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Effects of Nitrogen application on snap beans production in Koibatek district Kenya

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Abstract

Snap bean (*Phaseolus vulgaris* L.) ranks first among vegetables produced for the export market in Kenya. All Snap beans were planted in different treatments containing various levels of Nitrogen of Calcium Ammonium Nitrate (CAN) Treatments T_1- T_2 had IgN,1.5gN, 2.0gN, 2.5gN, 5gN, 10gN and 15gN respectively while T_8 was inoculated with *Rhizobium*. The control T_9 lacked nitrogen. All were supplied with equal amounts of phosphorus fertilizer (5.5g) single super phosphate per plant. The effects of different levels of nitrogen were determined on the vegetative growth, seed and pod production and nodulation. It was found that an increase in nitrogen application increased vegetative growth, dry matter production, seed and pod production. Increased Nitrogen application had a negative effect on nodulation. T_1 which had the least level of nitrogen application managed to modulate moderately and also had high yields and dry matter production as compared to the control. However, inoculation alone had best nodulation but seed production, vegetative growth and dry matter production was low compared to the treatment with least nitrogen indicating that the nitrogen fixed through nodules was not enough for maximum production. From this study, it can be recommended that 22kg N/ha would be economical for snap beans production.

Keywords: Phaseolus vulgaris; Nitrogen; Phosphorous; Rhizobium; Nodulation

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1. Introduction

French bean (*Phaseolus vulgaris* L.) is the most important export vegetable in Kenya accounting for over 60% of all exported vegetables and about 21% by value of the horticultural exports (Nderitu et al, 2007a). It ranks second after cut flowers in terms of volume and value among export crops (Nderitu et al, 2007b). In Kenya, the crop ranks first among vegetables produced for the export market and accounts for a significant proportion of total horticultural exports (HCDA, 2009). In 2009, and 29,923 MT valued at KES 4.2 billion was marketed to various destinations as fresh produce and processed products (HCDA, 2009). Snap beans are crops with great potential for addressing food insecurity, income generation and poverty alleviation in the region (Ugen et al., 2005). The main source of income among the youth and women in the rural is small scale farming of snap beans (Ndung'u et al., 2004; Monda et al., 2003).

French bean occupies an important position among the various pulses and vegetable crops grown in Kenya. It is a valuable source of proteins, carbohydrates, calcium, iron, phosphorus and vitamins particularly vitamin B (Gopalan*et al*., 1982). It is an important vegetable grown both for tender pods and dry seeds, which form a rich source of crude protein (21.25%), fat (1.7%) and carbohydrates (70%). Besides, it contains 0.16 mg iron, 1.76 mg calcium and 3.43 mg zinc per 100 g of edible part. They require less energy to cook since they are consumed as vegetables and are rich in vitamins, minerals and dietary fibre (Kelly and Scott, 1992; Ndegwa*et al*., 2006). Compared to dry beans, snap beans have a high market value, mature much earlier and have longer harvest duration (Ugen *et al*., 2005).

Area for French bean farming has greatly reduced because of changes on the agronomic practices although exports from Kenya have been the same (Voor den Dag, 2003) suggesting that agronomic practices have been changing. Despite of the high sensitivity of french beans Nitrogen responds well for its growth (Shushant*et al*, 1999). This response may help in the popularization of the cultivation of French bean as a crop among farmers. Keeping in view these facts, the present investigation was carried out to study the effect of different levels of nitrogen on the growth yield components and yields of French bean. Snap beans lack NOD genes, hence it does not have nodulation and this makes them poor in symbiotic nitrogen fixing (Kushwaha, 1994). Because of this poor nodulation in snap beans, nitrogen and phosphorus is greatly needed for good establishment of roots, nodulation and growth (Ssali and Keya, 1986). Potassium is of great importance to increase nitrogenase activity which results to high levels of uricides in pod walls and good seed partitioning increasing seed production (Thomas and Hungaria, 1988). Therefore, the present study was to investigate fertility levels for snap beans and determine the effect and dosage of different levels of nitrogen, phosphorus and potassium on growth and yield.

