THE RESPONSE OF SMALL WHITE BEAN (*Phaseolus vulgaris* L.) TO DIFFERENT NITROGEN AND MOLYBDENUM FERTILIZER APPLICATIONS

By

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Dedicated to

My parents, *viz.* my father- Obbo Fayyisaa Araaramee, my mother- Aadde Meetii Guddataa, and my sister- Obbole Gaaddisee Fayyisaa

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DECLARATION

I declare that the thesis hereby submitted by me for the fulfillment of the Masters of Science degree in Agriculture at the University of the Free State is my own independent original work and has not been submitted by me at any university. I furthermore declare copyright of the thesis in favour of me and the University of the Free State.

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ABSTRACT

THE RESPONSE OF SMALL WHITE BEAN (*Phaseolus vulgaris* L.) TO DIFFERENT NITROGEN AND MOLYBDENUM FERTILIZER APPLICATIONS

Dry bean production is normally associated with high soil fertility rich in organic matter content. However, dry beans are not exhibited dramatic improvements of seed yield through the development of high yielding cultivars, improved cultural practices and the use of external inputs, especially fertilizers when compared to other crops. The current acute bean shortage resulted in the need for better production systems to increase yield through fertilization. This study was therefore conducted with the objectives of investigating the role of N and Mo fertilizers in determining the growth and yield of beans, the different rates of N in band and broadcast placement methods that can give optimum yield, and the amount of total protein and total Mo found in the dry seeds as a result of the applied fertilizers.

Two separate pot experiments of band and broadcast placement of N in different rates with and without Mo were executed during 2000/2001 growing season in the glasshouse at the University of the Free State, Bloemfontein, South Africa. Each pot was filled with red brown soil and planted to a dry bean cultivar, PAN 181. The plant density was maintained at three plants per pot. A completely randomized design with factorial combination consisting of four N levels (0, 20, 40 and 60 kg N ha^{-1}) and three Mo treatments (0, 100 g Mo ha^{-1} leaf spray and 100 g Mo ha^{-1} seed treatment) replicated four times was used in the experiment.

The results obtained indicated that the application of N and Mo fertilizers did not significantly affect the vegetative growth as well as the reproductive development of the tested dry bean cultivar. However, the application of N in band placement with Mo treatments affected seed yield more than the broadcast placement. With the band N placement method, higher seed yield was achieved at 60 kg N ha^{-1} with seed treated Mo while that of broadcast N placement was at zero N with seed treated Mo.

With regard to the nutrient content of the dry seeds, higher seed total protein was obtained at 60 kg N ha^{-1} with zero Mo in banded N and at zero N with seed treated Mo in broadcasted N. Higher seed Mo content was achieved at 60 kg N ha^{-1} with seed treated Mo in band N placement whereas in broadcast N placement it was at zero N with seed treated Mo.

Finally, further field trials are recommended in order to verify the glasshouse results under field conditions.

Keywords: beans, fertilizer, nitrogen, molybdenum, banding, broadcasting, leaf application, seed treatment.

UITTREKSEL

DIE REAKSIE VAN KLEINWIT BONE (*Phaseolus vulgaris* L.) OP VERSKILLENDE STIKSTOF EN MOLIBDEEN BEMESTING TOEDIENINGS.

Droëboon produksie word normaalweg geassosieer met hoë grondvrugbaarheid, hoog in organiese materiaal. Droëbone toon egter nie dramatiese verbetering in saadopbrengs as gevolg van die ontwikkeling van hoë opbrengs cultivars, verbeterde verbouingspraktyke en die gebruik van eksterne insette soos bemesting as dit vergelyk word met ander gewasse nie. Die huidige droëboon tekort laat die behoefte ontstaan vir verbeterde produksiepraktyke wat opbrengs kan verhoog deur byvoorbeeld bemesting. Hierdie studie is dus onderneem om die rol van N en Mo in die bepaling van groei en opbrengs by droëbone te ondersoek, om die verskillende peile van N in 'n band en breedwerpig wat optimum opbrengs tot gevolg het te bepaal en om die hoeveelheid totale proteïen en molibdeen in die saad vas te stel as gevolg van die toegediende bemestingstowwe.

Twee afsonderlike potproewe waar verskillende N-peile, in 'n band en breedwerpig, met en sonder Mo toegedien is, is gedurende die 2000/2001 groeiseisoen uitgevoer in 'n glashuis aan die Universiteit van die Vrystaat, Bloemfontein, Suid-Afrika. Die potte is gevul met rooi-bruin grond en die droëboon cultivar, PAN 181, is daarin geplant. Die plantdigtheid was deurgaans drie plante per pot. Die proefontwerp was 'n faktoriaalreëling van vier N-peile (0, 20, 40, en 60 kg ha^{-1}) en drie Mo-behandelings (0, 100 g Mo ha^{-1} as blaarbespuiting en 100 g Mo ha^{-1} as saadbehandeling) in die vorm van 'n volledig ewekansige ontwerp met vier herhalings.

Resultate het getoon dat die toediening van N en Mo nie 'n betekenisvolle effek gehad het op vegetatiewe groei en reproduktiewe ontwikkeling van die betrokke droëboon cultivar nie. Die toediening van N in 'n band met die Mo-behandelings het nietemin 'n groter effek op saadopbrengs gehad as die breedwerpige toediening. Met die bandplasing van N is die hoogste saadopbrens verkry met 60 kg N ha^{-1} en saadbehandelde Mo terwyl dit by breedwerpige N toediening verkry is met 0 kg N ha^{-1} en saadbehandelde Mo.

Wat die voedingswaarde van die droë saad betref, is die hoogste totale protëin verkry met 60 kg N ha^{-1} en geen Mo by die bandplaas bahandeling en met geen N en saadbehandelde Mo by die breedwerpige behandeling. Die hoogste Mo-inhoud is verkry met 60 kg N ha^{-1} en saadbehandelde Mo by bandplaas en met geen N en saadbehandelde Mo by breedwerpige N-plasing.

Ten slotte word aanbeveel dat veldproewe, met dieselfde behandelings, oorweeg moet word om die glashuisresultate onder veldtoestande te verifieer.

Sleutelwoorde: droëbone, bemesting, stikstof, molibdeen, bandplaas, breedwerpig, blaartoediening, saadbehandeling.

CHAPTER ONE

GENERAL INTRODUCTION

Beans are known by many common names in languages around the world. In the English language, the generic term "bean" is often used not only for *Phaseolus vulgaris* but also for other species, such as *Phaseolus coccineus*, and it may even refer to other genera, such as *Vigna*. For this reason, descriptive adjectives and common names distinguish between *Phaseolus vulgaris* L. and other species of edible seed legumes and among a wide number of bean classes, seed types, growth habits, and, of course, specific varieties. These descriptive adjectives include French beans, dry beans, food beans, beans, common beans, kidney beans, field beans, haricot beans, *Phaseolus* beans, and dry edible beans (van Schoonhoven & Voysest, 1991). Common beans or haricot beans are perhaps the most common species descriptors in English. In Ethiopia, the term "haricot bean" is the species descriptor, whereas in Uganda the same descriptor refers only to small seeded varieties (van Schoonhoven & Voysest, 1991). Production and acceptability of specific bean classes are often very restricted and determined by individual countries and regions.

The common bean was domesticated more than 7,000 years ago in the New World (Duke, 1981), in two centres of origin-Mesoamerica (Mexico and Central America) and the Andean region. Scientists believe dry beans, along with maize, squash, and amaranth, probably began as weeds in fields planted to cassava and sweet potatoes in Central America. Over the millennia, farmers grew complex mixtures of bean types as a hedge against drought, disease, and pest attacks. This process has produced an almost limitless genetic array of beans with a wide variety of colours, textures, and sizes to meet the growing conditions and taste preferences of many different regions.

Dry beans were introduced to Africa, Europe, and other parts of the Old World several centuries ago by Portuguese traders. Now common beans are the most widely cultivated of all beans in temperate regions, and widely cultivated in tropical and semitropical regions. Today, dry beans are by far the most important class of beans throughout the world. The most important production areas include Mexico, Central

America, most of South America, the highland densely populated regions of eastern Africa and the great lakes region, and the highlands of Southern Africa, where they are a preferred staple food because of their high protein content and storability (van Schoonhoven & Voysest, 1991). Common bean, as an export and food crop, is an established component of Ethiopian agriculture. Frew (1997) indicated that the estimated area of production of dry beans in Ethiopia is about 239,000 ha.

Bean production, like that of other crops, depends on internal and external factors. Internal factors are those governed by genetic potential of the plant, and external factors are environmental factors, which vary greatly from site to site. Beans are growing from temperate to tropical uplands and in soils ranging from infertile leached tropical soils to fertile alluvial soils in the temperate zone. Successful dry bean production is normally associated with high soil fertility in well-drained, sandy loam, silt loam, or clay loam soils rich in organic content. Dry beans are sensitive to high soil acidity and the associated problems of low calcium and high soluble aluminium. Nodule forming bacteria are also sensitive to low pH and under such conditions will fail to provide sufficient nitrogen for the requirement of the plant (Bornman, Ranwell, Venter & Vosloo, 1989). Dry beans react well to fertilization on soils with a low nutrient status.

Increases in productivity of most crops can be attributed to genetic gains due to improved cultivars, greater use of production inputs, better agronomic practices, and more favorable growing environments. It is the combination of all these factors which provides maximum yield per unit of cropped land. Often, improved cultivars have been the prime factor for increased productivity and have provided the stimulus for adoption of better agronomic practices and agrochemicals leading to further yield increases (van Schoonhoven & Voysest, 1991). High seed yield of dry bean is obtained when each of the yield components, pods per plant, seeds per pod, and seed weight is maximized. Adams (1967) suggested that developmentally induced associations occur among yield components when the yield components compete for limited nutrients or photosynthates, thereby preventing each component from achieving its genetic potential.

Dry, edible bean has not exhibited dramatic improvements of seed yield through the development of high yielding cultivars, improved cultural practices, and the use of external inputs, especially fertilizers, when compared to other crops such as maize and wheat (Grafton, Schnriter & Nagle, 1988). The aim with this study was therefore, to investigate:

(1) the role of nitrogen and molybdenum fertilizers in determining the growth and yield of dry beans,

(2) different rates of nitrogen fertilizer with different methods that can give optimum yield, and

(3) the amount of total protein and total molybdenum found in the dry seeds as a result of the applied fertilizers.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter reviews the importance of dry beans in world nutritional value, the limitations to bean production and the need to apply nutrients, in this regard fertilizers, to soils for dry bean production. The general nutritional importance of beans was thoroughly reviewed with special emphasis on proteins, carbohydrates, starch, dietary fibres, minerals & vitamins, and lipids. Fertilizer placement for general crop production was also well reviewed. Here, attention was paid to the three major fertilizer placement methods- *viz*, broadcast placement, band placement, and foliar application methods. Finally, bean response to nutrient application was reviewed with particular reference to nitrogen, phosphorus, potassium, and micronutrients.

2.2 NUTRITIONAL IMPORTANCE OF BEANS

Dry seeds of the bean (*Phaseolus vulgaris* L.) are a major food source throughout Central and South America and East Africa (Taylor, Day & Dudley, 1983). Nutritionists characterize the common bean as a nearly perfect food because of its high protein content and generous amounts of fibre, complex carbohydrates, and other dietary necessities. A single serving (1 cup) of beans provides at least half the US Department of Agriculture's recommended daily allowance of folic acid-a B vitamin, that is especially important for pregnant women. It also supplies 25 to 30% of the recommended levels of iron and meets 25% of the daily requirement of magnesium and copper as well as 15% of the potassium and zinc. In Britain, the crop is grown only as green vegetable although large quantities of navy bean (a small, white, dry seeded type) are imported for processing as 'baked beans'.

The compositional components of beans include proteins, carbohydrates, starch, fibre (non-starch polysaccharides), minerals & vitamins and lipids.

2.2.1 Proteins

Dry beans are dense (strong) sources of plant protein, with reported protein content of *Phaseolus vulgaris* L. ranging from 18.8% to 29.3% dry weight basis. The storage proteins are predominant (±80%) in the globulin fractions (Evans & Gridley, 1979; Meiners & Litzenberger, 1975; Sgarbieri, 1989) while the metabolic proteins are primarily found in the albumin fraction.

Amino acid composition of beans indicate limiting amounts of sulfur amino acids, methionine, cysteine, and cystine; fairly low concentrations of tryptophan and high concentrations of lysine. Most bean proteins contain carbohydrates in the molecules in addition to amino acids; therefore are glycoproteins (Sgarbieri, 1989). The globulin fraction contains the lowest content of sulfur amino acids and sugar. The albumins presented the highest contents of sulfur amino acids, tryptophan, and sugar, among the isolated glycoproteins.

Beans need more nitrogen than any other nutrient. A large quantity of nitrogen is needed for making the high percentage of protein in seeds. A study of nutritional requirements of 90 bean cultivars in Piracicaba, Brazil, found that the protein content of seeds varied between 21% and 34%, with a mean of 27%. Nitrogen extraction ranged from 50 kg to 450 kg of nitrogen per hectare (Schwartz & Pastor-Corrales, 1989). This study showed important differences among genotypes in their nutritional requirements. Protein content and quality of crops are influenced by the nutritional status of the soil. For example, protein quality in soybean is strongly influenced by the nutritional environment in which the embryo develops (Thompson & Madison, 1990). Sulfur deficiency causes soybean protein quality to decline (Gayler & Sykes, 1985; Sharma & Bradford, 1973), as does enhanced availability of reduced N (Paek, Imsande, Shoemaker & Shibles, 1997).

2.2.2 Carbohydrates

The total carbohydrates of dry beans range from 24% to 68%, depending on the type of bean, with total soluble sugars representing only a small percentage. Among the sugars, olygosaccharides of the raffinose family (raffinose, stachyose, verbascose, and ajugose) predominate in most legumes and account for 31.1% to 76.0% of the total sugars (De Lange, 1999). Olygosaccharides have been implicated in the flatulence problem associated with consumption of dry beans, since these sugars are not hydrolysed and absorbed in the small intestine. Therefore, substrate is formed for microbial fermentation in the lower parts of the gut (Olsen, Gray, Gumbmann & Wagner, 1982; Sgarbieri, 1989). The physicochemical properties and internal molecular structures of bean starches differ depending on the original source, maturation and environmental factors.

2.2.3 Starch

Starch is a glucose polymer and is usually stored as microscopically small granules in the seeds and roots of plants. It is more soluble than cellulose and serves as slowly available food supply for the plant organ during dormancy and germination. Most bean starch granules have wide variability in size and shape. This wide variation in granule size and shape could be due to genetic control and seed maturity (Reddy, Pierson, Sathe & Salunkhe, 1984).

Most starches contain two types of glucose polymers, amylose and amylopectin. Amylose is a linear chain molecule consisting of alpha-1, 4 linkages between the glucose units such that the chain can twist and coil around an axis. Amylopectin is a branched molecule containing one alpha-1,6 linkages per 30 alpha-1,4 linkages (Bennion, 1980; Sgarbieri, 1989). There is a wide range of amylose content in legume starches ranging from 10.2% for the great northern bean starch to about 44% for the black gram bean starch (Reddy et al., 1984; Sgarbieri, 1989).

2.2.4 Non-starch Polysaccharides (NSP)

An important feature of dry bean is their relatively high content of non-starch polysaccharides (NSP), and their reported hypocholesterolemic and hypoglycaemic effects. A cholesterol depressing effect by daily ingestion of appreciable amounts of grain legumes was reported (Sgarbieri, 1989) which was associated with a significant increase in faecal steroid excretion, especially of bile acids.

Although beans contain, in general, slightly more insoluble than soluble fibres, they are rich sources of soluble NSP. Cellulose is the major component of fibre in red kidney and navy beans, while in other legumes hemicellulose is the major component. Cotyledon cell walls contain higher levels of pectin than cellulose (Uebersax & Ruengsakulrach, 1989). The seed coats are primarily composed of cellulose (29-41%) with small amounts of lignin (1.2-1.7%).

2.2.5 Dietary Fibre

The dietary fibre consisted of a complex carbohydrate entity defined as remnants of cell walls which are not hydrolysed by digestive enzymes of man and lignin as plant material which are resistant to digestion by the secretion of the human gastrointestinal tract. Other minor polysaccharides in beans include pectic substances, arabinogalactans and xyloglucans (Sgarbieri, 1989).

Navy beans contain a water-soluble polysaccharide composed mainly of arabinose followed by low quantities of xylose, glucose and galactose (Sgarbieri, 1989).

2.2.6 Minerals and Vitamins

The total ash content of *Phaseolus vulgaris* L. ranges from 3.5% to 4.1% dry weight basis (db). Beans are generally considered to be a substantial sources of calcium and iron. They also contain significant amounts of phosphorus, potassium, zinc and magnesium.

Dry edible beans provide several water-soluble vitamins (thiamine, riboflavin, niacin and folic acid), but very little ascorbic acid and fat-soluble vitamins. However, variability of vitamin content is high.

2.2.7 Lipids

Dry beans possess relatively low total fat content, generally 1-2%. Neutral lipids are the predominant class and account for 60% of the total lipid content. Phospholipids make up 24 to 35%, while glycolipids account for up to 10% of the total lipid content of legume seeds. The fatty acid composition of legumes shows a significant amount of variability, however, legume lipids are generally highly unsaturated (1-2%), with linolenic present in the highest concentration. Palmitic acid is the predominant saturated fatty acid (de Lange, 1999). Dry bean lipids may be implicated in the deterioration of bean quality and nutritive value through its oxidation and degradation products by reacting with protein and other bean components like carbohydrates and vitamins through free radicals and carbonyl-amino reactions. These reactions are likely to cause loss of nutritive value as a consequence of a decrease in protein digestibility and essential amino acid bioavailability and cause deterioration of colour and flavour (Sgarbieri, 1989).

2.3 FERTILIZER PLACEMENT FOR CROP PRODUCTION

The method of fertilizer application involves many problems, ranging from the correct fertilization time through the labor saving distribution of the fertilizer on the ground, to its correct introduction into the soil for optimum utilization by the plant. Proper placement can result in more effective fertilizer use, reducing the quantity of fertilizers applied, lowering production cost and reducing pollution (Timmons, Burwell & Holt, 1973). Fertilizer placement options generally involve band and broadcast applications which in turn involve surface or subsurface applications before, at, or after planting (Bornman et al., 1989; California Fertilizer Association, 1980; Tisdale, Nelson, Beaton & Havlin, 1993). Placement practices depend on the crop and crop rotation, degree of deficiency or soil test level, mobility of the nutrient in the soil, and equipment availability.

2.3.1 Broadcast Placement

The broadcast method of fertilizer placement consists of uniformly distributing dry or liquid materials over the soil surface before or at planting the crop, and incorporation by tilling or cultivation. Where there is no opportunity for incorporation, such as on perennial crops and no-till cropping systems, fertilizer materials may be broadcast on the surface. However, broadcast applications of nitrogen in no-till systems can greatly reduce fertilizer nitrogen recovery by the crop due to immobilization, denitrification, and volatilization losses (Tisdale et al., 1993). Topdressing of P and K is not as effective as when these two nutrients are being broadcast before planting. Potassium fertilizers are usually broadcast (Mengel, Nelson & Huber, 1982) on soils with a low level of available K^+ while banded application in soil with a high potassium fixation capacity is recommended.

Broadcast applications usually involve large amounts of nutrients in building up or maintenance programs. Incorporation with tillage implements usually increases crop recovery of immobile nutrients (i.e., phosphorus), while rainfall or irrigation can move mobile nutrients into the root zone without incorporation. The main advantages of broadcast placement of nutrients are application of large amounts of fertilizers is accomplished without danger of injuring the plant; if tilled into the soil, distribution of nutrients throughout the plow layer encourages deeper rooting and improves exploration of the soil for water and nutrients; and saves labour during planting. Randall & Hoeft (1988) indicated that broadcasting of fertilizers remained the most popular method of fertilizer application, because it is fast, easy, and equipment is readily available. Especially preplant broadcasting of fertilizers has grown rapidly due to the need to reduce the time involved in planting and handling of fertilizers (Follet, Murphy & Donahue, 1981).

2.3.2 Band Placement

This method of application consists of placing fertilizers in a concentrated zone to the side and/or below the seed or on the soil surface after crop emergence (Tisdale et al., 1993). Usually subsurface banding of fertilizers is by far the most common practice compared to surface banding (Follet et al., 1981).

Even on very fertile soils, application of banded starter fertilizers is often practiced. In this practice, relatively small amounts of fertilizers are banded near the seed row to supply high nutrient concentrations at early growth stages. Most starter banded fertilizers are banded at least about 5 cm to the side and 5 cm below the seed row as nitrogen fertilizer bands create high local salt concentrations which generate high osmotic pressures that may be detrimental to plants, especially to seedlings. Therefore, with subsurface banding before and at planting the fertilizer is placed at a depth equal to or greater than that of the seed in order to separate the fertilizer from the drier surface soil and to allow interception of the nutrients in the band as the roots penetrate sideways and downwards (Bordoli & Mallarino, 1998; Follet et al., 1981; Smith, Demchak & Feretti, 1990; Tisdale et al., 1993).

Subsurface banding of nitrogen, phosphorus, and potassium and some micronutrients before and at planting has received greater attention as the most efficient method of fertilizer application. With subsurface banding, the fertilizer is placed in a smaller volume of soil than with broadcasting when the fertilizer is applied at the same rate per hectare (Welch, Mulvaney, Boone, McKibben & Pendleton, 1966). Peck, MacDonald & Barnard (1989) stated that the subsurface fertilizer band should be close enough to the seed for early seedling response, but far away enough from the seed to avoid injury to the germinating seed and seedlings, especially from high salinity and potentially phytotoxic substances like ammonia. To improve N utilization efficiency under zero tillage, N fertilizer placement in bands below the soil surface can prevent N losses through ammonia volatilization (Bouwmeester, Vlek & Stumpe, 1985; Maddux, Raczkowski, Kissel & Barnes, 1991) and improve the availability of fertilizer N to plants (Mengel et al., 1982; Reinertsen, Cochran & Morrow, 1984; Touchton & Hargrove, 1982). For example, research results of field experiments on barley in central Alberta showed that, barley grain yields were generally lower under zero tillage than conventional tillage when N fertilizer was broadcast on the soil surface (Malhi, Mumey, O'Sullivan & Harker, 1988), and band placement of urea reduced or eliminated yield differences between zero tillage and conventional tillage (Malhi & Nyborg, 1992).

In soils that have strong affinity to phosphorus fixation, the deficiency can be controlled chemically by band application of various rock phosphates or superphosphate fertilizers. If fertilizer P is broadcast and incorporated, the P is exposed to a greater surface area; hence, more fixation takes place than if the same amount of fertilizer had been band applied. Band placement reduces the contact between the soil and fertilizer and optimises the use of phosphate fertilizers because only 20-25% of this fertilizer can be used by plants. The remainder stayed fixed in the soil (Mandal & Khan, 1977; Schwartz & Pastor-Corrales, 1989; Tisdale et al., 1993). This residual fixed phosphorus is difficult to release and its effectiveness is therefore minimal.

2.3.3 Foliar Application

Under ideal conditions, dry bean is a deep-rooted crop, but is highly susceptible to soil compaction (Xu & Pierce, 1998) and to root diseases. This leads to the inefficiency of the root to absorb enough nutrients from the soil. In theory, plants can be completely nourished via the leaves, but the major importance of foliar nutrient application is the additional supply of some major and trace elements. Foliar fertilization consists in spraying leaves with diluted nutrient solutions or suspensions. Research results indicated that foliar fertilization of soybean during reproductive stages showed marked yield increases. The soybean plant has been characterized by markedly reduced root activity during late seed development and increased translocation of nutrients and metabolites from other tissue into the seed (Haq & Antonio, 1998). This depletion of nutrients from leaves could result in decreased photosynthesis, leaf senescence, and lower grain yields. If nutrients were applied directly to the foliage at this time, leaf senescence could be delayed and grain yields might be increased. Study on foliar fertilization of soybean during early vegetative stages had also been carried out. Haq, & Antonio (1998) indicated small amounts applied at early critical periods could be effective if foliar fertilization is viewed as a complement for soil fertilization.

A plant with a normally developed root system can get sufficient nutrients from the soil, but there are circumstances under which these nutrients are unavailable to the plant and thus under such circumstances foliar application of nutrients becomes indispensable (Bornman *et. al.*, 1989). Foliar application, however, can not replace soil application of plant nutrients, but can have an important function given the correct circumstances. The major importance of foliar nutrient application is the additional supply of nitrogen, magnesium, and trace elements. The advantage of leaf fertilization is the high recovery rate (Finck, 1982), but only limited amounts of nutrients are supplied through the leaves.

2.4 BEAN RESPONSE TO NUTRIENT APPLICATION

The purpose of using fertilizers is to obtain high and valuable yields by improving the supply of nutrients while maintaining or improving the fertility of the soil without harmful effects on the environment (Finck, 1982). Amongst the various agricultural inputs, fertilizers, perhaps next to water, contribute the most to increasing agricultural production (FAO, 1984). The introduction of high-yielding, fertilizer-responsive, dwarf varieties of crops gave a considerable boost to fertilizer consumption in recent years. The response of beans to major and micronutrient applications is thoroughly discussed in the following section.

2.4.1 Nitrogen

Although beans are legumes that can fix nitrogen when inoculated with appropriate strains of *Rhizobium* (Graham, 1981; Graham & Halliday, 1977; Graham & Rosas, 1977), cultural, varietal, or inoculation difficulties can limit this fixation ability. The plant is therefore left dependent on residual soil nitrogen or on applied nitrogen fertilizers.

The mineral nutrition of legumes is somewhat more complex than that of other plant species (Smith, 1982) because of the special symbiotic relationship existing between the legume host and the associated rhizobial bacteria. However, the nitrogen fixation capabilities of dry beans are less effective than those of other legumes (Bornman *et. al.*, 1989). The bacteria invariably do not supply sufficient nitrogen for the plant prior to flowering and good results can be achieved with top-dressing of nitrogen fertilizers or application to the plant through the foliage (Sauerbeck & Timmermann, 1983). Dry beans, unlike other legumes, usually respond to nitrogen fertilizers (Taylor, *et. al.*, 1983), indicating that strains of *Rhizobium phaseoli* are either absent or ineffective nitrogen fixers and thus fail to meet the nitrogen requirement of the host. A theoretical calculation by Sinclair & de Wit (1975) suggested that species (such as *Phaseolus*) which produce seeds with a high protein content need to withdraw protein nitrogen from their leaves, because the roots can not supply fixed nitrogen fast enough. The leaves then senesce and die, so setting a limit to yield. Therefore, an increase in the nitrogen supply not only delays leaf senescence and stimulates growth but also changes plant morphology in a typical manner, particularly if the nitrogen availability is high in the rooting medium during the early growth. An increase in root-shoot dry weight ratio with increase in nitrogen supply takes place in both perennial and annual plant species (Arnon, 1992; Marschner, 1995).

