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Evaluating the Effectiveness of Organic Foliar Fertilizer on Bean (*Phaseolus Vulgaris L*) Production in Makonde District of Zimbabwe

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Abstract

High cost of inorganic fertilizer has prompted some agro-chemical industries in Zimbabwe to develop organic foliar fertilizers that are claimed by the producers to be used in common bean production as a substitute for the soil applied chemical fertilizers. A field experiment was carried out in Makonde district to evaluate the potential of organic foliar fertilizer as an alternative to soil applied chemical fertilizer in the production of common beans. A randomized complete Block Design (RCBD) with three treatments, replicated three times in three blocks was used resulting in a total of 27 experimental plots. The results of the study showed that organic foliar fertilizer had no statistically significant effect on the emergence of the plants as well as the number of days to flowering though the number of days to emergence were less than the other treatments. Soil applied chemical fertilizers had significantly higher number of flowers per plant, number of beans per pod, pod length, bean seed mass and the final yield per hectare than the other treatments. Although foliar fertilizers had higher number of flowers per plant, pods per plant, pod length, seed mass and yield, these were not statistically significantly different from the control. The new organic foliar fertilizer that has just been produced cannot therefore be use in Zimbabwe as a substitute for the soil applied chemical fertilizer as has been envisaged but as a supplement to the soil applied chemical fertilizers.

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For the foliar fertilizer to be used as a substitute for the soil applied granular chemical fertilizers, there is need for strict formulation of the nutrients that are required for crop production that are currently absent in the fertilizer or further research on the frequency or timing of application that will result in high yields.

***Keywords**:* effectiveness; evaluating; foliar; organic; production

1. Introduction

Common bean (*Phaseolus vulgaris* L) is one of the important legumes in Zimbabwe. It is grown for its green leaves, green pods and dry seeds. The dry seeds are the ultimate economic part of the bean plant [1]. Millions of people in sub-Saharan Africa depend on the crop as a primary staple cultivated largely by women [8]. Due to increasing population and starvation in the developing countries, common beans are appreciated throughout the developing world because of their long storage life, excellent nutritional properties and ease of storage and preparation [13, 17].

In Zimbabwe the major limiting factor to high productivity in smallholder farming is high cost of chemical fertilizers among other contributing factors such as high cost of fertilizer transportation, full soil analysis ($25/plot), lack of adequate technical know-how. Some farmers especially small scale and communal farmers tend to spread the little fertilizers they have on large areas or do cropping without any fertilization due to lack of finance.

The use of foliar fertilizers started a few years back and is known to produce good results and it was promoted by industrialization. As a result of high costs and environmental hazards posed by use of inorganic fertilizers [9] there is mass campaign of launching the use of foliar fertilizers which work to produce similar results to inorganic fertilized crops [23]. The use of alternative fertilizer application strategies to achieve maximum yields and to enhance nutrient use efficiency has been proposed for decades. Often a combination of broadcast and band applications coupled with foliar applications can provide optimum nutrient uptake in low soil fertility conditions [18].

However, under current reduced tillage systems that is currently being advocated for, with high yield potential [15], broadcast nutrients can remain on the soil surface, limiting root contact on soils where the soil surface may have been compacted through wheel traffic. This means that alternative action must be considered [21]. This may be corrected through some combination of starter and foliar fertilizer application, fertilizer rate adjustment of both macro and micronutrients. Previous work by [16] showed that direct application of P and K to soybeans can have a significant impact on soybean yield. On the other hand, in maize, fluid fertilizer placed in a band near the seed at planting has frequently shown positive effects on yield [24].

Foliar nutrients are mobilized directly into a plant leaf, which is the goal of fertilization to begin with, increasing the rate of photosynthesis in the leaves, and by doing so stimulate nutrient absorption by plant roots [4]. Foliar fertilization is by far the most effective way to apply micro nutrients or trace elements, and supplement the major elements. The readily available nutrients are more easily utilized, because they do not have to be dissolved by moisture and go into the soil solution. In addition, foliar fertilization can correct deficiencies, strengthen weak or damaged crops, speed growth and grow better plants, which are of course, the bottom line [5].

Research to date on the effectiveness of foliar application under rain fed conditions has not been systematic, with research occurring in temporally and spatially isolated pockets. The majority of the research has occurred in the US [4] and only a small body of work has been published for plants grown in dry land cropping systems [6, 2].

