Effects of Ethephon on the Growth, Yield and Yield Components of Beans (*Phaseolus vulgaris* L.)

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ABSTRACT

Two experiments to determine the effects of timing and levels of application of ethephon on the growth and yield of common bean (*Phaseolus vulgaris* L). were conducted. Bean cultivar 'Mwezi moja' was used. Four levels of ethephon (0, 100, 200 and 300 mg/l) were sprayed to the plants at 7, 14 or at 28 days after emergence (DAE). Application of ethephon at all the three timings led to reduced plant height. Application of ethephon at 28 DAE reduced the leaf area index (LAI), fractional solar radiation interception, shoot dry mass and total dry mass. Root dry mass was not affected by ethephon application. Application of ethephon particularly at 28 DAE reduced yield and number of pods per plant. Application at 7 and 14 DAE in experiment 1 and 28 DAE in both experiments increased the number of seeds per pod. Ethephon application at 14 DAE increased the 100-seed mass in experiment 1 but reduced it in experiment 2. Most reduction in 100-seed mass occurred with application at 28 DAE. The harvest indices were reduced by application of ethephon at 28 DAE in both experiments and 14 DAE in experiment 1. It was concluded that ethephon (ethylene) application did not have any beneficial effects in bean production.

KEYWORDS: Beans; ethephon; growth; yield and yield components.

1.0 INTRODUCTION

Plant growth regulators (PGRs) have been proposed for commercial utilization in crop production to improve growth and development so as to increase the quantity and /or quality of crops (Emongor, 1997). The five major classes of phytohormones are auxins, gibberellins, cytokinins, abscisic acid and ethylene. Ethephon is commercially used as a precursor for ethylene. Ethephon (common name) is 2-Chloroethylphosphonic acid, rapidly breaks down in water to form ethylene, a Cl^- ion, and $H_2PO_4^-$ (Salisbury and Ross, 1992).

In legumes, ethylene has been shown to suppress stem elongation in some cultivars of soybean (*Glycine max*) (Bruce, 1990), pigeon peas (*Cajanus cajan*) (Hammerton, 1975) and beans (*Phaseolus vulgaris* L.) (Tozani *et al.*, 1978). Effects of ethylene on leaf area and number of leaves in beans is not well elucidated. Tozani *et al.* (1978) reported an increase in leaf area of beans upon application of ethephon at 18 and 38 days after germination. In contrast, concentrations of 2000 ppm applied at the 4 to 5 mature leaf stage have been shown to promote leaf abscission (Webster *et al.*, 1975) leading to reduced leaf area.

Ethephon applied during pod development has been shown to decrease seed yield per plant and seed weight in faba beans (Child and Yang, 1991). Similarly, ethephon application has been shown to decrease the seed size and seed yield of soybean (Grabau *et al.*, 1991). In contrast, yield increases have been reported in field beans (*Vicia faba* L.) (Jaiswal and Bhambie, 1989) and soybean (Bora and Bohra, 1989) following ethephon application. The yield increase was in part attributed to increase in pod set in pigeon peas (Hammerton, 1975) and faba beans (Jaiswal and Bhambie, 1989). In beans, late application of 1000 ppm ethephon led to higher yields (Forbes and Pratley, 1983). The influence of ethylene on growth and yield of common beans has not however been determined. The objectives of this study were, therefore, to determine the effects of timing and levels of application of ethephon on growth and yield of beans.

2.0 MATERIALS AND METHODS

Bean cultivar 'Mwezi moja' grown in East Africa was used. Two field experiments were conducted at the farm of University of Nairobi in 1997 (experiment 1) and 1998 (experiment 2). The annual average rainfall of the site is about 1000 mm. It has an annual mean temperature of 18°C, with the mean monthly temperatures varying between 14°C (in June) to 24°C (in February). The soil at the site is described as Humic Nitosol with kaolinitic clay minerals (Jaetzold and Schmidt, 1983). The soil is deep, well drained, dark reddish brown to dark brown in colour, friable clay. The soil had pH ranges from between 5.2 and 7.2 in topsoil and 5.2 to 7.7 in subsoil.

Beans were grown in a randomized complete block design with three replications in a split plot arrangement. Timing of application of ethephon (7, 14 and 28 days after emergence (DAE)) formed the main plots while levels of ethephon were allocated to the subplots. Ethephon was applied at 0, 100, 200 and 300 mg/l. Ethephon was applied on bean leaves in the morning between 0800 and 1000-h using a hand sprayer. Each subplot measured 3 m x 3 m with the furrows spaced 0.30 m apart. Diammonium phosphate (DAP) fertilizer was broadcast to provide N, P and K at the rates of 25 kg, 64 kg and 0 kg per hectare, respectively, and incorporated by raking before sowing. Beans were hands seeded in the rows at spacing of 0.15 m and covered with soil to a depth of 0.03 m. Routine cultural practices were maintained.

Data on plant height and leaf area index (LAI) was measured at 22, 32 and 57 DAE in both experiments. Fractional solar radiation interception measurements were made 16, 21, 47, 53 and 59 DAE. The beans were harvested 22, 32, 57 and 92 DAE and total dry mass, root dry mass and shoot dry mass determined. Plant height was determined on four plants in experiment 1 and three plants in experiment 2, randomly chosen in each plot.

