.95
10	2.95	3.02	5.97
20	2.90	3.05	5.95
40	3.29	3.71	7.00
Control	1.28	1.80	3.08

APPENDIX TABLE C2: Forage yields by cut, 1976.

Manure Treatment t/ha	Method of Application	Cut 1st	2nd	3rd	4th	Total
		----------	----------	t/ha	----------	----------
1.25	Single	4.72	1.31	2.33	1.68	10.04
	Split	4.17	1.54	2.61	1.72	10.04
2.5	Single	5.94	1.42	2.22	1.61	11.19
	Split	5.30	1.53	2.91	1.86	11.60
5.0	Single	5.97	1.58	2.72	1.59	11.86
	Split	5.78	1.74	3.74	2.14	13.40
10	Single	6.03	1.78	3.21	1.86	12.88
	Split	5.56	1.94	3.94	2.58	14.02
20	Single	5.77	1.54	4.48	3.32	15.11
	Split	6.06	1.65	4.63	3.74	16.08
40	Single	4.84	1.77	4.40	3.88	14.89
	Split	6.14	1.24	4.05	3.66	15.09
Control	-	4.50	1.24	2.54	1.87	10.11

APPENDIX TABLE D1: % total Kjeldahl N by cut, 1975.

Manure Treatment t/ha	First Cut	Second Cut
	%	
Control	2.37	2.45
1.25	2.30	2.40
2.5	2.64	2.18
5.0	2.99	2.18
10	3.13	2.38
20	3.40	2.72
40	3.39	2.90

APPENDIX TABLE D2: % nitrate-N by cut, 1975.

Manure Treatment t/ha	First Cut	Second Cut
	%	
1.25	0.04	0.01
2.5	-	-
5.0	0.16	0.02
10	0.22	0.05
20	0.19	0.13
40	0.29	0.19

APPENDIX TABLE D3: % total kjeldahl N and % nitrate-N in the forage by cut, 1976.

Manure Treatment t/ha	First Cut % N	First Cut $\%NO_3$-N	Second Cut % N	Second Cut $\%NO_3$-N	Third Cut % N	Third Cut $\%NO_3$-N	Fourth Cut % N	Fourth Cut $\%NO_3$-N
Single Method								
1.25	1.34	0.01	1.67	0.01	1.34	0.01	2.16	0.02
2.5	1.39	0.01	1.59	0.01	1.21	0.01	2.03	0.01
5.0	1.71	0.07	2.22	0.01	1.10	0.01	1.94	0.02
10	2.28	0.23	3.30	0.18	1.24	0.03	1.82	0.01
20	2.51	0.30	3.92	0.45	2.20	0.21	2.62	0.20
40	2.62	0.30	3.57	0.52	2.16	0.32	3.07	0.50
Split Method								
1.25	1.14	0.01	1.67	0.01	1.26	0.01	2.12	0.02
2.5	1.09	0.01	1.86	0.02	1.10	0.01	1.84	0.01
5.0	1.16	0.01	2.29	0.03	1.34	0.02	1.94	0.02
10	1.53	0.03	3.08	0.32	1.74	0.13	1.92	0.03
20	2.18	0.22	3.78	0.52	2.48	0.28	2.85	0.19
40	2.38	0.30	3.62	0.49	2.36	0.35	3.00	0.42
Control	1.17	0.01	1.74	0.00	1.39	0.00	2.09	0.02

APPENDIX TABLE D4: % P in the forage by cut, 1975.

Manure Treatment t/ha	First Cut	Second Cut
	%	
1.25	0.26	0.21
2.5	0.25	0.18
5.0	0.27	0.19
10	0.27	0.18
20	0.28	0.18
40	0.26	0.22

APPENDIX TABLE D5: % P in the forage by cut, 1976.

Manure Treatment t/ha	First Cut	Second Cut	Third Cut	Fourth Cut
		%		
1.25	0.29	0.38	0.40	0.39
2.5	0.29	0.39	0.38	0.41
5.0	0.28	0.44	0.36	0.39
10	0.30	0.48	0.32	0.37
20	0.28	0.46	0.30	0.37
40	0.31	0.48	0.32	0.35

APPENDIX TABLE D6: % K in the forage by cut, 1975

Manure Treatment t/ha	First Cut	Second Cut
	%	
1.25	2.68	2.10
2.5	3.30	2.36
5.0	3.22	2.64
10	3.67	2.90
20	3.98	3.32
40	3.94	3.56

APPENDIX TABLE D7: % K in the forage by cut, 1976

Manure Treatment t/ha	First Cut	Second Cut	Third Cut	Fourth Cut
		%		
1.25	2.96	3.20	2.64	2.72
2.5	2.98	3.42	2.88	2.79
5.0	2.89	3.42	2.54	2.64
10	3.03	3.52	2.90	2.99
20	3.15	4.38	3.41	3.04
40	3.44	4.50	4.59	4.15

APPENDIX TABLE D8: % Ca in the forage by cut, 1975.

Manure Treatment t/ha	First Cut	Second Cut
	---------- % ----------	
1.25	0.71	1.11
2.5	0.62	1.11
5.0	0.66	0.89
10	0.61	0.79
20	0.69	0.88
40	0.64	0.86

APPENDIX TABLE D9: % Mg in the forage by cut, 1975.

Manure Treatment t/ha	First Cut	Second Cut
	---------- % ----------	
1.25	0.20	0.30
2.5	0.20	0.26
5.0	0.23	0.25
10	0.23	0.27
20	0.26	0.28
40	0.22	0.29

APPENDIX TABLE D10: % Na in the forage by cut, 1975.

