EFFECT OF LITTER TYPE ON GROWTH AND NUTRIENT CONTENT OF PERENNIAL GRASSES

by

John Chege Ngethe

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As members of the Final Examination Committee, we certify that we have read

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ABSTRACT

Biomass, cover, density, height and concentrations of N, P, C, Fe, Mn, Cu and Zn were evaluated in Sporobolus cryptandrus and Eragrostis lehmanniana at flowering and at seed ripening stage to determine whether these attributes are affected by the type of litter used or by litter treatment. Annual rye, California poppy and rye-poppy mixture were the sources of litter while litter treatments included removing organic residue, leaving organic residue standing or roto-tilling organic residue into the surface soil. The effect of litter type and litter treatment on the soil was evaluated. A parallel greenhouse experiment was carried out.

Results indicate that California poppy contained a higher level of all nutrients studied compared to annual rye and contained about twice the concentrations of N, Mn, Zn and Fe. For both annuals and perennials, the nutrient content generally decreased between flowering and seed ripening with annuals indicating more decline than perennial grasses. The greatest decline was observed for N in California poppy. Field observation confirmed that the non-lignified California poppy shoots broke down faster than culms of annual rye.

Biomass production in Sporobolus and Eragrostis was unaffected by litter type. However, for both species the highest biomass was obtained in the tilled treatment. Litter tilling produced more vigorous and healthier plants compared to other treatments.

Except for P, nutrient concentrations were largely unaffected by litter type. The highest P concentrations were consistently obtained from perennial plants grown in annual rye plots. Fe and Cu concentrations were consistently higher in the tilled treatment. C and P appeared unaffected by litter treatment. N, Mn and Zn concentrations were more variable and more difficult to categorize.

In soil samples, all nutrient concentrations were higher at the end of the study than at the beginning. Litter source appeared to have minimum effect on nutrient concentration while tilled treatment was superior to standing which was superior to the removed treatment.

EFFECT OF LITTER TYPE ON GROWTH AND NUTRIENT CONTENT OF SPOROBOLUS CRYPTANDRUS AND ERAGROSTIS LEHMANNIANA

John Chege Ngethe, Ph. D.
The Univeristy of Arizona, 1984
Director: Dr. J. O. Klemmedson

Biomass, cover, density, height and concentrations of N, P, C, Fe, Mn, Cu and Zn were evaluated in *Sporobolus cryptandrus* and *Eragrostis lehmanniana* at flowering and at seed ripening stage to determine whether these attributes are affected by the type of litter used or by litter treatment. Annual rye, California poppy and rye-poppy mixture were the sources of litter while litter treatments included removing organic residue, leaving organic residue standing or roto-tilling organic residue into the surface soil. The effect of litter type and litter treatment on the soil was evaluated. A parallel greenhouse experiment was carried out.

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CHAPTER I

INTRODUCTION

In pristine conditions, vegetation was in dynamic equilibrium with the environment. Plant communities represented wide floristic diversity dominated by perennial species. Grazing impact was minor, and the relatively few large herbivores caused only minor vegetation disturbances. Increased human pressures through 1) grazing pressure by domestic livestock, 2) poor cropping systems coupled with recurrent fires over the past few hundred years have induced tremendous changes in vegetation composition and structure. The result is that millions of acres of former native vegetation are now decimated mainly by undesirable vegetation of low grazing value, and perennial rangeland communities are continuously being converted into undesirable annual vegetation. The end result is that range condition is poor and soil erosion is evident. Rangelands in this poor and unproductive state occur in all continents. There is urgent need for improving these rangelands through establishing desirable perennial plants to restore forage production and the quality of the environment. The problem has special significance in the developing world where every piece of land is needed to produce food and fiber to alleviate the ever-present ever-increasing food shortage for rapidly increasing populations. In this light there is absolute need to increase our abilities to produce food and fiber.

Current range seeding techniques attempt to achieve success in reclaiming degraded areas through direct seeding with desirable species. Results have been poor and erratic. Very few studies attempt to use plant residue to enhance establishment and growth, though it is economically, socially and ecologically sound. Plant residue from annuals would be the logical source. The exact role of annual plants in nutrient cycling has not been accurately categorized despite the fact that they are an integral component in primary and secondary successions. This is particularly true in rangelands where annuals possibly play a very significant role in nutrient cycling and in building up soil organic matter. There is absolute need to study and categorize the role of annuals in rangeland ecosystems.

A hypothesis was developed that annual plant residues concentrate nutrients, particularly micronutrients on the surface soil and these nutrients can be important in establishing growth and nutrient concentrations of perennial grasses grown shortly after litter production. A study involving cool season annuals and warm season perennials was designed to test the above hypothesis. The information provided by this study will hopefully indicate if there is a potential role that annuals can play in enhancing the establishment of desirable perennial grasses in range areas. If this concept can be demonstrated under ideal nursery and greenhouse conditions where soil moisture availability, the most important variable, is controlled, then pilot field trials to test the practical usage of the concept can be initiated. The information will have direct relevance in revegetation of disturbed areas with little or no soil organic matter. These types of ecosystems are common in arid and semiarid areas of the world. The specific objectives of this study were:

1. To determine the growth, biomass and nutrient content of annual rye (Lolium temulentum L), California poppy (Eschsholtzia californica Cham) and a mixture of the two grown together at flowering and at seed ripening.

2. To determine the influence of four litter types (i.e., litter from species mentioned in 1 above and a control) under three treatment regimes on growth, biomass and nutrient content of sand dropseed (Sporobolus cryptandrus [Torr.] Gray) and Lehmann Lovegrass (Eragrostis lehmanniana Nees).

3. To determine the effect of different litter types under three treatment regimes (i.e., litter standing,

litter removed, litter tilled) on nutrient content of the top 5 cm soil.

CHAPTER II

LITERATURE REVIEW

Litter

Litter has been defined in several ways by different authors. Medwecka-Kornas (1971) defined litter as material lying on the soil surface composed of dead plants and shed organs but not standing dead material. Rodin and Bazilevitch (1967) provided a more comprehensive description which included all dead organic matter from above-ground and below-ground plant parts whether they die naturally or whether they are added to the organic pool as a result of slower aging process or natural thinning. Heady (1956) reported that dead plant material above the soil surface in natural grasslands are referred to as litter, mulch or plant residue. The material varies in position from lying on the surface to standing in an upright tangled mass. It may be in various degrees of decomposition and in many degrees of compactness. Total mulch may be divided into 1) fresh mulch and forage residue (this portion may be eaten by animals and is equivalent to what foresters call litter [Heady 1956]), 2) the partially decomposed material on the surface known as raw humus, little of which is ever eaten by animals (Hendrick 1948).

The position of litter components varies with time and with different vegetation communities (Hendrick 1948). Leaves, flowers, glumes, seeds, fruits and small twigs are the major above-ground components which comprise surface litter. Debris from primary producers accumulates on the soil surface and within mineral soil horizons along the network of roots and rhizomes (Medwecka-Kornas 1971). Above-ground biomass from herbaceous plants add large quantities of organic matter to the litter pool on an annual basis (Heady 1956). However, organic material is added to the soil continuously throughout the year. Some of the litter may be buried in the soil through animal activities, e.g., hoof activity or arthropod activity (Dyksterhuis and Schmutz 1947).

Mulching Effect of Litter

Above-ground plant residues modify various environmental factors and enhance seed germination, emergence and establishment (Geiger 1965; Jacks, et al. 1955; Mathews and Cole 1938). Specifically, the mulching effect helps 1) to increase penetration and duration of moisture in the soil; 2) to reduce or prevent soil surface crusting; 3) to ameliorate temperatures in the seeding zone; and 4) to protect the soil surface from puddling, thereby reducing erosion.

Plastic films, cinders including various types of gravel and plant residues have all been employed as mulches to reduce water loss by evaporation (Gomn and Lavin 1968). Judd (1948) reported that natural mulches seem to improve establishment and maintenance of grass stands. Springfield (1972) reported that mulches conserve soil moisture mainly through modifying temperature of the soil surface.

Although mulching is expected to improve seed germination, emergence and establishment, the exact plant response is dependent on several other factors. Lavin et al. (1981) include 1) rainfall distribution pattern; 2) site characteristics; 3) species involved; 4) type of mulch employed; 5) weed competition; and 6) damage by small animals as some of the major factors which influence success. However, the crux of the problem is the capacity of the environment to meet the needs of the species, particularly in regard to moisture and temperature. Planting time or season should be based on species requirements and when the growing conditions are most favorable. Improvement of microenvironment, particularly seedbed preparation and planting using methods that ameliorate soil moisture, result in improved establishment (Lavin and Springfield 1955). Hull et al. (1958) reported that control of competing vegetation improves establishment.

Cultural methods and seedbed preparation techniques are well established (Anderson et al. 1957; Barnes et al. 1955). Summer fallow, tilled crop residues and standing residues have been employed in the agricultural industry (Douglas et al. 1960; Sittler 1958). In arid ecosystems the methods which have been used in seedbed preparations fall into three main categories: namely, mechanical, chemical and pyric (Hull et al. 1958). Ploughing and chaining are the oldest methods. Ploughing has the unique advantage of reducing competition to a minimum. It can, however, create artificial spatial heterogeneity by bringing impoverished soil to the surface (Young et al. 1969). Chemical methods kill most of the undesirable plants leaving the dead plant matter more or less _in situ_. The above-ground dead plant matter may cause planting difficulties (Larson et al. 1970; Henry and Johnson 1971).

Fire has been used extensively in seedbed preparation as a low cost brush conversion tool followed by reseeding (Pratt and Knight 1968). It is noteworthy that fire affects the chemical properties of soil by ashing organic material in the above-ground vegetation and organic residues which may be on the ground. The resulting ash changes the chemical properties of soil through changes in pH, changing the amount and concentrations of soluble ions in the soil which may be redistributed by soil water (Clayton 1976; Harwood and Jackson 1975). Wright and

Heinselman (1973) reported that fires may indirectly release mineral elements through increased decomposition rates of the remaining organic layer and other remains, leaching or erosion of mineral soils, physical breakdown of rocks and subsequent breakdown of rock fragments. Range soils have shown considerable variation in chemical properties following a fire (Christensen 1976; Hooker 1972; Vlamis and Gowans 1961). Fire may affect nutrient availability by mobilizing nutrients, inducing deficiency or causing no discernible effects (Wells 1971).

Decomposers on Leaves

The surfaces of above-ground plant parts constitute a differential trap for collecting airborne materials (Hirst and Stedman 1971). These surfaces, which assume a wide range of geometrical orientations varying from horizontal to vertical inclinations may have sticky, wet or dry textures (Holloway and Baker 1970). Textural characteristics fluctuate over time through various phenological stages. Important morphological characteristics used for trapping airborne particles include furrows, ridges, wax plates, glands and various forms of vestiture (Holloway and Baker 1970).

The organisms trapped on the phylloplane may be unable to germinate due to various physical limitations (Ruinen 1971). These include lack of essential nutrients and host specificity (Dickinson 1965), competition between resident organisms and condition of the host. An organism on the phylloplane may be inactive during most of the life of the host plant, but start to develop as senescence approaches. The change can be attributed to changes in character, quality or quantity of leacheates from the epidermis (Ruinen 1961; Tukey 1971), or as a result of limited growth on the area surrounding dead cells (Pappelis and Katsanos 1966). Bacteria and yeasts are the common residents on the phylloplane of most young plants (Dickinson 1965). Bacteria and fungi occur in anticlinal walls of epidermal cells (Ruinen 1961) and in cell depressions (Leben 1965; Ruinen 1961). Fungal hyphae generally occur on surfaces of young herbaceous leaves (Dickinson 1967).

Decomposition

Decomposition, a complex and continuous process largely takes place in the soil body but is initiated before death (Satchell 1974). Decomposition is central to all aspects of ecology (Barbour et al. 1980). Rate constants are a function of the nature of substrate as influenced by environmental variables (Bray and Gorham 1964). Specifically, these include: 1) the chemical composition of the litter involved which is largely influenced by species and age of the litter; 2) environmental conditions under which decomposition occurs with temperature and moisture being the most important; 3) the composition of soil micro-fauna and -flora; 4) soil characteristics with structure and texture being important; and 5) related human activities. Soil structure reflects pore size which influences aeration and moisture content. The wide variety of soil chemical compounds, e.g., simple inorganic salts, various exudates, may have beneficial or toxic effect on saprophytic organisms.

In natural ecosystems all production in absence of export from the system eventually enters the decomposer system (Bourliere and Hadley 1971). The decomposing population break down and simplify the organic debris making nutrients available for recirculation (Wood 1976). The elements retained at the time of physiological death in various plant parts are circulated and returned to the soil through several stages. Wiegert and McGinnis (1975) reported that the largest proportion of above-ground production in the terrestrial ecosystem enter the detritus food chain. They concluded that the saprophage food chain is more important than biophage food chains. Teal (1962) and Bray and Gorham (1964) reported that 88-99% of the annual net primary production is not consumed by herbivores but enters the soil litter system. Plant debris is the important and major component in nutrient cycling

(Odum and de la Cruz 1963; Odum 1971). The primary energy source for microorganisms in the soil system is the chemical energy bound in the organic debris. Heterotrophic organisms use it as a source of energy as well as a nutrient pool (Odum 1971).