The LAI of bean leaves was determined on ten fully expanded leaves selected from a sample of three bean plants randomly selected from each plot, using the specific leaf area method (Norman and Campbell, 1994). Using a cork borer, 40, 0.01m diameter discs were excised from the leaves, put into 0.164 m x 0.164 m envelopes. The remaining leaf portions in the envelopes were then dried in an oven (Model number TV80UL 508032, Memmert, Germany) at 66°C. After 72 hours the dry mass of the leaf discs and the total dry mass of the leaves were measured. The LAI was then calculated.

Fractional solar radiation interception measurements were made using a sunfleck ceptometer (SF 80 Decagon, Pulman, Washington) placed perpendicular to the rows of beans in experiment 2 only. An average of two readings on the intensity of radiation above the ground and five readings below the ground were made. Fractional solar radiation interception was computed as described in Norman and Campbell (1994).

Total dry mass, shoot dry mass and root dry mass were determined by the method described in Norman and Campbell (1994) on three randomly selected plants. Seed yield (g), number of pods and number of seeds per plant were determined at 92 DAE. The number of seeds per pod was calculated from the ratio of number of seeds per plant to the number of pods per plant. 100-seed mass was determined from the mass of three batches of 100 seeds from each plot. The mass of the seeds was determined after drying the seeds in an oven at 66°C for 72h. The harvest indices of three plants per plot were computed using the relationship: Harvest index = seed yield (g)/ total dry mass (g).

The data obtained from each experiment was subjected to analysis of variance using Systat computer software package (Wilkinson *et al.*, 1992). Multiple comparisons among means were determined using the protected least significant difference (LSD) at P= 0.05 as described by Steel and Torrie (1981).

3.0 RESULTS

Effect of ethephon on bean growth

Plant height differed significantly at all DAE following ethephon application. Increasing ethephon levels led to a decrease in plant height at the different DAE following ethephon application at 7 and 14 DAE in both experiments (Figure 1).

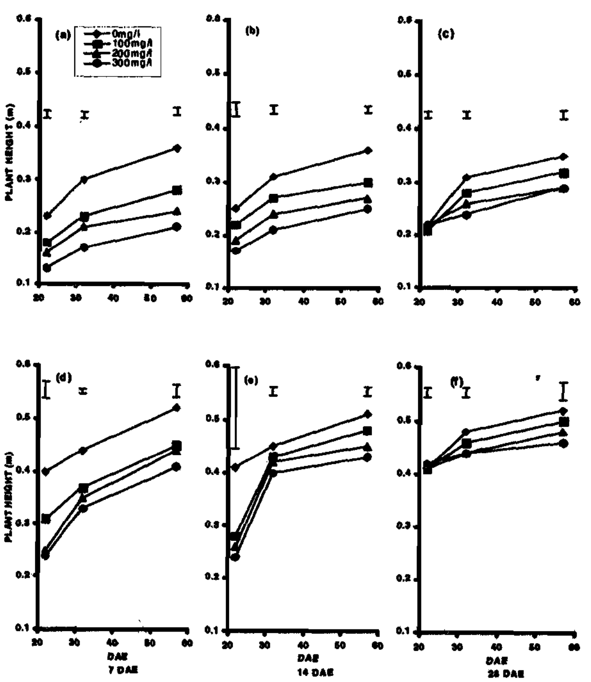

Figure 1. Effect of ethephon on plant height in experiment 1(a, b and c) and experiment 2 (d, e and f). Vertical bars are LSD ($_{0.05}$) bars. DAE = days after emergence

Similarly following ethephon application at 28 DAE increase in ethephon level led to a decrease in plant height at 32 and 57 DAE. However, there were no differences in plant height between beans treated with 200 and 300 mg/l ethephon.

LAI increased with the time of growth in all treatments attaining a maximum at 32 DAE and declining thereafter. The timing and level of ethephon had no effect on this trend (Figure 2). Late application of ethephon (28 DAE) lowered LAI.

