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CHEMICAL FACTORS INFLUENCING DRY BEAN YIELD

BY

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Dedicated to

My little brother, and friend, Mosito Molahlehi.

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DECLARATION

"I declare that the thesis hereby submitted by me for the Master of Science in Agriculture degree at the University of the Orange Free State is my own independent work and has not previously been submitted by me at another university/faculty. I further cede copy right of the thesis in favour of the University of the Orange Free State".

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CHAPTER 1

INTRODUCTION

Over a period of at least 7 000 to 8 000 years, the common bean has evolved from a wild growing vine, distributed in the highlands of middle America and the Andes, into a major leguminous food crop. It is grown world wide in a broad range of environments and cropping systems (Gepts & Debouck, 1991). During this period, which encompasses the initial domestication phases and subsequent evolution under cultivation, the evolutionary forces of mutation, selection, migration and genetic drift have acted on the raw material of a wild growing *Phaseolus vulgaris* (Gepts & Debouck, 1991). These forces have affected some striking changes in the common bean plant and have shaped the morphological, physiological and genetic characteristics of present day common bean cultivars.

According to Allen *et al.* (1989), the common bean is an ancient New World domesticate that has been introduced into other regions of the world. Based on archaeological, botanical, historical and linguistic data, Gepts and Debouck (1991) concluded that the Americas is the origin of the common bean. Observations made by Wittmack (1880) (as cited by Gepts & Debouck, 1991) on archaeological remains initially from Peru, and later from the southwestern United States, have also indicated that the common bean had originated in the Americas. This was contrary to the belief of an Asian origin, which has been held for several centuries.

Modern common bean can be grown as a summer crop in cool temperature regions, as a cool season crop under irrigation in the semi-arid tropics and all year round at high elevations in equatorial regions (Summerfield & Roberts, 1985). Common beans are suited to many soil types but grow best in well-drained sandy loam or clay loam soils high in organic matter, as they are very sensitive to excessive soil moisture. Under this condition, they are susceptible to diseases. Standing water will injure the plants in a few hours and where drainage is poor, tile drains are essential for producing good yields. Sandy soils are not well suited for bean production but by building up the organic content, soils of this class produce good yields (Wolfe & Kipps, 1953).

Beans are grown on more than 12 million hectares and constitute the most important food legume for more than 500 million people in Latin America and Africa (Nickel, 1989). However, Martin *et al.* (1976) indicated that beans are grown on more than 23 million hectares, with a production of about 11.5 million metric tons over the world, but at a low average of only 0.5 tons per hectare.

Bean production occurs on a wide range of cropping systems and environments, including regions as diverse as Latin America, Africa, the Middle East, China, Europe, the United States and Canada (Schwartz & Pastor-Corrales, 1989), and is a major staple food in these regions (Lynch & Rodriguez, 1994; Henson & Bliss, 1991). Latin America, the centre of origin for the common bean, is still the leading producer in the world with Brazil being the highest producer.

In Africa, production is concentrated in the cool highlands of central and tropical Eastern Africa where beans are the most important pulse crop (Allen *et al.*, 1989). In South Africa, dry bean is an annual crop, which grows well during the warm season (Liebenberg & Van Wyk, 1997). A large variety of dry beans are produced across the RSA, which include the large white kidney bean, small white canning beans, other small white beans, tepary beans, speckled sugar beans, patched sugar beans, yellow haricot, brown haricot and other dry beans. The Mpumalanga, Eastern Free State, Northwest, Gauteng and Northern Provinces of South Africa are the most important regions for bean production and Mpumalanga makes by far the greatest contribution to South Africa's bean production (Liebenberg & Van Wyk, 1997).

The common or dry bean is one of the most popular pulse crops with the immature fruit being used as a green vegetable. It is rich in digestible carbohydrate, mainly starch and concentrations of 50% or greater are common. Moreover, it also contains appreciable amounts of dietary fibre and protein (Martin *et al.*, 1976; Summerfield & Roberts, 1985; Muller & Pereira, 1995) making it especially important as a food source in those regions where animal proteins are scarce or where poverty, religious or ethnic preferences preclude the consumption of meat. This is despite the fact that the proteins in grain legume seeds, which may account for as much as 40% of their dry matter, are regarded as dietetically inferior to animal protein because of their low sulphur-amino acid concentrations (Summerfield & Roberts, 1985).

Another added advantage of the common bean is that it can also be used in cropping systems to reduce cereal root-rot diseases, provide cover and increase nitrogen through N-fixation for summer crops such as maize when inter-cropped. Schoonhoven & Voysest (1991) stated that common beans are versatile, because few crops can show such a broad range of adaptations to the most varied climatic conditions or exhibit such tremendous contrast in plant types and length of vegetative period, which make beans part of the most diverse production systems in all the world.

However, in spite of all the advantages that the versatility of beans offer and the fact that it is a food of great nutritive value consumed by millions of people living in the five mentioned continents, the bean crop has not captured the preference of medium and large scale farmers in the same way as other food crops (Schoonhoven & Voysest, 1991; Lynch & Rodriguez, 1994). There are a number of reasons contributing to the above statement. For example, beans are risky to produce because of the numerous pests and diseases that attack them, resulting in low and unstable yields. In Latin America and Africa, bean production is besieged by an array of biological, edaphic and climatic problems, and these make beans notoriously low in yields, when compared to the average yields obtained in temperate regions (Schwartz & Pastor-Corrals, 1989). In most of the tropical bean production regions, diseases are often the most important constraint to bean production.

However, according to Summerfield & Roberts (1985) there are also the nonbiological stresses which affect bean productivity, both in developed and developing countries. These stresses include drought, temperature extremes and toxicity or deficiency of certain elements, which may cause shedding or abscission of a high percentage of flowers and small pods resulting in reduced yields.

Seed yield, which is the most important economic trait of common bean (Acosta-G & Adams, 1991), is the ultimate consequence of dry weight accumulation and its partitioning (White & Izquierdo, 1991). According to Summerfield & Roberts (1985), yield can be measured as weight or volume of dry seeds or, in snap beans, as green fruits harvested. Seed yields may be expressed as the product of the following components: number of flowers formed per plant, percentage fruit set, seed number per fruit and single seed size or weight (Subhadrabandhu *et al.*, 1978; Summerfield & Roberts, 1985).

Accumulation of dry weight in the bean plant is a direct result of the balance between photosynthesis, respiration and losses caused by senescence and abscission. Partitioning, on the other hand, establishes equilibrium between vegetative and reproductive growth integrated during the development of beans resulting in an end product of yield (White & Izquierdo, 1991). If the equilibrium in not maintained, basically due to poor supply of photosynthetic assimilates (Huff & Dybing1980), the abscission of reproductive organs during the flowering and fruiting periods is often high (Izquierdo & Hosfield, 1981). Premature abscission is especially prevalent among younger fruits in the upper part of the raceme, while first formed fruits at the base of racemes abort less frequently (Tamas *et al.*, 1979). The percentage of ripened seeds is mainly determined by the dry matter distribution to them for about the first three weeks of flowering and photosynthates play a strong role in determining pod set (Hansen & Shibles, 1978).

Besides the biological, edaphic and climatic problems, it is clear that the problem of flower and pod abscission is a serious threat to bean yields. After photosynthesis and respiration, the processes of senescence and abscission play the most important roles in determining both plant growth and yield (White & Izquierdo, 1991). Whatever the cause, it is apparent that, although many large seeded legumes flower profusely, seed and pod yields are significantly reduced by high rate of flower and fruit abscission (Weis & Webster, 1990). As a result this study considered the problem of abscission, which is most probably a physiological problem affecting common bean yields.

The main aim of this study was to evaluate the effect of certain nutrients, other chemicals and ethylene (growth regulator) applied as foliar sprays on dry bean yield. In the light of the outlined problem of flower and pod abscission, the possible preventative roles of chemicals applied as foliar sprays were investigated. More precisely, the main aim included the following objectives:

1. To compare three bean cultivars and determine differences or similarities among them in as far as flower and pod abscission is concerned.
2. To determine the influence of the nutrients molybdenum, copper and potassium, applied as foliar sprays at different concentrations, on the abscission of flowers and pods and hence the ultimate yield of dry beans.

3. To determine the extent to which ethylene, applied as a foliar spray in the form of ethrel, can induce or prevent flower and pod abscission in dry beans.
4. To determine the extent to which silver nitrate, an ethylene antagonist, can affect flower and pod abscission.
5. To determine the influence of ComCat®, a biocatalyst of plant origin, applied as a foliar spray at different concentrations and at different growth stages on the abscission of flowers and pods of dry beans.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Phaseolus vulgaris L., is a member of the Fabaceae, tribe Phaseoleae, and subfamily Papilionoideae. Cultivated forms are herbaceous annuals, determinate or indeterminate in growth and bearing papilionaceous flowers in axilliary and terminal racemes. Racemes may be one to many-flowered (Summerfield & Roberts, 1985).

The differences between indeterminate and determinate growth forms lie in the behaviour of the growing apices. Determinate plants of the common bean have a central axis (the main stem) with five to nine nodes and from two to several branches which arise from the more basal nodes. Indeterminate plants have central axes with twelve to fifteen nodes, or even more, in climbing vine types. In the indeterminate form, all reproductive branches arise laterally, while in the determinate form they are produced terminally as well. The latter reduces node number and results in a more compact growth form, which can be further, enhanced by shorter internodes. Shorter internodes *per se* can produce a dwarf or bush growth habit (Summerfield & Roberts, 1985). There are two groups of indeterminate growth habits namely the prostate type, with profuse branching, and the climbing type with reduced branching (Debouck, 1991).

True determinate growth results when both main stems and lateral branches produce inflorescence quickly and almost simultaneously (Summerfield & Roberts, 1985; Debouck, 1991). The flowering season is very concentrated and the fruiting season even more so. All the fruits that can develop to maturity in a determinate plant may be set in a period of one or two weeks whereas fruit set may extent indefinitely in an indeterminate form (Summerfield & Roberts, 1985). According to Debouck (1991) two groups of determinate growth habits have been identified namely the few noded type (three to seven trifoliolate leaves on the main stem) and the many noded type with 7 to 15 trifoliolate leaves on the main stem. Beans following the few noded growth habit are also known as bush and/or dwarf cultivars, since the combination of terminal inflorescence reduces the number of nodes on the main stem and shorter internodes causes plant height to be reduced allowing mechanical harvesting. Summerfield & Roberts (1985) further stated that determinate growth and simultaneous fruit maturation is overall more advantageous in mechanized modern farming systems than in the more primitive ones.

Time to flowering in common beans vary with variety, temperature and photoperiod and is usually from 28 to 42 days. Flowering is usually completed in 5 to 6 days, in determinate genotypes or 15 to 30 days in indeterminate. The flower contains ten stamens and a single multi-ovuled ovary, which is normally self-fertilized, developing into a straight or slightly curved fruit (the pod) (Summerfield & Roberts, 1985). The flowers of common beans may be either white, yellow or purple (Arnon, 1972). As many as two thirds of all flowers produced may abscise and under temperature or moisture stress young fruits and/or developing seeds may also abort (Summerfield & Roberts, 1985; White & Izquierdo, 1991). Therefore, after the start of flowering, soil moisture should be maintained above the 50 per cent level (Arnon, 1972). Irrigation during this period will reduce flower and pod abscission hence increase the size of pods and seeds. According to Summerfield & Roberts (1985), abscission is greater in flowers formed on the node and branches that develop later and in the lately developed flowers on racemes with multiple flowers.

The seed filling period may extend from as few as 23 days to nearly 50 days. Physiological maturity, the stage where no further increase in dry matter in seeds takes place, may be reached in the earliest varieties in only 60 to 65 days. However, some indeterminate genotypes in cooler upland sites may require up to 150 days. Germination of common bean seeds is epigeal and requires 5 to 7 days at a soil temperature of 16°C (Summerfield & Roberts, 1985).

2.2 CLASSIFICATION

Voysest & Dessert (1991) indicated that bean cultivars, may be classified as follows:

- **Classification by utilization or mode of consumption:** Based on the stage of plant maturity when they are consumed, beans may be grouped as green or snap-beans, horticultural beans grown for and consumed as fresh or processed pods, green shell or fresh beans, full sized seed or dry shell beans grown for dried ripe seeds.

- **Classification by seed characteristics:** Dry beans are primarily characterized by the great diversity of seed types within the species, a rainbow of colours and colour patterns, varying degree of brilliance and several shapes and sizes. Seed type (colour, size, shape and surface texture) is the character most commonly used in this criterion.
- **Classification by growth habit:** Growth habit in beans varies from determinate dwarf beans to very vigorous indeterminate climbing beans and growth habit is of primary importance in describing bean varieties.
- **Classification by duration of growth period:** Bean varieties are usually labeled as early or late matured. However, the range of growth period duration may vary so much between one region and another or among varieties of different growth habits that the term "early" or "late" cannot be used properly without reference to the environment, especially for factors of day length and temperature. According to growth habit and region, bean cultivars range from 70 to 300 days to maturity. The difference is not only varietal but also environmental.

2.3 ABSCISSION

Abscission is the natural separation of leaves, flowers and fruits or buds from the stems or other plant parts by the formation of a special layer of thin walled cells (Martin *et al.*, 1976). The causes of abscission vary greatly with growth conditions and plant cultivars (White & Izquierdo, 1991). Abscission may result from water stress or from competition among developing pods for nitrogen, carbohydrates and other nutrients. It is also related to hormones regulating abscission of younger developing structures in the raceme, mainly of the older fruit. Other important causes of abscission are photoperiod and temperature, which regulate events such as growth rate, flowering and some other plant physiological processes (Masaya & White, 1991).

A number of plant parts may be affected by abscission. According to White & Izquierdo (1991), any tissue may undergo senescence and in stem borne tissues, especially the leaflets, petioles, flowers and pods, this process (senescence) is usually followed by abscission. They concluded that the tissues where senescence appears to be of greatest importance are leaflets, flowers and pods.

Flower and fruit abscission occurs as a result of critical physiological interactions (Weis & Webster, 1990). These may involve the entire plant and/or the reproductive organs (buds, flowers, fruits or pods) within the inflorescence. Quantitative analysis of reproductive growth development and fruit abscission in racemes of *P. vulgaris*, suggest that fruiting organs may abort as a result of nutritional competition within and among individual racemes (Adams, 1967). This is also maintained by White & Izquierdo (1991) who stated that tissues, which are at a disadvantage in competition among sources and sinks, are eliminated as far as senescence and abscission for legumes is concerned. Reproductive success of basal organs at the expense of those which are more distant, is a common pattern in many crop plants and has been attributed in part, to unequal allocation of nutrients to various reproductive structures (Adams, 1967; Binnie & Clifford, 1981). Weis & Webster (1990) examined spatial and temporal patterns of reproduction in tepary bean and observed that timing of anthesis, flower and fruit growth as well as abscission of reproductive organs are positively correlated with the spatial arrangement of reproductive structures on the raceme axis. They also found that the most basal reproductive organs of *P. aculifolius* develop more rapidly, flower first and abscise less frequently than those positioned more distally.

White & Izquierdo (1991) maintained that abscission of flowers or small pods can occur on every raceme of the plant. There is also evidence that the basal and older pods regulate the abscission of new flowers and small pods in general species of grain legumes. Whatever the cause, it is apparent that although many large seeded legumes flower profusely, seed and pod yield are significantly reduced by a high rate of flower and fruit abscission (Weis & Webster, 1990).

According to White and Izquierdo (1991), the abscission of reproductive organs during the flowering and fruiting period in grain legumes is often greater than 50 %. This is mainly attributed to pod-drop which accounts for a larger percentage of the total reproductive structures that abscise with the shedding of small pods less than 10 mm in length (White & Izquierdo, 1991). However, the authors have also reviewed some literature suggesting that if shedding of reproductive parts in beans could be prevented or reduced, yields could be increased. An average bean yield potential of up to 6200 kg/ha has been estimated from results obtained with nine dry bean cultivars when yield loss caused by abscission was added to actual yield (White & Izquierdo, 1991).

2.4 FACTORS INFLUENCING ABSCISSION

2.4.1 Photoperiod and temperature

Photoperiod and temperature have two effects on the development of beans (Masaya & White, 1991). One effect is on rate of nodal development while the other is on the rate of the development of flower buds. Rate of nodal development, in turn, affects plant size and, on the other hand, that of flower bud development strongly affects the timing of anthesis and maturity of the plant (Masaya & White, 1991). By changing the rate of flower bud development and presumably of pod growth, temperature affects the duration of flowering and seed filling and thus timing of maturity.

Research cited by Masaya & White (1991) indicates that growth responses are enhanced by certain diurnal temperature regimes as compared to other regimes of the same temperature. For instance, in a study which was conducted using 11 combinations of mean temperature and day/night differences, it was apparent that flowering was delayed by greater day-night temperature differences as well as by high temperatures (Masaya & White, 1991).

Length of day and night periods are equally important in determining adaptation of plants to photoperiod (Masaya & White, 1991). The duration of the dark period is crucial for internal control of the differentiation of tissues and organs that constitute plant reproductive structures. According to the authors, common beans are classified as short day plants, meaning that a photoperiod sensitive cultivar will flower only under days with a daylight period shorter than a certain length. In a study examining the photoperiodic control of flowering of a bush bean line (Privett & Stang, 1988), it was observed that when the primary leaves, the trifoliate leaf or both sets of leaves received short light periods, the plants flowered. However, when both sets of leaves received long light periods, plants failed to flower. This means that the number of days from planting to anthesis decreases as the daylength decreases below the threshold limit until a minimum number of days to flowering are obtained (Masaya & White, 1991).

Privett & Stang (1988) also showed that, whenever at least one of the sets of leaves received short light periods, flowering occurred at third, fourth and terminal nodes. However, more flowers were produced on the upper nodes in the event of the trifoliate leaf receiving short light periods. Consequently, under long-day primary/short-day trifoliate treatment, a larger total number of flowers were produced than under the short-day primary/long-day trifoliate treatment. Moreover, when the primary and first trifoliate leaves were given opposite photoperiods, flowering occurred at the node of the short-day leaf but not at the node of the long-day leaf.

Privett & Stang (1988) further followed inflorescence development to determine if the absence of flowering at the node of long day leaves was due to delayed development or to abscission after their development had begun. Inflorescence was identified as such when their largest flower buds reached 2.5 mm in diameter. It was observed that if the primary and first trifoliate leaves received opposite photoperiods, inflorescence developed at both node 1 (primary leaves) and node 2 (trifoliate leaf), but at the node of the long-day leaf abscission of virtually all the inflorescences occurred before any bud reached anthesis. If both sets of leaves received long light periods, no inflorescence development was apparent. Thus, the effect of long days is to delay or stop the differentiation of the flower buds. However, Masaya & White (1991) indicated that there is disagreement as to whether photoperiod has an effect on the initiation of flower buds in beans. Their argument stemmed from the literature, which indicated that there is no effect of photoperiod on differentiation of the first floral primordium.

Temperature is also an important factor limiting the growth of crops. The dry bean grows well during the warm season at optimum temperatures ranging from 18 to 24°C (Liebenberg & Van Wyk, 1997). Although many bean cultivars produce yields over a wide range of environments, both temperature and photoperiod have strong effects on crop growth and development. These effects often exert a primary influence on selection of cultivars and planting dates at a given site (Masaya & White, 1991).

Woolley, *et al.* (1991) stated that temperature affects both the length of the bean growth cycle and, through evapotranspiration, the length of time for which soil moisture is adequate for crop growth. The rate of flower bud development strongly affects the time of anthesis and maturity. By changing the rate of flower bud development and presumably of pod growth, temperature affects the duration of flowering and seed filling, and thus timing of maturity (Masaya & White, 1991).

Liebenberg & Van Wyk (1997) indicated that dry bean yield is highly dependent on temperature during flowering time and the average maximum temperature during flowering time should not exceed 30°C. Changes in flower development are highest at 24°C and decrease at temperatures below or above (Masaya & White, 1991). Studies, using controlled environments, provide clear evidence of cultivar differences for temperature effects on specific reproductive processes such as floral primordia, ovule fertility, pollen viability and pod and seed set (Masaya & White, 1991). The negative effect of high temperature on pod set is documented (Monterroso & Wien, 1990) and bean yield reductions, due to abscission of reproductive structures during dry weather, has been reported. Monterroso & Wien (1990) cited literature indicating that bean yield losses, sometimes observed under drought conditions, are mainly attributed to high temperature above 30°C in mid summer.

Kigel, *et al.* (1991) analyzed gradients in branching and flower differentiation in a determinate snap bean cultivar. They observed that excessive branching at 32/27°C resulted in prolific flower bud production but most reproductive units abscised at that temperature. Hence, very few flowers developed into mature pods. The authors also showed that mature pods were produced at 32/12°C although plants bore a large number of small pods that did not continue their development. Similar results of enhanced abscission of reproductive units that occurred at high temperature were observed by (Konsens *et al.*, 1991).

Monterroso & Wien (1990) investigated the effect of heat treatment given at various times during flower ontogeny on abscission and observed that heat treatment significantly increased flower abscission. Buds of less than six days old before anthesis were more susceptible to high temperature than were younger reproductive tissues. Heat treatment close to anthesis reduced fruit setting and heat had a greater adverse effect on male and female flower parts, by causing their malfunctioning.

2.4.2 Ethylene

The role of growth regulators appears to be one of transmission of regulatory information from one tissue to another (White & Izquierdo, 1991). A number of growth regulators can be involved in premature abscission of reproductive structures in grain legume (Clifford, *et al.*, 1992). Being one of the various growth regulators, ethylene can be considered a stress hormone because it is produced in much higher amounts when plants are subjected to various kinds of stress (Salisbury and Ross, 1992). For example, flowers synthesize ethylene especially just before they fade and wither and in most cases, this gas causes their senescence and abscission. Salisbury and Ross (1992) further maintain that the ability of ethylene to stimulate its own formation occurs in many senescing organs, including leaves, flowers, petals and ripened fruits.

The influence of ethylene on the abscission of various plant parts has been documented (Beaudry & Kays, 1988). White & Izquierdo (1991) reported on differences existing between bean cultivars regarding ethylene production by reproductive structures, which is related to levels of reproductive abscission. Sauter, *et al.* (1990) investigated the inheritance of ethylene evolution rate (EER) in high temperature stressed common bean progenies from several crosses and observed that there is increasing evidence for association between higher EER and flower as well as flower bud abscission in response to heat stress.

Tripp & Wein (1989) conducted experiments to determine if ethephon (an ethylene generating chemical) application could differentiate pepper cultivars as to its susceptibility to heat stress-induced abscission. They observed that under good growing conditions, very little abscission occurred in the control plants and differences between cultivars were not significant. In experiments where a single spray was applied, ethephon produced marked increases in bud abscission, with higher applications causing virtually complete bud loss. Spraying pepper seedlings, two or three times with ethephon appeared to increase abscission and decrease cultivar differences compared to single spraying.

Beaudry & Kays (1988) conducted similar experiments on pepper to test the effect of ethylene on abscission. They observed that increasing the concentration of ethylene gas, to which plants were exposed, induced a progressively greater degree of abscission.

Flower buds were highly sensitive to ethylene and the lowest concentration applied doubled abscission with respect to the control treatment. Increasing the concentration of foliar applied silaid (also an ethylene releasing compound) enhanced the abscission of flower buds and leaves of all sizes. Flower buds were most sensitive to silaid.

2.4.3 Role of nutrients

The availability of nutrients plays an important role as far as abscission is concerned. White & Izquierdo (1991) indicated that abscission may result from competition among developing pods for nitrogen, carbohydrates and other nutrients. The fruiting organs may abort as a result of nutritional competition among individual racemes. This emphasizes the importance of equal allocation of nutrients to various reproductive structures, so that the more distant organs do not suffer at the expense of the basal ones.

It is generally recommended that beans should be planted in soils that had been fertilized during previous seasons. This is because beans use available nutrients efficiently and respond poorly to direct fertilization, as they are sensitive to high concentrations of mineral salts (Liebenberg & Van Wyk 1997). Since micronutrients are not supplied in large quantities by the soil and are required in small quantities by plants, they are best supplied through foliar fertilization (Follet, *et al.*, 1981). Their role is equally important and deficiencies of micronutrients lead to severe depression in plant nutrition, growth and yield. Therefore, foliar sprays are excellent supplements to soil applications. Foliar fertilization results in rapid nutrient absorption and utilization (Follet *et al.,* 1981) and has the advantage of allowing immediate correction of deficiencies determined by observation or plant analysis.

Foliar fertilization can be accomplished by means of overhead sprinkler systems and by application through equipment customarily used for spraying pesticides. Ground spray equipment used for foliar feeding is usually of the high pressure, low volume type, designed for uniform spraying of foliage and for keeping water volume to a minimum. The nutrient spray may be applied through single or multiple nozzle hand guns, multiple nozzle booms or by oscillating or stationary cyclone type orchard sprayers. Droplet size must be carefully controlled since it will affect crop response (Tisdale *et al.*, 1993). Severe leaf burn can and does occur when large amounts of nutrients are applied or when certain forms of nutrients are used, hence care has to be taken when dealing with foliar fertilization.

2.4.3.1 Molybdenum

Molybdenum (Mo) is an essential component of two enzymes in plants, namely nitrogenase and nitrate reductase (Marschner, 1986; Mengel & Kirby, 1987; Arnon, 1992; Brodick *et al.*, 1992). Hence, the molybdenum requirement of higher plants depends on the mode of nitrogen supply. Gittens (1991) indicated that some leaf analysis have shown that Mo is an essential catalyst in the metabolism of the plant as nitrogen is taken up in the nitrate form NO_3-N, and is changed to NO_4. There have been many reports on increased crop yields due to molybdenum fertilization, since the effect of this element was first demonstrated (Bennet, 1989).

All biological systems fixing N_2 require nitrogenase and the nitrogenase molecule contains two molybdenum atoms (Marschner, 1986). According to Bergersen (1970) as cited by Mengel & Kirby (1987) the basic mechanism for N_2 fixation by nitrogenase, and thus the function too, is the same for free living N_2 fixing bacteria and for N_2 fixing microorganisms living in symbiosis with higher plants. This may be an indication that molybdenum is important in plant metabolism and is directly involved in the reduction of N_2 and NO_3^- (Marschner, 1986; Mengel & Kirby, 1987).

This suggests that the molybdenum requirement by root nodules in legumes and non-legumes is relatively high. Legumes that depend on N-fixation for their N supply require more molybdenum than those that depend mostly on fertilizer N (Brodrick *et al.*, 1992). Nitrogen fixation in beans needs Mo which is essential for root and nodule development and hence symbiosis of bean with rhizobia (Thung, 1991). Hence, the deficiency of Mo resembles nitrogen deficiency and the supply of Mo enhances N uptake (Mengel & Kirby, 1987). Molybdenum is also considered an essential element of respiratory nitrate reductase which is present in denitrifying bacteria and catalyzes the reduction of nitrate to nitrite (Mengel & Kirby, 1987).

Molybdenum is absorbed as molybdate by plants and it is required in small quantities, lower than that for any of the other mineral nutrients. However, deficiencies have been reported for a number of crops, especially legumes (Marschner, 1986; Arnon, 1992). The problem of molybdenum deficiency is particularly acute in acid soils (Gittens, 1991). The soils in many parts of South Africa are considered to have exceptionally low reserves of molybdenum and the soil chemistry may also inhibit the release of molybdenum (Bennet, 1989; Gittens, 1991). Hence, seedlings lacking this trace element will not grow well. The main reason for molybdenum deficiency in the soil is that in mineral soils of low pH, phosphate and molybdate are similar with respect to their strong adsorption to iron oxide hydrate. Moreover, in uptake by roots, sulphate and molybdate are competing anions (Marschner, 1986). Of all plant nutrient anions, molybdate ranks second after phosphate in its strength of adsorptive binding.

Molybdenum deficiency showed striking effects on pollen formation in maize (Marschner, 1986) as well as in legumes relying on N_2 fixation and symptoms of nitrogen deficiency dominate in molybdenum deficient plants. According to Mengel & Kirby (1987), molybdenum deficient plants are restricted in growth and their leaves become pale and eventually wither. Consequently, flower formation may be restricted. White & Izquierdo (1991) stated that the effect on flower formation could be due to the fact that under low Mo availability, nitrogen availability is restricted. Therefore, abscission may result from competition among developing pods for nitrogen.

As is generally applicable to all anion adsorption processes, the strength of Mo adsorption decreases with increasing pH (Mengel & Kirby, 1987). This pH dependence of Mo adsorption has practical consequences as deficiency can be controlled by liming. Molybdenum can be applied by soaking seeds or as a leaf spray (Thung, 1991). Nevertheless, this is not always adequate because it may wash off or leach away in the soil (Gittens, 1991). However, the application of foliar spray is the most appropriate procedure for correcting acute Mo deficiency (Marschner, 1986).

