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Research Article

Application of Buffalo Manure and Biochar Improved growth and Yield of Soybean (*Glycine max L. Merrill*)

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Abstract

Buffalo manure and rice-husk biochar (hereafter refer to biochar) are known as organic materials that their application to soil can enhance growth and production of crops. The appropriate dose of these organic materials to increase growth and yield of soybean is yet studied particularly on the southeast coast of Timor-Leste. This study aimed to identify appropriate doses of buffalo manure and biochar for producing soybean. The experiment was delivered using a Split Plot Design factorial 3 × 3. The first factor was buffalo manure (K) consisted of three level treatments; K0 = 0 t/ha (control), K1 = 5 t/ha, K2 = 10 t/ha, and the second factor were biochar (B) consisted of three level treatments; B0 = 0 t/ha (control), B1= 3 t/ha, and B2 = 6 t/ha. Parameters investigated were soil pH, crop phenology, plant height, leaf and branch numbers, filled pods, seeds per pod, biomass production, yield and harvest index. Analysis of variance showed that biochar significantly increased pH level of the soil by 4.01% and 6.80% for 3 t/ha and 6 t/ha biochar, respectively, compared to the control (5.33). Application of buffalo manure and biochar did not affect crop phenology. There was buffalo manure x biochar interaction for plant height and the rests showed an independent positive impact on growth and yield of soybean. The application of buffalo manure at 5 t/ha, in general, did not affect growth and yield. Buffalo manure at the rate of 10 t/ha significantly increased filled pods per plant, 100 seed weight, seed yield and plant biomass production by 32.55%, 5.93%, 36.24% and 35.17%, respectively, compared to the controls. Application of biochar with 3 t/ha increased filled pods per plant, 100 seed weight, seed yield, plant biomass and HI by 10.64%, 1.70%, 10.47%, 7.51% and 2.94%, respectively, compared to the controls. These results showed positive impact of buffalo manure and biochar on growth, yield and yield components of soybean.

Introduction

Soybean (Glycine max *L. Merrill*) which has ability to fix free atmosphere N2 contributing to soil nitrogen [1] and hence it is essential in crop rotation with other high economic value [2]. Other beneficial of growing soybean is that the seeds of soybean contain high essential protein of up to 44% [3] which benefits not only for livestock but also to human health [4]. This protein rich grain legume soybean leads to its production worldwide particularly in developing countries. In Timor-Leste, soybean could be an alternative nutritional option to human consumption when most of the household access to nutritional diet is mostly below 50% [5]. Although soybean is commonly cultivated in Timor-Leste for long time, however, the yield reported was relatively very low of 1.2t/ha [6], despite yield potential ranged between 2 t/ha [7] and 2.3 t/ha [8]. However, these soybean yields are still low compared to the yield reported [9] which was over 4 t/ha.

Some studies have shown that the application of animal manure enhances soybean yield. For example, adding 1.5 t/ha cattle manure significant increased soybean yield by 36.02% compared to the control [10]. The yield increased by the addition of cattle manure is that it contains essential macro and micro nutrients including N, P, K Ca, Mg for crops [11]. Further, a study showed chemical characterization of fresh and composted total C and N, extractable P, K, Na and B for buffalo manure [12] which are essential for growth and yield of crops.

Application of biochar can provide soil amendment through which it improves soil physics and chemicals. Addition of biochar decreased soil bulk density by 29%, but increased porosity by 59% [13]. Further, the authors showed that addition of biochar improved soil pH, cation exchange capacity and organic carbon by 46%, 20% and 27%, respectively. Another report showed that application of biochar increased P availability in soil by 45%, but decreased NO_3^-N and NH_4^+N by 12% and 11%, respectively [14], and these nutrients would be slowly released into the soil for plants to absorb [15].

The appropriate dose of buffalo manure and biochar for production of soybean on the southeast coast of Timor-Leste is yet known. The current research aimed at identifying the appropriate dose of buffalo manure and biochar for production of soybean.

Materials and Methods

This research was conducted in a farmland on the southeast coast of Timor-Leste at the village of Irabin de Cima, Post Administrative of Uato-Carbau, Municipality of Viqueque during rainy season from November 2021 to February 2022. Figure 1 shows a long-term average rainfall and humidity (A) and temperature (B) of the nearby Post Administrative of Iliomar, Municipality of Lautem. The research site was located at an altitude of 54 m above sea level and the soil was clay loam.

The research was delivered using a Split Plot Design factorial 3 × 3 with three replications repeated in three blocks. The first factor (main plot) was buffalo manure (K) with three level of treatments; K0 = control, K1 = 5 t/ha, and K2 = 10 t/ha, and the second factor (sub-plot) was rice-husk biochar (B) with three level of treatments; B0 = control, B1 = 3 t/ha, and B2 = 6 t/ha. Buffalo manure and biochar materials were collected from local farms.

Total research area was 161m^2 (7m by 23m). The soils were prepared using a tractor followed by preparing plots of 2m by 2m. There were 27 plots in total (9 plots in each block). Buffalo manure and rice-husk biochar were applied to seeding holes in each plot, based on the application treatments, two weeks before seeding. Seeds of soybean were obtained from local market and seeded three to four seeds per hole with a planting distance of 30cm by 30cm and reduced to 2 plants per hole once established.