Soil, the repository of most organic matter, is recognized as the primary reservoir of plant nutrients in the ecosystem and organic matter is a major factor in stabilization of soil structure (Allison 1927). In addition, most soils have the capacity to degrade and simplify organic material rapidly and in an economic manner (Dickinson 1967).

In a given locality, the major components in the terrestrial ecosystem are organisms, inorganic nutrients and a horde of organic compounds which interact with the physical environment in time. The major biological activities involved are immobilization and mineralization (Coleman et al. 1978). The primary arena of biological activity is soil solution in the small pore spaces.

Plant litter is composed of six main categories of chemical constituents, namely: cellulose, hemicellulose, lignin, water soluble sugars, amino acids and aliphatic acids, ether and alcohol soluble constituents which include fats, oils, waxes, resins and many pigments and finally proteins (Alexander 1976). Foster and Martin (1981) reduced these categories to three: 1) living cells which are mainly comprised of soil fauna and flora; 2) an electron microscope transparent component which is probably made of carbohydrate rich complexes; and 3) electron microscope dense components which are probably made of polyphenol rich compounds. They focused on biologically active nutrients rather than total nutrients. However, biologically active nutrients are transient and occur in small quantities, hence seasonal measurements of the soil level of various elements may not be a reliable index for biological activity.

The organisms which contribute to decomposition include microorganisms and soil macrofauna (Alexander 1976). The microorganisms include bacteria, actinomycetes, fungi and yeasts while the soil fauna include nematodes, various worms, various insects and rodents (Kevan 1962; Brandsberg 1969).

The soil bacteria fall into two functional groups: 1) the indigenous population whose numbers in the soil does not change dramatically with each addition of litter biomass; and 2) the zymogenous flora whose numbers peak with organic matter breakdown and then drop to insignificant levels (Dickinson 1974). This implies that litter decomposition is characterized by periodicity, i.e., the accumulation of a huge biomass of decomposer microorganisms and the resynthesis of organic compounds which are less degradable compared to original matter (Alexander

1976). Water soluble nitrogenous compounds, sugars and various organic acids are utilized first; more resistant humic complexes are broken down slowly (Alexander 1976). The role of bacteria in litter breakdown is twofold: 1) direct breakdown of litter constituents; 2) the indirect degradation of organic constituents which build up as a result of litter decomposition (Eklund and Gyllenberg 1974).

The actinomycetes have several ecological advantages over bacteria. Goodfellow and Cross (1974) listed four major advantages as follows: 1) actinomycetes are nutritionally more versatile and grow well on both nutritionally rich and poor substrates; 2) they are capable of attacking a wide variety of substrates both natural and artificial that are usually resistant to microbial attack; 3) they produce a wide array of secondary metabolites including antibiotically active compounds which give them some competitive advantage; and 4) they have the ability to produce mycelium which allows them to radiate outwards and attack organic matter at a distance from initial growth center.

Fungi play an important role in decomposition. The "Sugar fungi" flare up in numbers on addition of organic matter to utilize easily decomposable organic matters (Pugh 1974), while the fungi which utilize more stable substrate such as cellulose and lignin grow much more steadily over a longer period of time. The fungi constitute the primary decomposer population in most environments and the bacteria appear as a secondary population (Eklund and Gyllenberg 1974).

In the soil, bacteria in the rhizosphere produce indole acetic acid or IAA-like substances, i.e., gibberellins, cytokinins and possibly other growth regulators suitable for root uptake in exchange for soluble or labile carbon compounds from root systems (Brown 1975). A large range of soil microorganisms (bacteria, algae, fungi, yeast and actinomycetes) produce growth regulating compounds similar to those occurring in higher plants (Greene 1980; Brown 1976).

Immobilization and mineralization of nutrients may occur in a temporal sequence along the root length from the root tip (Rovira 1979). Most exudation occurs near the tip, while behind the region of elongation N and P are immobilized by microflora. Further back, C from exudates are exhausted as the grazer population increases. In more mature root regions, readily available C decreases and high activity of grazers mineralizes nutrients increasing their concentration in the root absorption zone (Brown 1976). Consequently, net nutrient mobilization provides nutrients for root uptake. The foregoing implies that reduced C released during vegetation growth, senescence and death is the main source of energy and the basis for the detritus food chain.

Organic matter breakdown provides energy and tissue building blocks for microorganisms (Wiegert et al. 1970). This process may be preceded by ingestion and breakdown by invertebrates. There are two major cycles of decomposition; namely the fast and slow cycle (Anderson 1979). In the fast cycle, microorganisms act on low molecular weight carbon sources like root exudates sloughed off cells and amino acids. The slow cycle involves more difficultly decomposed organic matter like cell walls (Coleman et al. 1978). Anderson (1979) reported that dissolving inorganic phosphates from inorganic detritus proceeds faster and more completely in the presence of bacterial grazers than in the presence of bacteria alone. In other words, soil animals change rates of substrate utilization and mineral nutrient release. These animals mechanically process litter and detritus and thereby influence organic matter distribution. This affects the decomposition process by bringing about even nutrient distribution at decomposing sites. Absence of grazers cause litter accumulation and nutrient immobilization and ultimately reduces nutrient turnover.

Barsdate et al. (1974) reported that bacteria and fungi release little P or N during decomposition since they require it for building their body tissues. Consequently, these organisms are indirectly responsible for nutrient regeneration (Anderson 1979). Bacteria consumers which constitute secondary saprophages are necessary for recycling bacterially-bound nutrients (Wiegert and Owen 1971). Reichle (1977) and Coleman et al. (1978) stipulated that nutrient release operated in two stages. First, the plant actively produces a low molecular weight mass of carbon compounds which stimulate and maintains bacterial population growth. Carbon compounds are broken down with evolution of CO_2 while N and P are utilized in new tissue production. During this phase various phenolic polymers are produced (Wood 1976). Secondly, nematodes and other bacterial grazers, which have high intake rates and low productivity, consume large amounts of microorganisms most of which are returned to the soil through waste products. The two stages result in high nitrogen and trace element turnover and formation of stable organic mineral complexes.

Nielsen (1949) reported an increase in nutrient mobilization, particularly N, in the presence of nematodes. The nutrient cycle through bacteria and bacterial grazers and back into the soil is much faster when all the relevant niches are occupied.

Forms of Nitrogen in the Soil

Inorganic Nitrogen

Nitrogen is the soil nutrient plants require in the greatest quantity. It enters into protoplasm structure of living organisms.

Nitrogen occurs in either organic or inorganic forms in the soil. Organic and inorganic forms of N in the soil plough layer constitute 0.02 to 0.4% by weight (Black 1968). Nitrate N and ammonium N constitute less than 2% of the total N in the soil (Waksman and Starkey 1931), while organic forms constitute about 98% of total N in the soil (Bremner 1951). Black (1968) reported that N in gaseous elemental form occurs in the soil atmosphere, dissolved in the soil solution and adsorbed on the surface of soil particles. Buckman and Brady (1969) speculated that the sources of this N could be the atmospheric N reservoir as well as biological denitrification. Nitrogen gas is fixed by some symbiotic and non-symbiotic microorganisms. Atmospheric nitrogen is not directly available to most green plants. The triple chemical bond in the nitrogen molecule ($N \equiv N$) requires high energy input to break it up and only a few organisms can break the bond and make N available for plant use (Hardy and Gibson 1977).

Inorganic forms of nitrogen in the soil are nitrous and nitric oxides, nitrite, nitrate and ammonium. Nitrous and nitric oxides are in gaseous form and occur in insignificant amounts. Nitrate and ammonium occur in ionic forms in soil solution and they are readily absorbed and utilized by green plants (Alexander 1976).

Ammonium Nitrogen

Organic matter must first be mineralized before plant roots can adsorb it. Dickinson (1965) estimated that 1.3% of organic N in the soil is mineralized during a growing season. Numerous microorganisms in the soil are responsible for degradation of organic residues. Ammonium (NH_4^+) is the first product in mineralization of nitrogenous organic matter; it may be oxidized further through several intermediate stages to nitrate (Alexander 1976; Black 1968; Waksman 1952). Mineralization is a two stage process; ammonification and nitrification.

Ammonification is controlled by many factors: the quantity and composition of substrate, pH, the amount of ammonium nitrogen in the soil and the microorganism population. A diverse flora liberates ammonium from organic N compounds. Bacteria, fungi and actinomycetes are all involved (Kevan 1962). However, the rate of decomposition and compounds utilized vary with the species and genus. The amount of NH_4^+ that accumulates varies with the organism, the substrate, soil type and the environmental conditions (Brandsberg 1969; Schaller 1968). Jenny (1928) reported that ammonification is active at temperatures as low as 0 to 5 degrees C. Ammonification proceeds both under aerobic and anaerobic conditions (Amer and Bartholomew 1951). Smith and Cook (1947) reported that nitrogen mineralization proceeded only up to the ammonium stage in pots where large amounts of nitrogenous compounds were incorporated in compacted soil. Ammonification proceeds both in acid and alkaline condition. Cornfield (1953) reported that ammonium accumulated at pH 4.0.

Available ammonium in the soil is reduced by leaching, volatilization and interlayer fixation (Adams and Stevenson 1964). Ammonium is strongly retained by adsorption, especially in fine textured soils (Jones 1942). Allison et al. (1953) reported that more ammonium is fixed in subsoils than in surface soils.

Nitrate Nitrogen

Ammonium (NH_4^+), the most reduced form of inorganic nitrogen is the substrate for nitrifying organisms in nitrification. Ammonium is oxidized to nitrite and ultimately to nitrate (Alexander 1976; Harmsen and Van Schreven 1955). This implies conversion of ammonium to nitrite is slower than conversion of nitrite to nitrate.

In soil, nitrification is largely accomplished by chemosynthetic autotrophs, though a small amount is produced by various heterotrophic microorganisms (Alexander 1976). Nitrosomonas, (NH_4^+ oxidizers) and nitrobacter, (NO_2^- oxidizers) are abundant in most moist soils (Alexander 1976). NO_2^- producers are found among bacteria and actinomycetes while NO_3^- producers include fungi (Harmsen and Kolenbrander 1965). NO_2^- and NO_3^- accumulation is related to C:N of the substrate and little NO_2^- and NO_3^- is accumulated when C:N ratio is high (Brandsberg 1969).

Most aerated soils and moist soils are conducive to both ammonification and nitrification (Floate 1970). Waterlogged soils favor NH_4^+ accumulation since nitrification is inhibited by anaerobic conditions (Smith and Cook 1947). However, the heterogeneity of microflora involved in mineralization implies that degradation of nitrogenous material is a continuous process as long as microbial proliferation is possible (Kevan 1962). The process rates are affected by environmental factors, physical and chemical characteristics of habitat, e.g., moisture content of the soil, pH, aeration, temperature and inorganic nutrient supply (Shields 1953). Little nitrification occurs outside the range of 5 to 40°C with optimum temperature of 20 to 30°C (Harmsen and Kolenbrander 1965; Shields 1953). The optimum pH range for nitrification is pH 5 to 8°; NH_4^+ accumulates outside this range (Cornfield 1953).

Nitrate is mobile in both plant and in soil (Jones 1942; Krantz et al. 1943; Larsen and Kohnke 1946). During periods of prolonged drought nitrate moves upward in soil solution as a result of capillarity. Soil texture affects the movement of nitrates in the soil significantly. Nitrates, when present in large quantities, can be leached from soils (Jones 1942).

Brown (1963) reported that heterotrophs and autotrophs compete for ammonium- and nitrate-N. At times microorganisms might outcompete green plants in acquiring nitrogen. Microbially bound N is returned to the soil by microorganism grazers (Holling 1973). In some systems the absence of grazers cause litter accumulation and nutrient immobilization which reduces nutrient turnover (Coleman et al. 1982).

Organic Nitrogen

Although most of the soil nitrogen occurs in organic form only one to two percent is made available during the growing season (Waksman and Iyer 1932). Bremner (1951) reported that under laboratory conditions, 30% of soil N is resistant to acid or alkaline hydrolysis. The seasonal flush of litter mineralization provides various N forms which are partitioned as follows: 1) the amount immobilized; 2) the amount converted into humic complexes; 3) the amount adsorbed on colloidal complexes; 4) the amount utilized by plants; and 5) the amount lost through leaching, volatilization or biological denitrification. Black (1968) reported that the stable humic complexes in the soil degrade slowly due to the following reasons: 1) polyphenols, amino acids and other nitrogenous derivations condense into large molecules with relatively small surfaces for enzymatic action; 2) the physical sorption of humus by clay renders the active humus protein group inaccessible to microbial proteases; 3) most of the soil organic matter is located within pores too small to be accessible to microorganisms; 4) the structure of terminal products of decomposition are highly irregular. This reduces the probability of a particular enzyme coming into contact with the specific bonds they attack. The stable humic complexes in the soil are very important and play a long range effect such as maintaining good soil structure, increasing soil cation exchange, pH buffering, improving water holding capacity and finally acting as a nutrient store-house from which various nutrients are released slowly into soil solutions (Bohn et al., 1979).