Response to nitrogen depends on soil conditions, the particular crop species and the plant nutrition supply in general. Nitrogen response is generally poorer the higher the N content of the soil. In the absence of a response, residual N and/or the rate of N release by microbial decomposition of soil organic matter or the rate of N fixation by micro-organisms is probably adequate to meet the demands of the crop (Mengel & Kirkby, 1987). The response to N also depends on how well the crop is supplied with other nutrients (Thönnissen, Midmore, Ladha, Olk & Schmidhalter, 2000). Without P and K applications, the yield response to increasing N levels was smaller than when adequate amounts of P and K were applied.

Nitrogen requirements vary considerably at different stages of development of the plant: minimal in the early stages, the requirements increase as the rate of growth accelerates, to reach a peak in most crops during the period between the onset of flowering and early fruit and grain formation (Arnon, 1992). In certain plants, such as small grain cereals and maize, excessive N increases the proportion of straw to grain, and in combination with succulent growth is conducive to lodging of the tall but weak straw. This undesirable effect of high levels of N fertilization can be alleviated by proper placement and timing of application and, particularly, by a well balanced supply of P and K. Research results comparing rate and time of N application (Limon-Ortega, Sayre & Francis, 2000) on wheat showed that, N application at the first node stage of wheat gave greater wheat yields. At the six-leaf stage (V6) (Ritchie & Hanway, 1982), maize starts its most active growth and substantially increases N and water consumption. Fertilization at V6 is more efficient than the application at planting, particularly under no-tillage (Fox, Kern & Piekielek, 1986; Wells & Bitzer, 1984; Wells, Thom & Rice, 1992). The greater N uptake and yield in no-tillage maize observed could be due to the decrease in N losses due to denitrification (Wells & Bitzer, 1984), immobilization (Brinton, 1985; Jokela & Randall, 1997; Murwira & Kirchmann, 1993; Paul & Beauchamp, 1993)), and leaching (Thomas, Blevins, Phillips

& McMahon, 1973), because of the reduction in soil water content (Jokela & Randall, 1997; Linn & Doran, 1984) associated with crop water consumption.

Nitrogen deficiency occurs on all acid soils. It is essentially severe in sandy soils that have low organic matter content. Nitrogen deficiency first appears on lower leaves as a uniformly pale green color; these leaves later turn yellow. This deficiency is always most serious in the lower leaves because nitrogen is a mobile element. Normal, unfurled, trifoliolate leaves contain about 5% nitrogen, but if these leaves are deficient, they may contain as little as 3% nitrogen (Schwartz & Pastor-Corrales, 1989).

Seeds contain 6-20 mg of nitrogen. At first, beans fulfil their nitrogen requirements from the reserve present in cotyledons. However, beans begin to exhibit symptoms of nitrogen deficiency 14-20 days after emergence if they do not receive nitrogen fertilizer (Schwartz & Pastor-Corrales, 1989). It is at this stage of development that beans form nitrogen-fixing nodules. However, because nodules do not function well until they are about 30 days old, beans during this time are especially prone to nitrogen deficiencies. From about 30-60 days, the nitrogen requirement increases almost linearly, with maximum absorption occurring at about day 56. With the formation of pods, a great part of the nitrogen of the plant passes to the developing seeds. By harvesting time almost 90% of the nitrogen in a bean plant is found in the seeds.

Pod filling is another stage when bean plants require nutrient nitrogen. After flowering, photosynthesis, and consequently nitrogen fixation, decreases. Some researchers obtained positive results by applying foliar nitrogen fertilizer at this stage, although the majority of recent studies have not confirmed it (Schwartz & Pastor-Corrales, 1989).

There is clear evidence that differences in nitrogen fixing capacity exist among genotypes. In general, genotypes with long vegetative cycles have the highest capacity for nitrogen fixation. Slow growing cultivars also fix more nitrogen. Nitrogen deficiencies can be controlled by applications of nitrogen fertilizers and organic matter. There is little difference in quality between the principal sources of nitrogen which are urea, sodium nitrate, and ammonium sulfate. Neither are there important differences in times of application, except that repeated application of nitrogen in rainy areas are helpful (Graham, 1978 and 1981; Graham & Rosas, 1977).

2.4.2 Phosphorus

Phosphorus is particularly important for leguminous plants, possibly by its influence on the activity of the rhizobium bacteria (Mengel & Kirkby, 1987). The phosphorus requirement for optimal growth is in the range of 0.3-0.5% of the plant dry matter during the vegetative stage of growth. Beans respond to phosphorus applications primarily by increasing the number of pods per plant (Schwartz & Pastor-Corrales, 1989). Also, better root development and penetration occurs, thereby improving the plant's ability to withstand dry periods and to compete more successfully with soil-borne pests.

In plants suffering from P deficiency, reduction in leaf expansion and leaf surface area, and also number of leaves are the most striking effects (Marschner, 1995). In contrast to the severe inhibition in leaf expansion, the contents of protein and chlorophyll per unit leaf area are not much affected. However, the photosynthetic efficiency per unit of chlorophyll is much lower in phosphorus deficient leaves.

In contrast to shoot growth, root growth is much less inhibited under P deficiency, leading to a typical increase in shoot-root dry weight ratio. In bean (*P. vulgaris* L.) this ratio decreases from 5.0 in P sufficient to 1.9 in P deficient plants (Marschner, 1995). As a rule, the decrease in shoot-root dry weight ratio in P deficient plants is correlated with an increase in partitioning of carbohydrates towards the roots, indicating a steep increase particularly in sucrose content of the roots of P deficient plants. In bean, of the total amount of carbohydrates per plant, 22.7% were partitioned in the roots of P deficient plants.

Despite this adaptive responses in increasing P acquisition by roots, not only is shoot growth rate retarded by P limitation but also formation of reproductive organs. It causes short, sometimes dwarfed, plants with thin stems and shortened internodes. Upper leaves are small and dark green and when the deficiency is severe, early defoliation occurs. The vegetative period is prolonged for some days and the reproductive phase is shortened. Flowering is late, few flowers are produced, and the level of aborted blossoms is high. Few pods form and contain only a small number of seeds (Schwartz & Pastor-Corrales, 1989)

2.4.3 Potassium

Beans have a high uptake of potassium from the soil. Potassium fertilizers play a great role in respect of increasing bean seed quality and disease resistance. In soils with a low potassium analysis application of potassium containing compounds prior to planting is necessary (Bornman et al., 1989). Potassium deficiencies occur in Oxisols and Ultisols with very low fertility, in soils with high calcium and magnesium contents, or in highly permeable sandy soils.

Potassium functions mainly in osmoregulation, the maintenance of electrochemical equilibra in cells and the regulation of enzyme activities (Marschner, 1986). Most of the K requirement of the plant is during the vegetative stage. The role of K in the water status of the plant is of major significance for crops grown in dry regions. In young tissues, K^+ is indispensable for optimum cell turgur (Marschner, 1995). K^+ plays a key role as the most important osmotic solute in the vacuole, in maintaining a high water level in the plant tissue and by reducing water losses due to transpiration, through stomatal regulation.

Potassium is a mobile element and therefore a deficiency first appears on the lower leaves. Primary leaves manifest serious symptoms when potassium deficiency is severe. The affected plant has very weak stems with short internode length, reduced root growth, and a proneness to collapse (Schwartz & Pastor-Corrales, 1989). Genotypes differ in their ability to efficiently use small quantities of soil potassium. Potassium deficiency can be corrected by applying commercial products such as potassium chloride (KCl, 50%K) and potassium sulfate (K_2SO_4, 42%K).

2.4.4 Micronutrients

Micro- nutrients or trace elements are nutrients which are taken up in very small quantities by plants, but which play an essential role in the physiology of the plant (Bornman *et. al.*, 1989). If one or more of these nutrients are absent, normal growth and production are not possible. The most important micro- nutrients for normal growth and development are iron, copper, boron, zinc, and molybdenum.

Among the most important food crops, beans are the most responsive to all microelement application. Lucas & Knezek (1972) compared six important food crops and found that only beans and sorghum have shown a good response to Zn, Fe, and Mn.

Most microelements in soils do not move to any great extent with the mass flow (Barber, Walker & Vasey, 1963; Oliver & Barber, 1966). Micronutrient becomes available to the plant as the roots explore new volumes of soil as a result of the relatively diffusion process. Only Mo moves freely by means of mass flow to the plant root.

The solubility and thus availability of Mo to plants, is highly governed by soil pH and drainage conditions. On acid soils (pH< 5.5) low in Mo, and especially on those with a high Fe oxide level, Mo is hardly available to plants (Kabota-Pendias & Pendias, 1989). The low availability of Mo in this acid soil seems to be effected by strong fixation of Mo^{5+} by humic acid following the earlier reaction of the MoO_4^{2-}. Molybdenum deficiency can be corrected by applications of sodium molybdate, NH_4 molybdate, soluble molybdenum trioxide and molybdenized superphosphate.

Some nutrients are specifically required for nitrogen fixation and are needed in larger amounts when the legume is in symbiosis (Janssen & Vitosh, 1974). One of the elements needed is molybdenum. It is a constituent of the nitrogen fixation enzyme, nitrogenase, and functions in the fixation of nitrogen by weakening the dinitrogen bond. Legumes, not only for nitrogen fixation but also for nitrate reduction and other plant functions, require this element. Molybdenum is closely related to nitrogen metabolism through the fixation of free nitrogen and the assimilation of nitrates by the plants (Ashmead, Ashmead, Miller & Hsu, 1986). Thus legumes, relying on the symbiotically fixed nitrogen, develop symptoms of N deficiency when subject to molybdenum deficiency. Therefore, legumes growing non-symbiotically on nitrate as a sole N source may also develop nitrogen deficiency symptoms when the molybdenum supply is restricted. Molybdenum deficiencies are usually found in acid soils and rarely in alkaline soils. The correction of the deficiency by liming is much more gradual than spraying the foliage (Ashmead *et. al.*, 1986), so the latter method is usually the preferred one.

CHAPTER THREE

RESPONSE OF DRY BEANS TO BAND AND BROADCAST PLACEMENT OF NITROGEN AT DIFFERENT RATES WITH MOLYBDENUM

3.1 INTRODUCTION

Seeds of the common bean (*Phaseolus vugaris* L.) are an important staple food for people in countries of Central and South America and Central and East Africa, where animal protein is limited and beans are consumed in large quantities. Bean proteins are rich in the essential amino acid lysine to which cereal grains are limited. Therefore, the proteins of beans and cereal grains, when consumed together complement each other and provide adequate amounts of all the essential amino acids. In lower latitudes, dry beans furnish a large portion of the protein needs of low- and middle-class families (Duke, 1981). The green immature pods are used as vegetable; marketed fresh, frozen or canned, whole, cut, or French-cut. Mature ripe beans are widely consumed in different parts of the world. In Ethiopia, the crop is grown for use as a green vegetable, dry seeds are boiled, fried, cooked and consumed as local sauce, and also exported to generate foreign currency for the national economy.

There is a general agreement that, of all the nutrient amendments made to soils, nitrogen fertilizer application has had by far the most important effects in terms of increasing crop production. Numerous field experiments carried out in the past have shown that for many soils, nitrogen is the most growth limiting factor (Mengel & Kirkby, 1987; Arnon, 1992). In agricultural soils, available N (mainly NH_4^+ and NO_3^-) accounts for <2% of total soil N (Keeney & Nelson, 1982). Therefore, addition of N containing fertilizers, either chemical or organic, increases the soil inorganic N pool and the seasonal N mineralisation available to the plant (Chang, Sommerfeldt, & Entz, 1993; Murwira & Kirchmann, 1993; Westerman & Kurtz, 1973). Cultivated plants require N primarily at the time of maximum vegetative growth, i.e., during production of the principal leaf mass; and can, however, use later N supplies for increased synthesis of proteins in the reserve organs, e.g., in the grains.

There are various forms of N fertilizer. The N fertilizer form used for this study was urea because urea is the widely used dry N fertilizer in the world and is the only commonly used form of nitrogen fertilizer in my country, viz. Ethiopia. Urea, because of its lower bulk and relatively lower price per unit of N, is the dominant dry N fertilizer all over the world (Beaton, 1978; Bremner & Krogmeier, 1988; Volk, 1959). When urea is applied to soil it is converted rapidly to ammonium carbonate (FAO, 1984) and high concentrations of ammonium build up in the soil. If the urea is mixed with the soil, the ammonia is held on the soil colloids, but if it is applied on the soil surface, considerable amounts of ammonia may be lost by volatilization to the atmosphere; and also ammonia may damage young seedlings if urea is placed in contact with them. Therefore, to avoid these loss and detrimental effects of NH_3 proper placement is required.

The most efficient and most effective placement of fertilizers is that which provides for an adequate supply of soluble nutrients in a well-aerated zone of most soil occupied by actively absorbing plant roots at periods of growth when the demands of the plant for nutrients is most acute. Band application of fertilizers is believed to be more efficient than broadcast application and reduces nutrient losses. Research reports by Kanwar & Rego (1983) indicated the greater effectiveness for sorghum and pearl millet of split band application of urea compared with broadcast application. The recovery of applied N was greater for the split-band method than for surface application.

Little has been done with beans so far to determine the rate and method of N and Mo fertilizer applications elsewhere in the world in general and in Ethiopia in particular. Therefore, this study was conducted with the objectives to investigate:

1. the role of nitrogen and molybdenum in determining the growth and yield of dry beans, and
2. different rates of nitrogen fertilizer with banding and broadcast method of application that can give optimum yield.

3.2 MATERIALS AND METHODS

3.2.1 Execution of experiment

Two separate pot experiments of band and broadcast placement of N in different rates with Mo were executed during 2000/2001 growing season in the glasshouse at the University of the Free State. Asbestos pots having the size of 0.34 m length, 0.34 m width, and 0.35 m height were used for the experiment. A flexible plastic pipe (0.5 m long with a diameter of 16 mm) in which 2 mm holes were punched 25 mm apart on either side of the pipe was placed at the bottom of each pot to drain excess water (through a suction force of 20 kPa) and keep the soil water content at field capacity after the plants have been watered. In each pot two sets of openings (each set with three openings) were made on either side of the pot which are used to take subsoil plant samples. These holes were sealed with corks and papers during experimentation.

A gravel layer, approximately 30 mm thick (3 kg), was placed at the bottom of each pot. This gravel layer covered the drainage pipe, thus holding it in position. Gauze was placed on top of the gravel layer to prevent the soil from penetrating the gravel layer and block the drainage pipe holes. Thereafter each pot was filled with manually sieved red brown soil up to the level of fertilizer (110 mm from the top of the pot). For the band placement treatment, the fertilizer band was then applied by filling a hard plastic pipe (12 mm in diameter with a slit on one side) with the correct amount of fertilizer after which it was stuck through one of the bottom openings of the pot (51 mm opening) and inverted to release the fertilizer. Band placement of one-half nitrogen was applied at planting 5 cm below and 5 cm to the side of the plant rows in order to avoid the effect of fertilizer burn to the seedlings. The remaining one-half was side dressed at the 4-leaf stage of the crop (25 days after planting). For the broadcast treatment, one-half of the nitrogen levels was broadcast and incorporated into the soil just before planting and the remaining one-half was applied when the crop was at 4-leaf stage (25 days after planting). After the fertilizer was placed, 50 mm of soil was added up to the planting depth. Six seeds of small white bean cultivar (PAN 181), with a Mo content of 0.17 ppm. (seed Mo < 2 ppm is deficient) were planted in a 0.40 m x 0.10 m single row spacing. It is a cultivar with wide adaptation and short growing period. Another 50 mm of soil was added so that the final level of the soil was 10 mm from the top of the pot. The six seeds planted were thinned to three seedlings per pot at about 10 days after planting to obtain a plant population of 250 000 plants per hectare. This is a standard bean plant population in areas having no moisture stress problems. Pots were watered with distilled water throughout the growing period of the crop. The temperature of the glasshouse was adjusted to 23°C day and 18°C night, which is conducive for bean growth. Weeds were frequently removed from all experimental units (pots) by hand.

The study investigated the effects of four nitrogen levels, 0, 20, 40, and 60 kg ha^{-1}, placed in band and broadcast methods and three molybdenum treatments, 0, 100 g ha^{-1} leaf spray and 100 g ha^{-1} seed treatment, on bean yield. The N source used for the experiment was urea, which is a widely used N fertilizer in the world and the only pure nitrogen source in my country, Ethiopia, and that of molybdenum was sodium molybdate. The foliar spray of molybdenum took place at the 4-leaf stage of the crop. All plants received water two to three hours before foliar application of Mo. During application the neighbouring plants were covered with a paper box in order to avoid fertilizer drifts.

Basal phosphorus and potassium fertilizers were broadcast and incorporated into the soil at a rate of 20 kg P ha^{-1} as Maxiphos (20) and 20 kg K ha^{-1} as Potassium sulfate (42) respectively before planting to all experimental units, in this case pots.

The general characteristics and nutrient composition of the experimental soil are shown in Tables 3.1a and 3.1b, while the chemical composition of the seeding material is shown in Table 3.1c.

3.2.2 Experimental Design

Both experiments (band and broadcast placements of N) were laid out in a factorial arrangement in completely randomised design with four replications for both experiments.

Table 3.1a. General characteristics of the experimental soil.

Texture		Soil Class	Conductivity	Sodium Adsorption Ratio	pH
Clay + Silt	Sand		ms/m		
%					
16.00	84.00	Sandy Loam	18.00	0.2	5.7

Table 3.1b. Nutrient composition of the experimental soil

Ca	Mg	K	P	Zn	Ca:Mg Ratio	KAR*, me/100 g soil
mg/kg soil						
361	162	75	11	1.00	2:1	6

*Note: *KAR = Potassium adsorption ratio*

Table 3.1c. Chemical composition of the seeding material (Cultivar PAN 181)

CNS Method												
N	S	C	Ca	Mg	K	Na	P	Zn	Cu	Mn	B	Mo
%			%					ppm				
4.43	0.26	44.71	0.19	0.22	1.70	0.02	0.43	36	10	20	24	0.17

3.2.3 Observations during experiment

3.2.3.1 Yield and Yield Components

- Pod length of 10 pods per pot was measured using a ruler.
- Pod weight was taken after pods were harvested and oven-dried at 70^0C for 24 hours.
- Pod number per plant was obtained by counting all pods in the pot and dividing them by number of plants in the pot.
- Number of seeds per pod was obtained by counting all seeds harvested from a pot and dividing them by all pods harvested from that particular pot.
- Seed weight per pod was determined by dividing the total seed weight per pot by the total pod weight per pot.
- Number of seeds per plant was taken by counting all seeds per pot and dividing them by number of plants in that pot.
- 100 seed weight was measured by counting 100 seeds from each pot and weighing them
- Pod abscission was taken by counting all pods dropped off the plant prematurely.
- Seed yield per plant was determined by dividing the weight of all seeds per pot by the number of plants per pot. Seed yield used for analysis was determined per plant basis.
- Total aboveground dry biomass yield was determined as the total yield of seeds in a pot plus the total oven dry weight of stems and leaves.
- Seed yield per hectare was determined as the ratio of total plants per hectare (250 000 plants ha^{-1}) to the yield of total plants per pot.

3.2.4 Data processing

All data were subjected to analysis of variance using an MSTAT-C (1989) microcomputer software program. The results of the two experiments were separately analysed and interpreted for all parameters. The least significance difference (LSD) test (Gomez & Gomez, 1984) at $P<0.05$ was used to assess the differences among treatment means.

3.3 RESULTS AND DISCUSSION

3.3.1 Effect on Yield and Yield Components

Both main and interaction effects of nitrogen and molybdenum fertilizers with both band and broadcast N placement methods on the yield and yield components were thoroughly discussed in the following sections. The analysis of variance is shown in the appendix for all parameters measured.

3.3.1.1 Pod Length

The analysis of variance (Table 7.1 in appendix) showed that the interaction between N levels and Mo treatments in band placement method of N significantly ($p<0.05$) affected pod length. In the application of N with the three Mo treatments, zero N with zero Mo treatment significantly increased pod length over leaf sprayed and seed treated Mo applications. Zero N with leaf sprayed and seed treated Mo did not significantly differ in pod length. Application of 20 kg N ha^{-1} with leaf sprayed Mo significantly reduced pod length as compared to 20 kg N ha^{-1} with zero Mo treatment. Zero and seed treated Mo are not significantly different from each other. Application of 40 kg N ha^{-1} with the three Mo treatments did not give significant differences in pod length from each other. Application of 60 kg N ha^{-1} with leaf sprayed Mo significantly reduced pod length as compared to seed dressed Mo treatments (Table 3.2). In the interaction of Mo treatments across the increasing N levels, only application of seed treated Mo with 60 kg N ha^{-1} significantly increased pod length over zero, 20 and 40 kg N ha^{-1}. The rest did not significantly differ from each other.

In the case of broadcast application of N, the interaction between N and Mo treatments did not significantly affect pod length (Table 7.2 in appendix). However, increasing levels of N with zero and leaf sprayed Mo showed an increasing trend of pod length except 20 kg N ha^{-1} with zero Mo which slightly reduced pod length as compared to zero N with zero Mo treatments (Table 3.3). Seed treated Mo with increasing N levels reduced pod length, but with 40 kg N ha^{-1} it slightly increased over the zero N level. Application of zero, 20 and 60 kg N ha^{-1} with leaf sprayed and seed treated Mo reduced pod length as compared to zero Mo treatment. However, 40 kg N ha^{-1} with leaf sprayed and seed treated Mo increase pod length over the zero Mo treatment

Table 3.2 Interaction and main effects of N and Mo fertilizer on pod length (cm)[1], with band N placement method.

Mo Levels,	N Levels, kg ha^{-1}				
g ha^{-1}*	0	20	40	60	Mean
0	8.803[a]	8.680[ab]	8.595[abcd]	8.620[abc]	8.674[a]
100L	8.490[bcd]	8.400[cd]	8.563[abcd]	8.410[cd]	8.466[b]
100S	8.507[bcd]	8.537[bcd]	8.347[d]	8.815[a]	8.552[ab]
Mean	8.600	8.539	8.502	8.615	
P Level	N = NS	Mo = 0.0086***	N x Mo = 0.0288**		
CV%			2.1		
	Mo LSD1% = 0.172		N x Mo LSD5% = 0.2565		

Note. * *L = Leaf Application, S = Seed treated, NS = non-significant*

, * *Significant at 5% and highly significant at 1% level respectively.*

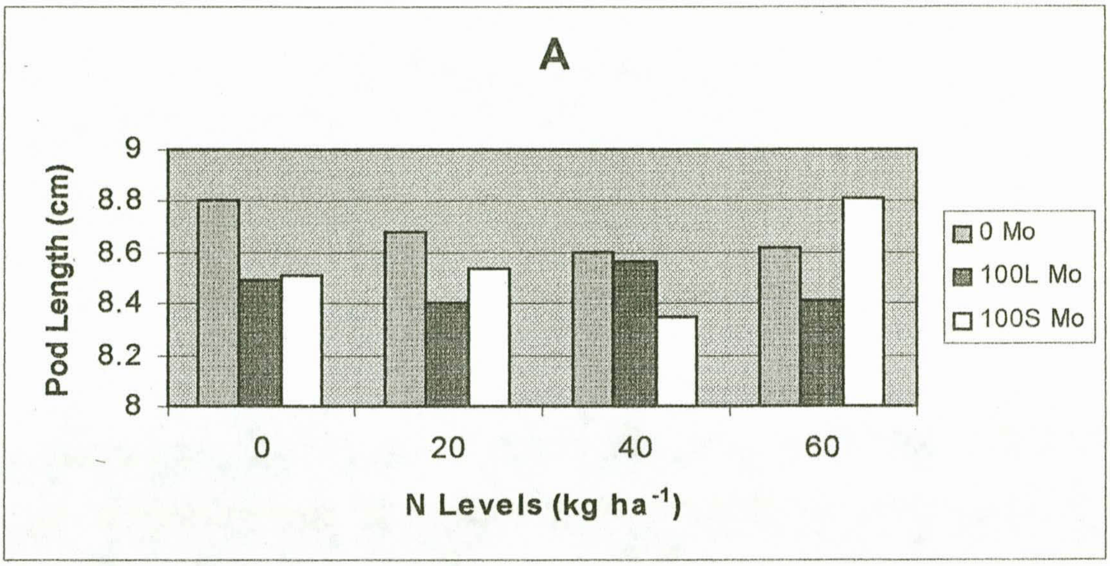
[1]*Means followed with the same letters are not significantly different at the given level.*

Table 3.3 Interaction and main effects of N and Mo fertilizers on pod length (cm), with broadcast N placement method.

Mo Levels,	N Levels, kg ha^{-1}				
g ha^{-1}*	0	20	40	60	Mean
0	8.608	8.600	8.662	8.700	8.643
100L	8.538	8.600	8.713	8.670	8.630
100S	8.550	8.475	8.752	8.518	8.574
Mean	8.565	8.558	8.709	8.629	
P Level	N = NS	Mo = NS	N x Mo = NS		
CV%			2.39		

Note: **L = Leaf Application, S = Seed Treatment, NS = Non-significant*

The main effect of N application on pod length was statistically not significant with both band and broadcast N placement methods. However, with band N placement method, increasing levels of N reduced pod length except 60 kg N ha^{-1} which slightly increased over the zero level. With broadcast placement of N, increasing levels of N increased pod length over the zero level except 20 kg N ha^{-1}.