2. Materials and methods

2.1. Research design

The study was a complete randomized designed with nine individual treatments each replicated twenty times giving a total of 1870 plants. The result was evaluated by comparing the percentage performance of the treatment with the control.

2.2. Sample size

Seed of *Phaseolus vulgaris* were obtained from Kenya seeds branch in Nakuru Kenya. The seeds were first germinated in Petri dishes lined by moistened filter paper and germinated seeds (radicles size 1-2 mm) were transplanted into polythene bags which were filled with soil having different levels of fertilizer. A few seeds (about 25 were inoculated with commercial inoculums (B1oFix) or mixed strains obtained from Kenya Agricultural research institute. The inoculum was administered by placing 8g of the inoculums in 10mls of water and then pouring it on the germinated seeds just before planting.

The sowing was done on 15th September 2010 in black polythene bags of size 22.5 X 15.5cm perforated with a few holes each about 16mm sq. each bag was filled 1Kg soil having 5.5g of single phosphate (P_2O_5) fertilizer as a source of phosphorous and different amount of calcium ammonium nitrate (CAN) to provide different levels of nitrogen as described below in treatment 1-7. The fertilizer (CAN) was used as a source of nitrogen it is the most common and widely used by farmers. It contains 26% nitrogen was added after calculating the amount of CAN containing the required nitrogen e.g. 1g N=3.8g CAN and then weigh it out. The fertilizer was then mixed out thoroughly with the soil before filling the bags with the treatment as follows:

- Treatment 1 (T_1); each plant was supplied with 1g of nitrogen and 5.5g of single super phosphate (P_2O_5).
- Treatment 2 (T_2); each plant was supplied with 1.5g of nitrogen and 5.5g of single supper phosphate (P_2O_5).
- Treatment 3 (T_3); each plant was supplied with 2.0g of nitrogen and 5.5g of single super phosphate (P_2O_5).
- Treatment 4 (T_4); each plant was supplied with 2.5g of nitrogen and 5.5g of single super phosphate (P_2O_5).
- Treatment 5 (T_5); each plant was supplied with 5.0g of nitrogen and 5.5g of single super phosphate (P_2O_5).
- Treatment 6 (T_6); each plant was supplied with 10g of nitrogen and 5.5g of single super phosphate (P_2O_5).
- Treatment 7 (T_7); each plant was supplied with 15g of nitrogen and 5.5g of single super phosphate (P_2O_5).
- Treatment 8 (T_8); the seed were inoculated with *Rhizobium* inoculum just before planting and they were planted in bags containing 5.5g single super phosphate (P_2O_5).
- Treatment 9 (T_9); no nitrogen was supplied but only 5.5g single super phosphate. It was the control. The bags were placed in the field selected by Mogotio farmer's society in Koibatek (MFS).

Other cultural practices including weeding, pest and disease control and irrigation were conducted in a similar manner in all the treatments during the experimental period.

2.3. Data collection

Collection of data was taken at flowering stage when maximum number of flowers per plant was observed and maturity stage when pods were fully developed. Five plants per treatment were sampled for each parameter as follows:

- Flowering stage:-Leaf area (cm^2), Leaf fresh weight(g),Leaf dry weight (g), Stem and branch fresh weight(g)Stem and branch dry weight (g),Nodule fresh weight (mg), Nodules dry weight (mg),Root length(cm), Root dry weight and number of flower buds.
- Maturity stage: -Root length(cm) , root dry weight(g), Shoot dry weight(g), Shoot length(cm), Number of pods, Pod fresh weight(g), Pod dry weight and Seed dry weight(g). Each dry weight was attained by placing the samples in an oven at 80^{o}C for 48 hours after which the dry weights were recorded.