Phosphorus

Phosphorus (P) occurs in plants, soil and microorganisms in various organic and inorganic compounds

(Alexander 1976; Bohn et al. 1979). It is the second most important inorganic nutrient required both by plants and microorganisms (Cole et al. 1977). It is important because of the major physiological roles it plays in accumulation and release of energy during cellular metabolism. It occupies a critical position both in plant growth and in the biology of the soil (Cole and Olsen 1959b).

Phosphorus occurs in soil either in organic or inorganic form, and each category includes numerous compounds (McGeorge 1935). Microorganisms directly or indirectly bring about several important transformations of the element. They alter the solubility of inorganic phosphorus compounds, initially through the production of inorganic or organic acids which convert insoluble P complexes to more soluble monobasic forms (McGeorge 1935; Troug 1946). They mineralize organic compounds with release of inorganic P. They immobilize inorganic P. Lastly, they indirectly assist oxidation or reduction of inorganic P compounds (Bohn et al. 1979).

Organic P

Plant and animal remains and various metabolic products constitute the largest source of P entering the soil body (Alexander 1976). On death agricultural crop residues which contain 0.05 - 0.5% P in their tissues return most of it on the soil surface (Fuller and McGeorge

1951). Of the total P in most agricultural soils, 15 - 85% is in organic form and is mainly comprised of inositol phosphates, various nucleic acids, phosphorylated sugars and various co-enzymes (Alexander 1976). Phosphorus in nucleic acids and phospolipids may be readily available to plants (Halstead and McKercher 1975). Gupta and Cornfield (1962) reported that in calcareous soils organic P accounts for 4 - 50% of total P. However, most of the organic P is unavailable to plants and must be converted to inorganic orthophosphates by bacteria, fungi and actinonycetes before it can be utilized by plants. Organic P complexes are stabilized through adsorption or precipitation and may be mineralized enzymatically as required (Coleman et al. 1982). This process is bio-chemical since it occurs outside the cell.

Inorganic P

Phosphorus is one major element in soil organic matter supplied entirely by parent material (Gardner and Kelly 1940). The inorganic P fraction is very complex and mainly occurs as compounds of Fe, Al and Ca. It also occurs in several mineral forms and as phosphates in crystal lattice in clays (Bohn et al. 1979). In most calcareous soils in Arizona most inorganic P occurs as calcium phosphate (Fuller and McGeorge 1951).

The solubility of P is a function of pH and calcium ion activity (Fuller and McGeorge 1951; Gardner and Kelly 1940; McGeorge 1935). Bohn et al. (1979) reported that P forms difficultly soluble compounds with Fe^{3+} and Al^{3+} at low pH and forms more soluble compounds with Ca^{2+} and Mg^{2+} at pH values near neutrality and difficultly soluble compounds with Ca^{2+} at higher pH values. In calcareous soils most inorganic P occurs as calcium phosphate (Chang and Jackson 1957). However, in acid soils the prodominant forms of P are Fe^{3+} and Al^{3+} (Chai Moo Cho and Caldwell 1960). Ligand complexes adsorb large amounts of P through substitution of P ion for the hydroxyl ion (Dean and Rubins 1947). These adsorbed ions are released into the soil solution to maintain the dynamic equilibrium as plant roots absorb P (Alexander 1976).

Iron

Iron, a major constituent of earth's crust, is the third most abundant mineral element in soil (Bohn et al. 1979; Gotoh and Patric 1974). In most well-drained soils, the most reactive species is iron oxide in various hydrated forms which exist as coatings on clay, silt and sand particles (Alexander 1976; Bohn et al. 1979; Gotoh and Patric 1974). Ferric complexes are unavailable for plant utilization (Duff et al. 1963) since higher plants absorb iron in its reduced soluble ferrous form (Alexander

1976). Ionic iron forms simple and complex molecules which may form iron-organic complexes in the soil, varying from sugars, simple organic acids and highly polymerized humus constituents. These organic complexes are available for microbial attack with the organic portions of the molecule providing energy for microbial proliferation (Bohn et al. 1979). The transformations are brought about by numerous bacteria and fungi restricted to a few genera (Pugh 1973).

Iron Transformation

Microorganisms bring about oxidation of soluble available ferrous forms (Fe^{2+}) to insoluble and unavailable ferric forms (Fe^{3+}) which precipitate as ferric hydroxide (Spencer et al. 1963). Alexander (1976) reported that microorganisms attack soluble organic compounds releasing inorganic iron complexes which are insoluble. Microorganisms reduce the oxidation reduction potential of the environment (Bloomfield 1954), which allows species mainly in the genus bacillus to produce soluble Fe^{2+} into ferrous sulfide. Chemically Fe^{2+} predominates below pH 5 and Fe^{3+} above pH 6 (Duff et al. 1963).

The foregoing implies that iron may be precipitated by iron oxidizing bacteria, by heterotrophs decomposing organic salts of iron or by increasing pH from acid conditions to alkaline conditions. Conversely, solubilization is increased by acid formation in the soil medium, synthesis of certain organic soluble products or by creating reducing conditions like waterlogging or soil compaction.

Manganese

Manganese Forms in Soil

Manganese is an essential micronutrient for growth and development of higher plants. In soil it occurs in several oxidation states, but only three, the tetravalent, the trivalent and divalent states are well known (Alexander 1976). Tetravalent manganic ion is exceedingly insoluble and occurs largely as insoluble MnO_2. The trivalent Mn^{3+} ion is highly transitory and quickly converts to Mn^{4+} or Mn^{2+}; however, Alexander (1976) reported that it may occur in organic complexes. Manganous ion, Mn^{2+}, is the only soluble ion of significance. Patric and Turner (1968) reported that manganous ions which constitute the water soluble and exchangeable forms are readily available to plants. However, the easily reducible component and the residual components which are made of manganic oxide and chelated forms, respectively, are not readily available to plants.

Manganese Oxidation

The balance of Mn^{2+} and Mn^{4+} in the soil depends on pH, the available microorganisms, the partial pressure of oxygen and the availability and abundance of organic matter (Alexander 1976). At pH below pH 5.5, Mn^{2+} dominates the chemical equilibrium, while at 5.5 - 8.0 the microbiological reactions dominate. However, above pH 8.0, Mn^{2+} is unstable and chemical auto-oxidation takes over oxidizing Mn^{2+} to MnO_2 (Ehrlich 1968). The optimum pH range for biological oxidation is pH 6.0 to 6.5 (Alexander 1976), and within this range, manganese deficiency can occur in soils rich in organic matter since soluble Mn^{2+} is converted to insoluble MnO_2 (Meek et al. 1973). Ehrlich (1968) reported that increase in oxidation of Mn^{2+} caused by bacteria may be the result of enzymatic catalysis biodegradation of manganese chelates followed by auto oxidation of Mn^{2+} due to favorable conditions of pH and redox potential.

It is doubtful whether microorganisms obtain energy for growth by oxidation of manganous ions. Ehrlich (1968) doubted the existence of chemoautotrophic manganese bacteria. However, Alexander (1976) reported that the number of manganese oxidizers in the soil is low and account for 5 - 15% of the total viable microflora. Johnson and Stokes (1966) reported that bacterial cells had to be grown with MnO_2 to be able to oxidize Mn^{++}, indicating that an enzyme was involved. Ehrlich (1968) postulated that Mn^{2+} was initially adsorbed by MnO_2 and then oxidized. In all these transformations immobilization is of little significance since microbial cells rarely contain more than 0.05% of the element in their tissues (Alexander 1976; Johnson and Stokes 1966; Patric and Turner 1968).

Manganese Reduction

Manganic oxide interconversions to generate Mn^{2+} is facilitated by acid production during bacterial metabolism or by bacterial reduction (Alexander 1976; Bohn et al. 1979). A decrease in pH, lowering of oxidation-reduction potential or removal of O_2 as a result of microbial metabolism increases the level of exchangeable manganese in soil solution (Meek et al. 1973). Patric and Turner (1968) reported that with disappearance of O_2 and NO_3 a significant increase in measurable Mn^{2+} in the soil solution and cation exchange complex is the first measurable change following waterlogging. They also stated that the effect is temporary and reverts to normal once the soil is aerated. Soil organic matter itself reduces higher oxides slowly (Alexander 1976).

Zinc and Copper

The availability of zinc and copper is a function of their solubility and dissolution rate as they affect ionic activities in the soil solution over time (Baker and Suhr 1982). Zinc and copper which are absorbed by plants in their ionic forms have similar equilibrium solution activities and dissolution rates (Bohn et al. 1979).

Zinc and copper are essential plant micronutrients; however, in excess they cause phytotoxicity (Alexander 1976). Zinc and copper in soil fall into three forms: water soluble, which is mainly in soil solution, the exchangeable and the fixed forms (Bohn et al. 1979; Macias 1973). Microorganisms play an important role in converting fixed forms into soluble and exchangeable forms. Bohn et al. (1979) reported that microorganisms produce organic and inorganic acids which dissolve the cations from silicate clays. The fall in pH due to oxidation of ammonium salts by nitrifiers increases the solubility of zinc and copper (Alexander 1976; Brady 1974). Macias (1973) reported that increasing acidity accompanied by plant decomposition or oxidation of various sulfides results in increasing soluble Zn^{2+} and Cu^{2+} in soil solution. Formation of complex ions and ion pairs increase availability of Zn^{2+} and Cu^{2+} (Bohn and Husayn 1971).

CHAPTER III

MATERIALS AND METHODS

Study Area

The study area is an irrigable 70x20M field with known cropping history and history of no fertilization. The field lies in an east-west direction and is located at the Plant Materials Center (PMC) in Tucson. Lack of a fertilizer history was important in considering possible complications in micronutrients due to artificial addition in soil. The soil in the field was a Gila loam, a member of the loamy, mixed thermic typic torrifluvents.

Field Study

Field plantings involved planting a winter annual crop, followed by warm season perennial grasses planted in various litter treatment subplots. A split-split plot design with 4 main plots, 12 subplots and 24 sub-sub plots in each treatment was used in field studies. The experiment was replicated 3 times (Figure 1).

Four annual plantings including a control (no annual) were annual rye (*Lolium temulentum*), California poppy (*Eschscholtzia californica*) and a mixture of the

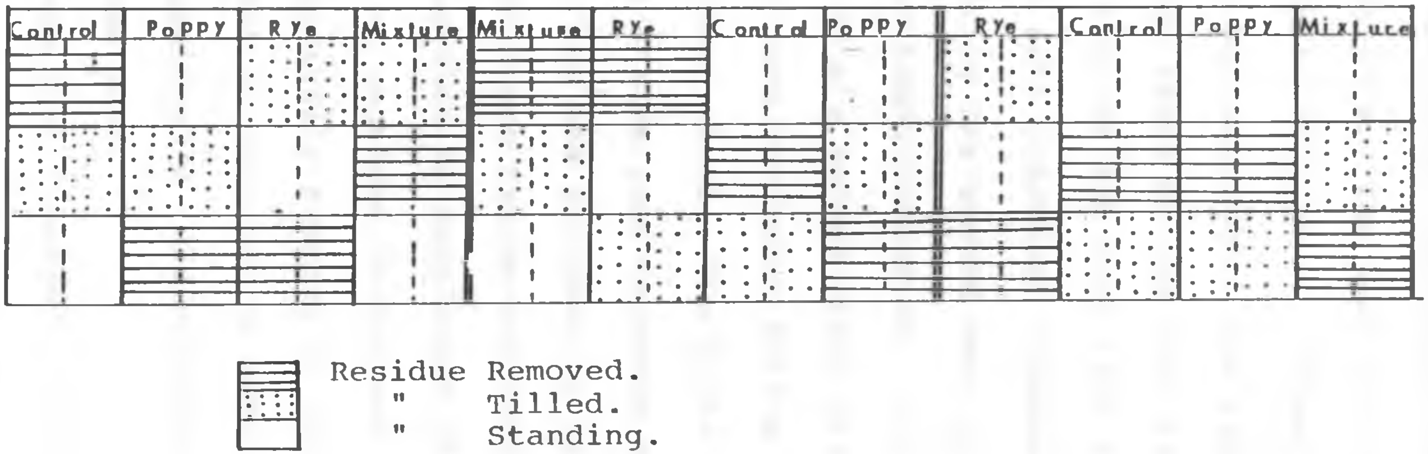

Figure 1. Field outlay indicating litter types, litter treatments and the perennial grasses planted.

Sp = dropseed
Er = lovegrass

annual rye and the poppy designated hereafter as rye-poppy for convenience. The four plantings constituted the main treatments (Figure 1). These were planted in plots 5x6M, and the experiment was replicated three times.

Certified seeds of the cool season annuals were planted at the rate of 220 pure live seeds (PLS) per square meter in each treatment (Jordan 1981). The seeds were planted during the second week in December using a small calibrated handbroadcaster. PLS was determined in the laboratory trials before field planting.

Special care was taken during seed broadcasting to ensure a uniform stand. The plots were raked following broadcasting to ensure seed coverage and adequate seed-soil contact. This was followed by flood irrigation to maintain soil moisture regime suitable for germination. Subsequent irrigation to supplement the scanty rainfall was maintained as required throughout the growing season. Weeds were periodically removed by hand. Although insect and rodent predation occurred to some degree, no control measures were instituted. In addition, no artificial fertilization was used.

