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Growth and Yield Response of Green Beans (*Phaseolus vulgaris* L.) to Application of Nutriplant Organic Plus Fertiliser

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Abstract: Production of green beans in Zambia is still low despite high demand on local and the global market. With increasing prices in vegetable basal and top dressing fertilisers, use of alternative nutrient sources such as Nutriplant Organic Plus Fertiliser (NOPF) could reduce the cost of production and induce more smallholder farmers to engage in vegetable production. Contender a dwarf variety with self-support growth mechanism popularly grown by farmers was planted in a randomized complete block design with four replications and applied with inorganic fertiliser, NOPF and the combination of the two treatments. Plant height, leaf length, leaf width, number of branches per plant, number of pods per plant, pod length, pod mass and yield were assessed and analysed using GENSAT Eighteenth Edition. Treatment means were separated by using Turkeys LSD test at 5% confidence level. Results showed significant differences ($P \leq 0.05$) among the treatments for all parameters measured. The means of combined treatments and NOPF remained statistically the same. Green beans plants applied with NOPF recorded longer and wider leaves, and taller plants compared to the inorganic fertilisers. Similarly, NOPF plants recorded more branches than inorganic. Also, longer and heavier fresh pods were obtained from NOPF–treated plants than from inorganic fertiliser-treated plants, ultimately resulting into higher yield. Thus, the results suggest that use of organic fertiliser could double the yield of green beans and boost its production while encouraging environmental stewardship in agriculture production.

Keywords: Green Beans, Vegetables, Organic Fertiliser, Fresh Pods, Yield

1. Introduction

Green bean (*Phaseolus vulgaris* L.), is a legume vegetable grown worldwide for its edible unripe fruit. It plays a major role under soil fertility management as a rotational crop for fixing nitrogen [1-3]. It is one of the dominant important fresh vegetables exported from developing countries to high-value European markets [4]. On the list of food legumes grown in Zambia, green beans ranks second (after groundnuts) in terms of its economic importance and as a human nutrition [5, 6]. The freshly tender and immature pods of green beans are consumed either cooked, raw or processed, the leaves are used as green vegetables while the straw is used as folder.

In Zambia, the green beans production for export begun in the late 1980s following declines in the copper industry and liberalisation of foreign exchange controls [7]. Export rose from 0 to 4 000 tones from 1996 to 2002 [4]. The rise in export was due to commercial farming that established out-grower schemes in addition to their cultivated land which boosted production although production fall again in 2004 [4].

Although there has been an increase in export after 2004 of up to 213 tons by 2018 [8], production is low especially with an increasing local consumption (about 75 - 80% of the production) [8, 9] Average green beans yield of 0.83 to 2 t ha^{-1} are common among the smallholders when potential yields range from 10 to 20 t ha^{-1} [6, 10]. This situation may lead to failure by the country to sustain both export market and supply to the local consumers. Probably extension of green beans production from commercial farmers to smallholder farmers would increase its availability. However, several constraints are known to limit vegetable production; pests and diseases, soil fertility and water supply in the dry season.

Use of synthetic soil applied fertilisers to meet overwhelming demand is the quickest option to avert low soil fertility but the prices of these fertilisers have not only increased cost of production but also caused environmental pollution, decreased soil fertility and unattainable by smallholder farmers [11, 12]. Low nutrition availability limits the response of plants to exploit its full potential from early establishment, formation of yield components and the ultimate yield. This calls for new strategies which are farmer resource limited inclusive, direct feeding of plants and environmental friendly. Foliar feeding represents a useful technique for provision of mineral nutrition of plants despite being considered as a complementary feeding to soil fertiliser application [13-15]. Foliar nutrients are mobilised directly into the plant leaves and stems, which are the goal of fertilisation to begin with increasing the rate of photosynthesis in the leaves and by doing so, stimulate other nutrient absorption by plant roots [15]. Foliar organic fertilisers are friendly, cheap and potential source for supplying nutrients and can reduce dependence on expensive conventional chemical fertilisers [16, 17].