If the soil has a pH (water) of less than 6.0, then a seed treatment of 100 g sodium molybdate per 50 kg of seed and/or leaf-spray of 100 g of sodium or ammonium molybdate per hectare have to be administered (Liebenberg & Van Wyk, 1997; Bennet, 1989). Enough deposits of molybdenum in the seed will ensure healthy seedlings (Gittens, 1991). For example, tests were conducted in various parts of South Africa where crops such as maize, soya beans and sunflowers were sprayed with about

200-g ha^{-1} of sodium molybdate at various stages of growth. It was observed in crops sprayed just before flowering, that an adequate secretion of molybdenum resulted in the seeds (Gittens, 1991).

Individual plants differ considerably in their requirement for Mo (Mengel & Kirby, 1987). For example, legumes have a high demand because of the requirement of the root nodule bacteria. Molybdenum deficiency may restrict nitrogen nutrition by affecting both NO_3^- reduction and N_2 fixation. Bennet (1991) mentioned a need to examine the effects of supplementary foliar applications of Mo on plants already adequately supplied with Mo in the growing medium. For example, foliar applications of sodium molybdate solutions adversely affected the growth of tomato plants so that reductions in plant height and dry matter yield were associated with most treatments applied.

2.4.3.2 Copper

Most of the functions of copper, as a plant nutrient, are based on the participation of enzymatically bound copper in the redox reactions of the terminal oxidation process in mitochondria where copper containing oxidase enzymes react directly with molecular oxygen (Marschner, 1986). The author further maintained that a large proportion of copper is also localized in chloroplasts and is bound to plastocyanin, which is a component of the electron transport chain of photosystem-1.

Copper is strongly bound to soil particles, is very immobile in soil and the copper content of many soils therefore decreases down the profile (Mengel & Kirby, 1987). Tisdale *et. al.* (1993) stated that copper deficiencies are less common than deficiencies of other micronutrients. However, according to Mengel & Kirby (1987), copper deficiency is well known in a number of different crop plants.

In copper deficient plants, the rate of photosynthesis can be reduced for other reasons directly related to the role of copper in chloroplasts (Marschner, 1986). In addition, in plants suffering from copper deficiency the content of soluble carbohydrates is considerably lower than normal during the vegetative growth stage. It is, however, clear that crop plants differ in their sensitivity to Cu deficiency. The most responsive crops to

Cu fertilizer are oats, spinach, wheat and lucerne. Beans, grass, potatoes and Soya beans show a low response.

Low Cu supply in legumes depresses nodulation and N_2 fixation. Although this effect of copper possibly indicates a large specific copper requirement in root nodules for the N_2 fixation mechanism, an indirect effect involving a shortage of carbohydrate supply for nodulation and N_2 fixation in copper deficient plants is more likely (Marschner, 1986). The processes most affected by copper deficiency in plants are grain, seed and fruit formation; much more than vegetative growth. The primary causes of failure in grain set in copper deficient plants are inhibition of anther formation, the production of a much smaller number of pollen grains per anther and particularly the non availability of the pollen (Marschner, 1986).

In copper deficient soils, especially in dry soils, the lack of fertilization can be a major yield limiting factor, but it can be overcome by the application of foliar sprays containing Cu salts (Marschner, 1986). Foliar sprays are important, since Cu is strongly bound to the soil (Mengel & Kirby, 1987). Nevertheless, under conditions where copper has to be supplied to the soil, the amount of Cu fertilizer applied must exceed the crop uptake to some extent. Besides the strong adsorption of copper and immobility in soil, copper deficiencies are less common than deficiencies of other micronutrients. Soil texture, pH, cation exchange capacity (CEC), organic matter (OM) content and hydrous oxides influence the availability and movement of copper. The copper concentration in the soil solution is usually very low. The dominant solution species are $Cu^{2+}$and Cu $(OH)_2^0$. The $CuSO_4^0$ and $CuSO_3^0$ complexes are also important forms of Cu (Tisdale *et al.*, 1993). Solubility of Cu is pH dependent and it increases hundred fold for each unit decrease in pH. On the other hand, the concentration of soil solution copper decreases with increasing pH and its supply to plants is reduced because of decreased solubility and increased adsorption. Soil and foliar applications are both effective, but soil applications are more common. Application of copper in foliar sprays is confined mainly to emergency treatment of deficiencies identified after planting (Tisdale *et al.*, 1993).

Copper deficiency in dry bean is controlled by the application of 0.5 to 1.0 kg/ha of copper in the form of copper sulphate to the soil. The foliar application of 0.1% of copper sulphate or copper chelates are also commonly recommended (Thung, 1991).

2.4.3.3 Silver nitrate

Silver (Ag^{2+}) is known to be an antagonist of ethylene action (Beyer, 1976). Among the ethylene effects found to be nullified or inhibited by Ag^{2+} (applied as $AgNO_3$) were the triple responses of etiolation of pea seedlings, promotion of abscission of leaves, flowers and fruits of cotton and induction of senescence in orchid flowers (Beyer, 1976).

The involvement of ethylene (C_2H_4) in the regulation of growth and development in higher plants is a well, accepted concept (Veen, 1983). Hence, compounds inhibiting C_2H_4 action can be useful in the study of the action mechanism of this hormone. Small quantities of ethylene play an essential part in many physiological processes in plants, i.e. growth of roots and leaves, fruit ripening, stress reactions and senescence (Hoyer, 1986). In high concentrations, however, ethylene can accelerate senescence and cause bud, flower and leaf drop. Whether the concentration is injurious depends on, among other things, exposure time, temperature, the developmental stage of the plant and the species (Hoyer, 1986).

For many plant species, silver thiosulphate (STS) has been shown to delay or prevent the negative effect of endogenous and exogenous ethylene (Hoyer, 1986). Beyer (1976), indicated that the silver ion (Ag^+) has been shown to be a potent C_2H_4 antagonist. The impression is that Ag^+ interferes with the binding sites for C_2H_4, since Ag^+ appreciably lowers C_2H_4 binding by a plant extract (Veen, 1983). Beyer (1979) showed that Ag^+ is also capable of inhibiting C_2H_4 metabolism suggesting that action and metabolism are interrelated. One of the typical anti ethylene effects of Ag^+ is the delay in senescence of C_2H_4 sensitive flowers.

Moe and Smith-Eriksen (1986), working with flowering pot plants, observed that spraying the plants with increasing ethephon concentrations enhanced flower malformation and flower bud abscission. The plants were sprayed at the following stages of development: first visible flower bud, flower bud just before opening, first open flower and 10-15 open flowers per plant. Treatments at later stages of flower bud development resulted in higher degree of damage than earlier treatments.

However, Moe and Smith-Eriksen (1986) found that silver thiosulphate (STS) treated plants partially overcame the ethephon induced flower bud abscission and at higher concentrations of STS flower bud abscission was almost completely eliminated. The plants were sprayed with various concentrations of STS when they had reached the first open flower and at the 10-15 open flower stages. The amount of abscised flowers was most pronounced with low STS concentrations. With higher STS concentrations, the flower bud abscission was less, and the highest STS concentration (6.25 mM) completely overcame the ethephon treatment while flower bud abscission was not significantly different from the control plants. However, the 6.25 mM STS caused some injuries of the petals. Because of this, Moe and Smith-Eriksen (1986) recommended to spray several times with a lower STS concentration before flower bud opening.

2.4.3.4 Potassium

Macro nutrients are applied pre-plant or at planting in most cases. Nevertheless, according to Arnon (1992), phosphorus, nitrogen and potassium, in solution when sprayed on the foliage, are easily absorbed and spread rapidly to all parts of the plant. Spraying fertilizer solutions directly on the foliage of a crop has the advantage of avoiding the problem of fixation, loss of availability and loss by leaching which occur when fertilizers are applied to the soil. However, care has to be taken when dealing with macronutrients not to apply highly concentrated solutions which can cause scorching of the foliage and hence, damage to the crop.

Common bean production in many regions occurs under rainfed conditions where water deficit limits yield and causes instability of production (White *et al.,* 1994). Sangakkara, *et al.* (1996) maintained that water stress and mineral nutrients are important environmental parameters that determine growth and yields of food crops. They stated that environmental stress, especially that of soil moisture and temperature on plant growth is reduced by the fertilizer potassium.

Sangakkara *et al.* (1996) determined the effect of K as fertilizer on the root branching pattern of seedlings of *P. vulgaris* and on plant water status when grown under optimal and suboptimal soil moisture conditions. They observed that potassium played a significant role in promoting dry matter accumulation in roots and increasing the number of branches in plants grown under both moisture regimes. Moreover, an adequate supply increased nodulation under a lower soil moisture regime. Potassium is thought to have a significant role in increasing root development of legumes grown under water stress by enhancing assimilate transport from source to sink, therefore minimizing the imbalance in the distribution of nutrients from the basal to the more distant reproductive structures.

2.4.3.5 ComCat® (a natural biocatalyst with plant origin)

ComCat® is a plant extract that contains a combination of natural substances, which are involved in the regulation of plant development (Huster, 1999; personal communication). Due to this, ComCat® is described as a plant-strengthening agent which increases yield by improving the root, leaf and fruit development of a crop. If applied at an early growth stage, ComCat® can be of benefit to the farmer providing that sufficient nutrients and water were applied.

Other advantages of ComCat® include its ecologically friendly nature, its induction of resistance against pathogens and its improvement of product quality without leaving residues in the crop (Huster, 1999; personal communication). The product is water-soluble and is applied in small dosages as a seed treatment and/or as a foliar spray.

2.5 RATIONALE FOR THIS STUDY

From the literature review, it became evident that bean yields in general, are far below potential due to the premature abscission of flowers or pods. Although several physiological factors have been implicated in the past to be the cause of abscission, as a result of nul-hypothesis research, this study concentrated on chemical treatment of the plants at different growth stages, in an attempt to circumvent the problem.

The effects of photoperiod and temperature as factors influencing abscission were not considered in this study. However, a brief overview of how photoperiod and temperature effects can affect bean yield was supplied in the literature review. Neither temperature nor day length were adjusted but maintained at an optimum level for bean growth, since the study was carried out under semi-controlled conditions in a green house. In order to curb the problem of water, which has been indicated to affect flower and bud abscission, plants were maintained at field capacity throughout the growing period.

Subsequently, chemical treatments were applied at different stages of plant development during the first set of trials as well as at varying concentration levels during the second set of trials. The chemical treatments were applied with the aim to determine which ones were able to curb or accentuate the problem of flower and/or pod abscission, based on the concentration levels and/or stage of development when the chemical was applied. Foliar sprays were used in all cases as a method of application.

CHAPTER 3

MATERIALS AND METHODS

3.1 MATERIALS

All experiments were conducted in a green house during the 1998/99 and 1999/2000 growing seasons at the University of the Orange Free State, Bloemfontein, South Africa. The experiments were carried out under semi-controlled temperature conditions.

Three bean cultivars, namely Kranskop, Leeukop and Stormberg were used in an initial trial in order to compare their overall performances with regard to yield and how it related to flower and pod abscission, while no chemical treatments were applied. During the 1998/99 growing season, two trials were run concurrently.

Subsequently, the cultivar Kranskop was chosen for further trials as it is regarded as one of the best performers in South Africa. The seed material, for all trials, was obtained from the Grain Crops Institute, Agricultural Research Council (ARC) Potchefstroom. A sandy loam soil, obtained from Ficksburg, was used in all trials during the two seasons.

Plastic pots (cylindrical) with the following measurements: height 17 cm, top diameter 20 cm and bottom diameter 13 cm, were used. Fertilizer (LAN, super phosphate and potassium nitrate) applied during seed planting was purchased from SENWES co-op, Bloemfontein. All chemicals used as foliar treatments were obtained from either Merck (Germany) or Sigma (Germany) and were of the highest purity available. ComCat®, a biocatalyst with plant origin, was supplied by Agraforum (Germany).

3.2 METHODS

3.2.1 Experimental design

Two sets of trials were run simultaneously in the green house during the 1998/99 growing season and a complete randomized design (CRD) was used in both cases. The first trial, comparing three bean cultivars (Kranskop, Leeukop and Stormberg) regarding their harvestable yield capacity and daily morphological changes, was replicated four times with each pot containing one plant representing a replicate. Only one cultivar (Kranskop) was used in the second set of trials (3 in total for treatment at 3 different growth stages) and treated with five different chemicals (table 3.3). Each trial had its own untreated control, and was replicated three times.

The third set of trials (3 in total for treatment at 3 different growth stages) was run during the 1999/2000 growing season and was planted in October 1999. A complete randomized design (CRD) was also used in this case. These trials had a purpose similar to that of the previous trials except that chemical treatments were applied at different concentration levels. The same cultivar (Kranskop) was used and four chemicals, namely silver nitrate, potassium chloride, potassium nitrate and ComCat® were used as treatments. Three concentration levels for each treatment were applied. Each trial had its own control and was replicated three times.

3.2.2 Preparation of soil and seed before planting

Soil was obtained from the Ficksburg area in the eastern Free State and sieved through a 2-mm sieve before potting, in order to remove debris and weed seed. Pots were first filled with soil to a level of 4.5 cm from the bottom of the pot. After filling the pots to this level, fertilizer was applied in a band on top and was covered with a 5-cm soil layer. Three bean seeds per pot, spaced 2 cm apart, were planted in a row and placed in such a manner that it was 5 cm above and 5 cm away from the fertilizer row. This was done to reduce the risk of burning the seed or germinating seedlings, which was possible if the fertilizer was placed directly below the seed or in the same row with the seed. The seeds were then covered with a 5-cm soil layer. In this way, pots were filled sufficiently, with a space of about 2-cm left at the top for water application.

Plants were watered with distilled water throughout the growing period, in order to avoid the mineral content of pure water from influencing the results of the research, and the soil moisture was maintained at field capacity. For the entire period of the experiment, plants were shifted around at random in order to prevent exposure to different conditions that could have applied to different areas in the glasshouse.

3.2.3 Fertilization

Nitrogen, phosphorous and potassium were applied as a side band at planting (see 3.2.2). Nitrogen was supplied as LAN (28%), phosphorous as super-phosphate (10%) and potassium as potassium nitrate (50%). In order to meet the optimum nutrient requirements for the bean crop, application rates indicated in table 3.1 below were used, based on soil analysis results (table 3.2) and recommendations from the FSSA fertilizer hand book. Nitrogen was applied in two portions. At planting, 1.0125 g LAN was applied, while 0.868 g LAN was applied as a top dressing when the plants were at the three to four-leaf growth stages.

Table 3.1: Application rates used for the different nutrients and for all experiments

PER HA	PER POT
N=65kg	0.00188kg (1.880g) LAN
P=30kg	0.002314kg (2.314g) Super-phosphate
K=30kg	0.000486kg (0.486g) Potassium nitrate

Table 3.2: Soil analysis, illustrating some of the characteristics of the sandy loam soil, which was used in the experiments

		pH				Exchangeable & Soluble Cations (1N NH_4OAc)				
Location	Total N (ppm)	Water	1N KCl	Electrical Resistance (Ohms)	Olsen P (ppm)	Ca (ppm)	Mg (ppm)	K (ppm)	Na (ppm)	Zn (0.1N HCl)
Ficksburg-1	399	6.42	5.42	1620	28.8	488	114	112	7	6.5
Ficksburg-2	236	5.63		1600	4.8	480	150	110	23	1.5

Ficksburg-1 soil (table 3.2) was used in the first and second set of trials, while Ficksburg-2 soil was used in the third set of trials

3.2.4 Treatments

The nutrients copper (as copper count N), molybdenum (as sodium molybdate) and potassium (as potassium nitrate) were used as treatments for one of the first set of trials. Ethrel (an ethylene releasing compound), which acts as a growth regulator, and silver (as silver nitrate) which acts as an ethylene antagonist, were included as treatments. The chemical treatments were applied as foliar sprays at different stages of vegetative plant growth, which included the four-leaf (growth stage 14), eight-leaf (growth stage18) and 12 leaf (growth stage 20) stages (table 3.3) (Meier, 1997).

Table 3.3: Treatments and concentrations of different chemicals used for the first set of trials during the 1998/99 season. In all instances, chemicals were sprayed at a rate equivalent to 300 L ha^{-1}.

TREATMENTS (CHEMICALS)	CONCENTRATION
Copper count N (Cu)	1.2% (11.56g l^{-1})
Ethrel 0.12% solution (Ethylene)	0.12% (2.52g l^{-1})
Sodium molybdate (Mo)	0.1% (1.0g l^{-1})
Potassium nitrate (K^+)	2.0% (20.0g l^{-1})
Silver nitrate (Ag^{2+})	0.023% (0.23g l^{-1})
Control	No treatment

Based on the results obtained with the first set of trials during the 1998/99 growing season, the nutrients silver nitrate, potassium nitrate, potassium chloride and the biocatalyst ComCat® were used as treatments for the second set of trials during the 1999/2000 season. For silver nitrate and potassium nitrate, the lower and upper limits of the former concentration levels were used. The treatments were applied as foliar sprays at different stages of plant growth (four, eight and twelve leaf stages) as well as at different concentration levels (table 3.4).

Table 3.4: Treatments and concentration levels of different chemicals used for the second set of trials during the 1999/2000 season. In all instances, chemicals were sprayed at a rate equivalent to 300 L ha^{-1}

TREATMENTS (CHEMICALS)	CONCENTRATION LEVELS		
	1	2	3
Silver nitrate (Ag^{2+})	0.012% (0.7mM) (0.12g l^{-1})	0.022% (1.4mM) (0.23g l^{-1})	0.046%(2.8mM) (0.44g l^{-1})
Potassium chloride (K^+)	1.0% (13.4mM) (10.0g l^{-1})	2.0% (26.8mM) (20.0g l^{-1})	4.0% (53.6mM) (40.0g l^{-1})
Potassium nitrate (K^+)	1.0% (9.8mM) (10.0g l^{-1})	2.0% (19.8mM) (20.0g l^{-1})	4.0% (39.6mM) (40.0g l^{-1})
ComCat®	0.02% (0.20mg l^{-1})	0.04% (0.40mg l^{-1})	0.08% (0.80mg l^{-1})
Control	–	–	–

The bean plants were treated when they were at the four-leaf (± 17 days after emergence), eight to ten leaf (± 28 days after emergence) and at the twelve to fourteen leaf stage (± 35 days after emergence). A specially designed spraying machine, resembling spraying equipment used under field conditions, was used for foliar spraying of the treatments. The machine was calibrated in such a way that it delivered 300 litres ha^{-1} of the different solutions used as treatments. This was obtained by calibrating the speed at which the solutions were delivered through a single nozzle over a distance of four metres. Plants to be treated were placed directly under the nozzle and in a row. All the treated plants were sufficiently covered by the spray.

3.2.5 Parameters Measured

In all experiments, only the aerial plant parts were monitored. The main aims were to closely monitor the flowering and pod formation pattern of the bean plant as well as to ascertain which flowers and /or pods tended to abscise based on their placement on the raceme. This data was correlated with final yield results in order to establish whether the final yield was affected most by flower or pod abscission or both.

The parameters, measured to establish the effects of exogenously supplied chemicals on the development and yield of beans, included number of flowers formed and abscised, pods formed and abscised, number of pods that matured at harvest, mature pod mass, seed mass per pod and seed number per pod.

In order to follow the flowering and pod formation patterns of the bean plants, a white paint was used for marking the flowers, while a yellow paint was used for marking the pods. This enabled the counting of flowers and location of flowers and pods that abscised prematurely. Measurements were taken every day from inception of flowering until the last day of flowering. Every flower and pod was marked with the respective colour as they formed. Plants did not start flowering at the same time, hence completion of flowering and podding was also not uniform.

At the end of the drying cycle and after harvesting, the mass of the dry bean pods (pod plus seed) was determined. Finally, both the number of seeds and seed mass per pod and per plant, that developed to maturity, were determined while the total yield per hectare was calculated by converting grams per plant to kilograms per hectare. In the latter instance, a plant stand of hundred and twenty thousand plants per hectare, general for the production of dry beans under irrigation in South Africa, was taken as a median for calculating the extrapolated yield per hectare.

3.3 PLANT PROTECTION

Pest problems were encountered during both growing seasons. During the 1998/1999 season a fungal disease, diagnosed as a *Rhizoctonia* species, infected the base of stems ten days after emergence. Spore kill® was applied on the soil surface at a concentration of 1 ml l^{-1} of distilled water and at 100 ml per pot. This was carried out three times at ten-day intervals. Plants were also infected by red spider mites (Acarina). Red Spidercide® was applied at a rate of 2 ml l^{-1} of distilled water by spraying on the under side of leaves using a knapsack sprayer.

During the 1999/2000 season, plants were infected by *Fusarium* root rot. Benomyl®, a systemic fungicide, was used to treat the soil surface at a concentration of 0.75 g l^{-1} of distilled water and at 100 ml per pot.

3.4 DATA ANALYSIS

Data analyses were conducted using the SAS software system for data analysis (SAS 1985). The T test LSD (least significant difference) procedure, at the $P<0.05$ level, was used for comparing mean values and to show the variation between the treatment means (Gomez & Gomez 1984). A summary of the ANOVA (Analysis of variance) for the study is given in the appendices A, B and C.

CHAPTER 4

PRELIMINARY COMPARISON OF THREE DRY BEAN CULTIVARS REGARDING MORPHOLOGICAL CHANGES DURING THE REPRODUCTIVE PHASE AS WELL AS YIELD POTENTIAL UNDER GLASSHOUSE CONDITIONS

4.1 INTRODUCTION

Besides the problem of nutrient deficiency, especially nitrogen which is an important limitation to bean (*Phaseolus vulgaris L.*) production (Lynch & Rodriguez, 1994), yields are reduced due to flower abscission (Catlin & Olsson, 1990). Abscission may occur under conditions of environmental stress, probably due to production of the abscission causing hormone ethylene (Tripp & Wien, 1989).

Beaudry & Kays (1988) indicated that environmental factors, such as temperature, humidity and light significantly alter the release kinetics of ethylene from ethylene releasing compounds. Therefore, since common bean is not well adapted to high temperature stress, it is greatly affected at or near bloom resulting in decreased yields (Sauter *et al.*, 1990). The bean plant parts most affected by abscission, due to ethylene synthesis, are flower buds, flowers and small pods.

In the light of this well documented problem, three bean cultivars namely Leeukop, Stormberg and Kranskop were grown under semi-controlled conditions in a greenhouse where environmental stresses, which promote abscission, were minimized. Bean plants were not treated in any way but the different cultivars only compared concerning morphological changes in flower and pod formation and abscission during the reproductive phase. Plants were allowed to reach maturity and differences in yield determined after completion of the drying cycle.

The main aim of this comparative study was to monitor both the flowering and pod formation patterns of the different bean cultivars closely, to ascertain which flowers and pods tended to abscise based on their placement on the raceme and to establish whether the final yield was affected most by flower or pod abscission.

4.2 RESULTS

It became evident that the cultivar Kranskop tended to form more flowers on average, as compared to the other two cultivars, while there were no marked differences between Leeukop and Stormberg regarding flower formation (Table 4.1). Relatively more flowers abscised from plants of the cultivar Stormberg with no clear differences between Leeukop and Kranskop.

Table 4.1: Comparison of three bean cultivars, Leeukop, Stormberg and Kranskop, in terms of flower formation and abscission during the reproductive phase.

	Bean cultivars		
	Leeukop	Stormberg	Kranskop
Flowers formed	23.50 ± 4.44a	24.00 ± 0.82a	28.50 ± 3.11a
Flowers that abscised	2.75 ± 2.87a	5.25 ± 2.87a	2.50 ± 1.29a

Mean values denoted by the same letter did not differ significantly at the P<0.05 level according to the T test, LSD procedure.

A similar tendency to that of flower formation was observed for the number of pods that were formed for the three cultivars (Table 4.2). However, Kranskop lost more pods through abscission relative to the other two cultivars. Not much variation was observed between the three cultivars for the number of pods that reached maturity, though that of Kranskop seemed to be slightly higher.

Table 4.2: Comparison of three bean cultivars, Leeukop, Stormberg and Kranskop, in terms of pod formation and abscission as well as the number of pods that reached maturity, during the reproductive phase.

	Bean cultivars		
	Leeukop	Stormberg	Kranskop
Pods formed	20.75 ± 6.02a	18.75 ± 2.99a	26.00 ± 3.92a
Pods that abscised	10.50 ± 5.26a	9.50 ± 1.29a	15.00 ± 3.56a
Pods that matured (harvested)	10.25 ± 0.96a	9.25 ± 2.63a	11.00 ± 2.45a

***Mean values denoted by the same letter did not differ significantly at the $P<0.05$ level according to the T test, LSD procedure.**

No marked differences in pod mass, number of seeds per pod or seed mass per pod were observed between the three cultivars (Table 4.3). Since no apparent differences were observed for most of the parameters, the final yields per hectare for the three cultivars were also quite similar.

Table 4.3: Comparison of three bean cultivars, Leeukop, Stormberg and Kranskop, in terms of yield expressed as dry pod mass, dry seed mass, seed number per pod and Kg ha^{-1}.

	Bean cultivars		
	Leeukop	Stormberg	Kranskop
Dry pod mass(at harvest)	2.14 ± 1.03a	2.33 ± 1.08a	1.96 ± 0.72a
Dry seed mass/pod	1.55 ± 0.84a	1.65 ± 0.87a	1.46 ± 0.60a
Seed number/pod	3.29 ± 1.59a	3.23 ± .57a	3.38 ± 0.13a
Yield per hectare (kg)	1441.05 ± 314.7a	1481.29 ± 155.90a	1495.25 ± 60.68a

***Mean values denoted by the same letter did not differ significantly at the $P<0.05$ level according to the T test, LSD procedure.**

The analysis of variance for the different parameters indicated that there were no statistically significant differences between the three cultivars. Even the observed differences, especially for flower and pod formation including pod abscission, were not significant. Moreover, no statistically significant differences in total yield were observed between the different cultivars.

4.3 DISCUSSION

The three been cultivars Leeukop, Stormberg and Kranskop are all sugar beans and have similar characteristics; e.g. growth habit (indeterminate), seed size and length of growing season (Liebenberg & Van Wyk, 1997). They grow optimally at temperatures between 18-24°C and high temperatures adversely affect their yield, at flowering time. The yield potentials of these cultivars have been increased from 0.6 tons ha^{-1}, obtained in the early seventies, to approximately 1.2 tons ha^{-1} in the eighties.

The results of this trial suggest that the three been cultivars Leeukop, Stormberg and Kranskop, do not differ significantly in terms of their yield potential when grown under similar conditions in a greenhouse. It was also evident from the results that relatively few flowers were lost compared to the number of pods that abscised. This may imply that yield reductions in bean production is rather due to pod loss than early flower abscission. This is consistent with the findings of Izquierdo & Hosfield (1981), who indicated that pod abscission may account for 64 to 82% of the total reproductive structures that are lost, with the shedding of small pods less than 10 mm in length accounting for most of this. From this, it seemed that the chemical treatments aimed towards improving the yields of dry beans should be directed towards minimizing pod abscission

Chemicals known to affect bean plants and which their presence is essential for optimizing their yield potential include molybdenum (Bennet, 1989; Padma *et al.*, 1992) and potassium (Mengel & Kirby, 1987; Sangakkara *et al.*, 1996). Moreover, ethylene synthesis especially under stress conditions is known to play a role in both flower and pod abscission (Cameron & Reid, 1983; Hoyer, 1986; Sauter *et al.*, 1990; Wien, 1990). In this light, it seemed appropriate to investigate the effects of different chemicals applied at different growth stages on the development and yield outcome of dry beans.

In further investigations, it was decided to use only the cultivar Kranskop, as it is a popular cultivar in the Free State province of South Africa (Liebenberg & Van Wyk, 1997). Different chemicals were applied as foliar sprays at the four, eight and twelve-leaf growth stages and their possible circumventive effects on flower formation and abscission, pod formation and abscission, number of pods that reached maturity, seed mass, seed number and final yield outcome were monitored.

CHAPTER 5

CIRCUMVENTION OF FLOWER AND POD ABSCISSION IN *Phaseolus vulgaris* L. cv. KRANSKOP BY TREATMENT WITH DIFFERENT CHEMICALS AT ONE CONCENTRATION LEVEL

5.1 INTRODUCTION

Bean yield reductions, due to premature abscission of reproductive structures, has been a problem to farmers even under optimal agronomic conditions but is further enhanced by dry and hot weather conditions (Monterroso & Wien, 1990). This is a critical physiological trait determining harvestable yield (Clifford *et al.*, 1992). According to Izquierdo and Hosfield (1987), the average abscission of flowers and pods may be as high as 48% and the tendency of abscission is more marked in determinate bush types than in indeterminate types. The authors also observed that the problem of abscission is associated with high levels of ethylene production and lower levels of total non-structural carbohydrate in stems during the pod elongation stage.

In light of the apparent biochemical basis of flower and pod abscission in beans, the aim of this study was to find a way of circumventing the problem by means of treatment with different chemicals at one concentration level. Molybdenum, copper, silver and potassium salts as well as the growth regulator ethylene were applied as foliar sprays at different growth stages of *Phaseolus vulgaris* L cv. Kranskop in an attempt to circumvent flower and pod abscission.

