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Improving Bush Bean (*Phaseolus vulgaris* L.) Yield and Quality by Increasing Soil Nutrients with Organic Fertilizer

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ABSTRACT

Background: Evaluate the effect of organic fertilizers and amino acid foliar fertilizers in combination with different chemical fertilizers levels on the change of soil nutrients and bush bean yield (*Phaseolus vulgaris*).

Methods: With six treatments and three duplicates, the experiment was designed using full randomization, each corresponding to 3 pots. The treatments in the experiment included- (1) 100% NPK (200 kg N/ha + 150 kg P_2O_5/ha + 100 kg K_2O/ha, (2) 70% NPK + 2 tons of organic fertilizer (O.F)/ha, (3) 50% NPK + 4 tons of O.F, (4) 100% NPK + amino acid (4 ml/liter), (5) 70% NPK + 2 tons of O.F + amino acid (4 ml/liter) and (6) 50% NPK + 4 tons of O.F + amino acid (4 ml/liter). The experiment was carried out over two successive seasons.

Result: The results show that applying 4 tons/ha of organic fertilizer combined with 4 ml/liter of amino acid foliar fertilizer reduces NPK by 50% (100 kg N/ha+75 kg P_2O_5/ha+50 kg K_2O/ha+4 tons/ha of organic fertilizer+4 ml/liter amino acids) helps to improve pH and N, P available in the soil and at the same time helps to increase significantly and statistically ($p<0.05$) in terms of plant height, trunk diameter compared to fertilizer application of 100% NPK. In addition, the amount of nitrate in the bean decreased significantly. The increase in brix level was statistically different from the control when applying a 50-70% reduction of NPK, using 2-4 tons of organic fertilizer and spraying with amino acids.

Key words: Dwarf beans, NPK fertilizer, Organic chicken manure.

INTRODUCTION

Of all the beans, the dwarf bush bean is one of the three most commonly grown beans in the world due to its delicious taste and excellent yield potential; suitable for many soil types and can be developed in different areas. However, long-term synthetic fertilizers result in soil degradation, diminished nutrient and organic matter levels and decreased soil microbial activity and diversity, which can lead to reduced yields, threatening future farming potential (Albiach *et al*., 2000). Adding organic fertilizers to the soil is an option to help reduce the use of inorganic fertilizers, maintain fertility and overcome nutrient deficiencies or imbalances in the soil, helping to maintain and stabilize crop yields (Thy and Buntha, 2005). Many studies show that dwarf bush beans' growth rate and yield significantly increase when applied with organic fertilizers (Arjumandbanu, 2013). In addition, using organic fertilizers helps reduce root rot disease and gives the dwarf bush bean plant good vigor (Cespedes *et al*., 2006). Furthermore, when combined with bulky organic manures, liquid organic manures can effectively release nutrients as needed by the crop to sustain greater productivity (Sutar *et al*., 2019). According to Mahto and Dutta (2021), organic intervention may be a suitable alternative to organically growing French beans for producing at least comparatively safer green pods. Seaweed extracts and fish protein are good potential sources of amino acids, which can be exploited as fertilizers for crops (Rai, 2002). In addition, there is very little information on using organic fertilizers and amino acids for bush beans.

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Therefore, the study aims to evaluate the effect of organic fertilizers and amino acid foliar fertilizers in combination with different chemical fertilizers levels on the change of soil nutrients and bush bean yield (*Phaseolus vulgaris*).

MATERIALS AND METHODS

Research materials

Varieties

Rado 11 bush beans, green pods with white seeds and non-climbing dwarf plants were used in the experiment.

Experimental pot

Cylindrical PE bag with a diameter of 30 cm and a height of 25 cm.

Fertilizers

+Inorganic fertilizers (I.F): Urea (46% of N), Superphosphate (18% of P_2O_5) and KCl (60% of K_2O).

+Organic fertilizer (O.F): The organic chicken manure used in the experiment is organic fertilizer in the form of pellets with the following nutritional content: Organic matter (O.M): 81%; pH_{H2O}: 6.3; C/N ratio: 11.4; P_2O_5: 3,02%; humidity: 12%.

+ Amino acids: Amino Plus is nanotechnology's amino acid source. The manure is extracted from seaweed and fish protein. The composition of nutrients in feces includes 2,000 ppm Boron (B); 15 ppm Zn; 15 ppm Garlic solution; 18 kinds of amino acids (Cystine, Glutamic acid, Tyrosine, Proline, Leucine, Serine, Lysine, Valine, Isoleucine, Aspartine, Phenylanie), humic acid and fulvic acid.