In Zimbabwe, there is limited research that has been carried out to show the effectiveness of the organic foliar fertilizer on crops. This research investigates the effect of organic foliar fertilizer on rain fed sugar bean production in Zimbabwe. The manufacturers of the organic fertilizers claim that it replaces convectional use of solid fertilizers whilst achieving similar or a higher yield than chemical fertilizers.

1.1 Statement of the problem

Smallholder farmers in Makonde district have been growing sugar beans for many years but realizing low yields of about 0.5-0.85t ha^{-1}. This could be attributed to lack of adequate income to purchase inorganic manure, or use of kraal and poultry manures as a substitute which have very low nutrient content for example cattle manure have chemical composition of N-0.5%, P_20_5-0.2% and K_20-0.5% whilst poultry have N-1%,P_20_5-0.8% and K_20 0.4%, which require bulk applications of 24 t/ha and 20t/ha respectively and sometimes they are available in small quantities to small holder farmers.

1.2 Justification of the study

Since there are low yields of sugar beans recognized by farmers due to high cost of production, unavailability of manures, there is need to find out cheaper alternatives to boost production and offers a reduction in damage to ecosystem.

2. Methods and materials

The study was carried out in ward ten of Makonde District in Mashonaland West province. The area falls under the agro-ecological region 2a which is characterised by mean annual rainfall of 750-1000mm per annum and temperatures of 15-29^{0}C. Frost occurrence is common in June and July in the low lying areas and the area is cool with occasional winds. The soils are red clays that are slightly acidic. The altitude of the study area is 1380 m and there is a savannah type of woodland.

2.1 Research Design

The trial was set out in a Randomised Complete Block Design (RCBD) with three treatments and three replicates. The area was divided into 3 blocks along the gradient as the blocking factor. The treatments were composed of D.I Grow foliar fertiliser, granular chemical (compound D and AN) and lastly the control where no fertiliser was applied for both basal and top dressing. Each bed was $0.45m^2$ (0.9m×0.5m) and composed of 20 plants which means each treatment had 180 plants and the whole trial had 540 plants.

2.2 Land preparation and planting

The land was disc ploughed and harrowed to a fine tilth. Plots were marked just before planting in December. The plot sizes were 0.9*0.5m with rows of beans spaced at 45cm and in row spacing of 5cm. Planting furrows were opened using hoes at 45cm spacing and 5cm in row spacing for all the treatments. Planting of beans was done on the 10^{th} of December 2013. Seed rate of 80kg ha^{-1} was used. A basal dressing of compound D (7%N, 14%P_2O_5, and 7% K_20) was applied at a rate of 300kg ha^{-1}. Seed fertiliser contact was avoided by covering the fertiliser slightly with soil before placing the bean seed.

Two bean seeds were dropped onto the planting stations and were later thinned to one plant per planting station at two weeks after crop emergence (WACE). The beans were top dressed with 150kg ha^{-1} Ammonium Nitrate (34.5%) at 4 WACE in chemical fertiliser treatments only. For foliar organic fertiliser treatments, the bean seeds were pre-soaked in D.I Grow green for three hours before planting at 3ml/litre. At 15^{th} day after crop emergence, D.I Grow green was applied as crop booster at a rate of 4litre per hectare. On the 45^{th} day after emergence, D.I Grow red was applied at a rate of 4litre/ha as top dressing. For the control, no fertiliser was applied to the plots.

Watering was done twice per week when there was no rainfall and removal of weeds was carried out manually when necessary. Scouting for pests and dieses were done and routine sprays of Dimethoate$^{(R)}$, and Copper-oxy Chloride$^{(R)}$ were carried out for the control of insect pests and fungal diseases respectively. At 2-3 WACE Dimethoate (40EC) was used to control aphids and red spider mites at a rate of 75ml/100 of water per hectare. As for the fungal protection, copper oxychloride was applied three times as full cover spray at 2kg ha^{-1} to control bacterial (*Ascochyta*) blight during flowering.

2.3 Measurements

Measurements were taken from the net plot area and these were number of days to germination, number of days to flowering, number of pods per plant, number of bean seed per pod, 1000 bean weight, bean grain yield and yield per hectare were measured. A net plot measuring 0.9*0.2m consisting of two middle bean rows and 0.45m from either edges of the field were used and ten plants were randomly selected. Sugar beans pods were harvested when they were brown and rattling within the pod but before they shattered.

