APPLICATION OF SUPPLEMENTAL NITROGEN ON BROCCOLI

(*Brassica oleracea* L. ssp. *italica* Plenck)

GROWN ON ST BLAISE SOILS.

by

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ABSTRACT

M.Sc. BERNARD VIGIER RENEWABLE RESOURCES

APPLICATION OF SUPPLEMENTAL N ON BROCCOLI (*Brassica oleracea* L. ssp. *italica* Plenck) GROWN ON ST-BLAISE SOILS.

Experiments on the methods of application of urea were tested in combination with Mo for two years at two soil pH levels. Feed-grade urea was applied in bands at a rate of 60 kg N/ha and as foliar sprays at a rate of 13.5 kg N/ha. Mo was applied, as a foliar spray, at 0.2 kg Mo/ha.

Mo treatments delayed maturity significantly when compared to control plots in all trials, while they increased plant NO_3-N levels significantly during the 1981 trial at a soil pH of 6.5. Banded urea treatments increased broccoli yields significantly during 1982 trials and increased plant NO_3-N and total N in the three trials at soil pH values of 6.5 and 7.3.

The estimated fertilizer N recovery by broccoli plants was increased with foliar urea compared to banded urea applications.

RESUME

M.Sc. BERNARD VIGIER RENEWABLE RESOURCES

FERTILISATION AZOTEE SUPPLEMENTAIRE APPLIQUEE AU BROCOLI (<u>Brassica</u> <u>oleracea</u> L. ssp. <u>italica</u> Plenck) CULTIVE SUR SOLS ST-BLAISE.

Des essais de fertilisation combinés d'urée et de Mo ont été effectués durant deux années à deux niveaux de pH de sol. L'urée de type alimentaire fut appliquée à raison de 60 kg N/ha en bandes et 13,5 kg N/ha en solution foliaire. Une solution de Mo fut appliquée sur le feuillage à raison de 0,2 kg Mo/ha.

Les applications de Mo ont diminué significativement la maturité hâtive dans tous les essais, tandis qu'elles ont augmenté la teneur en NO_3-N du feuillage sur un sol à pH 6.5 en 1981. L'urée en bandes a augmenté de manière significative le rendement en brocoli durant les essais de 1982 et a accru le niveau des NO_3-N et du N total du feuillage dans trois essais sur des sols à pH 6.5 et 7.3.

La récupération estimée de l'engrais N par le brocoli a été supérieure avec l'application d'urée foliaire lorsque comparée à celle d'urée en bandes.

Suggested short title:

UREA APPLICATIONS AND BROCCOLI YIELDS

B. VIGIER

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FOREWORD

This thesis is presented as two papers, noted as Chapters 3 and 4 respectively, to be submitted for publication. It contains an overall introduction and ends with a combined summary.

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CHAPTER 1

INTRODUCTION

Intensive fertilization programs which are required by most vegetable crops have promoted the development of application techniques which minimize labour and integrate these operations with other cultural practices. Foliar applications of fertilizers have been found to be practical with vegetables, such as *Brassica* crops, which require a large amount of N fertilizer and a variety of micro-nutrients.

This method, which is less energy consuming, is already in use by some farmers on broccoli (*Brassica oleracea* L. ssp. *italica* Plenck). It is preferred to the more conventional technique of side-dressed or banded applications along the row with supplemental N.

The benefits of added N, which will be discussed in the following chapter, can be significant but high levels of N applications can result in problems specific to *Brassicae*.

The following experiment was designed to study the effect of urea, used as a N fertilizer source, applied in bands along the row and in solution on the foliage in combination with foliar applications of Mo, on broccoli yields. The performance of the crop, soil NO_3-N, and total N, K, Mg, Ca and B levels in the plant were monitored in an attempt to relate these nutrient levels to added N and Mo. The Mo treatment was applied mainly to determine if it had an effect on the recovery of the N fertilizer by the plant. Trials were undertaken at different soil pH values with similar soil fertility levels and texture.

A general literature review will follow on N fertilization and *Brassicae* with more emphasis on broccoli plants. The next two consecutive chapters (3 and 4) will be presented discussing first, yield results and N recovery by plants and second, the effects of the treatments on the plant nutrient status. The final chapter will be a summary of the results obtained.

CHAPTER 2

GENERAL LITERATURE REVIEW

a) Forms of nitrogen absorbed by plants

Plants take up N either in the nitrate or ammonium forms of N. Steward et. al. (1959) mentioned that the contrast between the two N sources (NO_3-N or NH_4-N) was self-evident, with NO_3-N leading to low soluble N in the plant or little more than enough N for the protein synthesis and glutamine formation, while the use of NH_4-N salts led to an accumulation of soluble N beyond the needs of synthesis. According to Bollard (1959), ammonium nutrition can limit growth by concentrating the energy production of the plant into making carbon skeletons required for the storage of NH_4-N, thus diverting energy away from growth. Therefore, even if both forms are required, NO_3-N is the primary form of inorganic N available for nutrition.

Okalebo and Mackenzie (1978) reported that plant roots were shown to have little tolerance to NH_3-N, especially in a situation where nitrification was reduced. Bollard (1959) reported that plant response to N-forms can vary according to the crop concerned, but generally, NO_3-N gives the most consistent results in experiments done on sterile soils.

According to Barker and Hills (1980), the horticulture industry depends increasingly on ammoniacal fertilizers since soil NO_3-N leaching and denitrification losses are quite high with NO_3-N sources. However, Gorin (1962) stated that the rapid conversion of NH_4-N into NO_3-N limits the effectiveness of applying ammoniacal N as a means of increasing N fertilizer utilization by plants. Geraldson (1967) reported that, in most soils, about 80 to 90% of the soluble N is present as NO_3-N and 10 to 20% as NH_4-N. Plant abnormalities could be induced by NH_4^+ when in large proportions in the soil solution, because this cation can become competitive to the uptake of other cations.

In an experiment conducted by Pimpini (1973) with ammonium nitrate (NH_4NO_3) and urea ($CO(NH_2)_2$) fertilizers, both applied to the soil at a rate of 300 kg N/ha on cauliflower (Brassica oleracea var. botrytis L.) plants, the NO_3-N level in leaves was 11% higher with urea, showing a higher utilization of urea by this Brassica crop.

High rates of added N can also result in NO_3-N accumulation in the plant, especially in Brassicae which are considered to be NO_3 accumulators and may reach toxic levels with regard to human consumption (Maynard, 1976). However, in the case of broccoli and Brussels sprouts (Brassica oleracea var gemmifera L.), Munro et al. (1978) found that plant N levels declined as plant maturity increased, therefore reducing the risk of toxicity.

b) Methods of N applications

Controversy still exists between foliar and soil banded applications of N, as to which method is to be preferred. The first experiments on these methods were made on fruit trees, where benefits of foliar applications were related to the deep rooting depth of trees that could delay the absorption of fertilizers applied to the soil surface. Experiments carried out on apple (Malus sylvestris Mill.) trees have shown equal benefits in yields from either foliar or banded applications of urea (Fisher, 1952; Leece, 1979; Thorne, 1953). However, leaf sprays of urea caused a more rapid, albeit more temporary, N response than soil applications. Experiments conducted by Nelson (1956) showed that urea sprays on corn (Zea mays L.) did not produce superior yield benefits compared to the same amount of N applied to the soil as side-dressing.

Magnifico et al. (1979) reported that broccoli plants removed 559 kg N/ha and 723 kg K/ha; whereas, P uptake was in the range of only 23 kg/ha. The same authors indicated that only 10% of N fertilizer was actually recovered in the harvested broccoli spears when 135 kg N/ha was applied in bands, suggesting that a large amount of N was applied in relation to a small recovery by the plants. Cutcliffe (1971) reported a 5% increase of marketable broccoli spears as fertilizer N applied in bands was increased from 90 to 180 kg N/ha.

Other experiments on cauliflower by Rajput and Singh (1975) indicated a better response in plant height and number of leaves to split basal (in bands) applications of urea compared to split N foliar applications. Smith and Chalk (1980) compared fertilizer band applications of aqueous ammonia, ammonium sulphate and ^{15}N labelled urea and noticed that urea and ammonia produced an alkaline environment in the soil, while ammonium sulphate produced an acid one, affecting the Nitrobacter activity in nitrate formation through the biological oxidation of nitrate.

To conclude this section, benefits from either method are debatable because higher plants can take up urea as well as the products of its hydrolysis by both the root systems and the aerial part. Panak et al. (1981) observed that not only the translocation and the assimilation of N from urea was possible but some carbon was absorbed as well.

c) Efficiency of nutrients applied in sprays

According to Engelstad and Russel (1975), application of micro-nutrients by foliar sprays is an accepted practice, since metals applied this way are not fixed in the soil and are more readily available to the plants. This technique is a common practice on fruit trees which have deep roots, because the nutrients applied as foliar sprays are more readily absorbed by the plant as compared to nutrients which are applied to the soil. However, foliar applications of macro-nutrients have not generally been successful because of the difficulty in getting significant quantities of N, P or K into the plant foliage without causing serious leaf damage. Thorne (1953) noticed that the response to foliar applications of N, P and K was similar only to N applications on apple trees suggesting that N is the macro-nutrient mostly absorbed in sprays.

Mengel and Kirkby (1978) reported that urea is the most common form of N applied which is readily taken up and metabolized in the leaf tissue. Hinsvark et al. (1953) and Islam and Rashid (1973) observed a number of horticultural crops which did respond favorably to foliar applications of urea and noted that plants such as cucumbers which showed the least tolerance to urea had the greatest urease activity response. The greater effectiveness of foliar-applied urea as compared to the other inorganic ionic forms, was believed to be a result of its non-polar organic properties.

d) Mechanisms affecting the absorption of N

Different aspects of nitrogen absorption have been extensively reviewed concerning soil water content, soil cation exchange capacity, temperature, soil pH, urease activity and nitrification rate.

Nutrient uptake by leaf cell is the same as that of nutrients absorbed by plant root cell, the main step being the transport through the biological membrane; i.e., the plasmalemma. Mengel and Kirkby (1978) mentioned that the uptake of nutrients in ionic forms from a solution was limited to the outer epidermal cells of the leaves which are covered by the cuticle, which consists of wax films alternating with cutin lamellas. The rate of uptake is controlled by the diffusion of plant nutrients from the water film on the leaf surface through the cuticle and cell wall to the plasmalemma.

The efficiency of the nutrient uptake by leaf tissue is directly related to the amount of time the nutrient solution will remain as a fine film covering the leaf surface. Therefore, spraying should be done on cool, cloudy days or in the evening to reduce the evaporation and the crystallization of minerals on the leaves (Volk and McAuliffe, 1954).

Bollard (1959) suggested that the urea-N in the leaves may be broken down on the surface of the plant by the urease-enzymatic activity producing carbon-dioxide and ammonium ions which are converted into nitrate. In soil application of urea, temperature is an important factor for improving the rate of hydrolysis. Terman (1979) reported an increase in the rate of hydrolysis from 50 to 85% with temperature ranging from 10 to 20°C on a silt-loam after two weeks.

On the foliage, the rapid hydrolysis induced by high urease activity will cause an accumulation of hydrolytic products which could increase foliage injury (Hinsvark _et al._, 1953). In this experiment the most rapid rate of hydrolysis occurred when urea was applied to cucumber (_Cucumis sativus_ L.) leaves, which had the greatest sensitivity to toxicity and had the greatest urease activity.

Other work done by Volk and McAuliffe (1954), on the rate of foliar absorption of urea by tobacco (_Nicotiana tobacum_ L.) plants, has shown that the 'cutinized layer' of the leaves acted as a physical barrier and may be one of the major factors limiting absorption. Therefore, it is possible that thickly cutinized leaves of _Brassica_ crops would be less permissive to nutrient absorption. Another aspect investigated, by these authors, was the time of foliar application which gave an uptake 3 to 10 times larger when applications were done at night compared to during the day; further, the absorption in the morning was three times greater than in the afternoon. Therefore, the time of application is also very important.

e) _Urea toxicity_

Urea toxicity could occur if ammonia or nitrite toxic levels are reached, during the ammonification process, which is a transient state. However, urea grading could be a source of toxicity by itself because it is related to biuret content. This toxic compound is formed through the process involving the conversion of urea into pellets by spraying a concentrated solution at high temperature. Biuret, when present in foliage sprays has some toxic effects on some plants; however, soil applications of a urea-biuret mixture (10% biuret) at a rate of 100 kg N/ha were not found harmful to corn, cotton (_Gossypium hirsutum_ L.), tomato (_Lycopersicon_ esculentum Mill.) and oats (Avena sativa L.) (Jacob, 1959). On the other hand, foliage burning could occur if there is more than 1% biuret if urea is applied on the foliage (Tisdale and Nelson, 1975).

The type of foliage sprays seems to affect toxicity as well. Chesnin and Shafer (1953) found a higher tolerance of corn, wheat (Triticum vulgare, Vill.) and alfalfa (Medicago sativa L.) when urea solutions were sprayed with fine droplets and more toxicity when droplet size was relatively larger.

f) Effect of Mo on N absorption

It is well known that molybdenum (Mo) deficiency is responsible for the whiptail disorder of broccoli and cauliflower (Stout and Johnson, 1956). Field responses to Mo by Brassicae have been reported from widely separated geographical regions.

Treatments of horticultural and field crops with Mo must be moderate because there is a link between high levels of Mo in feeds and molybdenosis in livestock. However, Mo has many functions in the plant. Spencer and Wood (1954) identified at least three metabolic roles of this element. It was found to be required for the nitrogen-fixation reactions of both free-living and symbiotic nitrogen-fixing bacteria and the composition of the nitrate-reductase systems of non-leguminous plants. The third metabolic role suggested by the authors is that molybdate in physiological concentrations, inhibits the acid phosphatase of higher plants.

