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# Growth, Yield and Seed Nutrient Quality of Soybean (*Glycine max* L.) as Affected by Organic, Biofertilizer and Synthetic Fertilizer Application

**Dhanushi Samarakoon[1] and Neelamanie Yapa[1*]**

[1]*Faculty of Applied Sciences, Rajarata University of Sri Lanka, Mihintale, Sri Lanka.*

***Authors' contributions***

*This work was carried out in collaboration between both authors. Author NY designed the study, wrote the protocol, gave scientific suggestions, managed the statistical analyses and results interpretation of the study and corrected the first draft of the written manuscript. Author DS managed the literature search of the study, carried out the study and wrote the first draft of the manuscript. Both authors read and approved the final manuscript.*

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## ABSTRACT

Pot experiment was carried out in dry zone of Sri Lanka in the year 2015 with the aim of investigating the effects of organic manure, biofertilizers and synthetic fertilizer application on growth, yield and seed nutrient quality of soybean (*Glycine max* L.). Treatments were field soil only ($T_0$), field soil and 5% biochar ($T_1$), field soil and 5% cow dung ($T_2$), field soil, 2.5% biochar and 2.5% cow dung ($T_3$), field soil, 5% biochar and *Bradyrhizobium* ($T_4$), field soil, 5% biochar and mycorrhizae ($T_5$), field soil, 5% cow dung and *Bradyrhizobium* ($T_6$) field soil, 5% cow dung and mycorrhizae ($T_7$), field soil and synthetic fertilizer ($T_8$), field soil, 2.5% cow dung 2.5% biochar and synthetic fertilizer ($T_9$), field soil, 5% cow dung, mycorrhizae and *Bradyrhizobium* ($T_{10}$), field soil, 5% biochar, mycorrhizae and *Bradyrhizobium* ($T_{11}$). The treatments were tested in a randomized complete block design (RCBD) with six replicates.
The results indicated that application of organic and biofertilizers with synthetic fertilizers ($T_9$) significantly ($p<0.05$) improved the relative growth rate, number of leaflets, root dry weight, shoot dry weight of soybean. However, soybean yield such as the number of pods and the dry weight of

**Corresponding author: Email: pnyapa40@yahoo.co.uk;*

100 seeds, was significantly high ($p<0.05$) with field soil, 5% cow dung, mycorrhizae and *Bradyrhizobium* ($T_{10}$). Higher seed protein percentage was observed in $T_{10}$, fat percentage in $T_4$ and crude fibre percentage in $T_8$ treatments. In conclusion, the application of organic and biofertilizers together resulted in an improvement of the yield components and nutrient quality of soybean seeds, except for the case of crude fiber content which increased by the application of synthetic fertilizer. Overall, organic and biofertilizers could be used as efficient substitutes for synthetic fertilizers, without compromising the yield and nutrient quality of soybean.

*Keywords: Organic manure; biofertilizers; synthetic fertilizer; growth; yield; nutrient quality.*

## 1. INTRODUCTION

Utilization of organic manure and biofertilizer can be a reliable solution to avoid soil pollution and many other threats to the environment and life caused by overuse of synthetic fertilizers. Synthetic fertilizers would not replenish the soil N, P, K, level, so frequent addition is needed to sustain the crop productivity [1]. Conventional farming systems contain higher levels of nitrate, which is a nutritional disadvantage [2]. Biofertilizers are ecofriendly, cost effective and a renewable source of plant nutrients in sustainable agricultural systems [3]. Organic manures and biochar have been associated with desirable soil properties, improve the higher plant available water holding capacity, can foster beneficial microorganisms [4,5] and lead to high crop productivity. Previous studies showed that a higher grain yield and nutrient quality can be achieved by using biofertilizer with organic fertilizer or synthetic fertilizer [6]. Soybean (*Glycine max* L.) is one of the major and widely cultivated legume crops in dry zone of Sri Lanka. In Sri Lanka, soybean cultivation relies on addition of synthetic fertilizer, pesticides and genetically modified high yielding soybean varieties. These agricultural systems lead to adverse effects on environmental quality, soil productivity and nutritional quality of plant and also adversely affect human health. Application of organic manure and biofertilizer to improve the growth yield and nutrient quality of this crop against the continuing depletion of soil organic nutrients will help in improving the livelihood of the rural population in the dry zone of Sri Lanka. Therefore, this study was carried out to investigate the effect of organic manure, biofertilizers and synthetic fertilizer application on growth, yield and seed nutrient quality of soybean (*Glycine max* L.) in the dry zone of Sri Lanka.