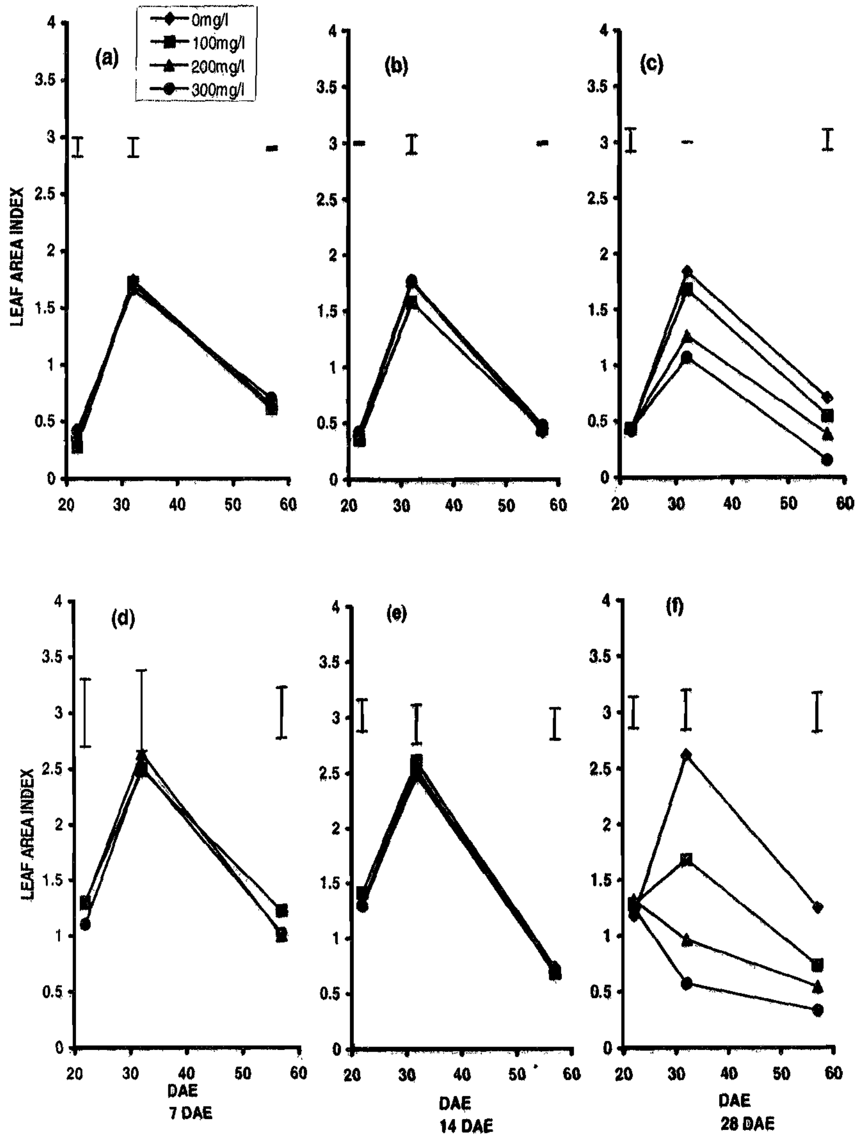

Figure 2. Effect of ethephon on leaf area index (LAI) in experiment 1(a, b and c) and experiment 2 (d, e and f). Vertical bars are LSD $_{(0.05)}$ bars. LAI = Leaf area index. DAE = days after emergence.

Solar radiation interception increased early in the growing season, decreased as the beans matured (Fig. 3). Timing or level of ethephon did not affect this trend.

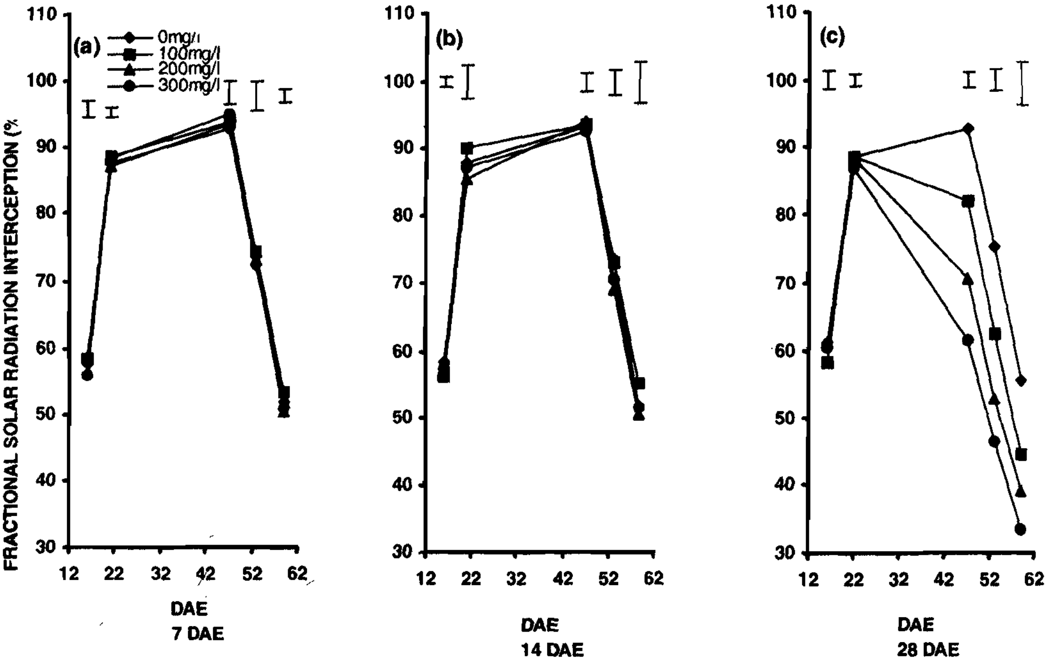

Figure 3. Effect of ethephon on fractional solar radiation interception in experiment 2 (a, b and c). Vertical bars are LSD ($_{0.05}$) bars. DAE = days after emergence.

Total dry mass increased throughout the growing season. Early application of ethephon (7 and 14 DAE) had no effect on total dry mass (Fig. 4). Late application of ethephon (28 DAE) tended to lower total dry mass, the higher the level the greater the effect.

Root dry mass increased early in the season, and decreased towards maturity (Fig. 5). Timing and level of ethephon had no effect on this trend. Shoot dry mass followed the same trend as total dry mass (Fig. 6).