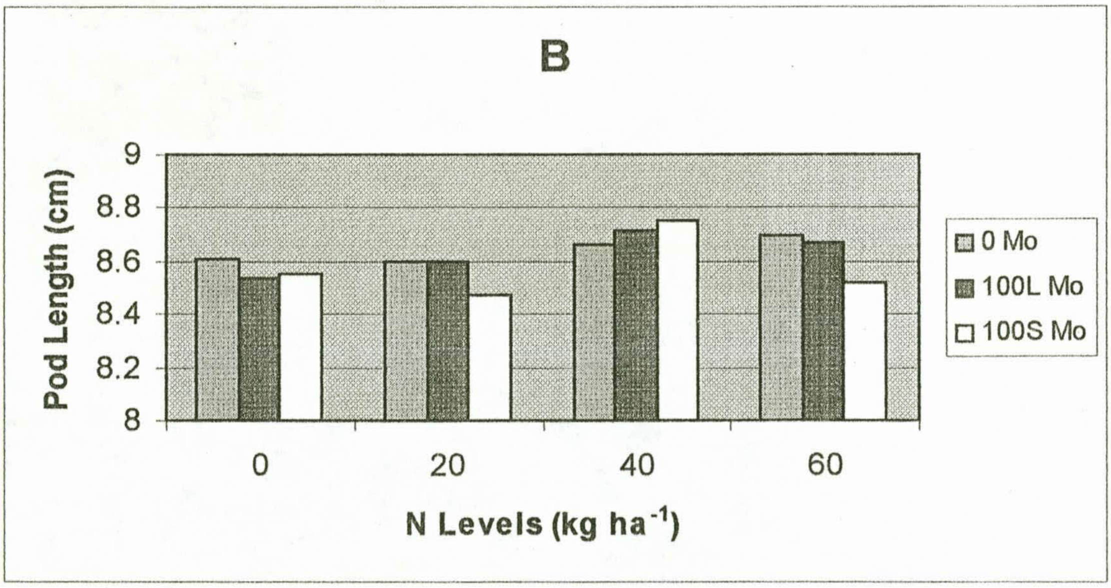


Figure 3.1 Interaction effects of N and Mo fertilizers in band (A), and broadcast (B) placement methods of N on pod length, (100L Mo and 100S Mo are 100 g Mo ha^{-1} leaf application and seed treatment respectively)

Application of Mo as leaf spray and/or seed treatment decreased pod length highly significantly ($p<0.01$) with band N placement method. Leaf sprayed Mo reduced pod length highly significantly as compared to zero Mo. Pod length was not significantly reduced with seed treated Mo when compared with zero and leaf sprayed Mo application. Generally with band placement of N, application of Mo to the foliage and/or to the seed gave negative results of pod length. With the broadcast placement of N, though statistically non-significant, application of Mo as leaf spray and seed treatment reduced pod length. Here, the reduction in pod length with seed treated Mo is more pronounced than leaf sprayed Mo fertilizer.

As Figure 3.1 shows, greater pod length was generally obtained with the interaction of N and Mo in broadcast placement method of N. Except zero Mo with increasing N levels, in most interaction levels, the values for broadcast N placement were greater than that of band placed N. With band N placement method interaction of zero Mo with increasing N levels showed a decreasing trend on pod length. The three higher N levels gave lower pod length as compared to zero N level. Leaf sprayed and seed treated Mo showed inconsistent trends with increasing N levels. With broadcast N placement, zero and leaf sprayed Mo with increasing N levels increased pod length except zero Mo with 20 kg N ha^{-1}. Seed treated Mo with N levels reduced pod length except at 40 kg N ha^{-1}. With broadcast placed N, 40 kg N ha^{-1} with seed treated Mo gave the highest pod length while that of band gave the lowest pod length at this interaction level. With band N placement method, the highest peak is achieved at zero N with zero Mo and 60 kg N ha^{-1} with seed treated Mo.

3.3.1.2 Pod Weight

According to the analysis of variance shown in the appendix (Tables 7.3 & 7.4), the interaction of N and Mo levels has non-significantly affected pod weight with both band and broadcast N placement methods. However, with band placed N, all Mo treatments with increasing N levels reduced pod weight except zero and leaf sprayed Mo with 40 kg N ha^{-1} and seed treated Mo with 60 kg N ha^{-1}. Interactions of the individual N levels with leaf sprayed and seed treated Mo reduced pod weight compared to their interaction with zero Mo treatments. Only 60 kg N ha^{-1} with leaf sprayed and seed treated Mo increased pod weight over the zero Mo application (Table

3.4). With broadcast N placement method, application of the Mo treatments across the increasing N levels generally reduced pod weight. Seed treated Mo with all N levels increased pod weight over zero Mo with the increasing N levels, but leaf sprayed Mo increased pod weight only at the interaction of zero and 60 kg N ha^{-1} over the zero level. (Table 3.5).

Table 3.4 Interaction and main effects of N and Mo fertilizers on pod weight (g), with band N placement.

Mo Levels,	N Levels, kg ha^{-1}				
g ha^{-1}*	0	20	40	60	Mean
0	1.388	1.379	1.412	1.255	1.359
100L	1.328	1.298	1.331	1.310	1.317
100S	1.364	1.216	1.345	1.403	1.332
Mean	1.360	1.298	1.363	1.323	
P Level	N = NS	Mo = NS		N x Mo = NS	
CV%			6.69		

*Note. *L = Leaf Application, S = Seed Treatment, NS = non-significant*

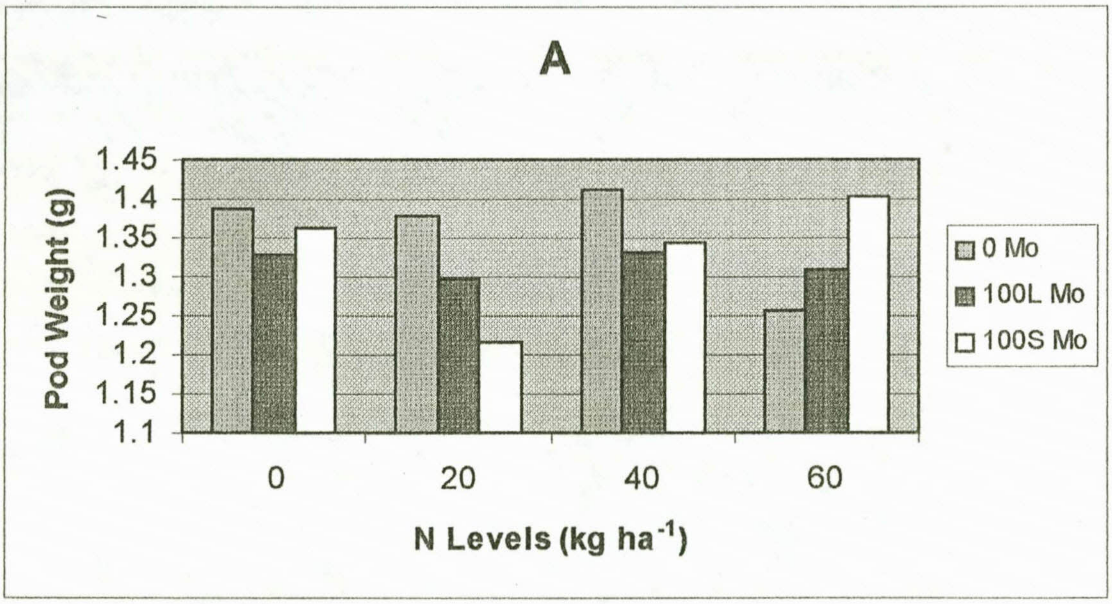
Table 3.5 Interaction and main effects of N and Mo fertilizers on pod weight (g), with broadcast N placement.

Mo Levels,	N Levels, kg ha^{-1}				
g ha^{-1}*	0	20	40	60	Mean
0	1.359	1.357	1.315	1.295	1.332
100L	1.369	1.354	1.271	1.309	1.326
100S	1.431	1.387	1.354	1.338	1.378
Mean	1.387	1.366	1.313	1.314	
P Level	N = NS	Mo = NS		N x Mo = NS	
CV%			6.94		

*Note: *L = Leaf Application, S = Seed Treatment, NS = Non-significant*

The main effect of individual N fertilizer levels on pod weight was not significant with both band and broadcast placed N. With band N placement method, increasing levels of N decreased pod weight except for 40 kg N ha^{-1} which gave slightly greater pod weight than zero N treatment (Table 3.4). With the broadcast N placement method, all N levels gave lower pod weight than the zero N fertilizer application (Table 3.5).

Application of Mo non-significantly affected pod weight with band N placement method. Both leaf sprayed and seed treated Mo reduced pod weight as compared to the zero level. With the broadcast placement of N, application of Mo did not significantly affect pod weight (Table 3.5). Mo as seed treatment increased pod weight over the zero and leaf sprayed Mo treatments. Leaf sprayed Mo reduced pod weight and gave lower results than the zero Mo treatment.



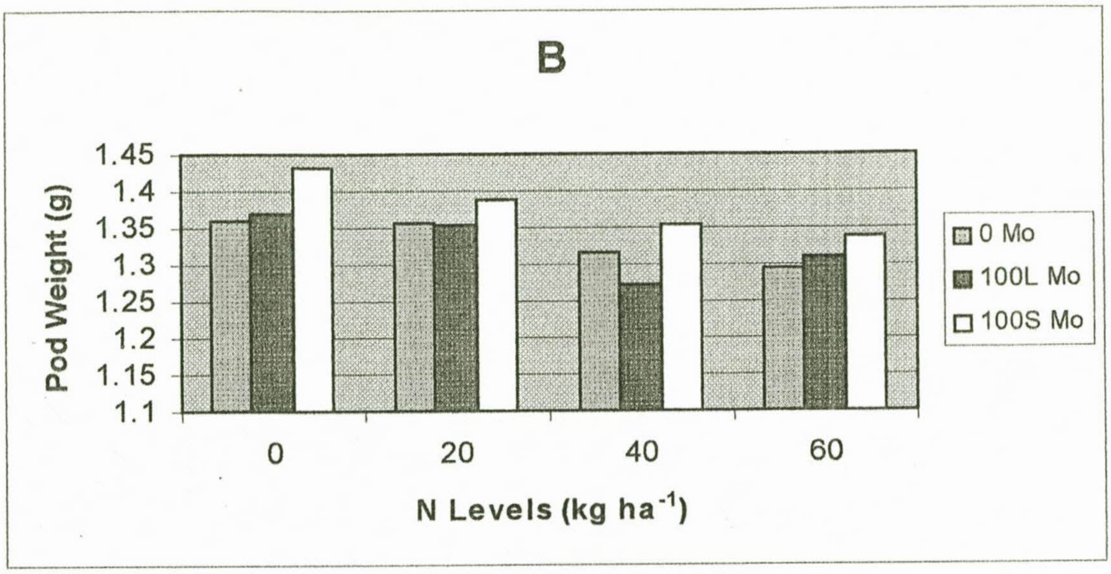


Figure 3.2 Interaction and main effects of N and Mo fertilizers on pod weight (g), with band (A) and broadcast (B) placement methods of N fertilizer, (100L Mo and 100S Mo imply 100 g Mo ha^{-1} as leaf application and seed treatment respectively).

As Figure 3.2 shows, increasing levels of N in the absence of Mo increased pod weight only at 40 kg N ha^{-1} with band N placement method. Leaf sprayed Mo linearly decreased pod weight while seed treated Mo reduced pod weight at 20 kg N ha^{-1} and then increased linearly with increasing N levels. Maximum pod weight was attained at the interaction between 40 kg N ha^{-1} and zero Mo for band placement method of N, but for broadcast N placement method, the highest pod weight was obtained at zero N with seed treated Mo fertilizer. The rest of the interaction levels either reduced or gave almost similar pod weight with the zero level. Broadcast N placement generally increased pod weight at the lower rates of N with Mo treatments while with band N placement pod weight seem to be increased uniformly.

3.3.1.3 Number of Pods per Plant

As shown in the appendix (Tables 7.5 & 7.6), number of pods per plant was observed to be non-significant with the interaction of N and Mo fertilizers for both band and broadcast N placement methods. However, with the band placement method of N, the interaction between N levels and Mo treatments gave positive number of pods per plant in most cases (Table 3.6). Only application of zero N with seed treated Mo, 20kg N ha^{-1} with zero and leaf sprayed Mo, and 40 kg N ha^{-1} with seed treated Mo gave lower number of pods per plant than the zero N and zero Mo interaction. The rest of the interaction levels increased pod number per plant over the zero levels. With the broadcast N placement method, almost all treatment combinations increased number of pods per plant over the zero levels except zero N with leaf sprayed Mo and 20 kg N ha^{-1} with zero Mo treatments. Zero and leaf sprayed Mo treatments across the increasing N levels increased number of pods per plant over the zero N level whereas seed treated Mo with increasing N levels reduced number of pods per plant.

With both band and broadcast placed N, although statistically shown non-significant, the main effect of N on number of pods per plant was positive. Increasing levels of N increased number of pods per plant over the zero level (Tables 3.6 & 3.7). With both N placement methods, application of 60 kg N ha^{-1} gave greater number of pods per pant over the other levels.

Table 3.6 Interaction and main effects of N and Mo fertilizers on pod number per plant with band N placement method.

Mo Levels,	N Levels, kg ha^{-1}				
g ha^{-1}*	0	20	40	60	Mean
0	13.000	11.750	13.832	15.625	13.552
100L	13.250	12.582	13.418	14.415	13.416
100S	11.960	14.418	12.335	14.835	13.387
Mean	12.737	12.917	13.195	14.958	
P Level	N = NS		Mo = NS	N x Mo = NS	
CV%			21.46		

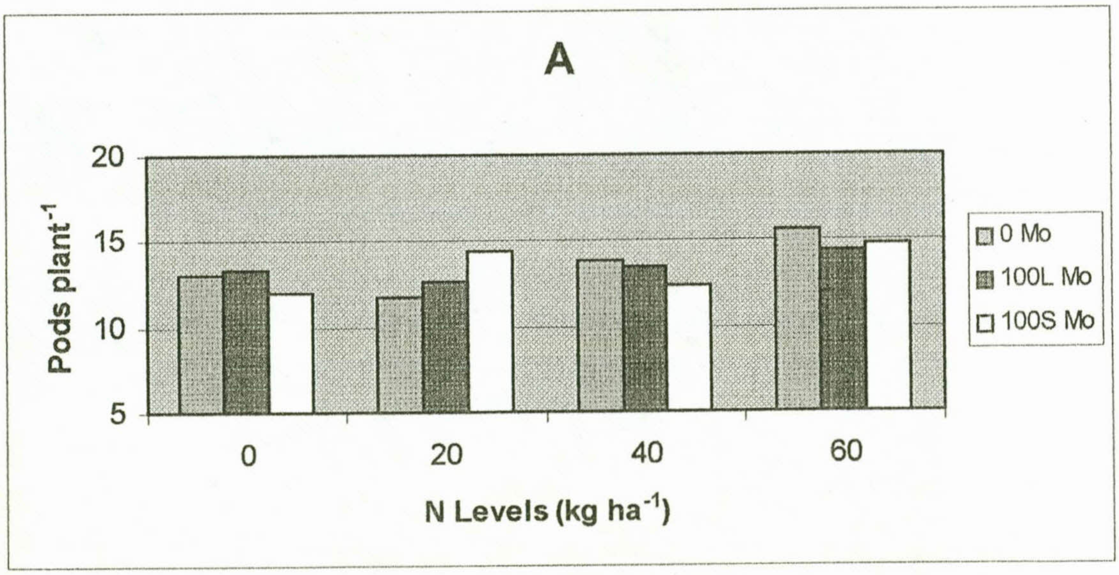
*Note. *L = Leaf Application, S = Seed Treatment, NS = Non-significant*

Table 3.7 Interaction and main effects of N and Mo fertilizers on number of pods per plant, with broadcast N placement method.

Mo Levels,	N Levels, kg ha^{-1}				
g ha^{-1}*	0	20	40	60	Mean
0	11.918	11.418	12.582	12.415	12.083
100L	10.500	12.915	13.250	13.582	12.562
100S	13.168	13.165	12.418	12.500	12.813
Mean	11.862	12.499	12.750	12.832	
P Level	N = NS	Mo = NS		N x Mo = NS	
CV%			17.75		

***Note:** *L = Leaf Application, S = Seed Treatment, NS = Non-significant*

Application of Mo showed decreasing trend on number of pods per plant with band placed N. Both leaf sprayed and seed treated Mo applications negatively and non-significantly responded to number of pods per plant (Table 3.6). With broadcast N placement method, application of Mo both as leaf spray and seed treatment non-significantly increased number of pods per plant over the zero Mo treatment. Seed treated Mo gave greater number of pods per plant over the other two (Table 3.7).



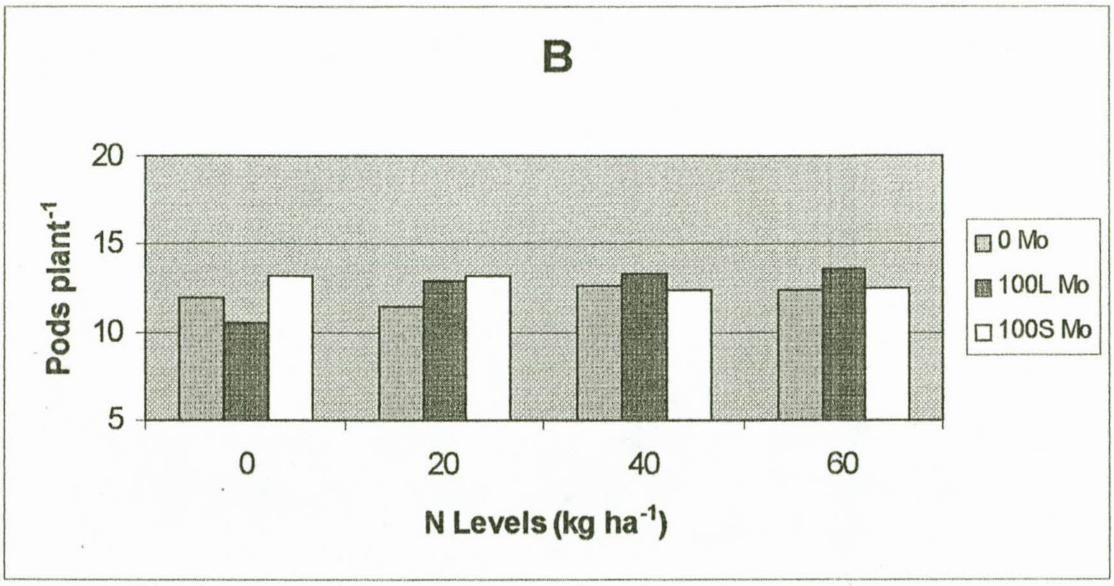


Figure 3.3 Interaction effects of N and Mo fertilizers on number of pods per plant with both band (A) and broadcast (B) N placement methods, (100L Mo and 100S Mo imply 100 g Mo ha^{-1} leaf applied and seed treated respectively).

As it can be observed from Figure 3.3, more pods per plant were achieved with band N placement method. In almost all cases band placed N gave greater number of pods per plant than the broadcast method. The highest peak was observed at 60 kg N ha^{-1} with zero Mo with band N placement method whereas with the broadcast method this level gave smaller and similar results with zero N and zero Mo treatments. Only at one interaction level (zero N with seed treated Mo) the broadcast method exceeded the band method of N placement.

3.3.1.4 Number of Seeds per Pod

According to the analysis of variance (Tables 7.7 & 7.8) shown in the appendix, the interaction of N levels with Mo did not-significantly affect number of seeds per pod with both band and broadcast N placement methods. With band N placement method, all interaction levels yielded lower number of seeds per pod than the zero interaction levels of both N and Mo fertilizers. Application of no Mo with all N levels gave greater number of seeds per pod than application of Mo as leaf spray or seed treatment with all increasing N levels except leaf treated Mo with 40 and 60 kg N ha^{-1}, and seed treated

Mo with 60 kg N ha^{-1} (Table 3.8) which slightly increased number of seeds per pod over zero Mo. With broadcast N placement method, all interaction levels gave higher

Table 3.8 Interaction and main effects of N and Mo fertilizers on number of seeds per pod, with band N placement method.

Mo Levels, g ha^{-1}*	N Levels, kg ha^{-1}				
	0	20	40	60	Mean
0	6.031	5.984	5.781	5.697	5.873
100L	5.490	5.647	5.870	5.700	5.677
100S	5.895	5.579	5.737	5.931	5.785
Mean	5.805	5.737	5.796	5.776	
P Level	N = NS	Mo = NS		N x Mo = NS	
CV%			4.90		

*Note. *L = Leaf Application, S = Seed Treatment, NS = Non-significant*

Table 3.9 Interaction and main effects of N and Mo fertilizers on number of seeds per pod, with broadcast N placement method.

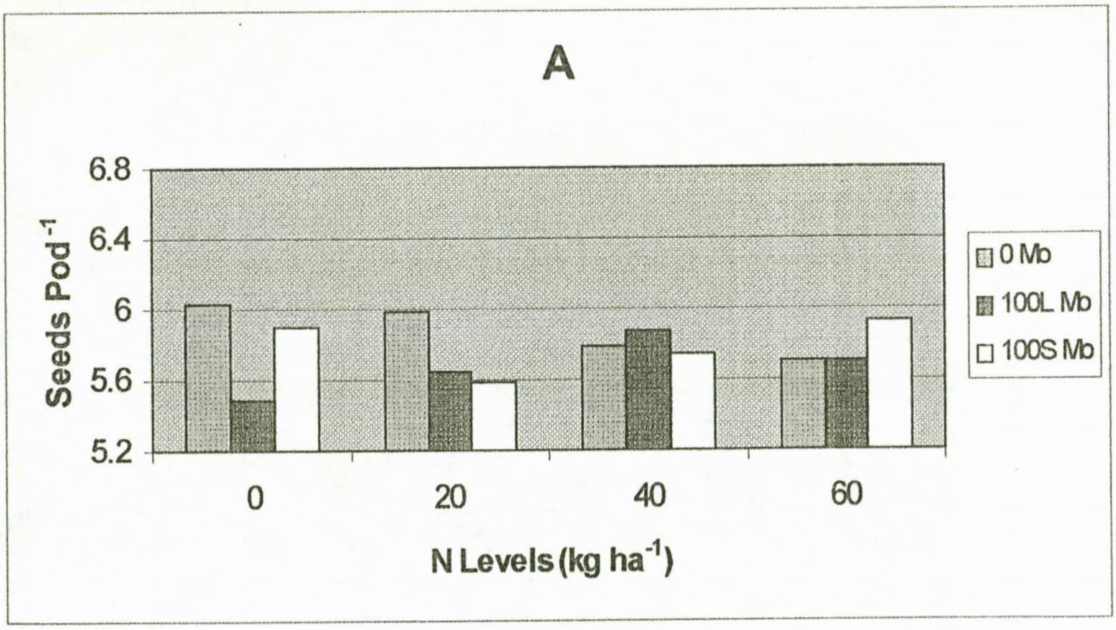
Mo Levels, g ha^{-1}*	N Levels, kg ha^{-1}				
	0	20	40	60	Mean
0	5.738	5.882	5.997	6.669	6.071
100L	5.818	5.871	5.674	5.732	5.774
100S	5.985	5.954	5.811	5.810	5.890
Mean	5.847	5.902	5.827	6.071	
P Level	N = NS	Mo = NS		N x Mo = NS	
CV%			8.18		

*Note: *L = Leaf Application, S = Seed Treatment, NS = Non-significant*

number of seeds per pod than zero N with zero Mo interaction, other than leaf sprayed Mo with 40 and 60 kg N ha^{-1}. Both leaf sprayed and seed treated Mo with zero N increased number of seeds per pod over the zero N with zero Mo interaction. However, these Mo treatments with the other three N levels gave lower number of seeds per pod than their respective zero interaction levels (Table 3.9) except seed treated Mo with 20 kg N ha^{-1}.

For the main effects, the response of number of seeds per pod to increasing levels of N was statistically non-significant with both band and broadcast N placement methods. With band N placement method, increasing N levels decreased number of seeds per pod as compared to zero N level (Table 3.8). With the broadcast N placement method, increasing N levels increased number of seeds per pod, but 40 kg N ha^{-1} slightly decreased number of seeds per pod (Table 3.9).

Application of Mo did not significantly affect number of seeds per pod with both band and broadcast N placement methods. With both N placement methods, both leaf sprayed and seed treated Mo fertilizer decreased number of seeds per pod (Tables 3.8 & 3.9). In both cases leaf sprayed Mo reduced number of seeds per pod more than seed treated Mo.



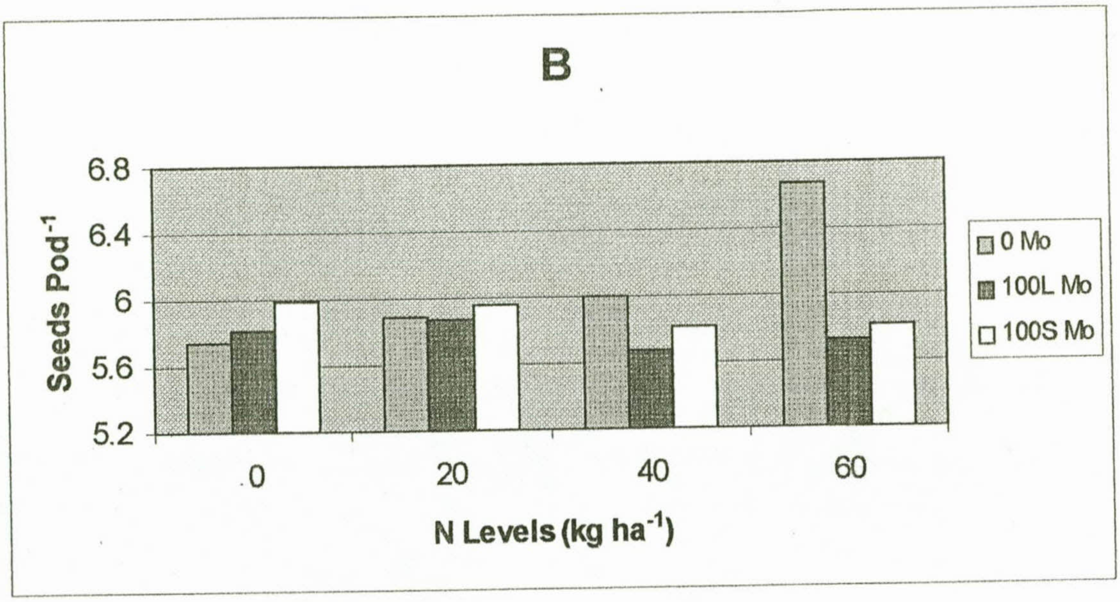


Figure 3.4 Interaction and main effects of N and Mo fertilizers on number of seeds per pod, with band (A) and broadcast (B) N placement methods, (100L Mo and 100S Mo imply 100 g Mo ha^{-1} leaf application and seed treatment respectively).

Figure 3.4 shows that increasing N levels reduced number of seeds per pod with zero Mo treatments with band N placement method. Leaf sprayed Mo with N levels linearly increased number of seeds per pod whereas seed treated Mo reduced number of seeds per pod with increasing N levels. With broadcast N placement method 60 kg N ha^{-1} with zero Mo gave the best result on number of seeds per pod. The other interaction levels did not significantly differ from and gave almost similar number of seeds with zero N and zero Mo treatments (check treatment). Generally, more number of seeds per pod was achieved with broadcast N placement method than with band N placement method in most interaction levels of N and Mo fertilizers.