A hundred seeds were weighed and then converted to determine 1000 grain weight. Moisture content was measured for each bean sample using a moisture metre and the final bean grain yield was standardised to 11% moisture content. Bean grain yield were expressed in kg/ha before analysis of Variance (ANOVA). Data for the experiment was subjected to ANOVA using GENSTAT version 7. Mean comparisons were done using the Least Significant Difference (LSD) at $P< 0.05$.

3. Results and discussions

3.1Effect of foliar fertiliser on number of days to germination

There was no significant difference (P=0.065) in germination of sugar bean between bean seeds treated with inorganic fertiliser and those applied with foliar fertiliser though the longest period to germination was obtained in the control experiment. Chemical fertiliser treatment took (3.6) days to germination. Faster germination was obtained on the foliar treatment (3.4) (Fig 1) and the control took the longest time before germination though not statistically different from the other treatments. From the results of the study, there was no statistically significant difference in the days to germination for all the treatments although the foliar treatment germinated faster. This could be because, the application of the foliar fertiliser involved soaking the bean seeds in the fertiliser solution. This means that the bean seed for the three hours they were soaked, they imbibed the water into the cotyledon, stimulating germination therefore the radical developed faster than the unsoaked bean seed in the control and the inorganic fertiliser treatment, hence quicker germination. The earlier though not significant period to germination is also similar to a research carried out by [20], in maize where they found out that pre-soaked maize seed germinated earlier compared to unsoaked maize.

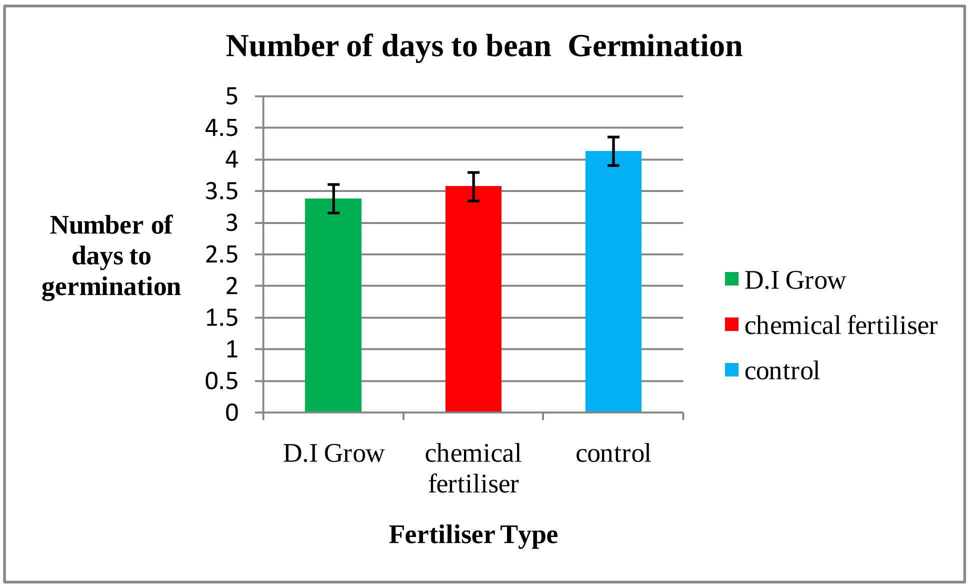

Fig 1: Effect of type of fertiliser on number of days to germination

3.2 Effect of fertiliser type on number of days to flowering

There was no significant effect (P>0.05) between foliar fertiliser and other treatments on number of days to flowering. The longer period to flowering were obtained in foliar treatments (34.30), while chemical fertiliser treatment had (33.98) days to flowering and the lowest number of days to germination was obtained in unfertilised treatment (33.59) though all of these results were not statistically significant.

Table 1. Effect of type of fertiliser on number of days to flowering

Treatment	Days to flowering
Foliar fertiliser	34.30[a]
Soil applied Chemical fertiliser	33.98[a]
Control	33.59[a]
P.Value	0.451
Sed	0.513
$LSD_{0.05}$	1.425

The results obtained in the study shows that there was no significant difference in number of days to flowering for the three treatments. Though not statistically significant, foliar fertiliser took a longer period of days to flowering than the other treatments. This is in contrast with research done by [23] where they found that use of foliar fertilisers in soyabeans production resulted in shorter days to flowering and early maturity compared to those plants that were not applied with foliar fertilisers. A longer period to flowering by foliar fertiliser could have been attributed to luxurious vegetative growth at the expense of flower initiation [12].