## 2. METHODOLOGY

The study was conducted under greenhouse conditions and natural light at the Rajarata University of Sri Lanka in Anuradapura district, dry zone of Sri Lanka (8º21'0" North latitude, 80º30'0"East longitude) from July to December 2015. The soils were red yellow podzolic soils. Biochar used in this study was produced from wood chips using barrel method applying 250-450ºC temperature for pyrolysis. After pyrolysis biochar was ground and passed through a 2mm sieve. *Bradyrhizobium* sp. was isolated from the surface sterilized fresh nodules of soybean into congo red yeast mannitol agar (CRYMA). Pure cultures of the isolated strains were used to prepare the inoculum (Husain, et al. 2009). Arbuscular mycorrhizal fungal inoculum was prepared by trap culture method.

A randomized complete block design (RCBD) was used with six replicates in this experiment. The experiment included control and eleven treatments as add only soil($T_0$), field soil and 5% biochar ($T_1$), field soil and 5% cow dung ($T_2$), field soil, 2.5% biochar and 2.5% cow dung ($T_3$), field soil, 5% biochar and *Bradyrhizobium* ($T_4$), field soil, 5% biochar and mycorrhizae ($T_5$), field soil, 5% cow dung and *Bradyrhizobium* ($T_6$) field soil, 5% cow dung and mycorrhizae ($T_7$), field soil and synthetic fertilizer ($T_8$), field soil, 2.5% cow dung 2.5% biochar and half dosage of synthetic fertilizer ($T_9$), field soil, 5% cow dung, mycorrhizae and *Bradyrhizobium* ($T_{10}$), field soil, 5% biochar, mycorrhizae and *Bradyrhizobium* ($T_{11}$). Growth and yield data were recorded. After the 75 days of sowing, soybean seeds were subjected to the nutrient analysis using AOAC [7] standard procedures. Data were subjected to analysis of variance (ANOVA) and mean separation using the Duncan multiple Range test was used to compare the treatment means.

## 3. RESULTS AND DISCUSSION

Relative growth rate was significantly higher ($p<0.05$) in ($T_9$) (Table 1). Above results revealed that biofertilizer, organic manure and lesser amount of synthetic fertilizer are effective in plant growth promotion. Microorganisms present in biofertilizer and organic manure possess the capacity to promote plant growth by enhancing nutrient availability, uptake and producing plant hormones supports the health of plants [8]. The number of leaflets was significantly higher ($p<0.05$) in the treatment ($T_9$). PGPR present in biofertilizer and organic manures enhance the plant growth by producing growth regulators that enhance the activity of other beneficial microorganisms, accelerating the mineralization of plant nutrients and uptake of certain nutrients. Increased leaf area, chlorophyll concentration and total biomass production in wheat was observed [9].

The root dry weight was significantly higher in ($p<0.05$) ($T_9$) treatment. Above result s shows biofertilizer with the combined use of chemical fertilizer and organic manure has a significant effect on increasing the dry weight of the shoot compared with chemical fertilizer treatments. Studies of Egamberdiyeva, et al. [10] showed that inoculation of *Bradyrhizobium japonicum* on soybean increased the dry weight of shoot. There was no significant difference in root dry weight ($p<0.05$) among ($T_9$) and ($T_8$). Biofertilizer and organic manures that contain PGPR affect nutrient uptake in plant and enhance growth and development of plant roots, leading to root systems with larger surface area and increased number of root hairs, which are then able to access more nutrients [8].

Number of pods and dry weight were significantly higher ($p<0.05$) in ($T_{10}$ ) (Table 2). Biofertilizer were more effective on increasing number of pods and dry weight of seed than chemical fertilizer, due to providing of balance nutrients during the pod maturation by using various mechanisms such as fixing N, solubilizing P and decomposition of organic matter providing the in available form to plant leading to higher yield. Integrated use of organic manure with efficient

**Table 1. Variations in plant growth parameters. Means that do not share a same letter is significantly different ($p < 0.05$)**