3.3.1.5 Seed Weight per Pod

The analysis of variance showed that seed weight per pod was non-significantly affected by the interaction of N and Mo fertilizers with both band and broadcast N placement methods (Tables 7.9 & 7.10 in appendix). With band N placement method, increasing N levels in the absence of Mo linearly increased seed weight per pod. Leaf sprayed Mo decreased seed weight per pod whereas seed treated Mo increased seed weight per pod except at 40 kg N ha^{-1} (Table 3.10). Interaction of zero N with leaf sprayed and seed treated Mo increased seed weight per pod over zero Mo treatment whereas with 60 kg N ha^{-1} they reduced seed weight per pod. Seed treated Mo with 20 kg N ha^{-1} and leaf sprayed Mo with 40 kg N ha^{-1} also increased seed weight per pod over zero Mo treatments. With broadcast N placement method, the three Mo treatments across the increasing levels of N linearly increased seed weight per pod (Table 3.11). Leaf sprayed and seed treated Mo with the increasing N levels reduced seed weight per pod as compared to zero Mo with the increasing N levels except with 60 kg N ha^{-1} which slightly increased seed weight over zero Mo treatment.

Table 3.10 Interaction and main effects of N and Mo fertilizers on seed weight (g pod^{-1}), with band N placement method.

Mo Levels,	N Levels, kg ha^{-1}				
g ha^{-1}*	0	20	40	60	Mean
0	1.372	1.377	1.377	1.392	1.379
100L	1.423	1.367	1.409	1.368	1.392
100S	1.385	1.388	1.371	1.391	1.384
Mean	1.393	1.377	1.386	1.384	
P Level	N = NS	Mo = NS	N x Mo = NS		
CV%			2.03		

*Note. *L = Leaf Application, S = Seed Treatment, NS = Non-significant.*

As shown in the appendix (Table 7.9) the main effect of N did not significantly affect seed weight per pod with band N placement method. However, increasing N levels decreased seed weight per pod as compared to zero N level. Relatively greater seed weight per pod was obtained from zero N application (Table 3.10). With the broadcast N placement method, increasing levels of N significantly ($p<0.01$) increased seed weight per pod. Application of 40 and 60 kg N ha^{-1} highly significantly increased seed weight per pod over zero and 20 kg N ha^{-1}. There were no significant differences between zero and 20 kg N ha^{-1}, and 40 and 60 kg N ha^{-1}.

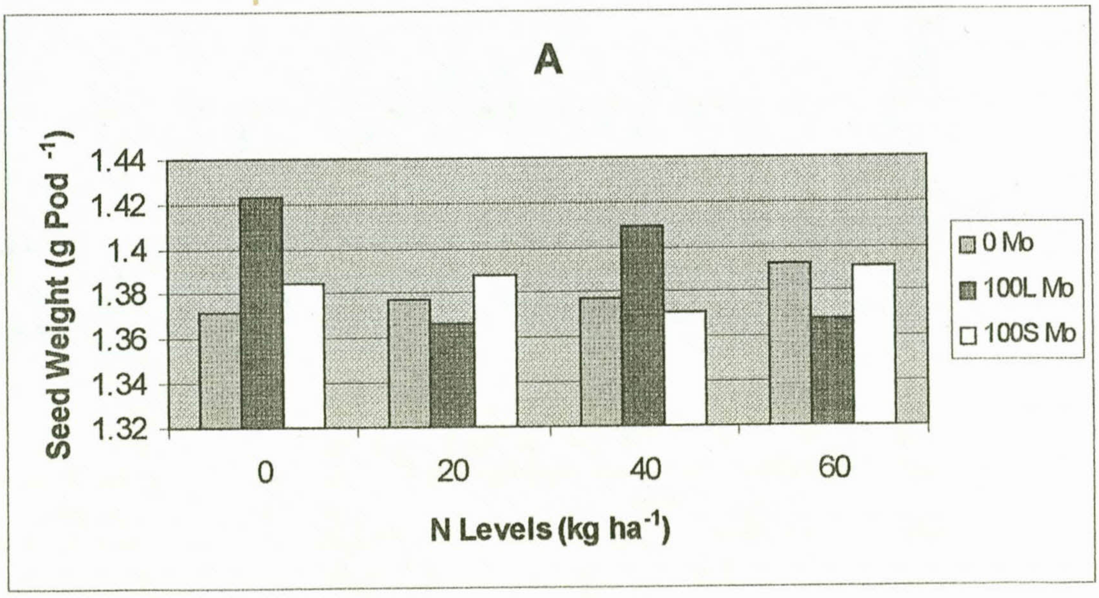
Table 3.11 Interaction and main effects of N and Mo fertilizers on seed weight (g Pod $^{-1}$), with broadcast N placement method.

Mo Levels,	N Levels, kg ha^{-1}				
g ha^{-1}*	0	20	40	60	Mean
0	1.361	1.363	1.374	1.372	1.367
100L	1.349	1.346	1.371	1.381	1.362
100S	1.345	1.351	1.356	1.379	1.358
Mean	1.352^{b}	1.353^{b}	1.367^{a}	1.377^{a}	
P Level	N = 0.0034**		Mo = NS	N x Mo = NS	
CV%			1.32		
	N LSD1% = 0.0111				

*Note: *L = Leaf Application, S = Seed Treatment, NS = Non-significant*

*** Significant at 1% level.*

Application of Mo, both as leaf spray and seed treatment, did not significantly affect seed weight per pod with both N placement methods. However, with band N placement method, both leaf sprayed and seed treated Mo increased seed weight per pod over the zero Mo application (Table 3.10), but with broadcast N placement method, these Mo treatments reduced seed weight per pod as compared to the zero Mo treatment.



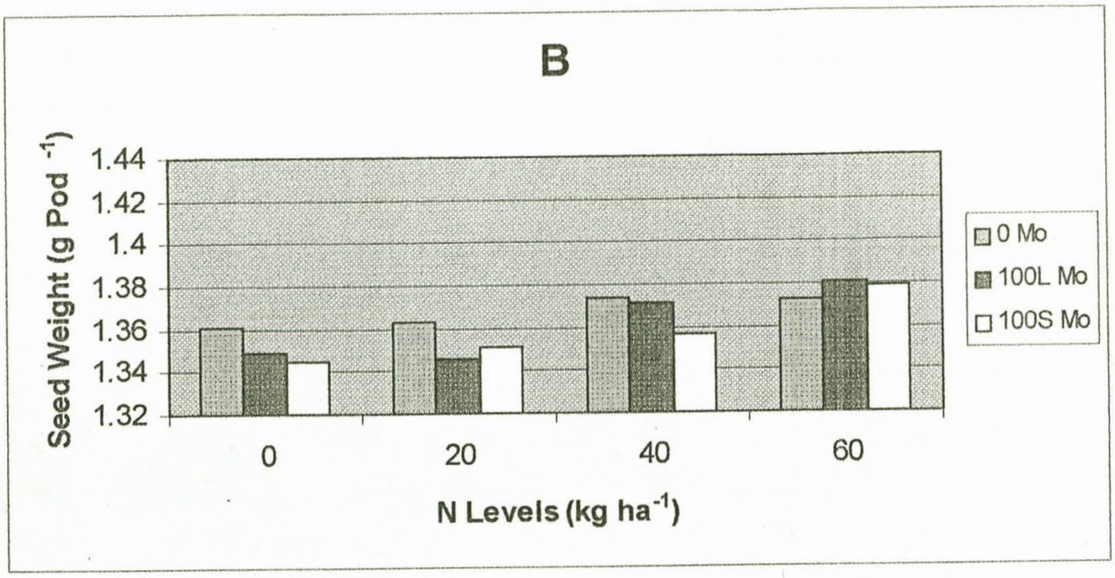


Figure 3.5 Interaction and main effects of N and Mo fertilizers on seed weight (g pod $^{-1}$), with band (A) and broadcast (B) N placement methods, (100L Mo and 100S Mo imply 100 g Mo ha^{-1} leaf application and seed treatment respectively).

As it can be observed from Figure 3.5, greater seed weight per pod was obtained with the interaction of N and Mo fertilizers with band N placement than with broadcast N placement methods. The graph shows that almost all interaction levels with band placed N were greater than the levels of broadcast N placement method. With band placed N, interaction of zero and seed treated Mo with increasing N levels increased seed weight per pod. Leaf sprayed Mo showed a decreasing effect on seed weight per pod. With broadcast placed N, all Mo treatments with increasing N levels linearly increased seed weight. With band placed N, application of zero N with leaf sprayed Mo gave the highest peak whereas with broadcast placed N this point is at its lowest result of seed weight. With broadcast N placement method, the highest peak was at 60 kg N ha^{-1} with leaf sprayed Mo.

3.3.1.6 Number of Seeds per Plant

For the overall treatment combinations, the analysis of variance (Tables 7.11 & 7.12) revealed that there were no significant effects of N and Mo treatments on number of seeds per plant with both band and broadcast N placement methods. With band N placement method, the individual levels of N with the three Mo treatments decreased number of seeds per plant except for the treatment with 20 kg N ha^{-1} (Table 3.12). However, the Mo treatments with increasing N levels increased number of seeds per plant as compared to zero N except 20 kg N ha^{-1} with zero and leaf sprayed Mo. With broadcast N placement method, other than 20 kg N ha^{-1} with zero Mo and zero N with leaf sprayed Mo, all the interaction levels gave greater number of seeds per plant than the zero N with zero Mo treatments. Application of leaf sprayed and zero Mo across the increasing levels of N, in most cases, increased number of seeds per plant as compared to the interaction with zero N level (Table 3.13). Seed treated Mo with the increasing N levels decreased number of seeds per plant as compared to its interaction with zero N level.

According to the analysis of variance (Tables 7.11 & 7.12) shown in the appendix, the main effects of N and Mo gave non-significant responses to number of seeds per plant with both band and broadcast N placement methods. With both N placement methods, however, increasing levels of N almost linearly increased number of seeds per plant (Tables 3.12 & 3.13). The highest seed number per plant was reached with the highest level of N (60 kg N ha^{-1}) with both band and broadcast N placement methods.

Table 3.12 Interaction and main effects of N and Mo fertilizers on number of seeds per plant, with band N placement method.

Mo Levels,	N Levels, kg ha^{-1}				
g ha^{-1}*	0	20	40	60	Mean
0	78.500	70.333	83.667	89.042	80.385
100L	71.375	70.833	78.750	82.375	75.833
100S	70.500	80.667	70.833	87.833	77.458
Mean	73.458	73.944	77.750	86.417	
P Level	N = NS	Mo = NS		N x Mo = NS	
CV%			21.55		

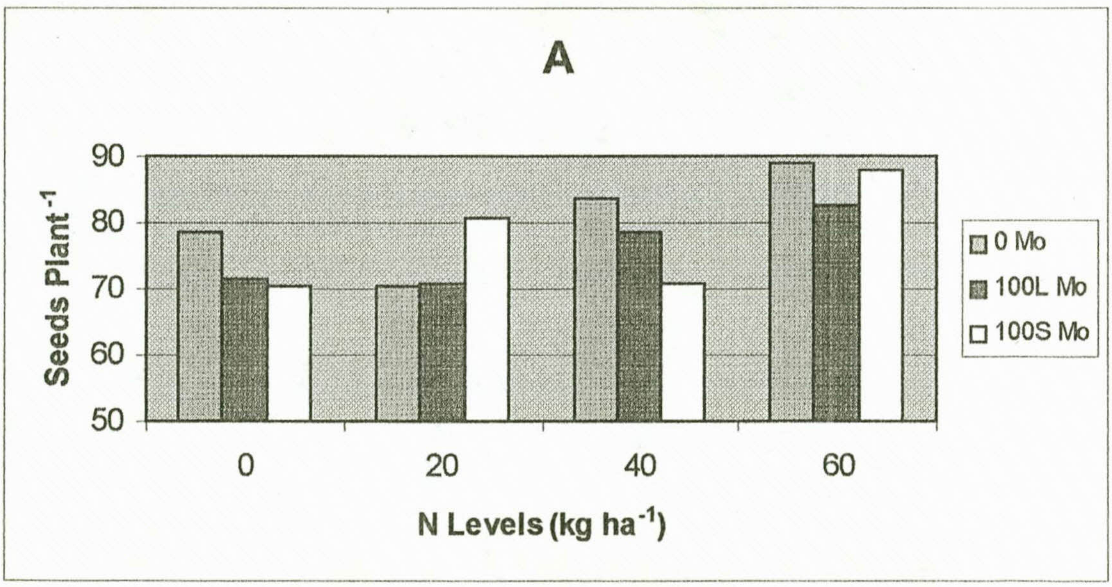
Note. **L = Leaf Application, S = Seed Treatment, NS = Non-significant*

Table 3.13 Interaction and main effects of N and Mo fertilizers on number of seeds per plant, with broadcast N placement method.

Mo Levels,	N Levels, kg ha^{-1}				
g ha^{-1}*	0	20	40	60	Mean
0	68.167	67.250	75.333	73.583	71.083
100L	61.000	75.583	75.083	78.167	72.458
100S	78.833	78.667	71.917	72.750	75.542
Mean	69.333	73.833	74.111	74.833	
P Level	N = NS	Mo = NS		N x Mo = NS	
CV%			18.21		

*Note: *L = Leaf Application, S = Seed Treatment, NS = Non-significant*

Application of Mo responded negatively to number of seeds per plant with band N placement method. Both leaf sprayed and seed treated Mo gave lower number of seeds per plant than the zero Mo treatment. With broadcast N placement method, Mo treatments positively increased number of seeds per plant. Both leaf sprayed and seed treated Mo gave greater number of seeds per plant than the zero Mo application.



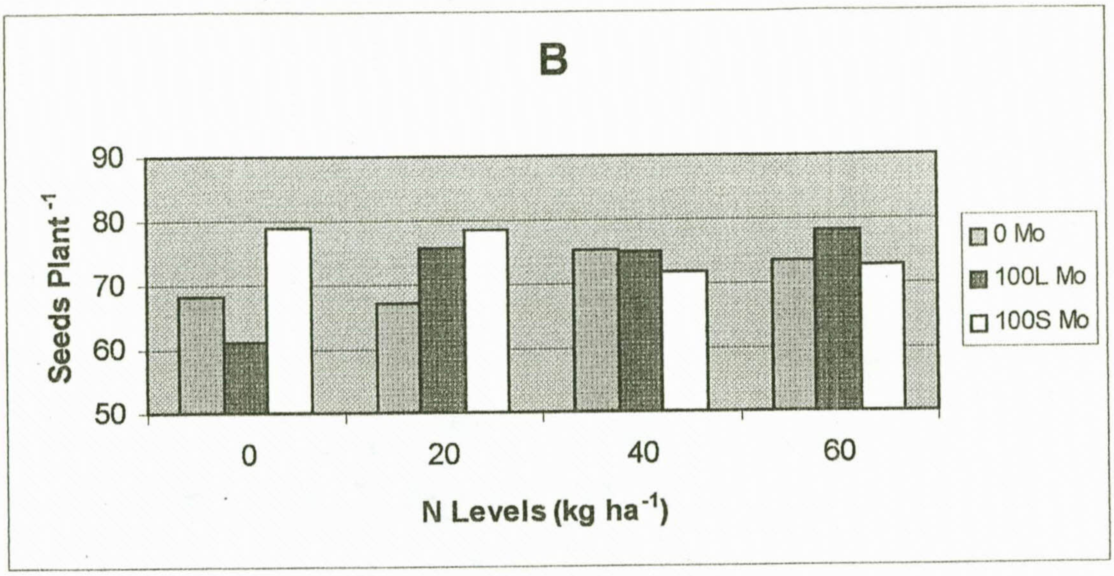
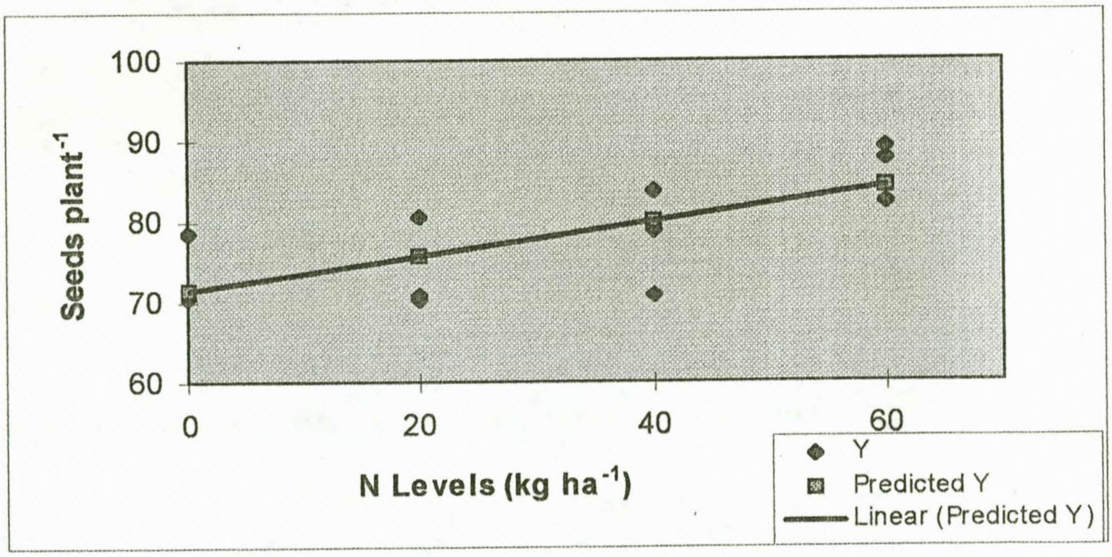


Figure 3.6 Interaction and main effects of N and Mo fertilizers on number of seeds per plant, with band (A) and broadcast (B) N placement methods, (100L Mo and 100S Mo imply 100 g Mo ha^{-1} leaf application and seed treatment respectively).



$Y = 71.49023 + 0.2134X$, $R^2 = 0.5067$

Figure 3.7 Regression relation of N and number of seeds per plant for band placement of N.

As Figure 3.6 shows, the interaction effects of N and Mo on number of seeds per plant is more pronounced with band N placement method than with broadcast N placement method. In most interaction levels, the values for band N placement is greater than the values for broadcast N placement method. There is an increasing trend in number of seeds per plant with the interaction of increasing N levels with Mo treatments in both N placement methods except seed treated Mo with 40 and 60 kg N ha^{-1} with broadcast N placement method. With band placed N, the highest peak was achieved at the interaction of 60 kg N ha^{-1} with zero Mo treatments. With broadcast placed N, zero and 20 kg N ha^{-1} with seed treated Mo and 60 kg N ha^{-1} with leaf sprayed Mo gave higher and almost similar number of seeds per plant.

Figure 3.7 shows that number of seeds per plant is strongly and positively (R^2 = 0.5067) associated with the increasing levels of N. The regression equation obtained for this parameter (Y = 71.49023 + 0.2134X) indicates that the predicted number of seeds per plant when no N is applied is 71.49 and an increase in 1 kg of N increases number of seeds per plant by 0.21.

3.3.1.7 100 Seed Weight

The interaction of N and Mo treatments did not significantly affect 100 seed weight with both band and broadcast N placement methods (Tables 7.13 & 7.14 in appendix). With band N placement method, interaction of zero and leaf sprayed Mo treatments across the increasing N levels decreased 100 seed weight except zero Mo with 40 kg N ha^{-1}. However, seed treated Mo showed an increasing effect on 100 seed weight except at 20 kg N ha^{-1}. Leaf sprayed Mo with 40 kg N ha^{-1} gave lower, but with the other N levels gave higher 100 seed weight compared to zero Mo treatments. Seed treated Mo increased 100 seed weight only with 40 and 60 kg N ha^{-1} over the zero Mo treatments (Table 3.14). With the broadcast N placement method, interaction of all N levels with leaf sprayed and seed treated Mo increased 100 seed weight as compared to zero Mo, whereas all the Mo treatments across the increasing N levels decreased 100 seed weight as compared to the zero N level (Table 3.15).

The main effect of N on 100 seed weight was found to be non-significant with band N placement method. Application of N reduced 100 seed weight as compared to zero N level (Tables 3.14). With broadcast N placement method, application of N significantly ($p<0.05$) affected 100 seed weight. Zero N significantly increased 100 seed weight over 40 and 60 kg N ha^{-1}. The highest 100 seed weight was obtained with zero N treatment (Table 3.15). Application of Mo with both N placement methods did not significantly affect 100 seed weight. Mo applied as leaf spray and seed treatment increased 100 seed weight over zero Mo with both band and broadcast N placement methods. With band N placement, better 100 seed weight was obtained from leaf sprayed Mo whereas with broadcast N placement method seed treated Mo gave greater 100 seed weight.

Table 3.14 Interaction and main effects of N and Mo fertilizers on 100 seed weight (g), with band N placement method.

Mo levels,	N Levels, kg ha^{-1}				
g ha^{-1}*	0	20	40	60	Mean
0	16.780	16.755	17.030	15.807	16.593
100L	17.570	16.787	16.098	16.810	16.816
100S	16.710	15.737	17.115	16.993	16.639
Mean	17.020	16.427	16.748	16.537	
P Level	N = NS	Mo = NS	N x Mo = NS		
CV%			5.40		

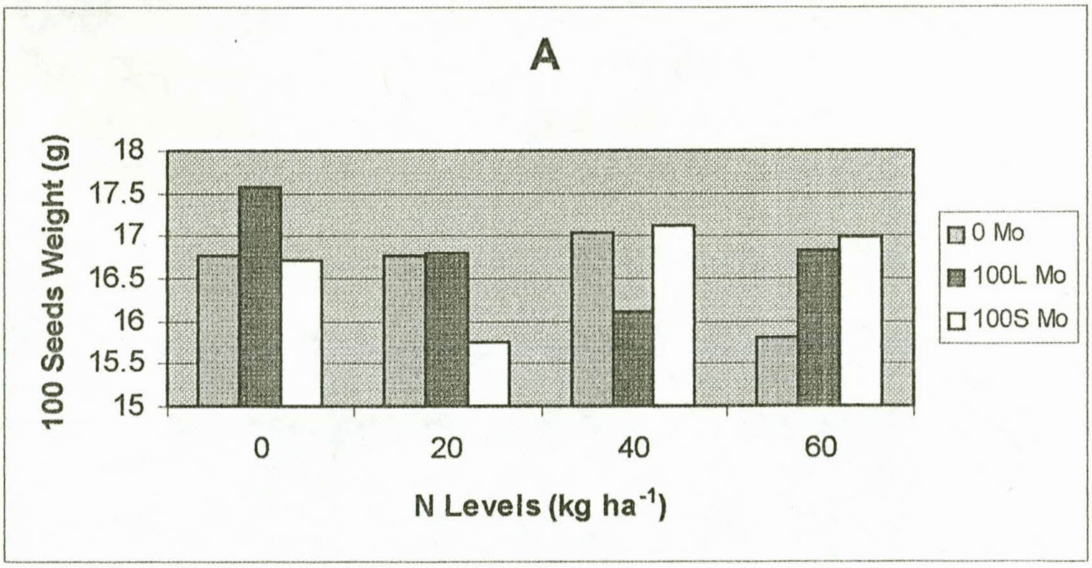
*Note. *L = Leaf Application, S = Seed Treatment, NS = Non-significant*

Table 3.15 Interaction and main effects of N and Mo fertilizers on 100 seed weight (g), with broadcast N placement method.

Mo Levels,	N Levels, kg ha^{-1}				
g ha^{-1}*	0	20	40	60	Mean
0	17.403	16.953	15.960	15.963	16.569
100L	17.453	17.153	16.362	16.495	16.866
100S	17.795	17.242	17.190	16.705	17.233
Mean	17.550^{a}	17.116^{ab}	16.504^{b}	16.388^{b}	
P Level	N = 0.0183**		Mo = NS	N x Mo = NS	
CV%			5.73		
	N LSD5% = 0.8006				

*Note: *L = Leaf Application, S = Seed Treatment, NS = Non-significant*

***Significant at 5% level.*



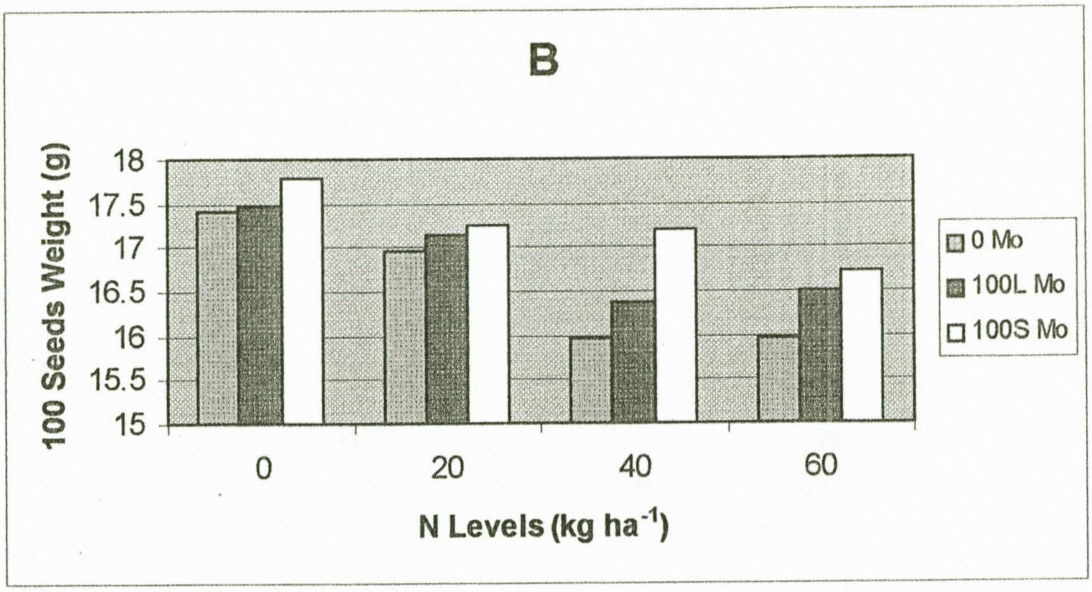


Figure 3.8 Interaction and main effects of N and Mo fertilizers on 100 seed weight (g), with band (A) and broadcast (B) N placement methods, (100L Mo and 100S Mo imply 100 g Mo ha^{-1} leaf application and seed treatment respectively).

Figure 3.8 shows that the interaction effect of N and Mo on 100 seed weight was more pronounced with broadcast N placement than with band N placement methods. With band N placement method zero N with leaf sprayed Mo gave the highest 100 seed weight, however, with broadcast N placement method the highest peak was observed at the interaction levels of zero N with seed treated Mo application.