Molybdenum application was tested as it is one of the most important trace elements and poor crop growth, hence lower yield, may result in molybdenum deficient soils where supplements are not provided (Gittens, 1991). For example, nitrogen fixation in beans is dependent on Mo availability, as it is essential for root and nodule development. It also plays an important catalytic role in the metabolism of the plant as nitrogen is taken up in the nitrate form and is reduced to nitrite. Hence, under low Mo availability and since nitrogen availability is restricted, abscission may result from competition among developing pods for nitrogen. Molybdenum deficiency can also result in leaves becoming pale and withering as well as flower formation being restricted (Gittens, 1991).

It was indicated in the past that low copper availability can depress nodulation and nitrogen fixation in legumes (Marschner, 1986). Thung (1991) indicated that beans are barely sensitive to copper deficiency in comparison with other crops. However, copper absorption occurs throughout the vegetative cycle of the bean and copper accumulates in most of the roots as well as in the pod and stem walls. Copper deficiency can also inhibit anther formation or result in production of a much smaller number of pollen grains per anther, and hence poor grain set (Thung, 1991).

Ethylene is one of the growth regulators that are involved in premature abscission of reproductive structures in grain legumes. According to Hoyer (1986) small quantities of ethylene can play an essential role in many physiological processes in plants such as growth of roots and leaves, fruit ripening, stress reactions and senescence. Ethylene in higher concentrations can accelerate senescence and cause bud, flower and leaf drop. Therefore, ethrel (ethylene releasing compound) was applied exogenously to ascertain the extent to which it would influence flower and pod abscission.

Silver (as silver nitrate) on the other hand, was used as an ethylene antagonist. According to Abraham and Kofranek (1977), the silver ion delays or prevents the negative effect of ethylene and the same ion has been used for many years especially for increasing the longevity of many cut flowers. Silver ions have also been indicated to be more effective in delaying abscission when applied as a foliar spray treatment than as a basal treatment.

Potassium, an essential macro-nutrient, promotes physiological pathways in plants and it was also applied as a foliar spray in the light of the essential role it plays in the translocation of photosynthate (sucrose) in the plant (Mengel & Kirby, 1987). It also induces nodulation and promotes nitrogen fixation in food legumes, especially under soil moisture stress. This happens through enhanced root growth, and especially root hairs, which act as principal sites for infection by Rhizobia (Sangakkara, *et. al.*, 1996). The increased root hairs facilitate a greater absorption surface for the roots, which in turn helps moisture absorption. Smithson *et al.* (1993) identified leaf chlorosis as a problem caused by potassium deficiency, among other nutrients, in the common bean (*Phaseolus* *vulgaris* L.). They also observed large growth and yield responses to N, P and K, unlike when K was omitted. Greater numbers of pods and seeds per pod accompanied these responses. According to Thung (1991), potassium chloride is mostly used as the potassium supplying fertilizer in the production of beans.

The different chemicals were applied separately as foliar sprays and its effect on different parameters, as outlined in chapter 3, compared.

5.2 RESULTS

5.2.1 Flowers formed and abscised

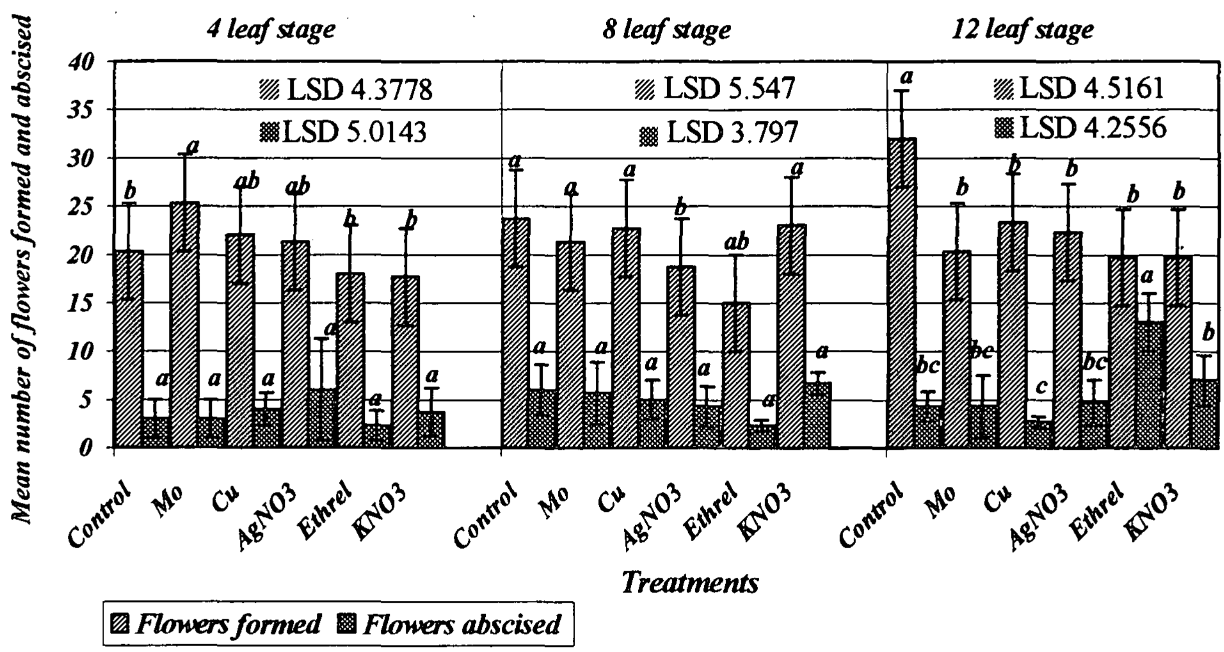

Figure 5.1: Mean total number of flowers per plant that formed and abscised during the reproductive phase of *Phaseolus vulgaris* L. cv. Kranskop as influenced by foliar spray treatment with different chemicals at the four, eight and twelve leaf growth stages. Bars denoted by the same letter do not differ significantly (at the $P<0.05$ level) according to the T test (LSD) procedure.

Plants sprayed with molybdenum at the four-leaf growth stage (vegetative) showed a marked increase in the number of flowers formed as compared to the untreated control (figure 5.1). However, the opposite was true for plants sprayed with molybdenum at the eight and twelve leaf growth stages. There were no marked differences in the number of flowers that abscised from the control and the molybdenum treated plants at all three growth stages (figure 5.1).

Plants treated with copper at the four-leaf stage produced slightly more flowers than did the control (figure 5.1). Treatment at the eight-leaf growth stage showed no effect on flower formation while treatment at the twelve-leaf stage resulted in fewer flowers formed as compared to the respective control plants. Flower abscission in plants treated with copper at the four-leaf stage was slightly higher than in the control, whereas treatment at the eight and twelve leaf stages resulted in less flowers that abscised compared to the controls.

Flower formation in plants treated with a silver salt at the four-leaf stage was slightly higher than in the control but the opposite was true for treatment at the eight and twelve-leaf growth stages (figure 5.1). However, treatment at the four and eight leaf growth stages tended to enhance flower abscission but this was not observed in plants treated at the twelve-leaf stage.

Flower formation was not induced by treatment with ethrel at any of the three growth stages when compared to the controls (figure 5.1). Relatively few flowers that abscised from plants treated with ethrel at the four and eight-leaf stages while treatment at the twelve-leaf stage resulted in more abscised flowers compared to the respective controls.

Spraying plants with potassium nitrate at the four and eight-leaf growth stages slightly decreased flower formation but this was enhanced in plants treated at the twelve-leaf stage (figure 5.1). More flowers that abscised from plants after treatment with potassium at all the growth stages when compared to the controls.

When the number of flowers formed in plants treated with different chemicals were statistically compared to each other and to the controls, significant differences were observed for all growth stages. Molybdenum treatment at the four-leaf stage significantly increased flower formation compared to the ethrel and potassium treatments but did not differ significantly from the control as well as the silver and copper treatments in this regard. Treatment with ethrel at the eight-leaf stage significantly reduced flower

formation compared to other treatments. Control plants significantly out performed all chemical treatments at the twelve-leaf stage with regard to flower formation.
No statistically significant differences in flower abscission were observed between the respective controls and all the different chemical treatments at the four and eight-leaf growth stages. However, the ethrel treatment enhanced flower abscission significantly when the plants were treated at the twelve-leaf stage.

It is clear from the results that treatment with molybdenum at the four-leaf stage improved flower formation, while no treatment at the eight and twelve-leaf stages was superior. Ethrel, and especially when the plants were treated at the twelve-leaf stage, mostly enhanced flower abscission.

5.2.2 Pods formed and abscised

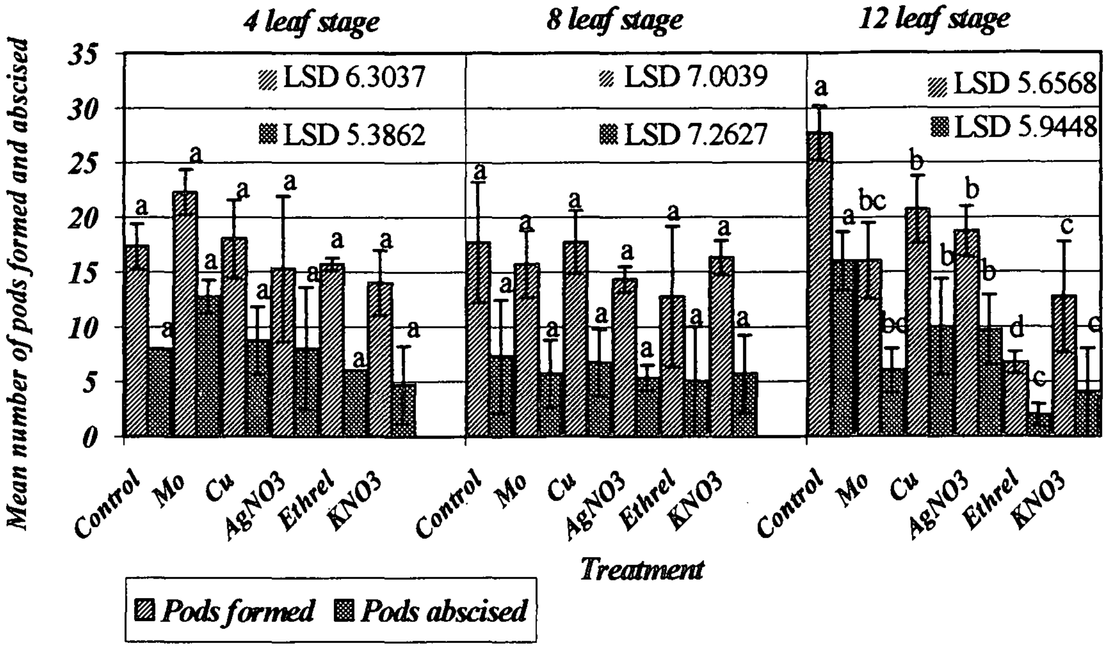

Figure 5.2: Mean total number of pods per plant that formed and abscised during the reproductive phase of *Phaseolus vulgaris* L. cv. Kranskop as influenced by foliar spray treatment with different chemicals at the four, eight and twelve leaf growth stages. Bars denoted by the same letter do not differ significantly (at the $P<0.05$ level) according to the T test (LSD) procedure.

Treating plants with molybdenum at the four-leaf stage markedly induced pod formation as compared to the control (figure 5.2). However, treatment at the eight-leaf stage slightly decreased the number of pods formed, while treatment at the twelve-leaf stage resulted in a significantly lower number of pods, compared to the respective untreated controls. More pods were abscised from plants after treatment with molybdenum at the four-leaf stage but treatment at the eight and twelve-leaf stages reduced pod abscission substantially.

Pod formation by plants treated with copper at the four and eight leaf-stages was similar to that of the respective controls, while treatment at the twelve-leaf stage showed a significant reduction in pod formation (figure 5.2). There were no marked differences between the copper treated plants and the respective controls at the four and eight-leaf stages, in terms of number of pods that abscised. However, the twelve-leaf copper treatment significantly reduced pod abscission compared to the control.

Treating plants with silver nitrate did not induce pod formation at the four and eight-leaf growth stages, while treatment at the twelve-leaf stage reduced the number of pods formed (figure 5.2). There was no marked difference in pod abscission between the silver treated plants and the control at the four-leaf stage but, treatment at the eight and twelve-leaf stages, prevented a high pod loss compared to that of the untreated controls.

Ethrel treatment at the four-leaf stage resulted in a slightly less number of pods that formed as compared to the control plants (figure 5.2), but pod formation was markedly reduced when plants were treated with ethrel at the eight and twelve-leaf stages. Treatment with ethrel at all growth stages did not substantially enhance pod abscission. Overall, the number of pods that formed and abscised from plants treated with potassium at the three growth stages tended to be lower than that of the untreated controls.

No statistically significant differences in the number of pods that formed were observed between all of the chemical treatments and the respective controls at both the four and eight leaf growth stages while, at the twelve-leaf stage these differences were significant.

In as far as pod abscission is concerned, statistically significant differences were observed only at the twelve-leaf stage where all chemical treatments showed lower pod loss than the control. Treatment with ethrel at the twelve-leaf stage caused relatively fewer pods to abscise but this was probably due to the initial high flower loss. As was the case with pods formed, more pods were abscised from plants treated with molybdenum at the four-leaf stage.

The results indicated that molybdenum treatment at the four-leaf stage induced pod formation but at the same time caused more pods to abscise. The same tendency applied for the untreated controls at the twelve-leaf stage.

5.2.3 Pods that matured at harvest

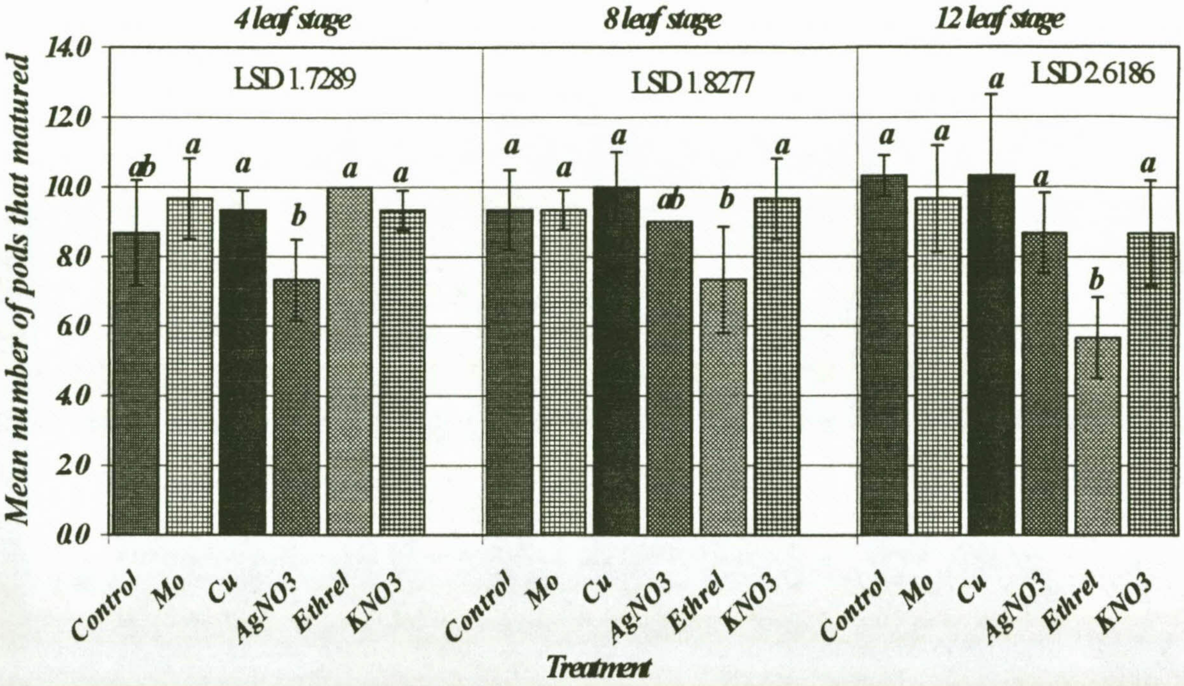

Figure 5.3: Mean total number of pods per plant that matured at harvest for *Phaseolus vulgaris* L. cv. Kranskop as influenced by foliar spray treatment with different chemicals at the four, eight and twelve leaf growth stages. Bars denoted by the same letter do not differ significantly (at the $P<0.05$ level) according to the T test (LSD) procedure.

Slightly more pods reached maturity and were harvested in plants treated with molybdenum at the four-leaf stage than in the control (figure 5.3) but treatment at the eight and twelve-leaf growth stages, showed no differences from the controls. Treating plants with copper at the four and eight leaf stages resulted in slightly more pods reaching maturity compared to the respective controls, while treatment at the twelve-leaf stage did not differ from the control.

The number of pods that reached maturity after treatment with a silver salt at the four and twelve-leaf stages was lower than that of the respective controls, while treatment at the eight-leaf stage was similar to the control (figure 5.3). Treatment with ethrel at the four-leaf stage resulted in a slightly higher number of pods that reached maturity compared to the control, while the opposite was true for treatment at the eight and twelve leaf stages. In the latter instance treating bean plants with ethrel at the eight and twelve leaf stages caused a significant reduction in pods that reached maturity. Potassium treatment at the four and eight leaf stages had no effect on the number of pods that reached maturity while treatment at the twelve-leaf stage decreased the number of pods slightly.

Except for the silver treatment at the four leaf and ethrel treatment at the eight-leaf stages, that decreased the number of mature pods significantly, no statistically significant differences were observed for the other chemical treatments when compared to the respective controls. However, although not dramatic, molybdenum, copper and ethrel treatments at the four-leaf stage tended to cause an increase in the number of pods that reached maturity.

5.2.4 Mature Pod mass at harvest

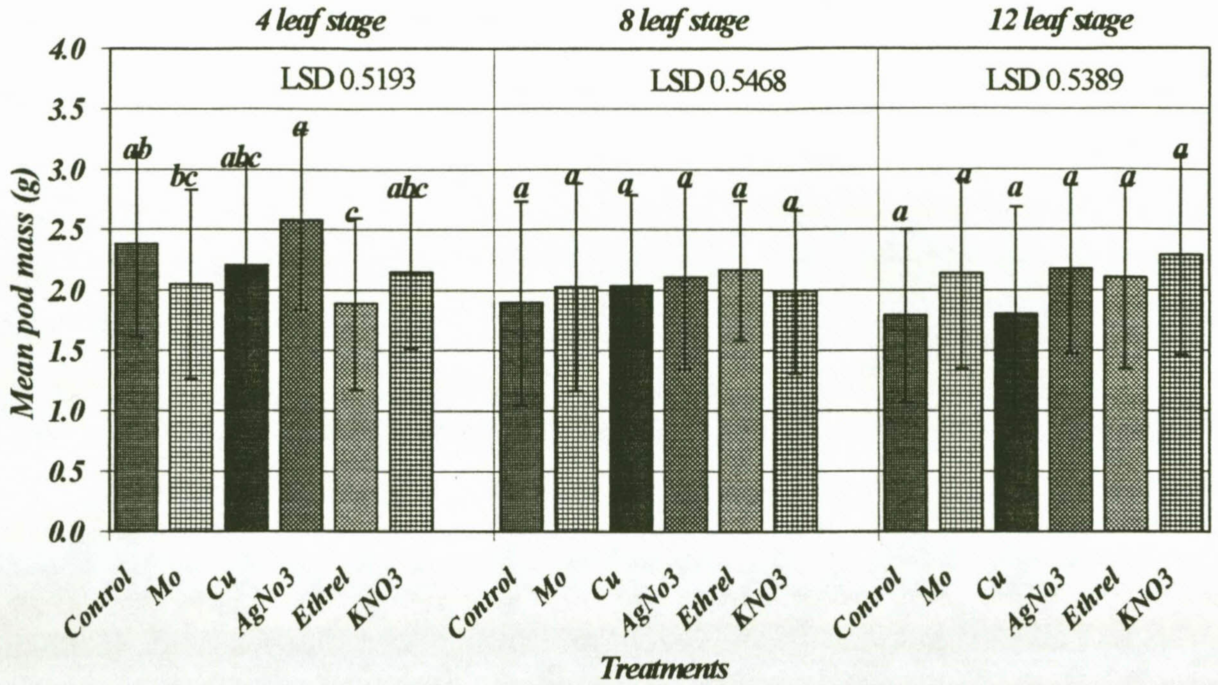

Figure 5.4: Mean pod mass per plant at harvest of *Phaseolus vulgaris* L. cv. Kranskop as influenced by foliar spray treatment with different chemicals at the four, eight and twelve leaf growth stages. Bars denoted by the same letter do not differ significantly at (P<0.05) according to the T test (LSD) procedure.

Although more pods matured after treatment with molybdenum at the four-leaf growth stage (figure 5.3) the mass of mature dry pods was slightly lower than that of the untreated control (figure 5.4). Exactly the opposite was true for the number and mass of mature pods after molybdenum treatment at the eight and twelve leaf growth stages. More pods were harvested from copper treated plants at the four-leaf stage (figure 5.3) but the pod mass was lower compared to that from control plants (figure 5.4). Treatment at the eight and twelve-leaf stages did not result in much variation between the copper treatment and the respective controls with regard to mature pod mass (figure 5.4).

Silver treatment at all three growth stages resulted in a slight pod mass increase but this was not significant (figure 5.4). Treatment with ethrel either decreased (four-leaf) or increased pod mass slightly (eight and twelve-leaf stages) (figure 5.4). This was the direct opposite of what was observed with the number of mature pods at harvest (figure 5.3). Exactly the same tendency as for the ethrel treatment was observed with the potassium treatments.

Statistical analysis of the above data revealed some differences in the four-leaf treatment where the silver treatment was significantly higher than the molybdenum and ethrel treatments regarding pod mass but not significantly different from the control and other chemical treatments. No significant variation was observed in plants treated at the eight and twelve leaf growth stages.

5.2.5 Seed mass per pod at harvest

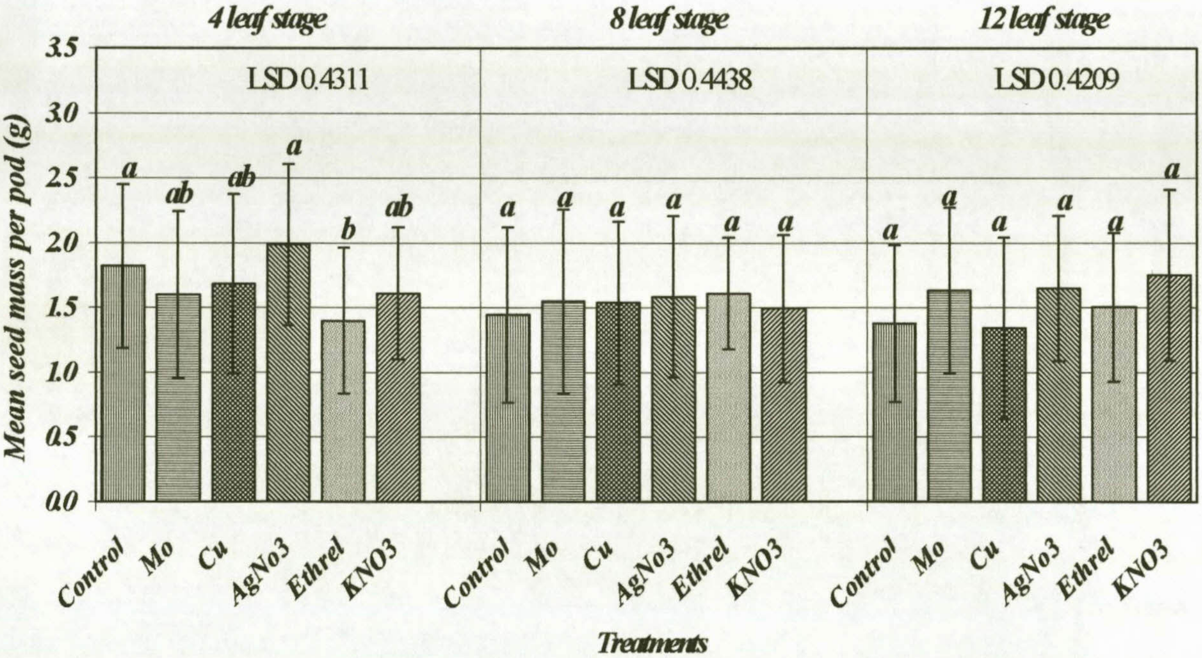

Figure 5.5: Mean seed mass per pod per plant at harvest of *Phaseolus vulgaris* L. cv. Kranskop as influenced by foliar spray treatment with different chemicals at the four, eight and twelve leaf growth stages. Bars denoted by the same letter do not differ significantly (at the $P<0.05$ level) according to the T test (LSD) procedure.

Interpretation of both the raw data and the analysis of variance for seed mass per pod (figure 5.5) revealed exactly the same tendencies as for the analysis of pod mass (figure 5.4) for all treatments. Again plants treated with the silver salt showed marked increases in seed mass per pod at all growth stages compared to the controls, but this was not statistically significant at the eight and twelve-leaf stages.

5.2.6 Seed number per pod at harvest

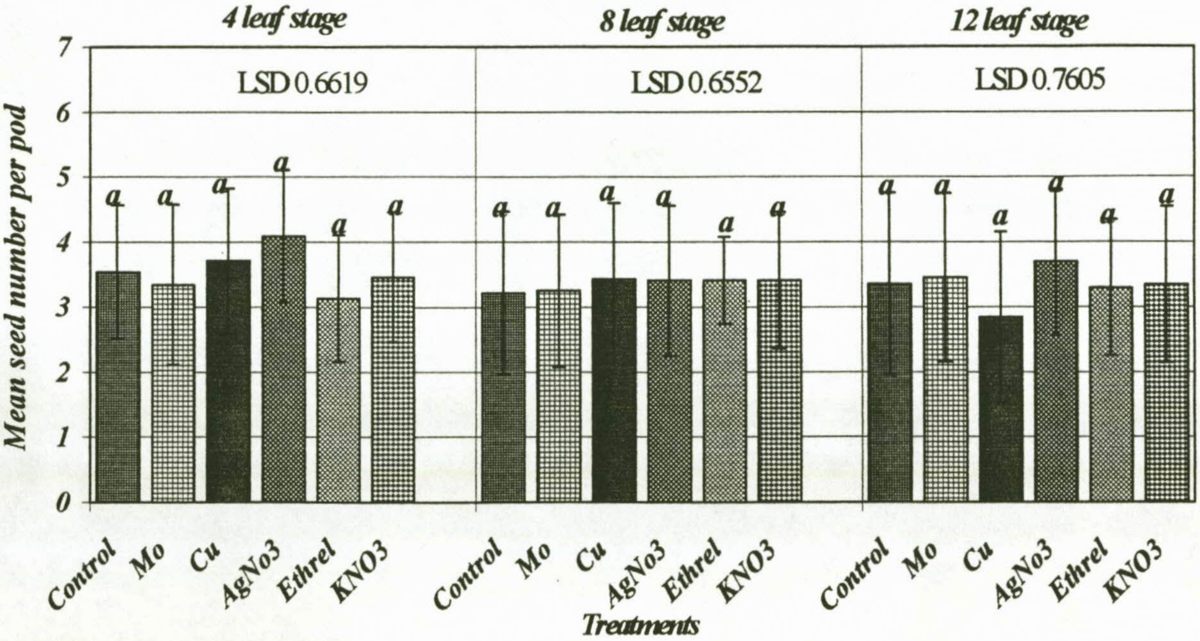

Figure 5.6: Mean seed number per pod per plant at harvest of *Phaseolus vulgaris* L. cv. Kranskop as influenced by foliar spray treatment with different chemicals at the four, eight and twelve leaf growth stages. Bars denoted by the same letter do not differ significantly (at the $P<0.05$ level) according to the T test (LSD) procedure.

Except for the copper and silver treatments at the four-leaf stage, that tended to show a slight increase in the number of seeds per pod, no clear differences between the respective controls and the other chemical treatments and for all the growth stages (figure.5.6) were observed. However, the observed increases by copper and silver treatments were not statistically significant.

5.2.7 Total yield in kilograms per hectare

Table 5.1: Yield of *Phaseolus vulgaris* CV. Kranskop in kilograms per hectare as influenced by fouler spray treatment with different chemicals at the four, eight and twelve leaf stages.