Several studies have shown that organic fertiliser promotes and boosts plant roots, stems and leaf growth, reproduction and improves the nutritional quality [17-20]. Shooshtari et al., (2020) reported higher cucumber plant heights when a dosage of 250 to 500 mg/plant of organic fertiliser were applied compared to inorganic fertilisers [21]. Pod numbers of green beans increased from 55 to 85, plant height by 19.57 to 23.08% and pod yield by 15 to 16% when organic fertiliser was applied compared to inorganic fertilisers [22]. In chili, Souri (2016) reported maximum plant heights, number of branches, leaf area, fruits and total yields when organic foliar application was applied compared to inorganic fertilisers [17]. Using broad beans, Jasin and Mhanna (2014) also found increased plant height of 15.88%, number of seeds per pod by 16.54% when organic fertiliser was applied compared to chemical fertilizers [17, 18]. Souri and Aslani (2018) testing the application of organic chelates on green beans found increased plant height, number of seeds per pod, number of pods per plant, pod length and pod quality compared to inorganic fertilisers [23]. It is evident from these studies, that organic fertilisers either applied as foliar or incorporated in the soil, can improve green beans growth and yield. Thus, organic foliar fertilisers present an opportunity for smallholder farmers to produce green beans dominated by commercial farmers and add to the foreign exchange the country receives from exports.

Use of organic fertiliser in food production is becoming a huge demand in the awake of high demand on the organic foods on the European market and NOPF is known for encouraging agriculture stewardship while maintaining crop productivity. According to Green World Zambia (2019) NOPF is composed of both micro and macro nutrients containing multiple small molecules of amino acids, peptides, chitosan chelate, and their chelate with trace elements is a kind of natural nutrition for plants. It is non-poisonous, non-toxic and safe for the environment which provides plants (vegetables, fruits, flowers, field crops, etc.) with various nutrients i.e macro (N, P, K, Ca, Mg, S) and micro (Fe, Zn, Cu, B, Mn, Mo, Na, Co, Cl). It promotes the growth of plant roots, stems and leaves, renews soils, boosts soil nutrients, retains flowers and fruits, improves the quality and flavour of the harvestable parts of crops significantly, enhances the drought resistance, infertility resistance, diseases and insect pest resistance of plants, helps the seeds germinate faster and stronger, improves soil structure and enhances the bioactivity of the soil [24]. In this study therefore, the effect of Nutriplant Organic Plus Fertiliser (NOPF), was evaluated on green beans growth and yield traits in order to encourage more production to meet the market demand.

2. Materials and Methods

2.1. Experimental Site

The research was carried out at Rusangu University Research Station in Monze during 2019/2020 growing season. The Research Station is located on 16.3808° S, 27.5244° E and 1, 279 meters above sea level. The soil in the site is Clay-loamy with soil pH by Calcium Chloride of 6.1 and organic matter of 3.2%. The field had been fallowed for over three previous seasons.

2.2. Experimental Design and Treatments

A Randomized Complete Block Design (RCBD) was used. The experiment comprised three treatments; NOPF with composition of 5.19 N: 0.05 P: 4.68 K: 0.017 Ca: 0.013 Mg: 0.43 Fe: 0.40 Zn: 0.18 Mn: 0.06 B: 0.00034 Cu: 0.00037 Mo (NOPF), in organic fertilisers (Veg mix A (0 N: 18 P: 15 K: 10 S: 0.01 B) as basal dressing and Veg Top 32 (21 N: 0 P: 32 K) as top dressing. The treatments were replicated four times.

2.3. Land Preparation and Planting

Prior to planting, existent shrubs were cleared off manually and land portion watered in readiness for tillage. Subsequently the land was tilled, hard soil clods thoroughly broken and raked to achieve a fine tilth. Treatment plots measured 1.8 m X 1.8 m and each had rows marked at spacing of 0.45 m. Planting furrows were dug to a depth of 10 cm. The green bean seeds were planted on the furrows at intra-row spacing of 10 cm and depth of 2 cm giving plant population of 72 per plot.