Experimental soil

Experimental soil was taken from rice-crop rotation land in the Thien My village, Tra On district, Vinh Long province (9°57′12.9″N 105°55′57.6″E), belonging to the Gleyic Fluvisol soil group (FAO, 2018). Diagonally experimental topsoil was collected (0-20 cm). First, a significant sample of the undisturbed soil is mixed. Then, place 8 kg (dry weight) of soil in black plastic containers (25 cm in height × 30 cm in diameter). Before sowing, soils are dried for laboratory analysis. The physical and chemical soil parameters before experimentation are shown in Table 1.

Research methods

Study area

The experiment was conducted in 2 consecutive cropping seasons. The 1st season starts in October 2021 and ends in November 2021. The 2nd season begins in January 2022 and ends in February 2022. This experiment was carried out in a greenhouse of Can Tho University.

Experimental design in a completely random block design (CRD), including 6 treatments and three replications. Each replicate was represented by three pots with one plant/pot. The experimental treatments are detailed in Table 2.

Fertilizer and timing

Before sowing

All organic and phosphorus fertilizers are applied before sowing (except for treatments 1 and 2 that do not apply organic fertilizers).

After sowing

Nitrogen and potassium fertilizers are applied at the time of 15, 30 and 45 days after sowing (DAS). In addition, amino acid foliar fertilizer is sprayed strictly as recommended (10-15 ml/16 liter) at three times 15, 30 and 45 DAS.

Prepare seeds

Four seeds of each bush bean were sown in each pot. Bean plants were chosen to grow in each pot after having two to three leaves. Watering was done every morning and afternoon until the end of the experiment.

Data collection

Soil sampling

Samples were collected individually for each treatment and each replicate at the end of the season. After collection, the samples were dried and sieved to analyze the indicators of pH_{H2O}, available N and P.

Plants sampling

Collecting indicators (1) The plant height and stem diameter were collected and monitored 15, 30, 45 and 60 days after sowing (DAS) periodically; (2) Yield and yield components including number, diameter, length, the yield of pod; (3) Evaluating bean quality such as ºBrix, nitrate content in the pod.

Methods of analyzing soil samples and assessing criteria related to bush bean

Soil analysis method

Soil pH was estimated on a 1:5 soil/water scale (mass/volume). Available N in the soil was extracted with KCl 2N and measured *via* colorimetry. Finally, available P was estimated by the Olsen method (Sparks *et al.* 1996).

Table 1: Soil physical-chemical properties (0-20 cm) before setting up the experiment to grow beans at the study site.

pH_{H20}	$EC_{(1:2,5)}$	OM	CEC	N_{total}	P_{total}	Density	% Soil texture		
(1:2,5)	mS/cm	%	meq/100 g	%N	$\%P_2O_5$	g/cm³	Sand	Silt	Clay
5.63	0.64	4.62	12.80	0.17	0.15	1.26	1.36	53.54	45.10

Table 2: Experiments in the experiment of growing bush beans in the form of dust.

Treatments	Explain			Symbol
	$N\text{-}P_2O_5\text{-}K_2O$ (kg/ha)	O.F (ton/ha)	Amino acids (ml/liter)	
T1	200-150-100	0	0	100% NPK
T2	140-105-70	2	0	70% NPK + 2 O.F
T3	100 -75-50	4	0	50% NPK + 4 O.F
T4	200-150-100	0	4	100% NPK + Amino acid
T5	140-105-70	2	4	70% NPK + 2 O.F + Amino acid
T6	100 -75-50	4	4	50% NPK + 4 O.F + Amino acid

Evaluation method of criteria related to plant

Morphology and quality parameters

When harvesting, weigh the whole number of pods/plants to calculate the average pod weight. At the same time, measure the length and diameter of the pod with the Mitutoyo 500-182-30 electronic caliper. The °Brix was measured with a Brix RHB0-90 (Hand Refractometer). Nitrate content in pod fresh was analyzed by the method TCVN 8160-7:2010.

The number of pods (pods/plant) was the total number for all stage harvest. Pod yield (g/pot) is the harvest weighing the total actual yield of the plant.

Data processing

Experimental data were analyzed using ANOVA test software Minitab 16.0 and the Duncan test at 1% and 5% significance levels to evaluate the significance level.