3.3.1.8 Pod Abscission

The appendix (Tables 7.15 & 7.16) showed that the interaction of N levels with Mo treatments did not significantly affect pod abscission with both band and broadcast N placement methods. However, the interaction of zero and leaf applied Mo treatments with increasing levels of N showed an increasing trend on pod abscission (Table 3.16 & 3.17) with both N placement methods. In both methods, seed treated Mo with increasing N levels decreased pod abscission except with 60 kg N ha^{-1} which slightly increased pod abscission over the zero N level.

Table 3.16 Interaction and main effects of N and Mo fertilizers on number of pod abscission, with band N placement method.

Mo Levels,	N Levels, kg ha^{-1}				
g ha^{-1}*	0	20	40	60	Mean
0	3.418	4.082	4.335	4.707	4.136
100L	3.418	3.582	4.168	3.668	3.709
100S	4.082	3.915	3.082	4.415	3.874
Mean	3.639	3.860	3.862	4.263	
P Level	N = NS	Mo = NS		N x Mo = NS	
CV%			25.67		

*Note. *L = Leaf Application, S = Seed Treatment, NS = Non-significant*

Table 3.17 Interaction and main effects of N and Mo fertilizers on number of pod abscission, with broadcast N placement method.

Mo Levels,	N Levels, kg ha-1				
g ha^{-1}*	0	20	40	60	Mean
0	3.750	4.085	5.000	4.668	4.376^{a}
100L	3.750	4.003	4.085	4.250	4.022^{ab}
100S	4.042	3.500	2.500	4.335	3.594^{b}
Mean	3.848	3.863	3.862	4.418	
P Level	N = NS	Mo = 0.0384**		N x Mo = NS	
CV%			20.71		
	Mo LSD5% = 0.5935				

*Note: *L = Leaf Application, S = Seed Treatment, NS = Non-significant.*

With the interaction of each N levels with Mo treatments, more pods were abscised and dropped off the plant before seed setting with zero Mo than leaf sprayed and seed treated Mo except seed treated Mo with zero N treatments in both N placement methods. In other words, in the absence of Mo increasing levels of N increased pod abscission, but as Mo was applied, either as leaf spray or as seed treatment with N levels, pod abscission was decreased.

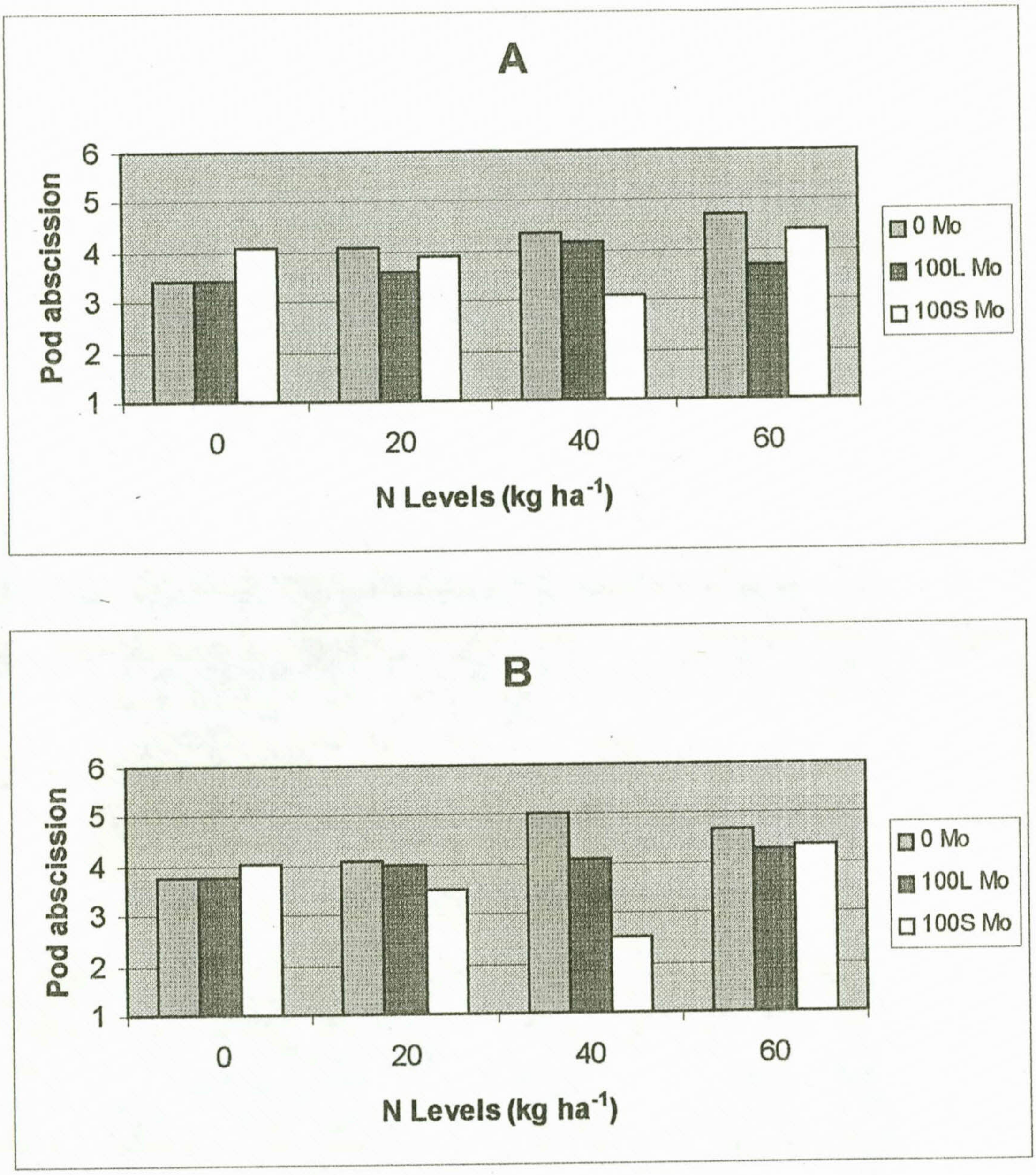


Figure 3.9 Interaction and main effects of N and Mo fertilizers on pod abscission, with band (A) and broadcast (B) N placement methods, (100L Mo and 100S Mo imply 100 g Mo ha^{-1} leaf application and seed treatment respectively).

The main effect of N on pod abscission was statistically non-significant with band and broadcast N placement methods. However, the increasing levels of N linearly increased pod abscission with both N placement methods (Tables 3.16 & 3.17). More pods were dropped off the plant at early seed setting stage with the highest level (60 kg N ha^{-1}) of N application with both N placement methods.

Mo treatments did not significantly affect pod abscission with band N placement method. Application of Mo reduced pod abscission as compared to zero Mo treatments. Higher pod abscission was obtained with zero Mo treatments. With broadcast N placement method, application of Mo significantly ($p<0.05$) affected pod abscission. Seed treated Mo significantly reduced pod abscission compared to zero Mo treatments.

As can be observed from Figure 3.9, pod abscission was more pronounced with broadcast than with band N placement method. In most interaction levels, the values of broadcast N placement is greater than that of band N placement. With both band and broadcast N placement methods, application of 40 kg N ha^{-1} with seed treated Mo gave the lowest pod abscission. With band N placement method, zero Mo with 60 kg N ha^{-1} gave higher pod abscission whereas with broadcast N placement method zero Mo with 40 kg N ha^{-1} gave the highest pod abscission. Generally, there is a linear increase in pod abscission with both N placement methods in the application of increasing N levels with Mo treatments except Mo seed treatment. Overall, band N placement better saved pods from dropping off the plant before seed setting.

3.3.1.9 Seed Yield per Plant

The analysis of variance (Tables 7.17 & 7.18) showed that seed yield per plant was not significantly affected by the interaction of N and Mo treatments with both band and broadcast N placement methods. With band N placement method, however, the Mo treatments with increasing N levels increased seed yield per plant except zero and leaf sprayed Mo with 20 kg N ha^{-1}, and seed treated Mo with 40 kg N ha^{-1} which slightly reduced seed yield per plant as compared to their respective interaction with zero N level (Table 3.18). Leaf sprayed and seed treated Mo with zero and 40 kg N ha^{-1} reduced seed yield per plant whereas with 20 and 60 kg N ha^{-1} they increased seed yield per plant as compared to zero Mo treatment. Generally, only the interaction of 60 kg N ha^{-1} with the three Mo treatments and 40 kg N ha^{-1} with zero Mo gave greater seed yield per plant over the zero N with zero Mo treatments. The highest seed yield

Table 3.18 Interaction and main effects of N and Mo fertilizers on seed yield (g Plant $^{-1}$), with band N placement method.

Mo Levels, g ha^{-1}*	N Levels, kg ha^{-1}				
	0	20	40	60	Mean
0	13.123	11.749	13.949	13.877	13.175
100L	12.569	11.883	12.678	13.807	12.734
100S	11.770	12.675	11.383	14.764	12.648
Mean	12.487	12.103	12.670	14.149	
P Level	N = NS		Mo = NS	N x Mo = NS	
CV%			19.48		

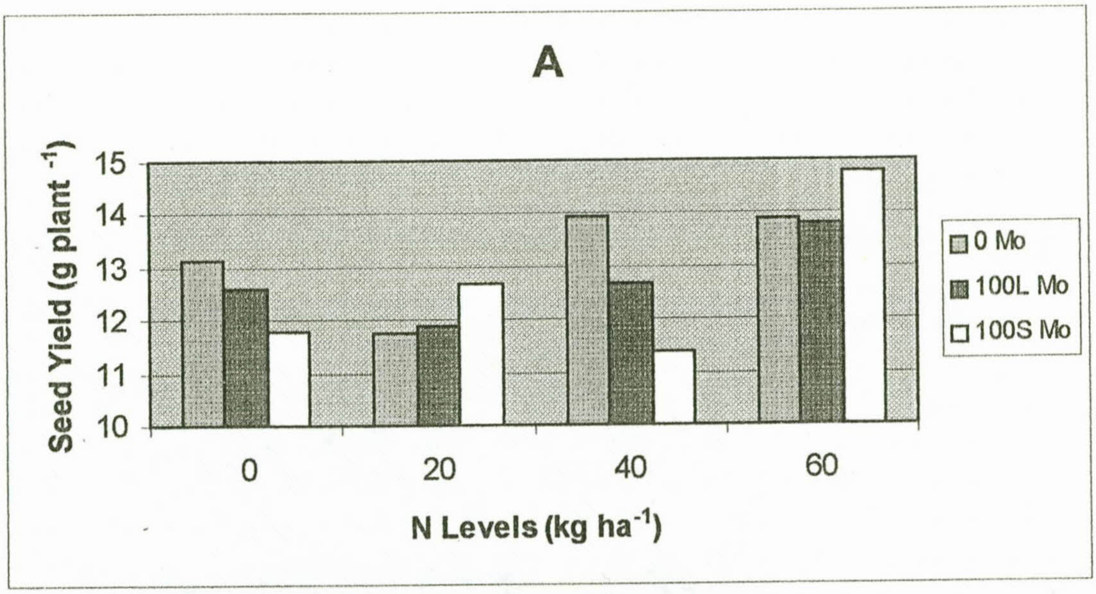
*Note. *L = Leaf Application, S = Seed Treatment, NS = Non-significant*

Table 3.19 Interaction and main effects of N and Mo fertilizers on seed yield (g plant $^{-1}$), with broadcast N placement methods.

Mo Levels, g ha^{-1}*	N Levels, kg ha^{-1}				
	0	20	40	60	Mean
0	11.832	11.818	11.990	11.630	11.818
100L	10.623	12.941	12.243	12.711	12.129
100S	14.067	13.587	12.365	12.215	13.058
Mean	12.174	12.782	12.199	12.185	
P Level	N = NS		Mo = NS	N x Mo = NS	
CV%			19.48		

*Note: *L = Leaf Application, S = Seed Treatment, NS = Non-significant*

per plant was obtained from the interaction of 60 kg N ha^{-1} with seed treated Mo, and the lowest was from 40 kg N ha^{-1} with seed treated Mo. With broadcast N placement method, unlike the band placed N, zero and seed treated Mo with increasing N levels reduced seed yield per plant except zero Mo with 40 kg N ha^{-1} which slightly increased seed yield per plant over the zero interaction levels. Only leaf sprayed Mo showed an increasing trend with increasing N levels (Table 3.19).



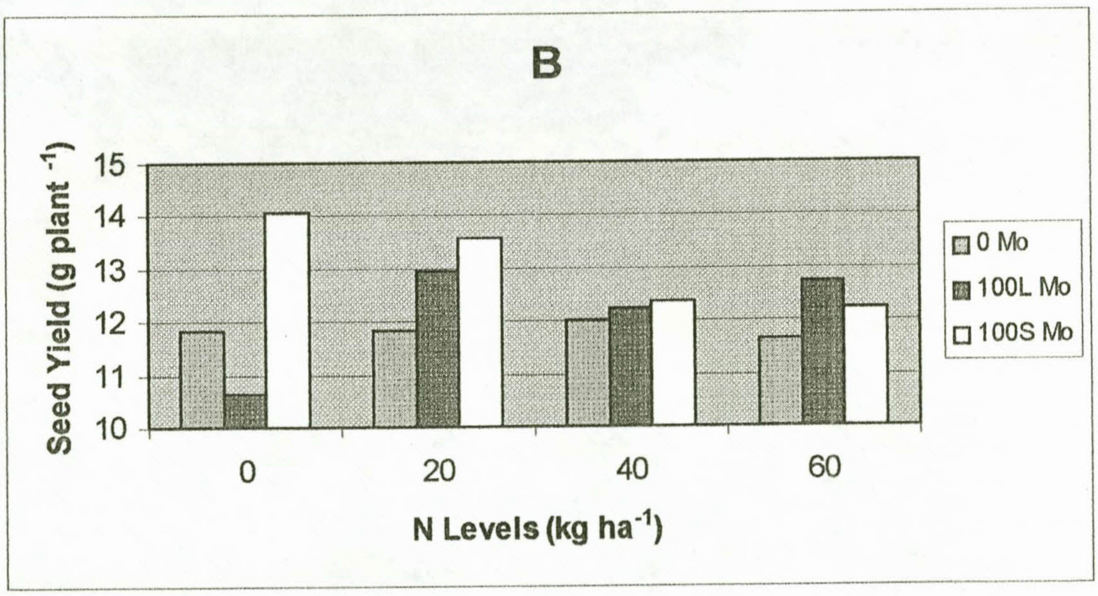


Figure 3.10 Interaction and main effects of N and Mo fertilizers on seed yield (g plant $^{-1}$), with band (A) and broadcast (B) N placement methods, (100L Mo and 100S Mo imply 100 g Mo ha^{-1} leaf application and seed treatment respectively).

However, each of the N levels with the Mo treatments increased seed yield except zero N with leaf sprayed Mo treatment. Here, most interaction levels gave greater seed yield per plant over the zero N and zero Mo treatments except zero Mo with 20 and 60 kg N ha^{-1}, and leaf sprayed Mo with zero N which slightly reduced seed yield per plant. The highest seed yield per plant was achieved at seed treated Mo with zero N application.

As indicated in the appendix (Tables 7.17 & 7.18), the main effects of N and Mo treatments did not significantly affect seed yield per plant with both band and broadcast N placement methods. However, with band N placement method, increasing levels of N increased seed yield per plant (Table 3.18). All N levels gave greater seed yield per plant than the zero N treatment except a slight decrease with 20 kg N ha^{-1}. The Mo treatments as leaf spray and seed treatment decreased seed yield per plant. With the broadcast N placement method, seed yield per plant was linearly increased with increasing levels of N (Table 3.19). There was positive response of seed yield per plant to Mo treatments. Both leaf sprayed and seed treated Mo gave greater seed yield than zero Mo.

As Figure 3.10 shows, with band N placement method, 20 kg N ha^{-1} with zero and leaf sprayed Mo decreased seed yield per plant whereas seed treated Mo with 40 kg N ha^{-1} gave seed yield per plant lower than the zero level. With broadcast N placement method, zero Mo with increasing N levels almost gave constant values while seed treated Mo linearly decreased seed yield per plant. Leaf applied Mo increased seed yield with increasing N levels. With band N placement method, the highest seed yield per plant was reached at 60 kg N ha^{-1} with seed treated Mo whereas with broadcast method it was at zero N with seed treated Mo.

3.3.1.10 Total Aboveground Dry Biomass Yield

With the band N placement method, the interaction effect of N and Mo on total aboveground dry biomass yield was significantly ($p<0.05$) different among the treatment means (Table 7.19 in appendix). Seed treated Mo with 60 kg N ha^{-1} significantly increased total aboveground biomass yield over zero, 20 and 40 kg N ha^{-1} treatments. Zero and leaf sprayed Mo with increasing levels of N did not significantly differ from each other (Table 3.20). Comparing between the Mo treatments with N levels, in the absence of N, zero Mo treatment significantly increased total biomass yield over seed treated Mo. Seed treated Mo with 40 kg N ha^{-1} significantly decreased total biomass yield as compared to leaf sprayed and zero Mo treatments. Seed treated Mo with 60 kg N ha^{-1} also significantly increased total biomass over zero Mo. The rest of the interaction levels did not significantly differ from each other. The highest total aboveground dry biomass yield was obtained with the application of 60 kg N ha^{-1} and seed treated Mo. The lowest response was obtained from zero N and seed treated Mo. Only few of the interaction levels (40kg N ha^{-1} with zero and leaf sprayed Mo, and 60 kg N ha^{-1} with seed treated Mo) gave biomass yield greater than the zero levels of N and Mo. Most of the results were below the check. The difference between the highest and the lowest (zero N with seed treated Mo) biomass yield was about 16.597 g pot^{-1}. The highest response increased biomass by 28.79% and 3.87% over the lowest response and the zero fertilizer applied check respectively.

Table 3.20 Interaction and main effects of N and Mo fertilizers on total aboveground dry biomass yield (g pot^{-1})[1], with band N placement method.

Mo Levels,	N Levels, kg ha^{-1}				
g ha^{-1}*	0	20	40	60	Mean
0	70.058^{abc}	66.330^{abcde}	70.460^{abc}	60.865^{bcde}	66.928
100L	60.850^{bcde}	64.367^{abcde}	70.883^{ab}	66.497^{abcd}	65.649
100S	56.170^{e}	60.562^{cde}	57.915^{de}	72.767^{a}	61.854
Mean	62.359	63.753	66.419	66.170	
P Levels	N = NS	Mo = NS	N x Mo = 0.0137**		
CV%			11.00		
	N x Mo LSD5%=10.23				

*Note. *L = Leaf Application, S = Seed Treatment*

***Significant at 5% level, [1]Means followed with the same letters are not significantly different at the given level.*

Table 3.21 Interaction and main effects of N and Mo fertilizers on total aboveground dry biomass yield (g pot^{-1}), with broadcast N placement method.

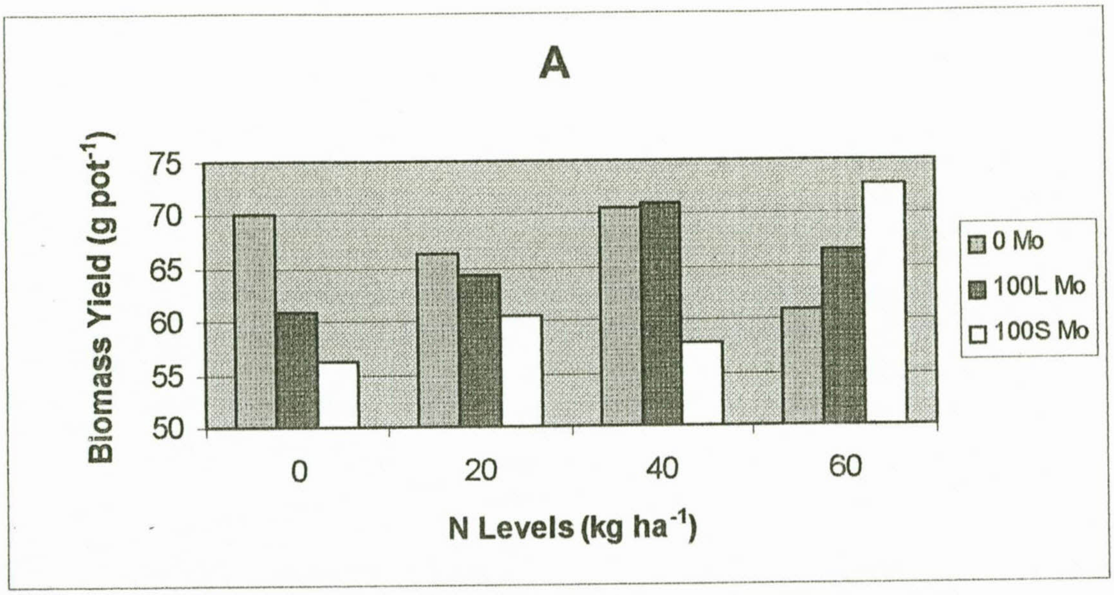
Mo Levels,	N Levels, kg ha^{-1}				
g ha^{-1}*	0	20	40	60	Mean
0	66.160	64.050	64.720	65.085	65.004
100L	57.860	62.325	63.720	65.313	62.304
100S	59.727	60.745	66.190	59.605	61.567
Mean	61.249	62.373	64.877	63.334	
P Level	N = NS	Mo = NS		N x Mo = NS	
CV%			8.45		

*Note: *L = Leaf Application, S = Seed Treatment, NS = Non-significant*

With the broadcast N placement method, the interaction of N and Mo treatments did not significantly affect total aboveground dry biomass yield (Table 7.20 in appendix). However, there is a general trend between the interaction levels. Increasing levels of N in the absence of Mo gave lower total biomass yield than zero N (Table 3.21). Leaf sprayed and seed treated Mo with increasing N levels increased total biomass yield over zero N except seed treated Mo with 60 kg N ha^{-1} which slightly reduced biomass yield as compared to zero N level. Both leaf sprayed and seed treated Mo with zero and 20 kg N ha^{-1} decreased total biomass yield as compared to zero Mo. Leaf sprayed Mo with 40 kg N ha^{-1} and seed treated Mo with 60 kg N ha^{-1} also reduced biomass yield compared to zero Mo treatments. However, leaf sprayed Mo with 60 kg N ha^{-1} and seed treated Mo with 40 kg N ha^{-1} slightly increased total biomass over the zero Mo treatment. For the overall treatment combinations, almost all interaction levels gave lower total aboveground dry biomass yield than the zero N with zero Mo treatments except seed treated Mo with 40 kg N ha^{-1} that slightly increased biomass over zero levels. The lowest result was obtained from zero N with leaf sprayed Mo which was about 8.3 g/pot lower than the no fertilizer application.

The main effect of N and Mo on total aboveground dry biomass yield was not significant among the treatments with both band and broadcast N placement methods.

With both methods, increasing levels of N increased total biomass yield. Application of 40 kg N ha^{-1} gave greater biomass yield in both N placement methods.



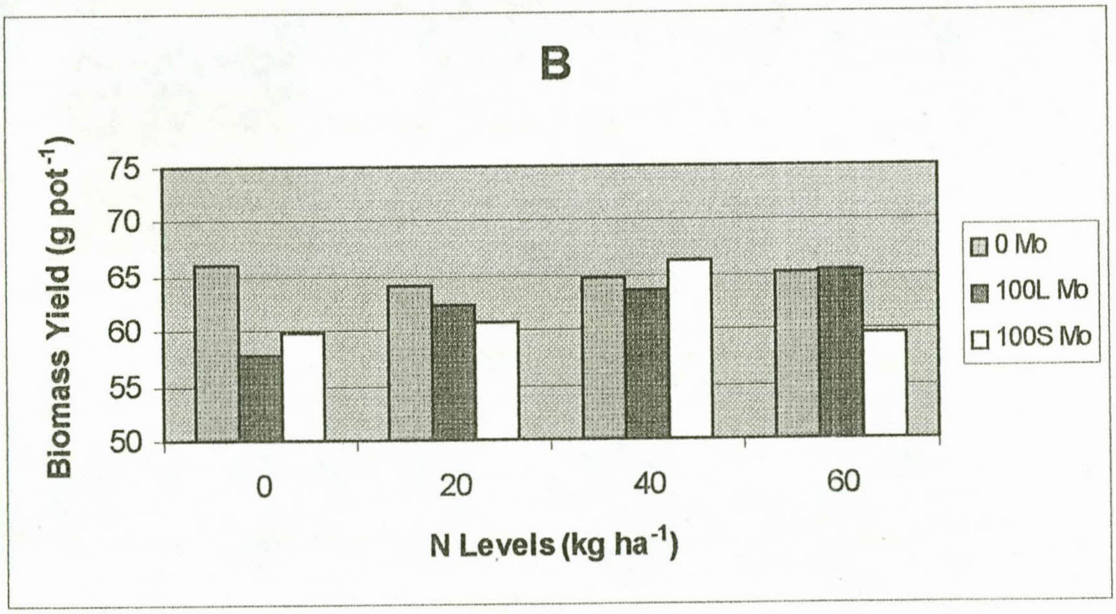


Figure 3.11 Interaction and main effects of N and Mo fertilizers on total aboveground dry biomass yield (g pot^{-1}), with both band (A) and broadcast (B) N placement methods, (100L Mo and 100S Mo imply 100 g Mo ha^{-1} leaf application and seed treatment respectively).

Application of Mo as leaf spray and seed treatment responded negatively to biomass yield in both N placement methods. Although the differences among the treatments were insignificant, the highest biomass was obtained with zero Mo application and the lowest with seed treated Mo (Tables 3.20 &3 3.21).

Figure 3.11 shows that, with band N placement method, total dry biomass yield in the absence of Mo was not consistent. Only 40 kg N ha^{-1} exceeded the zero level while 60 kg N ha^{-1} highly reduced biomass yield. Leaf sprayed and seed treated Mo, with increasing levels of N, showed an increasing trend. With broadcast N placement method, zero Mo with increasing N levels showed a negative relationship on biomass yield. Leaf sprayed and seed treated Mo, with increasing N levels, linearly increased biomass yield. With band N placement method, the highest total biomass yield was gained at 60 kg N ha^{-1} with seed treated Mo. With the broadcast method, the highest was at zero N with zero Mo and 40 kg N ha^{-1} with seed treated Mo. Generally, greater biomass yield was obtained with band placed N than with broadcast N placement method.