3.3 Effect of fertiliser type on number of flowers per plant

There was a significant difference at ($P<0.05$) between D.I grow foliar fertiliser and chemical fertiliser on number of flowers per plant. However, D.I Grow and control treatments were different but statistically similar (Fig 2). The highest number of flowers per plant was obtained in chemical fertiliser treatments (20.73), while foliar treatments achieved (16.34) flowers per plant and the control had (12.28) (Fig 2).

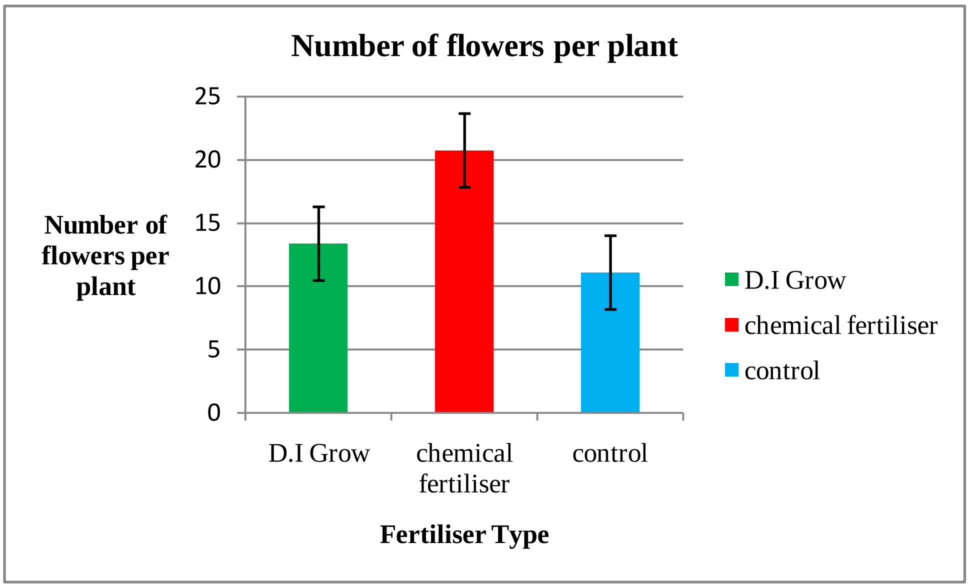

Fig 2: Effect of fertiliser type on number of flowers per plant

3.4 Effect of fertiliser type on number of pods per plant

There was a significant effect (P=0.002) between foliar fertiliser, chemical fertiliser and the control on number of pods per plant The highest number of pods per plant was obtained in a treatment applied with a chemical fertiliser (26.22), while foliar treatments had (16.34) pods per plant which were not significantly different from the control (12.28). Number of pods under foliar treatment was fewer by 37.68% than that of chemical fertiliser. However the number of pods was higher by 30.43% compared to control treatments though statistically not different (Table 2).

Table 2. Effect of type of fertiliser on number of pods per plant

Treatment	**Number of pods/plant**
Foliar fertiliser	16.34^{a}
Chemical fertiliser	26.22^{b}
Control	12.28^{a}
P.value	0.002
Sed	1.631
$LSD_{0.05}$	4.528

The results of the experiment indicate that foliar fertiliser has no statistically different effect on the number of pods compared to the control treatment. The results obtained are in contrast with the study by [16] where application of foliar fertilisation resulted in increased pod length in soyabeans. The timing of application could have been contributory towards the non significance of the treatment compared to the control since the foliar fertiliser was applied only twice after germination. This is supported by work by [22]which shows that applying foliar fertiliser three times, at shooting, flowering and podding stages increased the number of pods of the common beans compared to soil application. In another study with beans [3] found out that foliar application of Zinc increased the number of pods per plants of the common bean. This was also in line with the research of [26] in wheat who found out that foliar application of fertiliser in wheat increases the yield components of wheat. The chemical, soil applied fertiliser achieved the highest number of pods per plant probably because the amount of fertiliser that was applied was at optimum concentration and as well as applied at the right time than the foliar fertiliser that was applied once only.

3.5 Effect of fertiliser type on number of seeds per pod

There was no significant difference (P>0.05) between foliar fertiliser, chemical fertiliser and the control on number of seeds per pod. Chemical fertiliser had the highest number of seeds per pod (5.10), while unfertilised treatment had (4.18) seeds per pod and the lowest number of seeds per pod was obtained from foliar treatments (4.10). However all the treatments were not statistically significantly different.