2.4. Agronomic Practices

2.4.1. Fertilisation

Fertiliser was applied to green beans according to the treatment. Treatment that received in organic fertilisers, the basal fertiliser was split applied at 5 g plant^{-1} at 7 days after planting and 10 g plant^{-1} at intervals of 14 days thereafter using Veg Top 32. NOPF was applied early morning on the first two weeks at rate of 5 mL L^{-1}, subsequent three weeks at 10 mL L^{-1} and later 20 mL L^{-1} was applied every after a week till the first harvest. The combination treatment was applied at the same time the individual treatments were applied. A 2 m plastic was enclosed each time the treatment plot received a foliar application to avoid spray drift to the adjust treatment plot.

2.4.2. Water Management

A 20 L bucket was used to apply water in treatment plots basing on crop growth stage water requirements. Two buckets per plot was used from 0 DAS to 20 DAS and thereafter, four buckets per plot from reproduction to harvesting crop stage.

2.4.3. Weed Management

Weeding was carried to achieve a weed free environment. A hand hoe was used for removal of weeds and was integrated with hand-pulling in-between plants where use of hoe would cause root and stem damage.

2.4.4. Pest Management

Farm guard (Cypermethrin) - insecticide was used to control yellow and red spider mites and fruit borers, Boxer (Lambda cyhalothrin) was used for control of white flies and aphids, while Diathane (Mancozeb) was used for control of fungal disease (anthracnose and powdery mildew) at a dosage rate of 2 g L^{-1} every seven days. Equally insecticides (Lambda and Cypermethrin) were applied for systemic and contact control of insects at rate of 1 mL L^{-1} each. Dosth, an adjuvant was used as a sticking agent each time the fungicide and insecticide was applied.

2.4.5. Data Collection

The following parameters were collected from the middle 2 rows per treatment plot on three tagged plants per row in the net area. The average of the six plants were recorded for the treatment plot. With the use of a measurement tape, plant height was the distance from soil surface up to growing point in centimeters (cm) at 10 day interval. The length and width of fully expressed mature leaves around the central portion of plant measured in centimeters (cm) at 10 day interval basing on the method of Chalwe (2013) [25]. The leaf width was carried at the widest part of the leaf. The numbers of formed primary branches were counted per plant on the last harvest date (60 days after sowing). Number of harvested pods per plant at 50 and 60 days after sowing were counted. The pod lengths of harvested green beans were measured in centimeters (cm) from the beginning point of stalk to the peak end of pods. Pod mass in grams was obtained for the pods after length was measured. To obtain green beans yield, all physiological mature pods that were harvested in the net area were cumulated and reported in tons per hectare**.**

2.4.6. Data Analysis

The collected data on growth, yield and yield components were compiled and analysed statistically using the GENSTAT 18th Edition. Data were subjected to analysis of variance (ANOVA) at 5% level of significance using General linear model procedure after the assumptions of ANOVA were tested. Finally, the means were separated using Turkeys LSD at 5% precision.

3. Results and Discussion

3.1. Effect of Fertiliser Application on Leaf Size of Green Beans

Leaf length of green beans applied with inorganic fertiliser remained short while those fertilised with Nutriplant Organic Plus Fertiliser (NOPF) and the combination with inorganic fertiliser were statistically the same and the longest during the assessment period. The leaves were 4.32% (10 DAS) to 15.90% (30 DAS) shorter in the inorganic fertiliser compared to the combination treatment which recorded longer leaves. The leaf length in inorganic fertiliser and NOPF remained statistically the same from 10 DAS to 30 DAS but different from 40 DAS to 50 DAS (Table 1). The leaves were 13.5% and 15.7% longer for plants applied with NOPF than those of inorganic fertilisers. Leaf growth in terms of width was not significantly influenced by the type of fertiliser applied at 10 DAS, 20 DAS and 50 DAS. However, leaf width of green beans in the inorganic fertilisers was 12.1% narrower than those in the combination treatment (8.958 cm) although there were the same with those in the NOPF at 30 DAS. At 40 DAS, leaves were wider by 11.34% and 7% in the combination treatment and NOPF, respectively compared to the inorganic fertiliser treatment (7.75 cm) though there were no significant difference between the width of leaves in the combination treatment and NOPF.

