AGRONOMIC EVALUATION OF LEONARDITE ON YIELD AND CHEMICAL COMPOSITION OF CANOLA AND WHEAT

BY

SEAN B. DILK

A Thesis
Submitted to the Faculty of Graduate Studies
in Partial Fulfillment of the Requirements
for the Degree of

MASTER OF SCIENCE

Department of Soil Science
University of Manitoba
Winnipeg, Manitoba

0-612-76751-5

THE UNIVERSITY OF MANITOBA

FACULTY OF GRADUATE STUDIES

*****

COPYRIGHT PERMISSION PAGE

AGRONOMIC EVALUATION OF LEONARDITE ON YIELD AND CHEMICAL COMPOSITION OF CANOLA AND WHEAT

BY

SEAN B. DILK

A Thesis/Practicum submitted to the Faculty of Graduate Studies of The University of Manitoba in partial fulfillment of the requirements of the degree

of

Master of Science

ABSTRACT

Dilk, Sean Brian. M.Sc. The University of Manitoba, October 2002. Agronomic Evaluation of Leonardite on Yield and Chemical Composition of Canola and Wheat. Major Professor; Geza J. Racz.

Studies were conducted on the agronomic potential of leonardite affecting the emergence, chemical composition, and yield of canola and wheat. Fertilizer use efficiency was also evaluated. Field studies assessed the soil application of leonardite as a broadcast pre-plant or post-plant application. Leonardite did not affect the emergence, chemical composition, or yield of wheat or canola. A trend was noted in which the low rates of leonardite tended to increase the emergence and yield; however, this trend was not significant. The efficiency of phosphorus (P) fertilizer was studied with and without humic acid, derived from leonardite. Application of leonardite in a P fertilizer band significantly increased the P concentration of canola tissue in the early stages of development. However, the increase in P concentration did not result in an increase in yield. A growth chamber study was performed to determine whether humic and fulvic acids prepared from leonardite could increase plant absorption of copper (Cu) and zinc (Zn). Treatments were applied as a broadcast, band, or foliar application and were compared to Zn-or Cu-EDTA and an inorganic form of fertilizer. Fulvic and humic acid were ineffective when soil applied; however, Cu- or Zn-fulvic acid was superior to an inorganic source or EDTA as a foliar application. A field study was then conducted on the use of fulvic acids as a foliar carrier for Cu. Foliar application of Cu-fulvic acid was compared to an inorganic and organic source of Cu. Treatments were applied at 0.2, 0.4,

and 0.6 kg ha^{-1} Cu. Cu-fulvic acid improved the Cu concentration of wheat tissue versus Cu-EDTA but was inferior to $CuCl_2$. Final yield and biomass of the $CuCl_2$ treatment was superior to all treatments while the Cu-fulvic acids were similar to Cu-EDTA. A final growth chamber study was conducted on the effectiveness of leonardite in reducing cadmium (Cd) concentration of durum wheat tissue. Nitrogen (N) fertilizer was applied as urea and the leonardite was applied to the surface of the urea granule. Treatments were applied as a broadcast or band application. The Cd tissue concentrations were elevated with application of N fertilizer as a broadcast and band treatment. Broadcast application of leonardite significantly increased the Cd concentration of durum wheat tissue. However, the broadcast applications of leonardite in the previously mentioned studies did not increase the tissue concentrations of Cd. This suggests that leonardite will elevate Cd concentration only when applied to the surface of the N fertilizer.

ACKNOWLEDGEMENTS

I would like to thank Dr. Geza Racz for the opportunity to pursue my Master of Science Degree in Soil Science. Your many hours of support and guidance have made this thesis possible.

I would also like to thank Dr. Don Flaten, Dr. Burton, and Dr. Anita Brule-Babel for their support and guidance throughout the completion of the thesis.

Many thanks to Tim Stem for the help in establishing and maintaining the plots, as well as Gregg Morden and Michael Nightingale for their technical assistance in the laboratory. I would also like to thank the numerous summer students who spent many hours in the field helping me collect data.

The quality of education in the Department of Soil Science is great, as well as the friendship. I have made many friends throughout the time spent in the Department of Soil Science. Your support throughout the years was very much appreciated and I look forward to many more years of friendship as we move on in life.