Each main plot treatment (5x6M) was subdivided into three equal subplots. In one subplot, the standing plant residue was removed, in another the residue was left standing, while in the third the residue was incorporated in the surface soil using a mechanical rototiller. Subplot treatments were assigned randomly. Each subplot described above was divided into two halves (Figure 1); one-half was planted with sand dropseed (Sporobolus cryptandrus [Torr.] Gray), the other half was planted with lehmann lovegrass (Eragrostis lehmanniana Nees). Each perennial grass species was planted in five even rows in all treatments. Perennial grass seeds at the rate of 50 PLS per meter were planted during the first week in July about one month following incorporation of annual plant residue. Care was taken to avoid disturbing non-incorporated plots particularly where plant residue was left standing. Flood irrigation was used as required throughout the growing season. The same procedure was adopted during the second crop of perennial grasses.

Field Measurements

Observations regarding condition of plants, soil moisture, stage of growth, weeds, insects and rodent use were made on a weekly basis. The plots were weeded in the course of the growing season as necessary.

Density, cover and height measurements of annuals were taken at flowering and seed ripening stage. Three $0.1M^2$ quadrats were sampled in each treatment. Plant density in each quadrat was converted to density per square meter and recorded. Percentage cover was estimated and recorded. Average height for three randomly selected plants in each quadrat was recorded. Two weeks following emergence density measurements were taken to evaluate the need for replanting.

Biomass samples of annuals were collected twice during the growing season, at flowering and seed ripening stage. Plant material from three $0.1M^2$ randomly selected quadrats were harvested in each treatment. In each case, green weight and oven dry weight was taken and data recorded as kg/ha. The material was saved for laboratory analysis. The same procedure was used for the second crop of annuals except that field sampling was done on litter treatment subplots.

Data for density, cover, height and biomass of perennials was collected twice during each growing season: at flowering and at seed ripening stage.

Density was obtained by counting rooted individual plants on three 50 cm transects which were randomly selected in each litter treatment. Percentage cover was estimated on each transect used for density determinations. Average cover was recorded. Height of three randomly selected plants on each 50 cm transect were measured to the nearest cm and average height was recorded.

Data for above-ground plant biomass was obtained by harvesting plant material on one 100 cm transect randomly placed in each subplot. Harvested material was bagged and green weight recorded. The material was oven-drived at 70°C to constant weight. A subsample of dry material was ground to pass a 40 mesh sieve (0.42 mm openings) and saved for chemical analysis.

Initially soil samples were collected in each main plot in the field. From each plot, three randomly located soil cores (98 cm^3) were collected from the upper 5 cm and composited. Both field and potted soils were sampled in the same manner after the first and second crop of perennial grasses.

Greenhouse Study

Simultaneously with the field study, a parallel greenhouse study was conducted to fulfill the same objectives. Plants were grown in six inch plastic pots filled with soil from corresponding field plots. Soil was collected from the upper six inches and placed in pots in profile sequence as it occurred in the field profile.

Each of the three replications consisted of 48 pots with 12 pots for each of the main treatments. Pots containing main treatments were similar to the field study, namely: control, annual rye, California poppy and rye-poppy mixture. Main treatment pots were randomly arranged in the greenhouse and were rotated on a weekly basis during the growing season.

Density (plants/pot), height (cm) and biomass data were collected at flowering and seed ripening stage. Plant materials on two randomly selected pots for each treatment were measured at each stage. At each stage the above-ground plant material was harvested, oven-dried at 70°C and weighed.

In the 12 pots for each of the main treatments, annual plant residue was tilled in the soil in four pots, left standing in four pots and removed in the remaining four pots. Two of each set of four pots were planted with sand dropseed and two with lehmann lovegrass.

Density, height, percentage cover and biomass data were collected at flowering and at seed ripening stage. One pot with each species was harvested at flowering stage and the other at seed ripening stage. The herbage was oven-dried at 70°C, weighed and saved for laboratory analysis. The same procedures were employed during the second year.

Laboratory Methods

Plant materials were oven-dried at 70°C for 24 hours and ground to pass a 40-mesh sieve (0.42 mm openings). Soil samples were air-dried, screened through a 2 mm sieve and then ball-milled for laboratory analysis.

Subsamples were oven-dried to constant weight at 105°C to determine moisture content for adjusting laboratory results.

Soil and plant materials were analyzed for N, P, C, Fe, Mn, Cu and Zn. Total nitrogen in plants was determined by micro-Kjeldahl (Bremner 1965); total N in the soil samples was determined by macro-Kjeldahl with the salicylic thiosulphate modification (Bremner 1965). Total carbon in plants and soils was determined by dry combustion (Allison, Bollen and Moodie 1965), using a LECO high frequency induction furnace. Plant phosphorus was determined by the magnesium nitrate-dry ashing method with color development by ammonium molybdate-vanadate (Chapman and Pratt 1961; Jackson 1958). Soil P was determined by sodium bicarbonate extraction (Olsen and Summers 1982) and color development by ammonium molybdate and these determined by spectrophotometer.

Iron, Mn, Cu and Zn in plants were extracted by perchloric acid (Earley 1950; Gieseking et al. 1935; Johnson and Ulrich 1959) and determined by atomic absorption (AA) (Baker and Suhr 1982; Sotera 1982). Iron, Mn, Cu and Zn in soils were extracted using 0.05 DTPA (Diethylene triamine pentaacetic acid) (Soltanpour et al. 1976) and determined by AA (Baker and Suhr 1982; Sotera 1982).

CHAPTER IV

RESULTS AND DISCUSSION

Although plant data was collected at flowering and at seed ripening stages, little difference in physical data for both annuals and perennials was observed between flowering and seed ripening data. Hence, only flowering period physical data are presented in this paper, although reference is made to seed ripening stage when necessary. Analysis of variance was carried out and means were tested by LSD at 0.05 when significant F values were obtained.

Attributes of Annual Species Used for Litter

Attributes of Abundance

Rye produced 230 kg/ha more biomass than poppy in 1982 (Table 1). However, poppy had more aerial cover (91%) compared to rye (84%) despite the higher density in rye plots. This is explained by the spreading habit exhibited by poppy which was considerably shorter than rye plants.

In 1983, biomass and cover were significantly higher in poppy than in rye (Table 1). Poppy produced

Table 1. Biomass, cover, density and height of rye, poppy and rye-poppy in the field at flowering stage during 1982 and 1983.

Source	Biomass	Cover	Density	Height
	kg/ha	%	$\#/m^2$	cm
		1982		
Rye	1150	84	150	72
Poppy	920	91	86	51
Rye-Poppy	980	84	154	71
LSD	210	6	44	16
		1983		
Rye	1140	39	66	55
Poppy	2000	78	73	50
Rye-Poppy	1350	55	67	53
LSD	390	16	9	7

860 kg/ha more biomass in 1983 than rye (Table 1). It was interesting to note that more biomass was produced in poppy and rye-poppy types in 1983 than in 1982.

Nutrients

In both years at flowering period, nutrient content of poppy was significantly higher than that of rye for all nutrients studied except Mn in 1983 (Table 2). At flowering poppy contained up to twice as much N, Mn, Zn and Fe as in rye (Table 2). The data indicates that biomass and all nutrients studied, except C, declined

Table 2. Nutrient content of rye, poppy and rye-poppy at flowering (F) and seed ripening (S) stages in 1982 and 1983.

		N		P		C		Fe		Mn		Cu		Zn	
Year	Type	F	S	F	S	F	S	F	S	F	S	F	S	F	S
		%						ppm							
1982															
	Rye	0.90	0.39	0.27	0.13	38.8	38.9	309	241	135	116	20	16	22	21
	Poppy	3.69	1.96	0.43	0.22	39.0	38.7	458	357	421	115	26	21	54	53
	Rye-Poppy	1.06	0.47	0.27	0.13	39.5	39.0	308	239	277	115	18	15	24	23
	LSD	1.69	1.01	0.11	0.06	0.1	0.1	98	77	162	4	5	4	21	21
1983															
	Rye	1.11	0.89	0.26	0.12	38.6	38.7	351	271	192	173	23	18	22	21
	Poppy	3.36	1.95	0.40	0.19	39.1	38.8	507	427	137	100	57	29	47	41
	Rye-Poppy	0.97	0.42	0.29	0.14	39.2	40.0	394	380	154	140	21	28	22	21
	LSD	0.86	0.76	0.17	0.03	0.6	0.4	15	159	24	31	3	7	10	10

F = Flowering stage
S = Seed ripening stage

significantly between flowering and seed ripening in annual plants. N in annual rye and poppy declined by 56% and 46%, respectively, while Mn in poppy declined by about 73% (Table 2). Charley (1977) reported that large nutrient losses occur from senescing aerial plant parts. It is noteworthy that C concentrations remained stable in both species while other nutrients declined substantially between flowering and seed ripening. Welch (1980) reported that C concentration in Festuca arizonica and Muhlenbergia montana remained stable during senescence.

The nutrient decline was apparently due to translocation of nutrients to below-ground parts and to losses into the environment via leaching and oxidation (Clark 1977). Since I was unable to determine if the nutrient decline represented translocation or loss to the environment, I simply refer to it as "withdrawal" hereafter.

Carbon stability is explained by the fact that the bulk of C in plants is non-labile structural components which include cellulose, hemicellulose and lignin (Alexander 1976; Moser 1977). Decomposition of structural components by phylloplane microorganisms is negligible during senescence and may not increase appreciably until the plant part is dead, detached and in the soil (Moser 1977; Satchell 1974). In the field, a dense pattern of yellow spots developed on leaves of poppy following flowering; these may have been sites of leaf microorganisms.

An interesting observation was C:N ratio of the three annual types. Those values were as follows:

	Flowering		Seed Ripening	
	1982	1983	1982	1983
Rye	43	35	99	44
Poppy	11	12	20	20
Rye-Poppy	37	40	82	93

The C:N ratios at seed ripening stage suggest that net immobilization would ensue at least initially in the rye and rye-poppy plots while net mineralization would ensue in the poppy plots. Alexander (1976) reported that C:N ratio greater than 40 favors net immobilization while that less than 30 favors net mineralization. Dropseed and lovegrass were planted and studied in this context.

Effect of Litter Type on Perennial Grasses

Attributes of Abundance

In 1982, litter type significantly influenced biomass and aerial cover of Sporobolus cryptandrus (hereafter called dropseed) and Eragrostis lehmanniana (hereafter called lovegrass) at both phenological stages (Table 3); density and height were not affected. Data

Table 3. Table of mean squares on biomass, cover, density, height and nutrient concentrations in dropseed in 1982.

Source	DF	Biomass F	Cover F	Density F	Height F
		kg/ha	%	$\#/m^2$	cm
Type	3	798076*	997*	217	64
Treatment	2	2287632*	965*	2134*	61
Type x Tmt	6	555575*	475*	292*	36

Source	DF	N F	N S	P F	P S	C F	C S
		%					
Type	3	0.04	0.03*	0.02*	0.02*	1.33	1.46
Treatment	2	0.04*	0.04*	0.01*	0.01*	0.23	0.04
Type x Tmt	6	0.01	0.01	0.002*	0.001	0.27	0.11

Source	DF	Fe F	Fe S	Mn F	Mn S	Cu F	Cu S	Zn F	Zn S
		ppm							
Type	3	15366*	17383*	1690*	887*	0.05	5.2	103	141*
Treatment	2	11437*	8075*	385*	329*	9.7*	14.1*	92*	85*
Type x Tmt	6	606	134	17*	22*	1.04	0.53	5.2	3.0

F = Flowering period
S = Seed ripening stage
* = Significant at 0.05 level

indicate that poppy residue was superior to rye or rye-poppy residue (Table 4). In 1982, dropseed produced 340 kg/ha more biomass with poppy residue than with rye residue (Table 4). Dropseed produced similar biomass with rye residue and the control.

Litter type had a significant effect on lovegrass biomass (Table 4). Lovegrass produced more biomass in poppy or rye residue than in rye-poppy residue or the control. For both species, biomass, cover and height at seed ripening were considerably greater than at flowering time. This was due to unexpected rains which caused tremendous growth following the flowering period.

The effect of litter type on cover of dropseed was highly variable for both years (Table 4) with a range of 22% in 1982 and a range of 33% in 1983. Similar variance in lovegrass cover was observed among litter types in 1983. Rye residue was associated with greater dropseed density.

Nutrient Content

In 1982, litter type significantly influenced P, Fe, Mn in dropseed at both phenological stages (Table 3). The N and Zn concentrations show a significant effect of litter type at seed ripening stage only, while C and Cu concentrations were not affected by litter type.

Table 4. Biomass, cover, density and height of dropseed and lovegrass under various litter types at flowering in 1982 and 1983.