RESULTS AND DISCUSSION

Changes in soil chemical properties in different fertilizer treatments over two crops of bush beans

The analysis results of soil samples for bush beans at the end of the crop (Fig 1) showed statistically significant differences in the soil pH, available N and P over the two bush bean crops. Soil pH value ranges from 5.63 to 5.73. The available N content ranged from 13.33 to 21.67 mg/kg and 13.20 to 24.29 mg/kg for available P. Research results have shown that applying organic fertilizers has improved soil chemical properties, helping to increase pH and available nutrients in the soil, especially when using 25-50% NPK + organic fertilizer (2 or 4 tons/ha) + amino acid spray. However, improving the pH value and available nutrients in the soil was most effective in the treatment with a 50% reduction of NPK + 2 tons of organic fertilizer + additional spraying of amino acid foliar fertilizers (treatment 5).

The content of available nutrients (N, P) in the treatments increased in organic fertilizer. Due to the organic matter containing macro and micronutrients, intermediates and organic fertilizers that stimulate the activity of soil microorganisms, helps the mineralization processes of N and P increase (Anant-Bahadur *et al*., 2006).

Increase in available P with the application of Amino Acid (4 ml/liter) on top of 70%+2 ton of or 50%+4 ton O.F (in T5 and T6) due to one of the following reasons 1) Organic matter itself contains a large amount of phosphorus (3.02% P_2O_5) and (2) Because amino acids contain humic acids, acid fulvic. Wang *et al*. (2020) experiment showed that humic acid increased soil nutrient content, including total nitrogen, phosphorus, potassium, available nitrogen, phosphorus and potassium. As a result, the fixation rate of soil to phosphorus was reduced. The COOH and O.H. functional groups are mainly responsible for H.A. functions such as improving soil physical and chemical properties and plant growth (De Melo *et al*., 2016). The combination of amino acid and organic fertilizer (O.F) significantly increased the available nitrogen, phosphorus and the amount of water-soluble phosphate strongly retarded the formation of occluded phosphate and increased P uptake and yield crop (Nardi *et al*. 2021).

Growth and development of bush beans

Experimental results show that the reduction of chemical fertilizers (25%-50% NPK), the f organic fertilizers (2-4 tons/ha), or a reduction of 25-50% NPK + (2-4 tons/ha) organic fertilizer+Amino acid significantly improved the bean plants growth and development (Fig 2 and 3). However, the statistical significance is different compared with 100% fertilization NPK. Statistical analysis revealed that treatment 1 had a minor plant diameter and height (100% NPK) and the highest in the 50% NPK combined 4 tons of organic fertilizer and amino acid spray. For both crops, there was no statistically significant difference in trunk diameter and height between the treatments of 50% NPK+4 tons of organic fertilizer+Amino acid and 70% NPK+2 tons of organic fertilizer+Amino acid.

Experimental results have shown that applying organic fertilizer has provided the soil with essential nutrients for plant growth and development, helping plants absorb nutrients better than using 100% NPK. Tugume (2018) show that organic fertilizers can be considered soil conditioners. In addition to providing more macro, micronutrients and organic matter to the soil. It also improves soil quality (increases the soil water holding capacity and nutrients), helping plants grow better.

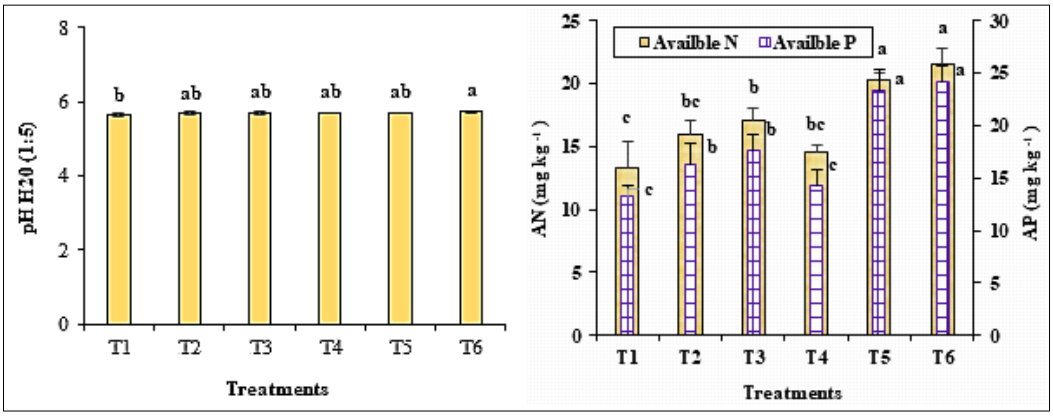

Fig 1: Soil properties in different fertilizer treatments at the stage of bean harvest.