Effect of ethephon on yield and yield components of bean

Increase in ethephon led to a significant decrease in bean seed yield per plant following applications at 7 DAE in experiment 1 (Table 1). However, the yield was less sensitive to ethephon since it showed only a significant quadratic response to ethephon level in experiment 2 (Table 2). It decreased with increase in ethephon level following application at 14 and 28 DAE in both experiments. The decrease in seed yield per plant was more pronounced at 28 DAE. The seed yield was twice much higher in experiment 2 than in experiment 1. The number of pods per plant was significantly reduced by increase in ethephon level when applied at 7 DAE in experiment 1 (Table 1). It was less sensitive to increase in ethephon level since it showed a significant quadratic response with no significant decrease occurring beyond 200 mg/l ethephon when applied at 7 DAE in experiment 2 (Table 2).

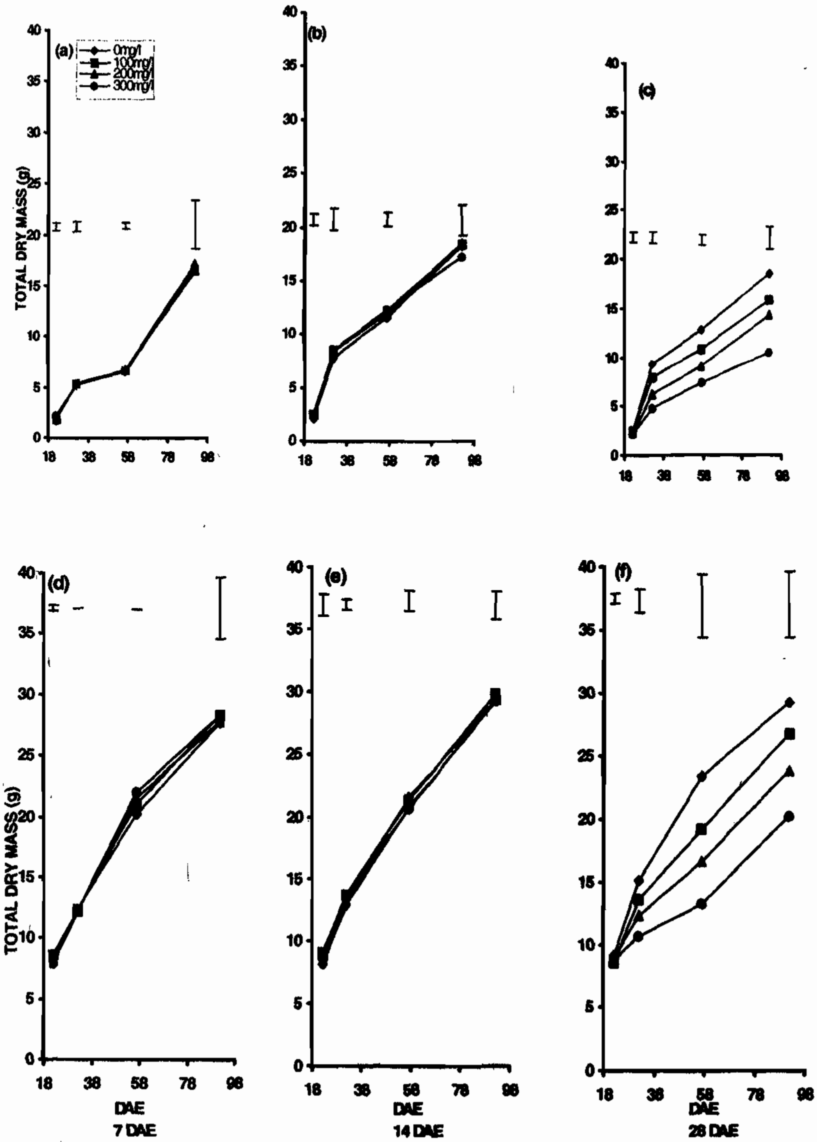

Figure 4. Effect of ethephon on total dry mass in experiment 1(a, b and c) and experiment 2 (d, e and f). Vertical bars are LSD ($_{0.05}$) bars. DAE = days after emergence.