Treatment	Four-leaf stage	Eight leaf stage	Twelve leaf stage
Control	1891.88 ± 146.69a	1618.43 ± 147.93a	1709.65 ± 85.21ab
Molybdenum	1856.48 ± 181.70a	1736.99 ± 124.18a	1898.11 ± 99.36a
Copper	1884.60 ± 62.64a	1846.09 ± 72.02a	1664.06 ± 33.78b
Silver	1748.14 ± 63.24a	1714.13 ± 145.04a	1716.43 ± 162.17ab
Ethrel	1677.96 ± 189.83a	1418.38 ± 324.54a	1023.30 ± 173.76c
Potassium	1804.70 ± 136.40a	1734.59 ± 239.72a	1822.44 ± 119.35ab

***Means followed by the same letter did not differ significantly at the $P<0.05$ level according to the T test (LSD) procedure.**

No significant differences in total yield, expressed as kilograms per hectare, were observed between the respective controls and all the different chemical treatments for plants treated at the four-leaf growth stage (table 5.1). However not statistically significant, all treatments at this early stage in vegetative growth tended to have a decreasing effect on total seed mass with the ethrel treatment being the most damaging.

Except for the ethrel treatment that again reduced the total yield, all other chemical treatments at the eight-leaf growth stage tended to increase the total yield slightly. However, these increases were neither dramatic nor statistically significant (table 5.1) with the copper treatment showing the best result (14% increase) and the least standard deviation as compared to the control.

Both the molybdenum (11%) and potassium (7%) treatments at the twelve leaf growth stage resulted in slightly higher yields but compared to the control neither of these two treatments was considered statistically significant according to the T test (LSD) procedure at the $P<0.05$ level. Again, the ethrel treatment showed the most damaging effect in reducing the yield by 40%.

5.3 DISCUSSION

Foliar spraying of bean plants with different chemicals did not potentially influence flower formation, except for molybdenum (+ 25%) treatment at the four-leaf vegetative stage. Although the total yields were low for the molybdenum treatment at the four-leaf growth stage, yields increased after treatment at the twelve-leaf stage (+ 11%) indicating a potential for molybdenum treatment to increase bean yields. Padma *et al.* (1992) found that application of molybdenum 40 days after sowing increased both the number of flowers and pods per plant and increased pod yields from 4.06 to 5.44 tons per hectare compared to 3.01 tons without the trace element. Many reports have also attributed increased crop yields to molybdenum (Bennet, 1989). Slight yield increases were also demonstrated for treatment with potassium nitrate (7%) at the twelve leaf stage as well as copper (14%), silver (6%) and potassium (7%) treatments at the eight leaf stage.

It was evident from the results that most of the chemical treatments did not have a significant influence on the final yield outcome of the bean crop. Low seed yield is the most important economic problem of common beans (Schneider *et al.*, 1997) and the most practical method of improving its performance is through the direct measurement of yield related characteristics. The actual bean yields for this experiment were in the range of 1000 to 1900 kg ha^{-1} and they could have been better if flower and pod abscission was minimized to some extent. White *et al.* (1994) observed mean bean seed yields of 800 to 1900 kg ha^{-1} for rain fed trials and this was in a way lower than in the irrigated trials. However, maximum yields in the order of 4 to 6 tons ha^{-1} have been obtained (White & Izquierdo, 1991).

Low bean yields may not be attributed to poor flowering *per se* but rather to flower abscission in most cases. This tendency was observed at all growth stages and for most of the chemical treatments, except for the molybdenum treatment at the four-leaf stage. This accentuates that the normal growth pattern of the plants was not affected by the glasshouse conditions and that abscission is probably a secondary metabolic event. No single treatment seemed to have had any significant influence on the improvement of flower formation. However, reduced flower formation due to the ethrel treatment at the eight-leaf growth stage was observed and this was the result of increased flower bud loss that occurred just before anthesis. Monterroso and Wien (1990) demonstrated that buds less than four days from anthesis are more susceptible to abscission and flower bud abscission is mediated by ethylene (Wien, 1990). The findings of Tripp and Wien (1989) indicated that bud abscission contributed more to fruit set reduction than did flower or fruit abscission.

The application of ethrel at the twelve-leaf growth stage, when plants were already flowering, resulted in a substantial loss of flowers. Moe and Smith-Eriksen (1986) demonstrated that ethylene released from spraying plants with ethephon (also an ethylene releasing substance), induced both flower malformation and flower abscission. Therefore, much caution has to be taken in bean production during flowering to ensure that harmful effects of moisture stress and high temperature, under which ethylene is released (Beaudry & Kays, 1988; Sauter *et al.*, 1990), are kept at check. Because of the increased flower loss due to the ethylene effect, Moe and Smith-Eriksen (1986) suggested the use of a silver salt, which has been shown to counteract the effect of ethylene. However, the use of silver nitrate (an ethylene antagonist) in this experiment did not show any significance, in terms of final yield, with the single concentration at which it was applied. This may suggest that ethylene plays a less important role than has been reasoned in the past. Besides the harmful effect of ethrel at the twelve-leaf stage, not many flowers were abscised on average for all treatments and growth stages, when compared to the number of flowers that were formed.

Interestingly, more pods were formed on average for all treatments and at all growth stages, compared to the flowers that abscised and in relation to total number of flowers that were formed. The molybdenum treatment at the four-leaf growth stage was outstanding concerning pod formation and this was consistent with the findings of Padma *et al.* (1992). Ethrel application at the flowering stage (twelve leaf) decreased pod formation. The low pod formation was probably due to the initial high flower loss after treatment with ethrel.

Apart from the increase in pod formation observed with molybdenum treatment at four-leaf stage, the results indicated that reduced yields were a result of increased pod abscission rather than flower abscission. Pods that tended to abscise were about 1 cm in length. This was consistent with the findings of Kigel *et al.* (1991) who indicated that, when analyzing the variability in the response of yield components to environmental stress in legumes, the number of pods per plant is usually the component showing the greatest response. Izquierdo and Hosfield (1981) found that pod drop accounted for 64-82% of the total reproductive structures abscised, with the shedding of small pods less than 10 mm in length accounting for most of this.

It seemed, therefore, that treatment with the different chemicals at the one concentration level tested for each, did not potentially minimize pod abscission suggesting that there might be some other mechanism involved in accelerating abscission. The observed low pod loss, after treatment with ethrel at the twelve-leaf stage, was probably a result of the initial increased flower loss. Even the molybdenum treatment, which improved flower and pod formation significantly after application at the four-leaf stage, increased pod loss. Silver (ethylene antagonist) treatment also did not significantly minimize flower and pod abscission at any growth stage.

The pods that abscised in large numbers were those that formed at a later stage of plant development. Monterroso and Wien (1990) reported that the flowers that open first have a higher probability of setting than flowers that open later. Weis and Webster (1990) indicated that abortion of reproductive organs is positively correlated with the spatial arrangement of reproductive structures on the raceme axis. Force *et al.* (1988) demonstrated that premature abscission of flowers and pods often occur under conditions that limit the supply of photosynthate or from competition among developing pods for nitrogen and other nutrients (White & Izquierdo, 1991). Weis and Webster (1990) maintained that the most basal reproductive organs develop more rapidly, flower first and abort less frequently than those positioned more distally and this has been attributed in part to unequal allocation of nutrients among reproductive structures (Binnie and Clifford, 1981).

It is apparent from this preliminary study, where only one concentration level was tested for each chemical treatment, that less than half of the flowers formed developed into pods that reached maturity and this resulted in reduced total yields. This agrees with what was reported by Izquierdo and Hosfield (1981) namely that abscission of reproductive organs during the flowering and fruiting period in grain legumes is often greater than 50%. Binnie and Clifford (1981) found that flowers opened first were more likely to produce pods that would be retained until harvest than flowers that opened later. Some authors argue that developing pods promote the abscission of later formed flowers and young pods by competing with them for photoassimilates or other nutrients (Huff and Dybing, 1980). However, besides competition for assimilates, an alternative view is that the production of reproductive organs and hence yield is under hormonal control and that the hormonal process prevents these later formed flowers from developing into mature pods (Binnie and Clifford, 1981). The underlying results, however, demonstrated that the chemical treatments, including the silver salt, were not able to counteract the hormonal effect. However, ethrel, which is a growth regulator, clearly enhanced flower and pod abscission which resulted in decreased yield after application at the eight and twelve leaf growth stages.

Due to the initial high flower and pod abscission that resulted in reduced pod numbers, no single treatment had a significant influence on the yield components (mature pod mass, seed mass per pod and seed number per pod). However, silver treatment at the four-leaf growth stage showed signs of potentially improving the mentioned yield components albeit in a statistically non-significant manner. A uniform increase of yield components is vital for any crop production enterprise because it is a good determinant of yield improvement. For example, if there is an increase in seeds per pod but the seed mass does not increase, crop yield remains low. Singh *et al.* (1992) suggested that it is desirable to maintain seed size as larger seeds often fetch better prices in countries where common beans are consumed. White and Izquierdo (1991) maintained that the simplest strategy for increasing yield through selection is to ensure that an increase of certain yield components will not affect other yield components. For example, if seed number is increased through any form of manipulation but the seed mass is reduced in the process, nothing is gained.

Although no dramatic circumvention of flower and pod abscission was observed for any single chemical treatment, copper treated plants at the eight-leaf stage (+14%) and molybdenum treated plants at the twelve-leaf growth stage (+11%) resulted in significant yield increases. However, of the tested chemicals, molybdenum and copper can be considered as the most studied in the past. In this light, it was decided not to pursue the effect of molybdenum and copper any further. Instead, and in view of the fact that ethrel treated plants lost more flowers and pods on average through abscission, it was decided to investigate the possible circumventing effect of silver ions, at different concentrations, in a follow-up experiment. Moe and Smith-Eriksen (1986) working with flowering pot plants found that silver ions partially overcame ethephon induced flower bud abscission at a low concentration (0.03 mM) while at a higher concentration (1.05 mM) the flower bud abscission was almost completely eliminated.

Moreover, potassium nitrate treatment at both the four and eight-leaf growth stages tended to allow more pods to reach maturity, with resultant higher yields (+7% in both cases), as compared to the respective controls and other treatments. The uncertainty concerning the optimum concentration as well as the roles of either the potassium or the nitrate ions necessitated the inclusion of potassium chloride as a treatment at different concentrations in a follow-up experiment. Marschner (1986) indicated that flower formation is positively correlated with potassium supply and low potassium levels can be correlated with flower malformation.

Additionally, treatment with a new natural biocatalyst, ComCat® claimed to improve yields of agricultural crops (Huster, 1999; personal communication) was included in the later trial. This product is registered in Europe and has not been used extensively in South Africa. According to Huster (1999; personal communication), ComCat® is a general plant strengthening agent increasing root development, accelerating nutrient adsorption, intensifying nutrient assimilation and increasing the natural resistance of plants to pathogens.

CHAPTER 6

CIRCUMVENTION OF FLOWER AND POD ABSCISSION IN *Phaseolus vulgaris* L. cv. KRANSKOP BY TREATMENT WITH DIFFERENT CHEMICALS AT DIFFERENT GROWTH STAGES AND AT THREE DIFFERENT CONCENTRATION LEVELS

6.1 INTRODUCTION

The biochemical basis of flower and pod abscission in beans, resulting in lower yields, is well established. In a follow-up investigation the application of some of the chemicals that were tested in the previous chapter, as well as additional ones, were tested at different concentration levels in an attempt to circumvent flower and/or pod abscission. Silver nitrate (an ethylene antagonist), potassium nitrate, potassium chloride and ComCat® (a plant-strengthening agent) were applied as foliar sprays at three different growth stages of *Phaseolus vulgaris* L. cv. Kranskop.

Silver nitrate was shown by Beyer (1976) to prevent the abscission of fruits, leaves and flowers by ethylene. The involvement of ethylene in the regulation of growth and development in higher plants is a well-accepted concept (Veen, 1983). Treatment with silver nitrate in the previous screening trial showed some improvement in flower and pod formation but this was not reflected in the final yield outcome. Moe and Smith-Eriksen (1986) demonstrated that silver ions partially overcame ethephon induced flower bud abscission at low concentration (0.03-mM) in flowering pot plants. Even at a considerably higher concentration (1.05-mM), the flower bud abscission was almost completely eliminated. In this light, it was decided to apply silver nitrate at different concentration levels.

Potassium promotes physiological pathways in the plant and plays an essential role in the translocation of photosynthate such as sucrose (Mengel & Kirby, 1987). Huff and Dybing (1980) reported that poor assimilate supply could limit reproductive growth either by increasing shedding and thus decreasing the number of pods per plant, or by decreasing the number and/or size of seeds without altering the number of pods.

Quantitative analysis of reproductive growth development and fruit abscission in racemes of *Phaseolus vulgaris* L. suggest that fruiting organs may abort as a result of nutritional competition between older fruits and younger ones, within and among individual racemes (Adams, 1967; Tamas *et al.*, 1979; Binnie & Clifford, 1981; Weis & Webster, 1990).

Since treatment with relatively cheap potassium nitrate in the previous trial (see chapter 5) showed some promising effect with regard to the number of pods that reached maturity as well as the final yield outcome, it was decided to investigate its effect at different concentration levels. Moreover, in light of the uncertainty surrounding the roles of either the K^+ or the NO^-_3 moieties of the molecule, it was decided to include potassium chloride, also at different concentration levels, in this follow-up trial.

ComCat® is a new product, registered with the Federal Biological Research Centre for Agriculture and Forestry (BBA) in Germany as a biological active substance of plant origin with yield improvement qualities. So far it has not been tested extensively in South Africa and was therefore included as an additional treatment. Interest in this product emanated from a personal communication with the supplying company (Agraforum, Germany) as well as claims (Huster 1999; personal communication) that the product increases yields of agricultural crops such as wheat, maize and certain vegetables. Its effect on beans is unknown.

The same parameters as in the previous trial (chapter 5) applied and the aim was to closely monitor the formation and abscission patterns of flowers and pods as well as the final yield outcome under the influence of the mentioned chemicals, but at different concentration levels.

6.2 RESULTS

6.2.1. Treatment at the four-leaf growth stage

6.2.1.1 Flowers formed and abscised

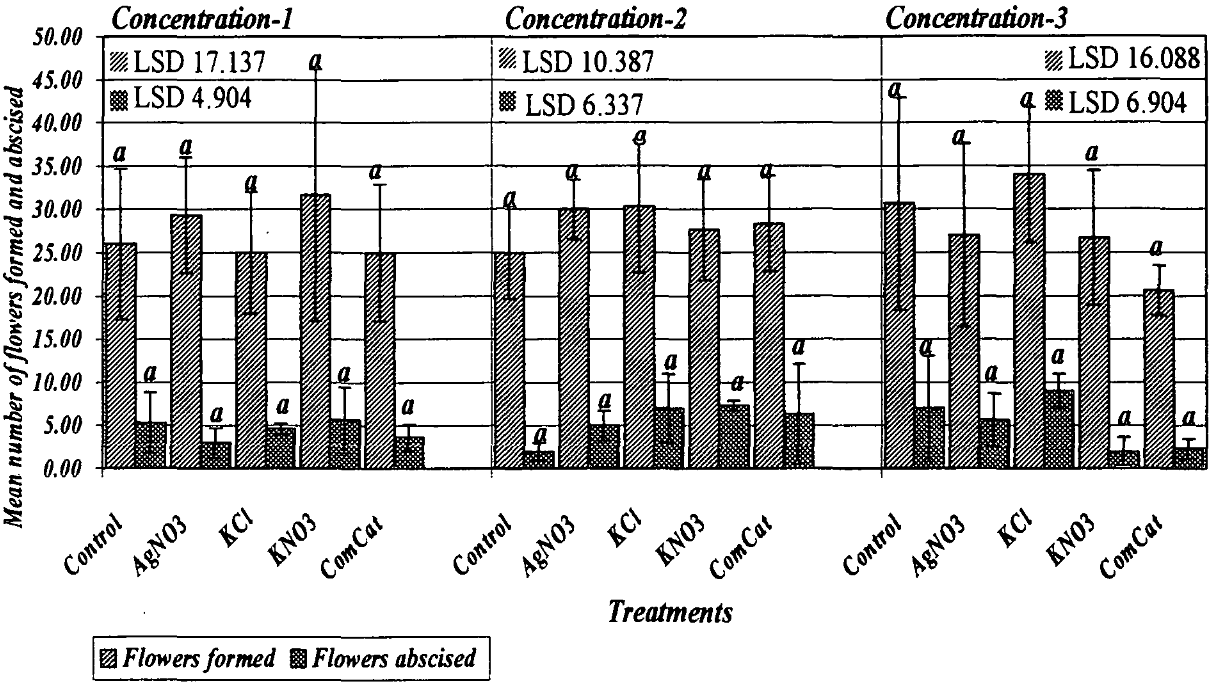

Figure 6.1: Mean total number of flowers per plant formed and abscised during the reproductive phase of *Phaseolus vulgaris* L. cv. Kranskop as influenced by foliar spray treatment with different chemicals at different concentration levels at the four-leaf growth stage. Bars denoted by the same letter do not differ significantly (at the $P<0.05$ level) according to the T test (LSD) procedure.

The silver nitrate treatment at the four leaf stage and at concentration levels one (0.7 mM) and two (1.4 mM) resulted in more flowers forming compared to the control while the opposite was true for concentration level three (2.8 mM) (figure 6.1). Less flowers that abscised after silver treatment with concentration one compared to the control but the opposite was true for concentration 2 while no marked differences were observed after treatment with concentration 3.

Treatment of plants with potassium chloride showed no effect on flower formation at concentration level one (13.4 mM) while treatment at concentration levels two (26.8 mM) and three (53.6 mM) improved flower formation markedly compared to the respective controls (figure 6.1). Flower abscission in plants treated with potassium chloride at concentration level one was similar to that of the control, whereas treatment at concentration levels two and three tended to enhance flower abscission. Plants treated with potassium nitrate showed exactly the opposite tendency than the potassium chloride treated plants regarding flower formation (figure 6.1) with concentration level one (9.8 mM) improving and levels two (19.8 mM) and three (39.6 mM) showing either no effect or decreasing flower formation slightly. There were significantly fewer flowers lost with the potassium nitrate treatment at concentration level three as compared to the control.

Treating plants with ComCat® at concentration levels one (200 mg l^{-1}) and three (800 mg l^{-1}) had a slightly decreasing effect on flower formation, while treatment at level two (400 mg l^{-1}) showed a slight increase compared to the respective controls (figure 6.1). However, treatment with ComCat® at concentration levels one and three resulted in reduced flower abscission while treatment at concentration two enhanced flower abscission compared to the controls.

Based on the analysis of variance (probability level $P<0.05\%$), there were no significant differences in both flower formation and abscission between the respective controls and all the different chemical treatments at the four-leaf stage and for the three concentration levels. Due to the large calculated standard deviations, no clear picture emanated from the treatment with different chemicals at different concentration levels at the four-leaf growth stage regarding flower formation and abscission.

6.2.1.2 Pods formed and abscised

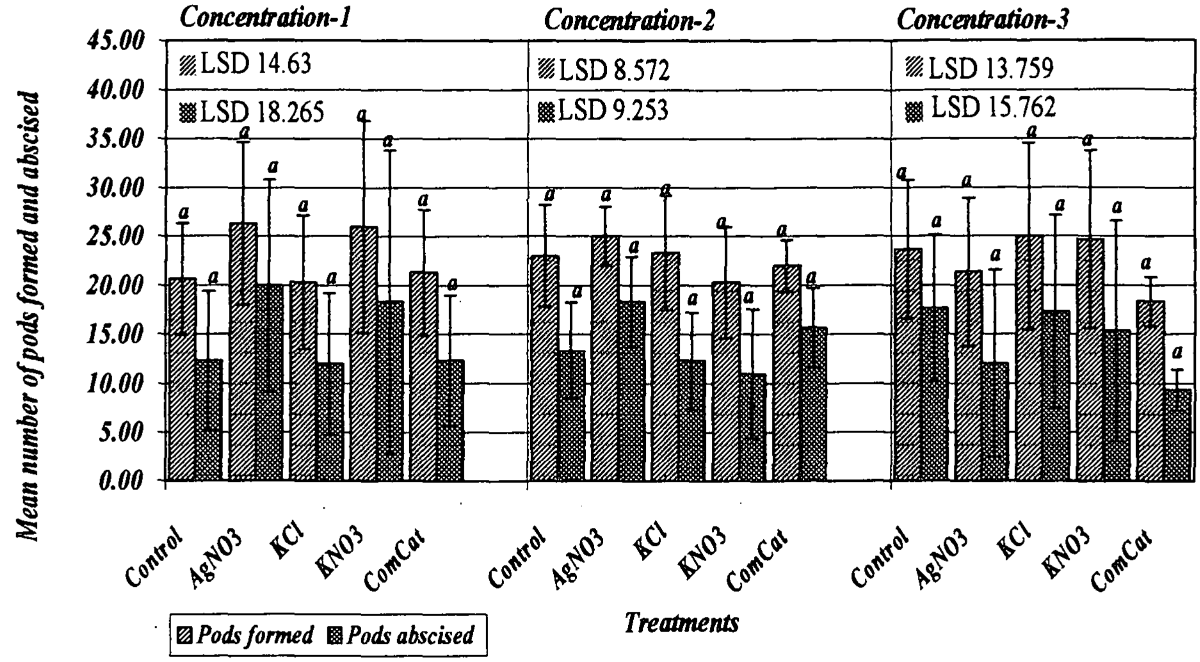

Figure 6.2: Mean total number of pods per plant formed and abscised during the reproductive phase of *Phaseolus vulgaris* L. cv. Kranskop as influenced by foliar spray treatment with different chemicals at different concentration levels at the four-leaf growth stage. Bars denoted by the same letter do not differ significantly (at the $P<0.05$ level) according to the T test (LSD) procedure.

As was the case with flowering, the silver nitrate treatment enhanced pod formation at concentration levels one and two, while reducing pod formation at level three compared to the respective controls (figure 6.2). Pod abscission followed the same pattern as that of pod formation.

Pod formation for plants treated with potassium chloride did not differ from that of the respective controls for all concentration levels (figure 6.2) and this tendency did also apply for pod abscission. However, more pods developed after potassium nitrate treatment at concentration level one, while treatment at level two and three resulted in either similar or a reduced number of pods compared to the respective controls. Treatment with potassium nitrate enhanced pod abscission at concentration level one while treatment at levels two and three decreased pod abscission slightly compared to the controls.

Pod formation in plants treated with ComCat® was similar to the respective controls at concentration levels one and two, while less pods were formed after ComCat® treatment at level three (figure 6.2). There were no marked differences in pod abscission between ComCat® treated plants and the respective controls at concentration levels one and two while treatment at concentration level three was characterized by decreased pod abscission.

Despite the observed differences, the analysis of variance did not reveal any statistically significant differences between the chemical treatments at the four-leaf growth stage and the respective controls in pod formation and abscission for all concentration levels. However, ComCat® treatment at concentration level three showed a marked decrease in pod abscission compared to the control. Pod abscission (figure 6.2) was relatively higher than flower abscission (figure 6.1) for all concentration levels, and for all treatments.

6.2.1.3 Pods that matured at harvest

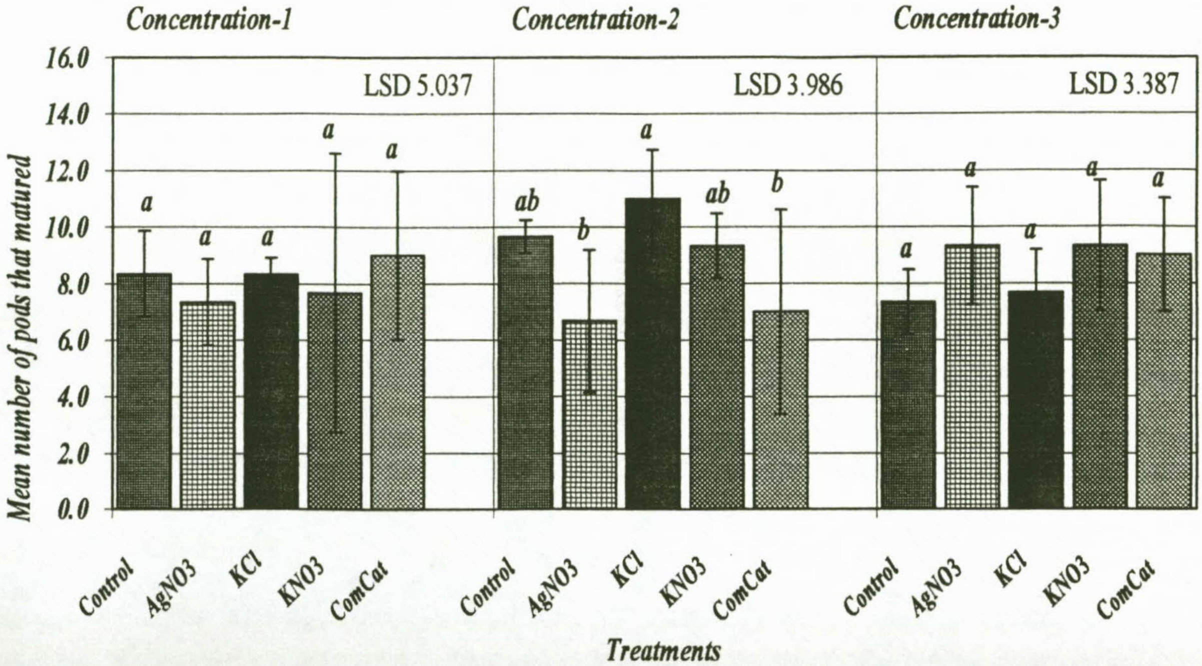

Figure 6.3: Mean total number of pods per plant that matured at harvest for *Phaseolus vulgaris* L. cv. Kranskop as influenced by foliar spray treatment with different chemicals at different concentration levels at the four-leaf growth stage. Bars denoted by the same letter do not differ significantly (at the $P<0.05$ level) according to the T test (LSD) procedure.

Although flower (figure 6.1) and pod formation (figure 6.2) for silver nitrate treated plants at concentration levels one and two were initially high, the number of flowers and pods that abscised ultimately led to a low pod count at harvest compared to the respective controls (figure 6.3). However, treatment at concentration level three produced more mature pods than the control.

No marked differences in the number of pods that reached maturity between plants treated with potassium chloride at concentration levels one and three were observed (figure 6.3), while a slight increase occurred after treatment at concentration level two. Potassium nitrate treatment at concentration levels one and two did not differ from the controls regarding the number of pods that reached maturity but a slight increase was observed after treatment at concentration level three.

ComCat® treatment at concentration levels one and three had a slight increasing effect on the number of pods that reached maturity (figure 6.3), whereas treatment at level two markedly reduced the number of pods as compared to the respective controls. Treatments with all the different chemicals at concentration levels one and three did not reveal statistically significant differences in the number of pods that reached maturity. However, treatment at concentration level two showed a significant decrease in the number of mature pods for both silver nitrate and ComCat® treatments while the increase observed with the potassium chloride treatment was also significant.

6.2.1.4 Mature pod mass at harvest

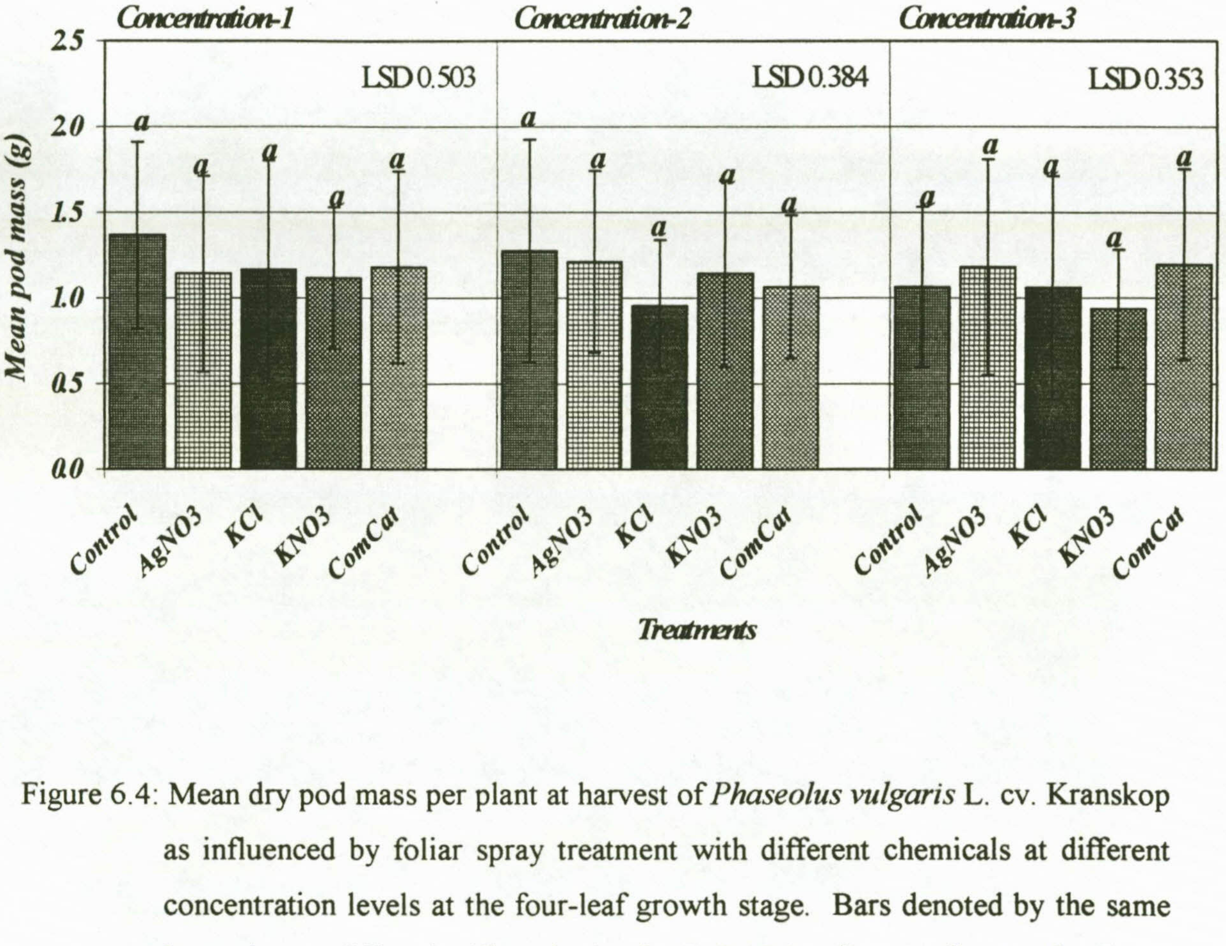

Figure 6.4: Mean dry pod mass per plant at harvest of *Phaseolus vulgaris* L. cv. Kranskop as influenced by foliar spray treatment with different chemicals at different concentration levels at the four-leaf growth stage. Bars denoted by the same letter do not differ significantly (at the $P<0.05$ level) according to the T test (LSD) procedure.