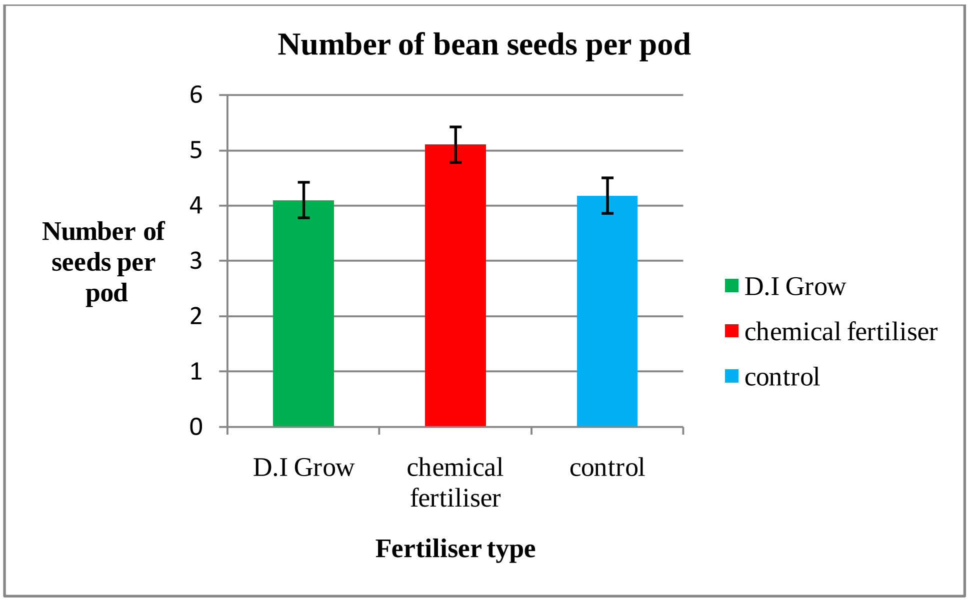

Fig 3: Effect of D.I Grow organic foliar fertiliser on number of seeds per plant

Soil applied chemical fertiliser treatment had more seeds (20%) than both the foliar treatment probably because it had more available source of plant nutrition. The control treatment had 1.91% more seeds than foliar treatment. The results are in contrast with the work of [22] who found out that foliar application of fertiliser was 44.47% superior compared to the control and when applied in three applications it resulted in an increase in number of seeds per pod by 37.1% compared to the control. The reduction in the number of seeds per pod in the foliar treatment can also be attributed to the inadequate application as well as the rainfall conditions during the rainy season that could have led to the loss of some nutrients that were applied to the bean plants [9].

3.6 Effect of fertiliser type on pod length

Type of fertiliser treatment had a significant effect (P=0.003) on pod length. The highest pod length was obtained in chemical fertiliser treatment (12.39cm), while foliar treatment came second with (7.95cm) pod length. The lowest pod length was obtained in unfertilised treatment (7.61cm) (Table 3). However foliar treatment had statistically similar pod length to the control treatment.

Table 3. Effect of fertiliser type on bean pod length

Treatment	Pod length (cm)
Foliar fertiliser	7.95^{a}
Chemical fertiliser	12.39^{b}
Control	7.61^{a}
P.Value	0.003
Sed	0.643
$LSD_{0.05}$	1.784

The results clearly show that foliar treatment had no statistically significant difference from the control experiment in bean pod length. However there is a 4.46% increase in pod length in the foliar treatment compared to the control. This is in line with research done by [11] which revealed that total leaf wax of field-grown cotton leaves increased significantly in size by use of foliar fertiliser in the cotton crop than the control which correspondingly has led to an increase in pod length.

3.7 Effect of type of fertiliser type on bean seed mass

There was a significant difference at ($P<0.05$) between foliar fertiliser treatment, chemical fertiliser and the control on seed weight. Chemical fertiliser treatment had the highest mass (5.73g), while foliar had (3.71g) and the lowest mass was recorded from the control treatment (3.11g). Although control and foliar treatment are not statistically different, these were lower than the chemical treatment (Fig 4). This could be the fact that in chemical fertilisers there were adequate nutrients that would be responsible for the grain filling process than in either the control or the foliar fertiliser.