I would like to acknowledge the financial support of Luscar Ltd., which has made this research possible.

To my parents Brian and Marilyn Dilk, thank you for your faith and confidence. Your support throughout the years was fundamental and a key factor in the completion of my Master of Science Degree.

Finally, to Roselle, my wife and partner in life. Your patience, support, and confidence in me have made this thesis attainable. Your constant words of

encouragement and enthusiasm were essential to the completion of this thesis. As we move on in our journey of life, I know with you by my side that any obstacle can be overcome.

FOREWARD

This thesis was written in manuscript style outlined in the Department of Soil Science *Guide to Thesis Preparation for Graduate Students.* Publication of results as notes and/or full papers is planned.

LIST OF TABLES

TABLE OF CONTENTS

1. INTRODUCTION

Leonardite is a naturally occurring material enriched in humic and other organic acids and is defined as oxidized lignite produced through the weathering of subbituminous coals and carbonaceous shales (Hoffman et al. 1993). In Canada, leonardite deposits have been discovered in Alberta and Saskatchewan.

Leonardite has been shown to have variable effects on plant growth. Preliminary research trials by Akinremi (1999) showed that application of leonardite increased root growth of canola. In other trials, humic acid, derived from leonardite, improved the fresh and dry weight of tomato roots (Adani et al.1998). The increase in root growth due to the application of leonardite suggests that the leonardite material may contain compounds that elicit hormone-like responses. O'Donnell (1972) discovered that leonardite contained polyphenolic compounds, some of which behaved similarly to auxin.

The growth and dry matter production of crops have been enhanced with the addition of leonardite. Corn dry matter increased with the application of leonardite (Duplessis and MacKenzie 1983, Tan and Nopamornbodi 1979). Zaifnejad et al. (1996) showed that lignite products enhanced cereal crop growth. Duplessis and MacKenzie (1983) found that corn grain yield was significantly increased with application of leonardite while charcoal and coal products improved the yield of legumes (Iswaran et al. 1979). In other studies, the application of lignite was found to be ineffective in increasing the yield of corn and bean (Adriano et al. 1978).

Application of leonardite also affects the chemical composition of crop species. Nitrogen and P concentration of tomato and corn crops were elevated in the presence of leonardite (Adani et al. 1998, Lee and Bartlett 1976). The application of leonardite on a loamy sand increased the P concentration of corn plants (Duplessis and Mackenzie 1983). Micronutrient concentration of crops has also been enhanced with the application of leonardite. Iron (Fe) concentration in tomato was elevated with leonardite application (Adani et al. 1998) and lignite improved the concentration of Fe in mustard (DeKock 1960). Application of organic amendments, also containing humic acids, enhanced the Cu, Zn, Mn, and Fe concentrations of wheat seedlings (Moris 1985).

Generally, the studies conducted to date showed highly variable effects of leonardite. In some studies, leonardite increased yields and/or altered the chemical composition of crops. In other studies, leonardite and/or its products had virtually no effect on yield and/or chemical composition. Our study was conducted to evaluate the agronomic potential of leonardite to improve crop production in Manitoba. Yield, chemical composition of grain, phytoavailability of micronutrients, and efficiency of P fertilizer was assessed.

The studies reported in this manuscript included several individual studies to examine the agronomic potential of leonardite and/or products made from leonardite. The objectives of this study were to:

1) the effect of leonardite on the yield and chemical composition of canola and wheat.
2) the effect of leonardite on the emergence of canola on poorly structured soils.
3) whether or not addition of humic acid to a P fertilizer band can improve P fertilizer use efficiency.

4) whether or not humic or fulvic acid can improve chelation and plant availability of Cu and Zn.

5) whether or not application of leonardite can reduce the concentration and accumulation of Cd in durum wheat.

Literature pertaining to the five areas listed above was reviewed and discussed.

2. LITERATURE REVIEW

2.1 HUMIC SUBSTANCES AND CROP GROWTH

Definition of Leonardite

Leonardite is defined as a naturally occurring oxidized form of lignite coal rich in humic and other organic acids (Hoffman et al 1993). Leonardite is formed through weathering of subbituminous coals and carbonaceous shales (Hoffman et al. 1993). Although leonardite is a heterogeneous mixture of various compounds, it is primarily the humic substances in leonardite that are of interest.