In the same way as amines (-NH_2) and carboxylic acids (-COOH) are biologically significant organic molecules with functional groups, amino acids are regarded as precursors and protein components (Rai, 2002). Furthermore, it comprises both acidic and primary groups, which serve as a buffer to maintain a healthy pH level in plant cells (Davies, 1982), which reduce the synthesis of amino acids from nitrogen fertilizers and help plants grow better, increasing the yield and bean quality. Boras *et al*. (2011) also recorded increased plant height, yield and quality of tomatoes grown under greenhouse conditions when amino acids were added.

Yield and yield component of bush beans

Pod dimensions (pod length and pod diameter)

Data presented in Table 3 shows that pod dimensions can be affected by the amount of organic matter and amino acids. Fruit dimensions increased markedly in treatments reduction 25-50% NPK+O.F (2-4 tons/ha) + amino acids spraying through both growing seasons; increased bean size can lead to increased bean yield getting a raise. Experimental results showed that the application of 100% NPK had the most diminutive pod dimensions, significantly different from the other fertilizer treatments. The cause of pod dimensions in treating O.F alone or in combination with amino acid spray is that organic fertilizers provide nutrients NPK and additional minerals and trace elements needed for plants. In addition, amino acids are also regarded as biostimulants with favorable impacts on plant yield and growth (Abo Sedera *et al*., 2010). Compared with nitrogen from fertilizers, nitrogen from amino acid sources is more easily absorbed by plants and more effective in improving yield (Hildebrandt *et al*., 2015).

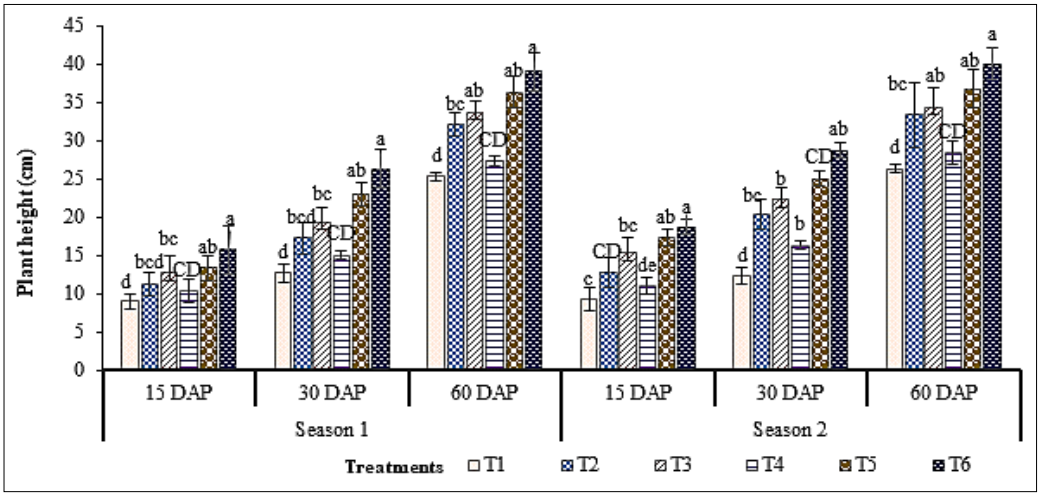

Fig 2: The bush beans height under the influence of organic fertilizer and amino acid dosages through 02 growing seasons under net house conditions.