| Treatments | Relative growth rate | Number of leaflets | Shoot dry weight (g) | Root dry weight (g) |
|---|---|---|---|---|
| $T_0$ | $0.094^{def}$ ± 0.0132 | $36.5^{e}$ ± 3.74 | $1.60^{e}$ ± 0.102 | $1.31^{e}$ ± 0.108 |
| $T_1$ | $0.086^{ef}$ ± 0.006 | $53.5^{cde}$ ± 6.85 | $1.95^{de}$ ± 0.083 | $3.21^{abcd}$ ± 0.211 |
| $T_2$ | $0.121^{bcdef}$ ± 0.007 | $61.5^{abc}$ ± 3.35 | $4.23^{b}$ ± 0.370 | $3.20^{abcd}$ ± 0.212 |
| $T_3$ | $0.149^{abcd}$ ± 0.007 | $60.5^{abc}$ ± 2.11 | $4.54^{b}$ ±0.187 | $4.12^{a}$ ± 0.109 |
| $T_4$ | $0.0813^{f}$ ± 0.008 | $41^{ed}$ ± 1.84 | $1.99^{de}$ ± 0.046 | $3.05^{bcd}$ ± 0.270 |
| $T_5$ | $0.140^{abcde}$ ± 0.009 | $49^{cde}$ ± 3.68 | $3.03^{cd}$ ± 0.176 | $2.40^{d}$ ± 0.168 |
| $T_6$ | $0.098^{cdef}$ ± 0.022 | $63^{abc}$ ± 3.50 | $3.80^{bc}$± 0.392 | $3.38^{bcd}$ ± 0.141 |
| $T_7$ | $0.112^{bcdef}$ ± 0.016 | $57^{bcd}$ ± 2.44 | $3.87^{bc}$ ± 0.242 | $2.50^{dc}$ ± 0.294 |
| $T_8$ | $0.151^{abc}$ ± 0.006 | $73.5^{ab}$ ± 6.56 | $4.90^{b}$ ± 0.319 | $3.69^{ab}$ ± 0.211 |
| $T_9$ | $0.183^{a}$ ± 0.008 | $76.16^{a}$ ± 1.40 | $6.52^{b}$ ± 0.327 | $3.99^{a}$ ± 0.187 |
| $T_{10}$ | $0.164^{ab}$ ± 0.003 | $72^{ab}$ ± 2.89 | $4.55^{b}$ ± 0.150 | $3.29^{abcd}$ ± 0.200 |
| $T_{11}$ | $0.105^{cdef}$ ± 0.013 | $45.5^{cde}$ ± 3.32 | $2.08^{de}$ ± 0.139 | $2.48^{dc}$ ± 0.110 |

**Table 2. Variations in plant yield parameters. Means that do not share a same letter is significantly different ($p < 0.05$)**

| Treatments | Number of pods | Dry weight of 100 seeds (g) |
|---|---|---|
| $T_0$ | $19.16^{d}$ ± 1.194 | 7.83 ± $0.21^{e}$ |
| $T_1$ | $27.00^{d}$ ± 1.341 | $10.44^{dc}$ ± 1.05 |
| $T_2$ | $59.33^{abc}$ ± 2.962 | $10.77^{bcd}$ ± 0.40 |
| $T_3$ | $52.50^{bc}$ ± 4.121 | $12.78^{abc}$ ± 0.10 |
| $T_4$ | $27.16^{d}$ ± 2.197 | $11.05^{bcd}$ ± 0.62 |
| $T_5$ | $46.16^{c}$ ± 2.508 | $11.79^{abcd}$ ± 0.16 |
| $T_6$ | $48.50^{c}$ ± 3.537 | $9.64^{de}$ ± 0.21 |
| $T_7$ | $64.33^{ab}$ ± 3.211 | $12.50^{abc}$ ± 0.20 |
| $T_8$ | $46.00^{c}$ ± 3.130 | $10.73^{bcd}$ ± 0.230 |
| $T_9$ | $58.33^{abc}$ ± 4.142 | $12.89^{ab}$ ± 0.411 |
| $T_{10}$ | $66.66^{a}$ ± 1.909 | $13.70^{a}$ ± 0.200 |
| $T_{11}$ | $24.83^{d}$ ± 1.077 | $11.82^{abcd}$ ± 0.020 |

microbes and half dosage NPK fertilizer yielded similar to the yield obtained from full recommended NPK fertilizer [11].

Field soil only ($T_0$), field soil and 5% biochar ($T_1$), field soil and 5% cow dung ($T_2$), field soil, 2.5% biochar and 2.5% cow dung ($T_3$), field soil, 5% biochar and *Bradyrhizobium* ($T_4$), field soil, 5% biochar and mycorrhizae ($T_5$), field soil, 5% cow dung and *Bradyrhizobium* ($T_6$) field soil, 5% cow dung and mycorrhizae ($T_7$), field soil and synthetic fertilizer ($T_8$), field soil, 2.5% cow dung 2.5% biochar and synthetic fertilizer ($T_9$), field soil, 5% cow dung, mycorrhizae and *Bradyrhizobium* ($T_{10}$), field soil, 5% biochar, mycorrhizae and *Bradyrhizobium* ($T_{11}$).

Seed protein percentages were significantly ($p<0.05$) increased in ($T_{10}$) (Fig. 1). According to the above results biofertilizers and organic manure are more effective in increasing protein in seeds. Seed protein content was increased in response to application of phosphate solubilizing microorganisms and these phosphate solubilizing microorganisms increase the uptake of N of soybean [12]. Biofertilizer alone or in combination with nitrogen fertilizer increased crude protein level by uptake of N from soil [13]. The increase in the crude protein yield is an expected result to successive increase in N level in response to biofertilizer treatment [14].