Humic Substances

Humic substances are important components of soil that have been synthesized, do not have a defined composition (Sanchez-Andreu et al. 1994), and are believed to be highly degradation-resistant materials formed during decomposition of organic matter (Ashley 1996). Humic substances are described as amorphous, dark colored, hydrophilic, acidic, chemically complex organic materials of varying degrees of aromaticity that range in molecular weight from a few hundred to several thousand daltons (Ashley 1996). Humic substances may exist in either a dissolved or suspended form. When present as an organic solid phase, humic substances provide a surface for metal adsorption. The adsorption of a soluble free metal ion by an available humic substance solid phase can be viewed as a reversible equilibrium reaction that is dependent on the bulk concentration of both metal and humic substance.

Humic substances can be separated into three fractions: humic acids, fulvic acids, and humin. Humic acids are defined as the component of organic matter that is soluble in alkaline solutions and is subsequently precipitated through the process of acidification (Duval et al. 1998). Fulvic acids is the fraction of humic substances that is water soluble at all pH values (Sanchez-Andreu et al. 1994), while humin is the fraction of humic substances that is not soluble at any pH (Duval et al. 1998). Although the structures of humic and fulvic acids have not been entirely defined, there are some differences in properties that have been identified. Humic acids have a higher molecular weight and greater C and N concentration than fulvic acids, while fulvic acids have higher concentrations of O, are more acidic, and have greater cation exchange capacity (Duval et al. 1998).

Humic Substances and Germination

Humic substances are capable of increasing the rate of germination (Petrovic et al. 1982) as well as percent germination (Vaughan and Malcolm 1985, Petrovic et al.1982). Vaughan and Malcolm (1985) postulated that humic substances influence biochemical and physiological processes within the plant and soil, increasing rate and percent germination. For example, Smidova (1962) found that humic acids increase imbibition by seeds, which results in greater enzyme synthesis. Addition of potassium humates and fulvic acids to tobacco seeds stimulated respiration (Csicsor et al. 1994), which enhanced germination.

However, some other studies have shown that humic substances did not affect germination. Petrovic et al. (1982) discovered that high concentrations of humic extracts inhibited germination. Piccolo et al. (1992) found that humic acid derived from oxidized coal had no effect on germination of lettuce (*Lactuga sativa*) or tomato (*Lycopersicum esculentum*). Vaughan and Malcolm (1985) concluded that fulvic acid, at a concentration of 100 mg L^{-1} , had no effect on germination of wheat (*Triticum aestivum*) or barley (*Hordeum vulgare*).

Humic substances originate from a number of sources and vary in properties of pH, molecular weight, cation exchange capacity, and chemical composition. All of the previously mentioned properties influence germination. Seed species also vary in optimal conditions for germination such as temperature, pH, moisture, and nutrients. Therefore, the reason for variation in germination due to application of humic substances is believed to be due to the large variation of humic substance characteristics and the conditions required for seed germination.

Humic Substances and Emergence

Nuttal (1970) studied the effect of organic amendments on the emergence of rapeseed (*Brassica napus*) and found that organic amendments improved plant emergence by as much as threefold. The enhanced emergence was shown to be due to improved soil physical properties indicated by a reduced modulus of rupture.

Humic Substances and Root Growth

Several studies have shown that humic substances influence root growth. Humic acids (derived from leonardite) increased root growth of tomato (Adani et al. 1998), corn (*Zea mays*) (Tan and Nopamornbodi 1979), bean (Schnitzer and Poapst 1967), and wheat (*Triticum aestivum*) (Malik and Azam 1985). Tan and Tantiwiramanond (1983) found that there was a positive correlation between dry weight of roots and application of humic acid for soybean (*Glycine max*), peanut (*Arachis hypogaea*), and clover (*Trifolium vesiculosum*).

Humic materials affect the morphology of roots. Application of humic acid caused roots to be highly branched with proliferant root hair development (Lee and Bartlett 1976). Linehan (1976) found that the main axis extension and the development of laterals, as well as the fresh weight had all been elevated with application of fulvic acid. The increased root growth resulted in greater absorption of water and nutrients resulting in increased root area and biomass (Lee and Bartlett 1976).