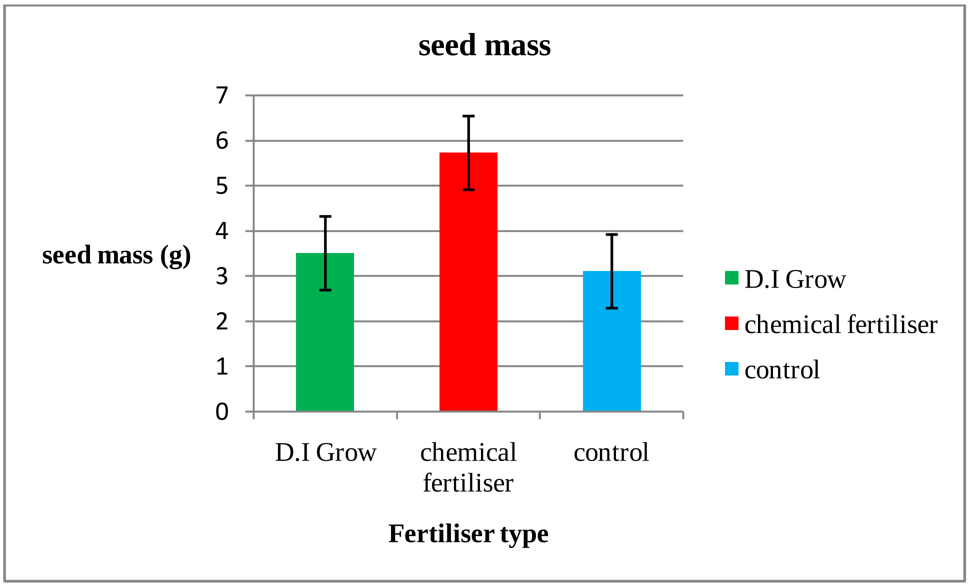

Fig 4: Effect of D.I Grow organic foliar fertiliser on seed mass

3.8 Effect of D.I Grow foliar fertiliser on bean yield per hectare

There was a significant difference ($P=0.001$) between foliar fertiliser, inorganic chemical fertiliser and the control treatment on bean yield per hectare. The highest yield per hectare was obtained from the chemical treatment (2 165) kg, while foliar treatment had (849) kg. The lowest yield was obtained in the control treatment (584) kg per hectare. Although the control had the lowest yields, these were not statistically significantly different from the foliar treatment (Table 4).

Soil applied chemical fertiliser treatment exceeded D.I grow foliar and the control in yield by 143% and 287% respectively. This is in line to the research by [23] who indicated that soil application of nutrients increased the yield of beans by 13.2% compared to the control experiment. This is in contrast to most researches done where foliar fertilisers would increase yield by less than 100% compared to chemical fertilisers (Sarkar e*t al*, 2007) compared to soil application only. In another related study, Faiyad (2005) showed that foliar application of micronutrients boosts the yields of sunflower significantly. The trend in the quantity of yields that were obtained in the three treatments corresponds to the other yield parameters that have been measured that are pod length, number of seeds per pod and the number of pods per plant.

Table 4: Effect of D.I Grow organic foliar fertiliser on yield per hectare

Treatment	Yield/ha^{-1} (kg)
Foliar fertiliser treatment	849^{a}
Chemical fertiliser	2165^{b}
Control	584^{a}
P.Value	0.001
Sed	157.8
$LSD_{0.05}$	438.1

4. Limitations of the study

The study concentrated on one season which was the rainy season only. It could have also been done during the winter season as the common bean can also be grown during the winter season where it will be used as green beans. The soil type that was use was also similar and the study could also have been done on different soil types to evaluate the effectiveness of the inorganic fertiliser.

5. Conclusion and recommendations

The results of the study has shown that the organic foliar fertiliser cannot compete equally with the soil applied fertilisers since the yields obtained were far less than those of the soil applied chemicals although the bean seeds under the foliar treatment have managed to emerge earlier compared to the control and the soil applied treatments.

From the results obtained from this study farmers are recommended to use the organic foliar fertiliser as a nutrient supplement rather than as the basic fertiliser as is envisaged. More research need to be carried out with various application periods of the foliar fertiliser than the two times application that was applied to the beans.

More research need to be done on nutrient formulation of the D.I grow fertiliser that will compete with the soil applied chemical fertiliser therefore increasing yields.

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