3. Results

The plants in treatments 5, 6, 7 that is the treatment having 5.0g or more nitrogen per plant germinated and then died off after a few days. The cause was established to be the scorching by the fertilizer. At flowering stage variation in different parameter due to different treatment was as follows:

Table 1. leaf area (cm2), fresh weight g/ plant and leaf dry weight g/ plant at flowering

Average leaf area (cm2/ plant)				Average leaf fresh weight g/ plant			Average leaf dry weight g/plant		
Mean std % control									
T_1	691.94	13.18	169	28.66	2.67	182	5.57	.47	198
T_2	701.07	16.56	172	30.34	1.32	193	6.70	092	238
T_3	730.58	13.38	178	31.90	2.74	202	7.40	.13	263
T_4	732.27	6.16	179	33.01	2.27	209	7.86	.64	280
T_8	433.88	9.35	106	16.53	1.08	105	2.95	.05	105
T_9	408.36	16.13	100	15.76	1.92	100	2.81	.014	100

- Leaf area (cm2/ plant)

The results were presented in table 1. There was a marked increase in the concentration of nitrogen. The best performance was 179% of the control in plants having 2.5g nitrogen (T_4). The second best performance was 178% of the control in T_3 while T_2 showed the third best performance with 172% of the control T_I was fourth with 169% of the control; while T 8 had been inoculated with *Rhizobium* had 106% leaf area of the control.

- Leaf fresh weight (g/ plant)

The results were as presented in table 1. The best overall performance was in T_4 which had 209% of the control. The second best performance was 202% of the control in T_3while the third best performance was 193% in T_2. TI had 182% leaf weight of the control while T_8 was the least with 105% of the control.

- Leaf dry weight g/plant

The results are presented in table 1. The highest recorded average dry weight was that ofT_4 which had 280% of the control. The next best performance was the one with the next lower level of nitrogen in T_3 and it had a performance of 263 % of the control. The third best performance was in T_2 with 238% of the control. T_1 was the lowest performance of105% of the control.

- Stem and branch fresh weight (g/plant)

The results were as presented in table 2. The best performance was 198% of the control in T_4. The next best performance was 186% of the control in T_3 while T_1 had 141 % of the control. T_8 had 114% of the control and this was the lowest performance.

- Stem and branch dry weight (g/plant)

The results are presented in table 2. The highest dry weight was a performance of 265%of the control in T_4. The second best performance was 251 % of the control which was inT_3 while the third best performance was T_2 with 201 % of the control. T_I had a performance of 200% of the control while T_8 had the lowest performance of105% of the control.

- Nodule fresh weight mg/plant

The average weight of the nodules is presented in table 2. From the results, it is evident that the best performance was recorded in the treatment which received inoculation. This was T_8 and it had a performance of 117% of the control. T_I was the second best performance had 43% of the control while the lowest performance was 0.2% of the control in T_2, T_3 and T4 had no nodules at all.

- Nodules dry weight mg/ plant

The results are presented in table 2. The best performance in dry weight was T_8 which had 110% of the control. The second best performance was T_1 with 16% of the control.T_2 had 0.1 % of the control which was almost negligible.

Table 2. Stem and branch fresh weight and dry weight, g/ plant, and nodule fresh weightand dry weight, mg/ plant at flowering stage

Stem & branch fresh wt. (g/ plant)				stem & branch dry WT (g/ plant)			Nodules fresh weigh mg/ plant			Dry wt. (mg/ plant)		
Means std % control				Means std % control			Mean std % control			Mean std % control		
T_1	13.24	2.4	141	2.72	.69	200	671	.15	43	114	.01	16
T_2	14.71	3.8	157	2.74	.05	201	3	.12	.2	.3	.04	.40
T_3	17.46	1.7	186	3.42	.12	251						
T_4	18.6	2.54	198	3.61	.08	265						
T_8	10.62	2.32	114	1.43	.41	105	1877	.08	117	785	.08	110
T_9	9.39	1.98	100	1.36	.72	100	1575	.03	100	713	.15	100

- Root length (cm/ plant)

The results were presented in table 3. The root length decreased with increased in nitrogen level. The best overall root length was recorded in T_8 which had been inoculated with *Rhizobium.* This had a performance of 91 % of the control. The second best performance was the one with the least nitrogen application (T_1) and had 87% of the control while the third best performed with 75% of the control and the least root length was T_4 which was 72% of the control and was the treatment with 2.5g of nitrogen per plant.