The second mentioned function of Mo in specific enzymes is corroborated by Haan and Zwerman (1976) who emphasized the evidence that Mo had an effect on N fixation, not only on legume crops through the nitrogenase contained in the root-nodule bacteria but on non-legume crops through the nitrate-reductase of Azotobacter micro-organisms. Anderson (1956) identified Mo as being an essential component of the enzyme nitrate-reductase, which is obtained from Neurospora and Aspergillus. Gupta and Lipsett (1981) reported that nitrate reductase and nitrogenase require Mo for the reduction of NO_3-N and in the fixation of N_2, respectively. Evans (1956) and Steward et al. (1959) reported that there is considerable evidence that more Mo is required for growth with NO_3-N than when NH_4^+-N is used. It is interesting to note that molybdate (MoO_4^{2-}), which is a common form of Mo, is readily absorbed by the leaves and can be translocated in plants whose requirements are approximately in the order of 0.1 to 1.0 μg/g of dry-matter (Haan and Zwerman, 1976; Mengel and Kirkby, 1978).

Fido et al. (1977) observed that, for many Brassicae grown either with NO_3-N or with NH_4-N (urea form), under non-sterile conditions, younger leaves started to develop whiptail disorder characteristics such as curling inwards or cupping of the leaf margin. Therefore, the presence of NO_3-N can increase Mo deficiency and the incidence of whiptail or a chloroplast breakdown encountered in cauliflower and broccoli.

Alexander and Stark (1959) reported similar results where high NO_3-N level in cauliflower gave a Mo deficient appearance to the plant. These observations were corroborated by Spencer and Wood (1954) who noticed that the addition of Mo in a sodium-molybdate form resulted in both a rapid decrease in the level of NO_3^--N and an increase in the protein content of tomato plants. At the same time, the nitrite (NO_2-N) level increased rapidly in plants treated with Mo. In this case, it is possible that Mo application had enhanced the denitrification process by increasing the nitrate- reductase activity discussed above.

g) Physiological disorders and N

Plants of the cruciferous family or Brassica crops are very susceptible to disorders, such as, hollow stem and whiptail observed in broccoli and cauliflower, and brown-heart in cabbage (*Brassica oleracea* var. *capitata* L.), turnips (*Brassica rapa* L.) and rutabagas (*Brassica napo brassica* Mill.). Such disorders have been related to nutrient deficiencies. Brown-heart has been associated with a B deficiency and whiptail with Mo, as observed above. Hollow-stem in broccoli has been associated with factors, such as, spacing and N fertilization increment (Cutcliffe, 1972; Gupta and Cutcliffe, 1972).

Corrective amounts of these nutrients are usually sufficient to correct these problems. However, N fertilization can affect the availability of these micro-nutrients.

In Prince Edward Island, Cutcliffe and Gupta (1980) reported experiments on cauliflower and Brussels sprouts where applied N affected the B concentration in the plant dry-matter. Increasing rates of ammonium nitrate fertilizer, from 0 to 336 kg/ha resulted in B increases from 22 to 40 ug/g of dry-matter at soil pH ranging from 5.3 to 5.9. This benefit of N on B availability has been observed by Chamberland (1981) on turnips where N applications reduced the brown-heart disease symptoms. These preliminary results show a reduction in B deficiency when N and P are supplied to the soil in a 1:2 ratio; i.e., 50 kg P/ha without any B application. However, in soils which have a high B content, it was found that as the rate of applied N was increased, the symptoms of B toxicity observed on plants, such as, citrus species, wheat (*Triticum aestivum* L.) and barley (*Hordeum distichon* L.) leaves decreased (Chapman and Vanselow, 1955; Gupta *et al*. 1973). Therefore, it appears that a balance must exist in the intake of B and N by plants.

Mo deficiency symptoms increased when there was an excess of N fertilizer applied on cauliflower (Wilson and Waring, 1948; Alexander and Stark, 1959).

This outlook on the fertilization of *Brassica* crops was necessary for a better understanding of the problems involved and to give a proper orientation to the following work.

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CHAPTER 3

EFFECTS OF BANDED VERSUS FOLIAR APPLICATIONS OF UREA IN COMBINATION WITH MOLYBDENUM ON YIELD AND N RECOVERY BY BROCCOLI

(*Brassica oleracea* L. ssp. *italica* Plenck)

INTRODUCTION
AND
LITERATURE REVIEW

Nitrogen requirement of Brassica crops is high compared to many other vegetable crops. Therefore, methods of application which can reduce input without decreasing yield can be beneficial. Because of its great solubility and rapid absorption in the leaf, urea fertilizer has the advantage of being applicable either to the soil or to the foliage.

The use of foliar or banded applications of urea is still controversial for N supplemental fertilization of Brassica crops. Fisher (1952), Leece (1979) and Thorne (1953) have shown equal benefits from either foliar or soil banded urea on fruit trees. On Brassicae, Rajput and Singh (1975) indicated an increase in plant height and number of leaves on cauliflower with soil-applied urea, compared to solutions applied on the foliage.

Smith and Chalk (1980) observed that a temporary alkaline environment in the soil was produced with banded urea and one could conclude that Cu, Zn, Mn and B availability would be reduced, whereas Mo would be increased. Hinsvark et al. (1953) reported other [illegible] benefits of foliar applications of urea on horticultural crops. Islam and Rashid (1973) noticed that plants which had the greatest urease activity had the least tolerance to urea. Bollard (1959) explained the urea utilization by leaves by saying that urea was broken down on the surface of the leaves producing carbon-dioxide through the urease activity. N was then transformed rapidly into NH_4-N and NO_3-N and absorbed by leaves. Therefore an important limiting factor in urea absorption may be the urease activity in the leaves. Bollard (1959) further stated that yield responses to the NO_3-N form gave the most consistent results; whereas, urea-N effects were difficult to estimate because its transformation into NH_4-N was very rapid.

An experiment by Pimpini (1973) on cauliflower demonstrated that 300 kg N/ha when broadcast on the soil, increased NO_3-N in plant leaves by 11% with urea compared with ammonium-nitrate, suggesting a greater utilization of the urea fertilizer. However, Okalebo and Mackenzie (1978) reported that release of free ammonia (NH_3) through the urea hydrolysis, may cause some injury to the roots in some cool soil conditions. According to Bollard (1959) ammonium fertilizers lead to an accumulation of soluble N in the plant beyond the needs of synthesis and limit growth by concentrating the energy production of the plant into making carbon-skeletons required for storage of NH_4-N and diverting this energy away from plant growth. Volk and McAuliffe (1954) reported that injuries caused by foliar applications of urea should be minimal with broccoli plants because the leaves have a cutinized layer which acts as a barrier against N absorption.

Wilson and Waring (1948) observed in field experiments that N fertilizers had a tendency to induce a greater amount of whiptail, caused by a Mo deficiency. They believed that Mo behaved as a catalyst in the reduction processes in cauliflower plants that reduced NO_3-N to NH_4-N and amino-acids. Hewitt and Gundry (1970) supported these views and suggested that Mo was not needed by plants when they were grown with NH_4-N in the absence of NO_3-N. Other work reported by Steward et al. (1959) described that Mo requirement was selective according to the N source used, because more Mo was required for NO_3-N than for NH_4-N fertilizer source. Fido et al. (1977) found that Mo deficiency was more likely to occur if N fertilizers were added.

The positive interaction of N and Mo was partially explained by Anderson (1956) who mentioned that in non-legumes, Mo could have an effect on N fixation through its activity on Azotobacter micro-organisms and the formation of nitrate-reductase in the soil. Candela et al. (1957) reported that high NO_3-N level in cauliflowers was a manifestation of Mo deficiency. As a result of this review, it is clear that foliar and soil urea applications may have a different impact on N absorption. Further, Mo seems to play a key role in N metabolism. Therefore, it was decided to study the effect of foliar and soil urea applications on broccoli yields and N recovery as influenced by added Mo.

MATERIALS AND METHODS

Field trials were conducted on a St-Blaise soil series (Lajoie, 1964), located at l'Acadie Experimental Farm of Agriculture Canada near St. Jean-sur-Richelieu, Quebec. All fields were tiled-drained. Four locations were selected for successive trials in 1981 and 1982. Two sites were selected each year to eliminate the potential hazard of fertilizer residues.

a) Field trials 1981 and 1982

The sites were selected on the Farm in a radius of a few hundred metres, with soil pH values of 6.5 and 7.3 in 1981 and 5.1 and 6.5 in 1982. The soil texture was loam and silt-loam at low and high pH sites in 1981, respectively and clay-loam at both sites in 1982 (Table 1).

Fertilizer was applied broadcast at a rate of 80 kg N/ha, 320 kg P_2O_5/ha and 160 K_2O/ha during both years except for a supplemental liming with hydrated limestone in 1981 at a rate of 1000 kg/ha on the low pH field for a final soil pH of 6.5 at the beginning of the experiment.

Soil hot-water-soluble B levels were in the range of 0.3 ug/g of dry soil and were considered as being below sufficiency levels. Therefore, in order to control this deficiency, foliar sprays of boron[1] were applied four times at ten-day intervals, at a rate of 0.7 kg B/ha on all plots in combination with a pesticide[2] used to control the cabbageworm (*Pieris rapae* (L.)).

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[1] SOLUBOR; 20.5% B.

[2] AMBUSH 50 EC (Permetrine)

Table 1. Some properties of St-Blaise soils (0 - 20 cm depth) at l'Acadie Experimental Farm in 1981 and 1982.

YEAR AND SOIL WATER pH	pH in $CaCl_2$	P	K	Mg	B	Sand	Silt	Clay	C.E.C.	O.M.*
		----- kg/ha -----			ug/g	--------- % ---------			me/100 g	%
1981 TRIALS:										
pH 6.5	5.8	251	194	316	0.22	36.9	41.0	22.1	23.2	6.2
pH 7.3	6.8	313	221	466	0.28	23.9	54.0	22.1	14.2	5.8
1982 TRIALS:										
pH 5.1	4.7	124	302	441	0.48	25.1	40.0	34.9	16.9	5.3
pH 6.5	6.2	104	248	522	0.32	31.1	34.0	34.9	13.7	4.3

* Organic-matter content by loss on ignition at 430°C for 16 hours.

The same broccoli variety (cv. Premium Crop) was used in both years with rows 90 cm apart and 45 cm in-row spacing. Direct seeding was done on June 2 in 1981, while in 1982, four-week-old plants were transplanted on June 22 to avoid some irregularity in plant growth observed the previous year with the direct seeded crop.

Two forms of applications of feed-grade urea[1] were used. One applied to the soil in bands, the other applied to the foliage, with and without Liquid Molybdenum[2], which were compared with a control, for a total of six treatments (Table 2). Banded applications of urea were applied twice at ten- day intervals with a Planet Junior hand-seeder at a rate of 30 kg N/ha to a depth of 2.5 cm, for a total application of 60 kg N/ha. Foliar treatments were applied three times at ten-day intervals at a rate of 4.5 kg N/ha for a total application of 13.5 kg N/ha. A Mo solution was sprayed three times in combination with urea treatments for a total application of 0.2 kg Mo/ha (Gupta, 1979). A surfactant[3] was used with all foliar treatments (Inden,1975). A tractor-mounted pesticide sprayer was used for all foliar treatments which applied 2800 L/ha of solution at a pressure of 2350 kPa using cone jet[4] sprayers.

All treatments were applied to plots measuring 5 by 5 m and were arranged in a factorial experiment in a completely randomized block design

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1 FEED GRADE UREA (1% biuret content). BULL'S EYE, GENSTAR CHEMICALS LTD.

2 THIS-LIQUID MOLYBDENUM (4% actual Mo). STOLLER CHEMICAL COMPANY INC.

3 AGRAL 90.

4 JOHN BEAN, NUMBER 2, TRADE MARK.

Table 2. Schedule and rates of applications of treatments at l'Acadie farm on broccoli plants.

TREATMENTS	Treatment applications: Total rate	Number	Time: 1981 Trials	1982 Trials
	--- kg/ha ---		Number of days after seeding	
BANDED UREA	60 kg	2	35, 45	56, 66
FOLIAR UREA	13.5 kg N	3	40, 51, 72	65, 76, 85
CONTROL	0	0		
FOLIAR Mo plus BANDED UREA	0.2 kg Mo 60 kg N	3 2	40, 51, 72 35, 45	65, 76, 85 56, 66
FOLIAR Mo plus FOLIAR UREA	0.2 kg Mo 13.5 kg N	3 3	40, 51, 72 40, 51, 72	65, 78, 85 65, 78, 85
FOLIAR Mo	0.2 kg Mo	3	40, 51, 72	65, 78, 85

with four blocks. Each plot was isolated by a 5 m buffer-zone to prevent any drift during the application of foliar treatments.

Harvest was done by sampling 10 consecutive broccoli spears in the center-row, weighing them and measuring their diameter, while a 4 spear-sample was dried at 60°C for 24 h. for an estimation of spear dry-weight. Plant heights and a spear damage index were recorded on the total sample and the percentage of spears harvested at mid-harvest was reported as early yield.

b) Sampling and analysis

Soil samples were taken at two depths (0-20 and 25-50 cm) before treatments in June, in the centre of each plot and after harvest in September. One week after banded urea was applied, an additional sampling was taken at the 0-20 cm soil depth. As suggested by Westfall _et al._ (1978), soil samples were oven-dried at 45°C within 12 hours after collection and stored for soil NO_3-N determination. Following a method published by McKeague (1978), NO_3-N was determined in a water extract (1:2) with an Orion specific electrode.

Leaf-midribs sections were collected for total N analysis four times during the 1981 and 1982 trials when a similar plant physiological development was reached at 50, 52, 71, 73 days and 75, 77, 84, 87 days after seeding, respectively in each year. Young leaf-midrib sections were taken from the highest mature leaf on the stem of 10 plants, as recommended by Lorenz and Tyler (1978) and were initially put in an ice-box and later frozen at -5°C within a few hours of collection. Prior to drying at 60°C, all leaf samples were thawed rapidly by washing in distilled and deionized water and digested for total N content, following a method established by Thomas et al. (1967) and analyzed by colorimetry with a Technicon auto-analyzer total N method[1].

c) Estimation of N recovery (ENR) by plants

The percentage of N recovery in the crop was calculated using the 'difference' method as reported by Westerman and Kurtz (1973) using the following equation: $((NF-NC)/R) \times 100$, where:

NF = kg of total N content in plants per ha in treated plots

NC = kg of total N content in plants per ha in control plots

R = kg of total N fertilizer per ha in urea treatments

Total N content in the midrib section of young, mature leaves was considered as representative of the total N content of the plant, as reported by Pimpini (1973). An estimate of the total plant dry-matter production was necessary for these calculations as well. Therefore, an additional 10-plant sample was obtained from each field during the 1982 trials in order to estimate the ratio of spear weight as compared to total plant weight. The spear dry-weight was found to be 20% of the total plant dry-matter production in the collected sample. This ratio was in accordance with ratios found by Magnifico et al. (1979) on broccoli plants.