Type & Year	Biomass	Cover	Density	Height
	Dropseed			
1982	kg/ha	%	$\#/m^2$	cm
Control	1080	81	60	41
Rye	1170	68	48	38
Poppy	1510	80	57	43
Rye-Poppy	780	59	54	38
LSD	320	2	9	4
	Dropseed			
1983				
Control	910	39	44	40
Rye	1060	73	55	46
Poppy	1090	46	42	46
Rye-Poppy	1100	60	49	49
LSD	152	11	7	7
	Lovegrass			
1983				
Control	1580	67	54	69
Rye	1820	70	59	75
Poppy	1690	64	49	75
Rye-Poppy	1560	68	54	42
LSD	140	9	5	3

Nitrogen. The N concentration in dropseed in 1982 at flowering was similar among litter types except for poppy litter (Table 5). Data indicate little N translocation between flowering and seed ripening.

In 1983, the average N concentration of dropseed and lovegrass for all litter types was variable; but plants from the control had the highest N concentration at flowering stage (Table 7). Dropseed and lovegrass plants grown in rye and poppy residue had similar N concentrations, both declined by about 50% from flowering to seed ripening stage (Tables 7 and 8).

Phosphorus. In 1982, P concentration in dropseed was variable. It was highest in plants grown in rye residue and least in plants grown in control plots; poppy and rye-poppy residue produced similar P response (Table 5).

In 1983, the concentration of P in dropseed was higher in rye residue than that of other litter types; dropseed from other litter types was similar in concentration. It is noteworthy that P concentration in dropseed was higher in 1983 than in 1982 (Tables 5 and 7). Phosphorus content of lovegrass plants grown on rye-poppy residue was greater than in plants grown on other litter types. Phosphorus withdrawal between flowering and seed ripening was greater in lovegrass than in dropseed (Tables 7 and 8).

Table 5. Nutrient content in dropseed at flowering and at seed ripening in 1982.

Litter Type	N		P		C		Fe		Mn		Cu		Zn	
	F	S	F	S	F	S	F	S	F	S	F	S	F	S
	%						ppm							
Control	1.12	0.91	0.17	0.17	39.2	38.0	369	357	63	59	18	16	45	43
Rye	1.18	0.94	0.28	0.28	38.3	38.3	464	459	77	75	18	18	53	52
Poppy	1.28	1.03	0.22	0.22	38.6	38.9	408	387	83	82	18	18	46	46
Rye-Poppy	1.13	0.92	0.20	0.20	38.7	38.7	387	381	79	77	18	18	49	48
LSD	0.08	0.07	0.03	0.04	0.5	0.4	28	27	5	6	0.6	1.5	3	2.7

F = Sampling at flowering period

S = Sampling at seed ripening period

Iron. The Fe content in dropseed was variable in 1982. Rye residue plots produced plants with the highest Fe concentration while the control and rye-poppy plots produced plants with similar Fe concentration (Table 5).

In 1983, at both flowering and seed ripening stage litter type significantly influenced the concentrations of all the nutrients studied except C at flowering stage (Table 6). Dropseed and lovegrass were statistically different in terms of all the nutrients (Table 6).

In 1983 the higherest Fe concentration in dropseed at flowering stage was observed in plants grown in rye residue and the lowest in plants grown in poppy residue (Table 7). The Fe concentration of plant growth in rye-poppy and the control were similar (Table 7). In lovegrass Fe concentration at flowering was variable, but the highest Fe concentration was obtained in plants grown in rye-poppy residue.

There was a large increase in Fe concentration in both dropseed and lovegrass between flowering and seed ripening. A decline was expected due to withdrawal during senescence (Clark 1977). A possible explanation is that the heavy rainfall obtained in the latter part of 1983, resulted in greater Fe-organic matter chelation, followed by release of Fe^{2+} ions into soil solution and uptake of ferrous ions by the perennials.

Table 6. Table of mean squares for nutrient content in dropseed and lovegrass at flowering and seed ripening in 1983.

Source	DF	N	P	C	Fe	Mn	Cu	Zn
				Flowering				
Type	3	0.26*	0.013*	2.4	34247*	4487*	105	503*
TMT	2	0.27*	0.005*	4.98	218460*	3431*	166*	589*
SPPS	1	2.40*	0.031*	29.3	490512*	430*	16*	81*
TMTx TYPE	6	0.07	<0.001	10.04	3008	322	12.7	52
SPPSx TYPE	3	0.10	0.002	0.81	36945*	207*	9.3	47
SPPSx TMT	2	0.03	0.004	3.83	47469*	44	0.1	21
SPPSx TMTx TYPE	6	0.06	0.001	2.04	2071	19	18.4	20
				Seed Ripening				
TYPE	3	0.01*	0.02*	0.71	27520*	680*	39.7*	822*
TMT	2	0.12*	0.01*	0.69	35053*	512*	50.4*	448*
SPPS	1	0.38*	0.09*	55.76*	128803*	740*	83.6*	167*
TMTx TYPE	6	0.01	0.01	0.94	1405	10	1.4	40
SPPSx TYPE	3	0.02	0.01	0.29	13581*	143*	1.5	45
SPPSx TMT	2	0.01	<0.01	0.72	526	17	1.9	14
SPPSx TMTx TYPE	6	0.01	<0.01	0.72	526	18	1.9	11

*Significant at 0.05 level
TMT = Treatment
SPPS = Species

Table 7. Nutrient content of dropseed and lovegrass in the field at flowering period in 1983.

Litter Type	N		P		C		Fe		Mn		Cu		Zn	
	Sp.*	Er.*	Sp.	Er.	Sp.	Er.	Sp.	Er.	Sp.	Er.	Sp.	Er.	Sp.	Er.
	%						ppm							
Control	2.42	2.16	0.31	0.24	38.6	40.0	484	272	80.7	76	19.3	17.1	52.3	50.2
Rye	2.30	1.86	0.36	0.28	38.6	39.3	559	292	115.3	113	24.4	23.0	65.2	62.7
Poppy	2.31	1.77	0.30	0.27	37.7	39.4	375	347	100.2	102	19.8	18.7	61.8	55.9
Rye & Poppy	1.17	1.91	0.32	0.30	37.9	39.2	416	523	93.5	79	18.9	20.1	58.9	60.8
LSD	0.18	0.16	0.03	0.02	0.9	0.5	82	40	10.7	11	1.9	2.6	3.9	4.8

*Sp = dropseed
*Er = lovegrass

Manganese. In 1982, dropseed plants grown in poppy residue contained higher Mn concentration than plants grown in annual rye residue. The effect of rye and rye-poppy residue on Mn concentration was similar. Little translocation occurred between flowering and seed ripening (Table 5). In 1983, the highest Mn concentration in dropseed at flowering was obtained in plants grown in rye residue followed by plants grown in poppy residue. Plants grown in the control and rye-poppy residue contained similar concentrations with plants grown in rye-poppy residue (Table 7). Dropseed plants grown in all litter types in 1983 contained higher Mn concentration than their 1982 counterparts. Dropseed plants contained higher concentrations of Mn than lovegrass plants (Table 7). The highest Mn concentration in lovegrass at flowering stage in 1983 was obtained in plants grown in rye and poppy residues (Table 7). At seed ripening stage Mn concentration in lovegrass plants from all litter types except plants from the control were similar (Tables 7 and 8). Withdrawal of Mn was about 30% in plants grown in rye residue.

Copper. The Cu content in dropseed for 1982 was about 18 ppm in all litter types (Table 5). In 1983, Cu concentration in dropseed and lovegrass at flowering was highest (about 24 ppm) in plants grown in rye

Table 8. Nutrient content of dropseed and lovegrass in the field at seed ripening stage, 1983.

Litter Type	N		P		C		Fe		Mn		Cu		Zn	
	Sp.*	Er.*	Sp.	Er.	Sp.	Er.	Sp.	Er.	Sp.	Er.	Sp.	Er.	Sp.	Er.
	%						ppm							
Control	1.21	1.01	0.19	0.18	38.2	40.3	560	490	78	73	17.7	15.2	44.9	41.3
Rye	1.15	1.04	0.31	0.20	38.4	40.1	690	540	96	83	21.4	18.6	58.4	51.8
Poppy	1.24	1.00	0.27	0.22	38.5	40.1	620	520	92	84	18.8	16.9	58.4	59.5
Rye & Poppy	1.14	1.01	0.30	0.20	38.8	40.4	560	540	83	84	19.3	17.8	54.9	51.8
LSD	0.05	0.06	0.04	0.06	0.5	0.5	34	30	5	4	1.3	1.2	4.2	4.7

*Sp = dropseed
*Er = lovegrass

residue. The Cu content in dropseed increased slightly from 1982 to 1983 (Tables 5 and 7).

Zinc. The Zn content in dropseed and in lovegrass was highest in plants grown on rye residue and lowest in that grown on control plots (Table 7). The effect of poppy and rye-poppy residue on Zn concentration was similar but higher than the control. In 1983, rye and poppy residue had similar effect on Zn concentration of dropseed (Table 7). The Zn concentration in lovegrass plants was more variable and not consistent between flowering and seed ripening stages.

Summary. In 1982 at flowering stage, the highest concentrations of Zn, Mn, Fe, P were obtained in dropseed plants grown in rye residue (Table 5), while the highest concentration of N was obtained in plants grown in poppy residue. Effect of litter type on Cu concentration in dropseed was similar between types.

In 1983, at flowering, the highest N concentration in dropseed was obtained in plants grown in the control. The highest Cu, Mn, Fe, P concentration in dropseed was obtained in plants grown in rye residue while the highest concentration of Zn was obtained in plants grown in rye-poppy residue (Table 7). In 1983, lovegrass plants grown in rye residue contained the highest concentration of Fe, Cu and Zn. The implication is that rye residue was associated with high concentration of more nutrients for both dropseed and lovegrass in both years than any other litter type.

Effect of Litter Treatment on Dropseed and Lovegrass in the Field

Attributes of Abundance

Litter treatments significantly influenced biomass, cover and density of dropseed in 1982 (Table 3) and only biomass and density of dropseed and lovegrass in 1983 (Table 9).

Biomass of dropseed and lovegrass was highest from plots with tilled litter (Table 10). In 1982, at flowering, dropseed on tilled plots produced 620 kg/ha more biomass than plots where litter was removed, while lovegrass produced 320 kg/ha more biomass in tilled plots than in plots with litter removed (Table 10). The standing and removed litter treatments had similar effects on dropseed and lovegrass biomass for both years (Table 10).

Nutrients

In 1982 and 1983 litter treatments significantly influenced concentrations of all nutrients except C in dropseed and lovegrass at both phenological stages (Tables 3 and 6).

In 1982, N content of dropseed at flowering was highest in plants grown in standing litter and equal in

Table 9. Table of mean square for biomass, cover, density, and height for dropseed and lovegrass at flowering stage in 1983.

Source	df	Biomass kg/ha	Cover %	Density $\#/m^2$	Height cm
Type	3	123459	1276	419	176
Treatment (Tmt)	2	1038691*	1135	405*	52
Species (SPPS)	1	6964845*	2938*	754*	14280*
Tmt x Type	6	41436	174	80.1	87
SPPS x Type	3	69617	767	30.4	16.5
SPPS x Tmt	2	147890	198	48.9	65.6
SPPS x Tmt x Type	6	22412	4.7	21.2	89.5

*Significance level 0.05.

Table 10. Biomass and nutrient concentrations in dropseed and lovegrass in 1982 and 1983 as a function of litter treatment.

Year & Litter Treatment	Biomass	N		P		C		Fe		Mn		Cu		Zn	
	F	F	S	F	S	F	S	F	S	F	S	F	S	F	S
1982	kg/ha	%						ppm							
Dropseed															
Standing	780	1.24	1.01	0.21	0.21	38.7	38.4	390	380	73	71	18	17	47	47
Removed	1000	1.14	0.96	0.20	0.20	38.5	38.4	390	380	72	69	17	17	46	45
Tilled	1620	1.15	0.89	0.25	0.24	38.8	38.6	440	420	82	79	19	19	51	50
LSD	560	0.09	0.09	0.05	0.05	0.42	0.4	47	46	9	10	0.8	1.2	3.9	4.4
1983															
Dropseed															
Standing	1020	2.36	1.25	0.31	0.25	38.9	38.4	450	590	92	86	20	20	60	54
Removed	790	2.20	1.16	0.31	0.27	37.3	38.5	320	590	88	84	19	18	55	51
Tilled	1310	2.30	1.08	0.33	0.29	38.3	38.8	600	640	113	92	24	21	64	57
LSD	240	0.15	0.09	0.03	0.05	5.1	0.5	140	65	18	8	3.5	2.0	6	7
1983															
Lovegrass															
Standing	1530	2.08	1.09	0.26	0.19	39.8	40.5	280	500	106	81	19	17	58	52
Removed	1590	1.83	0.98	0.26	0.20	39.5	39.8	250	500	85	76	18	16	51	45
Tilled	1910	1.87	0.98	0.28	0.21	39.3	40.3	350	560	104	86	23	19	63	56
LSD	220	0.22	0.54	0.03	0.02	0.9	0.5	57	42	19	7	4	1.2	8	8

F = Flowering stage
S = Seed ripening

plants grown in plots with litter removed or tilled. Litter treatments had no effect on C or P (Table 10). Iron and Cu concentrations were highest in dropseed from the tilled treatment while Zn and Mn concentrations were similar for plants from tilled and standing litter treatments (Table 10). The foregoing shows that plants grown in the tilled treatment had higher concentrations of micro-nutrients (Cu, Fe, Zn, Mn) while those grown where litter was removed had the lowest concentrations of micro-nutrients. Nitrogen concentration was highest in perennials grown where litter was left standing.