3.3.1.11 Seed Yield per Hectare

Interaction effects of N and Mo (Tables 7.21 & 7.22 in appendix) revealed non-significant differences on seed yield per hectare with both band and broadcast N placement methods. However, with band N placement method, Mo treatments with increasing N levels increased seed yield per hectare except zero and leaf sprayed Mo with 20 kg N ha^{-1}. Zero and 40 kg N ha^{-1} with leaf sprayed and seed treated Mo reduced seed yield per hectare as compared to zero Mo treatments. Application of 20 kg N ha^{-1} with leaf sprayed and seed treated Mo and 60 kg N ha^{-1} with seed treated Mo increased seed yield over zero Mo treatments. Application of 60 kg N ha^{-1} with the three Mo treatments and 40 kg N ha^{-1} with zero Mo increased seed yield over zero N with zero Mo treatment (Table 3.22). With broadcast N placement, leaf sprayed Mo with the increasing N levels increased seed yield whereas zero and seed treated Mo with increasing N levels decreased seed yield per hectare (Table 3.23). Application of all N levels with leaf sprayed and seed treated Mo increased seed yield over all N levels with zero Mo treatments except that zero N with leaf sprayed Mo slightly reduced seed yield as compared to zero Mo treatment. The highest seed yield was obtained from zero N with seed treated Mo.

Table 3.22 Interaction and main effects of N and Mo fertilizers on seed yield (kg ha^{-1}), with band N placement method.

Mo Levels,	N Levels, kg ha^{-1}				
g ha^{-1}*	0	20	40	60	Mean
0	3280.833	2937.292	3549.688	3469.375	3309.297
100L	3142.188	2970.833	3169.208	3451.667	3183.474
100S	2942.396	3168.854	3033.333	3689.938	3208.630
Mean	3121.806	3025.660	3250.743	3536.993	
P Level	N = NS	Mo = NS		N x Mo = NS	
CV%			19.84		

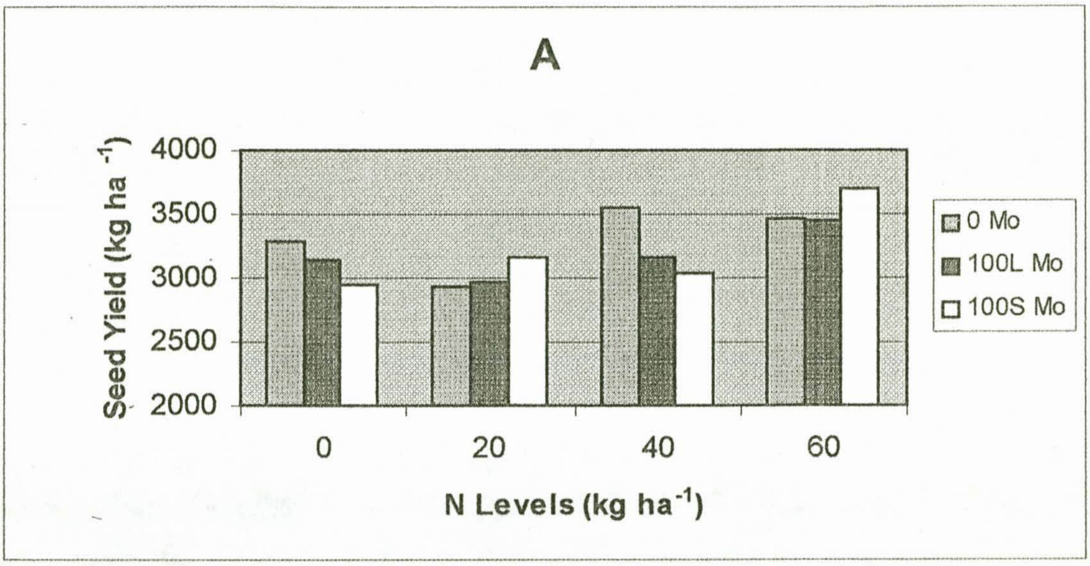
*Note. *L = Leaf Application, S = Seed Treatment, NS = Non-significant*

Table 3.23 Interaction and main effects of N and Mo fertilizers on seed yield (kg ha^{-1}), with broadcast N placement method.

Mo Levels,	N Levels, kg ha^{-1}				
g ha^{-1}*	0	20	40	60	Mean
0	2957.917	2844.583	2997.500	2913.125	2928.281
100L	2655.833	3235.315	3060.625	3240.208	3047.995
100S	3516.667	3396.771	3091.250	3053.646	3264.583
Mean	3043.472	3158.889	3049.792	3068.993	
P Level	N = NS	Mo = NS		N x Mo = NS	
CV%			19.10		

***Note:** *L = Leaf Application, S = Seed Treatment, NS = Non-significant*

The main effect of increasing N levels and Mo treatments on seed yield was non-significant with both band and broadcast N placement methods. However, seed yield was consistently and positively responded to increasing rates of N with both methods except 20 kg N ha^{-1} with band N placement method which slightly reduced seed yield below the zero N level. With band N placement method, maximum seed yield was obtained from 60 kg N ha^{-1} whereas with broadcast method, it was at 20 kg N ha^{-1}.



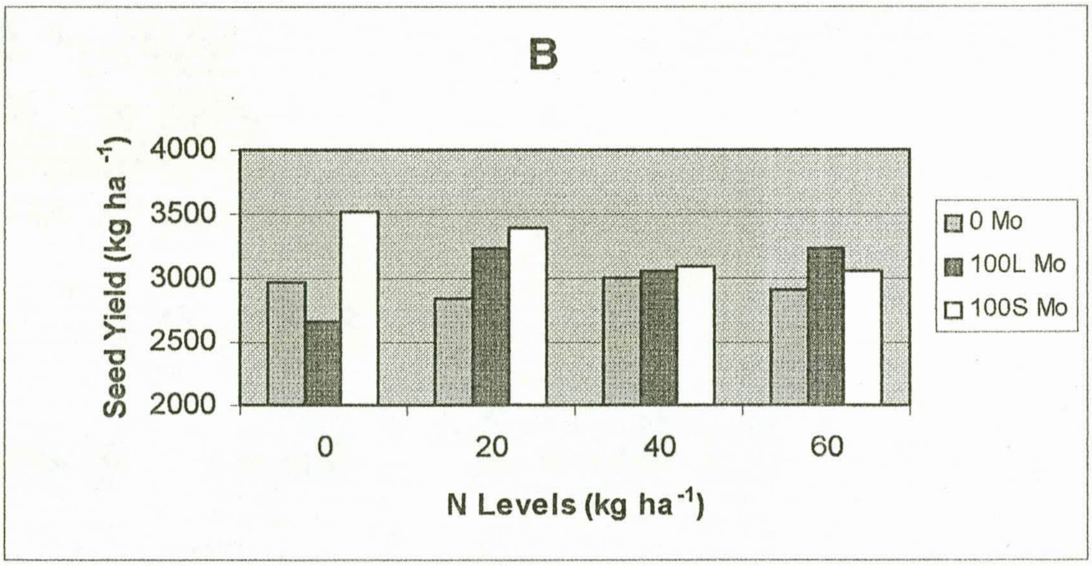


Figure 3.12 Interaction and main effects of N and Mo fertilizers on seed yield (kg ha^{-1}), with both band (A) and broadcast (B) N placement methods, (100L Mo and 100S Mo imply 100 g Mo ha^{-1} leaf application and seed treatment respectively).

Both leaf applied and seed treated Mo responded negatively to seed yield with band N placement method. Maximum seed yield was obtained with zero Mo application. Leaf applied Mo gave the least seed yield. With broadcast N placement method, both leaf sprayed and seed treated Mo positively increased seed yield per hectare. The highest seed yield was obtained with seed treated Mo.

As Figure 3.12 indicates, application of no Mo with increasing N levels showed an increasing effect on seed yield per hectare, except 20 kg N ha^{-1}, with band N placement method whereas with broadcast method it gave almost a constant graph. With band N placement method, both leaf sprayed and seed treated Mo with increasing N levels increased seed yield except that leaf sprayed Mo with 20 kg N ha^{-1} slightly reduced seed yield compared to zero N level. With the broadcast method, leaf sprayed Mo treatment showed an increasing effect whereas seed treated Mo showed a decreased effect on seed yield. With band N placement method, the highest seed yield per hectare was reached at the interaction of 60 kg N ha^{-1} with seed treated Mo whereas with broadcast N placement method zero N with seed treated Mo gave the highest seed yield.

A comparison was made between leaf sprayed and seed treated Mo within N band and broadcast placement methods. With the band N placement method, application of Mo as leaf or seed treatment gave inconsistent results of seed yield. Leaf sprayed Mo gave greater seed yield than seed treated Mo only at zero and 40 kg N ha^{-1}, and seed treated Mo gave greater yield than leaf sprayed Mo at 20 and 60 kg N ha^{-1} (Figure 3.13). Because 60 kg N ha^{-1} gave the highest seed yield ha^{-1}, seed treated Mo has got greater yield advantage with band N placement method.

With broadcast N placement method, seed treated Mo gave more yield advantage than leaf sprayed Mo. Only at 60 kg N ha^{-1} seed treated Mo gave lower seed yield than leaf applied Mo (Figure 3.14). However, with increasing N levels, leaf sprayed Mo showed an increasing trend whereas seed treated Mo showed a decreasing trend.

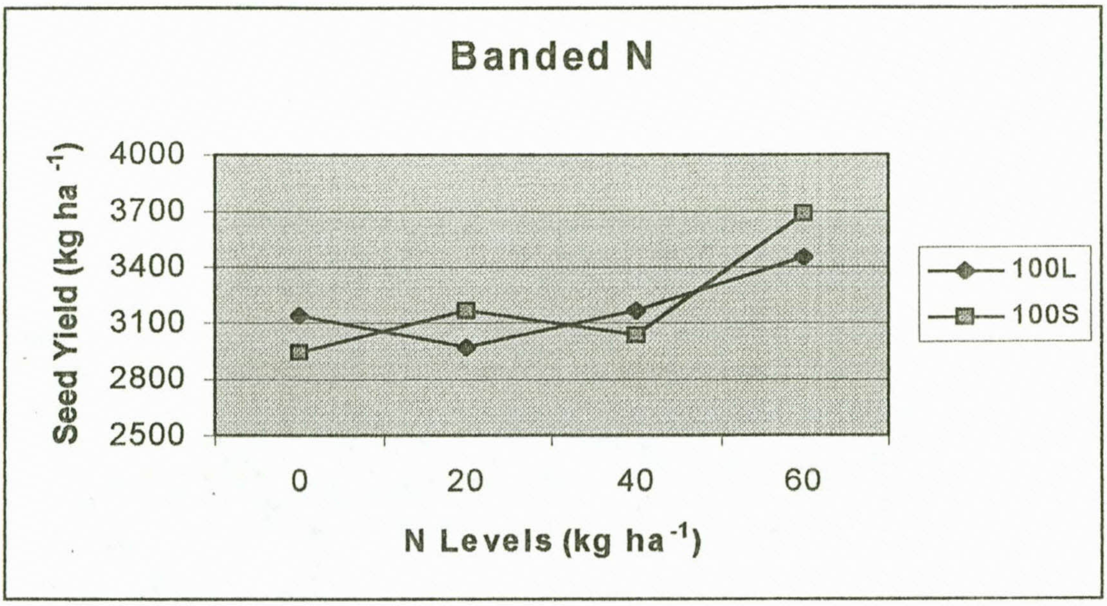


Figure 3.13 Effect of leaf sprayed and seed treated Mo fertilizer on seed yield in band N placement method, (100L and 100S imply 100 g Mo ha^{-1} leaf application and seed treatment respectively).

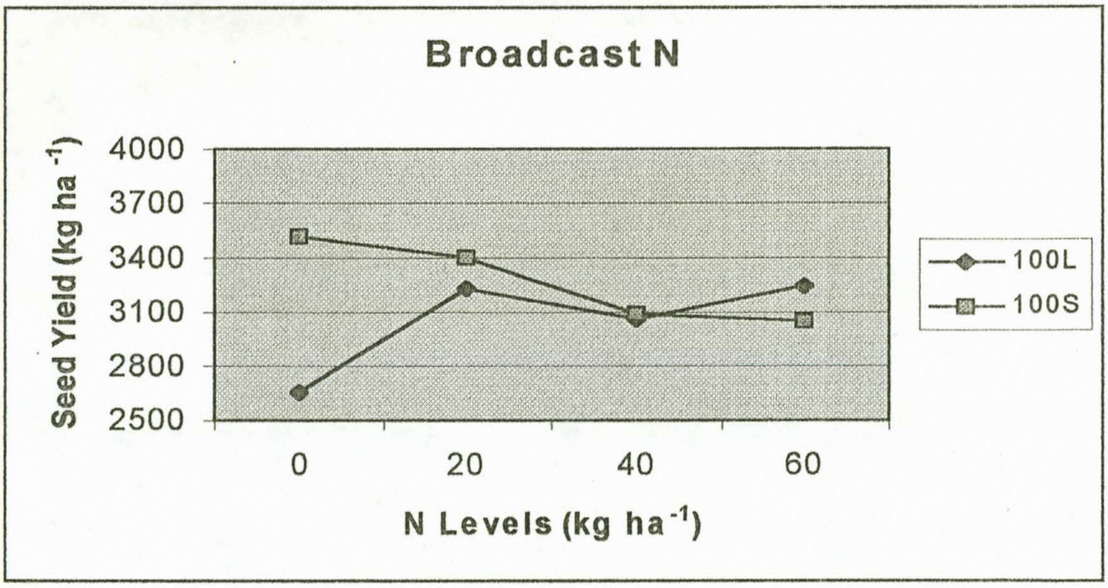


Figure 3.14 Effect of leaf sprayed and seed treated Mo fertilizer on seed yield in broadcast N placement method, (100L and 100S imply 100 g Mo ha^{-1} leaf application and seed treatment respectively).

Another comparison made was between the two N placement methods (band and broadcast) at leaf sprayed and seed treated Mo respectively. Comparing band - and broadcast N placement methods for leaf sprayed Mo, Figure 3.15 shows that band placed N gave higher seed yields than broadcast N, except at 20 kg N ha^{-1}. On the other hand, Figure 3.16 shows that, for seed treated Mo, the broadcast N placement method gave greater seed yield advantage than the band N placement method at the lower rates of N, but banded N showed an increasing trend and exceeded broadcast N beyond 40 kg N ha^{-1} and gave the highest seed yield at 60 kg N ha^{-1}. The broadcasted N showed a decreasing effect on seed yield ha^{-1} with increasing N levels.

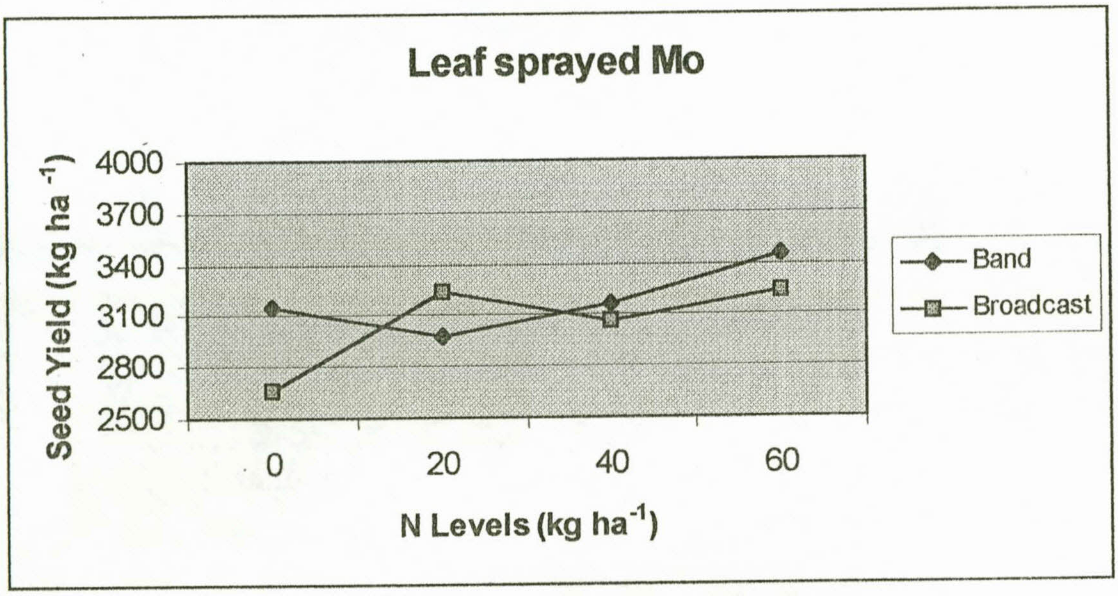


Figure 3.15 Effect of band and broadcast N placement methods on seed yield, for leaf sprayed Mo.

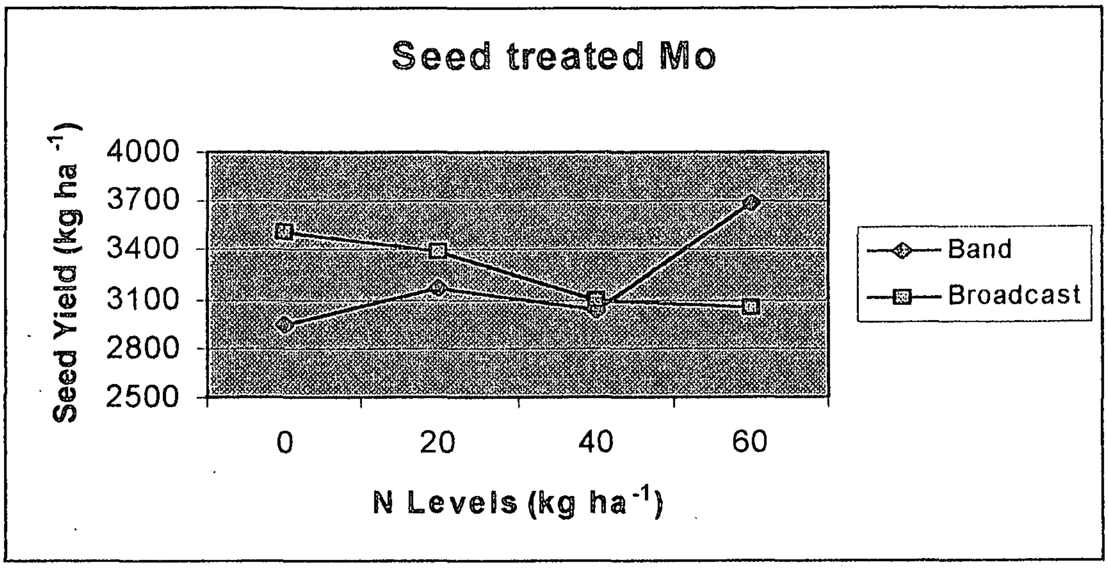
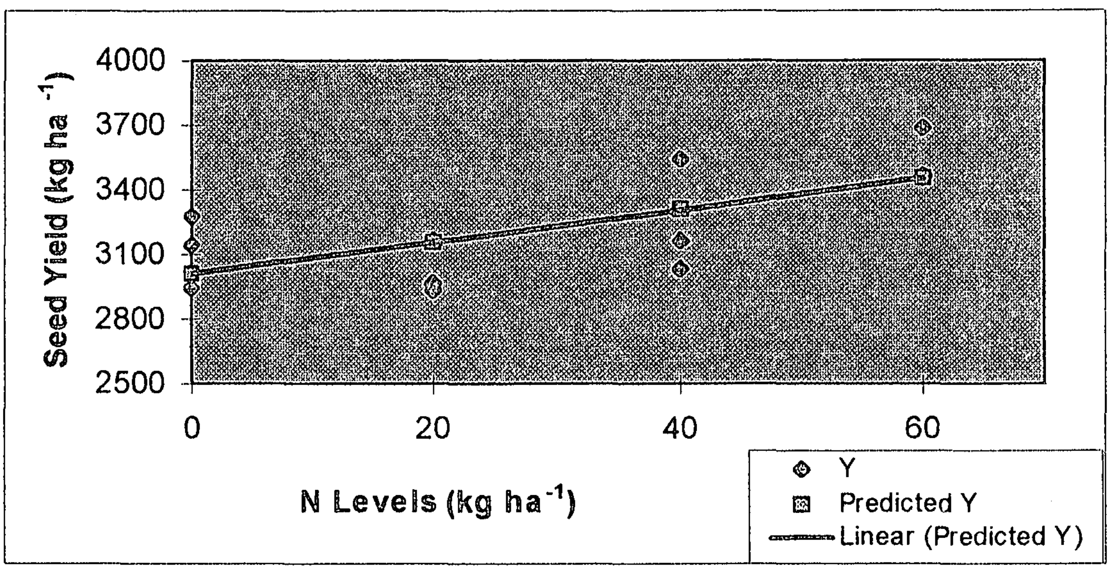


Figure 3.16 Effect of band and broadcast N placement methods on seed yield, for seed treated Mo.



$Y = 3013.203 + 7.3532X$, $R^2 = 0.4557$

Figure 3.17 Regression relation of N and seed yield per hectare for band placement of N.

As shown in Figure 3.17 (for band placed N), seed yield per hectare was strongly and positively (R^2 = 0.4557) associated with increasing levels of N. The regression equation (Y = 3013.203 + 7.3532X) implies that the predicted seed yield with no N application is 3013.203 kg ha^{-1} and an increase in 1 kg of N can increase seed yield by 7.3532 kg ha^{-1}.

Discussion

Mean seed yield varied from 2937 to 3690 kg ha^{-1} and 2656 to 3517 kg ha^{-1} with band and broadcast N placement methods respectively. Although statistically not significant, increasing levels of nitrogen generally increased seed yield with both N placement methods. This result is in line with the previous research results by Doss, Evans & Turner (1977) where application of N to beans generally increased seed yields. Goos, Schimelfenig, Bock & Johnson, (1999) indicated that application of increasing levels of nitrogen modestly increased seed yield and dry matter production of wheat. Ma, Dwyer & Gregorich, (1999) also found positive response of maize to increasing levels of nitrogen. They found that compared with the unfertilized control treatment, both fertilizer and manure application increased grain yield.

With band placed N, the highest seed yield ha^{-1} was achieved at 60 kg N ha^{-1} whereas with broadcast placed N the highest seed yield ha^{-1} was reached at 20 kg N ha^{-1}. However, greater mean seed yield was obtained with band than with broadcast N placement. This might be attributed to the efficient fertilizer use of the plants under band placement than broadcast placement. Early stimulation of the seedlings is usually advantageous, and it is desirable to have fertilizers near the plant roots. The early aboveground growth of the plant is essentially all leaves, and since photosynthesis is carried on in the leaves, the number of leaves produced in this period will influence the yield. This was confirmed by research results of field experiments on barley with zero and conventional tillage in central Alberta, where barley grain yields were generally lower when N fertilizer was broadcast on the soil surface (Malhi et al., 1988), and band placement of urea reduced or eliminated yield differences between zero tillage and conventional tillage (Malhi & Nyborg, 1992).

Some of the yield components were slightly affected by increasing nitrogen levels. There were significant differences between nitrogen levels on seed weight per pod, 100 seed weight and pod abscission with broadcast N placement method. With band N placement method, none of the yield components were significantly affected by N application. However, the increasing levels of nitrogen gave positive response to number of pods per plant, number of seeds per plant, seed yield per plant, and total biomass yield with band N placement method. This increase in yield components resulted in an increase in the final seed yield, which was similar to the previous research results. Asif (1970) indicated that in trials with beans, application of N generally increased pod yields. Adams (1967) suggested that high seed yield of dry bean is obtained when each of the yield components, pods per plant, seeds per pod, and seed weight is maximized. Oikeh, Kling & Okoruwa (1998) working with maize also indicated that increasing N levels increased grain yield, kernel weight and grain protein quadratically. However, negative responses were observed for pod length, pod weight, seed weight per pod, number of seeds per pod and 100 seed weight with band N placement method. With the broadcast N placement method, pod length, number of pods per plant, number of seeds per pod, seed weight per pod, number of seeds per plant, seed yield per plant, total biomass yield and seed yield per hectare were positively responded to increasing levels of N application. Negative response was obtained for pod weight and 100 seed weight. Application of N increased pod abscission non-significantly with band N placement and significantly with broadcast N placement. This significant increase in pod abscission may contribute to the non-significant increase in seed yield with both N placement methods.

The molybdenum treatments revealed a significant increase in pod length and positive response to seed weight per pod and 100 seed weight with band N placement. The other parameters were responded negatively to Mo treatments. With the broadcast N placement method, none of the parameters were significantly affected by Mo treatments. However, there were increasing effects of Mo on number of pods per plant, number of seeds per pod, 100 seed weight, seed yield per plant and seed yield per hectare. Pod abscission was reduced by Mo application in both N placement methods indicating that Mo increases the resistance of the pods to factors that increase abscission more than N fertilizer. Abscission of flowers or small pods occurs on practically every raceme of the plant. The abscission of reproductive organs during flowering and fruiting period in grain legumes is often greater than 50% (Subhadrabandhu, Adams & Reicosky 1978; Tucker, Miller & Webster 1975). This could result in sink limitation, and if shedding of reproductive parts in beans could be prevented or decreased, yields might be increased.

The interaction effects of nitrogen and molybdenum treatments showed inconsistent results on yield components. Significant interaction effects of nitrogen and molybdenum were achieved on pod length and total aboveground dry biomass yield, and non-significant effects were observed on the other parameters with the band N placement method. The total number of seeds per pod was decreased with the application of nitrogen and molybdenum, but compensated for by the increase in seed weight per pod. With the broadcast N placement method, no yield component was found to be significantly affected with the interaction between N levels and Mo treatments.

Regression analysis has been performed between N levels and all the yield and yield components as well as the seed nutrient content in both band and broadcast N placement methods. However, only number of seeds per plant and seed yield per hectare in band N placement method were found to be significant (Tables 7.27 & 7.28 in appendix). The regression analysis showed that there was a strong and positive association between N levels and number of seeds per plant ($R^2 = 0.5067$), and between N levels and seed yield per hectare ($R^2 = 0.4557$).

CHAPTER FOUR

EFFECT OF NITROGEN PLACEMENT METHODS AT DIFFERENT RATES WITH MOLYBDENUM ON NUTRIENT CONTENT OF THE DRY SEEDS

4.1 INTRODUCTION

The proper method of fertilizer placement can result in more effective fertilizer use by the plants throughout the growing period and can finally increase the seed nutrient contents. Beans need more N than any other nutrient, of which a large quantity is needed to produce the high percentage of protein in seeds. As previously discussed in the literature review, protein content and quality of crops are influenced by the nutritional status of the soil. The quality of a crop depends on the total N content which in turn influences the protein quantity in the seeds. In order to utilize the quality potential, the growing crop must be adequately supplied with nutrients, particularly N. As indicated by Mengel & Kirkby (1987), nitrogen supplied to cereals during the growing period increased the protein content of the grains substantially and thus increased baking quality. The addition of 40 and 60 kg N ha^{-1} at the flowering stage not only increased the grain yield but substantially improved grain quality. The protein content and the sedimentation value were raised so that a better baking quality was obtained.