Application of humic substances to above-ground plant tissue has been shown to increase root growth. Xudan (1986) found that foliar application of fulvic acid enhanced root activity in wheat, while Sladky (1959) discovered that foliar application of fulvic acid significantly increased the fresh and dry weight of roots in Begonias (*Begonia semperflorens*).

Researchers have suggested reasons for increased root growth in the presence of humic substances. Some researchers suggest that humic substances increase root growth via the polyphenolic compounds, some of which provide hormonal activity similar to auxin (O'Donnell 1972), a hormone known to increase the growth of plants. Other researchers have reported that humic substances increase the absorption capacity of roots, increasing the moisture and nutrient uptake by the roots resulting in greater growth (Vaughan and MacDonald 1976). Researchers have also suggested that humic substances may increase the permeability of the cell membrane of the root, resulting in greater absorption of water and nutrients (Cheng 1977).

Application of humic acid has caused cells to extend their growth for a greater length of time delaying the maturity of the cells and improving growth of the root (Vaughan 1974). In the same study, Vaughan noted that the fresh weight of the roots had increased despite a reduction in root cell numbers. In a separate study, Linehan (1977) concluded that cell expansion increased to an extent that more than compensated for the depressed cell numbers. Linehan (1977) also suggested that the growth of roots was due to the direct effect of polycarboxylic acid (PCA), a component of fulvic acid.

Humic Substances and Shoot Growth

Humic substances have positive effects on plant shoot growth (Moris 1985, Elgala et al. 1978). Corn dry matter was significantly increased with addition of leonardite (Duplessis and Mackenzie 1983, Tan and Nopamornbodi 1979). Humic acid, derived from leonardite, significantly increased the fresh and dry weight yields of tomato by 8% and 9%, respectively (Adani et al. 1998). Tan and Binger (1986) discovered that dry matter production of corn plants increased by 32.5 to 42.5% with addition of humic acids. Wheat growth has been reported to increase in the presence of organic amendments (Ishac 1986). Shoot dry matter of wheat increased with addition of coal combustion by-products (Zaifnejad et al. 1996) while humic acid increased seedling growth of wheat, by 30% and 33%, on a fresh and dry weight basis, respectively (Malik and Azam 1985).

The addition of lignite has occasionally hindered or not influenced plant growth. Schisler and Linderman (1989) discovered that application of high rates of leonardite reduced the growth of coniferous trees. Wallace and Romney (1980) found that application of coal reduced vegetative yields of bush bean plants (*Phaseolus vulgaris*) when applied to a noncalcareous soil. When the coal was applied to a calcareous soil, no effect on bush bean growth was observed. Coal and sulphomethylated coal (coal that has been processed for greater N content and solubility) had no effect on growth of barley (Cairns and Moschopedis 1970) while sulphonated coal was found to be toxic to barley plants. The toxic effect was believed to be due to a sulphur (S) compound produced during the sulphonation process that may have been toxic to crops (Cairns and Moschopedis 1970). Lee and Bartlett (1976) discovered that application of humic acid to a soil high in organic matter gave a slightly negative response in corn growth. Piccolo et al. (1992) found that dry weight of lettuce (*Lactuga sativa*) did not change with the application of humic acids.

Humic Substances and Yield

Humic substances and organic amendments increased yields of field crops in several studies. Duplessis and Mackenzie (1983) found that addition of leonardite to clay and loamy sand soils increased corn yields. Application of charcoal, coal, and peat improved the grain yields of legumes such as moong (*Vigna radiata*), soybean (*Glycine max*), and pea (*Pisum sativum*) (Iswaran et al. 1979). The increase in grain yield was believed to be due to phenolic compounds that were toxic to soil bacteria and protozoa that are antagonistic towards *Rhizobium* species. Xudan (1986) discovered that foliar application of fulvic acid increased the yields of wheat. This was believed to be due to the reduction in water stress on the wheat plants.

In other studies, organic amendments such as described above, have been ineffective in enhancing crop yields. Coal by-product application was ineffective in