In 1983 dropseed plants collected at flowering had similar concentrations of C, N and P, irrespective of litter treatment. The Cu, Mn and Fe concentrations were highest in plants from tilled treatments and similar in those from removed and standing litter treatment (Table 10). Zinc concentration was higher in dropseed grown on tilled and standing litter plots than that grown on plots with the litter removed (Table 10).

During 1983, litter treatment had no influence on C and P content of lovegrass (Table 10). However, Cu and Fe concentrations in lovegrass plants grown in tilled litter were higher than in plants grown in plots with litter left standing or removed. The N, Zn and Mn concentrations of lovegrass were lowest in plants grown in plots where litter was removed; they were similar in plants grown in standing and tilled litter treatments.

Field observations showed that the most vigorous perennial plants in both years were those grown in tilled litter plots, while those from standing litter treatments were least vigorous.

Field Soil Nutrient Status

Effect of Litter Type

At the beginning of the experiment all plot locations were equivalent in soil nutrient content (Table 12). However, at the end of each year's treatment, all nutrients studied except C and Cu were significantly affected by litter type (Table 11).

At time zero soil N in all litter types was similar (Table 12). However, dropseed and lovegrass had different effects on soil N. In 1982, the lowest N content was associated with rye residue plots and highest with poppy residue in plots where dropseed was grown. In 1983 litter type had no significant effect on soil N in plots where dropseed was grown. In plots where lovegrass was grown, the lowest N content was associated with control plots while the other three litter types had similar effect on soil N (Table 12).

Plant residue containing less than 1.3% total N cause net immobilization (Allison 1927). C:N ratio is

Table 11. Table of mean squares for field soil nutrients following the first and second crop of perennial grasses.

Source	DF	N	P	C	Fe	Mn	Cu	Zn
				1982				
Type	3	0.00011*	8.14*	0.002	11.9*	11.8*	0.2	0.28*
Treatment (TMT)	2	0.00027*	5.03*	0.067*	44.4*	33.1*	3.4*	0.80*
Species (SPPS)	1	0.00106*	2.97	0.038*	1.7	0.5	0.02	0.04
TMTxtype	6	0.00001	2.03*	0.007*	6.7*	2.1*	0.43*	0.04
SPPSxtype	3	0.00007	1.71	0.001	0.9	1.5	0.07	0.01
SPPSxTMT	2	0.00002	0.57	0.001	7.2	0.1	0.07	0.03
SPPSxTYPExTMT	6	0.00001	0.24	0.003	1.8	1.1	0.07	0.03
				1983				
Type	3	0.00032*	4.3*	0.060	318.1*	38.2*	8.5*	1.8*
Treatment (TMT)	2	0.00101*	2.5*	0.14*	259.8*	40.8*	30.4*	1.6*
Species (SPPS)	1	0.00047	2.2	0.04*	57.1*	16.0*	0.4	0.5*
TMTxtype	6	0.00005	2.5	0.010	7.6	1.0	1.7	0.1
SPPSxtype	3	0.0006	1.9	0.004	1.0	4.0	1.2	0.6
SPPSxTMT	2	0.00001	2.7	0.002	7.0	0.7	1.3	0.1
SPPSxTYPExTMT	6	0.00001	1.9	0.008	12.1	0.8	0.4	0.2

*Significance level 0.05.

Table 12. Mean soil nutrient levels in the field for 1982 and 1983.

Litter Type	Time Zero Values	1982 Dropseed	1982 Lovegrass	1983 Dropseed	1983 Lovegrass
		% N			
Control	0.040	0.046	0.032	0.047	0.037
Rye	0.041	0.043	0.038	0.054	0.048
Poppy	0.042	0.048	0.042	0.052	0.050
Rye-Poppy	0.040	0.045	0.039	0.050	0.047
LSD	.002	0.002	0.05	0.008	0.006
		P ppm			
Control	9.40	9.77	10.10	10.94	10.59
Rye	10.14	10.40	10.42	11.42	10.02
Poppy	10.24	11.52	11.73	12.21	10.42
Rye-Poppy	10.96	11.52	11.58	10.47	9.78
LSD	0.87	0.58	0.58	1.46	0.88
		% C			
Control	0.69	0.71	0.66	0.77	0.66
Rye	0.70	0.70	0.66	0.78	0.74
Poppy	0.70	0.73	0.67	0.74	0.76
Rye-Poppy	0.70	0.71	0.66	0.81	0.75
LSD	0.03	0.04	0.04	0.07	0.06
		Fe ppm			
Control	15.4	20.6	20.4	17.7	15.4
Rye	15.4	21.8	22.0	23.8	21.9
Poppy	15.6	21.2	20.3	27.3	26.1
Rye-Poppy	15.0	22.3	21.9	23.7	22.1
LSD	0.7	1.6	4.9	2.9	2.8

Table 12--Continued

Litter Type	Time Zero Values	1982 Dropseed	1982 Lovegrass	1983 Dropseed	1983 Lovegrass
		Mn ppm			
Control	10.8	17.5	17.5	8.8	10.7
Rye	11.5	17.6	17.0	12.7	13.6
Poppy	11.2	18.6	19.3	11.2	12.5
Rye-Poppy	10.4	18.3	18.8	12.6	12.3
LSD	1.1	1.0	1.2	1.4	1.1
		Cu ppm			
Control	5.9	6.5	6.6	8.6	8.6
Rye	6.0	6.8	6.7	10.0	10.5
Poppy	5.8	6.6	6.6	10.0	9.5
Rye-Poppy	6.9	6.7	6.6	10.0	9.0
LSD	0.3	0.3	0.3	2.5	1.0
		Zn pm			
Control	2.6	2.3	2.4	2.7	2.6
Rye	2.5	2.4	2.4	2.8	3.5
Poppy	2.6	2.2	2.2	3.1	3.5
Rye-Poppy	2.6	2.5	2.5	3.4	3.0
LSD	0.1	0.1	0.5	0.3	0.3

useful in predicting net effect of plant residue upon soil N (Stojanovic and Broadbent 1956). A C:N ratio of less than 15:1 favors nitrification while a C:N ratio of 35:1 or higher favors immobilization (Broadbent 1947). Based on %N and C:N of plant residue used in this study, annual rye added to the soil may have caused net immobilization, at least initially. However, no visual N deficiency was observed in plants in this study. Recently it has been observed that C:N ratios fail in many cases to provide a suitable index of the rate of decomposition or to account for the transitory effects of residues on soil nitrogen content (Chandra and Bollen 1960). The quantity of residue added to the soil influences the pattern of decomposition and addition of organic residue of under 2 tons/acre cause only small changes in soil N (Broadbent and Bartholomew 1948). In this light, the amount of organic residue added into the soil in this study would have caused little change on soil N. The observed effect was variable (Table 12).

Nutrient content in the soil increased during the study for all nutrients studied except Mn (Table 12). Percentage soil C increased from 0.69% to 0.76% under the poppy residue. Since up to 2000 kg/ha of organic matter was produced and returned to the soil in some plots this small increase in soil C suggests that C was quickly oxidized and lost from the soil system.

Carbon mineralization and immobilization is closely related to nitrogen content of plant residue (Bingeman et al. 1953). Stickler and Fredrick (1959) found that less N immobilization occurred where large particles of residue were incorporated into soil. They also reported that the magnitude of immobilization of nitrate-N during decomposition decreased as particle size of corn stalk incorporated in the soil increased. This explanation is based on the fact that nitrifying organisms function on colloidal surfaces which are greatly reduced with increasing particle size. The results in this study indicate that the non-lignified plant material applied was rapidly oxidized. Hence, there was no significant carbon accumulation. In both years the effects of litter type on C content of the soil was similar in plots where dropseed and lovegrass were grown (Table 9).

Effect of Litter Treatment

In both 1982 and 1983, litter treatments were statistically significant for all nutrients (Table 11). Litter treatment effects on soil N and P were all similar for plots planted with dropseed in 1982. However, soil Fe, Mn and Cu were highest in tilled plots and equal in plots with litter left standing or removed. Zinc and C content were equal in soil from plots with standing and tilled litter and higher than in soil from plots with litter removed (Table 13).

Data from the 1982 lovegrass plots indicated that the litter treatments had no effect on soil N and Fe. The Cu, Mn, P and C concentration of soil was all highest in tilled treatments and lowest where litter was removed (Table 13).

In 1983, on plots with dropseed, tilled and standing litter treatments were associated with increased soil N, Fe, Mn and C. Litter treatment had no effect on Zn and P. Soil Mn was lowest in plots with tilled litter and similar under plots with litter left standing or removed (Table 13).

Litter treatments had equal effect on soil Zn and P in plots where lovegrass was planted. However, standing and tilled litter treatments were associated with increased soil N, C and Fe when compared to litter removal. The Mn and Cu concentration of soil was highest in plots with tilled litter (Table 13).

It is evident that the tilled litter treatment had the most favorable effect in terms of increasing soil nutrient content. Removal of litter had the least favorable effect while the standing litter treatment was intermediate. The response of soil nutrients to annual crops, their treatment and growth of subsequent

Table 13. Effect of various litter treatments on soil nutrients following 1982 and 1983 crops of perennial grasses.

Year & Treatment	N Sp.	N Er.	C Sp.	C Er.	P Sp.	P Er.	Fe Sp.	Fe Er.	Mn Sp.	Mn Er.	Cu Sp.	Cu Er.	Zn Sp.	Zn Er.
1982	%				ppm									
Standing	0.05	0.04	0.71	0.65	10.9	10.9	20.8	21.3	17.7	17.9	6.6	6.6	2.3	2.4
Removed	0.04	0.04	0.65	0.63	10.4	10.9	20.0	20.6	17.0	17.1	6.2	6.3	2.2	2.1
Tilled	0.05	0.04	0.77	0.72	11.2	11.9	23.7	21.4	19.3	19.5	7.1	7.0	2.5	2.5
LSD	0.01	0.01	0.06	0.05	0.9	0.9	2.1	1.1	1.2	1.5	0.4	0.3	0.2	0.2
1983														
Standing	0.05	0.05	0.76	0.73	12.0	10.2	22.9	21.3	11.4	11.9	9.2	9.0	3.0	3.1
Removed	0.04	0.04	0.70	0.65	11.0	10.4	19.5	18.7	10.0	11.2	8.9	8.4	3.0	3.0
Tilled	0.06	0.06	0.86	0.80	10.9	10.1	27.1	24.2	12.7	13.6	10.6	11.0	3.1	3.4
LSD	0.01	0.01	0.01	0.08	1.1	0.7	5.0	4.8	2.1	1.5	1.1	1.4	0.4	0.5

Sp = Sand dropseed
Er = Lehmann lovegrass

perennials combine to produce the observed net effects. It is impossible to separate out the individual effects involved.

Attributes of Rye and Poppy in Greenhouse Studies

Poppy and rye were statistically different in all attributes studied (Table 14). During 1982 and 1983 poppy produced significantly more biomass and had a higher cover than rye or rye-poppy. However, annual rye plants were taller and more dense.

Poppy had a higher concentration of all nutrients except for Mn in 1983 when it contained significantly less than other types. Poppy contained 3 to 4 times more N, 1.3 - 1.4 times more Fe and about double the concentration of Zn compared to rye in both years (Table 15). The C:N ratios were as follows:

	Flowering		Seed Ripening	
	1982	1983	1982	1983
Rye	46	38	50	45
Poppy	11	13	13	16
Rye-Poppy	43	42	45	50

They compare well with C:N ratios of field crops at flowering stage, but C:N ratio were higher at seed ripening stage for field crop. There is no apparent

Table 14. Biomass, cover, density and height of rye, poppy and rye-poppy grown in the greenhouse at flowering stage in 1982 and 1983.

Litter Type	1982				1983			
	Biomass	Cover	Density	Height	Biomass	Cover	Density	Height
	kg/ha	%	#/pot	cm	kg/ha	%	$\#/m^2$	cm
Rye	5.1	49	11	35	8.9	50	13	14
Poppy	6.4	56	10	21	10.9	56	11	11
Rye-Poppy	5.9	52	11	35	10.2	54	11	13
LSD	1.0	5.1	0.8	10	1.1	4	1.0	1.7

Table 15. Nutrient content of rye, poppy and rye-poppy at flowering and seed ripening stage in greenhouse.

Year & Litter Type	N		P		C		Fe		Mn		Cu		Zn	
	F	S	F	S	F	S	F	S	F	S	F	S	F	S
1982	%						ppm							
Rye	0.83	0.77	0.25	0.23	38.68	38.62	289	266	126	116	22	17	20	18
Poppy	3.40	3.10	0.39	0.36	38.88	38.81	428	396	393	363	26	22	50	46
Rye-Poppy	0.90	0.84	0.25	0.22	39.05	38.51	287	264	258	238	20	15	22	20
LSD	1.68	1.54	0.10	0.10	0.39	0.40	92	86	151	140	7	4	19	18
1983														
Rye	1.03	0.85	0.25	0.23	38.79	38.70	340	310	180	168	21	19	21	19
Poppy	3.08	2.50	0.38	0.35	38.62	38.85	461	441	129	120	54	50	44	41
Rye-Poppy	0.93	0.77	0.24	0.22	38.73	38.69	371	355	145	136	20	17	20	19
LSD	0.77	0.62	0.05	0.05	0.52	0.41	73	70	22	21	13	12	9	8

F = Harvested at flowering stage
S = Harvested at seed ripening stage

reason for this anomaly. Based on C:N ratios at seed ripening stage shown above, net immobilization of N would have been expected with incorporation of rye and rye-poppy residues and net mineralization with poppy residue incorporation.