Grain yield, nitrogen content of the grain and nitrogen yield of a crop may vary from cultivar to cultivar, site to site and year to year under suboptimal growing conditions. The greater nitrogen requirement has been met by a larger input of nitrogen on cultivars with considerably improved lodging resistance, use of growth regulators and by the introduction of split N application (Mengel & Kirkby, 1987). Application of some microelements like Mo is used to activate the N use efficiency of the crop. Molybdenum is closely related to nitrogen metabolism through the fixation of free nitrogen and the assimilation of nitrates by the plants.

The feeding quality of proteins is mainly determined by the content of crude protein and the proportion of essential amino acids. These are amino acids which can not be synthesized by humans or animals, and for this reason must be supplied as constituents of the mammalian diet. Grains of cereals and maize are particularly low in lysine and therefore are rather poor in protein quality. Therefore, supplementation of beans to mammalian diet can complement the protein requirement of the consumers. Applications of N during the growing season of the crop increases the content of crude protein in the grains, but the individual grain proteins are affected to a different degree. According to investigations of Mengel & Kirkby (1987) with wheat, barley and maize, high rates of N application resulted in a substantial increase in the crude protein of the grains, but this was accompanied by a reduction of the proportion of lysine, threonine, cysteine, arginine, asparagine and glysine in the total grain proteins.

As already outlined in the literature review, the content of carbohydrates and the content of proteins in grains and cereals depend to a considerable extent on the N supply during grain or seed maturation. If the N supply is low during this stage of growth, a higher proportion of photosynthates is used for the synthesis of carbohydrates, whereas if there is an abundant N supply, a fairly proportion of photosynthates is converted to proteins. Although beans are rich sources of protein, little has been done so far on the influence of fertilizers, particularly N, on bean seed nutrient content. The aim of this study was to see the change in total N, total protein and total Mo contents of the dry seeds as a result of the applied fertilizers.

4.2 MATERIALS AND METHODS

For the execution of the experiment and the materials used, experimental design and data processing refer to chapter 3 sections 3.2.1, 3.2.2, and 3.2.4.

4.2.1 Total N

There are two methods recognised world-wide as suitable for the determination of total N in the sample material. These are the Dumas method, the procedure of which is actually dry oxidation, and the Kjeldahl method, the procedure of which is actually wet oxidation. The latter method was used to determine the total N in the seed samples according to Warren, Huber, Tsai & Nelson (1980). The Kjeldahl method for the determination of total N consists of the following steps:

(i) consumption of the plant material by concentrated H_2SO_4 in the presence of a catalyst in order to convert all organic N to NH_4^+-N;

(ii) steam distillation with NaOH so that the NH_4^+-N in the consumption solution is converted into NH_3-N, which is then retained in $H_3BO_3^-$ to form ammonia borate.

$$NH_3 + H_3BO_3 = NH_4^+ + H_2BO_3^-$$

(iii) titration of the distillate with H_2SO_4 so that H_3BO_3 is formed again.

$$H^+ + H_2BO_3^- = H_3BO_3$$

Procedure

Weigh out exactly 0.1 g of the catalyst in the consumption tube. Exactly 0.1 g of ground plant material (seed) is then weighed out in the consumption tube. Now add 4.0 ml of concentrated H_2SO_4 in portions of 1.0 ml, so that the catalyst and water clinging to the walls of the tube can be washed off. Mix the plant material, catalyst and acid thoroughly by using a shaking apparatus. Place the consumption tubes in a consumption block, set at a temperature of 350°C. It takes about an hour before the consumption block reaches this temperature, after which consumption must continue for at least another 2 hours. Allow to cool after consumption, after which about 20 ml of distilled water is added. Shake once again on the shaking apparatus, after which the mixture is poured into a steam distillation flask. Now add 20 ml of 8.0 N NaOH, and immediately begin with steam distillation. The distillate is retained in a 150 ml glass beaker to which 2.0 ml of the boracic acid indicator mixture has been added. Steam distillation is maintained until the volume of the distillate is approximately 30 ml. Now titrate the distillate with the 0.005 N H_2SO_4 until the colour changes from green to light pink. Make a note of the volume of H_2SO_4 which has been titrated and then calculate the total N present in the seed sample.

4.2.2 Total Protein

The total protein content was determined by measuring the total nitrogen content, which was executed in the laboratory of Soil Science (University of Free State, South Africa). The seed nitrogen content was converted to total protein content using a factor of 6.25 (Amsal et al., 1994) and the analysis of variance was computed only for total protein content (not for N content) of the seeds.

4.2.3 Total Mo

Determination of total Mo in the plant material (seed) was done by the procedure of dry ashing. Weigh out exactly 3 g of ground plant material (seed) and add into the consumption tube. Place the consumption tubes in the consumption block set at a temperature of 850°C so that the sample will be ashed. Add concentrated HNO_3, so that the sample will become black. Dry it on the sand bath. Place it back into the incinerator for half an hour until the sample is the right colour. Cool down. Add 10 ml 1:2 HNO_3. Wash into 100 ml flask with distilled water. Filter and read on the atomic adsorption method.

4.3. RESULTS AND DISCUSSION

4.3.1 Total Protein

The interaction of N levels with the three Mo treatments did not significantly affect the seed total protein content with both band and broadcast N placement methods (Appendix, Tables 7.23 & 7.24). With band N placement method increasing N levels with all Mo treatments showed a decreasing effect on seed total protein content (Table 4.1) as compared to zero N with the Mo treatments except 20 kg N ha^{-1} with zero Mo and 60 kg N ha^{-1} with leaf sprayed Mo which slightly increased seed protein content over their zero levels. In the interaction of individual N levels with the Mo treatments, zero and 60 kg N ha^{-1} with leaf sprayed and seed treated Mo linearly increased percent seed protein content over zero Mo treatments. Interaction of 20 kg N ha^{-1} with leaf sprayed and seed treated Mo decreased seed protein content comparing to zero Mo. Application of 40 kg N ha^{-1} with seed treated Mo gave slightly greater seed protein content than the other two levels. In general terms, most treatment combinations increased seed protein content over the zero level. The highest seed protein content was obtained from the interaction between zero N and seed treated Mo, and the lowest was from 60 kg N ha^{-1} with zero Mo application.

Table 4.1 Interaction and main effects of N and Mo fertilizers on percent seed protein content, with band N placement method.

Mo Levels,	N Levels, kg ha^{-1}				
g ha^{-1}*	0	20	40	60	Mean
0	19.958	20.503	19.600	18.944	19.751
100L	20.392	20.342	19.158	20.631	20.131
100S	20.925	19.455	20.180	20.808	20.342
Mean	20.425	20.100	19.646	20.128	
P Level	N = NS		Mo = NS	N x Mo = NS	
CV%			5.50		

*Note: *L = Leaf Application, S = Seed Treatment, NS = Non-significant*

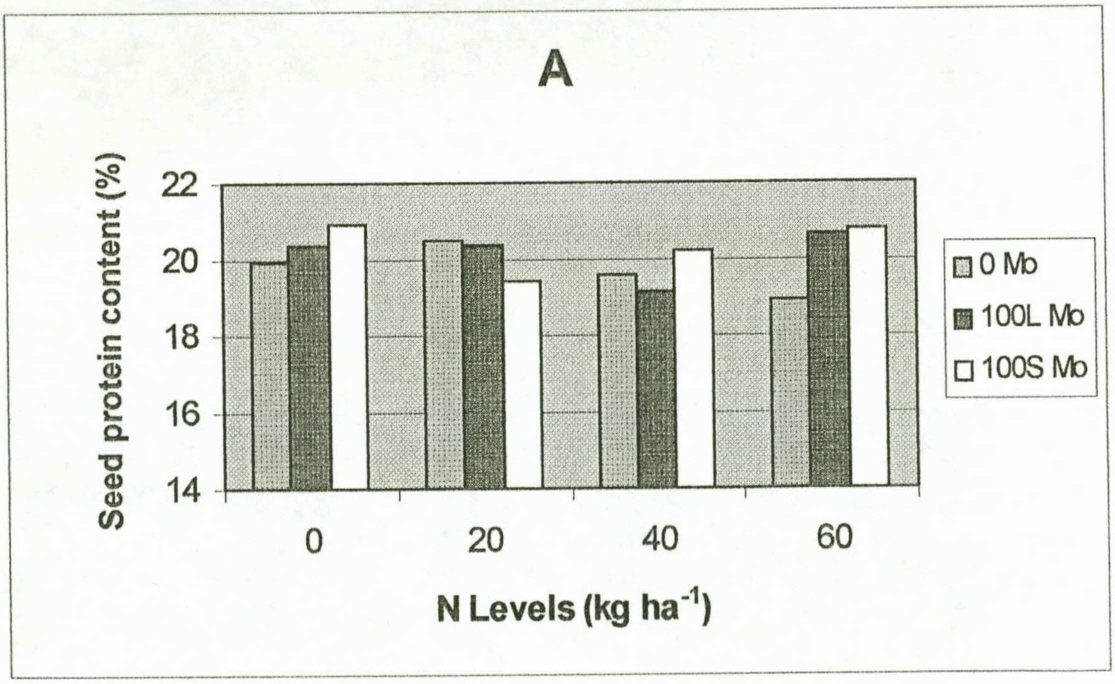
Table 4.2 Interaction and main effects of N and Mo fertilizers on percent seed protein content, with broadcast N placement method.

Mo Levels,	N Levels, kg ha^{-1}				
g ha^{-1}*	0	20	40	60	Mean
0	20.077	18.659	19.545	18.650	19.233
100L	19.330	20.569	19.703	20.231	19.958
100S	21.178	20.027	20.761	18.502	20.117
Mean	20.195	19.752	20.003	19.128	
P Level	N = NS		Mo = NS	N x Mo = NS	
CV%			7.88		

*Note: *L = Leaf Application, S = Seed Treatment, NS = Non-significant.*

In the case of broadcast N placement method, leaf sprayed Mo with increasing N levels showed an increasing effect, while zero and seed treated Mo showed a decreasing effect on seed total protein content (Table 4.2). Both leaf applied and seed treated Mo with all N levels increased seed total protein content over zero Mo with increasing N levels except leaf sprayed Mo with zero N and seed treated Mo with 60 kg N ha^{-1}. Here, most of the treatment combinations gave lower seed total protein content than zero N with zero Mo treatments.

The main effects of both fertilizers (N & Mo) showed non-significant differences on percent seed protein content with both N placement methods. However, in both N placement methods increasing levels of N decreased seed protein content, i.e., all applied N levels yielded seed protein content lower than the zero level (Tables 4.1 & 4.2). Application of Mo increased seed protein content with both N placement methods, though the increase was not significant. Both leaf sprayed and seed treated Mo increased seed protein content over the zero Mo treatment.



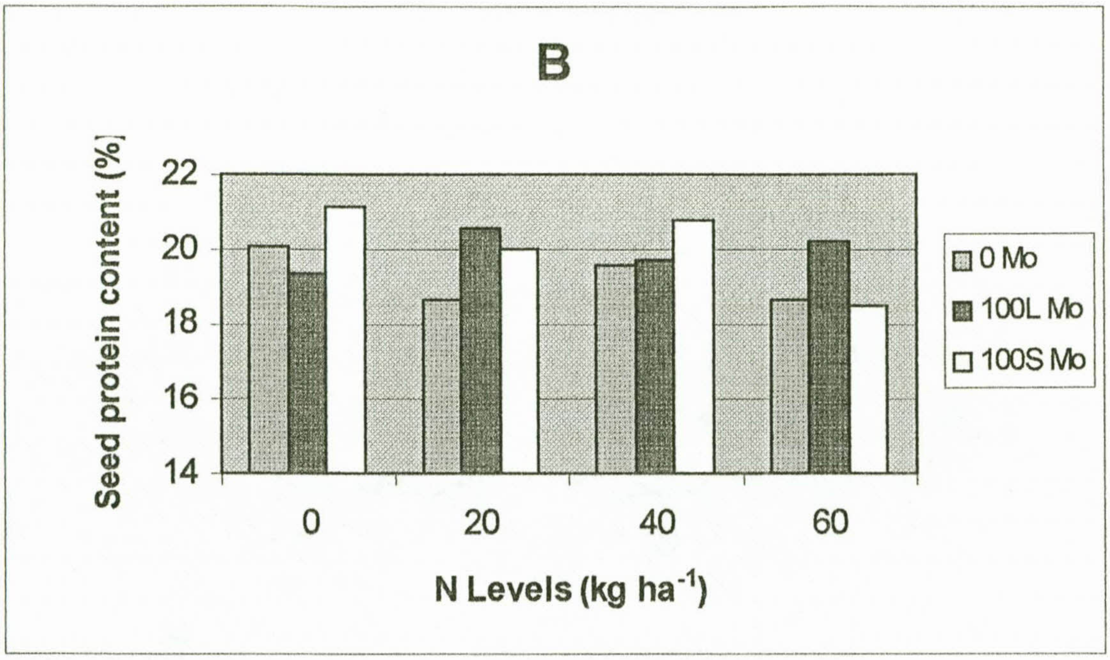


Figure 4.1 Interaction and main effects of N and Mo fertilizers on seed protein content (%), with band (A) and broadcast (B) N placement methods, (100L Mo and 100S Mo imply 100 g Mo ha^{-1} leaf application and seed treatment respectively).

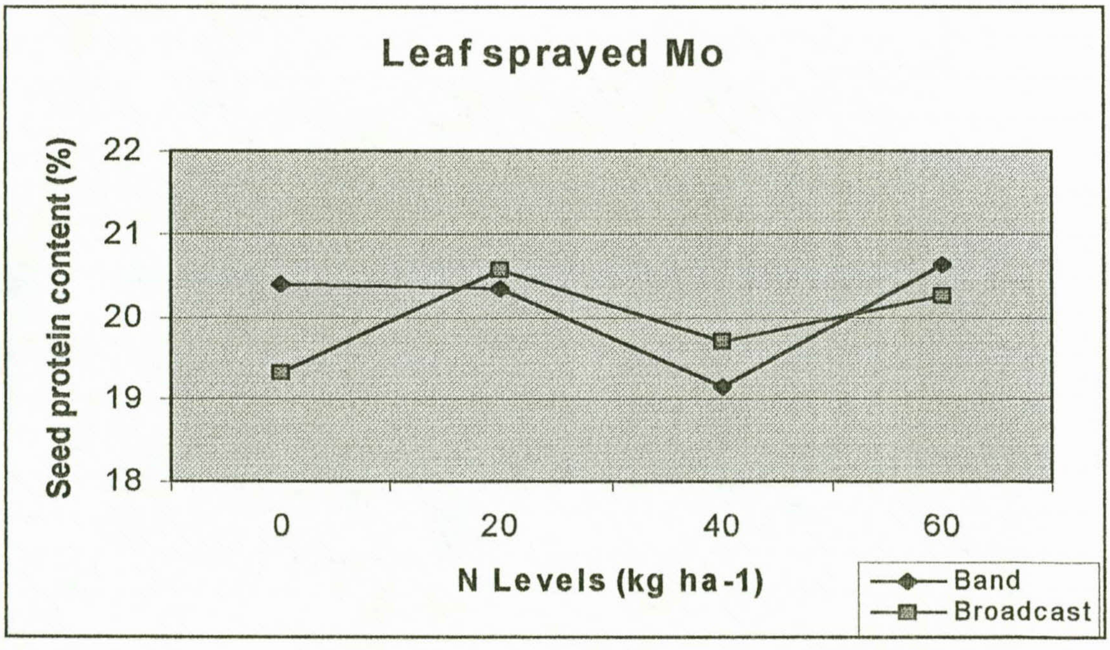


Figure 4.2 Effect of band and broadcast N placement methods on seed protein content, for leaf sprayed Mo.

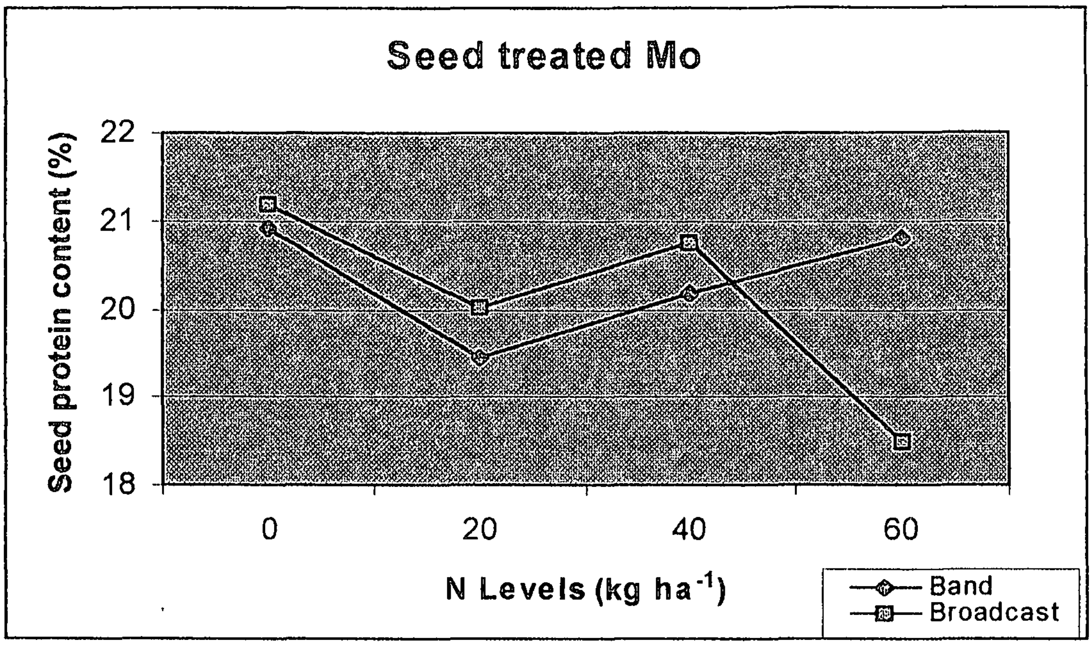


Figure 4.3 Effect of band and broadcast N placement methods on seed protein content, for seed treated Mo.

As can be observed from Figures 4.1, zero Mo with increasing N levels reduced seed protein content with both band and broadcast N placement methods except at 20 kg N ha^{-1} with band N placement method. Leaf sprayed and seed treated Mo treatments with increasing N levels gave inconsistent results but they also yielded below the zero interaction levels with both N placement methods. However, with broadcast N placement method, seed treated Mo with 60 kg N ha^{-1} gave the lowest seed protein content whereas with band N placement method this treatment was at its maximum (Figures 4.2 & 4.3).

4.3.2. Total Mo Content

The interaction between N levels and Mo treatments revealed non-significant effects on seed Mo content with both band and broadcast N placement methods (Tables 7.25 & 7.26 in the appendix). However, with band N placement method, increasing levels of N with zero Mo increased seed Mo content whereas leaf sprayed and seed treated Mo with increasing N levels decreased seed Mo content. Application of Mo as leaf spray and/or seed treatment with increasing N levels increased seed Mo content as compared to zero Mo with the increasing N levels. With broadcast N placement method, increasing N levels with all Mo treatments showed a decreasing effect on seed Mo content. However, leaf sprayed and seed treated Mo with increasing N levels increased seed Mo content as compared to zero Mo with increasing N levels. Generally, application of Mo as seed dressing with all the N levels gave the highest seed Mo content with both band and broadcast N placement methods. With band N placement method, the highest seed Mo content was obtained from the application of 60 kg N ha^{-1} with seed treated Mo and the lowest was from zero N with zero Mo application. All interaction levels increased seed Mo content over the zero level. With the broadcast N placement method, the highest seed Mo content was obtained from interaction of zero N and seed treated Mo whereas the lowest was from zero Mo with 60 kg N ha^{-1}. The coefficient of variation (CV%) was greater in both N placement methods because of variation within the treatments for the reason could not be justified.

Table 4.3 Interaction and main effects of N and Mo fertilizers on seed Mo content (ppm), with band N placement method.

Mo Levels,	N Levels, kg ha^{-1}				
g ha^{-1}*	0	20	40	60	Mean
0	2.895	3.793	4.938	3.230	3.714^{b}
100L	8.020	7.750	5.523	6.730	7.006^{b}
100S	57.958	53.665	50.230	58.000	54.963^{a}
Mean	22.958	21.736	20.230	22.653	
P Level	N = NS		Mo = 0.000**		N x Mo = NS
CV%			44.79		
	Mo LSD1% = 9.429				

*Note: *L = Leaf Application, S = Seed Treatment*

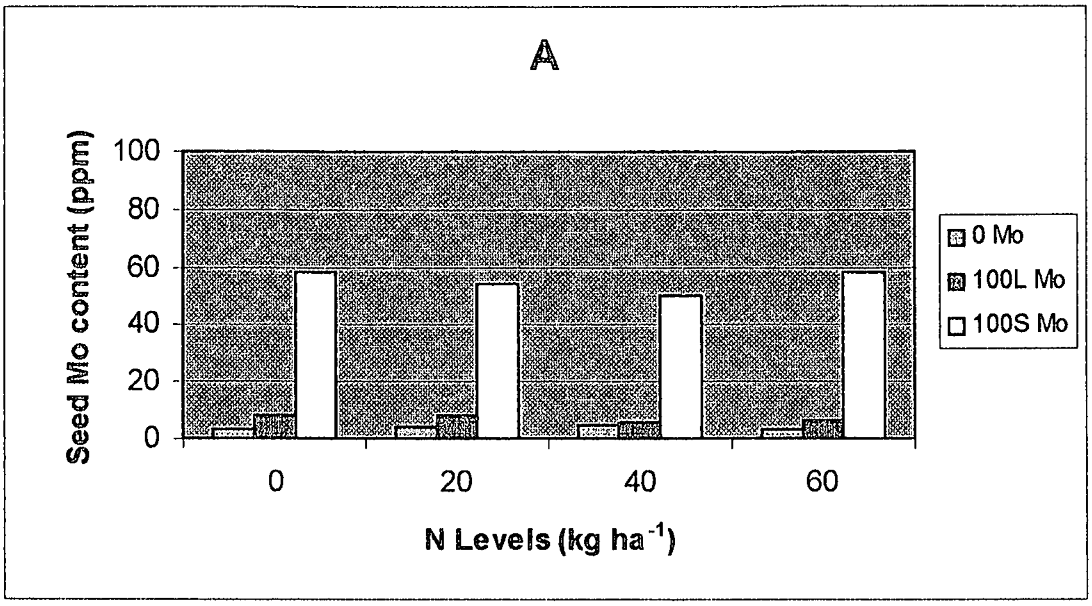
***Highly significant at 1% probability level*

Table 4.4 Interaction and main effects of N and Mo fertilizers on seed Mo content (ppm), with broadcast N placement method.

Mo Levels,	N Levels, kg ha^{-1}				
g ha^{-1}*	0	20	40	60	Mean
0	3.408	2.602	2.477	2.145	2.658^b
100L	8.445	6.372	5.500	4.770	6.272^b
100S	94.270	72.980	67.125	69.800	76.044^a
Mean	35.374	27.318	25.034	25.572	
P Level	N = NS		Mo = 0.000**		N x Mo = NS
CV%			53.57		
	Mo LSD1% = 14.59				

*Note: *L = Leaf Application, S = Seed Treatment, NS = Non-significant.*
***Highly significant at 1% probability level*

There were differential responses of seed Mo content to the main effects of N and Mo fertilizers. Increasing levels of N non-significantly reduced seed Mo content with both N placement methods. All N levels tested gave lower seed Mo content than the zero N level (Tables 4.3 & 4.4). Application of Mo highly significantly ($P<0.01$) increased seed Mo content with both band and broadcast N placement methods. With both methods, the highest seed Mo content was obtained with the application of Mo as seed dressing which highly significantly increased seed Mo content over zero and leaf sprayed Mo treatments.



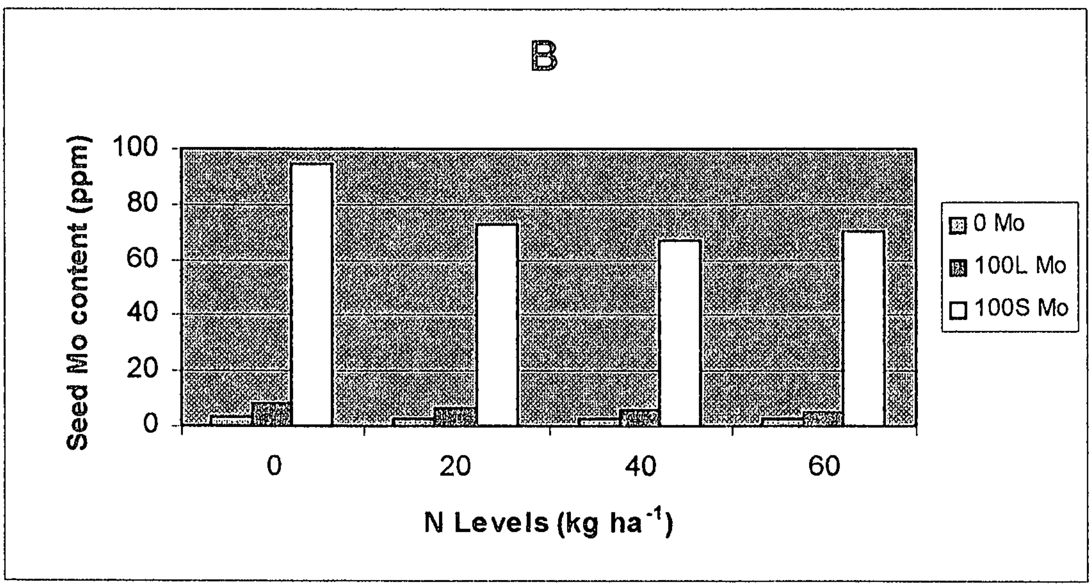


Figure 4.4 Interaction and main effects of N and Mo fertilizers on seed Mo content (ppm), with band (A) and broadcast (B) N placement methods, (100L Mo and 100S Mo imply 100 g Mo ha^{-1} leaf application and seed treatment respectively).