During the 1981 and 1982 trials, the ENR by plants was calculated over four sampling dates; one day prior and one day after two foliar urea applications. The data were analyzed as a split-plot-in-time experiment,

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1 INDUSTRIAL METHOD No.. 334-74W/B 1974. TECHNICON INDUSTRIAL SYSTEMS, TARRYTOWN, N.Y., 10591, U.S.A.

pooling the results of four dates into one analysis to overcome the effect of sampling dates on the ENR.

d) Statistical analyses

To assess the effects of soil pH, location and years, yield results were analyzed as a split-plot experiment with splits over four trials, over each year and over pH 6.5 during both years. The appropriate error term was used to estimate the main effects (Steel and Torrie,1980).

RESULTS AND DISCUSSION

a) Meteorological data

Meteorological data recorded over the two consecutive years of the trials indicated that rainfall over the growing season was 46% higher than the 14-year average during 1981 trials, while the 1982 season had 20% less rainfall (Table 3). Dry conditions observed in May and June of 1982 may have stressed young transplants which could explain the 12-day delay in harvesting compared to 1981 trials. Mean daily-temperatures were not different than the average year, over the four-month period studied.

b) Yields

The total harvesting period was spread over 78 to 85 days in 1981 trials and 90 to 110 days after seeding in 1982. A significant difference in yield was obtained by pooling the results of all four trials, showing that soil pH levels and year of trials had affected broccoli yield parameters. A possible pH effect was noticed during 1981 trials because the mean spear fresh-weight obtained at soil pH 6.5 was actually 8% higher (significant at the 0.05 level) than the trial at soil pH 7.3. This effect could be related to a deficiency in soil B which was more acute during 1981 trials (Table 1). During 1982 trials, the effect of soil pH on fresh and dry spear weight was not significant (Table 4).

Broccoli spear fresh-weights and plant heights obtained on the soil at pH 6.5 during 1981 trials, were significantly higher than in the 1982 trial at the same soil pH. It is suggested that climatic factors affected yields differently in each year.

Table 3. Monthly meteorological data at l'Acadie Farm in 1981 and 1982.

MONTH	Rainfall 1981	Rainfall 1982	Rainfall Avg.*	Mean daily temperature 1981	Mean daily temperature 1982	Mean daily temperature Avg.*
	(mm)			(°C)		
MAY	67	22	76	13.9	14.5	13.0
JUNE	141	80	98	18.3	16.6	17.8
JULY	129	84	89	20.7	20.6	20.4
AUGUST	186	101	96	18.5	17.1	19.3
TOTAL:	523	287	359			
AVERAGE:				17.9	17.2	17.5

* Average of 1968 to 1981.

Table 4. Broccoli growth results combined over: 4 trials during 1981-1982, 2 trials during 1981, 2 trials during 1982 and trials at pH 6.5 during 1981-1982 using a split-plot analysis.

COMBINATIONS	Broccoli spear Fresh weight	Broccoli spear Dry weight	Plant height	Early yield
	---- (g/spear)----		(cm)	(%)
<u>pH AND YEAR EFFECT</u>				
1981 at pH 6.5	532.8 a	50.5 a	77.8 a	43 b
1981 at pH 7.3	496.0 a	42.6 b	79.0 a	66 a
1982 at pH 5.1	483.9 a	44.0 b	65.6 b	82 a
1982 at pH 6.5	432.1 b	43.6 b	64.7 b	41 b
F-value	8.0*	4.4*	115.4*	14.0*
C.V. (%)	14	16	4	36
<u>pH EFFECT IN 1981</u>				
pH 6.5	532.8 a	50.5 a	77.8	43 b
pH 7.3	496.0 b	42.6 b	79.0	66 a
F-value	18.7*	14.3*	0.8	43.6**
C.V. (%)	12	14	4	34
<u>pH EFFECT IN 1982</u>				
pH 5.1	483.8	44.0	65.6	82 a
pH 6.5	432.1	43.6	64.7	41 b
F-value	2.7	0.02	4.2	23.2*
C.V. (%)	16	19	5	38
<u>YEAR EFFECT</u>				
1981 at pH 6.5	532.8 a	50.5	77.8 a	43
1982 at pH 6.5	432.1 b	44.0	64.7 b	41
F-value	22.7*	6.3	114.0**	0.08
C.V. (%)	14	18	4	58

* Significant differences at the 0.05 level; ** significant differences at the 0.01 level; means followed by the same letter are not significantly different according to Duncan's new multiple range test.

C.V. = coefficient of variability.

It is possible that the above-average rainfall observed during 1981 increased yields.

A decrease in the percent early-yield values, which reflect a delay in plant maturity, was observed over pooled results of all trials, when Mo treatment was applied (Table 5). However, there was no delay in plant maturity with the addition of N fertilizer, as observed by Cutcliffe et al. (1967, 1968) on cauliflower and broccoli.

Looking at individual trials, the effect of urea treatments on broccoli yield parameters appeared to be significant only during 1982 trial at soil pH 6.5 (Tables 6, 7, 8, 9). However, when results were pooled over both 1982 trials, dry spear-weights of broccoli were significantly increased by 18% with urea applied in bands when compared to the average values of foliar urea applications and control plots. Fresh spear-weights obtained with banded and foliar urea were not significantly different (Table 10).

c) Estimated percentage N recovery (ENR) by plants

The Mo treatment was found to have a significant effect in the 1981 trial at soil pH 7.3, reducing ENR by 87% when compared to untreated plots (Table 11). This trend was not significant in the other trials and was not improved by using logarithmic transformation of the data. Foliar urea treatments resulted in a significant increase in ENR at soil pH 6.5, while at soil pH 7.3, this increase was found but to a lesser extent; i.e. only at the 0.10 level of probability. ENR values for foliar urea were 235 and 72% more than for banded urea, at soil pH values of 6.5 and 7.3, respectively, during 1981 trials.

Table 5. Broccoli growth results combined over 4 trials in 1981-1982, using a split-plot analysis.

COMBINATIONS	Broccoli spear Fresh weight	Broccoli spear Dry weight	Plant height	Early yield
	---- (g/spear)----		(cm)	(%)
FOLIAR APPLICATION OF Mo OVER ALL N TREATMENTS				
0.0 kg Mo/ha	490.3	45.9	71.9	63 a
0.2 kg Mo/ha	482.1	44.4	71.6	54 b
F-value	0.4	1.0	0.3	4.3*
METHODS OF N APPLICATION OVER ALL Mo LEVELS				
Banded urea (60 kg N/ha)	508.3	47.4	72.3	58
Foliar urea (13.5 kg N/ha)	482.6	44.5	71.6	54
Control	467.7	43.6	71.5	62
F-value	3.0	2.3	0.6	1.2
INTERACTIONS	---------------- (F-value) --------------			
Mo and urea	1.6	1.2	1.2	0.2
(Trial) and Mo	0.5	0.5	2.0	0.1
(Trial) and urea	1.3	2.1	1.8	0.4
(Trial) and Mo and urea	0.8	1.1	0.9	1.4
Mean	486	45	72	58
C.V. (%)	14	16	4	36

* Significant difference at the 0.05 level; means followed by the same letter are not significantly different according to Duncan's new multiple range test.

(Trial) = soil pH and year effects

C.V. = coefficient of variability

Table 6. Broccoli growth characteristics at harvest during 1981 trials at pH 6.5.

TREATMENTS	Spear diameter	Plant height	Spear fresh weight	Spear dry weight
	-------- cm -------		------------ g -----------	
FOLIAR APPLICATION OF Mo OVER ALL N TREATMENTS				
(0.0 kg Mo/ha)	21.2	76.7	542.7	52.3
(0.2 kg Mo/ha)	21.2	78.8	522.8	48.7
F-value	0.08	2.90	0.49	1.35
METHODS OF N APPLICATION OVER ALL Mo LEVELS				
Banded urea (60 kg N/ha)	20.6	76.6	525.0	48.7
Foliar urea (13.5) kg N/ha)	21.9	78.0	555.7	53.7
Control	21.1	78.8	517.5	49.2
F-value	1.74	1.12	0.68	1.07
INDIVIDUAL TREATMENTS				
Banded urea	21.1	75.8	544.5	51.9
Foliar urea	21.5	76.7	540.8	52.9
Control	21.0	77.7	542.7	52.2
Mo and banded urea	20.2	77.4	505.6	45.5
Mo and foliar urea	22.3	79.2	570.5	54.5
Mo	21.2	79.9	492.4	46.2
Mean	21.2	77.8	532.8	50.5
F-value	0.81	0.05	0.78	0.70
C.V.(%)	6.5	3.9	13.0	15.1

C.V.= coefficient of variability

Table 7. Broccoli growth characteristics at harvest during 1981 trials at pH 7.3.

TREATMENTS	Spear diameter	Plant height	Spear fresh weight	Spear dry weight
	------- cm -------		------------ g ------------	
FOLIAR APPLICATION OF Mo OVER ALL N TREATMENTS				
(0.0 kg Mo/ha)	20.2	79.8	489.6	42.4
(0.2 kg Mo/ha)	20.7	78.2	502.4	42.8
F-value	1.21	2.78	0.31	0.03
METHODS OF N APPLICATION OVER ALL Mo LEVELS				
Banded urea (60 kg N/ha)	20.0	80.2	517.5	43.8
Foliar urea (13.5 kg N/ha)	20.6	78.2	485.5	40.3
Control	20.7	78.7	485.1	43.7
F-value	0.85	1.42	0.88	1.53
INDIVIDUAL TREATMENTS				
Banded urea	19.7	80.9	513.6	42.6
Foliar urea	20.2	78.9	470.4	40.0
Control	20.5	79.8	484.9	44.7
Mo and banded urea	20.3	79.5	521.4	45.1
Mo and foliar urea	20.9	77.6	500.7	40.6
Mo	20.9	77.7	485.2	42.7
Mean	20.5	79.0	496.0	42.6
F-value	0.03	0.08	0.16	0.48
C.V.(%)	5.8	3.0	11.3	10.8

C.V.= coefficient of variability

Table 8. Broccoli growth characteristics at harvest during 1982 trials at pH 5.1.

TREATMENTS	Spear diameter	Plant height	Spear fresh weight	Spear dry weight
	------- cm -------		------------ g ------------	
FOLIAR APPLICATION OF Mo OVER ALL N TREATMENTS				
(0.0 kg Mo/ha)	18.4	66.0	498.4	45.5
(0.2 kg Mo/ha)	18.1	65.1	469.4	42.4
F-value	0.48	0.54	0.92	1.03
METHODS OF N APPLICATION OVER ALL Mo LEVELS				
Banded urea (60 kg N/ha)	18.5	65.5	508.6	46.2
Foliar urea (13.5 kg N/ha)	18.1	66.5	457.0	42.3
Control	18.3	64.6	486.0	43.3
F-value	0.36	0.71	0.97	0.58
INDIVIDUAL TREATMENTS				
Banded urea	19.0	65.4	528.3	45.1
Foliar urea	17.6	67.2	436.8	42.6
Control	18.7	65.5	530.1	48.9
Mo and banded urea	18.0	65.6	488.9	47.3
Mo and foliar urea	18.6	65.8	477.2	42.0
Mo	17.8	63.8	442.0	37.8
Mean	18.3	65.6	483.9	44.0
F-value	2.21	0.21	1.53	1.69
C.V.(%)	2.9	2.5	0.8	8.7

C.V.= coefficient of variability

Table 9. Broccoli growth characteristics at harvest during 1982 trials at pH 6.5.

TREATMENTS	Spear diameter	Plant height	Spear fresh weight	Spear dry weight
	-------- cm	-------	------------ g	-----------
FOLIAR APPLICATION OF Mo OVER ALL N TREATMENTS				
(0.0 kg Mo/ha)	17.8	65.1	430.3	43.4
(0.2 kg Mo/ha)	17.9	64.3	433.9	43.8
F-value	0.12	0.52	0.02	0.01
METHODS OF N APPLICATION OVER ALL Mo LEVELS				
Banded urea (60 kg N/ha)	18.6	66.7	482.0 a	50.9 a
Foliar urea (13.5 kg N/ha)	17.7	63.7	432.1 ab	41.6 ab
Control	17.2	63.7	382.2 b	383.3 b
F-value	2.49	3.11	4.42*	4.11*
INDIVIDUAL TREATMENTS				
Banded urea	18.1	65.0	450.0	47.5
Foliar urea	17.7	65.8	446.9	45.1
Control	17.5	64.4	394.1	37.7
Mo and banded urea	19.1	68.3	513.9	54.3
Mo and foliar urea	17.8	61.5	417.3	38.1
Mo	16.9	63.0	370.4	39.0
Mean	17.9	64.7	432.1	43.6
F-value	0.84	3.95*	1.22	1.17
C.V.(%)	3.5	2.1	7.8	10.4

* Significant at the 0.05 level; means followed by the same letter are not significantly different according to Duncan's new multiple range test.

C.V. = coefficient of variability

Table 10. Effect of methods of application of urea on broccoli spear weight observed over combined pH trials during 1981-1982, in a split-plot analysis.

METHODS OF UREA APPLICATION	1981 trials		1982 trials	
	Fresh weight	Dry weight	Fresh weight	Dry weight
	g			
Banded urea (60 kg N/ha)	521	46	495 a	49 a
Foliar urea (13.5 kg N/ha)	521	47	445 ab	42 b
Control	501	46	434 b	41 b
Mean	511	46	458	44
F-value	0.5	0.1	3.4*	4.0*
C.V. (%)	13	14	16	19

* Significant at the 0.05 level; means followed by the same letter are not significantly different according to Duncan's new multiple range test.

C.V. = coefficient of variability

Table 11. Estimated percentage of N recovery (ENR) during 1981 and 1982 calculated over 4 sampling dates and analysed as a split-plot in time.