Based on nutrient concentrations of the annual plants it seems that poppy residue would have returned more nutrients to the soil than that of rye or rye-poppy residue (Table 15). However, differences in nutrient concentrations between species may not be a suitable measure of the proportions of elements returned to the soil in an available form. Other factors including intra-specific seasonal changes in plant tissue, internal redistribution of elements before death, and various environmental factors influence the magnitude and fate of nutrients in the plant residue (Charley 1977).

In this study nutrient concentration at seed ripening stage was assumed to be the best indicator of nutrients returned to the soil via litter. Although nutrient withdrawal in senescing organs has been recognized in agricultural crops for a long time (Moser 1977), it is only more recently that nutrient withdrawal has been noted in range plants as an important adaptive mechanism used by plants to conserve nutrients in short supply around the rooting medium (Charley 1977; Clark

1977). Charley and Cowling (1967) reported that large amounts of N and P are withdrawn from leaves and fruits of *Atriplex vesicaria* before they are shed. Members of the *Chenopods*, *Gramineae* and legumes and in particular *Acacias* are some of the important plants involved in heavy N withdrawal (Charley 1977; Siebert et al. 1968).

Effect of Litter Type on Perennial Grasses

Dropseed and lovegrass grown in the greenhouse were different in most of the factors investigated. Biomass and all nutrients concentrations, except that for C and Mn, were higher in dropseed than in lovegrass (Tables 16 and 17). The C and Mn concentrations were similar in both species.

The effect of litter type on biomass and concentrations of N, P, Fe, Mn, Cu and Zn in perennial grasses were statistically significant at both phenological stages (Table 18). Density and height were not different between species. Table 18 indicates that the effect of poppy and rye-poppy residue on biomass of perennials was similar in 1982. In 1983, at flowering stage, the lowest biomass for dropseed was obtained from plants grown in rye residue; biomass of plants from the other litter types were equal (Table 18). Biomass for lovegrass was similar in plants grown in rye and rye-poppy residue.

Table 18--Continued

Year & Litter Type	Biomass Sp	Biomass Er	N Sp	N Er	P Sp	P Er	C Sp	C Er	Fe Sp	Fe Er	Mn Sp	Mn Er	Cu Sp	Cu Er	Zn Sp	Zn Er
	kg/ha		%						ppm							
1983	Flowering															
Control	2.1	2.7	1.14	0.66	0.14	0.11	40.0	40.4	274	232	50	49	18	16	57	38
Rye	1.7	2.0	1.60	1.16	0.24	0.14	40.0	39.9	308	290	89	69	19	18	79	46
Poppy	2.3	2.7	1.10	0.99	0.24	0.14	40.5	39.5	296	278	82	72	17	16	56	57
Rye-Poppy	2.2	2.2	1.12	0.91	0.16	0.14	39.7	39.6	299	269	73	6	1	1	6	5
LSD	0.4	0.4	0.15	0.14	0.05	0.03	0.3	2.5	21	24	11	6	1	1	6	5
	Seed Ripening															
Control	1.1	1.8	0.65	0.45	0.07	0.06	41.0	41.4	206	177	57	46	12	12	56	42
Rye	0.7	1.2	0.73	0.45	0.24	0.16	39.9	41.4	262	213	63	57	16	13	55	49
Poppy	1.3	1.9	0.65	0.43	0.10	0.08	41.0	41.6	226	211	55	51	13	15	60	38
Rye-Poppy	1.2	1.2	0.71	0.43	0.20	0.13	38.9	41.0	216	208	64	62	17	15	74	42
LSD	0.4	0.3	0.05	0.02	0.05	0.05	0.5	0.4	22	20	6	7	2	3	13	3

Sp = dropseed
Er = lovegrass

Table 18. Biomass and nutrient concentrations of dropseed and lovegrass grown in the greenhouse under various litter types.

Year & Litter Type	Biomass		N		P		C		Fe		Mn		Cu		Zn	
	Sp	Er	Sp	Er	Sp	Er	Sp	Er	Sp	Er	Sp	Er	Sp	Er	Sp	Er
	kg/ha		%						ppm							
1982							Flowering									
Control	4.8	6.5	1.23	0.74	0.13	0.10	39.7	39.7	258	218	53	46	17	15	52	35
Rye	5.1	6.8	1.37	1.09	0.23	0.13	39.8	40.2	294	266	84	63	18	16	74	38
Poppy	5.6	6.6	1.32	0.97	0.15	0.13	39.1	39.6	279	261	77	63	17	15	51	35
Rye-Poppy	5.9	7.1	1.13	0.90	0.15	0.13	39.2	36.2	279	253	69	78	16	15	51	52
LSD	0.6	0.5	0.09	0.11	0.03	0.02	0.8	3.0	20	22	7	9	1	1	5	5
							Seed Ripening									
Control	3.9	5.4	1.18	0.70	0.13	0.10	38.8	39.3	231	195	48	42	15	14	47	32
Rye	4.0	5.7	1.29	1.04	0.22	0.12	39.1	39.3	263	239	77	57	17	15	67	35
Poppy	4.7	5.5	1.25	0.93	0.15	0.12	39.1	38.7	251	234	70	58	15	14	47	33
Rye-Poppy	4.9	6.0	1.08	0.85	0.14	0.12	38.9	39.0	251	225	62	72	14	14	48	49
LSD	0.5	0.5	0.10	0.10	0.03	0.02	6	0.4	17	20	7	7	1.	3	5	4

Table 17. Table of mean squares for biomass, density, height and nutrient concentrations for the pot experiment, 1983.

Source	DF	Biomass	Density	Height	N	P	C	Fe	Mn	Cu	Zn
					Flowering						
TYPE	3	1.5	2.4	179*	0.68*	0.020	0.9	6600*	2954*	14.0*	881*
TMT	2	1.4*	4.3	76	0.53*	0.016*	0.2	28108*	87	35.4*	326*
SPPS	1	1.3	1.7	223*	1.79*	0.074*	0.7	15768*	1554*	38.4*	538*
TMTxTYPE	6	0.8*	2.6	23	0.04*	0.007	0.2	594	72	1.9	7
SPPSxTYPE	3	0.4	0.3	11	0.18*	0.009	1.6	398	480*	0.5	1028*
SPPSxTMT	2	0.2	1.9	22	0.02	0.002	0.1	372	98	2.7	41
SPPSxTMTxTYPE	6	0.2	0.4	16	0.04	0.007	0.7	332	377	2.1	8
					Seed Ripening						
TYPE	3	1.2	4.5	296	0.009	0.078*	1.5	6503	588	54.7	295
TMT	2	1.6*	1.8	322*	0.017*	0.006*	0.7	13297*	2456*	213.6*	211
SPPS	1	3.7*	15.1*	2178*	1.082*	0.031*	7.6*	10900*	657*	19.6	6310*
TMTxTYPE	6	0.3	2.1	186*	0.005	0.001	0.4	943	13	15.8*	375
SPPSxTYPE	3	0.4	3.2	514*	0.007	0.006	1.5*	1456	63	12.3	537
SPPSxTMT	2	0.1	13.8	749	0.005	0.001	0.8	256	10	6.7	25
SPPSxTMTxTYPE	6	0.2	3.1	108	0.004	0.001	0.5	205	12	9.4	504

TMT = Treatment
SPPS = Species
* = Significant at 0.05 level

Table 16. Table of mean squares for biomass, density, height and nutrient concentration for pot experiment, 1982.

Source	DF	Biomass	Density	Height	N	P	C	Fe	Mn	Cu	Zn
					Flowering						
TYPE	3	0.1*	0.8*	20.6	0.01*	0.0002*	14.43	213*	211*	1.5	8*
TMT[1]	2	10.3*	2.4	5.9	0.20*	0.034*	19.44	24595*	435*	31.5*	238*
SPPS[2]	1	36.6*	0.1	310.7	2.06*	0.038*	1.67	14382*	1177	38.1	5112*
TMTx TYPE	6	0.8	2.2	17.0	0.01	0.0004	14.07	524	22	1.5*	2
SPPSxTYPE	3	0.7	1.6	44.5	0.06*	0.007*	14.65	367	775	0.0	1009*
SPPSxTMT	2	0.6	0.8	0.4	0.05*	0.002	17.53	324	22	2.6*	34*
SPPSxTMTxTYPE	6	0.2	2.8	5.4	0.03	0.0001	13.21	208	18	1.9*	6
					Seed Ripening						
TYPE	3	2.2*	2.1	14.3	0.20*	0.011*	0.24	4779*	1984*	11.6*	610*
TMT	2	1.3	0.7	11.5	0.16*	0.029*	0.11	18265*	351*	24.4*	142*
SPPS	1	29.0*	1.4	3253	1.82*	0.035*	0.09	11894*	1010*	26.9*	3859*
TMTxTPYE	6	1.2	0.5	6.1	0.002	0.0003	0.33	468	18	1.0*	8
SPPSxTYPE	3	0.8	1.1	17.2*	0.06*	0.007*	0.73	247	668*	0.2	820*
SPPSxTMT	2	1.2	2.1	1.1	0.05*	0.001	0.01	183	22	3.8*	36*
SPPSxTMTxTYPE	6	0.6	1.1	4.0	0.02	0.0001	0.27	196	22	1.4*	10

[1]treatment = TMT

[2]species = SPPS

*significant at 0.05 level

Nutrients

In 1982, the highest concentration of P, Mn, Zn and Cu in dropseed at flowering stage was found in plants grown in rye residue (Table 18). Litter type had no significant effect on C concentration in dropseed. The P concentration was equal in dropseed plants grown in control, in poppy and in rye-poppy residue plots. Rye, poppy and rye-poppy residue had similar effects on Fe concentration in dropseed (Table 18).

The decline in plant N and Fe between flowering and seed ripening in dropseed was up to 20% but minor for other nutrients (Table 18).

In 1983, the highest concentration of Zn and Cu in dropseed at flowering was found in plants grown in rye residue, however concentration of these nutrients was similar in plants grown in other litter types.

The concentration of Fe in dropseed plants was lowest in control and similar in plants grown in other litter types. The effect of litter type on N, P and Mn concentration in dropseed at flowering was variable, while litter type had equal effect on C concentration (Table 18).

Up to 40% nitrogen was withdrawn between flowering and seed ripening. Withdrawal of other nutrients was slight.

In 1983 the highest N concentration in lovegrass at flowering was associated with plants grown in rye residue. Poppy and rye-poppy residues had a similar effect on N concentration in lovegrass (Table 18).

The P, Fe and Mn concentration in lovegrass at flowering were lowest in plants from control plots, and similar in plants from the other litter types. Litter type had no significant effect on C concentration in lovegrass at flowering stage. However, high Cu concentration was associated with plants grown in rye residue; similar in plants grown in other litter types were similar in Cu content. Effect of litter type on Zn concentration was variable, however, high Zn concentration at flowering was associated with lovegrass plants grown in rye-poppy residue (Table 18).

Effect of Litter Treatment on Perennial Grasses

In 1982, biomass was significantly affected by litter treatment (Table 17). In 1982, at flowering stage, the highest biomass was obtained in tilled plots for both dropseed and lovegrass (Table 19). However, in 1983, litter treatment had no effect on biomass for either species (Table 19).

Table 19. Biomass and nutrient concentration of dropseed and lovegrass grown in greenhouse under various treatments.