Table 1. *Effect of fertiliser application on leaf size of green beans.*

Treatment	Leaf length (cm)					Leaf width (cm)				
	10 DAS	20 DAS	30 DAS	40 DAS	50 DAS	10 DAS	20 DAS	30 DAS	40 DAS	50 DAS
Inorganic fertiliser	5.117 b	6.896 b	10.44 b	10.33 b	10.73 b	4.071	6.487	7.867 b	7.750 b	8.063
Organic fertiliser	5.238 ab	7.404 ab	11.16 ab	11.95 a	12.12 a	4.212	6.729	8.142 b	8.329 a	8.450
Combination	5.338 a	7.596 a	12.10 a	11.29 ab	12.35 a	4.237	6.817	8.958 a	8.742 a	8.462
Lsd $_{T(0.05)}$	0.1608	0.4439	1.224	0.884	0.603	0.2490	0.3143	0.5141	0.4153	0.5681
Level of significance	*	*	*	*	**	NS	NS	**	**	NS

DAS: Days after sowing, Means followed by the same letter at the same DAS are not significantly different at 5% probability level ($P < 0.05$) using Turkeys LSD test; NS: Non-significant at 5% probability level, * = Significant at 5% probability level, ** = Significant at 1% probability level

Obtained results contradict findings of Santosa *et al.,* (2017) and Aslani and Souri (2018) [12, 26]. Santosa *et al.,* (2017) found bigger leaves in inorganic fertilisers and smaller leaves in organic fertiliser when cow manure was applied [26]. In the Santosa *et al.,* (2017) study, all fertiliser were applied through the soil while in the current study the organic fertiliser was fed regularly and directly to the green beans through the leaves which resulted in higher nutrient uptake and translocation efficiency [26]. The results are comparable to Aslani and Souri (2018) where bigger leaves that ranged between 11.5 to 12.9 cm^2 compared to smaller leaves of 10.3 cm^2 in inorganic applied fertilisers were reported in all foliar organic applied green beans [12]. Current study obtained smaller leaves compared to the finding of Aslani and Souri (2018) because the nutrient composition in the organic fertilisers in their study was higher than those found in NOPF [12].

3.2. Effect of Fertiliser Application on Plant Height of Green Beans

Plant growth in terms of plant height were significantly affected by the fertiliser application (Table 2). Apart from at 20 DAS, when plant heights remained statistically the same, fertiliser application influenced plant heights. Plants increased in heights from 10 – 50 DAS but those applied with NOPF and the combination treatment remained tallest and statistically the same, while those with inorganic fertiliser were shortest with a range of 5.44% (7.042 cm) at 10 DAS to 12.82% (29.38 cm) at 40 DAS. At 30 DAS, the heights of the plants in the inorganic fertiliser were statistically the same with those in NOPF.

Table 2. *Effect of fertiliser application on plant height of green beans.*

Treatment	10 DAS	20 DAS	30 DAS	40 DAS	50 DAS
Inorganic fertiliser	7.042 b	10.675	22.03 b	29.38 b	35.28 b
Organic fertiliser	7.346 a	11.215	23.57 ab	33.13 a	37.45 a
Combination	7.425 a	11.235	24.54 a	33.14 a	37.61 a
Lsd $_{T(0.05)}$	0.2074	0.5173	1.562	1.443	0.875
Level of significance	**	NS	*	**	**

DAS: Days after sowing, Means followed by the same letter at the same DAS are not significantly different at 5% probability level (P < 0.05) using Turkeys LSD test; NS: Non-significant at 5% probability level, * = Significant at 5% probability level, ** = Significant at 1% probability level