TREATMENTS	1981 trials pH 6.5	1981 trials pH 7.3	1982 trials pH 5.1	1982 trials pH 6.5
	(% ENR)			
DATES				
1	6	77	-86	85
2	177	125	-79	80
3	278	27	-5	143
4	89	122	-53	108
F-value	1.84	0.75	1.70	2.33
FOLIAR Mo				
0.0 kg Mo/ha	131	131 a	-58	120
0.2 kg Mo/ha	144	44 b	-54	88
F-value	0.03	4.35*	0.03	0.81
UREA APPLICATIONS				
In bands (60 kg N/ha)	20 b	52	-6 a	73
Foliar (13.5 kg N/ha)	255 a	124	-106 b	136
Means	138	88	-56	104
F-value	8.07**	2.91	21.05**	3.14
INTERACTIONS				
Date and Mo	0.17	0.15	0.04	0.14
Date and Urea	1.04	0.79	1.45	0.01
Mo and Urea	0.02	4.09*	4.15*	4.19*
Date and Mo and Urea	0.13	0.09	1.80	1.05
C.V. (%)	243	194	158	138

* Significant at the 0.05 level; ** significant at the 0.10 level; means followed by the same letter are not significantly different according to Duncan's new multiple range test.

Note: Statistical significance was similar using logarithmic transformations of X+1000 reducing C.V. in the range of 2-4%.

C.V. = coefficient of variability.

In 1982, at soil pH 5.1, ENR values were negative with a significantly larger deficit in ENR with the use of foliar urea. In this case, it was possible that the soil pH and nutrient levels were too low, and prevented a positive response with urea treatments. It is also possible that low ENR values may have been due to the enhancement of toxic materials in the soil which prevented nutrient uptake when treatments were applied. However, in all other trials more N appeared to be recovered by the plants than was supplied in the foliar treatments. It is possible that an over-estimation of urea recovery was calculated with the 'difference' method used, as reported by Jansson (1966) in comparative studies with tracer techniques. The so- called 'priming effect' reported by Westerman and Kurtz (1973) could have induced an extra plant growth due to other interactions between soil, fertilizer, microbe and plant, which induced more native soil N absorption than with control plants. The ENR of soil-applied urea could have been affected by the soil organic-matter content, since Tomar and Soper (1981) reported that, in incubation studies, the soil organic-matter content accounted for more than half of the variation in N tied up in the soil.

However, there was a significant interaction between Mo and urea on ENR in three of the trials (Table 11). This effect is better expressed in Table 12, where it appeared that significant differences occurred only with urea applications when there was no Mo addition. Therefore, the benefit of Mo application in improving the ENR was not verified, since there was no difference in ENR values between foliar and banded urea when Mo was added. It appeared that Mo reduced the ENR with foliar urea considerably, except at soil pH 6.5 in 1981.

Table 12. Results of interactions between each level of Mo treatment and methods of urea application for the estimation of the percentage N recovery (ENR) by broccoli plants during 1981 and 1982 trials.

INTERACTIONS	1981 trials pH 6.5	1981 trials pH 7.3	1982 trials pH 5.1	1982 trials pH 6.5
	(% ENR)			
METHODS OF N APPLICATION WITHOUT Mo				
Banded urea (60 kg N/ha)	19	53 b	15 a	53 b
Foliar urea (13.5 kg N/ha)	244	210 a	-130 b	188 a
Mean	132	132	-58	121
F-value	3.69	6.93**	19.38**	7.26**
METHODS OF N APPLICATION WITH Mo				
Banded urea (50 kg N/ha)	21 b	51	-26	93
Foliar urea (13.5 kg N/ha)	267 a	38	-82	84
Mean	144	45	-54	89
F-value	4.41*	0.05	3.31	0.03

* Significant at the 0.05 level; ** significant at the 0.01 level; means followed by the same letter are not significantly different according to Duncan's new multiple range test.

d) Soil NO_3-N

To assess the net effect of treatments, an analysis of covariance was performed on the NO_3-N level obtained at harvest using levels before treatment applications as a concomitant variable (Table 19, Appendix). Adjusted means of NO_3-N were in the range of 2.9 µg/g of dry-soil during 1981. The analysis of soil NO_3-N did not result in any significant effect of the treatments, even when logarithmic transformations were used to reduce the coefficient of variability. NO_3-N levels observed here could be considered as low according to sampling results reported by Chamberland (1976) in an earlier experiment at l'Acadie Farm.

However, soil NO_3-N data recorded for each field in 1981, before the application of treatments, correlated well with broccoli plant height at the 0.05 level of significance ($r = 0.77$), showing that plant growth was only affected by the initial NO_3-N level which was not dependent upon treatments.

CONCLUSIONS

Broccoli yields were affected by soil pH and climatic variation during each year of the trials. However, the application of foliar Mo, at a rate of 0.2 kg/ha, decreased early yield significantly when compared to untreated plants.

During the 1982 trials, broccoli dry spear weight was significantly increased when urea was applied in bands at a rate of 60 kg N/ha, when compared to foliar urea and control treatments.

The estimated percentage fertilizer N recovery by plants, with foliar applied urea, was significantly higher, compared to band applied urea, during the 1981 trial at soil pH 6.5. In 1982 at soil pH 5.1, negative ENR values were obtained with foliar urea, showing that foliar urea might be less effective than banded urea at low soil pH.

Fresh and dry weights of broccoli were significantly reduced by 7 and 16%, during 1981 trials at soil pH 7.3, when compared to trials at soil pH 6.5.

Native soil NO_3-N levels increased broccoli plant heights without increasing the weight of spears and these levels were not affected by treatments during sampling at the end of the season.

From this study, we can conclude that Mo application might not be necessary for improving fertilizer N absorption by the plant.

Banded urea appeared to be a better method to apply supplemental N than foliar urea, especially at higher soil pH levels. ~~This,~~ despite the fact that ENR was higher with foliar urea applications.

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CONNECTING PARAGRAPH

In Chapter 3, the N recovery by plants with different N treatments suggested that the proportion of N fertilizer used by plants, on a per kg basis, was greater with foliar applications of urea than with banded urea. Mo treatment reduced the N recovery at one site and the maturity of broccoli plants at all sites. Thus, Mo may have had an antagonistic effect on nutrient uptake. Further, N effects on yield may have been affected by changes in nutrient uptake as a result of N fertilizer treatments. However, broccoli plant heights were correlated positively with soil NO_3-N content which was not affected by the urea fertilizer treatments.

Because of possible N-nutrient interaction, further studies on the effect of N and Mo treatments on plant K, Ca, Mg and B status over the growing season were carried out. These results are reported in Chapter 4.

CHAPTER 4

EFFECT OF SUPPLEMENTAL N FERTILIZATION OF SOILS AT DIFFERENT pH VALUES ON NUTRIENT CONTENT OF BROCCOLI (*Brassica oleracea* L. ssp. *italica* Plenck) LEAVES

INTRODUCTION
AND
LITERATURE REVIEW

Nitrogen fertilization and its impact on Mo deficiency of *Brassica* crops has been observed. Stout and Johnson (1956) reported that whiptail was a physiological disorder associated with a Mo deficiency. Fido *et al*. (1977) noticed an increase in the incidence of whiptail, when NO_3-N fertilizer was used. Mo deficiencies associated with whiptail have been reported earlier by Wilson and Waring (1948) and subsequently by Alexander and Stark (1959) on cauliflowers (*Brassica* *oleracea* var. *botrytis* L.) which were fertilized with an excess of N. Anderson (1956), working with *Neurospora* and *Aspergillus*, noted that N and Mo interactions could be related to the role of Mo in the formation of the nitrate-reductase enzyme.

However, the interaction of N-Mo with foliar or banded urea may be different. Absorption sites for banded urea are at the root level where competition with other nutrients may occur. Foliage applications should not affect other nutrients because there is no competition for sites. Thus, nutrient interactions with foliar-applied N may be less than those with soil-applied N, as observed by Forshey (1963).

Concerning the utilization of foliar-applied urea, Bollard (1959) suggested that urea-N may be hydrolyzed on the leaf surface with consequent uptake of ammonium-ion and production of carbon-dioxide, through the activity of the urease enzyme. Following this uptake, there is a rapid conversion of NH_4-N to NO_3-N in the plant.

Soil N fertilization can affect the availability of micro-nutrients to a larger extent, since some nutrients could compete for absorption sites at the root level. Cutcliffe and Gupta (1980) have reported that soil applied N increased the B concentration in dry-matter of cauliflower whereas, Chamberland (1981) observed that N applications reduced B deficiency symptoms on turnips (Brassica rapa L.). Therefore, it is possible that B can be better utilized with N fertilization. On the other hand, the Mo deficiency observed in cereals and grasses was found to be related to the N status since Mo deficiency symptoms may be essentially those of NO_3^- ion accumulation, which can be reduced by supplying Mo (Gupta and Lipsett, 1981).

According to Bohn et al. (1979), the strength of ion adsorption by minerals generally increases with increasing ion charge and with decreasing hydrated ion size. Therefore, monovalent ions are more easily displaced from soil exchange sites and should compete more for plant absorption sites than would divalent and trivalent ions which are retained in soil more strongly. The relatively small hydration energies of NH_4^+ and K^+ result in easy dehydration and strong retention by soils, according to the same author. However, an anion, such as NO_3^-, is retained weakly and is, therefore, rather mobile in the soil and readily moves to plant roots by mass flow.

Coleman et al. (1958) reported that divalent cations such as, Ca^{++} and Mg^{++} compete with one another, but high levels of K^+ markedly depress the quantities of Ca^{++} and Mg^{++} in plants. Moreover, Bohn et al. (1979) observed that a high Ca^{++} status in the soil is desirable because it reflects low concentrations of other, potentially troublesome exchangeable cations such as, Al^{+++} in acid soils.

Krauskopf (1972) and Chesnin (1972) observed that large anions such as, MoO_4^{2-} were found at pH values above 5 or 6, while at lower pH values, $H_2MoO_4^-$ was more predominant. Other anions such as, $B(OH)_4^-$ are not abundant since neutral soluble B species, mainly H_3BO_3 (uncharged) appeared to predominate in plants and in soil solutions at pH values under 9.2. Thus, it seemed pertinent to study the effect of N and Mo additions and methods of N applications on nutrient contents in broccoli leaves.

MATERIALS AND METHODS

Two methods of N application, foliar vs banded urea, were used with broccoli plants (Brassica oleracea L. spp. italica Plenck, cv. Premium Crop), in combination with Mo applied on the foliage. This experiment was carried out during 1981 and 1982, at selected locations on l'Acadie Experimental Farm of Agriculture Canada near St. Jean-sur-Richelieu, Quebec. Details of soil conditions, rates of fertilizer application and experimental design are reported in Chapter 3.

Samples of leaf-midribs were collected four times during the growing season. The midrib of the youngest fully-developed leaf was sampled on a total of 10 plants from two rows, at 50, 52, 71 and 73 days after seeding in 1981 and at 75, 77, 84 and 87 days in 1982. The first sampling date in each year was selected when plots had approximately 25% of the plants with spears reaching 2.5 cm in diameter.

Leaf-midribs were stored at -5°C, prior to washing with distilled, deionized water and then dried at 60°C before being ground to pass a 20 mesh sieve. Chemical analyses were performed within one and five months following sample collection during 1981 and 1982, respectively.

Total N determinations were reported earlier (Chapter 3). NO_3-N was extracted in boiling water as reported by Look Kin and Mackenzie (1970) and analyzed by colorimetry with a technicon auto-analyzer NO_3-N method[1].

Leaves were digested according to the method of Thomas et al. (1967) and analyzed for K, Ca and Mg using a flame atomic absorption spectrophoto-

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[1] Industrial method No. 487-77A. 1977. Technicon Industrial Systems, Tarrymore, N.Y., 10591, U.S.A.

meter. Boron content determination of the 1981 samples was carried out according to the method of Hatcher and Wilcox (1950), while, in 1982, samples were prepared according to the method of Basson et al. (1969) and analyzed by colorimetry with azomethine-H (McKeague, 1978

A visual index was computed to assess the damage caused by hollow stem on spear rot at harvest time. Damages were ranked into four categories as follows:

Category 0 = no visual disorder

Category 1 = damaged spear canopy due to rot

Category 2 = hollow stem in spear

Category 3 = hollow stem and spear rot

This ranking was transformed into a damage index (DI) percentage, according to a method reported by Basu et al. (1973) in which

$$DI = [\Sigma (No. \times Cat.)]/(3 \times No.P.) \times 100 \text{ where,}$$

No. = number of plants per category

Cat. = category number

No.P. = number of plants sampled

Results were treated using non-parametric statistics and median values were reported as suggested by Steel and Torrie (1980). A Spearman correlation coefficient (r_s) was computed according to Daniel (1978).

RESULTS AND DISCUSSION

a. Leaf Total-N and NO_3-N Contents

Total N level was markedly lower than the 5.2 to 6.0% sufficiency levels for optimum broccoli yield (Table 1) as reported by Munro et al. (1978) However, NO_3-N level was generally above the critical level of 7000 µg/g of dry-matter, established by Lorenz and Maynard (1980), (Table 2).

NO_3-N and total N variations with time were more significant in 1981 trials than in 1982 trials because the longer sampling period in 1982 may have represented a greater variation in plant maturity. However, during both years the NO_3-N and total N levels in the plants decreased.

Total N and NO_3-N levels with banded urea were significantly higher than control plants in all trials, except on the soil of pH 6.5 in 1981. In two out of the three trials with significant results, total N and NO_3-N levels were higher with banded urea compared to foliar urea, while at soil pH 5.1 there was only an increase in N and NO_3-N when compared to control plants. Therefore, foliar urea had no effect on total and NO_3-N contents.

The Mo treatment significantly increased the NO_3-N level in the leaf-midribs only in the 1982 trial at soil pH 6.5. At this same site (see Chapter 3), Mo reduced broccoli early yield, which is associated with a delay in plant maturity. Thus, increased NO_3-N levels were associated with delayed maturity.

Yield parameters were related more consistently to total N than with NO_3-N (Table 3). There was a positive correlation of total N and NO_3-N with fresh spear weight in 3 of the 4 trials. Total N was correlated positively with plant height at all sites, but NO_3-N only at 2 sites.