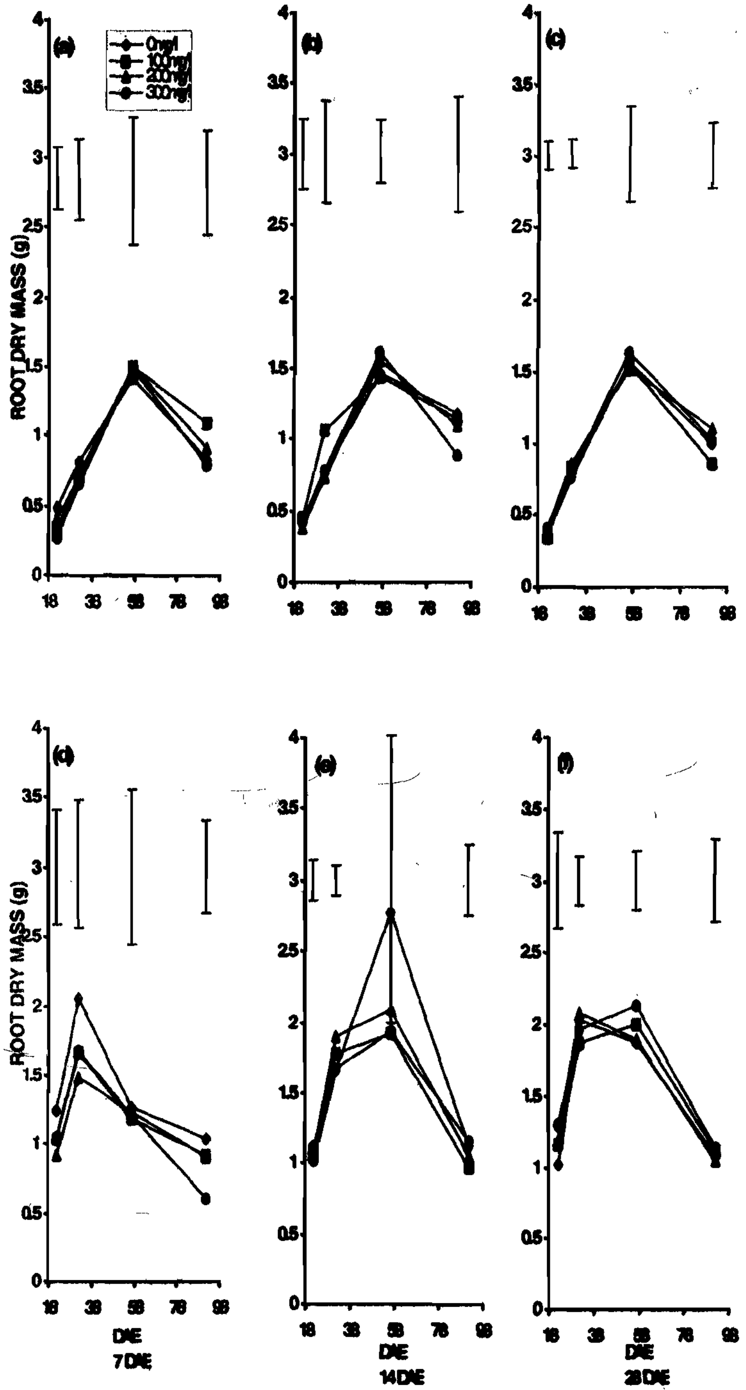

Figure 5. Effect of ethephon on root dry mass in experiment 1(a, b and c) and experiment 2 (d, e and f). Vertical bars are LSD ($_{0.05}$) bars. DAE = days after emergence.

The number decreased with increase in ethephon level following application at 14 and

28 DAE in both experiments. The decrease was more pronounced at 28 DAE. The number of pods was about twice greater in experiment 2 than in experiment 1.