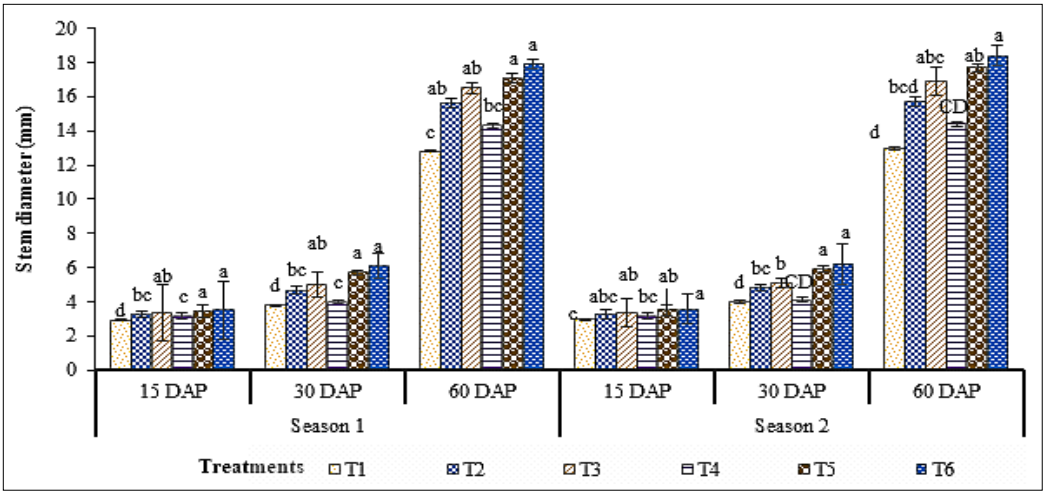

Fig 3: Effects of organic fertilizers and amino acids on the change of stem diameter of bush beans over 02 growing seasons under greenhouse conditions.

The pod's number, pod weight and yield

Data presented in Table 4 show a clear and statistically significant difference in whole bean, bean weight and bush bean yield in different treatments. Compared to 100% NPK treatment, all organic fertilizer applications combined with amino acid spray resulted in better beans per plant and beans per pound yields. The experiment results demonstrate a 50% reduction in NPK fertilizer and applying 4 tons of organic fertilizer. In both growing seasons, the use of amino acid foliar fertilizers led to a considerable increase in pod number per plant (24 beans), pod weight (>3 g) and total yield (>75 g/plant). Apply 100% NPK for the lowest pod number, weight and yield.

However, there was no statistically significant difference in the beans numbers per plant, bean weight, or overall yield in the treatment with 30% NPK reduction + 2 tons of O.F plus amino acid spray. Besides, organic fertilizers can help partially replace inorganic fertilizers. Similarly, Amino acids' favorable effects on plant growth enhanced bean setting and yield. According to Sadak *et al*. (2015), amino acids are considered the best nitrogen source for plant nutrition, which can partially replace nitrate nitrogen. Kocira (2019) also documented the influence of amino acids on crop growth and yield.

Quality of bush beans

The bush bean quality was significantly different in different fertilizer treatments (Fig 4). Single organic fertilizer or O.F + amino acid increased °Brix of bean compared considerably to 100% NPK application alone. °Brix tends to increase when adding organic fertilizer or adding organic fertilizer combined with amino acid spray. It may be because organic fertilizers and amino acids have provided additional micronutrients such as copper, iron and manganese-enhanced the metabolic activity of plants, stimulating the accumulation of carbohydrates and increasing the sweetness of beans (Sharma *et al*., 2012).

In contrast, the nitrate concentration in bush beans was highest in the 100% NPK treatment and tended to decrease when using O.F or O.F + amino acid through both growing seasons. Numerous factors, including genotype, growing conditions, harvesting, storage, processing conditions and environmental factors, influence how much nitrate plants absorb and accumulate (Bian *et al.,* 2020). The experimental results show that the retention of nitrate content in bush beans is not significant because they are deficient compared to food hygiene and safety requirements. According to Veronica *et al.* (2017), the typical nitrate concentration in vegetables such as green beans, carrots, cauliflower and potatoes is between 100 and 300 ppm NO_3^-.

Table 3: Effect of organic fertilizers and amino acids on the size change of bush beans over two growing seasons under greenhouse conditions.

Treatments	1st season		2nd season	
	Pod width (mm)	Pod length (mm)	Pod width (mm)	Pod length (mm)
100% NPK	6.35^{d}	84.8^{c}	6.56^{d}	85.5^{d}
70 % NPK + 2 O.F	7.24^{c}	86.8^{bc}	7.35^{b}	87.4^{cd}
50% NPK + 4 O.F	7.54^{b}	87.8^{b}	7.54^{b}	88.9^{bc}
100% NPK + Amino acid	6.58^{d}	86.2^{bc}	6.94^{c}	86.3^{cd}
70 % NPK + 2 O.F + Amino acid	7.88^{a}	91.4^{a}	7.97^{a}	91.8^{ab}
50% NPK + 4 O.F + Amino acid	8.06^{a}	93.4^{a}	8.23^{a}	93.6^{a}
F	*	*	*	*
CV (%)	6.29	3.79	8.03	3.52

Note: Values of t in the same column followed by the same pattern are not statistically different at the 5% level through the LSD test; *: Difference at the 5% significance level.

Table 4: Effects of organic fertilizers and amino acids on yield and yield components of bush beans through two growing seasons under greenhouse conditions.