Table 1 Total N levels[1] in broccoli plants during 1981 and 1982 trials, at different soil pH values

TREATMENTS	1981 Trials pH 6.5	1981 Trials pH 7.3	1982 Trials pH 5.1	1982 Trials pH 6.5
	% N, dry-matter basis			
DATES				
1	3.80 a	4.11 a	2.95 a	2.48 bc
2	3.57 a	3.88 a	3.51 bc	2.45 c
3	3.07 b	3.27 b	2.63 b	2.80 ab
4	2.65 b	2.92 b	2.41 c	3.10 a
F-value	41.34**	25.78**	39.99**	11.97**
FOLIAR APPLICATION OF Mo OVER ALL N TREATMENTS				
(0.0 kg Mo/ha)	3.20	3.55	2.64	2.71
(0.2 kg Mo/ha)	3.34	3.53	2.61	2.70
F-value	1.55	0.06	0.64	0.04
METHODS OF N APPLICATION OVER ALL Mo LEVELS				
Banded urea (60 kg N/ha)	3.34	3.75 a	2.70 a	2.91 a
Foliar urea (13.5 kg N/ha)	3.31	3.44 b	2.63 ab	2.68 b
Control	3.17	3.44 b	2.54 b	2.53 b
Mean	3.27	3.54	2.63	2.71
F-value	0.80	6.37**	7.63**	21.16**
INTERACTIONS	F-value			
Date and Mo	0.98	0.83	0.13	0.45
Date and Urea	0.56	1.83	2.38*	1.16
Mo and Urea	0.05	0.17	0.29	1.44
Date and Mo and Urea	0.44	0.72	0.49	0.37
C.V. (%)	17	11	6	9

* Significant at the 0.05 level; ** significant at the 0.01 level; means followed by the same letter are not significantly different according to Duncan's new multiple range test.

C.V. = coefficient of variability.

[1] Levels in $\mu g/g$ of dry-matter = levels in % x 10000.

Table 2. NO_3-N levels[1] in broccoli plants during 1981 and 1982 trials, at different soil pH values.

TREATMENTS	1981 Trials		1982 Trials	
	pH 6.5	pH 7.3	pH 5.1	pH 6.5
	--------- % NO_3-N dry-matter basis --------			
DATES				
1	1.34 a	1.42 a	1.47 a	1.37 a
2	1.21 a	1.15 b	1.54 a	1.40 a
3	0.63 b	0.82 c	1.22 b	1.16 b
4	0.59 b	0.71 d	1.55 a	1.30 a
F-value	92.20**	20.17**	21.85**	4.73**
FOLIAR APPLICATION OF Mo OVER ALL N TREATMENTS				
(0.0 kg Mo/ha)	0.88 b	1.05	1.44	1.33
(0.2 kg Mo/ha)	1.01 a	1.00	1.45	1.30
F-value	4.55*	1.06	0.05	0.57
METHODS OF N APPLICATION OVER ALL Mo LEVELS				
Banded urea (60 kg N/ha)	1.00	1.15 a	1.54 a	1.42 a
Foliar urea (13.5 kg N/ha)	0.92	0.93 b	1.42 ab	1.30 b
Control	0.92	0.99 b	1.37 b	1.21 b
Mean	0.95	1.03	1.45	1.32
F-value	0.69	8.19**	7.29**	11.29**
INTERACTIONS	---------------- F-value --------------			
Date and Mo	0.17	0.48	0.35	0.31
Date and Urea	0.40	0.97	1.37	0.89
Mo and Urea	0.30	0.68	0.63	0.24
Date and Mo and Urea	0.48	0.31	0.95	0.50
C.V. (%)	32	21	12	13

* Significant at the 0.05 level; ** significant at the 0.01 level; means followed by the same letter are not significantly different according to Duncan's new multiple range test.

C.V. = coefficient of variability.

[1] Levels in µg/g of dry-matter = levels in % x 10000.

Thus, it was obvious that N was deficient in all sites, with the exception of the site at soil pH 5.1, in 1982. At this site, NO_3-N leaf contents were the highest, but total N values were the lowest. Thus, the status of the soil at pH 5.1 was different than in the other trials. It is possible that there was an accumulation of NO_3^- ions which were not assimilated or converted to protein-N as readily by the plant due to antagonistic ions interfering in acid soils (Bohn et al., 1979).

Positive interaction between total N and NO_3-N in plants was observed throughout the trials (Table 4). Positive correlations between total N as well as NO_3-N with B were found during 1981 trials; whereas, there was no correlation in 1982. Therefore, it is possible that B was less limiting during 1982 than in 1981. Total N was correlated positively to K only at soil pH 5.1 and 7.3, while NO_3-N and K correlated only at soil pH 7.3. Other plant-N correlations were observed between NO_3-N and Ca in three trials. Negative correlations were observed between total N and Ca as well as total N and Mg in the 1982 trial at soil pH 6.5. This relationship of Ca or Mg to N was reflected in a decrease in yield with added Ca and Mg (Table 3).

It is clear that NO_3-N levels found in this experiment were not excessive, and in fact, were in the range of normal values.

b) Leaf K Content

Potassium decreased in time, as expected, in all trials (Table 5). Levels were higher than critical levels in broccoli of 1.7 to 2.2% observed by Munro et al. (1978). Therefore, K was not considered to be limiting growth.

Table 3. Coefficients of regression analyses between the nutrient-content of broccoli plants and yield parameters taken at 4 sampling dates over 24 plots during 1981 and 1982.

VARIABLES	1981 Trials pH 6.5	1981 Trials pH 7.3	1982 Trials pH 5.1	1982 Trials pH 6.5
	---------- R^2 ----------			
FRESH SPEAR WEIGHT VERSUS				
NO_3-N	0.20*	0.52**	NS	0.34*
Total N	0.22*	0.53**	NS	0.26**
B	NS	0.19*	NS	NS
K	NS	0.41**	(-)0.19*	NS
Ca	NS	NS	NS	(-)0.22*
Mg	NS	NS	NS	(-)0.48**
TOTAL PLANT HEIGHT VERSUS				
NO_3-N	0.28**	0.37**	NS	NS
Total N	0.20*	0.33**	0.22*	0.26**
B	NS	NS	NS	NS
K	NS	0.19*	NS	NS
Ca	NS	NS	NS	(-)0.26**
Mg	NS	NS	NS	NS

* Significant at the 0.05 level; ** significant at the 0.01 level.

(-) = r values were negative

NS = R^2 values were not significant

Table 4. Coefficients of regression analyses between the nutrient-content of broccoli plants taken at 4 sampling dates over 24 plots during 1981 and 1982.

TISSUE NUTRIENTS		1981 Trials pH 6.5	1981 Trials pH 7.3	1982 Trials pH 5.1	1982 Trials pH 6.5
		R^2			
NO_3-N	X Total N	0.83**	0.81**	0.49**	0.67**
	X B	0.30**	0.16**	NS	NS
	X K	NS	0.59**	NS	NS
	X Ca	0.31**	0.50**	0.26**	NS
	X Mg	NS	NS	NS	NS
Total N	X B	0.53**	0.16**	NS	NS
	X K	NS	0.58**	0.19*	NS
	X Ca	0.19*	0.24*	NS	(-)0.21*
	X Mg	NS	NS	0.51**	(-)0.28**
B	X K	NS	NS	NS	NS
	X Ca	NS	NS	NS	NS
	X Mg	NS	NS	NS	NS
K	X Ca	NS	0.35**	NS	NS
	X Mg	NS	NS	(-)0.19*	NS
Ca	X Mg	0.16*	NS	0.51**	0.27**

* Significant at the 0.05 level; ** significant at the 0.01 level.

(-) = r values were negative

NS = R^2 values were not significant

Table 5. K levels in broccoli plants grown at different soil pH values during 1981 and 1982 trials.

TREATMENTS	1981 Trials pH 6.5	1981 Trials pH 7.3	1982 Trials pH 5.1	1982 Trials pH 6.5
	----------- % K, dry-matter basis ---------			
DATES				
1	4.59 a	4.47 a	4.29 a	3.88 a
2	4.57 a	4.18 a	3.88 b	3.52 ab
3	3.37 b	3.30 b	3.54 c	3.29 bc
4	3.45 b	3.19 b	3.39 c	3.03 c
F-value	88.48**	31.48**	83.92**	10.07**
FOLIAR APPLICATION OF Mo OVER ALL N TREATMENTS				
(0.0 kg Mo/ha)	3.76 b	3.78	3.83 a	3.40
(0.2 kg Mo/ha)	4.24 a	3.79	3.73 b	3.46
F-value	15.08**	0.00	4.84*	1.30
METHODS OF N APPLICATION OVER ALL Mo LEVELS				
Banded urea (60 kg N/ha)	3.77 b	3.86	3.73	3.39
Foliar urea (13.5 kg N/ha)	4.13 a	3.60	3.78	3.39
Control	4.09 a	3.89	3.82	3.50
Mean	4.00	3.79	3.78	3.43
F-value	3.37*	2.92	1.24	2.07
INTERACTIONS	----------------- F-value ---------------			
Date and Mo	0.15	0.28	0.11	0.74
Date and Urea	0.54	0.49	0.95	1.37
Mo and Urea	2.67	0.43	0.39	0.88
Date and Mo and Urea	0.88	0.12	0.49	0.61
C.V. (%)	15	14	6	7

* Significant at the 0.05 level; ** significant at the 0.01 level; means followed by the same letter are not significantly different according to Duncan's new multiple range test.

C.V. = coefficient of variability.

The effect of Mo treatment on K levels was not constant as there was significantly higher K with Mo in 1981 at soil pH 6.5 but less K with Mo was observed in 1982 at soil pH 5.1. The reason for this difference is not clear.

Banded N reduced K, but foliar N did not, in one trial only. Thus, the banded N treatment could have competed for root absorption of K^+ through the presence of NH_4^+ in the soil. Therefore, ion competition could have occurred only for banded urea, as was mentioned earlier.

c) Leaf Ca and Mg Content

Calcium content decreased in 1981 at soil pH 6.5 and increased with time in 1982 (Table 6). Ca and Mg levels were not affected by treatments in 1981. In 1982, Ca levels in plants appeared to be higher with banded urea at soil pH 5.1, but were lower with banded urea at soil pH 6.5. Foliar urea did not change Ca contents from control levels. Thus, banded N effects on Ca seem limited and inconsistent.

Magnesium tended to decrease with time, except at soil pH 5.1 (Table 7). Interestingly, at this site both foliar and banded urea increased Mg content. However, this increase in Mg was not related to increased yields. Thus, Mg did not appear to be deficient. Mo had no effect on Mg or Ca levels in the leaves.

d) Leaf B Content

Boron was the only nutrient studied which did not decrease in concentration as the plants matured (Table 8). B levels were lower than sufficiency requirements of 20 to 53 μg B/g of dry-matter established by

Table 6. Ca levels in broccoli plants grown at different soil pH values during 1981 and 1982 trials.

TREATMENTS	1981 Trials pH 6.5	1981 Trials pH 7.3	1982 Trials pH 5.1	1982 Trials pH 6.5
	---------- % Ca, dry-matter basis			--------
DATES				
1	~~1.17~~ a	1.25	0.94 c	1.09 b
2	1.07 ab	1.12	1.01 b	1.11 b
3	0.98 b	1.20	0.98 bc	1.07 b
4	0.96 b	1.13	1.20 a	1.32 a
F-value	5.76*	1.05	86.83**	14.57**
FOLIAR APPLICATION OF Mo OVER ALL N TREATMENTS				
(0.0 kg Mo/ha)	1.05	1.21	1.02	1.14
(0.2 kg Mo/ha)	1.04	1.14	1.04	1.16
F-value	0.17	3.09	0.60	1.68
METHODS OF N APPLICATION OVER ALL Mo LEVELS				
Banded urea (60 kg N/ha)	1.08	1.19	1.06 a	1.12 b
Foliar urea (13.5 kg N/ha)	1.05	1.14	1.02 b	1.17 a
Control	1.00	1.21	1.00 b	1.15 ab
Mean	1.05	1.18	1.03	1.15
F-value	1.26	1.27	4.15*	3.35*
INTERACTIONS	---------------- F-value			--------------
Date and Mo	2.44	0.83	0.82	0.35
Date and Urea	0.40	2.11	0.75	0.95
Mo and Urea	1.50	0.36	2.65	0.44
Date and Mo and Urea	0.61	0.45	1.74	0.40
C.V. (%)	21	23	8	7

* Significant at the 0.05 level; ** significant at the 0.01 level; means followed by the same letter are not significantly different according to Duncan's new multiple range test.

C.V. = coefficient of variability.

Table 7. Mg levels in broccoli plants grown at different soil pH values during 1981 and 1982 trials.

TREATMENTS	1981 Trials pH 6.5	1981 Trials pH 7.3	1982 Trials pH 5.1	1982 Trials pH 6.5
	% Mg, dry-matter basis			
DATES				
1	0.35 a	0.39 a	0.33 b	0.41 a
2	0.34 a	0.37 a	0.36 a	0.41 a
3	0.22 b	0.30 b	0.29 c	0.36 b
4	0.23 b	0.28 b	0.32 bc	0.33 b
F-value	70.55**	7.59*	11.18**	16.11**
FOLIAR APPLICATION OF Mo OVER ALL N TREATMENTS				
(0.0 kg Mo/ha)	0.28	0.33	0.32	0.38
(0.2 kg Mo/ha)	0.29	0.34	0.33	0.38
F-value	1.27	0.12	1.97	0.10
METHODS OF N APPLICATION OVER ALL Mo LEVELS				
Banded urea (60 kg N/ha)	0.30	0.34	0.33 a	0.38
Foliar urea (13.5 kg N/ha)	0.28	0.34	0.33 a	0.39
Control	0.28	0.33	0.31 b	0.37
Mean	0.29	0.34	0.32	0.38
F-value	1.18	1.04	3.26*	0.74
INTERACTIONS	F-value			
Date and Mo	1.05	0.47	1.15	0.27
Date and Urea	0.37	0.47	1.04	0.85
Mo and Urea	1.31	3.62*	3.91	3.00
Date and Mo and Urea	0.08	0.87	1.08	0.24
C.V. (%)	18	12	11	11

* Significant at the 0.05 level; ** significant at the 0.01 level; means followed by the same letter are not significantly different according to Duncan's new multiple range test.