As was the case with the number of mature pods (figure 6.3), the silver nitrate treatment followed the same pattern by reducing the mass of matured pods at concentration levels one and two (figure 6.4) and slightly increasing it at concentration level three.

Although the number of pods that matured after potassium chloride treatment was similar to that of the control (figure 6.3), the mature pod mass was, however, lower than that of the control at concentration level one (figure 6.4). Treatment at concentration level two resulted in more matured pods (figure 6.3) while the pod mass was much lower compared to the control (figure 6.4). The mature pod mass followed the same tendency as that of the number of mature pods for the potassium chloride treatment at concentration level three. Treatment of plants with potassium nitrate, at all concentration levels, did not influence mature pod mass (figure 6.4), not even at level three where there was an initial enhanced number of pods that reached maturity (figure 6.3).

Although more pods that matured after ComCat® treatment at concentration level one and three (figure 6.3) the pod mass did not differ significantly from that of the controls (figure 6.4). However, treatment with ComCat® at level two reduced pod mass, compared to the control, as was the case with the number of matured pods, while treatment at concentration level three improved the pod mass as was the case with the number of pods that matured.

Besides the observed differences, statistical analysis of the data revealed no significant differences between the chemical treatments and the respective controls for the three concentration levels.

6.2.1.5 Seed mass per pod at harvest

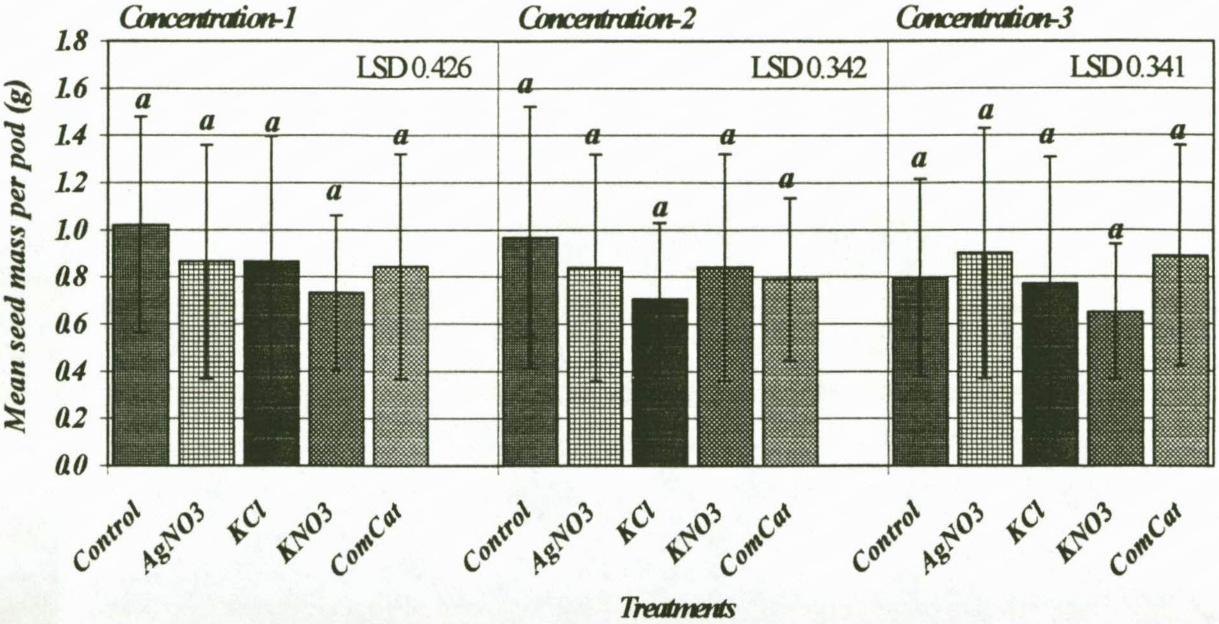

Figure 6.5: Mean seed mass per pod per plant at harvest of *Phaseolus vulgaris* L. cv. Kranskop as influenced by foliar spray treatment with different chemicals at different concentration levels at the four-leaf growth stage. Bars denoted by the same letter do not differ significantly (at the $P<0.05$ level) according to the T test (LSD) procedure.

The seed mass per pod for the controls as well as all the chemical treatments (figure 6.5) and at all concentration levels followed the same trend as was observed for pod mass at harvest (figure 6.4). Moreover, no statistically significant differences were observed in all cases.

6.2.1.6 Seed number per pod at harvest

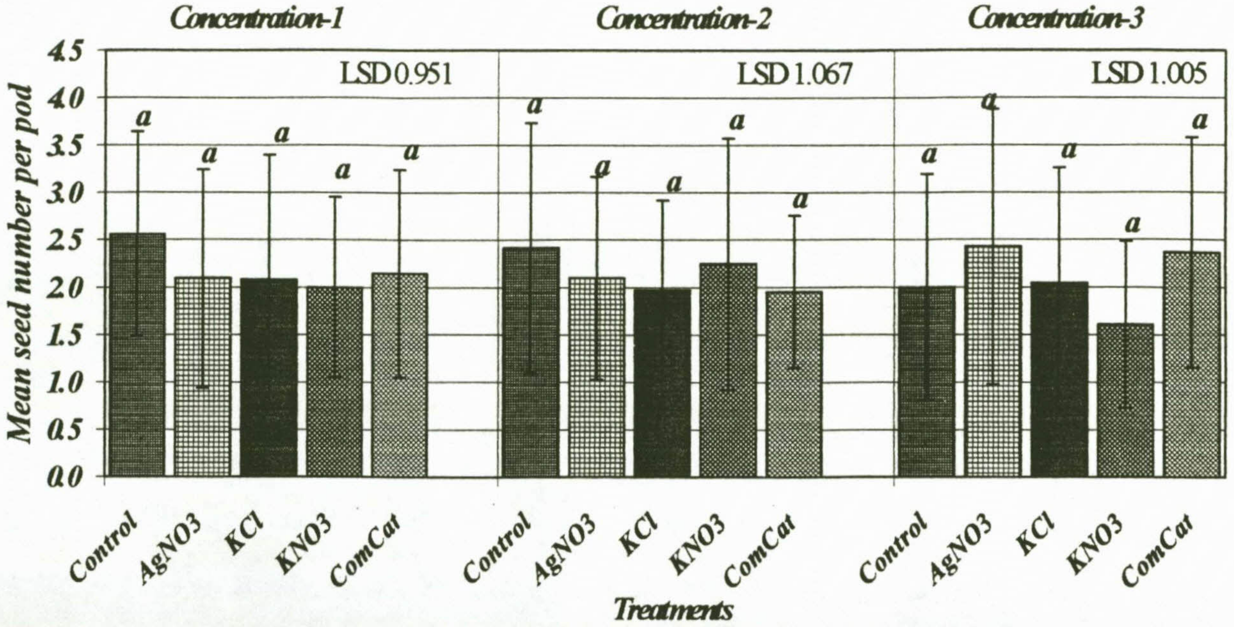

Figure 6.6: Mean seed number per pod per plant at harvest of *Phaseolus vulgaris* L. cv. Kranskop as influenced by foliar spray treatment with different chemicals at different concentration levels at the four-leaf growth stage. Bars denoted by the same letter do not differ significantly (at the $P<0.05$ level) according to the T test (LSD) procedure.

For number of seeds that formed per pod (figure 6.6), exactly the same trend as for mature pod mass (figure 6.4) was observed for at all treatments and all concentration levels. The observed differences were again not statistically significant.

6.2.1.7 Total yield in kilograms per hectare

Table 6.1: Total yield of *Phaseolus vulgaris* L. cv. Kranskop in kilograms per hectare as influenced by foliar spray treatment with different chemicals and at different concentration levels at the four-leaf growth stage.

Treatment	Concentration-1	Concentration-2	Concentration-3
Control	1020.36 ± 263.98a	1121.96 ± 57.12a	701.36 ± 387.47a
Silver nitrate	761.04 ± 455.75a	670.64 ± 312.78a	1010.52 ± 347.84a
Potassium chloride	761.68 ± 524.52a	931.36 ± 240.54a	709.32 ± 205.92a
Potassium nitrate	673.72 ± 380.39a	942.52 ± 422.92a	731.00 ± 218.04a
ComCat®	913.00 ± 156.56a	663.00 ± 370.57a	961.60 ± 240.61a

Means followed by the same letter did not differ significantly at the P<0.05 level according to the T test following the LSD procedure.

All chemical treatments at the four-leaf growth stage and at concentration levels one and two tended to reduce the total yield outcome compared to the respective controls (table 6.1). On the other hand, all chemical treatments at concentration level three tended to increase the total yield outcome albeit not significantly in the case of the potassium chloride and potassium nitrate treatments, compared to the respective controls. Both the silver nitrate (44%) and ComCat® (37%) treatments increased the total yield markedly at the third concentration level. However, the yield measured for the control at this concentration level was substantially lower than what was measured for the other two controls. If the means for the three controls (947.3 ± 178.9-kg ha^{-1}) is considered, both the silver nitrate and ComCat® treatments still outperformed the control, albeit less pronounced.

6.2.2 Treatment at the eight leaf growth stage

6.2.2.1 Flowers formed and abscised

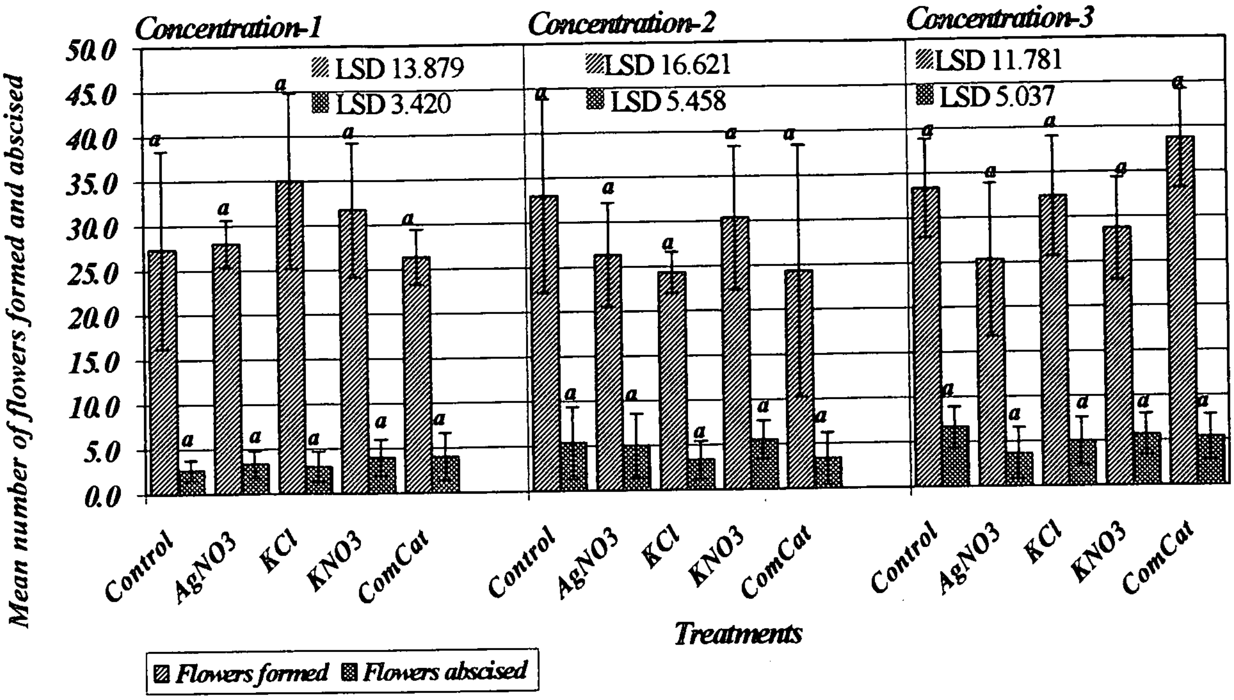

Figure 6.7: Mean total number of flowers per plant that formed and abscised during the reproductive phase of *Phaseolus vulgaris L.* cv. Kranskop as influenced by foliar spray treatment with different chemicals at different concentration levels at the eight-leaf growth stage. Bars denoted by the same letter do not differ significantly (at the $P<0.05$ level) according to the T test (LSD) procedure.

No clear difference was observed in flower formation after the plants were treated with the silver salt at the eight-leaf stage with concentration level one (0.7 mM) as compared to the control (figure 6.7). However, flower formation was negatively affected after treatment with both concentrations two (1.4 mM) and three (2.8 mM). There were no marked differences in the number of flowers that abscised between the silver treatment and the control at concentration levels one and two, while treatment at level three, reduced flower abscission.

Plants treated with potassium chloride at the eight-leaf growth stage and with concentration one (13.4 mM) showed a marked increase in the number of flowers that formed while treatment at concentration levels two (26.8 mM) and three (53.6 mM) rather had the opposite effect (figure 6.7). Flower abscission in plants treated with potassium chloride at concentration one was similar to that of the control whereas treatment at levels two and three slightly reduced flower loss. Both flower formation and abscission responded to the potassium nitrate treatment at all concentration levels in a similar way as for potassium chloride (figure 6.7).

Treating plants with ComCat® at level one (0.20 mg l^{-1}) did not show any difference from the control in flower formation whereas treatment at concentration level two (0.40 mg l^{-1}) resulted in less flowers formed while treatment at concentration level three (0.80 mg l^{-1}) improved flower formation markedly (figure 6.7). Plants treated with ComCat® at concentration one slightly induced flower abscission while treatment at concentration levels two and three resulted in decreased flower abscission.

There were no statistically significant differences in both flower formation and abscission between the respective controls and the chemical treatments at the eight-leaf stage and for the three concentration levels. However, the ComCat® treatment enhanced flower formation at concentration level three and tended to decrease flower abscission.

6.2.2.2 Pods formed and abscised

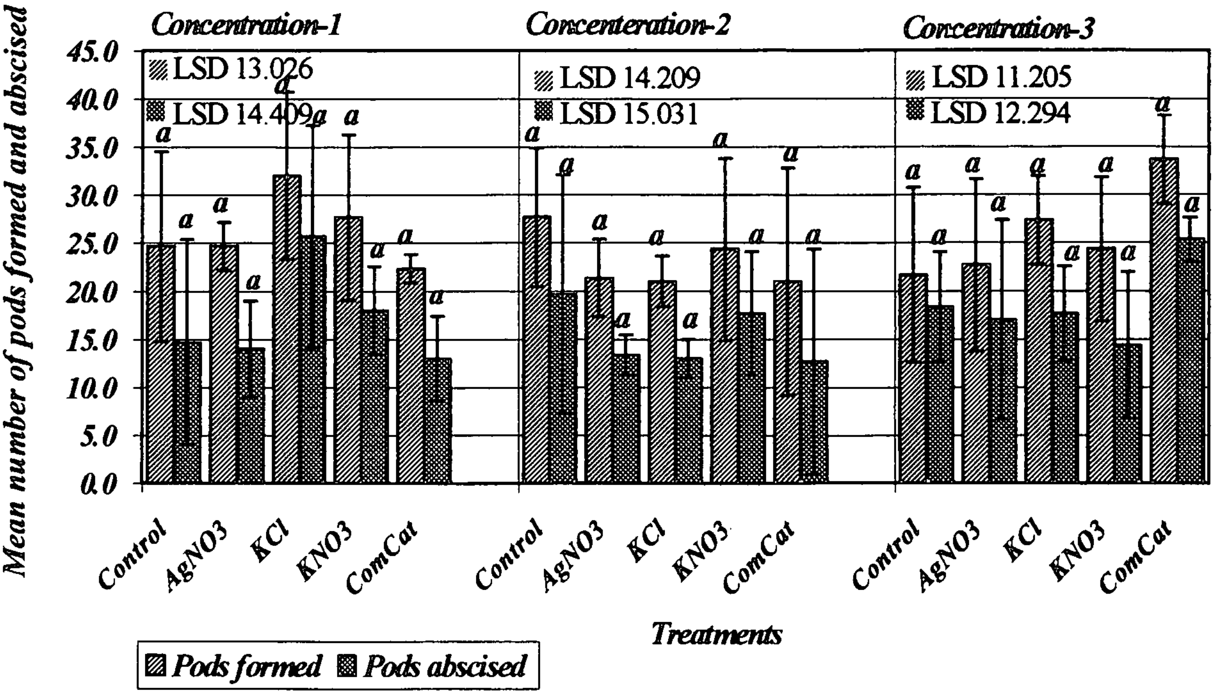

Figure 6.8: Mean total number of pods per plant that formed and abscised during the reproductive phase of *Phaseolus vulgaris* L. cv. Kranskop as influenced by foliar spray treatment with different chemicals at different concentration levels at the eight-leaf growth stage. Bars denoted by the same letter do not differ significantly (at the $P<0.05$ level) according to the T test (LSD) procedure.

The pattern of pod formation (figure 6.8), at all concentration levels, followed a similar trend to that of flower formation (figure 6.7) with both potassium salts outperforming the control at concentration level one and the ComCat® treatment following the same trend at concentration level three. It is clear from figure 6.8 that the two potassium treatments resulted in increased pod abscission at concentration level one having a decreasing effect at concentration levels two and three. The ComCat® treatments, however, had the opposite effect by increasing pod abscission at concentration level three.

The observed differences in pod formation and abscission (figure 6.8) between all treatments and at all concentration levels were not statistically significant at the $P<0.05$ level. However, both potassium chloride, at concentration level one (+28.5%), and

ComCat® treatments, at concentration level three (+50%), showed marked increases in pod formation. Unfortunately, this was also true for enhanced abscission for potassium chloride (66%) and for ComCat® (38%).

6.2.2.3 Pods that matured at harvest

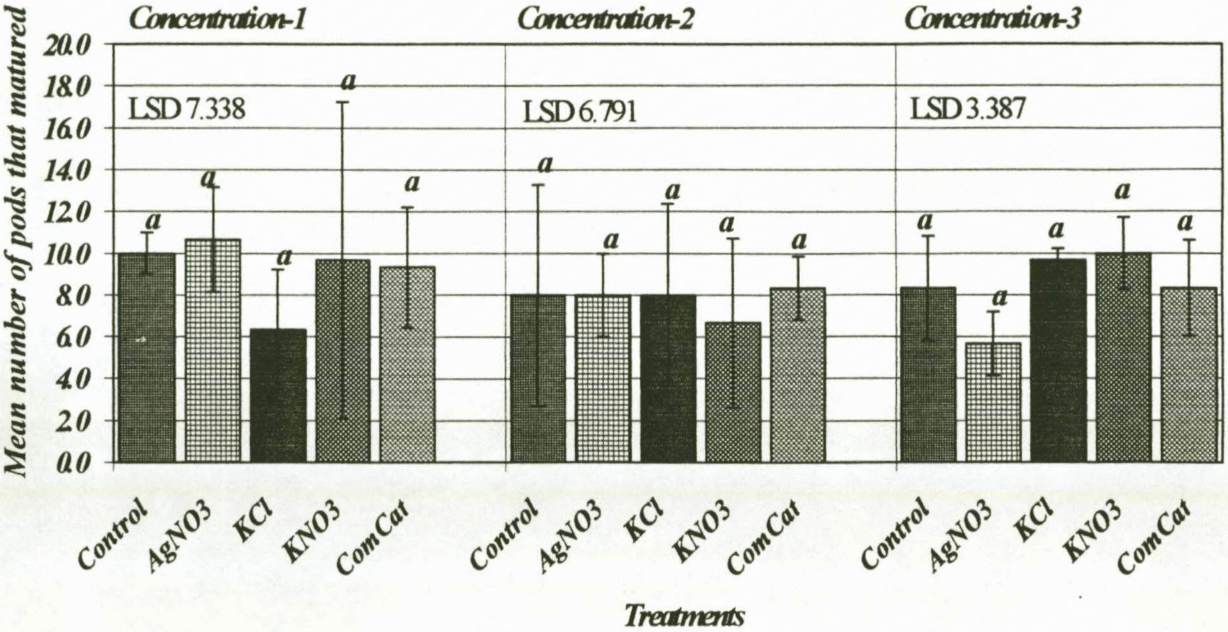

Figure 6.9: Mean total number of pods per plant that matured at harvest for *Phaseolus vulgaris* L. cv. Kranskop as influenced by foliar spray treatment with different chemicals at different concentration levels at the eight-leaf growth stage. Bars denoted by the same letter do not differ significantly (at the $P<0.05$ level) according to the T test (LSD) procedure.

Except for the decrease caused by potassium chloride treatment at level one, no marked differences were observed between the control and the chemical treatments for the number of pods that reached maturity at concentrations one and two for all the treatments (figure 6.9). Plants treated with potassium chloride and potassium nitrate at concentration level three slightly improved the number of pods that reached maturity while the opposite was true for the silver nitrate treatment. ComCat® had no effect at concentration 3.

However, treatment with all the different chemicals at all concentration levels did not reveal any statistically significant differences in the number of pods that reached maturity.

6.2.2.4 Mature pod mass at harvest

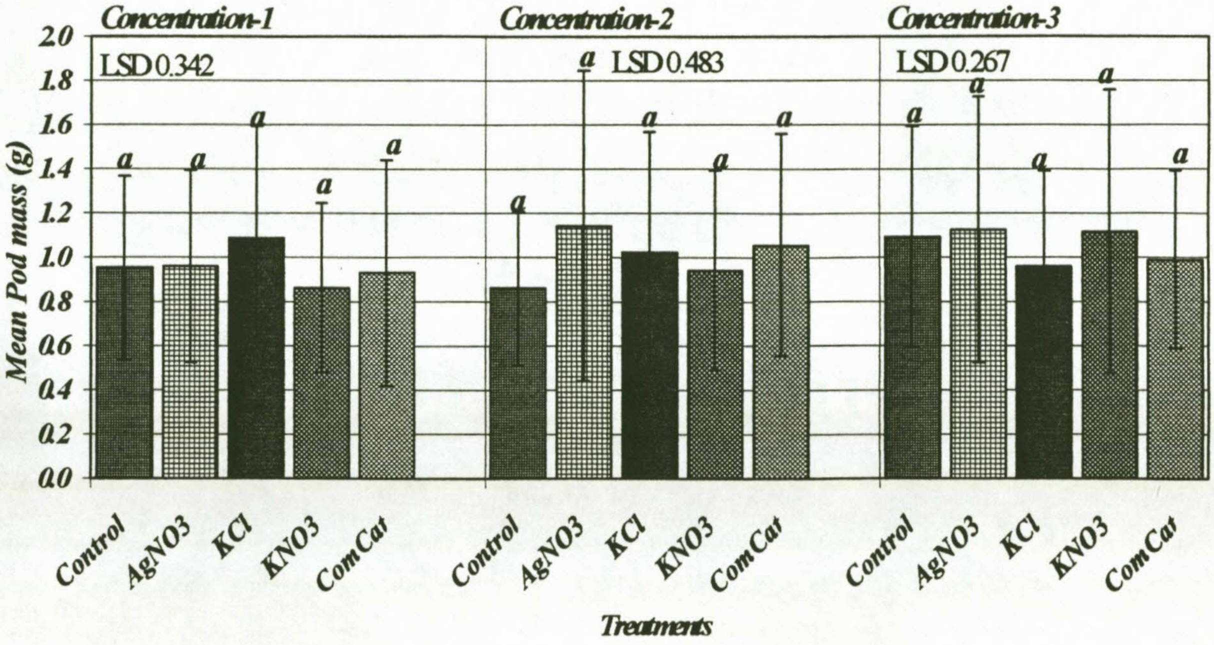

Figure 6.10: Mean pod mass per plant at harvest of *Phaseolus vulgaris* L. cv. Kranskop as influenced by foliar spray treatment with different chemicals at different concentration levels at the eight leaf growth stage. Bars denoted by the same letter do not differ significantly (at the P<0.05 level) according to the T test (LSD) procedure.

The mean pod mass of plants treated with silver nitrate at levels one and three was not different from that of the respective controls, while treatment at level two increased the pod mass by 27% (figure 6.10). Treatment with potassium chloride at levels one (22%) and two (19%) improved pod mass markedly while the opposite was true for treatment at level three, as compared to the controls. Treating plants with potassium nitrate did not show clear differences in pod mass from the respective controls and at all concentrations. Treatment with ComCat® also did not show clear differences in pod mass after treatment at concentration levels one and three, but slightly increased (21%) pod mass at concentration level 2.

Despite the observed differences, the statistical analysis did not reveal any significant differences between the chemical treatments and the respective controls for mature pod mass at all concentration levels.

6.2.2.5 Seed mass per pod at harvest

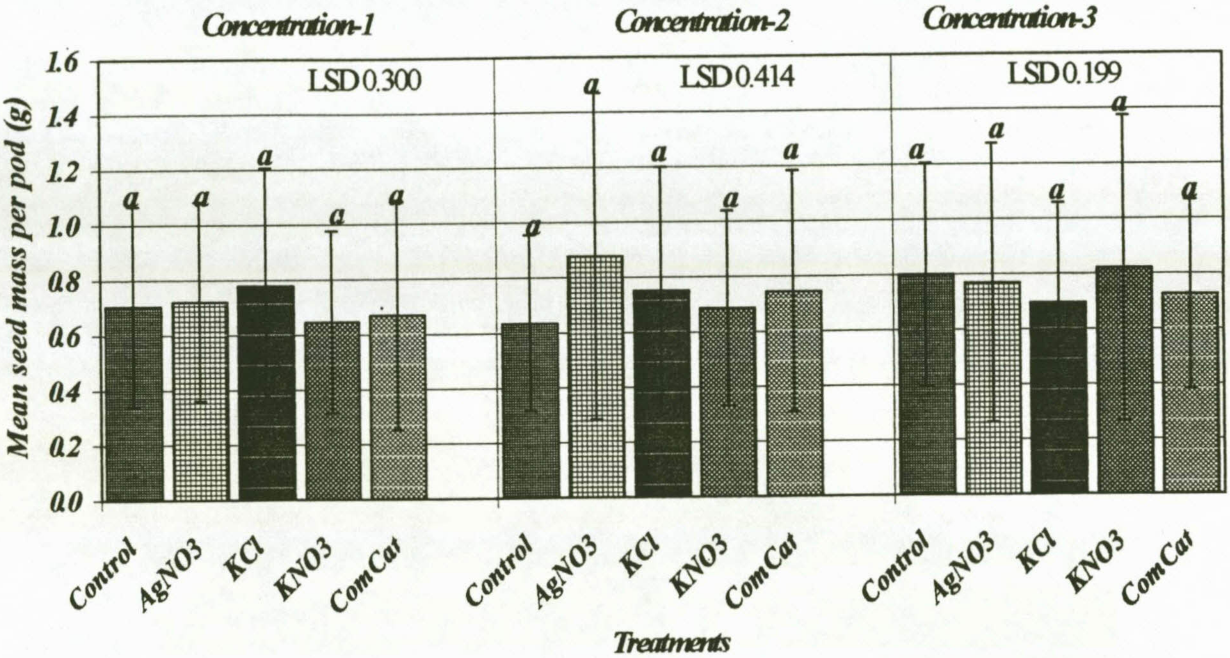

Figure 6.11: Mean seed mass per pod per plant at harvest of *Phaseolus vulgaris* L. cv. Kranskop as influenced by foliar spray treatment with different chemicals at different concentration levels at the eight-leaf growth stage. Bars denoted by the same letter do not differ significantly (at the $P<0.05$ level) according to the T test (LSD) procedure.