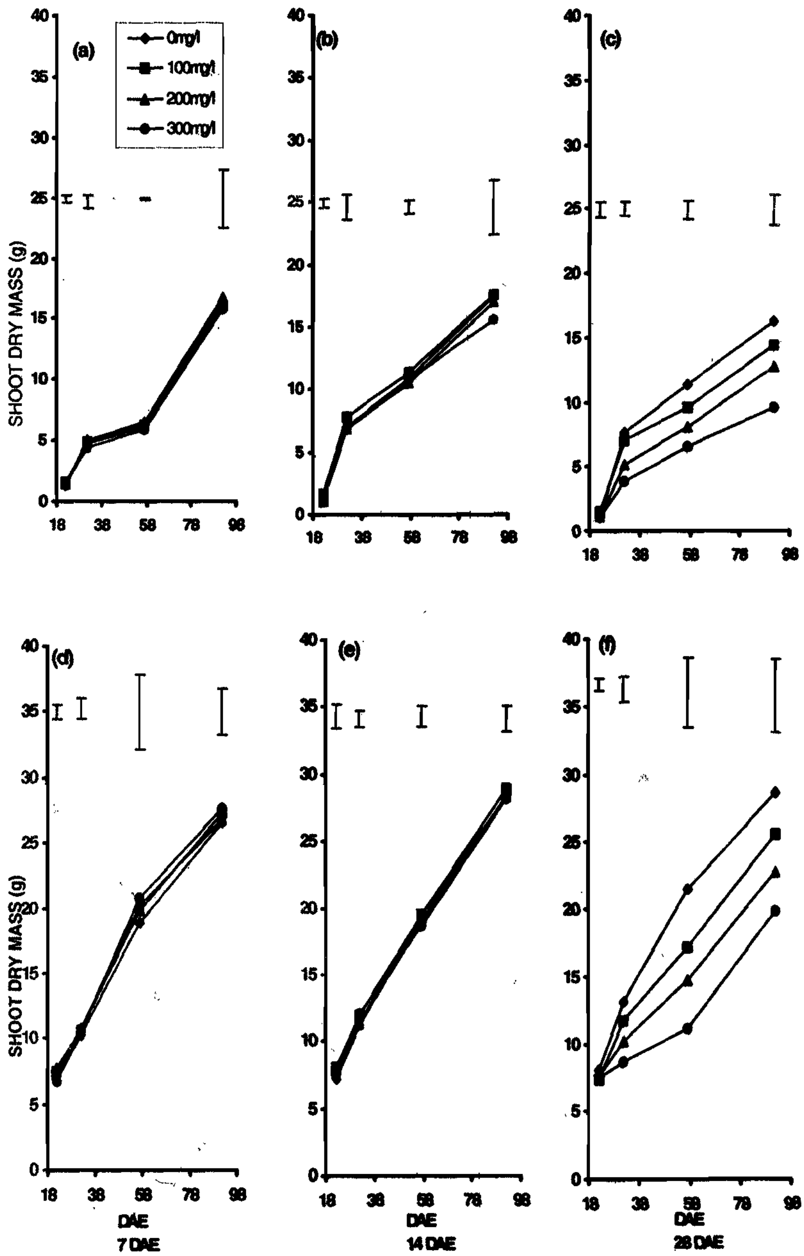

Figure 6. Effect of ethephon on shoot dry mass in experiment 1(a, b and c) and experiment 2 (d, e and f). Vertical bars are LSD ($_{0.05}$) bars. DAE = days after emergence.

When applied at 7 DAE, the number of seeds per pod increased with ethephon level, attaining a maximum at 200 mg/l and declining thereafter in experiment 1 (Table 1). However, ethephon level did not affect the number of seeds per pod when applied at 7 DAE in experiment 2 (Table 2). The number increased with increase in ethephon applied at 14 and 28 DAE in both experiments. However, the increase was more pronounced at 28 DAE.

One hundred seed mass (100-seed mass) showed a quadratic response with increase in ethephon levels applied at 7 DAE in experiment 1(Table 1). Application of ethephon at 7 DAE in experiment 2 had no significant effect on the 100-seed mass (Table 2). Application at 14 DAE increased the 100-seed mass in experiment 1 but reduced it in experiment 2. However, application at 28 DAE led to a decrease in 100-seed mass with increase in ethephon levels in both experiments.

The harvest index was lowered with increase in ethephon levels at 7 DAE in experiment 1 (Table 1). However, the index increased with increase in ethephon level when applied at 14 DAE. Application of ethephon at 7 and 14 DAE had no effect on harvest index in experiment 2 (Table 2). Increase in ethephon level, when applied at 28 DAE, led to significant reduction in harvest index.

Table 1. Effects of ethephon on seed yield per plant (g), number of pods per plant, number of seeds per pod, 100-seed mass and harvest index in experiment 1.

	SEED YIELD PER PLANT (g)			NUMBER OF PODS PER PLANT			NUMBER OF SEEDS PER POD			100-SEED MASS (g)			HARVEST INDEX		
Ethephon level (mg/l)	7 DAE	14 DAE	28 DAE	7 DAE	14 DAE	28 DAE	7 DAE	14 DAE	28 DAE	7 DAE	14 DAE	28 DAE	7 DAE	14 DAE	28 DAE
0	6.00	6.11	6.93	4.93	5.57	5.70	3.25	2.96	3.31	38.07	38.19	37.70	0.36	0.33	0.35
100	5.96	6.14	4.37	4.80	5.03	3.87	3.30	3.52	3.27	37.55	38.59	34.23	0.36	0.33	0.27
200	6.05	6.20	3.71	4.63	4.83	3.43	3.81	3.26	3.19	38.08	39.23	32.19	0.35	0.34	0.26
300	5.95	5.84	2.62	4.70	4.83	2.53	3.30	3.18	3.78	38.12	39.19	28.58	0.35	0.34	0.25
$LSD_{p \leq 0.05}$	1.82	1.12	0.69	1.60	2.67	1.38	2.99	0.82	1.22	1.76	1.82	2.68	0.02	0.02	0.04
Significance	L,Q	L,Q	L,Q	L,Q	L,Q	L,Q	Q	L,Q	L,Q	Q	L	L	L	L,Q	L,Q

L = Linear, Q = Quadratic (Significance at $P \leq 0.05$) and DAE = Days after emergence

Table 2. Effects of ethephon on the seed yield per plant (g), number of pods per plant, number of seeds per pod, 100-seed mass and harvest index in experiment 2

	SEED YIELD PER PLANT (g)			NUMBER OF PODS PER PLANT			NUMBER OF SEEDS PER POD			100-SEED MASS (g)			HARVEST INDEX		
Ethephon level (mg/l)	7 DAE	14 DAE	28 DAE	7 DAE	14 DAE	28 DAE	7 DAE	14 DAE	28 DAE	7 DAE	14 DAE	28 DAE	7 DAE	14 DAE	28 DAE
0	11.42	11.54	13.24	8.70	8.80	8.43	3.45	3.42	3.27	41.75	41.97	41.68	0.41	0.39	0.40
100	11.67	11.93	9.26	8.23	8.43	6.83	3.46	3.28	3.43	41.34	41.53	39.45	0.41	0.40	0.31
200	11.52	11.54	7.15	8.40	8.23	5.70	3.37	3.37	3.33	41.29	41.54	37.40	0.42	0.39	0.27
300	11.59	11.59	5.54	8.70	8.33	4.53	3.46	3.28	3.80	41.49	41.87	33.49	0.41	0.39	0.25
$LSD_{p \leq 0.05}$	1.60	1.00	1.95	1.94	1.38	1.91	1.26	0.98	1.96	2.56	2.45	2.92	0.02	0.02	0.03
Significance	Q	L,Q	L,Q	Q	L,Q	L,Q	ns	L	L,Q	Ns	L	L,Q	ns	ns	L,Q

L = Linear, Q = Quadratic, ns = not significant (Significance at $P \leq 0.05$) and DAE = Days after emergence

4.0 DISCUSSON

Ethephon can be translocated throughout the plant and it is therefore widely used to promote flowering in pineapples (Nickell, 1979). It is also used in various aspects of horticulture such as fruit production (Emongor, 1997). Ethylene initiates fruit ripening and regulates many aspects of plant growth, development and senescence (Abeles *et al.*, 1992).