Similar results were reported by Kamble *et al.,* (2016) who found taller green beans when inorganic and organic fertilisers were combined compared to the treatments separately [27]. According to Fernandez and Ebert (2005), applying plant nutrients though the foliar results in better fertiliser efficiency and improved plant growth than soil application [14]. The finding of the study implies that NOPF can be used as an alternative to support the growth of green beans over the use of inorganic fertilisers. The results in current study contradict findings of Santosa *et al.,* (2017) who reported taller green beans plants in inorganic fertilisers than organic fertilisers in lower rates of organic fertilisers compared with higher rates of inorganic fertilisers [26]. However, lower rates of inorganic fertiliser produced statistically same plant heights like those produced by green beans fertilised with high rate of organic fertilisers in the study of Santosa *et al.,* (2017) in both years [26].

3.3. Effect of Fertiliser Application on Yield Components of Green Beans

Freshly harvested pods statistically remained the same at 50 DAS and 60 DAS for the plants in NOPF and the combination treatment but longer than those in the inorganic fertilisers (Table 3). Fresh pods in plants applied with inorganic fertilisers were 16.89% and 9.67% shorter than those of NOPF at 50 DAS (17.34 cm) and 60 DAS (17.24 cm), respectively. Obtained results in the study agrees with findings of Aslani and Souri (2018) Kamble *et al.,* (2016), Ranjbar-Moghaddam and Aminpanah (2015) who reported the shortest pod length in inorganic fertiliser applied green beans [12, 22, 27]. The longer pods indicate availability of nutrients to support the pod growth and may entail quality of green beans.

Table 3. *Effect of fertiliser application on yield components of green beans.*

Treatment	Pod length (cm)		Branch	Pod numbers		Total pod mass (kg)	
	50 DAS	60 DAS	Numbers	50 DAS	60 DAS	50 DAS	60 DAS
Inorganic fertiliser	14.86 b	15.72 b	2.792 b	18.83	21.5	1.421 b	1.585 b
Organic fertiliser	17.34 a	17.24 a	3.388 a	21.67	23.6	1.924 a	2.266 a
Combination	16.64 a	17.07 a	3.394 a	19.58	23.8	1.919 a	2.123 a
Lsd $_{T(0.05)}$	0.902	1.073	0.287	8.50	7.87	0.3902	0.368
Level of significance	**	*	**	NS	NS	**	**

DAS: Days after sowing, Means followed by the same letter at the same DAS are not significantly different at 5% probability level (P < 0.05) using Turkeys LSD test; NS: Non-significant at 5% probability level, * = Significant at 5% probability level, ** = Significant at 1% probability level

Plants in the combined treatment and NOPF produced 21.56% and 21.35%, respectively more branches than the inorganic fertiliser treated plants (2.792) (Table 3). However, the number of branches per plant in the NOPF were statistically similar to those in the combination treatment. Although the number of branches in plants is determined by genetic make-up, this study found significant differences among the fertiliser treatments. The results offer an option of using NOPF to increase the number of branches that may bear harvestable pods. Just like in this study, applying different rates of inorganic fertilisers resulted in different numbers of branches per green bean plant [28, 29]. Sitinjak and Purba (2018) reported more branching of 8.9 when chicken manure was applied [29]. However, the 8.9 branches are more than the 3.4 branches found in this study. The less branches obtained in this study could be attributed to differences in the quantity of fertiliser applied. The improvement in number of branches also indicates availability of nutrients to support yield components.

No significant differences in number of pods per plant were found among the different fertilisers in the study at the two harvesting dates (Table 3). No consensus has been reached by scientists on the effect of organic fertilisers on number of pods per plant [12, 22, 26-27]. Ranjbar-Moghaddam and Aminpanah (2015) reported 16% more pods when organic fertiliser was applied compared to inorganic fertiliser; Santosa *et al.,* (2017) found 20 - 42% few pods in organic fertilisers than inorganic fertiliser; Kamble *et al.,* (2016) found more pods in the combination treatment and Aslani and Souri (2018) found same number of pods in both organic and inorganic fertilised green beans [12, 22, 26-27]. Obtained results are in agreement with the findings of Aslani and Souri (2018) who did not find significant differences among inorganic fertiliser and various organic fertilisers [12].