- Root dry weight (g/plant)

The results in table 3 indicate the highest dry weight a performance of 155% of the control in T_4, the second best weight was 153% of the control which was T_3 while the third best performance was T_2 with 146% of the control. T_1 had a performance of 145%of the control while T_8 had the lowest performance of 103% of the control.

- Cumulative number of flower buds

The mean cumulative number of buds per plants per treatment was as presented in table3. The highest average was T_4 and had 259% of the control while the second best performance was in T_3 and was 231 % of the control. The third best performance was inT_2 with 183% of the control and T1 had 172% of the control. T_8 showed the lowest performance with 114% of the control.

At maturity the variation in different parameter due to different levels of nitrogen were as follows:

- Root length (cm/ plant)

Table 3. Root dry weight g/ plant root length cm/ plant and number of flower buds perplant at flowering stage

Stem & branch fresh wt (g/ plant)				stem & branch dry WT (g/ plant)			Nodules fresh weigh mg/ plant		
Means std % control				Means std % control			Mean std % control		
T_I	1.76	0.26	145	24.67	2.29	87	15.5	0.15	172
T_2	1.77	0.03	146	23.25	2.16	81	16.5	0.8	183
T_3	1.85	0.14	153	21.5	3.47	75	20.75	0.46	231
T_4	1.88	0.04	155	20.75	1.13	72	23.33	1.39	259
T_8	1.25	0.05	103	26.20	1.53	91	10.3	2.01	114
T_9	1.21	0.28	100	28.67	1.48	100	9	3.5	100

The results were presented in table 4. Root length showed a decreasing trend with increasing level of nitrogen. The best performance in root length was (TB) and a performance of 96% of the control while the second best was T_1 with 82% of the control. The third best performance was in T_2 with 79% of the control while T_3 had a performance of 74% of the control. T_4 had the least root length performance of 70% of the control.

- Root dry weight g/ plant

From table 4, T_4 had the highest performance with 290% of the control while T3 had the second best performance of 275% of the control. T_2 was next with a performance of 256% of the control and T_1 showed 253% of the control. T8 had a performance of 151 % of the control which was the lowest.

- Shoot dry weight g/ plant

The results of the mean shoot dry weight were as presented in table 4. The highest performance was 231 % of the control in T_4. The second best performance was in T_3 with225% of the control while T_2 had 221 % of the control. T_1 had 194% of the control while the lowest performance was in T8 with 152% of the control.

- Shoot length cm/ plant

The mean shoot lengths of the plants were as presented in table 4. The most vigorous growth with the tallest plants was that of T_4 with a performance 'of 228% of the control. While T_3 showed the second best performance with 209% of the control. T_2 was the third best in performance with 200% of the control while T_8 had 111 % of the control and the least in performance.

- Number of pods

Table 4. shoot dry weight g/ plant, shoot and root length cm/ plant at the stage of maturity

Shoot dry weight g/ plant				Root dry weight g/ plant			Root length cm/ plant			Shoot length cm! plant		
Mean std % control				Mean std % control			Mean std % control			Mean std % control		
T_1	29.47	6.30	194	5.8	1.43	253	25.2	1.24	82	80	0.13	170
T_2	33.6	4.17	221	5.87	0.50	256	24.3	0.19	79	94	0.44	200
T_3	34.23	2.24	225	6.29	0.96	275	22.8	0.61	74	98	0.95	209
T_4	35.11	2.61	231	6.63	1.43	290	21.6	1.32	70	107	0.68	228
T_8	23.14	4.37	152	3.46	2.12	151	29.7	0.05	96	52	0.76	III
T_9	15.18	1.28	100	2.29	2.49	100	30.8	0.18	100	47	0.32	100

The results in table 5 show that the highest performance was in T_4 which had 315% of the control while the second best performance was T_3 with 300% of the control. T_2 had 282% of the control while T had 277% of the control. The lowest in performance was T_8 with 140% of the control.