Manure Treatment t/ha	First Cut	Second Cut
	%	
1.25	0.02	0.05
2.5	0.04	0.05
5.0	0.06	0.08
10	0.06	0.10
20	0.05	0.07
40	0.06	0.12

APPENDIX TABLE D11: % Ca in the forage by cut, 1976.

Manure Treatment t/ha	First Cut	Second Cut	Third Cut	Fourth Cut
		%		
1.25	0.16	0.21	0.31	0.27
2.5	0.15	0.22	0.27	0.27
5.0	0.16	0.24	0.21	0.26
10	0.15	0.24	0.21	0.22
20	0.18	0.27	0.23	0.22
40	0.18	0.28	0.23	0.20

APPENDIX TABLE D12: % Mg in the forage by cut, 1976.

Manure Treatment t/ha	First Cut	Second Cut	Third Cut	Fourth Cut
	%			
1.25	0.12	0.20	0.18	0.21
2.5	0.11	0.21	0.18	0.20
5.0	0.14	0.24	0.17	0.20
10	0.13	0.24	0.17	0.20
20	0.13	0.24	0.20	0.24
40	0.13	0.22	0.20	0.27

APPENDIX TABLE D13: % Na in the forage by cut, 1976.

Manure Treatment t/ha	First Cut	Second Cut	Third Cut	Fourth Cut
	-----------	----------- %	-----------	-----------
Single Method				
1.25	0.05	0.03	0.02	0.05
2.5	0.06	0.04	0.03	0.04
5.0	0.07	0.10	0.02	0.04
10	0.11	0.18	0.06	0.03
20	0.19	0.23	0.33	0.32
40	0.17	0.10	0.12	0.28
Split Method				
1.25	0.04	0.03	0.04	0.06
2.5	0.02	0.02	0.02	0.02
5.0	0.05	0.15	0.14	0.10
10	0.08	0.22	0.26	0.10
20	0.09	0.17	0.31	0.44
40	0.13	0.10	0.15	0.26

APPENDIX TABLE E1: Chemical composition of the Ladino clover by cut, 1976.

Manure Treatment t/ha	Method of Application	N	P	K	Ca	Mg	Na	Nitrate-N
		%						
First Cut								
Control	-	3.20	0.38	3.82	1.05	0.23	0.07	0.01
1.25	Single	3.37	0.40	3.68	1.08	0.23	0.10	0.01
1.25	Split	3.28	0.37	3.33	1.18	0.22	0.08	0.01
2.5	Single	3.58	0.40	3.22	1.00	0.23	0.08	0.01
2.5	Split	3.20	0.39	4.00	1.03	0.24	0.07	0.01
Second Cut								
Control	-	2.90	0.34	2.86	1.69	0.24	0.07	-
1.25	Single	2.89	0.35	2.16	1.56	0.22	0.10	-
1.25	Split	2.82	0.36	2.44	1.98	0.26	0.12	-
2.5	Single	2.87	0.39	2.40	1.60	0.25	0.12	-
2.5	Split	2.63	0.36	2.80	1.50	0.24	0.08	-
Third Cut								
Control	-	2.70	0.31	2.10	1.67	0.23	0.27	-
1.25	Single	2.62	0.31	1.66	1.95	0.30	0.26	-
1.25	Split	2.60	0.30	1.45	1.84	0.29	0.26	-
2.5	Single	2.68	0.24	1.24	1.76	0.28	0.27	-
2.5	Split	2.81	0.30	2.20	1.73	0.30	0.28	-
Fourth Cut								
Control	-	3.09	0.34	2.36	1.94	0.32	0.11	-
1.25	Single	3.27	0.36	2.15	1.73	0.33	0.22	-
1.25	Split	3.37	0.36	1.73	1.84	0.34	0.27	-
2.5	Single	3.19	0.38	1.91	2.05	0.34	0.22	-
2.5	Split	3.16	0.34	2.06	1.76	0.32	0.18	-

APPENDIX TABLE F1: Site Description in Grigg Series[1]

Horizon	Depth	Description
Aha	0 - 15 cm	Very dark grayish brown (10YR 3/2 moist) silty clay. Weak medium granular structure; friable, porous, many fine roots. Abrupt change to:
Bg	15 - 30 cm	Dark grayish-brown (2.5Y 4/2 moist) silty clay. Rare to common distinct yellowish-brown (10YR 5/6 moist) mottles. Modern medium subangular blocky structure, many roots. Clear change to:
Cg-1	30 - 60 cm	Olive gray (5Y 4.5/2 moist) silty clay. Common distinct yellowish-red (5YR 4/8 moist) mottles. Massive, firm, a few cracks, roots common but decrease with depth. Gradual change to:
Cg-2	60 - 80 cm	Olive gray (5Y 4.5/2 moist) silty clay. Many distinct to faint yellowish-red (5YR 4/8 moist) mottles. Massive, firm, rare cracks, a few roots. Gradual change to:

[1]From Comar *et al*., 1962.

Horizon	Depth	Description
Cg-3	80 - 110 cm	Olive gray (5Y 5/2 moist) silty clay. Many distinct and faint yellowish-red to strong brown (5YR 4/8 - 7.5YR 5/6 moist) mottles which give slight colour to the mass. Massive, firm, a few roots, an occasional crack terminating with depth.