The seed mass for the chemical treatments and the respective controls at all levels (figure 6.11) followed a similar pattern as was observed for mature pod mass (figure.6.10). However, the observed differences were not statistically significant.

6.2.2.6 Seed number per pod at harvest

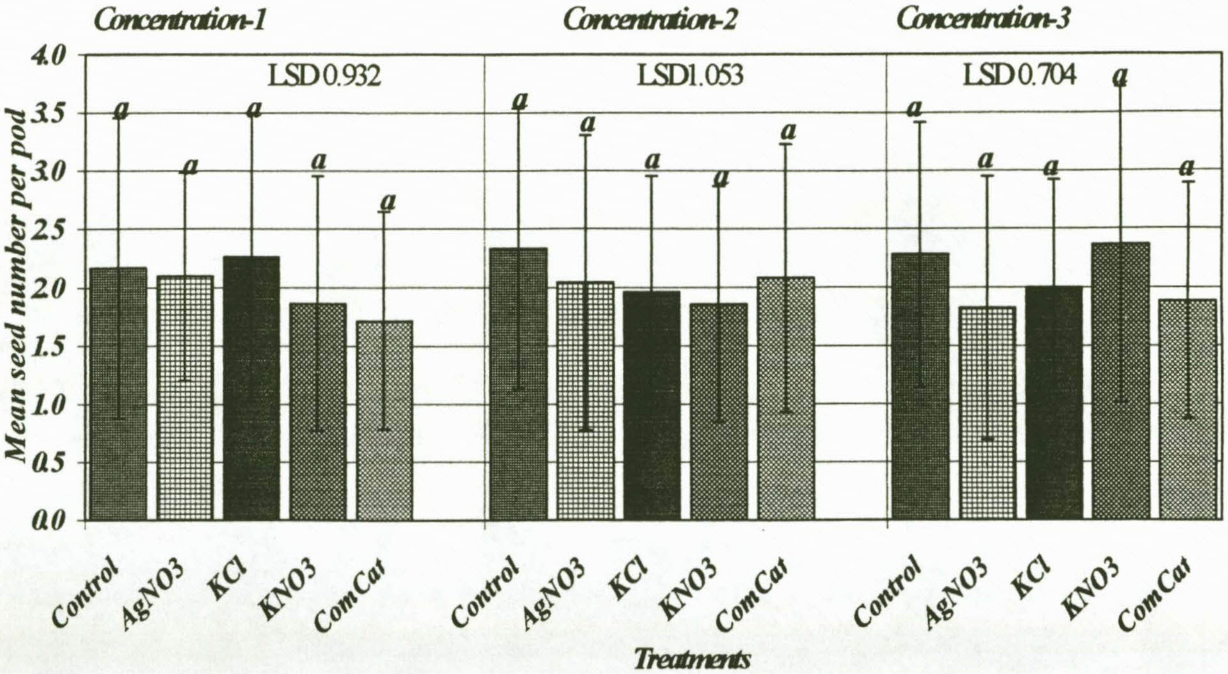

Figure 6.12: Mean seed number per pod per plant at harvest of *Phaseolus vulgaris* L. cv. Kranskop as influenced by foliar spray treatment with different chemicals at different concentration levels at the eight-leaf growth stage. Bars denoted by the same letter do not differ significantly (at the $P<0.05$ level) according to the T test (LSD) procedure.

None of the chemical treatments improved the number of seeds per pod at all concentration levels when compared to the respective controls (figure 6.12). This was statistically confirmed by the analysis of variance.

6.2.2.7 Total yield in kilograms per hectare

Table 6.2: Total yield of *Phaseolus vulgaris* L. cv. Kranskop in kilograms per hectare as influenced by foliar spray treatment with different chemicals and at different concentration levels at the eight leaf growth stage

Treatment	Concentration-1	Concentration-2	Concentration-3
Control	844.64 ± 193.02a	610.48 ± 466.95a	799.64 ± 192.00a
Silver nitrate	884.08 ± 303.91a	842.32 ± 48.49a	523.00 ± 215.48a
Potassium chloride	591.36 ± 409.29a	672.16 ± 271.08a	806.32 ± 126.97a
Potassium nitrate	750.52 ± 599.69a	525.36 ± 354.55a	985.32 ± 169.66a
ComCat®	749.360 ± 129.33a	744.80 ± 172.33a	724.76 ± 258.22a

Means followed by the same letter did not differ significantly at the P<0.05 level according to the T test following the LSD procedure

The silver nitrate treatment at concentration level one, and all the chemical treatments except the potassium nitrate treatment at level two, tended to increase the total bean yield, albeit not statistically significant, as compared to the respective controls (table 6.2). Moreover, treatment with both potassium chloride (9%) and potassium nitrate (23%) at concentration level three tended to increase the total yield outcome as compared to the controls. The ComCat® treatment at concentration level-2 also had a substantial increasing effect on the total yield (22%).

6.2.3 Treatment at the twelve leaf growth stage

6.2.3.1 Flowers formed and abscised

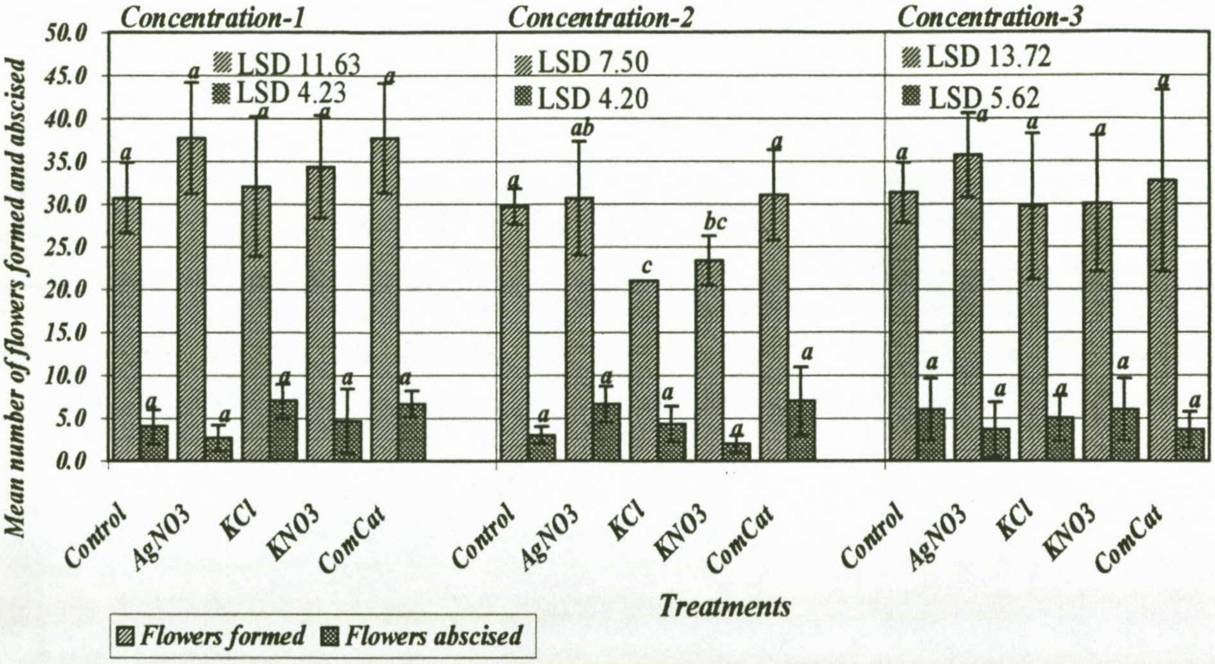

Figure 6.13: Mean total number of flowers per plant that formed and abscised during the reproductive phase of *Phaseolus vulgaris* L. cv. Kranskop as influenced by foliar spray treatment with different chemicals at different concentration levels at the twelve-leaf growth stage. Bars denoted by the same letter do not differ significantly (at the P<0.05 level) according to the T test (LSD) procedure.

The number of flowers that formed after treating plants with silver nitrate at the twelve leaf stage showed a marked increase compared to the respective controls and other chemical treatments at all concentration levels (07 mM, 1.4 mM, 2.8 mM) (figure 6.13). Moreover, the silver treatment did not induce flower abscission except at concentration level two.

No clear differences in flower formation were observed between potassium chloride treated plants and the controls at concentration levels one (13.4 mM) and three (53.6 mM), but treatment at concentration level two (26.8 mM) resulted in less flowers formed (figure 6.13). Treating plants with potassium chloride at concentration levels one and two tended to induce flower abscission compared to the controls, while the opposite was true for treatment at concentration level three. Treating plants with potassium nitrate at concentration level one (9.8 mM) induced flower formation while treatment at levels two (19.8 mM) and level three (39.6 mM) had a reducing effect (figure 6.13). Flower abscission did not differ markedly between the chemical treatments and the respective controls and at all concentration levels.

Flower formation was induced markedly by the ComCat® treatment at concentration level one (200-mg l^{-1}) with no clear differences at levels two (400-mg l^{-1}) and three (800 mg l^{-1}) as compared to the respective controls (figure 6.13). However, a marked increase in flower abscission from treating plants with ComCat® at concentration levels one and two was observed with the opposite pertaining to the level 3 treatment.

Although the silver nitrate treatment at levels one and three, and the ComCat® treatment at level one, seemed to have improved flower formation, the observed differences between the chemical treatments and the respective controls, were not statistically significant. At level two, both potassium salts decreased flower formation significantly.

Flower abscission was not influenced significantly by all chemical treatments and at all concentration levels, compared to the respective controls. However, though not significantly, potassium chloride and ComCat® treatments at level one, together with silver nitrate and ComCat® treatments at level two, enhanced flower abscission.

6.2.3.2 Pods formed and abscised

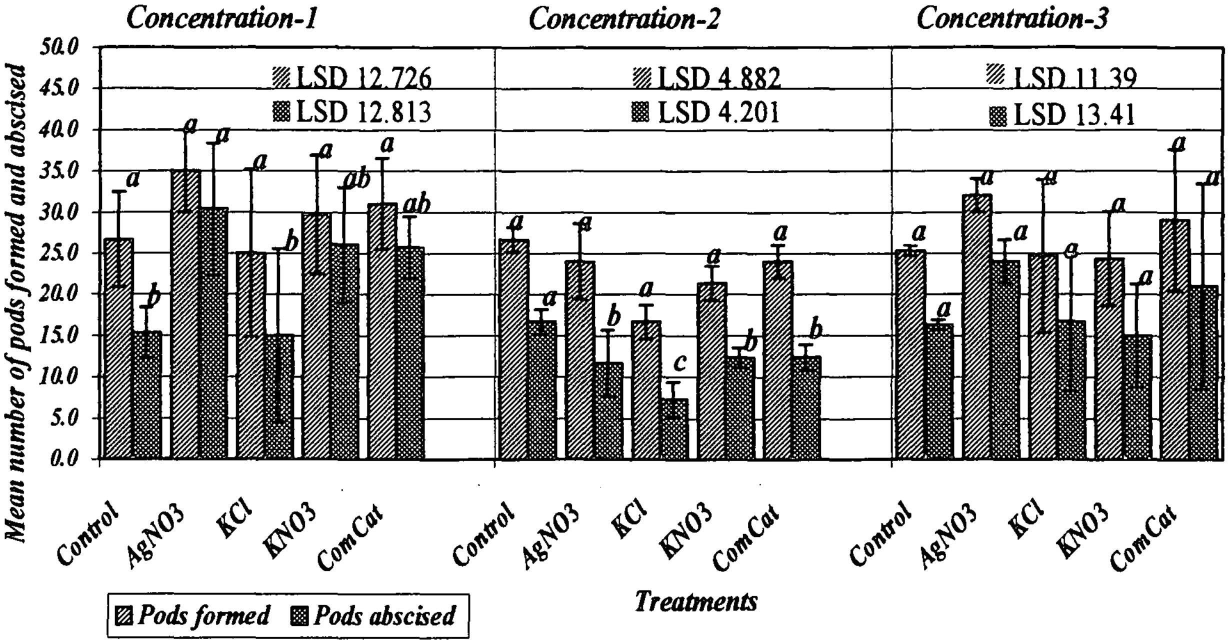

Figure 6.14: Mean total number of pods per plant that formed and abscised during the reproductive phase of *Phaseolus vulgaris* L. cv. Kranskop as influenced by foliar spray treatment with different chemicals at different concentration levels at the twelve-leaf growth stage. Bars denoted by the same letter do not differ significantly (at the P<0.05 level) according to the T test (LSD) procedure.

Pod formation (figure.6.14) in a way followed a similar trend to that of flower formation (figure.6.13) in as much as the silver nitrate, potassium nitrate and ComCat® treatments tended to induce pod formation at concentration level-1, while all treatments followed the same pattern as for flower formation at levels 2 and 3. However, pod abscission was significantly higher than flower abscission for the respective controls and all treatments at all concentration levels, with the nitrate salts and ComCat® seemingly enhancing pod abscission especially after treatment at concentration levels one and three. All treatments tended to reduce pod formation at concentration level-2 and this was especially significant in the case of the potassium salts. However, the potassium salts as well as silver nitrate and ComCat® reduced pod abscission markedly at this concentration level.

Statistical analysis, however, revealed that only the mentioned differences in pod abscission at concentration level 1 and 2 were significant whereas the observed differences in enhanced pod formation were not at all levels.

Comparing the different chemical treatments and the respective controls, it was observed that the silver treatment at concentration levels one and two respectively significantly enhanced pod abscission. No significant differences in pod abscission were observed between all of treatments and the respective controls at concentration three.

6.2.3.3 Pods that matured at harvest

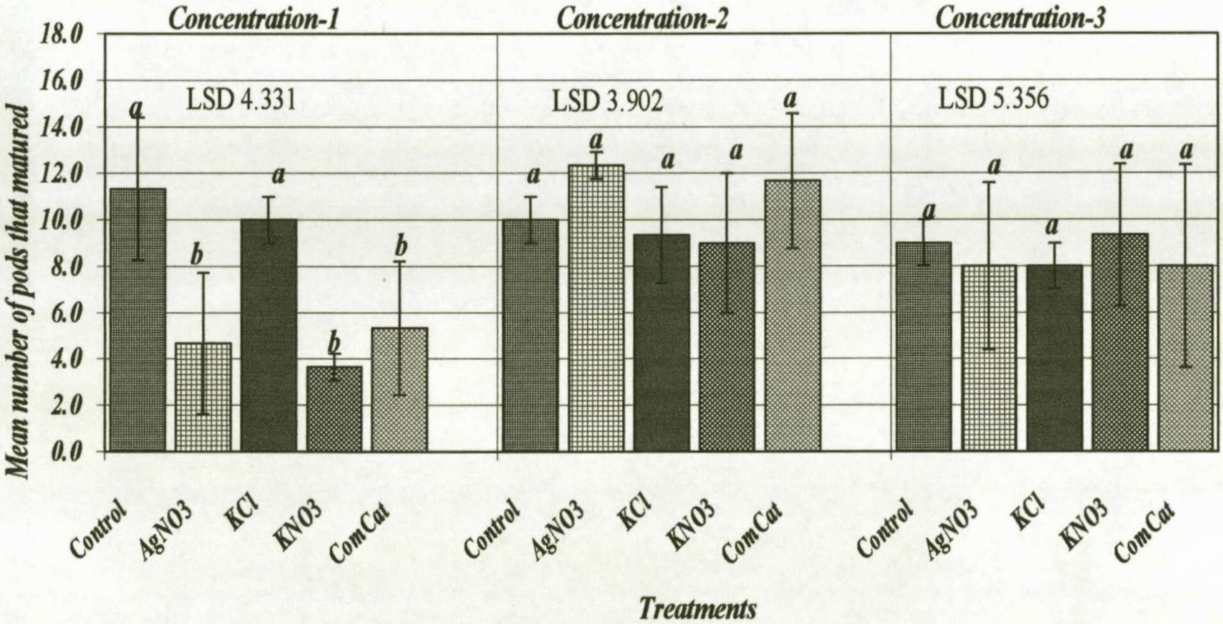

Figure 6.15: Mean total number of pods per plant that matured at harvest of *Phaseolus vulgaris* L. cv. Kranskop as influenced by foliar spray treatment with different chemicals at different concentration levels at the twelve-leaf growth stage. Bars denoted by the same letter do not differ significantly (at the $P<0.05$ level) according to the T test (LSD) procedure.

Since marked increases in pod abscission, after treatment with silver nitrate, potassium nitrate and ComCat®, were observed at concentration level one (figure 6.14), it could be expected that a corresponding low number of pods would reach maturity for these treatments and this was the case (figure 6.15). Treatment with potassium chloride at concentration level one also resulted in a slightly decreased number of mature pods compared to the control, but the negative effect was less pronounced than that observed for the other treatments. On the other hand, more mature pods were harvested after treatment with silver nitrate and ComCat® at concentration two, probably due to reduced pod abscission initially. Treatment of plants with both potassium salts at concentration level two tended to reduce the number of mature pods as compared to the control. Treatment at concentration level three revealed no pronounced differences in the number of pods that reached maturity for all the different treatments as compared to the control.

Statistical analysis indicated that only the mentioned differences in mature pods at concentration level one were significant, whereas the observed differences for treatment at concentration levels two and three were not significant.

6.2.3.4 Mature pod mass at harvest

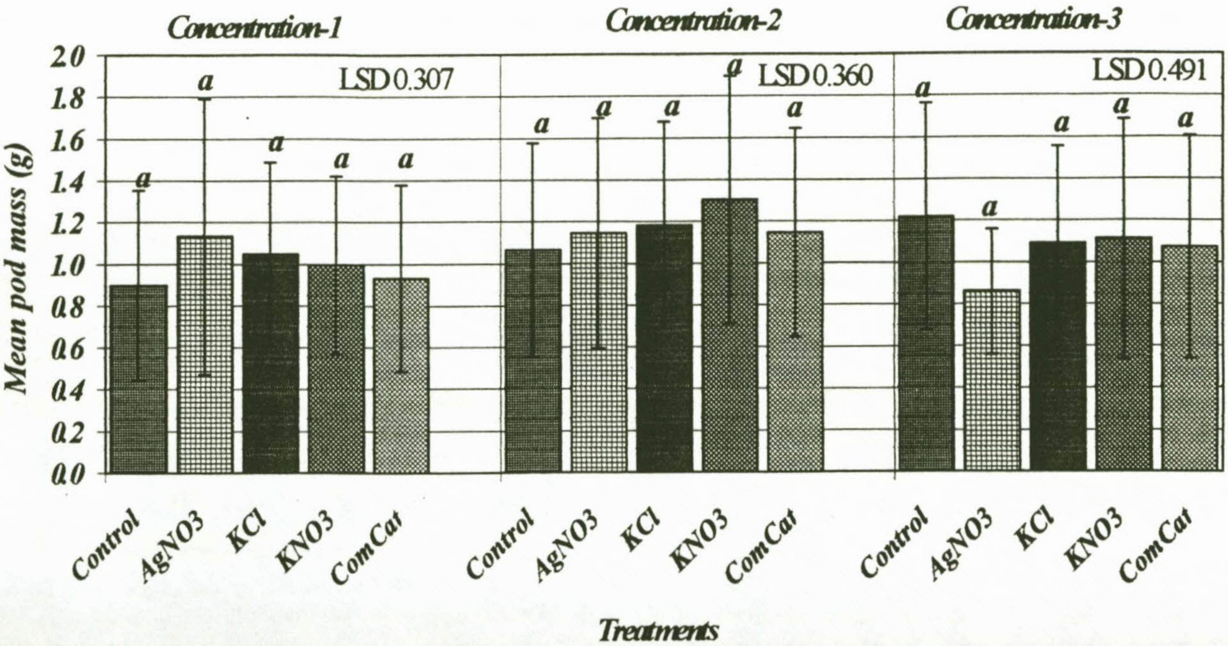

Figure 6.16: Mean pod mass per plant at harvest of *Phaseolus vulgaris* L. cv. Kranskop as influenced by foliar spray treatment with different chemicals at different concentration levels at the twelve leaf growth stage. Bars denoted by the same letter do not differ significantly (at the P<0.05 level) according to the T test (LSD) procedure.

It is interesting to note that despite the differences on both flower and pod abscission observed with the different treatments, all chemicals tended to increase pod mass at concentration levels 1 and 2 while reducing it at concentration level 3 (figure 6.16). Statistically these differences were, however, not significant.

6.2.3.5 Seed mass per pod at harvest

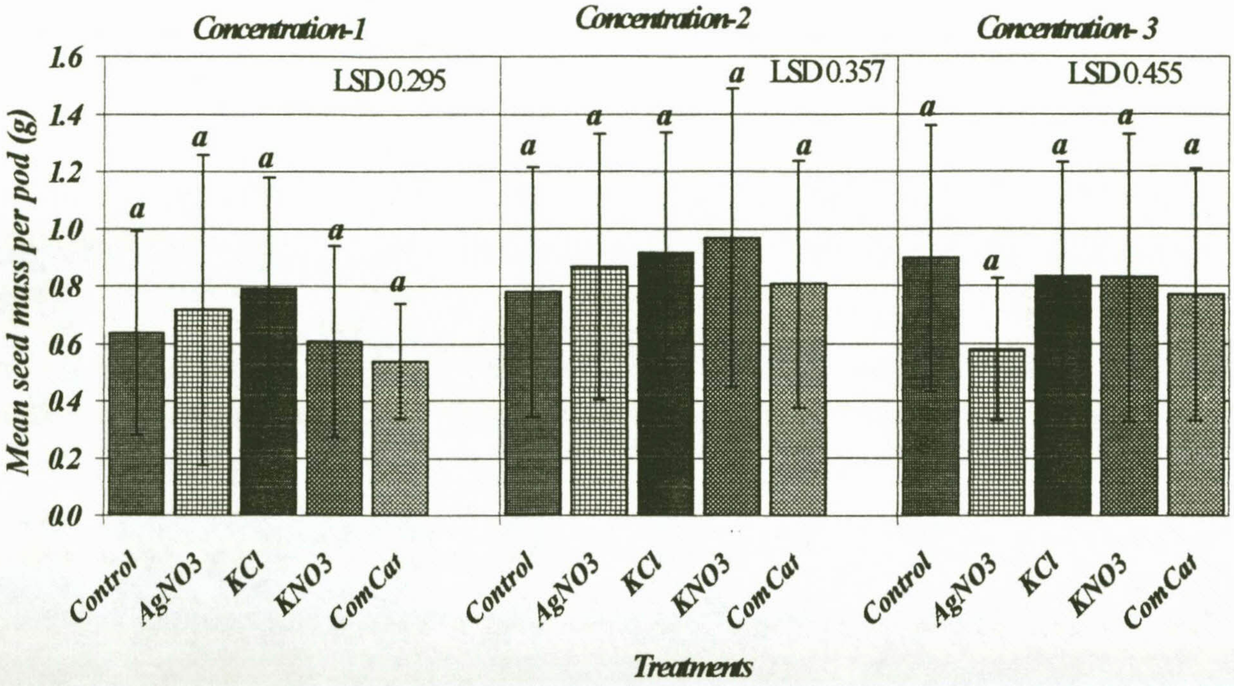

Figure 6.17: Mean seed mass per pod per plant at harvest of *Phaseolus vulgaris* L. cv. Kranskop as influenced by foliar spray treatment with different chemicals at different concentration levels at the twelve-leaf growth stage. Bars denoted by the same letter do not differ significantly (at the $P<0.05$ level) according to the T test (LSD) procedure.

Except for potassium nitrate and ComCat®, which tended to reduce the seed mass per pod after treatment at concentration level 1, all chemicals increased the seed mass at concentration level 2, as was the case with pod mass (figure 6.17), albeit not statistically significant.

6.2.3.6 Seed number per pod at harvest

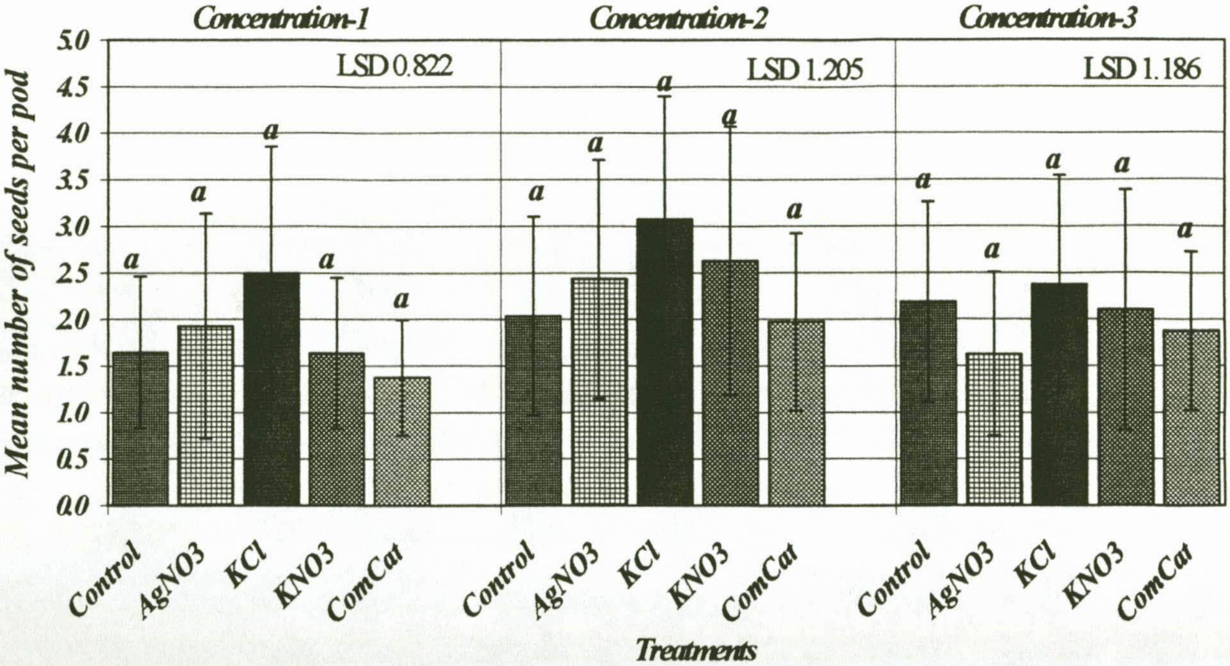

Figure 6.18: Mean seed number per pod per plant at harvest of *Phaseolus vulgaris* L. cv. Kranskop as influenced by foliar spray treatment with different chemicals at different concentration levels at the twelve-leaf growth stage. Bars denoted by the same letter do not differ significantly (at the P<0.05 level) according to the T test (LSD) procedure.

The number of seeds counted per pod (figure 6.18) followed exactly the same trend as for seed mass (figure 6.17) with potassium chloride clearly inducing seed formation at all concentration levels as compared to the respective controls and all other treatments. However, again statistical analysis revealed no significant differences.

6.2.3.7 Total yield in kilograms per hectare

Table 6.3: Total yield of *Phaseolus vulgaris L.* cv. Kranskop in kilograms per hectare as influenced by foliar spray treatment with different chemicals and at different concentration levels at the twelve leaf growth stage.

Treatment	Concentration-1	Concentration-2	Concentration-3
Control	865.68 ± 162.80a	935.00 ± 114.16a	969.44 ± 236.61a
Silver nitrate	402.00 ± 384.80b	1284.00 ± 90.27a	556.20 ± 237.93a
Potassium chloride	948.36 ± 228.06a	1026.24 ± 261.44a	800.36 ± 166.79a
Potassium nitrate	266.96 ± 23.272b	1045.96 ± 760.63a	930.00 ± 663.97a
ComCat®	344.76 ± 144.69b	1128.92 ± 269.34a	740.80 ± 463.00a

Means followed by the same letter did not differ significantly at the $P<0.05$ level according to the T test following the LSD procedure

The most pronounced yield increase (table 6.3) after treatment at the twelve-leaf growth stage was observed for silver nitrate at concentration two (37%), as compared to the untreated controls. This was followed by the ComCat® treatment (concentration two), which increased the final yield by 21%, and potassium chloride (9.6% yield improvement at concentration level one and 9.7% at concentration level two). At concentration level three, all chemical treatments at the twelve-leaf growth stage failed to increase the final yield.

6.3 DISCUSSION

Treatment with different chemicals at different concentration levels and at three growth stages did not statistically show much variance in flower formation. This was despite the differences observed when raw data were compared. However, treatment with ComCat® at the twelve-leaf growth stage improved flower formation substantially (24.6%) at concentration level two. The prominence shown by this treatment, in terms of flower formation, was also considered statistically significant by the LSD procedure at the $P<0.05$ level. The ComCat® treatment also increased the final yield by 21% on a kilogram per hectare basis, though the difference was again not considered statistically significant by the LSD procedure at the $P<0.05$ level. The "harshness" of the statistical program comes to the fore when considering a yield increase of 21%, which in economical terms can mount to an increased profit of up to R840.00 per hectare. Moreover, the same relatively high yield increase was observed for ComCat® treatment at the eight-leaf growth stage (22%) and at concentration level two.