- Pod fresh weight (g/plant)

The highest pod weight as indicated in Table 5 was recorded in T_4 which had 256% of the control while the second in performance was 222% in T_3. The third best performance was in T_2 which had 215% of the control while T_1 had 197% of the control.T_8 had the least performance which was 133% of the control.

- Pod dry weight (g/plant)

The results are presented in table 5 treatment 4 (T_4) recorded the highest pod dry weight of which was 250% of the control and was followed by T_3 with a performance of 229%of the control. T_2 had a mean performance of 21 0% of the control and was third best. T_1had a performance of 207% of the control.T_8 had a performance of 161 % of the control.

- Seed dry weight (g/ plant)

The average seed dry weight per plant was as presented in table 5. T_4 had the best performance of 295% of the control while the second highest seed dry weight was in $T_3$with a performance of 292% of the control. T_2 was the next with a performance of 276%of the control while T_1 had 262% of the control. T_8 was the lowest performance with 155%.

4. Discussion

Soils are frequently deficient of several nutrients so that two or more fertilizers have to be applied to crops, either separately or as a mixture. Ideally, each of the nutrients should be applied at an optimal rate, with due allowance for costs and returns in terms of yield maximization. This has been the major challenge facing the production of snap beans*(Phaseolus vulgaris)* as it is a n important foreign exchange earner vegetable crop. In this study, phosphorus was added in all the treatments as it is an established fact that phosphorus is important for root development, nodulation and nitrogen fixation (Malavolta et a1.,1982). The main purpose of inoculation is to increase chances of effective nodulation for nitrogen fixation. Inoculation in this study showed the increase of 17% and10% nodule fresh weight and dry weight respectively. Nodules are able to fix nitrogen but it is an energy consuming process. Further, considerable amounts of photosynthetic assimilates are consumed in development of nodules and *Rhizobium* metabolic activities. From the present work it was observed that improved nodulation had only a little positive effect on the vegetative growth though at the reproductive stage the effect of inoculation and improved nodulation and more positive effects as pod dry weights showed 38% and seed dry weight showed 55% more as compared to the control. Inoculation also showed a positive effect on number of pods and pod fresh weight had 40% and 33% more compared to the control respectively. In Kenyan soils there is enough *Rhizobium* to form nodules in bean plants without inoculation and additional inoculation has only marginal effects (Mbugua, 1983). Further the effects of inoculation depend on species of *Rhizobium* and cultivar of beans. It is evident from the results that with increasing levels of nitrogen, the plant response was higher. At flowering stage there was a marked increase in vegetative growth (i.e. leaf area,) dry weight, shoot and root dry weights compared to the control and the increments showed ascending trends with increase in amount of nitrogen applied. The increase in leaf dry weight was more pronounced as compared to leaf area with increase in nitrogen per plant. Leaf dry weigh showed 180%, 163%, 138%, and 98% more in treatments T_4, T3, T2, and T1 respectively. While leaf area was 79%, 78% 72% and 69% more in treatments T_4,T_3, T_2, and T_1 respectively as compared to the control. This indicates that applied nitrogen has significant effect on the dry matter accumulation of leaves. The dry matter of the leaf is important as during reproductive growth there is retranslocation of proteins and carbohydrates from the leaves to developing fruits.

At the flowering stage the stem also showed significant increase in fresh and dry weight with increase in nitrogen from T_1 to T_4. The difference in the stem dry weight between T_1 and the control was 100%. The difference in dry weight of stem between T_1 and T_2 was negligible while between T_1 and T_4 was 65% only. At maturity also the stem showed increase in dry weight with increase in nitrogen but the increase was not in proportion to added nitrogen. At maturity the difference of the stem dry weight between T_1 and T_4 was only 37%.

In root dry matter, production increased with an increase in nitrogen supply. At flowering stage T_1 showed 45% increase as compared to the control while between T_1 and T_4 the difference was only 10%. At maturity the difference in root dry weight was not proportional to added nitrogen though it showed an increasing trend with increase in supplied nitrogen.