C.V. = coefficient of variability.

Table 8. B levels in broccoli plants grown at different soil pH values during 1981 and 1982 trials.

TREATMENTS	1981 Trials pH 6.5	1981 Trials pH 7.3	1982 Trials pH 5.1	1982 Trials pH 6.5
	-------- ug/g B, dry-matter basis			--------
DATES				
1	27.0 a	28.0 a	31.4 ab	24.6 b
2	23.8 b	23.2 b	29.2 b	24.8 b
3	22.8 b	19.0 c	26.5 b	28.5 a
4	27.7 a	25.4 ab	36.1 a	25.7 b
F-value	8.92**	15.93*	3.87*	10.96**
FOLIAR APPLICATION OF Mo OVER ALL N TREATMENTS				
(0.0 kg Mo/ha)	25.0	23.6	30.8	25.8
(0.2 kg Mo/ha)	25.7	24.2	30.7	26.2
F-value	1.45	1.13	0.04	1.78
METHODS OF N APPLICATION OVER ALL Mo LEVELS				
Banded urea (60 kg N/ha)	25.8 a	24.0	30.8	26.5 a
Foliar urea (13.5 kg N/ha)	26.0 a	24.1	30.9	25.5 b
Control	24.2 b	23.6	30.7	25.8 ab
Mean	25.3	23.9	30.8	26.0
F-value	4.21*	0.29	0.04	4.03*
INTERACTIONS	----------------	F-value		----------------
Date and Mo	0.99	0.93	0.48	2.13
Date and Urea	0.87	0.45	0.85	0.60
Mo and Urea	0.20	2.11*	0.34	0.18
Date and Mo and Urea	0.21	0.95	0.16	1.37
C.V. (%)	11	9	8	6

* Significant at the 0.05 level; ** significant at the 0.01 level; means followed by the same letter are not significantly different according to Duncan's new multiple range test.

C.V. = coefficient of variability.

Cutcliffe and Gupta (1980) for some *Brassicae*, namely, cauliflower and Brussels sprouts.

Plant B levels increased as soil pH values decreased. This was probably a function of soil B levels (see Chapter 3). There was no effect of Mo on plant B levels. Urea treatments influenced B levels in plant-leaves at the two sites with pH values of 6.5 (1981 and 1982). In 1981, both N treatments increased plant B levels. In 1982, plants with banded urea had higher B content than plants with foliar urea, but neither treatment differed from the control.

The increase in plant B observed at one site (1981) at pH 6.5, is in accordance with work reported by Cutcliffe and Gupta (1980) where *Brassica* crops appeared to utilize B better when N was applied. The difference due to the methods of urea applications was not consistent and no site related properties were clearly related to these inconsistencies.

The N effect on plant B did not appear at low soil pH values, probably because B availability was sufficient at soil pH 5.1, with a soil B content of 0.5 ug B/g of dry soil. The lack of N effect on the soil with pH 7.3 with a soil B content of 0.3 ug B/g of dry soil, could be due to low B levels. For example, broccoli spear weight appeared to be affected by plant B levels only at this site, where B levels were correlated positively with spear weight (Table 3). Thus, the major impact of added N on B uptake appeared to be only at neutral pH values.

e) Broccoli Damage Index (DI)

A median value of 75% was observed for the damage index (DI) during 1981 trials, compared to a DI of 25% in 1982. The DI differences were not associated with treatments. However, DI values in 1981 trials were positively correlated at the 0.01 level (r_s = 0.59) with plant NO_3-N content across all plots (n = 48). There was no significant correlation of plant B with DI, which indicated that the hollow stem disorder was not related to B contents or possible deficiencies, as observed by Gupta and Cutcliffe (1973).

The NO_3-N and DI correlation was not found in 1982 trials despite higher NO_3-N levels compared to 1981 levels. Thus, neither B or added N were necessarily associated with DI values.

CONCLUSIONS

Methods of added N influenced N contents in plants with banded urea being more effective in increasing N uptake. However, this increased N uptake was not necessarily antagonistic with regards to K, Ca, Mg and B uptake. However, the tendency for banded urea to decrease K (1981, pH 6.5) and Ca (1982, pH 6.5) in one site out of four indicated that there may have been competition between NH_4^+ released in urea hydrolysis and K^+ and Ca^{++} for root absorption sites. Obviously, this competitive effect was not widespread.

Molybdenum had no effect on Ca, B and Mg levels despite the tendency to increase K content in one trial which was not felt to indicate a trend. Thus, in general, added N and Mo had little effect on the concentration of nutrients in the plant leaves and, at the rates used, did not create serious nutritional imbalances. However, K and Ca depressions have to be considered as possibilities.

The damage index observed seemed to be related to NO_3-N levels, but the NO_3-N level required varied from year to year. Thus, other environmental factors seemed to interact with NO_3-N as regards to the expression of the index.

Boron levels in broccoli leaves were higher with banded urea during both years at soil pH 6.5 when compared to B levels in control plots. Thus, the effects of added urea on the plant nutrient concentrations were marginal.

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CHAPTER 5

SUMMARY

This experiment constitutes original work as the direct effect of Mo on N recovery by broccoli had not been reported in the literature. The benefits of either banded or foliar applied urea on broccoli and other members of the cruciferous family were still inconclusive. This experiment showed that Mo treatment decreased the number of plants harvested early by an average of 14% in all trials, without affecting total yields.

The delay in plant maturity observed with Mo application could be quite detrimental for the fresh market because it is much more profitable to produce as early as possible. But for processing, this would not make any difference because harvest is done in a single harvest operation done later during the season.

The estimated percentage N recovery by plants of the supplemental fertilizer was 13 times greater with foliar applied urea compared to banded urea at soil pH 7.3 and 6.5, during both years.

The use of foliar N had only slight effects on broccoli as compared to banded urea, although it was noted that the use of the former method resulted in higher recovery by plants.

Banded urea applications increased broccoli fresh-spear weights by 14% during 1982 and appeared to be a better method to apply supplemental N fertilizer. Therefore, the interpretation of supplemental N effects on broccoli could be based mostly on yield results, rather than on leaf-nutrient concentrations.

APPENDIX

Table 1. Summary of broccoli nutrients content interactions over 24 plots, at different dates during 1981 trials at two soil pH.

INTERACTIONS	pH 6.5 DAYS 50	pH 6.5 DAYS 52	pH 6.5 DAYS 71	pH 6.5 DAYS 73	pH 7.3 DAYS 50	pH 7.3 DAYS 52	pH 7.3 DAYS 71	pH 7.3 DAYS 73
	R^2							
NO_3-N x T.N.	0.46**	0.79**	0.72**	0.58**	0.16*	0.35**	0.72**	0.61**
x B	NS	NS	0.19*	0.25**	0.40**	NS	NS	NS
x K	0.23*	0.38**	NS	NS	0.55**	0.50**	0.53**	0.56**
x Ca	NS	0.34**	NS	0.35**	0.24**	0.25*	0.36**	0.21*
x Mg	0.37**	NS	0.61**	NS	NS	NS	0.41**	0.56**
T.N. x B	NS	NS	0.37**	0.48**	NS	NS	0.19*	NS
x K	0.41**	0.34*	NS	NS	0.21*	0.19*	0.58**	0.59**
x Ca	NS	0.25*	NS	NS	NS	NS	NS	NS
x Mg	NS	NS	0.34**	NS	(-)0.17*	NS	0.21*	0.22*
B x K	NS	NS	NS	NS	0.26**	NS	NS	NS
x Ca	NS	NS	NS	NS	0.19*	NS	NS	NS
x Mg	NS	NS	0.18*	NS	NS	NS	NS	NS
K x Ca	NS	NS	NS	NS	NS	NS	0.20*	NS
x Mg	NS	NS	NS	NS	NS	NS	0.23*	0.30*
Ca x Mg	0.21*	0.26*	NS	NS	0.20*	NS	0.21*	NS

* Significant at the 0.05 level; ** significant at the 0.01 level.

R^2 = coefficient of regression

(-) = negative r values

NS = non significant

Table 2. Summary of broccoli nutrients content correlations with plant yield parameters, at different sampling dates, during 1981 trials at two soil pH.

INTERACTIONS	pH 6.5 DAYS 50	pH 6.5 DAYS 52	pH 6.5 DAYS 71	pH 6.5 DAYS 73	pH 7.3 DAYS 50	pH 7.3 DAYS 52	pH 7.3 DAYS 71	pH 7.3 DAYS 73
	R^2							
F.S.W.[a] VERSUS:								
NO_3-N	N.S.	N.S.	0.23*	0.22*	0.33**	0.19*	0.46**	0.35**
Total N	N.S.	N.S.	0.24*	0.20*	0.33**	0.42**	0.46**	0.37**
B	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	0.18*	N.S.
K	N.S.	N.S.	N.S.	N.S.	0.28**	N.S.	0.26**	0.29**
Ca	N.S.	0.16*	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Mg	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	0.19*	0.21*
T.P.H.[b] VERSUS:								
NO_3-N	0.19*	N.S.	0.25*	0.23*	0.35**	N.S.	0.19*	0.33**
Total N	0.26*	0.16*	N.S.	N.S.	0.34**	0.30**	0.26*	N.S.
B	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
K	0.36*	N.S.	N.S.	N.S.	0.24*	N.S.	N.S.	N.S.
Ca	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Mg	N.S.	N.S.	0.23*	N.S.	N.S.	N.S.	N.S.	N.S.

[a] F.S.W. = fresh spear weight

[b] T.P.H. = total plant height

* Significant at the 0.05 level; ** significant at the 0.01 level.

Correlations were calculated over data collected on each plot.

N.S. = non significant results

Table 3. Summary of broccoli nutrients content interactions over 24 plots at different sampling dates, during 1981 trials at two soil pH.

INTERACTIONS	pH 5.1 DAYS				pH 6.5 DAYS			
	75	77	84	87	75	77	84	87
	R^2							
NO_3-N x T.N.	N.S.	N.S.	0.20*	0.18*	0.23*	0.51**	0.28**	0.69**
x B	N.S.	N.S.	0.21*	(-)0.25*	N.S.	N.S.	N.S.	N.S.
x K	N.S.	0.24*	0.38**	0.22*	N.S.	N.S.	N.S.	N.S.
x Ca	0.25*	0.50**	N.S.	0.24*	0.19*	N.S.	0.18*	N.S.
x Mg	N.S.	0.25*	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
T.N. x B	N.S.	N.S.	0.50**	N.S.	N.S.	N.S.	N.S.	0.17*
x K	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
x Ca	(-)0.29**	N.S.	N.S.	N.S.	N.S.	(-)0.30*	N.S.	N.S.
x Mg	(-)0.44**	N.S.	N.S.	N.S.	(-)0.35**	(-)0.34**	N.S.	N.S.
B x K	N.S.	N.S.	(-)0.19*	(-)0.45**	N.S.	N.S.	N.S.	0.22*
x Ca	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
x Mg	N.S.	0.19*	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
K x Ca	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
x Mg	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Ca x Mg	0.40**	0.44**	0.35**	0.31**	0.25*	0.51**	0.53**	0.38**

* Significant at the 0.05 level; ** significant at the 0.01 level

N.S. = non significant

(-) = negative r value

Table 4. Summary of broccoli nutrients content correlations with plant yield parameters, at different sampling dates, during 1982 trials at two soil pH.

	pH 5.1				pH 6.5			
	DAYS				DAYS			
INTERACTIONS	75	77	84	87	75	77	84	87
	R^2							
F.S.W.[a] VERSUS:								
NO_3-N	N.S.	N.S.	N.S.	N.S.	N.S.	0.33*	0.20*	0.33**
Total N	N.S.	N.S.	N.S.	N.S.	0.52**	0.58**	0.68**	0.54**
B	N.S.	0.19*	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
K	N.S.	(-)0.20*	N.S.	N.S.	(-)0.26**	N.S.	N.S.	N.S.
Ca	N.S.	N.S.	N.S.	N.S.	N.S.	(-)0.21*	N.S.	N.S.
Mg	N.S.	N.S.	N.S.	N.S.	(-)0.41**	(-)0.37*	(-)0.22*	N.S.
T.P.H.[b] VERSUS:								
NO_3-N	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	0.17*
Total N	N.S.	N.S.	0.19*	0.22*	0.19*	N.S.	0.16*	0.31**
B	0.20*	N.S.	N.S.	N.S.	N.S.	N.S.	0.24*	N.S.
K	N.S.	N.S.	N.S.	N.S.	N.S	N.S.	N.S.	N.S.
Ca	N.S.	N.S.	N.S.	N.S.	N.S.	(-)0.18*	N.S.	N.S.
Mg	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

* Significant at the 0.05 level; ** significant at the 0.01 level.

[a] F.S.W. = fresh spear weight

[b] T.P.H. = total plant height

N.S. = non significant results

(-) = negative r values

Table 5. Plant nitrate-N levels at 50, 52, 71 and 73 days sampling during 1981 trials at two soil pH levels.

	NO_3-N							
	pH 6.5				pH 7.3			
TREATMENTS	50	52	71	73	50	52	71	73
	%							
FOLIAR APPLICATION OF Mo OVER ALL N TREATMENTS								
(0.0 kg Mo/ha)	1.25	1.17	0.59	0.51	1.45	1.15	0.84	0.78
(0.2 kg Mo/ha)	1.44	1.25	0.68	0.67	1.40	1.15	0.80	0.64
F-value:	2.81	0.41	0.79	1.27	0.20	0.01	0.16	1.46
METHODS OF N APPLICATION OVER ALL Mo LEVELS								
Banded urea (60 kg N/ha)	1.44	1.25	0.68	0.67	1.40	1.15	0.80	0.64
Foliar urea (13.5 kg N/ha)	1.27	1.26	0.62	0.52	1.36	1.12	0.70	0.61
Control	1.41	1.15	0.58	0.54	1.37	1.17	0.82	0.65
F-value:	0.46	0.26	0.44	0.66	1.32	0.25	2.36	2.04
INDIVIDUAL TREATMENTS								
Banded	1.26	1.11	0.72	0.52	1.59	1.15	0.94	0.94
Foliar urea	1.14	1.29	0.53	0.46	1.37	1.14	0.79	0.76
Control	1.36	1.13	0.51	0.55	1.38	1.14	0.78	0.63
Mo and banded urea	1.45	1.35	0.69	0.89	1.49	1.18	0.93	0.80
Mo and foliar urea	1.41	1.24	0.72	0.59	1.34	1.08	0.61	0.45
Mo	1.46	1.18	0.65	0.53	1.37	1.21	0.87	0.67
Mean:	1.34	1.22	0.64	0.59	1.42	1.15	0.82	0.71
F-value:	0.20	0.43	0.30	0.60	0.07	0.31	0.79	0.83
Coefficient of variation (%):	38.3	26.3	44.8	61.9	18.4	16.1	27.1	37.6

Table 6. Plant nitrate-N levels at 75, 77, 84 and 87 days sampling during 1982 trials at two soil pH levels.