Application of biofertilizer increased the fat percentage over the un-inoculated treatment (Fig. 2). Crude fiber percentage in soybean seeds was higher in synthetic fertilizer treatment ($T_8$) but there was no significant difference with ($T_{10}$) (Fig. 3). This result agrees with previous

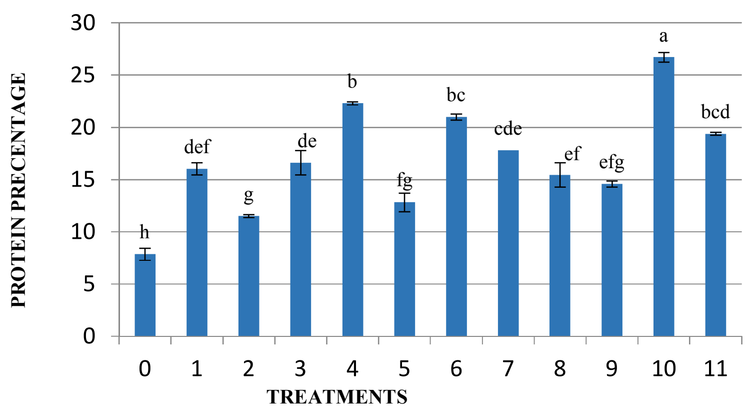


**Fig. 1. Changes in protein content with different treatments. Means that do not share a same letter is significantly different (p < 0.05)**

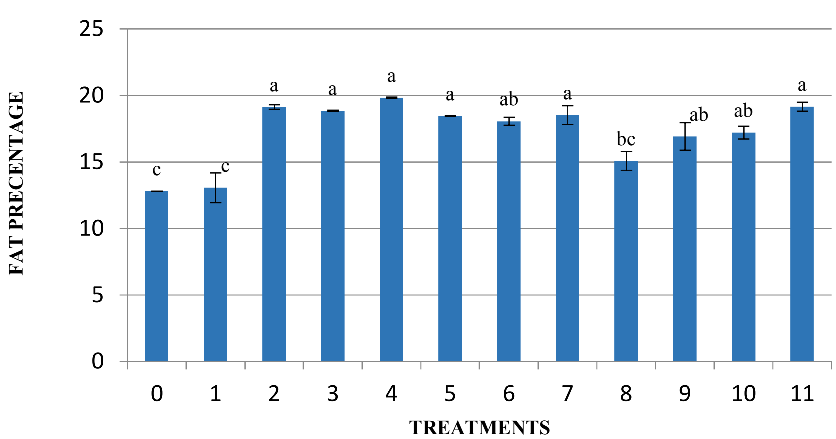


**Fig. 2. Changes in fat content with different treatments. Means that do not share a same letter is significantly different (p < 0.05)**

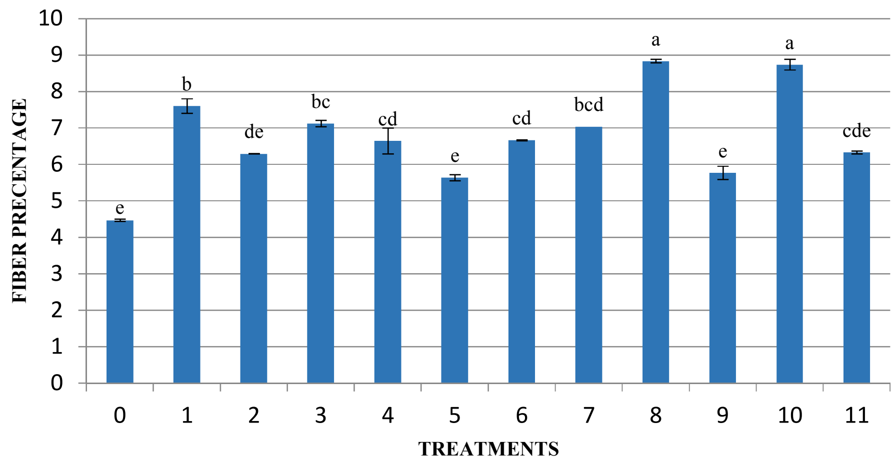


**Fig. 3. Changes in crude fiber with different treatments. Means that do not share a same letter is significantly different ($p < 0.05$)**

studies indicating that inoculation of snap bean (*Phaseolus vulgaris* L.) with biofertilizers reduces the seed fiber percentage [15].

## 4. CONCLUSION

The application of organic and biofertilizers together resulted in an improvement of the yield components and nutrient quality of soybean seeds, except for the case of crude fiber content which increased by the application of synthetic fertilizer. Overall, organic and biofertilizers could be used as efficient substitutes of synthetic fertilizers, not compromising yield and nutrient quality of soybean.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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