Year & Litter Treatment	Biomass Sp[1]	Biomass Er[2]	N Sp	N Er	P Sp	P Er	C Sp	C Er	Fe Sp	Fe Er	Mn Sp	Mn Er	Cu Sp	Cu Er	Zn Sp	Zn Er
	—kg/ha—		%						ppm							
1982								Flowering								
Standing	4.6	6.4	1.29	0.86	0.17	0.122	39.53	40.22	262	237	70.7	61	17	14.9	56	40
Removed	5.3	6.5	1.18	0.83	0.12	0.24	38.87	39.55	257	227	65.6	66	15	14.7	54	38
Tilled	6.1	7.4	1.32	1.07	0.21	0.15	39.22	36.96	315	285	75.5	66	18	16.5	62	42
LSD	0.8	0.6	0.13	0.18	0.06	0.16	0.90	3.06	32	35	12.8	17	2	1.2	11	8
1982								Seed Ripening								
Standing	4.0	5.7	1.22	0.82	0.16	0.12	39.05	39.09	237	217	65	56	15	14	50	37
Removed	4.4	5.3	1.13	0.80	0.12	0.09	38.88	39.10	230	200	60	55	14	14	49	36
Tilled	4.7	5.8	1.24	1.02	0.20	0.14	38.98	39.04	281	254	69	60	17	15	56	39
LSD	0.6	0.5	0.11	0.17	0.05	0.02	0.27	0.36	27	31	12	11	2	1	10	7
1983								Flowering								
Standing	1.8	2.2	1.22	0.84	0.18	0.12	40.17	39.89	279	257	75	65	18	16	60	44
Removed	2.2	2.3	1.09	0.83	0.18	0.12	39.89	39.84	273	236	70	64	16	16	58	41
Tilled	2.3	2.4	1.42	1.11	0.22	0.15	40.04	39.80	335	285	76	63	19	18	67	49
LSD	0.5	0.4	0.3	0.23	0.07	0.04	0.48	0.43	33	39	16	12	2	1	11	9
1983								Seed Ripening								
Standing	0.7	1.3	0.70	0.46	0.13	0.11	40.91	41.48	224	193	54	50	13	14	58	42
Removed	1.2	1.3	0.71	0.43	0.14	0.10	40.35	41.40	204	186	53	47	13	11	61	41
Tilled	1.3	1.7	0.64	0.42	0.18	0.11	40.78	41.12	254	229	72	76	18	17	65	46
LSD	0.5	0.4	0.1	0.04	0.08	0.01	0.60	0.43	31	27	10	11	3	4	15	5

[1] Dropseed

[2] Lovegrass

Nutrients

In 1982, N, P, Fe, Mn, Cu, and Zn concentrations in dropseed were significantly affected by litter treatment at flowering and seed ripening stage (Tables 17 and 18).

In 1982, dropseed plants grown in standing and tilled litter treatments had similar concentrations of N, P, Cu and Zn. High Fe and Mn concentrations were associated with plants grown in tilled treatments and low Fe and Mn concentrations were associated with plants from plots where litter was removed (Table 19). Translocation effects for most nutrients were small.

In 1982, at flowering, high N, Fe, and Cu concentration were associated with lovegrass plants grown in plots with tilled litter. Other litter treatments had a similar effect on P, C, Mn and Zn concentrations in lovegrass (Table 19).

In 1983, litter treatments had an equal effect on P, C and Mn concentrations in dropseed at flowering period (Table 19). High Fe and Zn concentrations in dropseed plants were associated with plants grown in plots where litter was tilled in the soil.

Litter treatment had similar effect on P, C, Mu and Zn concentrations in lovegrass plants at flowering. However, high N and Cu concentrations were associated with plants from tilled litter plots (Table 19).

For lovegrass plants, standing and tilled litter treatments had a similar effect on Fe concentration (Table 19).

The foregoing indicates that plants with high concentrations of various micronutrients were associated with the tilled litter treatment, while plants with low micronutrient concentrations were associated with plants from plots where litter was removed. In most cases this applied to Fe, Mn, Zn and Cu.

Effect of Litter Type on Soil Nutrients in Greenhouse

In 1982 and 1983, species had a significant influence on P, C, Fe, Mn and Cu concentrations in the soil (Table 20). Species influence on Zn was significant only in 1983 (Table 20).

In 1982 the effect of litter type on soil nutrient concentration in pots planted with dropseed was highly variable. The N, P, Fe and Cu content of soils was similar among litter types regardless of the perennial grass species. However, Mn and Cu were lower in control soils than in soils with the three litter types. Effects of litter type on soil C were more complex (Table 20).

Soil from pots planted with lovegrass and with any one of the three litter types contained higher

Table 20. Table of mean squares for greenhouse soils following first and second crop dropseed and lovegrass.

Source	DF	N	P	C	Fe	Mn	Cu	Zn
<u>1982</u>								
Type	3	0.002	94.8*	0.0364*	73.3*	24.9*	2.5*	0.031
TMT	2	0.0017*	80.5	0.0214*	55.1*	36.7*	19.4*	0.675*
SPPS	1	0.00007	157.4	0.0005	91.9*	15.4*	1.0*	0.494*
TMTxType	6	0.00012*	112.2	0.0027	2.8	0.8	0.5	0.054
SPPSxType	3	0.00001	89.7	0.00018	4.5	1.8	0.02	0.008
SPPSxTMTxTYPE	6	0.00004*	106.0	0.0004	2.5*	0.8	0.14*	0.025
<u>1983</u>								
Type	3	0.0002	7.8*	0.020*	58.4*	3.8*	15.1*	0.6*
TMT	2	0.0005*	0.5	0.025*	188.4*	27.0*	12.8*	0.9*
SPPS	1	0.00007	3.8	0.033	3.4*	3.8*	3.0	0.3
TMTxType	6	0.00004*	1.1	0.001	5.9	1.0	0.2	0.03
SPPSxType	3	0.0003	7.2	0.004	3.5	1.2	0.8	0.3
SPPSxTMT	2	0.00006	1.3	0.002	2.2	0.1	1.2	0.1
SPPSxTMTxTYPE	6	0.00006	0.5	0.002	6.1	0.5	0.2	0.1

* = Significant at 0.05 level
TMT = Treatment
SPPS = Species

concentrations of Fe, Mn and Cu than the control. Litter type had no effect on concentration of Zn in pot soils. Soil P and C were highly variable among treatments (Table 21).

In 1983, the effect of litter type on soil nutrient concentration for samples obtained from dropseed grown in pots falls into three groups: 1) where the effects are similar between litter types as exemplified by N; 2) where soil under poppy litter had the highest nutrient concentrations with soils for other three litter types showing similar responses as exemplified by P and C; 3) where soils of the control were lower in nutrient concentration that that of the three litter types as exemplified by Fe, Mn, Cu, and Zn (Table 21).

It is evident that effect of litter type on nutrient concentration of top soil is not straightforward, but rather complex and difficult to describe. However, in many instances soil samples from the control pots were lower in nutrient concentration when compared with any of the litter types. The conclusion based on data obtained in this study is that litter regardless of type, had a positive role in accumulating some nutrients on the soil surface; Fe, Zn, Mn and Cu appear to fall in this category.

Table 21. Soil nutrient concentration by litter type following the first and second crop of dropseed and lovegrass.

Year & Litter Type	N		P		C		Fe		Mn		Cu		Zn	
	Sp	Er	Sp	Er	Sp	Er	Sp	Er	Sp	Er	Sp	Er	Sp	Er
1982	%		ppm		%		ppm							
Control	0.04	0.04	10.8	11.5	0.68	0.69	19.5	14.9	10.0	9.6	5.9	5.7	2.3	2.1
Rye	0.05	0.05	9.9	10.4	0.77	0.78	20.3	18.2	12.8	11.2	6.6	6.4	2.4	2.2
Poppy	0.05	0.05	10.6	11.5	0.74	0.78	20.8	17.7	13.0	11.6	6.6	6.3	2.4	2.3
Rye & Poppy	0.05	0.05	10.5	12.1	0.68	0.68	21.1	18.2	12.3	11.9	6.6	6.5	2.4	2.3
LSD	0.01	0.01	0.7	0.9	0.02	0.03	1.8	0.7	1.2	0.7	0.6	0.5	0.2	0.1
1983														
Control	0.04	0.04	10.1	12.0	0.72	0.7	15.4	13.7	9.4	9.6	6.5	6.3	2.2	2.2
Rye	0.04	0.04	9.8	11.0	0.73	0.72	18.0	18.1	10.5	10.2	7.8	6.9	2.7	2.7
Poppy	0.05	0.04	11.9	11.4	0.82	0.74	18.4	18.3	10.9	10.2	8.1	8.2	2.7	2.7
Rye & Poppy	0.04	0.05	10.5	9.9	0.74	0.67	17.9	17.9	10.7	9.6	8.7	8.2	2.7	2.7
LSD	0.01	0.01	0.9	0.9	0.06	0.06	1.9	2.3	1.0	0.8	0.9	0.8	0.2	0.2

Sp = Dropseed
Er = Lovegrass

Effect of Litter Treatment on Soil Nutrient

Soils contained about the same amount of nutrients irrespective of perennial grass species grown. Litter treatments significantly influenced the concentration of soil N, C, Fe, Mn, Cu and Zn (Table 20).

In 1982, soil nutrient elements from pots where dropseed was grown responded in three ways: 1) N and Zn concentrations were highest in soil with standing and tilled litter; 2) the P, Fe, Mn and Cu concentrations were highest in soil with tilled litter; 3) about similar nutrient concentrations in treatments where litter was removed or left standing included P, Mn, Cu and Zn. Litter treatment had no effect on soil C (Table 22).

In 1983, in pots where dropseed was grown, the effect of treatment on soil Zn, N and P was similar. However, the effects of litter on soil Cu, Mn, Fe and C concentration were highest in pots with tilled litter treatment and similar in pots where litter was left standing or removed. In pots where lovegrass was grown, litter treatments had similar effects on soil P and N. Zn concentration was highest in soil associated with tilled litter. Standing and tilled litter treatments had similar effects on soil Cu, Fe, Mn and C (Table 22).

The above remarks imply that the highest nutrient concentrations were obtained consistently from soil with

Table 22. Soil nutrient concentrations under dropseed and lovegrass by treatment in greenhouse.

	N		P		C		Fe		Mn		Cu		Zn	
	Sp[1]	Er[2]	Sp	Er	Sp	Er	Sp	Er	Sp	Er	Sp	Er	Sp	Er
1982	%		ppm		%		ppm							
Standing	0.05	0.05	9.8	10.8	0.72	0.72	19.0	16.7	11.6	10.7	6.2	5.9	2.4	2.2
Removed	0.04	0.04	10.3	10.6	0.69	0.69	13.0	16.2	10.7	10.5	5.6	5.6	2.2	2.0
Tilled	0.06	0.06	11.2	11.5	0.74	0.76	21.4	18.8	13.8	12.1	7.5	7.1	2.5	2.4
LSD	0.01	0.01	0.8	0.8	0.05	0.05	2.8	1.9	1.9	1.1	1.0	0.8	0.2	0.2
1983														
Standing	0.04	0.04	10.4	11.3	0.73	0.71	16.7	16.9	10.2	10.0	7.2	7.3	2.5	2.3
Removed	0.04	0.04	10.7	11.3	0.72	0.68	15.2	14.1	9.9	8.9	7.5	6.7	2.4	2.3
Tilled	0.05	0.05	10.7	10.7	0.80	0.74	20.4	20.0	11.5	11.0	8.7	8.1	2.7	2.7
LSD	0.01	0.01	0.9	0.9	0.05	0.04	2.7	3.5	1.1	1.1	1.1	1.1	0.3	0.3

Sp[1] = Dropseed

Er[2] = Lovegrass

tilled litter , although in some instances the effects of tilled litter were similar to effects of standing litter. In most cases, removal of litter seemed to reduce nutrient concentration of soil nutrients.

CHAPTER V

SUMMARY AND CONCLUSIONS

Field and greenhouse experiments were conducted to find the effect of annual rye, California poppy and rye-poppy residues on growth and nutrient status of sand dropseed and lehmann lovegrass and their associated impact on the soil.

In 1982 and 1983 annual rye and poppy produced 850 to 2000 kg/ha of organic material each year. Chemical analysis data showed that poppy contained significantly higher concentrations of most nutrients than rye. Poppy contained almost twice as much N, Mn, Zn and Fe as rye. This was true for greenhouse as well as field experiments. Observations in the field and in the greenhouse showed that organic residue from poppy disappeared faster than that for rye. This was particularly evident in plots and pots where plant residue was left standing. Furthermore, it was noted that withdrawal of most nutrients was higher in poppy plants than in rye plants. It was also evident that annuals had higher withdrawal rates compared to perennials. The implication is that poppy had a higher rate of nutrient turnover than rye.

Dropseed contained higher concentrations of most nutrients studied than lovegrass.

High concentrations of P, Zn, Fe and Mn in drop-seed and lovegrass at flowering stage (shown in field and greenhouse studies) was mostly associated with plants grown in rye residue. This was unexpected for two reasons: 1) poppy contained higher concentrations than rye plants for most nutrients studied; and 2) poppy residue appeared to decompose faster than rye residue. The implication here is that poppy would be expected to return more nutrients to the soil at a faster rate than rye. Why the latter did not happen is without explanation.

Chemical data indicated that high concentrations of Cu, Fe, Mn and Zn in perennials at flowering were in most cases associated with plants grown in tilled litter and low concentrations were associated with plants grown in plots where litter was removed. In most cases, both in the greenhouse and in the field, P and C concentrations in perennial plants were not affected by litter treatment. The N concentration was more difficult to categorize in terms of specific response to litter treatment.

The concentration of all soil nutrients increased following the two crops of annuals. Litter appeared important in accumulating Fe, Zn, Mn and Cu on the surface soil. Results indicate that the tilled litter treatment was superior to other treatments insofar as most soil nutrients were concerned.

In terms of management strategies, the results of this short term study indicate that residue of cool season plants may be employed to increase the fertility of surface soil and to increase nutrient concentrations of perennial grasses seeded into the litter of annual plants. Both are desirable attributes which would help to reduce the cost in reclaiming areas infested with cool season annuals. Certainly the method is simple, cheap and ecologically sound. The best results may be achieved with moderate grazing of the annual crop where hoof action would help in incorporating plant parts into the surface soil for more rapid decomposition. Certainly more research work is required in this area to indicate the long term trends.

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