TREATMENTS	NO_3-N pH 5.1 75	77	84	87	pH 6.5 75	77	84	87
	%							
FOLIAR APPLICATION OF Mo OVER ALL N TREATMENTS								
(0.0 kg Mo/ha)	1.48	1.52	1.20	1.57	1.38	1.41	1.17	1.35
(0.2 kg Mo/ha)	1.47	1.56	1.24	1.52	1.37	1.32	1.16	1.18
F-value:	0.36	0.20	0.68	0.32	0.08	0.66	0.02	1.78
METHODS OF N APPLICATION OVER ALL Mo LEVELS								
Banded urea (60 kg N/ha)	1.50	1.70a	1.31	1.66	1.41	1.52	1.32a	1.41
Foliar urea (13.5 kg N/ha)	1.46	1.58ab	1.14	1.52	1.36	1.36	1.16ab	1.34
Control	1.45	1.36 b	1.21	1.47	1.35	1.20	1.02 b	1.04
F-value:	0.28	3.70*	3.63	2.21	0.27	3.03	6.46**	3.28
INDIVIDUAL TREATMENTS								
Banded urea	1.47	1.73	1.22	1.65	1.39	1.57	1.37	1.41
Foliar urea	1.51	1.47	1.12	1.52	1.41	1.35	1.14	1.41
Control	1.45	1.35	1.24	1.54	1.32	1.30	0.99	1.22
Mo and banded urea	1.52	1.63	1.40	1.66	1.43	1.48	1.27	1.42
Mo and foliar urea	1.42	1.68	1.16	1.51	1.31	1.38	1.16	1.26
Mo	1.46	1.37	1.17	1.40	1.37	1.11	1.04	0.85
Mean:	1.47	1.54	1.22	1.55	1.37	1.36	1.16	1.26
F-value:	0.61	0.91	1.90	0.44	0.37	0.35	0.40	0.75
Coefficient of variation (%):	8.6	15.8	10.4	12.4	14.8	19.9	15.2	25.5

* Significant at the 0.05 level; ** significant at the 0.01 level; means followed by the same letter are not significantly different according to Duncan's multiple range test.

Table 7. Plant total N levels at 50, 52, 71 and 73 days sampling during 1981 trials at two soil pH levels.

TREATMENTS	Total N							
	pH 6.5				pH 7.3			
	50	52	71	73	50	52	71	73
	%							
FOLIAR APPLICATION OF Mo OVER ALL N TREATMENTS								
(0.0 kg Mo/ha)	3.83	3.52	2.83	2.63	4.13	3.86	3.37	2.84
(0.2 kg Mo/ha)	3.77	3.63	3.30	2.67	4.08	3.90	3.16	2.99
F-value:	0.07	0.32	3.52	0.04	0.11	0.11	0.76	0.46
METHODS OF N APPLICATION OVER ALL Mo LEVELS								
Banded urea (60 kg N/ha)	3.87	3.46	3.26	2.78	4.18	3.99	3.46	3.11
Foliar urea (13.5 kg N/ha)	3.69	3.75	3.09	2.70	4.14	3.89	3.08	2.84
Control	3.85	3.51	2.85	2.48	4.00	3.76	3.26	2.80
F-value:	0.27	0.80	0.87	0.52	0.49	1.28	0.94	0.79
INDIVIDUAL TREATMENTS								
Banded urea	3.93	3.29	3.14	2.63	4.08	4.00	3.59	2.95
Foliar urea	3.63	3.88	2.79	2.72	4.19	3.90	3.24	2.95
Control	3.94	3.89	2.57	2.54	4.13	3.69	3.27	2.64
Mo and banded urea	3.82	3.63	3.37	2.93	4.28	3.98	3.34	3.27
Mo and foliar urea	3.62	3.40	2.68	4.10	3.88	3.84	3.24	2.97
Mo	3.76	3.63	3.14	2.42	3.87	3.84	3.24	2.97
Mean:	3.83	3.57	3.07	2.65	4.11	3.88	3.27	2.92
F-value:	0.17	0.88	0.22	0.27	0.73	0.23	0.14	0.66
Coefficient of variation (%):	14.8	14.1	20.7	23.6	9.7	7.6	17.9	17.3

Table 8. Plant total N levels at 75, 77, 84 and 87 days sampling during 1982 trials at two soil pH levels.

TREATMENTS	Total N pH 5.1 75	77	84	87	pH 6.5 75	77	84	87
	%							
FOLIAR APPLICATION OF Mo OVER ALL N TREATMENTS								
(0.0 kg Mo/ha)	2.98	2.51	2.64	2.42	2.48	2.47	2.76	3.13
(0.2 kg Mo/ha)	2.92	2.51	2.62	2.39	2.48	2.42	2.84	3.07
F-value:	1.40	0.00	0.10	0.08	0.02	0.25	0.73	0.46
METHODS OF N APPLICATION OVER ALL Mo LEVELS								
Banded urea (60 kg N/ha)	2.94	2.54	2.75a	2.58a	2.60	2.60	3.10a	3.34a
Foliar urea (13.5 kg N/ha)	2.97	2.50	2.70a	2.36 b	2.49	2.38	2.80 b	3.06 b
Control	2.94	2.49	2.44 b	2.29 b	2.36	2.36	2.51 c	2.90 b
F-value:	0.17	0.64	5.26*	3.89*	2.10	2.33	13.00**	8.17**
INDIVIDUAL TREATMENTS								
Banded urea	2.98	2.46	2.78	2.58	2.54	2.65	3.00	3.28
Foliar urea	3.00	2.54	2.74	2.37	2.54	2.45	2.79	3.19
Control	2.95	2.54	2.41	2.30	2.38	2.32	2.50	2.93
Mo and banded urea	2.89	2.62	2.73	2.57	2.66	2.55	3.20	3.40
Mo and foliar urea	2.93	2.47	2.66	2.35	2.44	2.31	2.82	2.94
Mo	2.93	2.45	2.46	2.27	2.34	2.40	2.52	2.88
Mean:	2.95	2.51	2.63	2.41	2.48	2.45	2.80	3.10
F-value:	0.16	4.48*	0.20	0.01	0.44	0.43	0.40	1.40
Coefficient of variation (%):	4.2	3.8	8.2	9.2	9.9	10.5	8.5	7.3

* Significant at the 0.05 level; ** significant at the 0.01 level; means followed by the same letter are not significantly different according to Duncan's multiple range test.

Table 9. Plant potassium levels at 50, 52, 71 and 73 days sampling during 1981 trials at two soil pH levels.

TREATMENTS	K							
	pH 6.5				pH 7.3			
	50	52	71	73	50	52	71	73
	%							
FOLIAR APPLICATION OF Mo OVER ALL N TREATMENTS								
(0.0 kg Mo/ha)	4.30 b	4.37	3.17 b	3.19	4.53	4.13	3.39	3.14
(0.2 kg Mo/ha)	4.89a	4.78	3.57a	3.72	4.42	4.23	3.21	3.25
F-value:	5.30*	2.34	5.01*	3.62	0.15	0.37	0.69	0.44
METHODS OF N APPLICATION OVER ALL Mo LEVELS								
Banded urea (60 kg N/ha)	4.41	4.51	2.98a	3.19	4.48	4.22	3.16	3.21
Foliar urea (13.5 kg N/ha)	4.57	4.62	3.69 b	3.63 b	4.22	4.03	3.26	3.12
Control	4.80	4.59	3.44 b	3.54	4.73	4.28	3.48	3.25
F-value:	0.79	0.06	5.61*	0.93	1.14	0.77	0.79	0.24
INDIVIDUAL TREATMENTS								
Banded urea	4.13	4.00	2.74	2.48	4.58	4.17	3.15	3.19
Foliar urea	4.16	4.57	3.53	3.63	4.23	4.04	3.58	3.10
Control	4.62	4.56	3.25	3.46	4.77	4.18	3.43	3.12
Mo and banded urea	4.70	5.03	3.22	3.90	4.38	4.27	3.16	3.23
Mo and foliar urea	4.98	4.67	3.85	3.63	4.21	4.04	2.94	3.13
Mo	4.99	4.62	3.64	3.62	4.68	4.37	3.53	3.38
Mean:	4.60	4.57	3.37	3.45	4.47	4.18	3.30	3.19
F-value:	0.23	1.44	0.07	2.61	0.04	0.12	1.22	0.22
Coefficient of variation (%):	13.3	14.5	13.3	20.4	15.6	10.0	16.4	14.0

* Significant at the 0.05 level; means followed by the same letter are not significantly different according to Duncan's multiple range test.

Table 10. Plant potassium levels at 75, 77, 84 and 87 days sampling during 1982 trials at two soil pH levels.

TREATMENTS	K							
	pH 5.1				pH 6.5			
	75	77	84	87	75	77	84	87
	%							
FOLIAR APPLICATION OF Mo OVER ALL N TREATMENTS								
(0.0 kg Mo/ha)	4.35	3.92	3.57	3.45	3.82	3.54	3.22	3.02
(0.2 kg Mo/ha)	4.23	3.84	3.51	3.34	3.93	3.49	3.35	3.05
F-value:	2.02	0.09	0.38	2.51	1.05	0.30	2.46	0.07
METHODS OF N APPLICATION OVER ALL Mo LEVELS								
Banded urea (60 kg N/ha)	4.17	3.88	3.55	3.34	3.84	3.51	3.29	2.93
Foliar urea (13.5 kg N/ha)	4.26	3.93	3.54	3.40	3.73	3.43	3.32	3.09
Control	4.43	3.84	3.54	3.45	4.06	3.61	3.25	3.08
F-value:	2.93	0.31	0.00	0.84	2.94	1.25	0.23	0.95
INDIVIDUAL TREATMENTS								
Banded urea	4.17	3.92	3.51	3.44	3.75	3.52	3.24	2.79
Foliar urea	4.36	3.94	3.61	3.41	3.76	3.45	3.26	3.13
Control	4.53	3.92	3.60	3.50	3.95	3.65	3.16	3.14
Mo and banded urea	4.18	3.84	3.58	3.23	3.93	3.50	3.34	3.08
Mo and foliar urea	4.16	3.92	3.48	3.39	3.71	3.41	3.37	3.04
Mo	4.34	3.77	3.47	3.39	4.17	3.56	3.34	3.02
Mean:	4.29	3.88	3.54	3.39	3.88	3.52	3.29	3.03
F-value:	0.52	0.20	0.46	0.66	0.53	0.04	0.08	1.76
Coefficient of variation (%):	5.3	5.7	6.7	5.2	7.4	6.5	6.5	8.5

Table 11. Plant boron levels at 50, 52, 71 and 73 days sampling during 1981 trials at two soil pH levels.

TREATMENTS	B pH 6.5 50	52	71	73	pH 7.3 50	52	71	73
	µg/g							
FOLIAR APPLICATION OF Mo OVER ALL N TREATMENTS								
(0.0 kg Mo/ha)	27.4	23.6	22.4	26.9	28.2	22.8	18.3	24.5 b
(0.2 kg Mo/ha)	26.6	23.9	23.5	28.5	27.8	23.6	19.6	26.3a
F-value:	0.79	0.13	0.54	2.27	0.16	0.78	1.48	4.63*
METHODS OF N APPLICATION OVER ALL Mo LEVELS								
Banded urea (60 kg N/ha)	28.0	23.3	23.9	27.8	28.6	23.0	19.2	25.3
Foliar urea (13.5 kg N/ha)	27.0	24.2	23.7	29.2	27.8	23.0	19.8	25.3
Control	26.0	23.7	21.3	26.2	27.7	23.6	17.9	25.1
F-value:	2.00	0.30	1.04	2.51	0.27	0.25	1.21	0.20
INDIVIDUAL TREATMENTS								
Banded urea	28.9	23.1	23.0	26.3	29.4	21.3	17.6	24.2
Foliar urea	27.4	24.4	22.9	29.0	27.3	22.9	18.8	24.7
Control	25.8	23.3	21.3	25.5	27.9	24.3	18.5	24.5
Mo and banded urea	27.2	23.6	24.8	29.3	27.7	24.6	20.7	26.4
Mo and foliar urea	26.5	24.1	24.5	29.3	28.2	23.2	20.8	26.8
Mo	26.1	24.1	21.4	27.0	27.5	23.0	17.3	25.6
Mean:	27.0	23.8	23.0	27.7	28.0	23.2	18.9	25.4
F-value:	0.45	0.12	0.12	0.50	0.49	2.61	1.48	0.20
Coefficient of variation (%):	8.0	10.1	16.6	9.8	9.5	9.2	13.7	7.5

* Significant at the 0.05 level; means followed by the same letter are not different according to Duncan's multiple range test.

Table 12. Plant boron levels at 75, 77, 84 and 87 days sampling during 1982 trials at two soil pH levels.