Growth and development of plants occurs as a result of increase in dry mass accumulation (Bleasdale, 1984) and change individual organ, cell or whole plant form, anatomy and morphology. Characteristics such as leaf area development and leaf area duration affect the rate of plant dry mass accumulation (Weber *et al.*, 1966). The present study showed a decrease in total dry mass when ethephon was applied at 28 DAE. It was further observed that differences in total dry mass were mainly accounted for by the shoot dry mass. Increase in shoot and root dry mass results from increase in carbon fixation (Bleasdale, 1984). Plants with high carbon fixation rates show increase in stem girths, plant heights and high LAI. In this study increase in ethephon level, especially at 28 DAE reduced plant heights and decreased LAI. Ethephon has been reported in most species to reduce stomatal aperture and photosynthesis (Pallas and Kays, 1982) hence reduction in carbon fixation. The decrease in LAI in response to late ethephon treatment may be attributed to the role of ethylene in senescence and leaf abscission. Ethylene promotes chlorophyll degradation and promotes leaf abscission (Emongor, 1997). The decrease in LAI after 32 DAE was because of ethephon induced accelerated onset of senescence leading to leaf abscission in beans. As plants age they show increased senescence and abscission of leaves (Bleasdale, 1984) leading to low LAI and lowered light interception. A similar trend was observed in beans in this study.

Senescing of leaves is accompanied by translocation of dry mass to other plant parts and hence does not affect the total dry mass of the plant. The results of this study showed that minor decreases in root dry mass with increase in ethephon level only occurred when ethephon was applied at 7 DAE. The results further showed that the contribution of root dry mass to the total dry mass was less pronounced at 28 DAE. This suggests that changes in shoot dry masses are more sensitive to changes in ethephon when applied after 7 DAE than changes in root dry mass. Ethephon has been shown to reduce root dry weight in cowpea (Adedipe and Omrod, 1977). The decrease in root weight at 57 or 92 DAE observed in the present study could partly be attributed to remobilization of assimilates from the various plant parts towards the reproductive structures. Similar observations have been made in beans (Coulson and D Souza, 1989).

The yield of a plant depends on its growth and development (Stephenson and Wilson, 1977) which in turn will depend on dry mass accumulation. Dry mass accumulation in many legumes may affect yield by determining rate of podset, seedset, and dry mass accumulation in seeds. This study showed that yields per plant decreased with increase in ethephon level when applied at 28 DAE. The yield decreases could have occurred due to decrease in LAI, number of pods per plant, 100-seed mass and harvest index induced by ethylene.

Accumulation of dry mass in harvested portions (seeds) or partitioning of dry mass towards the harvested portions may affect increase in yield of a plant. Harvest index has been used to indicate translocation of photoassimilates from other plant parts to the seeds (Child and Yang, 1991). High harvest indices in plants indicates higher efficiency in translocation of photoassimilates from other plant parts including roots, shoots and leaves (Gardner *et al.*, 1985) towards the seeds. The lower yield per plant observed in this study at high ethephon levels could partly be due to the less accumulation of dry mass to the seeds and due to less translocation of dry mass from other plant parts.

Ethylene has been found to increase the number of seeds per 100 pods in pigeon peas (Chanekar *et al.*, 1996). In this study beans treated with ethephon tended to have a higher number of seeds per pod. It is possible that ethylene reduced seed abortion and hence led to increased seedset. It is also likely that less number of pods per plant could have led to a reduced demand for available assimilates and hence leading to increased seedset. However, benefits of an increased number of seeds per pod were outweighed by decreases in number of pods per plant and 100-seed masses and harvest index leading to lower yields.

Experiment 2 beans realized a higher dry mass and yield in comparison to those of experiment 1. This could be attributed to differences in agro-climatic factors, especially rainfall, which was higher during experiment 1. It is possible that the excess water could have led to loss of nutrients through leaching or water logging. It may have inhibited metabolism and led to production of toxic substances that interfere with normal root functioning (Fitter and Hay, 1987) due to gaseous imbalance and also led to prevalence of root diseases. Photosynthesis may have been reduced by the prolonged cloudiness. The yield increase was mainly due to high number of pods per plant, mainly due to increased pod set in experiment 2. This may be due to the increased shoot dry mass and a higher LAI resulting in increased photosynthetic area exhibited by the plants with higher shoot dry mass.