Though the dry matter production increased with an increase in nitrogen supply, the effect on the root length was negative. This may have been due to presence of ammonium in calcium ammonium nitrate (CAN). Root length is generally affected in presence of ammonium ions. However root branching was much more as nitrogen supply was increased and that must have contributed to their dry weight. The snap beans plants showed profound effects on reproductive growth with supply of nitrogen. That is evident from the number of flower buds, fresh and dry weight of pod sand dry weight of seeds per plant. Very low level of nitrogen application i.e. *(*1g*l* plant) showed remarkable increase in flower and pod number, pod fresh and dry weight and seed dry weight. The increase in reproductive organs was 97% to 117% with lowest level of nitrogen applied and with increase in nitrogen level all the parameters showed increasing trends. In T_4 i.e. where 2.5gN/ plant as applied, the increase was 150% to215% more than the control. From this work, it can be clearly observed that application of nitrogen fertilizer had a positive effect on the overall performance of plant and nitrogen fixed by root nodules was not sufficient fix optimum growth and development.

This was also suggested by Bouldin *et al*., (1979). Edge *et al*., (1975) also showed there is an increase in plant growth and yield in dry beans in response to varying levels of nitrogen In the present experiment it was observed that nitrogen fertilizer had adverse effects on nodulation, inoculation increased weight of nodule but it was only 17% more than the control. In T_1 when only one gram nitrogen was applied nodules decreased but still 43% of the control was recorded while in higher concentration of nitrogen that is in treatment T_2, $T_3$and T_4 nodules were not observed. However even with the best nodulation in T_8 the overall performance of plants was not as good as that of T_1 which had moderate nodulation and little nitrogen application from this study it is clearly evident that the amount of nitrogen fixed through the nodules was not sufficient for maximum growth and production. It agrees with the findings of LaRue and Paterson (1981) that most of the nitrogen fixing plants can obtain only one fourth of the nitrogen by symbiotic activity while the remaining amount is absorbed from the soil. Thus the establishment of legumes may be delayed or retarded due to nitrogen stress and supply of starter nitrogen is desirable. In the present experiment remarkable response of applied nitrogen on snap beans was observed in most of the vegetative and reproductive parameters studied, they showed 70- 100% increased with the application of one gram nitrogen the difference was not big. For example production was not doubled when applied nitrogen was doubled in T_3compared to T_l, this is because when the little amount of nitrogen (T_l) was applied moderate amount of root nodules were produced and plant benefited by both nitrogen fixation and soil nitrogen. However with increase with nitrogen application nodule growth was completely inhibited and plants became entirely dependent on applied nitrogen. From this study it can be deduced that 22kg nitrogen per hectare would be most suitable for economical use of fertilizer and improvement of production of snap beans. This is calculated considering that most common plant population in bean monoculture is 22000plants/ hectare. This findings agree with the recommended application of 26kg / ha as starter nitrogen for dry beans by Haule (1988).

5. Conclusion

Nutrient deficiencies can be corrected by simply applying appropriate fertilizers (nitrogen in this case), but it is neither practicable nor economical to attempt to eliminate the deficiencies to maximize crop production by massive application of fertilizers. Rather the fertilizers should be applied sparingly to each crop, with the allowance for all practical and economical factors that are involved as well as the actual deficiency levels in the soils. The application of nitrogen fertilizers does not only increase yields but also yield of crop residues which can either be returned to the soil directly or be used for feeding animals. Increased crop residue availability may be used to increase animal production and leading to increased production of farm yard manure which can be returned to the soil. This will improve the organic matter content, biological activity and soil structure. Considering all the above factors treatment I (T_l) can be considered to be the most appropriate application of nitrogen fertilizer to snap beans for high yields, high amount of crop residue and without suppressing biological activity (fixation of nitrogen) in the plants. This is because more than half (75%) of the fertilizer used in T_4 is saved thus reducing the cost and still maintain a high yield as compared to the control.

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