	B							
	pH 5.1				pH 6.5			
TREATMENTS	75	77	84	87	75	77	84	87
	µg/g							
FOLIAR APPLICATION OF Mo OVER ALL N TREATMENTS								
(0.0 kg Mo/ha)	31.0	29.6	26.6	36.2	24.6	24.9	27.9 b	25.6
(0.2 kg Mo/ha)	31.9	28.8	26.4	35.9	24.5	24.6	29.6a	25.9
F-value:	0.37	0.85	0.06	0.13	0.01	0.39	4.19*	0.70
METHODS OF N APPLICATION OVER ALL Mo LEVELS								
Banded urea (60 kg N/ha)	31.9	27.8	26.7	36.7	24.9	25.2	29.5	26.6a
Foliar urea (13.5 kg N/ha)	31.0	29.9	26.7	35.9	23.7	24.6	28.4	25.2 b
Control	31.4	29.8	26.0	35.5	25.1	24.4	28.4	25.4 b
F-value:	0.13	2.37	0.37	0.71	1.72	0.82	0.73	4.53*
INDIVIDUAL TREATMENTS								
Banded urea	31.0	28.0	27.0	36.4	24.7	26.5	28.3	26.2
Foliar urea	30.7	30.8	26.7	36.6	23.9	24.1	28.0	25.4
Control	31.3	29.9	26.1	35.7	25.2	24.3	27.4	25.1
Mo and banded urea	32.8	27.7	26.5	37.1	25.1	24.0	30.6	27.0
Mo and foliar urea	31.3	28.9	26.8	35.3	23.6	25.2	28.9	25.0
Mo	31.6	29.7	25.9	35.3	24.9	24.6	29.4	25.8
Mean:	31.4	29.2	26.5	36.1	24.6	24.8	28.8	25.7
F-value:	0.09	0.40	0.05	0.46	0.16	4.14*	0.30	0.82
Coefficient of variation (%):	12.1	10.0	7.3	6.1	6.5	5.5	7.1	4.0

* Significant at the 0.05 level; means followed by the same letter are not different according to Duncan's new multiple range test.

Table 13. Plant calcium levels at 50, 52, 71 and 73 days sampling during 1981 trials at two soil pH levels.

	Ca							
	pH 6.5				pH 7.3			
TREATMENTS	50	52	71	73	50	52	71	73
	%							
FOLIAR APPLICATION OF Mo OVER ALL N TREATMENTS								
(0.0 kg Mo/ha)	1.12	1.13	1.06	0.91	1.28	1.16	1.19	1.20
(0.2 kg Mo/ha)	1.22	1.01	0.90	1.01	1.21	1.08	1.21	1.07
F-value:	1.94	2.97	3.47	0.71	0.02	1.67	0.13	2.17
METHODS OF N APPLICATION OVER ALL Mo LEVELS								
Banded urea (60 kg N/ha)	1.20	1.12	0.99	1.02	1.31	1.02	1.24	1.17
Foliar urea (13.5 kg N/ha)	1.22	1.10	0.96	0.94	1.23	1.18	1.17	0.98
Control	1.08	0.98	1.00	0.94	1.22	1.16	1.21	1.25
F-value:	1.42	1.71	0.07	0.22	0.56	2.90	0.43	2.94
INDIVIDUAL TREATMENTS								
Banded urea	1.21	1.14	1.18	1.03	1.35	1.05	1.19	1.25
Foliar urea	1.12	1.19	0.99	0.85	1.24	1.28	1.22	1.05
Control	0.97	1.04	1.00	0.86	1.28	1.15	1.17	1.31
Mo and banded urea	1.18	1.10	0.79	1.01	1.26	0.99	1.28	1.10
Mo and foliar urea	1.27	1.01	0.93	1.02	1.22	1.09	1.11	0.91
Mo	1.20	0.91	1.00	1.01	1.14	1.17	1.25	1.19
Mean:	1.17	1.07	0.98	0.86	1.25	1.12	1.20	1.13
F-value:	1.10	0.39	2.14	0.26	0.26	1.00	1.20	0.01
Coefficient of variation (%):	15.6	51.9	21.3	31.3	13.6	13.0	12.4	18.3

Table 14. Plant calcium levels at 75, 77, 84 and 87 days sampling during 1982 trials at two soil pH levels.

TREATMENTS	Ca							
	pH 5.1				pH 6.5			
	75	77	84	87	75	77	84	87
	%							
FOLIAR APPLICATION OF Mo OVER ALL N TREATMENTS								
(0.0 kg Mo/ha)	0.91 b	1.00	0.99	1.19	1.09	1.10	1.06	1.30
(0.2 kg Mo/ha)	0.97 a	1.02	0.97	1.20	1.09	1.12	1.08	1.34
F-value:	10.64**	0.11	0.47	0.01	0.00	0.42	0.37	1.27
METHODS OF N APPLICATION OVER ALL Mo LEVELS								
Banded urea (60 kg N/ha)	0.96	1.06	1.02	1.21	1.06	1.10	1.06	1.27
Foliar urea (13.5 kg N/ha)	0.93	1.02	0.94	1.20	1.11	1.11	1.09	1.38
Control	0.92	0.94	0.98	1.18	1.11	1.12	1.06	1.30
F-value:	1.99	3.62	2.20	0.22	1.96	0.06	0.56	2.75
INDIVIDUAL TREATMENTS								
Banded urea	0.93	1.09	0.97	1.22	1.05	1.10	1.08	1.26
Foliar urea	0.90	0.95	0.98	1.16	1.11	1.08	1.07	1.36
Control	0.90	0.98	1.02	1.20	1.12	1.12	1.04	1.27
Mo and banded urea	1.00	1.04	1.07	1.21	1.06	1.10	1.04	1.29
Mo and foliar urea	0.96	1.10	0.91	1.24	1.11	1.14	1.12	1.40
Mo	0.94	0.91	0.93	1.15	1.11	1.11	1.09	1.33
Mean:	0.94	1.01	0.98	1.20	1.09	1.11	1.07	1.32
F-value:	0.29	3.66*	4.75*	0.55	0.06	0.47	1.24	0.06
Coefficient of variation (%):	4.7	9.3	6.7	10.1	5.6	6.6	6.7	7.4

* Significant at the 0.05 level; ** significant at the 0.01 level; means followed by the same letter are not different according to Duncan's new multiple range test.

Table 15. Plant magnesium levels at 50, 52, 71 and 73 days sampling during 1981 trials at two soil pH levels.

TREATMENTS	Mg							
	pH 6.5				pH 7.3			
	50	52	71	73	50	52	71	73
	%							
FOLIAR APPLICATION OF Mo OVER ALL N TREATMENTS								
(0.0 kg Mo/ha)	0.35	0.33	0.21	0.21	0.39	0.36	0.29	0.29
(0.2 kg Mo/ha)	0.36	0.35	0.23	0.24	0.37	0.37	0.30	0.28
F-value:	0.72	1.10	2.12	0.98	0.28	0.12	0.20	0.35
METHODS OF N APPLICATION OVER ALL Mo LEVELS								
Banded urea (60 kg N/ha)	0.36	0.34	0.24	0.25	0.39	0.36a	0.31	0.29
Foliar urea (13.5 kg N/ha)	0.35	0.34	0.21	0.20	0.40	0.39 b	0.29	0.28
Control	0.35	0.34	0.21	0.23	0.36	0.36a	0.29	0.27
F-value:	0.12	0.04	1.26	0.87	0.26	5.45*	0.45	0.20
INDIVIDUAL TREATMENTS								
Banded urea	0.37	0.35	0.23	0.25	0.40	0.34	0.29	0.28
Foliar urea	0.33	0.36	0.20	0.19	0.39	0.41	0.31	0.32
Control	0.34	0.34	0.18	0.20	0.37	0.34	0.28	0.27
Mo and banded urea	0.36	0.32	0.24	0.25	0.39	0.37	0.32	0.31
Mo and foliar urea	0.36	0.33	0.21	0.22	0.41	0.36	0.28	0.25
Mo	0.37	0.34	0.24	0.25	0.32	0.37	0.30	0.28
Mean:	0.35	0.34	0.22	0.23	0.39	0.37	0.30	0.28
F-value:	0.43	0.18	0.89	0.28	0.20	8.11**	1.30	1.60
Coefficient of variation (%):	15.7	14.6	18.4	30.2	10.3	5.8	13.7	19.6

* Significant differences at the 0.05 level; ** significant differences at the 0.01 level; means followed by the same letter are not different according to Duncan's new multiple range test.

Table 16. Plant magnesium levels at 75, 77, 84 and 87 days sampling during 1982 trials at two soil pH levels.

TREATMENTS	Mg							
	pH 5.1				pH 6.5			
	75	77	84	87	75	77	84	87
	%							
FOLIAR APPLICATION OF Mo OVER ALL N TREATMENTS								
(0.0 kg Mo/ha)	0.32a	0.35	0.30	0.32	0.42	0.41	0.36	0.33
(0.2 kg Mo/ha)	0.34 b	0.37	0.29	0.32	0.41	0.42	0.36	0.34
F-value:	7.12**	1.02	0.72	0.41	0.11	0.02	0.00	1.38
METHODS OF N APPLICATION OVER ALL Mo LEVELS								
Banded urea (60 kg N/ha)	0.33	0.38	0.31	0.32	0.40	0.42	0.37	0.34
Foliar urea (13.5 kg N/ha)	0.33	0.36	0.29	0.32	0.42	0.41	0.37	0.35
Control	0.32	0.33	0.29	0.32	0.43	0.41	0.34	0.32
F-value:	1.14	2.02	1.33	0.22	0.69	0.08	1.23	1.77
INDIVIDUAL TREATMENTS								
Banded urea	0.31	0.36	0.30	0.32	0.41	0.44	0.39	0.34
Foliar urea	0.32	0.33	0.29	0.31	0.42	0.41	0.37	0.34
Control	0.32	0.35	0.30	0.32	0.42	0.39	0.33	0.30
Mo and banded urea	0.35	0.40	0.31	0.32	0.39	0.40	0.35	0.34
Mo and foliar urea	0.34	0.39	0.28	0.33	0.41	0.42	0.37	0.35
Mo	0.32	0.31	0.28	0.32	0.43	0.52	0.36	0.34
Mean:	0.33	0.36	0.29	0.32	0.41	0.41	0.36	0.33
F-value:	1.20	2.28	1.17	0.64	0.08	1.28	1.52	1.46
Coefficient of variation (%):	5.9	15.3	10.1	7.9	12.3	10.1	11.7	9.3

* Significant at the 0.05 level; ** significant at the 0.01 level; means followed by the same letter are not different according to Duncan's new multiple range test.

Table 17. Estimated N recovery (ENR) by broccoli plants during the 1981 trials at 4 sampling dates.

TREATMENTS	ENR							
	pH 6.5				pH 7.3			
	50	52	71	77	50	52	73	77
	%							
FOLIAR APPLICATION OF Mo OVER ALL N TREATMENTS								
(0.0 kg Mo/ha)	37	178	226	85	125	155	95	162
(0.2 kg Mo/ha)	-25	176	330	93	39	94	-41	83
F-value:	0.12	0.00	0.53	0.00	0.53	0.79	1.91	1.82
METHODS OF N APPLICATION OVER ALL Mo LEVELS								
Banded urea (60 kg N/ha)	-22	-3	79a	25	33	57	45	71
Foliar urea (13.5 kg N/ha)	34	356	477b	153	120	192	9	175
F-value:	0.10	3.68	7.58**	0.74	0.69	3.92	0.14	3.16
INDIVIDUAL TREATMENTS								
Banded urea	-1	-14	77	14	28	63	63	58
Foliar urea	75	370	374	156	201	247	126	266
Mo and banded urea	-42	9	81	35	39	51	28	84
Mo and foliar urea	-7	343	580	151	39	138	-109	83
Mean:	6	177	278	89	77	125	27	123
F-value:	0.01	0.02	0.49	0.72	0.69	0.51	1.04	3.22
Coefficient of variation (%):	2955	106	52	168	182	55	363	48

** Significant at the 0.01 level; means followed by the same letter are not different according to Duncan's new multiple range test.

Table 18. Estimated N recovery (ENR) by broccoli plants during the 1982 trials at 4 sampling dates.

TREATMENTS	ENR							
	pH 5.1				pH 6.5			
	75	77	84	87	75	77	84	87
	%							
FOLIAR APPLICATION OF Mo OVER ALL N TREATMENTS								
(0.0 kg Mo/ha)	-93	-79	-2	-55	100	104	141	136
(0.2 kg Mo/ha)	-80	-78	-8	-50	71	58	145	80
F-value:	0.05	0.00	0.02	0.08	0.24	0.50	0.02	0.83
METHODS OF N APPLICATION OVER ALL Mo LEVELS								
Banded urea (60 kg N/ha)	-17a	-17a	7	4a	57	60	92	82
Foliar urea (13.5 kg N/ha)	-156 b	-140 b	-17	-10 b	115	101	193	133
F-value:	5.56*	6.44*	0.40	32.9**	0.98	0.38	1.21	0.67
INDIVIDUAL TREATMENTS								
Banded urea	3	-10	38	28a	37	51	65	58
Foliar urea	-189	-149	-42	-138 c	164	156	217	214
Mo and banded urea	-36	-25	-25	-19ab	76	70	120	107
Mo and foliar urea	-124	-131	9	-81 bc	67	45	170	53
Mean:	-87	-79	-5	-53	72	81	143	108
F-value:	0.76	0.12	2.43	6.95*	1.33	0.99	0.32	2.86
Coefficient of variation (%):	68	62	72	37	83	81	64	58

* Significant at the 0.01 level; ** significant at the 0.01 level; means followed by the same letter are not different according to Duncan's new multiple range test.

Table 19. Covariance analysis of soil NO_3-N levels, adjusted to initial levels at the end of the 1981 trials at two soil depths and soil pH levels.

TREATMENTS	ADJUSTED MEANS pH 6.5 (0-20 cm)	pH 6.5 (25-50 cm)	pH 7.3 (0-20 cm)	pH 7.3 (25-50 cm)
	(µg N/g dry-soil)			
FOLIAR APPLICATION OF Mo OVER ALL N TREATMENTS				
(0.0 kg Mo/ha)	2.94	2.78	2.93	3.00
(0.2 kg Mo/ha)	2.22	2.55	3.34	3.52
F-value:	0.80	0.46	0.58	1.94
METHODS OF N APPLICATION OVER ALL Mo LEVELS				
Banded urea (60 kg N/ha)	1.79	2.19	2.88	3.22
Foliar urea (13.5 kg N/ha)	3.32	2.85	3.08	3.13
Control	2.63	2.95	3.45	3.43
Mean:	2.58	2.67	3.14	3.26
F-value:	1.08	1.51	0.40	0.23
C.V. (%)	77	31	50	29