Treatment with silver nitrate (37%) at the twelve-leaf growth stage with concentration two increased the final yield even more substantially than did ComCat®. Both potassium chloride (12%) and potassium nitrate (12%) improved the final yield, albeit less pronounced, after treatment at the twelve-leaf stage and at concentration level two. The latter was despite the relatively low flower formation under the influence of the potassium salts observed initially.

Yield increases were also observed for silver salt treatment at the eight-leaf growth stage for concentration levels one (5%) and two (38%) respectively. The potassium salt treatments at the eight-leaf stage also increased the final yield (9% for potassium chloride and 23% for potassium nitrate) at concentration level three). Silver nitrate (44%) and ComCat® (37%) treatments at the four-leaf stage also substantially increased the final yield.

It has been reported that, although many large seeded legumes flower profusely, seed and pod yields are severely restricted by a high rate of flower and pod abscission (Hansen and Shibles, 1978; Mauk *et al.*, 1987; Weis & Webster, 1990). In this study, however, it was shown that none of the chemical treatments clearly enhanced flower formation nor restricted either flower or pod abscission. Nevertheless, relative yield increases were observed indicating that other factors (e.g. translocation of photosynthate) might have affected the seed biomass and hence final yields.

Flowering could be dependent on the genetic ability of the cultivar, environmental conditions and to some extent chemical manipulation such as fertilization. Work with both temperate and tropical grain legumes showed that a high proportion of flowers fail to produce harvestable pods (Subhadrabandhu *et al.*, 1978). For example, in temperate legumes, losses of flowers accounted to about 52-76% in *Phaseolus vulgaris* L. However, this study indicated that yield reductions in untreated plants were the result of increased pod abscission rather than flower abscission, especially under green house conditions. This was consistent with the results of Subhadrabandhu *et al.* (1978) who showed increased flower abscission in field cultivated beans as compared to green house cultivated ones. They concluded that the higher flower abscission rate under field conditions, as opposed to green house conditions, could be attributed to greater variations in the environmental conditions such as moisture stress, heat, wind, pests and diseases. Already in 1969, Kambal reported on the environmental effect.

Even though the observed differences in pod formation between the different chemical treatments were mostly not statistically significant, interpretation of the raw data showed that some treatments (silver and potassium salts as well as ComCat® resulted in marked increased in pod formation when compared to the respective controls. On average, more pods formed or remained on the plants after these treatments with respect to the total number of flowers that formed or abscised initially.

Despite the higher retention of pods under the influence of the above-mentioned chemical treatments, more pods were still lost through abscission than those that remained on the plants. This agrees with what was reported by Izquierdo and Hosfield (1981), namely that pod abscission may account for 64-82% of the total number of pods formed, with the shedding of small pods less than 10 mm in length accounting for most of this. Kambal (1969) also observed a large number of pods to drop (86-93%) before maturity is reached. Tamas *et al.* (1979) found that the relative age of developing bean pods within a raceme affected their rate of abortion, with older fruits at the base of the raceme aborting less frequently than the younger ones above them. They also found that when older fruits were removed from each raceme, the abortion rate of the younger fruits greatly decreased. This emphasizes the role of pod abscission in the decrease of yields as well as the need to find a solution.

In this study, even the treatment with a silver salt, known to be a potent ethylene antagonist (Beyer, 1976), did not inhibit pod abscission indicating that factors other than hormone action might be more important in regulating pod abscission. A number of factors may contribute. Huff and Dybing (1980) reported on the possible role of photosynthetic assimilate in determining the number of pods that formed, abscised or remained on the bean plant. They indicated that assimilate supply could limit reproductive growth either by increasing shedding, and thus decreasing pods per plant, or the competition that exists among developing and older pods could cause premature senescence and abscission of younger pods. This view was shared by Tamas *et al.* (1979).

It is clear from the results that none of the chemical treatments applied in this study succeeded in minimizing the abscission of the reproductive organs. More than half of the total reproductive structures that formed abscised either as flowers or as younger pods. This was consistent with the findings of Izquierdo and Hosfield (1981) namely that abscission of reproductive organs during the flowering and fruiting period in grain legumes is often greater than 50%. Extensive studies on flowering and fruiting suggest that flower and pod abortion in beans occur as a result of critical physiological interactions (Weis & Webster, 1990). However, the physiological basis for these losses is still unclear (Monterroso & Wien, 1990). From the results obtained with the different chemical treatments, it remains difficult to explain the observed yield increases despite the high loss of flowers and/or pods.

CHAPTER 7

GENERAL DISCUSSION AND CONCLUSIONS

According to Subhadrabandhu et al., (1978), Mauk et al., (1984, 1987) and, Weis and Webster (1991), the common bean performs poorly in terms of final yield outcome, the average yields obtained are well below the estimated potential and no solution to this problem has been offered to date. The latter was the main reason for undertaking this study. It was confirmed by the results from this study that abscission of reproductive organs (flowers and pods) of the common bean is a serious problem affecting the total yields. This was demonstrated by a high proportion of flowers and pods that abscised, despite the application of different treatments that were expected to circumvent the problem. Moreover, it also became clear that flower and pod production or the lack thereof, could not be considered as the primary or major underlying problem, but rather the relative high rate of organ abscission. Any attempts to improve on this state of affairs should be to minimize losses caused by abscission.

The preliminary comparison of the three untreated bean cultivars Leeukop, Stormberg and Kranskop did not reveal any major differences between the cultivars in terms of the measured parameters (flower and pod production as well as abscission as representative of the yield components) and hence the final yields. The total yields for the three cultivars averaged 1.4 tons ha^{-1} and the impression here is that all three cultivars performed similarly. No cultivar was clearly better in terms of yield potential than the others. All suffered the same fate in terms of flower and pod loss during the growing season. Moreover, this also seemed to indicate that the underlying problem was universal for all bean cultivars. Because of this, only Kranskop was chosen, as the representative cultivar, for further investigation of the possible circumventive roles different chemicals could play in alleviating the high loss of flowers and /or pods.

Initially chemicals were applied in one concentration, only to screen the potential of these chemicals to act as agents alleviating organ loss in the common bean cv. Kranskop. The application of different chemicals as foliar sprays at different growth stages revealed potential for some chemicals to act as alleviating agents to flower and pod abscission, albeit not spectacular in all cases. These included molybdenum, copper and potassium. For example, in the case of the molybdenum treatment at the four-leaf stage, a 25% increase in flower formation was observed. However, due to a corresponding high pod loss, the increase was not revealed in the final yield confirming organ abscission to be of greater importance affecting the final yield outcome in beans than the rate of flower formation. This corresponded with the findings of Heindl and Brun (1983) as well as Brun and Betts (1984). The use of the silver salt, which is considered an antagonist of ethylene action (Beyer, 1976; Halevy & Kofranek, 1977), did not show any pronounced alleviating effects in terms of inhibiting flower and pod abscission and the resulting final yield was equally low. However, the application of ethrel at different growth stages accelerated flower and pod abscission and decreased final yields substantially. The outcome of the ethrel application confirmed the findings of Sauter et al. (1990) and Wien (1990) namely that flower and pod abscission is aggravated by the release of ethylene during the critical stages of growth in bean plants. The incapacity of the silver salt to circumvent the ethylene effect is difficult to explain. It might be worth while to investigate the effect of other known ethylene antagonists such as AVG (L-α-(2-aminoethoxyvinyl)-glycine-hydrochloride; an inhibitor of ethylene synthesis) and NBD (2,5-norbornadiene; an inhibitor of ethylene action) in future.

Apart from the limitations indicated above, some relative yield increases were obtained by treating bean plants at different growth stages with some chemicals, which could have a financial impact for the farmer. For example, molybdenum treatment at the twelve-leaf growth stage increased the final yield by 189kg ha^{-1} or 11.1% at the average price of R 3,200.00 ton^{-1} during the 1999 season. This means an increased income of R 350.00 ha^{-1} for the farmer. Potassium nitrate treatment at the twelve-leaf growth stage increased the yield by 7% while treatment at the eight-leaf growth stage with molybdenum (7%), copper (14%), silver (6%) and potassium (7%) also increased the final yield albeit not spectacular. As the latter treatments did not clearly reduce flower and pod abscission, it seems from the results that, these chemicals had some other effects, which most probably were on the physiological level and this will have to be investigated in future.

In light of the results obtained with the initial application of different chemicals in one concentration, which did not reveal clear indications of any circumventive effects by the chemicals applied, a follow-up study was conducted where chemicals were applied at different concentrations. As molybdenum and copper have been studied extensively in the past, no further attention was given to them but rather to the less known ones, namely potassium nitrate, potassium chloride, silver nitrate and a new product, ComCat®, some of which showed potential to offer a solution for the high rate of flower and pod abscission in beans. The uncertainty about the role of the potassium or the nitrate ions made it necessary to include potassium chloride together with potassium nitrate in the follow-up trial. ComCat®, which is a natural biocatalyst, was included in the trial for the first time on grounds of claims that the product accelerates nutrient adsorption through stimulation of root development and intensifies nutrient assimilation (Huster, 1999; personal communication). This apparent role played by ComCat® was considered important, because one of the main factors which have been reported to accelerate abscission, is the competition for nutrients during the critical stages of plant development (Tamas, *et al.*, 1979). Ethrel was eliminated from the follow-up study because of its aggravating effect, on reproductive structure abscission that was well demonstrated in the preliminary trial.

The results obtained after application of different chemicals at different concentration levels did not reveal any significant differences in terms of either inhibiting flower or pod abscission or stimulating flowering. Despite the apparent lack of an inhibiting effect on flower or pod abscission by the different chemicals, clear yield differences for the chemical treatments were observed compared to the respective controls. However, the total yields measured in this follow-up trial were relatively low compared to the yields of the former trial and this was probably due to different planting dates. Moreover, although precautions were taken, a problem with fungal infection of a Rhizoctonia species and a Fusarium root rot was encountered. This potentially could have influenced the yield outcome. However, apart from the limitations, the flowering percentage was quite similar to that of the previous trials. Nevertheless, relative yield increases by treatment with especially ComCat® was observed. Treatment with ComCat® at the twelve leaf stage and at concentration level-2 (400 $mg\ l^{-1}$) contributed to a 24.6% increase in flower formation and a yield increase of (193.92 kg ha^{-1} or 20.7%) compared to the untreated control. With the average price of R 3,200.00 ton^{-1}, this means an increase of R 640.00 ha^{-1} for the farmer. It therefore seems imperative that the mechanism of action of ComCat® should be elucidated. Other chemicals that showed some yield increases, at the same concentration level, though not very significant, were silver nitrate (37.7%), potassium chloride (9.7%) and potassium nitrate (11.9%).

In this study, there was a strong indication that profuse flowering, especially under suitable growing conditions, is not a major problem limiting bean yields. However, this needs to be proven under field conditions. What still remains of major importance is to find a means of reducing abscission of the reproductive structures. Moreover, the observation that yield reductions were mainly due to higher pod than flower abscission necessitates a study on the effect of these chemicals at other growth stages, especially after flowering. In this regard, other ethylene antagonists (previously mentioned) might be worthwhile to include in the study. Tamas *et al.* (1979) and Catlin and Olsson, (1990) have shown that increased fruit abscission is due to competition for resources between the developed pods and the newly forming pods. It seems, therefore, that further investigations into the underlying physiological factors involved in pod abscission during the early stages of development, as well as the influence of the oldest pods on those that developed later, should be undertaken.

In conclusion, although this study did not single out one specific chemical treatment as a spectacular solution to the problem of either flower or pod abscission in beans, some indications of possible treatments with yield improving effects were observed. Especially treatment with copper (eight leaf stage) molybdenum (twelve leaf stage) trial-1, and ComCat®, silver nitrate, potassium chloride and potassium nitrate at the twelve leaf growth stage trial–2 increased yields significantly in terms of the economic impact for the farmer. Moreover, the fact that none of the chemicals really reduced flower or pod abscission significantly, but some still contributed to an increase in the final yield, indicated that factors other than only abscission of reproductive organs are probably involved. The latter needs further investigation in light of the fact that previous studies on the abscission frequency of flowers and pods did not contribute to a long-term solution to the problem of low yields from beans in this country. Methods to improve the harvest index, e.g. chemical treatments which influence translocation of essential substrates from the source to the sink during the grain filling period, might be worthwhile to investigate. Field trials with ComCat® as a treatment to improve bean yields, seems essential. Additionally, means to circumvent the ethylene effect on flower and pod abscission seems equally important. Finally, seed treatment with different micro and macronutrients might also be of value to investigate.

SUMMARY

The abscission of the reproductive organs (flower buds, flowers and pods) of the common bean, *Phaseolus vulgaris* L., has proved to be a very serious problem affecting bean yields. The yield reductions are mainly significant under conditions of environmental stress, which aggravate production of the abscission causing hormones such as ethylene. The study therefore evaluated the effect of certain nutrients, other chemicals and ethylene (growth regulator) applied as foliar sprays to determine their effect in as far as abscission of the reproductive organs in beans is concerned.

Glasshouse trials were carried out during the 1998/99 and 1999/00 seasons to investigate the possible preventative role of some micro and macro-nutrients, abscission inhibitors (e.g. Silver) and growth regulators (e.g. ethylene) all applied as foliar sprays. In another trial, three cultivars were compared where no treatments were applied. Data were collected and the following parameters were measured; number of flowers and pods that abscised, pods formed and abscised, pods that matured and could be harvested, dry pod mass at harvest, seed number per pod, dry seed mass per pod and total yield per hectare. Data were analyzed using a SAS software system and interpreted accordingly.

The results of this study indicated that flower and pod formation might not be considered as the major factor affecting bean yields. The reason being that flowering percentage was not very different between the treated and the untreated plants. The abscission of flower buds, flowers and pods, however, was relatively high in general, indicating that this is possibly a primary factor affecting poor yields in beans.

Ethrel, an ethylene releasing compound, applied as a foliar spray, aggravated the problem of flower and pod abscission. An ethylene antagonist (silver salt) had a slight alleviating effect on organ abscission but did not improve the final yield significantly. Molybdenum and potassium salts improved flower formation to a certain extent but had no real alleviating effect on organ abscission. This was also revealed in the lack of yield improvement. Foliar application of a copper salt as well as treatment with ComCat®, a

natural product with biocatalytic properties, did not influence flower and pod abscission significantly, but increased the final yields to some extend. The latter indicates that other factors besides organ abscission could have had an effect on determining the final yield outcome.

In the light of these findings, it is suggested that further studies be undertaken to test a wider range of chemicals for their potential to circumvent flower and pod abscission and improve bean yields. The latter could also include treatment at other growth stages, including post flowering. Other attempts could include an investigation into the effect of other known ethylene antagonists such as AVG (L-α-(2-aminoethoxyvinyl)-glycine-hydrochloride), an inhibitor of ethylene synthesis and NBD (2,5-norbornadiene), an inhibitor of ethylene action, on organ abscission and yield outcome in beans. As the results also showed that other factors besides organ abscission could have played a role in yield improvement, it might be worthwhile to investigate the effect of promising chemicals on physiological processes.

OPSOMMING

Die afspening van reproduktiewe organe (blomknoppe, blomme en peule) van die boontjie, *Phaseolus vulgaris* L., was nog altyd as 'n ernstige probleem beskou vanweë die uiters nadelige effek op oesopbrengs. Oesopbrengs verlaging is die ergste onder stremmingstoestande, waarskynlik vanweë verhoogde sintese van hormone soos etileen. Tydens hierdie studie is die effek van verskillende bemestingstowwe, ander chemikalieë en etileen (groei reguleerder), aangewend as blaar bespuitings, geëvalueer in terme van hulle potensiaal om die afspening van reproduktiewe organe in die boontjie te voorkom

Glashuisproewe is aanvanklik uitgevoer gedurende die 1998/99 en 1999/2000 seisoene om die moontlike absissie voorkomende rolle van sekere mikro- en makro-elemente, 'n groei reguleerder (etileen) en 'n etileen antagonis (silwer soute), aangewend as blaarbespuitings in 'n enkel konsentrasie, te ondersoek. Vooraf is drie boontjie cultivars, sonder enige behandeling, ook met mekaar vergelyk ten opsigte van groeipatrone. Die cultivar Kranskop, is in alle verdere proewe gebruik. Versamelde data in alle proewe het die volgende ingesluit: aantal blomme en peule gevorm en afgespeen, aantal peule wat wasdom bereik het en geoes kon word, droë peulmassa, aantal sade per peul, droë saadmassa en totale oesopbrengs per hektaar. Data is deur middel van 'n SAS sagteware program statisties geanaliseer.

Resultate het daarop gedui dat blom- en peulvorming, of die gebrek daaraan, nie blyk om die primêre rede vir swak oesopbrenste by boontjies te wees nie aangesien die aantal blomme en peule wat gevorm is nie betekenisvol verskil het tussen behandelde en kontrole plante nie. Die afspening van blomknoppe, blomme en peule was egter oor die algemeen hoog wat daarop dui dat dit eerder as 'n primêre rede vir swak oesopbrengste by boontjies gereken kan word.

Ethrel, 'n etileen vrystellende produk wat kommersieël in die handel beskikbaar is en as blaarbespuiting aangewend, het die probleem van blom en peul afspening vererger. 'n Etileen antagonis (silwer sout) het 'n geringe voorkomende effek op afspening gehad maar nie oesopbrengste noemenswaardig verbeter nie. Molibdeen en kaliumsoute het tot verhoogde blomvorming aanleiding gegee maar nie afspening of oesopbrengs noemenswaardig beïnvloed nie. Blaarbespuiting met 'n kopersout asook behandeling met ComCat®, 'n natuurlike produk met biokatalitiese eienskappe, het nie blom en peul afspening noemenswaardig beïnvloed nie maar tog tot aansienlike oesopbrengsverhoging aanleiding gegee.

In die lig van hierdie bevindinge word voorgestel dat verdere studies onderneem word om 'n wyer reeks van chemikalieë vir hulle potensiaal om blom- en peulafspening te voorkom, te toets. Laasgenoemde kan ook op ander groeistadia getoets word. Verder kan dit lonend wees om ander etileen antagoniste, te wete AVG (L-α-(2-aminoetoksieviniel)-glisien-hidrochloried), 'n inhibeerder van etileensintese, en NBD (2,5-norbornadiene), 'n inhibeerder van etileen aksie, se effek op afspening te toets. Aangesien die resultate daarop gedui het dat ander faktore, buiten blom- en peulafspening, ook 'n rol by oesopbrengs verhoging kon gespeel het, kan dit lonend wees om die effek van belowende chemikalieë op fisiologiese prosesse te ondersoek.

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APPENDIX A

TABLE 4.1: Analysis of Variance of data for flowers formed comparing three bean cultivars.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	2	60.66666667	30.33333333	3.03	0.0984
Error	9	90.00000000	10.00000000		
Corrected Total	11	150.66666667			

R^2= 0.402655 %CV= 12.48267 LSD= 5.0583

TABLE 4.2: Analysis of Variance of data for pods formed comparing three bean cultivars.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	2	112.1666667	56.0833333	2.78	0.1147
Error	9	181.5000000	20.1666667		
Corrected Total	11	293.6666667			

R^2= 0.381952 %CV= 20.56823 LSD= 7.1833

TABLE 4.3: Analysis of Variance of data for flowers that abscised comparing three bean cultivars.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	2	18.50000000	9.25000000	1.53	0.2684
Error	9	54.50000000	6.05555556		
Corrected Total	11	73.00000000			

R^2= 0.253425 %CV= 70.30868 LSD= 3.9363

TABLE 4.4: Analysis of Variance of data for pods that abscised comparing three bean cultivars.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	2	68.66666667	34.33333333	2.45	0.1412
Error	9	126.00000000	14.00000000		
Corrected Total	11	194.66666667			

R^2= 0.352740 %CV= 32.07135 LSD= 5.9851

TABLE 4.5: Analysis of Variance of data for pods that matured comparing three bean cultivars.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	2	2.66666667	1.33333333	0.52	0.6104
Error	9	23.00000000	2.55555556		
Corrected Total	11	25.66666667			

R^2= 0.103896 %CV= 19.57482 LSD= 2.5571

TABLE 4.6: Analysis of Variance of data for dry pod mass at harvest comparing three bean cultivars.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	2	0.36399017	0.18199508	0.83	0.4658
Error	9	1.96733875	0.21859319		
Corrected Total	11	2.33132892			

R^2= 0.156130 %CV= 21.19960 LSD= 0.7479

TABLE 4.7: Analysis of Variance of data for seed number per pod comparing three bean cultivars.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	2	0.02272550	0.01136275	0.02	0.9777
Error	9	4.52855050	0.50317228		
Corrected Total	11	4.55127600			

R^2= 0.004993 %CV= 20.93085 LSD= 1.1347

TABLE 4.8: Analysis of Variance of data for Dry seed mass per pod comparing three bean cultivars.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	2	0.10611650	0.05305825	0.34	0.7182
Error	9	1.39030550	0.15447839		
Corrected Total	11	1.49642200			

R^2= 0.070913 %CV= 24.42743 LSD= 0.6287

TABLE 4.9: Analysis of Variance of data for yield per hectare (Kg) comparing three bean cultivars.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	2	6333.761112	3166.880556	0.07	0.9285
Error	9	381031.451784	42336.827976		
Corrected Total	11	387365.212896			

R^2= 0.016351 %CV= 13.97319 LSD= 329.13

APPENDIX B

FOUR LEAF STAGE

TABLE 5.1: Analysis of Variance of data for flowers formed as influenced by foliar spraying with different chemicals.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	5	120.4444444	24.0888889	3.98	0.0233
Error	12	72.6666667	6.0555556		
Corrected Total	17	193.1111111			

R^2= 0.623705 %CV= 11.84344 LSD= 4.3778

TABLE 5.2: Analysis of Variance of data for pods formed as influenced by foliar spraying with different chemicals.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	5	129.1111111	25.8222222	2.06	0.1421
Error	12	150.6666667	12.5555556		
Corrected Total	17	279.7777778			

R^2= 0.461477 %CV= 20.70808 LSD= 6.3037

TABLE 5.3: Analysis of Variance of data for flowers that abscised as influenced by foliar spraying with different chemicals.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	5	24.66666667	4.93333333	0.62	0.6869
Error	12	95.33333333	7.94444444		
Corrected Total	17	120.00000000			

R^2= 0.205556 %CV= 76.87061 LSD= 5.0143

TABLE 5.4: Analysis of Variance of data for pods that abscised as influenced by foliar spraying with different chemicals.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	112.0000000	22.4000000	2.44	0.0951
Error	12	110.0000000	9.1666667		
Corrected Total	17	222.0000000			

R^2= 0.504505 %CV= 37.84563 LSD= 5.3862

TABLE 5.5: Analysis of Variance of data for pods that matured as influenced by foliar spraying with different chemicals.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	13.61111111	2.72222222	2.88	0.0617
Error	12	11.33333333	0.94444444		
Corrected Total	17	24.94444444			

R^2= 0.545657 %CV= 10.73181 LSD= 1.7289

TABLE 5.6: Analysis of Variance of data for dry pod mass as influenced by foliar spraying with different chemicals.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	1.00112502	0.20022500	2.35	0.1046
Error	12	1.02238318	0.08519860		
Corrected Total	17	2.02350820			

R^2= 0.494747 %CV= 13.11293 LSD= 0.5193

TABLE 5.7: Analysis of Variance of data for seed number per pod as influenced by foliar spraying with different chemicals.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	5	1.72888857	0.34577771	2.50	0.0900
Error	12	1.66103141	0.13841928		
Corrected Total	17	3.38991999			

R^2= 0.510009 %CV= 10.42047 LSD= 0.6619

TABLE 5.8: Analysis of Variance of data for seed mass per pod as influenced by foliar spraying with different chemicals.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	5	0.68796727	0.13759345	2.34	0.1054
Error	12	0.70473289	0.05872774		
Corrected Total	17	1.39270017			

R^2= 0.493981 %CV= 14.26343 LSD= 0.4311

TABLE 5.9: Analysis of Variance of data for yield per hectare (Kg) as influenced by foliar spraying with different chemicals.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	5	87454.26743	17490.85349	0.70	0.6326
Error	12	298952.79853	24912.73321		
Corrected Total	17	386407.06596			

R^2= 0.226327 %CV= 8.790114 LSD= 280.79

EIGHT LEAF STAGE

TABLE 5.10: Analysis of Variance of data for flowers formed as influenced by foliar spraying with different chemicals.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	5	164.9444444	32.9888889	3.39	0.0385
Error	12	116.6666667	9.7222222		
Corrected Total	17	281.6111111			

R^2= 0.585717 %CV= 15.04688 LSD= 5.547

TABLE 5.11: Analysis of Variance of data for pods formed as influenced by foliar spraying with different chemicals.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	5	57.61111111	11.52222222	0.74	0.6059
Error	12	186.00000000	15.50000000		
Corrected Total	17	243.61111111			

R^2= 0.236488 %CV= 25.04101 LSD= 7.0039

TABLE 5.12: Analysis of Variance of data for flowers that abscised as influenced by foliar spraying with different chemicals.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	5	35.33333333	7.06666667	1.55	0.2466
Error	12	54.66666667	4.55555556		
Corrected Total	17	90.00000000			

R^2= 0.392593 %CV= 42.68749 LSD= 3.797

TABLE 5.13: Analysis of Variance of data for pods that abscised as influenced by foliar spraying with different chemicals.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	5	8.94444444	1.78888889	0.11	0.9886
Error	12	200.00000000	16.66666667		
Corrected Total	17	208.94444444			

R^2= 0.042808 %CV= 67.41715 LSD= 7.2627

TABLE 5.14: Analysis of Variance of data for pods that matured as influenced by foliar spraying with different chemicals.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	5	13.11111111	2.62222222	2.48	0.0913
Error	12	12.66666667	1.05555556		
Corrected Total	17	25.77777778			

R^2= 0.508621 %CV= 11.27637 LSD= 1.8277

TABLE 5.15: Analysis of Variance of data for dry pod mass as influenced by foliar spraying with different chemicals.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	5	0.10738896	0.02147779	0.23	0.9434
Error	12	1.13373793	0.09447816		
Corrected Total	17	1.24112688			

R^2= 0.086525 %CV= 14.95037 LSD= 0.5468

TABLE 5.16: Analysis of Variance of data for seed number per pod as influenced by foliar spraying with different chemicals.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	5	0.16847270	0.03369454	0.25	0.9326
Error	12	1.62756618	0.13563052		
Corrected Total	17	1.79603888			

R^2= 0.093802 %CV= 10.89133 LSD= 0.6552

TABLE 5.17: Analysis of Variance of data for dry seed mass per as influenced by foliar spraying with different chemicals.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	5	0.04329762	0.00865952	0.14	0.9797
Error	12	0.74675181	0.06222932		
Corrected Total	17	0.79004943			

R^2= 0.054804 %CV= 16.03710 LSD= 0.4438

TABLE 5.18: Analysis of Variance of data for yield per hectare (Kg) influenced by foliar spraying with different chemicals.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	5	320556.6566	64111.3313	1.70	0.2092
Error	12	452633.4053	37719.4504		
Corrected Total	17	773190.0620			

R^2= 0.414590 %CV= 11.57274 LSD= 345.51

TWELVE LEAF STAGE

TABLE 5.19: Analysis of Variance of data for flowers formed as influenced by foliar spraying with different chemicals.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	5	331.6111111	66.3222222	10.29	0.0005
Error	12	77.3333333	6.4444444		
Corrected Total	17	408.9444444			

R^2= 0.810895 %CV= 11.01076 LSD= 4.5161

TABLE 5.20: Analysis of Variance of data for pods formed as influenced by foliar spraying with different chemicals.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	5	769.6111111	153.9222222	15.22	0.0001
Error	12	121.3333333	10.1111111		
Corrected Total	17	890.9444444			

R^2= 0.863815 %CV= 18.64376 LSD= 5.6568

TABLE 5.21: Analysis of Variance of data for flowers that abscised as influenced by foliar spraying with different chemicals.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	5	205.3333333	41.0666667	7.18	0.0025
Error	12	68.6666667	5.7222222		
Corrected Total	17	274.0000000			

R^2= 0.749392 %CV= 39.86861 LSD= 4.2556

TABLE 5.22: Analysis of Variance of data for pods that abscised as influenced by foliar spraying with different chemicals.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	5	421.6111111	84.3222222	7.55	0.0020
Error	12	134.0000000	11.1666667		
Corrected Total	17	555.6111111			

R^2= 0.758824 %CV= 43.27325 LSD= 5.9448

TABLE 5.23: Analysis of Variance of data for pods that matured as influenced by foliar spraying with different chemicals.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	5	45.77777778	9.15555556	4.23	0.0190
Error	12	26.00000000	2.16666667		
Corrected Total	17	71.77777778			

R^2= 0.637771 %CV= 16.55955 LSD= 2.6186

TABLE 5.24: Analysis of Variance of data for dry pod mass as influenced by foliar spraying with different chemicals.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	5	0.64086913	0.12817383	1.40	0.2932
Error	12	1.10124308	0.09177026		
Corrected Total	17	1.74211221			

R^2= 0.367869 %CV= 14.58032 LSD= 0.5389

TABLE 5.25: Analysis of Variance of data for seed number per pod as influenced by foliar spraying with different chemicals.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	1.13646719	0.22729344	1.24	0.3484
Error	12	2.19319176	0.18276598		
Corrected Total	17	3.32965895			

R^2= 0.341316 %CV= 12.69228 LSD= 0.7605

TABLE 5.26: Analysis of Variance of data for dry seed mass per pod as influenced by foliar spraying with different chemicals.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	0.40609403	0.08121881	1.45	0.2759
Error	12	0.67179502	0.05598292		
Corrected Total	17	1.07788905			

R^2= 0.376749 %CV= 15.10537 LSD= 0.4209

TABLE 5.27: Analysis of Variance of data for yield per hectare (Kg) as influenced by foliar spraying with different chemicals.