Mass of freshly harvested pods for plants treated with inorganic fertilisers, were lighter by 35.40% and 42.97% than those produced by plants fertilised with NOPF which were 1.924 kg and 2.266 kg at 50 DAS and 60 DAS harvesting dates, respectively (Table 3). Total pod mass at the two harvesting dates revealed significant differences among the different fertilisers applied. This could be attributed to the shorter pods which were 9.67% and 16.89% compared to NOPF and combination treatment, respectively. Similar results have been reported by Aslani and Souri (2018) who attributed the pod mass improvement to high bioavailability of nutrient elements to support pod development [12].

3.4. Effect of Fertiliser Application on Yield of Green Beans

Green beans applied with NOPF and the combination of the treatments statistically remained similar and higher with yields of above 4 t ha^{-1} (Figure 1). However, the yield of green beans applied with inorganic fertiliser (2.856 t ha^{-1}) were 51.08% and 43.28% lower than the green beans yields in the NOPF and the combination treatment, respectively. This yield differences are attributed to improvement effects; heavier total pods, high number of branches and longer pods of organic fertiliser applied green beans. Finding in this study is in conformity with Aslani and Souri (2018), Kamble *et al.,* (2016), Ranjbar-Moghaddam and Aminpanah (2015) who reported the highest green pod yield per hectare either due to organic fertiliser alone or the combination of inorganic and organic fertilisers [12, 22, 27]. These results demonstrate that use of NOPF can improve yield components and ultimately the green beans yield.

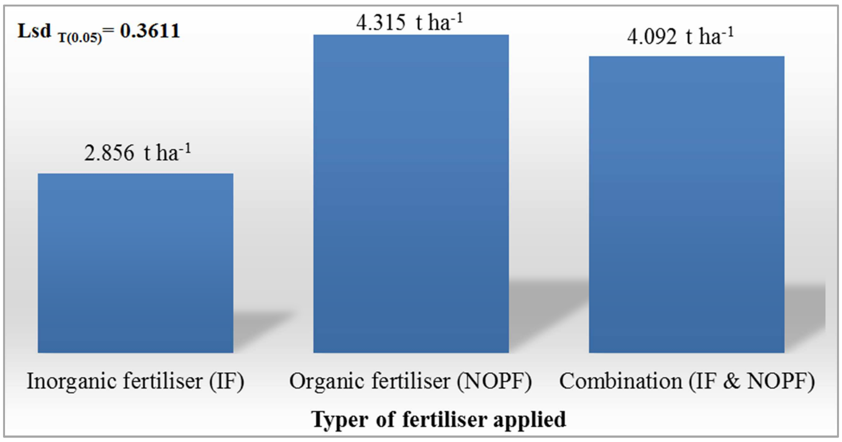

Figure 1. *Effect of fertiliser application on green beans yield.*

4. Conclusion

Basing on obtained results in this study, it was concluded that application of organic bio-fertiliser improved the growth and yield of green beans. NOPF the foliar organic fertiliser appear effective and could be an alternative for growing and producing more green beans than the inorganic fertiliser. The results imply that NOPF is an alternative option for smallholder farmers growing beans for dual purpose selling of fresh pods and leaves as green vegetables as leaves were wider and longer. Results further imply that by using organic fertilisers like NOPF, a cheaper source of plant nutrition agriculture stewardship is encouraged and advanced while maintaining crop productivity.

5. Recommendations

In the next studies of verifying the effect of this Nutriplant plus fertiliser the foliar organic bio-fertiliser, both indetermine and determine green beans varieties and seasons be included. Further an economic analysis be carried to determine the opportunity costs of foliar fertiliser and application of granular fertilisers.

Authors Contributions

Study conception, writing, revision and submission to Journal by Mushekwa Sakumona, execution and data collection by Malambo Mambo Mweene, data study design and data analysis by Able Chalwe and manuscript review and editing by Rasmus Masinja.

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