Ethephon application reduced bean yield in this study through its effects on both growth and yield components. Increasing levels of ethephon particularly when applied at the later stage of development (28 DAE) led to a decrease in plant height, LAI, shoot and total dry mass. These decreases may have led to reduced number of pods per plant, 100-seed mass and harvest index which translated to reduced yields. From this study ethephon application does not have any beneficial effects in bean production.

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REFERENCES

Abeles F.B., Morgan P.W. and Saltveit Jr.M. (1992). Ethylene in plant biology, p.1- 35. Academic Press Inc., London.

Adedipe N.O. and Omrod D.P. (1977). Effects of 2-chloroethyl trimethylammonium chloride (CCC) and 2-chloroethyl phosphonic acid (CEPA) on dry matter distribution in the cowpea (*Vigna unguiculata* L.). *Annals of Botany*, 41, 69-74.

Bleasdale J.K.A. (1984). Plant physiology in relation to horticulture, p. 25-136. Broadbent L. (editor). Macmillan press, London.

Bora K.K. and Bohra S.P. (1989). Effect of ethephon on growth and yield of Glycine max L. *Comparative physiology and ecology*, 14, 74 – 77.

Bruce A.P. (1990). The use of plant growth regulators to enhance yield and production efficiency of soybean (*Glycine max* L. Merrill). *Dissertation abstracts international. B, sciences and engineering*, 51, 2678B.

Chanekar M.A, Deotale R.D., Yewale A.K. and Sorte N.V. (1996). Influence of Ethrel on yield and yield contributory parameters of pigeon pea. *Journal of soils and crops*, 6, 169 - 172.

Child R.D. and Yang W.Y. (1991). Improvement in shoot structure of faba bean using plant growth regulators. Aspects of applied biology. 27, 173-178.

Coulson C.L. and Dsouza H.A. (1989). Quantitative analysis of dry matter production and distribution in relation to economic yield under different watering levels in beans (*Phaseolus vulgaris* L.). *Tropical agriculture (Trinidad and Tobago)*, 65, 179-181.

Emongor V.E. 1997. The prospective of plant growth regulators in Kenyan agriculture. *In:* Proceedings of national horticulture seminar. Jomo Kenyatta university of agriculture and technology, Kenya, p. 227-229.

Fitter A.H. and Hay R.K.M. (1987). Environmental physiology of plants. Academic press, London.

Forbes J.J. and Pratley J.E. (1983). The use of desiccant defoliant and growth regulating sprays to advance the harvest of edible dry beans (*Phaseolus vulgaris* L.) in Tasmania. *Australian journal of experimental agriculture and animal husbandry*, 23, 426 – 428.

Gardner F.P., Pearce R.B. and Mitchell R.L. (1985). Physiology of crop plants, p.164-186. Iowa State University Press, Ames.

Grabau L.J., Pearce R.C. and Konsier J.V. (1991). Influence of ethephon on lowest pod height and yield of soybean. *Agronomy journal*, 83,175- 177.

Hammerton J.L. (1975). Effect of growth regulators on pigeon pea (*Cajanus cajan*). *Experimental agriculture*, 11, 241-245.

Jaetzold R. and Schmidt H. (1983). Farm management handbook of Kenya, p.147-176. Natural conditions and farm management information part c. East Kenya. Ministry of Agriculture, Kenya and GTZ.

Jaiswal P.K and. Bhambie S. (1989). Effect of growth regulating substances on podding and yield of *Vigna radiata* (L.) wilczek (mungbean). *Acta botanica indica*, 17, 54-58.

Nickell L.G. (1979). Controlling biological behavior of plants with synthetic plant growth regulating chemicals, p. 263-279. American Chemical Society, Washington D. C.

Norman J. M. and Campbell G.S. (1994). Canopy structure. In: Plant physiological ecology; field methods and instrumentation (Pearcy, R.W.; Ehleringer, J.; Mooney, H.A. and

Rudel, P.W. eds.). Chapman and Hall, London. Glascow. N.Y. Tokyo. Melbuome-Madras.

Pallas J.E. and Kays S.J. (1982). Inhibition of photosynthesis by ethylene; a stomatal effect. *Plant physiology*, 70, 598- 601.

Salisbury F.B. and Ross C.W. (1992). Plant Physiology, 4th edition, p 377-399. Wadsworth, Belmont, California.

Steel G.D.R. and Torrie J.H. (1981). Principles and procedures of statistics. A biometrical approach. Mc Graw Hill book company, London, UK.

Stephenson R.A. and Wilson G.L. (1977). Patterns of assimilate distribution in soybean at maturity. II. *Australian journal of agricultural research*, 28, 395- 400.

Tozani R., Robitaille M.A., Vieira C. and Sediyama C.S. (1978). Crop physiology abstracts 4, 214.

Webster B.D., Craig M.E. and Tucker C.L. (1975). Effects of ethephon on abscission of vegetative and reproductive structures of *Phaseolus vulgaris* L. *Hortscience* 10, 154 – 156.

Weber C.R., Shibles R.M. and Byth D.E. (1966). Effect of plant population and row spacing on soybean development and production. *Agronomy journal*, 58, 99- 102.

Wilkinson L., Hill M.A, Welma P.J. and Birkenbeuel K.J. (1992). SYSTAT for windows: statistics version 5. SYSTAT, Inc., Evanston, IL, USA.