Dependent Variable: KGH

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	1474499.999	294900.000	19.88	0.0001
Error	12	178022.977	14835.248		
Corrected Total	17	1652522.976			

R^2= 0.892272 %CV= 7.431355 LSD= 216.68

APPENDIX C

FOUR LEAF STAGE (Concentration level-1)

TABLE 6.1: Analysis of Variance of data for flowers formed as influenced by foliar spraying with different chemicals at concentration level one.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	106.2666667	26.5666667	0.30	0.8718
Error	10	887.3333333	88.7333333		
Corrected Total	14	993.6000000			

R^2= 0.106951 %CV= 34.37897 LSD= 17.137

TABLE 6.2: Analysis of Variance of data for pods formed as influenced by foliar spraying with different chemicals at concentration level one.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	129.0666667	32.2666667	0.50	0.7375
Error	10	646.6666667	64.6666667		
Corrected Total	14	775.7333333			

R^2= 0.166380 %CV= 34.76178 LSD= 14.63

TABLE 6.3: Analysis of Variance of data for flowers that abscised as influenced by foliar spraying with different chemicals at concentration level one.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	26.26666667	6.56666667	0.90	0.4976
Error	10	72.66666667	7.26666667		
Corrected Total	14	98.93333333			

R^2= 0.265499 %CV= 63.17990 LSD= 4.9042

TABLE 6.4: Analysis of Variance of data for pods that abscised as influenced by foliar spraying with different chemicals at concentration level one.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	178.0000000	44.5000000	0.44	0.7763
Error	10	1008.0000000	100.8000000		
Corrected Total	14	1186.0000000			

R^2= 0.150084 %CV= 66.93280 LSD= 18.265

TABLE 6.5: Analysis of Variance of data for pods that matured as influenced by foliar spraying with different chemicals at concentration level one.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	5.06666667	1.26666667	0.17	0.9512
Error	10	76.66666667	7.66666667		
Corrected Total	14	81.73333333			

R^2= 0.061990 %CV= 34.04354 LSD= 5.0373

TABLE 6.6: Analysis of Variance of data for dry pod mass as influenced by foliar spraying with different chemicals at concentration level one.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	0.11004440	0.02751110	0.36	0.8313
Error	10	0.76347800	0.07634780		
Corrected Total	14	0.87352240			

R^2= 0.125978 %CV= 23.25459 LSD= 0.5027

TABLE 6.7: Analysis of Variance of data for seed number per pod as influenced by foliar spraying with different chemicals at concentration level one.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	0.65469933	0.16367483	0.60	0.6721
Error	10	2.73412400	0.27341240		
Corrected Total	14	3.38882333			

R^2= 0.193194 %CV= 24.15561 LSD= 0.9513

TABLE 6.8: Analysis of Variance of data for dry seed mass per pod as influenced by foliar spraying with different chemicals at concentration level one.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	0.08334893	0.02083723	0.38	0.8183
Error	10	0.54883400	0.05488340		
Corrected Total	14	0.63218293			

R^2= 0.131843 %CV= 26.81276 LSD= 0.4262

TABLE 6.9: Analysis of Variance of data for yield per hectare (Kg) as influenced by foliar spraying with different chemicals at concentration level one.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	230672.5920	57668.1480	0.40	0.8048
Error	10	1443465.3600	144346.5360		
Corrected Total	14	1674137.9520			

R^2= 0.137786 %CV= 45.99855 LSD= 691.19

FOUR LEAF STAGE (Concentration level-2)

TABLE 6.10: Analysis of Variance of data for flowers formed as influenced by foliar spraying with different chemicals at concentration level two.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	54.93333333	13.73333333	0.42	0.7900
Error	10	326.00000000	32.60000000		
Corrected Total	14	380.93333333			

R^2= 0.144207 %CV= 20.19920 LSD= 10.387

TABLE 6.11: Analysis of Variance of data for pods formed as influenced by foliar spraying with different chemicals at concentration level two.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	33.73333333	8.43333333	0.38	0.8181
Error	10	222.00000000	22.20000000		
Corrected Total	14	255.73333333			

R^2= 0.131908 %CV= 20.60505 LSD= 8.5718

TABLE 6.12: Analysis of Variance of data for flowers that abscised as influenced by foliar spraying with different chemicals at concentration level two.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	54.26666667	13.56666667	1.12	0.4009
Error	10	121.33333333	12.13333333		
Corrected Total	14	175.60000000			

R^2= 0.309036 %CV= 64.50543 LSD= 6.337

TABLE 6.13: Analysis of Variance of data for pods that abscised as influenced by foliar spraying with different chemicals at concentration level two.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	101.0666667	25.2666667	0.98	0.4622
Error	10	258.6666667	25.8666667		
Corrected Total	14	359.7333333			

R^2= 0.280949 %CV= 35.98534 LSD= 9.2527

TABLE 6.14: Analysis of Variance of data for pods that matured as influenced by foliar spraying with different chemicals at concentration level two.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	40.93333333	10.23333333	2.13	0.1512
Error	10	48.00000000	4.80000000		
Corrected Total	14	88.93333333			

R^2= 0.460270 %CV= 25.08653 LSD= 3.9858

TABLE 6.15: Analysis of Variance of data for dry pod mass as influenced by foliar spraying with different chemicals at concentration level two.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	0.17998907	0.04499727	1.01	0.4471
Error	10	0.44555267	0.04455527		
Corrected Total	14	0.62554173			

R^2= 0.287733 %CV= 18.50724 LSD= 0.384

TABLE 6.16: Analysis of Variance of data for seed number per pod as influenced by foliar spraying with different chemicals at concentration level two.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	0.50287893	0.12571973	0.37	0.8277
Error	10	3.43818667	0.34381867		
Corrected Total	14	3.94106560			

R^2= 0.127600 %CV= 27.79750 LSD= 1.0667

TABLE 6.17: Analysis of Variance of data for dry seed mass per pod as influenced by foliar spraying with different chemicals at concentration level two.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	0.11312893	0.02828223	0.80	0.5525
Error	10	0.35390600	0.03539060		
Corrected Total	14	0.46703493			

R^2= 0.242228 %CV= 22.77713 LSD= 0.3422

TABLE 6.18: Analysis of Variance of data for yield per hectare (Kg) as influenced by foliar spraying with different chemicals at concentration level two.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	465051.7114	116262.9278	1.22	0.3606
Error	10	950296.7616	95029.6762		
Corrected Total	14	1415348.4730			

R^2= 0.328578 %CV= 35.60114 LSD= 560.82

FOUR LEAF STAGE (Concentration level-3)

TABLE 6.19: Analysis of Variance of data for flowers formed as influenced by foliar spraying with different chemicals at concentration level three.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	298.4000000	74.6000000	0.95	0.4730
Error	10	782.0000000	78.2000000		
Corrected Total	14	1080.4000000			

R^2= 0.276194 %CV= 31.80963 LSD= 16.088

TABLE 6.20: Analysis of Variance of data for pods formed as influenced by foliar spraying with different chemicals at concentration level three.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	105.7333333	26.4333333	0.46	0.7623
Error	10	572.0000000	57.2000000		
Corrected Total	14	677.7333333			

R^2= 0.156010 %CV= 33.07464 LSD= 13.759

TABLE 6.21: Analysis of Variance of data for flowers that abscised as influenced by foliar spraying with different chemicals at concentration level three.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	98.93333333	24.73333333	1.72	0.2222
Error	10	144.00000000	14.40000000		
Corrected Total	14	242.93333333			

R^2= 0.407245 %CV= 76.92027 LSD= 6.9036

TABLE 6.22: Analysis of Variance of data for pods that abscised as influenced by foliar spraying with different chemicals at concentration level three.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	154.6666667	38.6666667	0.52	0.7267
Error	10	750.6666667	75.0666667		
Corrected Total	14	905.3333333			

R^2= 0.170839 %CV= 60.44722 LSD= 15.762

TABLE 6.23: Analysis of Variance of data for pods that matured as influenced by foliar spraying with different chemicals at concentration level three.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	11.06666667	2.76666667	0.80	0.5531
Error	10	34.66666667	3.46666667		
Corrected Total	14	45.73333333			

R^2= 0.241983 %CV= 21.81913 LSD= 3.3873

TABLE 6.24: Analysis of Variance of data for dry pod mass as influenced by foliar spraying with different chemicals at concentration level three.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	0.13061427	0.03265357	0.87	0.5162
Error	10	0.37656733	0.03765673		
Corrected Total	14	0.50718160			

R^2= 0.257530 %CV= 17.94133 LSD= 0.353

TABLE 6.25: Analysis of Variance of data for seed number per pod as influenced by foliar spraying with different chemicals at concentration level three.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	1.19100493	0.29775123	0.98	0.4630
Error	10	3.05332200	0.30533220		
Corrected Total	14	4.24432693			

R^2= 0.280611 %CV= 26.90121 LSD= 1.0053

TABLE 6.26: Analysis of Variance of data for dry seed mass per pod as influenced by foliar spraying with different chemicals at concentration level three.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	0.11899360	0.02974840	0.85	0.5265
Error	10	0.35106133	0.03510613		
Corrected Total	14	0.47005493			

R^2= 0.253148 %CV= 23.62554 LSD= 0.3409

TABLE 6.27: Analysis of Variance of data for yield per hectare (Kg) as influenced by foliar spraying with different chemicals at concentration level three.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	271670.5632	67917.6408	0.81	0.5462
Error	10	837947.6640	83794.7664		
Corrected Total	14	1109618.2272			

R^2= 0.244832 %CV= 35.18320 LSD= 526.63

EIGHT LEAF STAGE (Concentration level-1)

TABLE 6.28: Analysis of Variance of data for flowers formed as influenced by foliar spraying with different chemicals at concentration level one.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	155.3333333	38.8333333	0.67	0.6292
Error	10	582.0000000	58.2000000		
Corrected Total	14	737.3333333			

R^2= 0.210669 %CV= 25.71537 LSD= 13.879

TABLE 6.29: Analysis of Variance of data for pods formed as influenced by foliar spraying with different chemicals at concentration level one.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	166.2666667	41.5666667	0.81	0.5461
Error	10	512.6666667	51.2666667		
Corrected Total	14	678.9333333			

R^2= 0.244894 %CV= 27.25917 LSD= 13.026

TABLE 6.30: Analysis of Variance of data for flowers that abscised as influenced by foliar spraying with different chemicals at concentration level one.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	4.26666667	1.06666667	0.30	0.8702
Error	10	35.33333333	3.53333333		
Corrected Total	14	39.60000000			

R^2= 0.107744 %CV= 55.28577 LSD= 3.4197

TABLE 6.31: Analysis of Variance of data for pods that abscised as influenced by foliar spraying with different chemicals at concentration level one.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	319.6000000	79.9000000	1.27	0.3430
Error	10	627.3333333	62.7333333		
Corrected Total	14	946.9333333			

R^2= 0.337511 %CV= 46.40881 LSD= 14.409

TABLE 6.32: Analysis of Variance of data for pods that matured as influenced by foliar spraying with different chemicals at concentration level one.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	33.73333333	8.43333333	0.52	0.7245
Error	10	162.66666667	16.26666667		
Corrected Total	14	196.40000000			

R^2= 0.171758 %CV= 43.83908 LSD= 7.3375

TABLE 6.33: Analysis of Variance of data for dry pod mass as influenced by foliar spraying with different chemicals at concentration level one.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	0.06866573	0.01716643	0.49	0.7456
Error	10	0.35261600	0.03526160		
Corrected Total	14	0.42128173			

R^2= 0.162992 %CV= 19.94555 LSD= 0.3416

TABLE 6.34: Analysis of Variance of data for seed number per pod as influenced by foliar spraying with different chemicals at concentration level one.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	0.59606507	0.14901627	0.57	0.6920
Error	10	2.62432667	0.26243267		
Corrected Total	14	3.22039173			

R^2= 0.185091 %CV= 26.66560 LSD= 0.932

TABLE 6.35: Analysis of Variance of data for dry seed mass per pod as influenced by foliar spraying with different chemicals at concentration level one.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	0.02317107	0.00579277	0.21	0.9256
Error	10	0.27266667	0.02726667		
Corrected Total	14	0.29583773			

R^2= 0.078324 %CV= 24.13655 LSD= 0.3004

TABLE 6.36: Analysis of Variance of data for yield per hectare (Kg) as influenced by foliar spraying with different chemicals at concentration level one.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	153367.8758	38341.9690	0.28	0.8813
Error	10	1346988.2496	134698.8250		
Corrected Total	14	1500356.1254			

R^2= 0.102221 %CV= 48.03890 LSD= 667.7

EIGHT LEAF STAGE (Concentration level-2)

TABLE 6.37: Analysis of Variance of data for flowers formed as influenced by foliar spraying with different chemicals at concentration level two.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	178.6666667	44.6666667	0.54	0.7134
Error	10	834.6666667	83.4666667		
Corrected Total	14	1013.3333333			

R^2= 0.176316 %CV= 33.02172 LSD= 16.621

TABLE 6.38: Analysis of Variance of data for pods formed as influenced by foliar spraying with different chemicals at concentration level two.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	102.9333333	25.7333333	0.42	0.7896
Error	10	610.0000000	61.0000000		
Corrected Total	14	712.9333333			

R^2= 0.144380 %CV= 33.85946 LSD= 14.209

TABLE 6.39: Analysis of Variance of data for flowers that abscised as influenced by foliar spraying with different chemicals at concentration level two.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	17.60000000	4.40000000	0.49	0.7442
Error	10	90.00000000	9.00000000		
Corrected Total	14	107.60000000			

R^2= 0.163569 %CV= 65.21739 LSD= 5.4578

TABLE 6.40: Analysis of Variance of data for pods that abscised as influenced by foliar spraying with different chemicals at concentration level two.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	122.2666667	30.5666667	0.45	0.7720
Error	10	682.6666667	68.2666667		
Corrected Total	14	804.9333333			

R^2= 0.151897 %CV= 54.12029 LSD= 15.031

TABLE 6.41: Analysis of Variance of data for pods that matured as influenced by foliar spraying with different chemicals at concentration level two.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	5.06666667	1.26666667	0.09	0.9832
Error	10	139.33333333	13.93333333		
Corrected Total	14	144.40000000			

R^2= 0.035088 %CV= 47.85562 LSD= 6.7908

TABLE 6.42: Analysis of Variance of data for dry pod mass as influenced by foliar spraying with different chemicals at concentration level two.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	0.36423893	0.09105973	1.29	0.3364
Error	10	0.70424667	0.07042467		
Corrected Total	14	1.06848560			

R^2= 0.340893 %CV= 26.23853 LSD= 0.4828

TABLE 6.43: Analysis of Variance of data for seed number per pod as influenced by foliar spraying with different chemicals at concentration level two.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	0.46374427	0.11593607	0.35	0.8407
Error	10	3.34688267	0.33468827		
Corrected Total	14	3.81062693			

R^2= 0.121698 %CV= 29.34081 LSD= 1.0525

TABLE 6.44: Analysis of Variance of data for Dry seed mass per pod as influenced by foliar spraying with different chemicals at concentration level two.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	0.25922427	0.06480607	1.25	0.3513
Error	10	0.51857333	0.05185733		
Corrected Total	14	0.77779760			

R^2= 0.333280 %CV= 30.79822 LSD= 0.4143

TABLE 6.45: Analysis of Variance of data for yield per hectare (Kg) as influenced by foliar spraying with different chemicals at concentration level two.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	178050.2554	44512.5638	0.50	0.7399
Error	10	898585.6416	89858.5642		
Corrected Total	14	1076635.8970			

R^2= 0.165376 %CV= 44.14633 LSD= 545.35

EIGHT LEAF STAGE (Concentration level-3)

TABLE 6.46: Analysis of Variance of data for flowers formed as influenced by foliar spraying with different chemicals at concentration level three.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	304.0000000	76.0000000	1.81	0.2031
Error	10	419.3333333	41.9333333		
Corrected Total	14	723.3333333			

R^2= 0.420276 %CV= 20.44925 LSD= 11.781

TABLE 6.47: Analysis of Variance of data for pods formed as influenced by foliar spraying with different chemicals at concentration level three.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	211.6000000	52.9000000	1.39	0.3041
Error	10	379.3333333	37.9333333		
Corrected Total	14	590.9333333			

R^2= 0.358078 %CV= 22.86759 LSD= 11.205

TABLE 6.48: Analysis of Variance of data for flowers that abscised as influenced by foliar spraying with different chemicals at concentration level three.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	26.26666667	6.56666667	0.86	0.5217
Error	10	76.66666667	7.66666667		
Corrected Total	14	102.93333333			

R^2= 0.255181 %CV= 54.64884 LSD= 5.0373

TABLE 6.49: Analysis of Variance of data for pods that abscised as influenced by foliar spraying with different chemicals at concentration level three.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	201.0666667	50.2666667	1.10	0.4080
Error	10	456.6666667	45.6666667		
Corrected Total	14	657.7333333			

R^2= 0.305696 %CV= 36.46247 LSD= 12.294

TABLE 6.50: Analysis of Variance of data for pods that matured as influenced by foliar spraying with different chemicals at concentration level three.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	34.93333333	8.73333333	2.52	0.1076
Error	10	34.66666667	3.46666667		
Corrected Total	14	69.60000000			

R^2= 0.501916 %CV= 22.16546 LSD= 3.3873

TABLE 6.51: Analysis of Variance of data for dry pod mass as influenced by foliar spraying with different chemicals at concentration level three.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	0.08040760	0.02010190	0.93	0.4836
Error	10	0.21568200	0.02156820		
Corrected Total	14	0.29608960			

R^2= 0.271565 %CV= 13.86267 LSD= 0.2672

TABLE 6.52: Analysis of Variance of data for seed number per pod as influenced by foliar spraying with different chemicals at concentration level three.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	0.70257827	0.17564457	1.17	0.3789
Error	10	1.49585067	0.14958507		
Corrected Total	14	2.19842893			

R^2= 0.319582 %CV= 18.85664 LSD= 0.7036

TABLE 6.53: Analysis of Variance of data for dry seed mass per pod as influenced by foliar spraying with different chemicals at concentration level three.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	0.03828133	0.00957033	0.80	0.5539
Error	10	0.12013467	0.01201347		
Corrected Total	14	0.15841600			

R^2= 0.241651 %CV= 14.44084 LSD= 0.1994

TABLE 6.54: Analysis of Variance of data for yield per hectare (Kg) as influenced by foliar spraying with different chemicals at concentration level three.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	334776.0230	83694.0058	2.15	0.1491
Error	10	389772.6720	38977.2672		
Corrected Total	14	724548.6950			

R^2= 0.462048 %CV= 25.71302 LSD= 359.17

TWELVE LEAF STAGE (Concentration level-1)

TABLE 6.55: Analysis of Variance of data for flowers formed as influenced by foliar spraying with different chemicals at concentration level one.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	123.0666667	30.7666667	0.75	0.5785
Error	10	408.6666667	40.8666667		
Corrected Total	14	531.7333333			

R^2= 0.231444 %CV= 18.54750 LSD= 11.63

TABLE 6.56: Analysis of Variance of data for pods formed as influenced by foliar spraying with different chemicals at concentration level one.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	182.4000000	45.6000000	0.93	0.4836
Error	10	489.3333333	48.9333333		
Corrected Total	14	671.7333333			

R^2= 0.271536 %CV= 23.73949 LSD= 12.726

TABLE 6.57: Analysis of Variance of data for flowers that abscised as influenced by foliar spraying with different chemicals at concentration level one.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	40.00000000	10.00000000	1.85	0.1957
Error	10	54.00000000	5.40000000		
Corrected Total	14	94.00000000			

R^2= 0.425532 %CV= 46.47580 LSD= 4.2276

TABLE 6.58: Analysis of Variance of data for pods that abscised as influenced by foliar spraying with different chemicals at concentration level one.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	573.7333333	143.4333333	2.89	0.0789
Error	10	496.0000000	49.6000000		
Corrected Total	14	1069.7333333			

R^2= 0.536333 %CV= 31.34745 LSD= 12.813

TABLE 6.59: Analysis of Variance of data for pods that matured as influenced by foliar spraying with different chemicals at concentration level one.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	141.3333333	35.3333333	6.24	0.0088
Error	10	56.6666667	5.6666667		
Corrected Total	14	198.0000000			

R^2= 0.713805 %CV= 34.00680 LSD= 4.3307

TABLE 6.60: Analysis of Variance of data for dry pod mass as influenced by foliar spraying with different chemicals at concentration level one.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	0.04443173	0.01110793	0.39	0.8112
Error	10	0.28476667	0.02847667		
Corrected Total	14	0.32919840			

R^2= 0.134969 %CV= 16.67164 LSD= 0.307

TABLE 6.61: Analysis of Variance of data for seed number per pod as influenced by foliar spraying with different chemicals at concentration level one.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	1.86410240	0.46602560	2.29	0.1319
Error	10	2.03944733	0.20394473		
Corrected Total	14	3.90354973			

R^2= 0.477540 %CV= 25.20290 LSD= 0.8216

TABLE 6.62: Analysis of Variance of data for dry seed mass per pod as influenced by foliar spraying with different chemicals at concentration level one.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	0.06819640	0.01704910	0.65	0.6404
Error	10	0.26268600	0.02626860		
Corrected Total	14	0.33088240			

R^2= 0.206105 %CV= 24.69916 LSD= 0.2949

TABLE 6.63: Analysis of Variance of data for yield per hectare (Kg) as influenced by foliar spraying with different chemicals at concentration level one.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	1203822.983	300955.746	6.07	0.0096
Error	10	496136.083	49613.608		
Corrected Total	14	1699959.066			

R^2= 0.708148 %CV= 39.38473 LSD= 405.23

TWELVE LEAF STAGE (Concentration level-2)

TABLE 6.64: Analysis of Variance of data for flowers formed as influenced by foliar spraying with different chemicals at concentration level two.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	257.7333333	64.4333333	3.79	0.0398
Error	10	170.0000000	17.0000000		
Corrected Total	14	427.7333333			

R^2= 0.602556 %CV= 15.19572 LSD= 7.501

TABLE 6.65: Analysis of Variance of data for pods formed as influenced by foliar spraying with different chemicals at concentration level two.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	171.7333333	42.9333333	5.96	0.0102
Error	10	72.0000000	7.2000000		
Corrected Total	14	243.7333333			

R^2= 0.704595 %CV= 11.90805 LSD= 4.8816

TABLE 6.66: Analysis of Variance of data for flowers that abscised as influenced by foliar spraying with different chemicals at concentration level two.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	58.26666667	14.56666667	2.73	0.0900
Error	10	53.33333333	5.33333333		
Corrected Total	14	111.60000000			

R^2= 0.522103 %CV= 50.20437 LSD= 4.2014

TABLE 6.67: Analysis of Variance of data for pods that abscised as influenced by foliar spraying with different chemicals at concentration level two.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	131.6000000	32.9000000	6.17	0.0091
Error	10	53.3333333	5.3333333		
Corrected Total	14	184.9333333			

R^2= 0.711608 %CV= 19.13868 LSD= 4.2014

TABLE 6.68: Analysis of Variance of data for pods that matured as influenced by foliar spraying with different chemicals at concentration level two.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	25.73333333	6.43333333	1.40	0.3029
Error	10	46.00000000	4.60000000		
Corrected Total	14	71.73333333			

R^2= 0.358736 %CV= 20.49135 LSD= 3.9019

TABLE 6.69: Analysis of Variance of data for dry pod mass as influenced by foliar spraying with different chemicals at concentration level two.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	0.03955573	0.00988893	0.25	0.9015
Error	10	0.39139867	0.03913987		
Corrected Total	14	0.43095440			

R^2= 0.091786 %CV= 17.11697 LSD= 0.3599

TABLE 6.70: Analysis of Variance of data for seed number per pod as influenced by foliar spraying with different chemicals at concentration level two.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	2.46781160	0.61695290	1.41	0.3006
Error	10	4.38669400	0.43866940		
Corrected Total	14	6.85450560			

R^2= 0.360028 %CV= 27.68207 LSD= 1.2049

TABLE 6.71: Analysis of Variance of data for dry seed mass per pod as influenced by foliar spraying with different chemicals at concentration level two.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	0.03560173	0.00890043	0.23	0.9146
Error	10	0.38502467	0.03850247		
Corrected Total	14	0.42062640			

R^2= 0.084640 %CV= 22.98202 LSD= 0.357

TABLE 6.72: Analysis of Variance of data for yield per hectare (Kg) as influenced by foliar spraying with different chemicals at concentration level two.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	207006.1882	51751.5470	0.35	0.8387
Error	10	1481283.1008	148128.3101		
Corrected Total	14	1688289.2890			

R^2= 0.122613 %CV= 35.50423 LSD= 700.19

TWELVE LEAF STAGE (Concentration level-three)

TABLE 6.73: Analysis of Variance of data for flowers formed as influenced by foliar spraying with different chemicals at concentration level three.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	71.06666667	17.76666667	0.31	0.8633
Error	10	568.66666667	56.86666667		
Corrected Total	14	639.73333333			

R^2= 0.111088 %CV= 23.66422 LSD= 13.719

TABLE 6.74: Analysis of Variance of data for pods formed as influenced by foliar spraying with different chemicals at concentration level three.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	132.9333333	33.2333333	0.85	0.5263
Error	10	392.0000000	39.2000000		
Corrected Total	14	524.9333333			

R^2= 0.253239 %CV= 23.13174 LSD= 11.39

TABLE 6.75: Analysis of Variance of data for flowers that abscised as influenced by foliar spraying with different chemicals at concentration level three.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	16.40000000	4.10000000	0.43	0.7840
Error	10	95.33333333	9.53333333		
Corrected Total	14	111.73333333			

R^2= 0.146778 %CV= 63.44403 LSD= 5.6172

TABLE 6.76: Analysis of Variance of data for pods that abscised as influenced by foliar spraying with different chemicals at concentration level three.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	170.2666667	42.5666667	0.78	0.5612
Error	10	543.3333333	54.3333333		
Corrected Total	14	713.6000000			

R^2= 0.238602 %CV= 39.62965 LSD= 13.41

TABLE 6.77: Analysis of Variance of data for pods that matured as influenced by foliar spraying with different chemicals at concentration level three.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	5.06666667	1.26666667	0.15	0.9606
Error	10	86.66666667	8.66666667		
Corrected Total	14	91.73333333			

R^2= 0.055233 %CV= 34.77071 LSD= 5.3558

TABLE 6.78: Analysis of Variance of data for dry pod mass as influenced by foliar spraying with different chemicals at concentration level three.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	0.19354373	0.04838593	0.66	0.6316
Error	10	0.72946800	0.07294680		
Corrected Total	14	0.92301173			

R^2= 0.209687 %CV= 25.69480 LSD= 0.4914

TABLE 6.79: Analysis of Variance of data for seed number per pod as influenced by foliar spraying with different chemicals at concentration level three.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	1.27732533	0.31933133	0.75	0.5789
Error	10	4.24607200	0.42460720		
Corrected Total	14	5.52339733			

R^2= 0.231257 %CV= 32.90451 LSD= 1.1855

TABLE 6.80: Analysis of Variance of data for dry seed mass per pod as influenced by foliar spraying with different chemicals at concentration level three.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	0.17056693	0.04264173	0.68	0.6211
Error	10	0.62668667	0.06266867		
Corrected Total	14	0.79725360			

R^2= 0.213943 %CV= 32.96512 LSD= 0.4554

TABLE 6.81: Analysis of Variance of data for yield per hectare (Kg) as influenced by foliar spraying with different chemicals at concentration level three.

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Pr > F
Model	4	325653.2256	81413.3064	0.51	0.7290
Error	10	1591313.6160	159131.3616		
Corrected Total	14	1916966.8416			

R^2= 0.169879 %CV= 49.90401 LSD= 725.73