Treatments	No. of pods (Pod/plant)		Weight of pod (g/pod)		Yield (g/plant)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season
100% NPK	17.3^{d}	18.6^{c}	2.62^{c}	2.66^{c}	63.2^{d}	63.4^{e}
70% NPK + 2 O.F	19.6^{bcd}	20.6^{bc}	2.88^{b}	2.89^{cd}	67.3^{c}	68.5^{cd}
50% NPK + 4 O.F	21.0^{abc}	22.0^{abc}	2.94^{b}	2.98^{bc}	70.9^{b}	72.3^{bc}
100% NPK + Amino acid	18.6^{cd}	19.6^{bc}	2.69^{bc}	2.74^{cd}	64.4^{cd}	65.5^{de}
70% NPK + 2 O.F + Amino acid	22.3^{ab}	23.0^{ab}	3.14^{a}	3.14^{ab}	74.0^{a}	75.2^{ab}
50% NPK + 4 O.F + Amino acid	23.6^{a}	24.3^{a}	3.19^{a}	3.25^{a}	75.7^{a}	77.0^{a}
F	*	*	*	*	*	*
CV (%)	12.1	8.07	7.07	10.6	8.67	7.55

Note: Values of t in the same column followed by the same pattern are not statistically different at the 5% level through the LSD test; *: Difference at the 5% significance level.

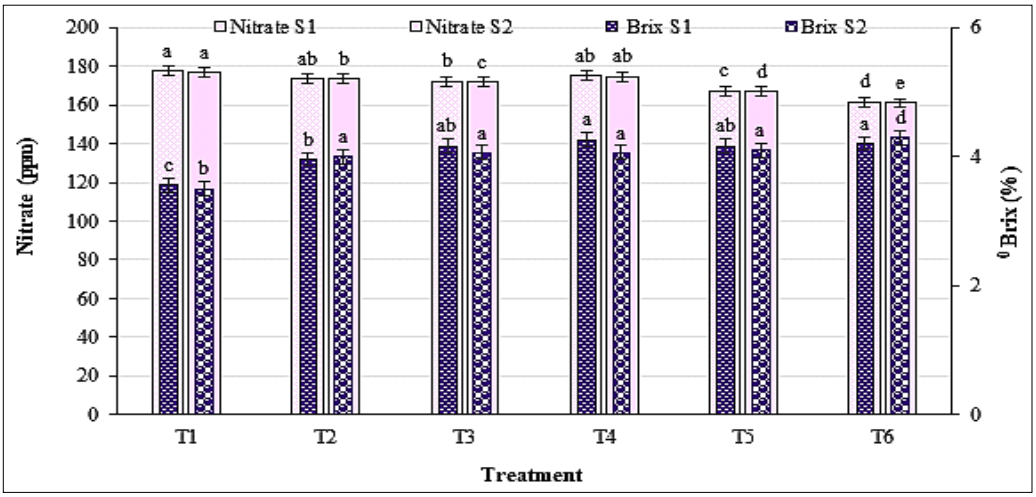

Fig 4: Effect of organic fertilizers and amino acid foliar fertilizers on the bush beans quality through two growing seasons under greenhouse conditions.

Note: The values shown are the mean± standard deviation (S.E- Standard error). Values of t in the same column followed by the same pattern are not statistically different at the 5% level through the LSD test; *: Difference at the 5% significance level. T1: 100% NPK; T2: 70%NPK+2 O.F.; T3: 50%NPK + 4 O.F.; T4: 100%NPK + Amino acid; T5: 70% NPK+2 O.F. + Amino acid and T6: 50% NPK + 4 O.F.+ Amino acid.

CONCLUSION

The results of two cropping seasons of bush beans revealed that a combination of 50% of NPK fertilizer with 4 tons of organic chicken fertilizer and sprayed amino acids is recommended. It increases the crop growth and yield components (plant height, stem diameter, bean length, width, number of beans and average weight). The total yield was higher compared to the control treatment (100% NPK), recorded statistically ($p<0.05$). The results also showed that Brix in pod increased in treatments with organic fertilizer or organic fertilizer combined with spray amino acid compared with 100% NPK only, recorded statistically significantly ($P<0.05$). The amount of accumulation in the pot of nitrate in all fertilizer treatments was within the allowable residue threshold. It tended to decrease when inorganic fertilizer was reduced and replaced with organic fertilizer or when it was lowered and replaced with organic fertilizer and amino acids. It is concluded that combined organic fertilizers application and spraying amino acids or only application of organic fertilizers improved pH and nutrient availability in soil ($P<0.05$).

Conflict of interest: None.

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