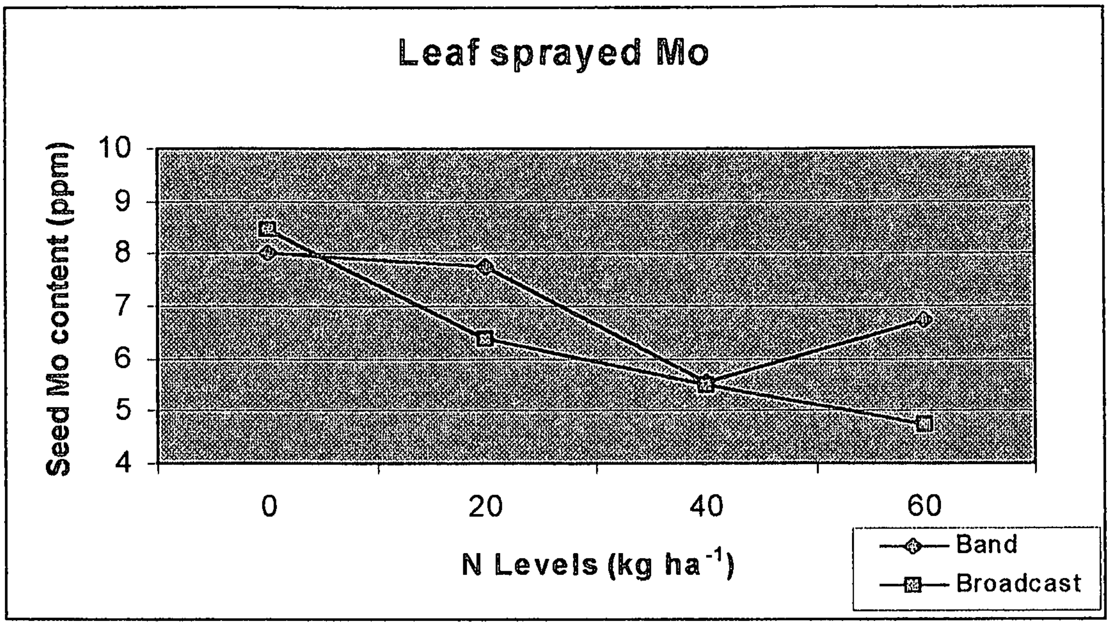


Figure 4.5 Effect of band and broadcast N placement methods on seed Mo content, for leaf sprayed Mo.

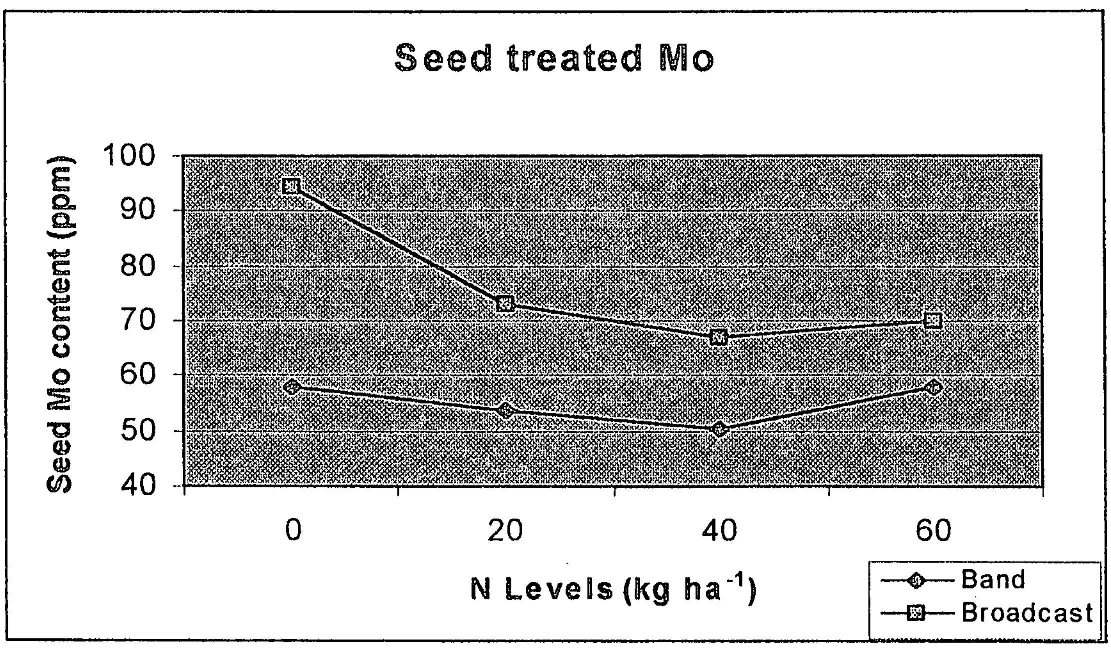


Figure 4.6 Effect of band and broadcast N placement methods on seed Mo content, for seed treated Mo.

As Figures 4.4, 4.5 and 4.6 show, the interaction of N levels with seed treated Mo is greater than that of N with other Mo treatments. Seed Mo content showed little response to zero and leaf sprayed Mo and did not significantly differ from each other. Much higher seed Mo content was obtained with broadcast N placement method than with band N placement method. With broadcast N placement method, all treatments of seed treated Mo with N levels gave seed Mo contents of more than 60 ppm, but with band N placement method all were less than 60 ppm.

Discussion

In contrast to previous research results by different researchers, the application of N in increasing rates generally reduced seed nitrogen, protein, and molybdenum contents. The previous result by Goos et al. (1999) indicated that grain N concentrations and protein contents of spring wheat were increased by N fertilization. Eriksen, Coale & Bollero (1999) also found maize total biomass, total biomass N content and grain N and protein content to be increased with increasing rates of N. As could be observed from Figures 4.1 & 4.2, in most interaction levels of N and Mo fertilizers, slightly greater seed protein percentage was obtained with band N placement than with broadcast N placement, supporting the results of Malhi, Nyborg & Solberg (1996) and Maddux et al. (1991). These researchers found that the percent seed N and protein content of spring barley and corn tended to be greater with band N placement than surface broadcasting. With tillage treatments, they also found that the recovery of labelled N in the total plants (ears plus straw plus roots) on zero tillage was markedly greater with the sidebanding (44.0%) or banding below seedrow (46.7%) than with surface broadcasting (24.6%).

Since seed protein content and quality is directly associated with the seed nitrogen content, as indicated by Sexton, Paek & Shibles (1998), reduction in seed nitrogen content, with this experiment, resulted in reduced seed protein content, as opposed to the results by Oikeh et al. (1998) and Alkanani & MacKenzie (1996). These researchers working with maize indicated that increasing N levels increased grain yield, kernel weight and grain protein quadratically for all the cultivars they have tested. The seed nitrogen and protein content, however, was not significantly different among the treatments. Although seed yield was increased with increasing N levels seed protein content was reduce, supporting the findings of Kniep & Mason (1991) that seed (grain) protein content was negatively associated with grain yield.

All Mo treatments substantially increased seed protein and molybdenum contents. This might be due to the function of Mo in nitrogen fixation and nitrate reduction to be available to the plant. This result is in line with the results of Ashmead et al. (1986). They indicated that legumes require Mo for nitrogen metabolism through the fixation of free N and the assimilation of nitrates by the plants. High (excessive) seed molybdenum content was observed with Mo seed treatment (Tables 4.3 & 4.4 and Figure 4.2), indicating that the amount of Mo seed dressing should be lower than that of leaf application as excess Mo in feed can cause the disease called Molybdenosis to animals. Previous research results by Marschner (1986) indicated that Mo contents above 5-10 mg kg^{-1} dry weight of forage are high enough to induce toxicity. Molybdenosis is actually caused by an imbalance of Mo and copper in the ruminant diet, i.e. induced Cu deficiency.

CHAPTER FIVE

GENERAL DISCUSSION AND CONCLUSION

Dry bean production, like that of other crops, depends on genetic potential of the crop and environmental factors which vary from site to site. Beans are grown from temperate to tropical uplands and in soils ranging from infertile leached tropical soils to very fertile alluvial soils in the temperate zone (van Schoonhoven & Voysest, 1991). Published research results on mineral nutrition is based on empirical trials and almost no emphasis has been placed on causal mechanisms, except for some minor elements such as Fe and Zn. In addition, information regarding interaction among elements is difficult to find. It may be assumed that beans are a poor man's crop, where fertilizer use is nil or minimal. Therefore, the current acute bean shortage in many countries resulted in the need for better production systems to increase yield through fertilization. This study aimed at investigating, under glasshouse conditions, the growth and yield performance of a dry bean cultivar, PAN 181, under the influence of N and Mo fertilizer applications. The study also aimed at investigating the different rates of N fertilizer with banding and broadcast method of application that can give optimum yields, including the total amount of seed protein and Mo contents as influenced by fertilizer application.

The direct interpretation of all the raw data as well as the statistical analysis of N x Mo treatment interactions and the individual effects of both N and Mo fertilizer treatments all consistently confirmed that the application of N in band placement method with Mo treatments affected seed yield more than with broadcast N placement method. This investigation agreed with the findings of Malhi et al., (1988) and Malhi & Nyborg, (1992), where they found that barley grain yields to be lower with broadcast N placement than with band N placement in zero and conventional tillage.

Comparing the Mo treatments within N placement methods (band and broadcast), leaf sprayed Mo gave greater seed yield than seed treated Mo only at zero and 40 kg N ha^{-1}, and seed treated Mo gave greater yield than leaf sprayed Mo at 20 and 60 kg N ha^{-1} in band placed N. Application of 60 kg N ha^{-1} gave the highest seed yield ha^{-1} with seed treated Mo and it has got greater yield advantage than leaf sprayed Mo with band N placement method. With broadcast N placement method, seed treated Mo gave higher yield advantage than leaf sprayed Mo except at 60 kg N ha^{-1}. However, with increasing N levels, leaf sprayed Mo showed an increasing trend whereas seed treated Mo showed a decreasing trend. This might be due to the fact that seed treated Mo was applied during planting time and by reducing nitrate the plant could make use of the available N early in the growing season. Leaf sprayed Mo was accomplished at four leaf stage of the crop so that the interaction could start later in the growing season and so the plant could use more N at higher rates.

Comparing band - and broadcast N placement methods for leaf sprayed Mo, the statistical analysis of data revealed that band placed N, in most cases, gave higher seed yields than broadcast N. This might be due to the fact that as Mo is highly phloem-mobile, foliar applied Mo could be translocated to the root where high concentration of N is available with banded N, and due to its nitrate reduction ability it could convert the nitrogen to an available form to be taken up by the plant. On the other hand, for seed treated Mo, greater seed yield advantage was gained with the broadcast than with the band N placement at the lower rates of N, but banded N showed an increasing trend whereas broadcasted N showed a decreasing effect on seed yield ha^{-1} with increasing N levels.

Regression analysis was performed for all parameters in relation to increasing N levels in both N placement methods. However, only few of the parameter (number of seeds per plant and seed yield per hectare) in band N placement method gave significant relations. The regression analysis showed that strong and positive regression was obtained between N levels and number of seeds per plant ($R^2 = 0.5067$), and between N levels and seed yield per hectare ($R^2 = 0.4557$).

Additionally, treatments with N in band and broadcast placement methods with leaf sprayed and seed treated Mo also had a significant effect on some yield components. In this regard, the interpretation of the data revealed that the application of N with Mo treatments tended to enhance and significantly affect pod length and total aboveground dry matter yield with band N placement. With the broadcast N placement, all the yield components were affected non-significantly by the application of N and Mo fertilizers. This could be attributed to the relative efficient fertilizer use of the crop in band than in broadcast method of fertilizer placement.

Nitrogen and Mo treatments also had some influence on nutrient contents of the dry seeds of the bean cultivar. In this regard, the direct interpretation of the raw data as well as the statistical analysis showed that for leaf sprayed Mo, increasing rates of band placed N tended to decrease total protein content of the dry seed up to 40 kg N ha^{-1} and thereafter showed an increasing effect. Broadcast placed N, for leaf sprayed Mo, increased seed protein with increasing N levels. However, the mean seed protein content was greater with band than with broadcast placed N when Mo was leaf sprayed. This could be explained by the results of Malhi et al., (1996) that the percent N (in this case percent protein) derived from fertilizer tended to be greater with band placement than with surface broadcasted N on zero tillage.

On the other hand, increasing N levels had either no appreciable effect or tended to decrease seed protein content in both band and broadcast N placement methods for seed treated Mo. At the lower rates of N, greater seed protein content was observed with broadcast N, but decreased beyond 40 kg N ha^{-1}. With banded N, it showed an increasing trend beyond 20 kg N ha^{-1}.

With regard to the effects of N and Mo applications on seed Mo content, it was observed that, increasing N levels, in both band and broadcast placed N, tended to reduce seed Mo content for leaf sprayed Mo. In this regard, greater seed Mo content was obtained in band than in broadcast N placement. On the other hand, for seed treated Mo, broadcast placed N, for all N levels significantly increased seed Mo content more than band placed N. However, as in the case of leaf sprayed Mo, increasing N levels in both band and broadcast N placement methods also tended to reduce seed Mo content for seed treated Mo.

The regression analysis showed that there was a strong and positive association between N levels and number of seeds per plant (R^2 = 0.5067), and between N levels and seed yield per hectare (R^2 = 0.4557) in band N placement method. With broadcast

N placement method, no significant association was observed between N levels and the parameters considered.

In conclusion, the observations made in this study indicated that, the application of N and Mo fertilizers did not significantly affect the vegetative growth and development or the reproductive development of the tested dry bean cultivar. The major reproductive part (the final seed yield) observed was non-significantly increased with the application of N and Mo fertilizers. With the band placed N, greater seed yield ha^{-1} was achieved with the interaction of 60 kg N ha^{-1} with seed treated Mo followed by 40 kg N ha^{-1} with zero Mo. With the broadcast placed N, higher seed yield was achieved at the interaction of zero N with seed treated Mo followed by 20 kg N ha^{-1} with seed treated Mo.

Additionally, in the individual effects of N and Mo fertilizers, higher seed yields were gained with 60 kg N ha^{-1} in band N placement whereas 20 kg N ha^{-1} gave higher seed yield in broadcast N placement. In band N placement, zero Mo gave higher seed yield whereas in broadcast N placement, seed treated Mo gave higher seed yield ha^{-1}.

With regard to the nutrient content of the dry seeds, greater seed total protein was obtained from the interaction of 60 kg N ha^{-1} with zero Mo followed by zero N with seed treated Mo in band N placement. The individual N and Mo effects on seed protein content were more pronounced with zero N and seed treated Mo. In the case of seed Mo content, the interaction of 60 kg N ha^{-1} with seed treated Mo was higher, followed by zero N with seed treated Mo. Here also, the individual effects were greater at zero N and seed treated Mo. With the broadcast N placement, higher seed protein content was achieved at the interaction of zero N with seed treated Mo followed by 40 kg N ha^{-1} with seed treated Mo. As to the individual effects of the fertilizers greater seed protein was obtained with the application of zero N and seed treated Mo. With regard to Mo content, higher seed Mo content was obtained in the interaction of zero N with seed treated Mo. The individual fertilizer effects also gave greater seed Mo content at zero N and seed treated Mo.

Because this study was executed in the glasshouse conditions and only for a single season, field trial for repeated periods is required for further confirmation of the effects of these fertilizers on the yield and yield components as well as their effect on the seed nutrient content of the dry beans. Furthermore, as the total protein fraction of dry bean seeds comprises a range of different protein species, it seems appropriate to further identify the specific proteins affected by N and Mo fertilizer applications. Further experimentation is also required to deeply identify whether the applied N can have a negative effect on the symbiotic microbial activities of the *Rhizobium* bacteria.

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7. APPENDIX

Table 7.1 Analysis of variance of N and Mo fertilizers on pod length (cm), with band N placement method.

Source	DF	SS	MS	F_b	Prob.
N (A)	3	0.101	0.034	1.0375	0.3877
Mo (B)	2	0.352	0.176	5.4368	0.0086***
A x B	6	0.524	0.087	2.6983	0.0288**
Error	36	1.166	0.032		
Total	47	2.143			

CV% = 2.10

Table 7.2 Analysis of variance of N and Mo fertilizers on pod length (cm), with broadcast N placement method.

Source	DF	SS	MS	F_b	Prob.
N (A)	3	0.177	0.059	1.3988	0.2590
Mo (B)	2	0.043	0.021	<1	
A x B	6	0.103	0.017	<1	
Error	36	1.521	0.042		
Total	47	1.844			

CV% = 2.39

Table 7.3 Analysis of variance of N and Mo fertilizers on pod weight (g), with band N placement method.

Source	DF	SS	MS	F_b	Prob.
N (A)	3	0.035	0.012	1.4559	0.2428
Mo (B)	2	0.014	0.007	<1	
A x B	6	0.106	0.018	2.2037	0.0652
Error	36	0.288	0.008		
Total	47	0.443			

CV% = 6.69

Table 7.4 Analysis of variance of N and Mo fertilizers on pod weight (g), with broadcast N placement method.

Source	DF	SS	MS	F_b	Prob.
N (A)	3	0.050	0.017	1.9051	0.1462
Mo (B)	2	0.026	0.013	1.4682	0.2438
A x B	6	0.007	0.001	<1	
Error	36	0.314	0.009		
Total	47	0.396			

CV% = 6.94

Table 7.5 Analysis of variance of N and Mo fertilizers on number of pods per plant, with band N placement method.

Source	DF	SS	MS	F_b	Prob.
N (A)	3	37.600	12.533	1.5041	0.2300
Mo (B)	2	0.248	0.124	<1	
A x B	6	26.199	4.366	<1	
Error	36	299.974	8.333		
Total	47	364.021			

CV% = 21.46

Table 7.6 Analysis of variance of N and Mo fertilizers on number of pods per plant, with broadcast N placement method.

Source	DF	SS	MS	F_b	Prob.
N (A)	3	6.957	2.319	<1	
Mo (B)	2	4.395	2.197	<1	
A x B	6	21.944	3.657	<1	
Error	36	176.826	4.912		
Total	47	210.122			

CV% = 17.75

Table 7.7 Analysis of variance of N and Mo fertilizers on number of seeds per pod, with band N placement method.

Source	DF	SS	MS	F_b	Prob.
N (A)	3	0.033	0.011	<1	
Mo (B)	2	0.310	0.155	1.9337	0.1593
A x B	6	0.880	0.147	1.8321	0.1203
Error	36	2.882	0.080		
Total	47	4.105			

CV% = 4.90

Table 7.8 Analysis of variance of N and Mo fertilizers on number of seeds per pod, with broadcast N placement method.

Source	DF	SS	MS	F_b	Prob.
N (A)	3	0.441	0.147	<1	
Mo (B)	2	0.721	0.360	1.5404	0.2281
A x B	6	1.796	0.299	1.2798	0.2911
Error	36	8.422	0.234		
Total	47	11.379			

CV% = 8.18

Table 7.9 Analysis of variance of N and Mo fertilizers on seed weight per pod (g), with band N placement method.

Source	DF	SS	MS	F_b	Prob.
N (A)	3	0.002	0.001	<1	
Mo (B)	2	0.001	0.001	<1	
A x B	6	0.010	0.002	2.1834	0.0674
Error	36	0.028	0.001		
Total	47	0.042			

CV% = 2.03

Table 7.10 Analysis of variance of N and Mo fertilizers on seed weight per pod (g), with broadcast N placement method.

Source	DF	SS	MS	F_b	Prob.
N (A)	3	0.005	0.002	5.4572	0.0034***
Mo (B)	2	0.001	0.000	1.1407	0.3309
A x B	6	0.001	0.000	<1	
Error	36	0.012	0.000		
Total	47	0.019			

CV% = 1.32

Table 7.11 Analysis of variance of N and Mo fertilizers on number of seeds per plant, with band N placement method.

Source	**DF**	**SS**	**MS**	F_b	**Prob.**
N (A)	3	1295.167	431.722	1.5315	0.2230
Mo (B)	2	170.294	85.147	<1	
A x B	6	691.699	115.283	<1	
Error	36	10148.148	281.893		
Total	47	12305.307			

CV% = 21.55

Table 7.12 Analysis of variance of N and Mo fertilizers on number of seeds per plant, with broadcast N placement method.

Source	**DF**	**SS**	**MS**	F_b	**Prob.**
N (A)	3	224.777	74.926	<1	
Mo (B)	2	166.797	83.398	<1	
A x B	6	853.554	142.259	<1	
Error	36	6364.168	176.782		
Total	47	7609.296			

CV% = 18.21

Table 7.13 Analysis of variance of N and Mo fertilizers on 100 seed weight (g), with band N placement method.

Source	**DF**	**SS**	**MS**	**F_b**	**Prob.**
N (A)	3	2.458	0.819	1.0091	0.4000
Mo (B)	2	0.445	0.222	<1	
A x B	6	10.038	1.673	2.0603	0.0826
Error	36	29.232	0.812		
Total	47	42.173			

CV% = 5.40

Table 7.14 Analysis of variance of N and Mo fertilizers on 100 seed weight (g), with broadcast N placement method.

Source	**DF**	**SS**	**MS**	**F_b**	**Prob.**
N (A)	3	10.656	3.552	3.7981	0.0183**
Mo (B)	2	3.538	1.769	1.8917	0.1655
A x B	6	1.322	0.220	<1	
Error	36	33.666	0.935		
Total	47	49.181			

CV% = 5.73

Table 7.15 Analysis of variance of N and Mo fertilizers on pod abscission, with band N placement method.

Source	DF	SS	MS	F_b	Prob.
N (A)	3	2.436	0.812	<1	
Mo (B)	2	1.483	0.741	<1	
A x B	6	6.215	1.036	1.0305	0.4217
Error	36	36.185	1.005		
Total	47	46.318			

CV% = 25.67

Table 7.16 Analysis of variance of N and Mo fertilizers on pod abscission, with broadcast N placement method.

Source	DF	SS	MS	F_b	Prob.
N (A)	3	2.827	0.942	1.3756	0.2658
Mo (B)	2	4.897	2.449	3.5747	0.0384**
A x B	6	9.322	1.554	2.2681	0.0586
Error	36	24.660	0.685		
Total	47	41.706			

CV% = 20.71

Table 7.17 Analysis of variance of N and Mo fertilizers on seed yield per plant (g), with band N placement method.

Source	DF	SS	MS	F_b	Prob.
N (A)	3	28.929	9.643	1.5388	0.2212
Mo (B)	2	2.554	1.277	<1	
A x B	6	18.594	3.099	<1	
Error	36	225.606	6.267		
Total	47	275.683			

CV% = 19.48

Table 7.18 Analysis of variance of N and Mo fertilizers on seed yield per plant (g), with broadcast N placement method.

Source	DF	SS	MS	F_b	Prob.
N (A)	3	3.202	1.067	<1	
Mo (B)	2	13.332	6.666	1.1545	0.3266
A x B	6	20.127	3.354	<1	
Error	36	207.872	5.774		
Total	47	244.533			

CV% = 19.48

Table 7.19 Analysis of variance of N and Mo fertilizers on total aboveground dry biomass yield (g pot^{-1}), with band N placement method.

Source	**DF**	**SS**	**MS**	F_b	**Prob.**
N (A)	3	159.870	53.290	1.0478	0.3833
Mo (B)	2	222.887	111.443	2.1911	0.1265
A x B	6	963.188	160.531	3.1563	0.0137**
Error	36	1831.003	50.861		
Total	47	3176.948			

CV% = 11.00

Table 7.20 Analysis of variance of N and Mo fertilizers on total aboveground dry biomass yield (g pot^{-1}), with broadcast N placement method.

Source	**DF**	**SS**	**MS**	F_b	**Prob.**
N (A)	3	85.017	28.339	1.0024	0.4029
Mo (B)	2	104.761	52.380	1.8527	0.1714
A x B	6	164.665	27.444	<1	
Error	36	1017.785	28.272		
Total	47	1372.227			

CV% = 8.45

Table 7.21 Analysis of variance of N and Mo fertilizers on seed yield (kg ha^{-1}), with band N placement method.

Source	DF	SS	MS	F_b	Prob.
N (A)	3	1776938.668	592312.889	1.4383	0.2477
Mo (B)	2	141856.125	70928.062	<1	
A x B	6	929104.192	154850.699	<1	
Error	36	14825320.277	411814.452		
Total	47	17673219.261			

CV% = 19.84

Table 7.22 Analysis of variance of N and Mo fertilizers on seed yield (kg ha^{-1}), with broadcast N placement method.

Source	DF	SS	MS	F_b	Prob.
N (A)	3	103093.230	34364.410	<1	
Mo (B)	2	929818.811	464909.405	1.3425	0.2739
A x B	6	1474696.091	245782.682	<1	
Error	36	12466642.877	346295.635		
Total	47	14974251.009			

CV% = 19.10

Table 7.23 Analysis of variance of N and Mo fertilizers on seed protein content (%), with band N placement method.

Source	**DF**	**SS**	**MS**	F_b	**Prob.**
N (A)	3	3.721	1.240	1.0157	0.3971
Mo (B)	2	2.867	1.433	1.1737	0.3208
A x B	6	12.134	2.022	1.6560	0.1604
Error	36	43.964	1.221		
Total	47	62.685			

CV% = 5.50

Table 7.24 Analysis of variance of N and Mo fertilizers on seed protein content (%), with broadcast N placement method.

Source	**DF**	**SS**	**MS**	F_b	**Prob.**
N (A)	3	7.774	2.591	1.0670	0.3752
Mo (B)	2	7.108	3.554	1.4635	0.2449
A x B	6	18.402	3.067	1.2629	0.2987
Error	36	87.427	2.429		
Total	47	120.711			

CV% = 7.88

Table 7.25 Analysis of variance of N and Mo fertilizers on seed Mo content (ppm), with band N placement method.

Source	DF	SS	MS	F_b	Prob.
N (A)	3	54.018	18.006	<1	
Mo (B)	2	26332.036	13166.018	136.889	0.000***
A x B	6	140.155	23.359	<1	
Error	36	3462.491	96.180		
Total	47	29988.700			

CV% = 44.79

Table 7.26 Analysis of variance of N and Mo fertilizers on seed Mo content (ppm), with broadcast N placement method.

Source	DF	SS	MS	F_b	Prob.
N (A)	3	829.375	276.458	1.2006	0.3234
Mo (B)	2	54755.326	27377.663	118.899	0.000***
A x B	6	1044.849	174.141	<1	
Error	36	8289.288	230.258		
Total	47	64918.837			

CV% = 53.57

Table 7.27 Regression analysis of N for number of seeds per plant with band N placement method.

Source	DF	SS	MS	Fb	P > F
Regression	1	273.2459	273.2459	10.2699	0.009417
Residual	10	266.0618	26.60618		
Total	11	539.3107			

Table 7.28 Regression analysis of N for seed yield per hectare with band N placement method.

Source	DF	SS	MS	Fb	P > F
Regression	1	324420.1	324420.1	8.370932	0.0161
Residual	10	387555.5	38755.55		
Total	11	711975.6			