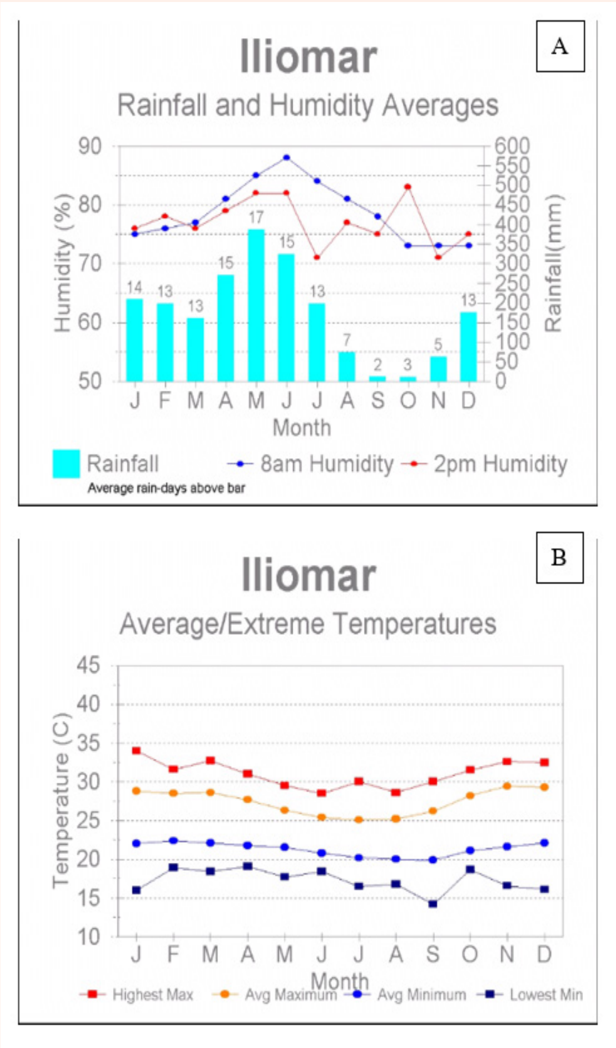

Figure 1: Long-term average rainfall and relative humidity (A) and temperature (B) of the research site represented by a nearby Iliomar Post Administrative, Lautem Municipality. Source: Defense Meteorological Support Unit, Australian Bureau of Meteorology.

Parameters investigated were soil pH, crop phenology, plant height, number of leaves and branches, filled pods, seeds per pod, plant biomass and harvest index. Soil pH was determined at maximum growth of soybean plant at 42 days after sowing (DAS) using a portable soil pH tester. Crop phenology was determined at 90% germination, flowering, pod set and physiological maturity. Plant height at its growth maximum of six weeks (or 42 days) after planting by measuring from soil level to the tallest shoot. This was done from three pre-randomized uniform selected plant samples in each plot. At the same time, number of leaves and branches were also manually counted. At harvest, five representative plants from $1m^2$ harvested were randomly selected for yield and yield components, including filled pods per plant and seeds per pod. Seeds were separated from the pods, with the pod walls added to the other plant components, oven-dried at 75°C for 48 h, and weighed for dry matter production. The seeds remained in oven for 2h to ensure that they were dry before weighing for seed yield. One hundred seeds were randomly selected and weighed for seed size. The harvest index was determined by seed weight per total biomass.

Analysis of variance was performed using GenStat Statistical Software Version 18 manufactured by VSN International (VSNi), Hertfordshire, UK to compare data between treatments.

Results

Soil pH measured at 42 days after sowing (DAS) significantly increased by 4.01% and 6.80% for 3 t/ha and 6 t/ha biochar, respectively, compared to the control (5.33) ($P < .001$) (data not shown). Buffalo manure did not affect the soil pH ($P > 0.05$).

Crop phenology did not differ significantly between treatments (Figure 2). In general, seeds of soybean germinated three days after sowing (DAS), reached 90% flowering at 25.7 DAS and set pod at least 8.6 days after flower initiation. Soybean plants reached physiological maturity at around 85 DAS.

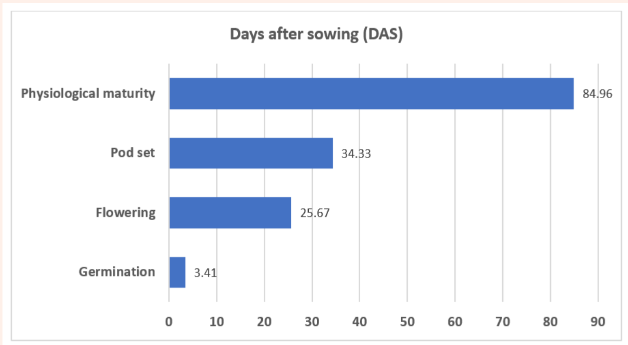

Figure 2: Phenological development of soybean

There was buffalo manure x biochar interaction for plant height ($P = 0.021$) (Figure 3). Treatment combination of buffalo manure with dose 10 t/ha and biochar with dose 6 t/ha had the highest plant height (51.78cm) followed by the combination of buffalo manure with dose 10 t/ha and biochar with dose 3 t/ha (47.67cm) and this followed by the combination of buffalo manure with dose 5 t/ha and biochar with dose 6 t/ha (44.66cm). The latter was comparable to the rests except combinations of the controls (40.11cm) and combination without buffalo manure and biochar with dose 3 t/ha (40.33cm) being the shortest plant height.

The application of buffalo manure did not affect growth and development of soybean at the rate of 5 t/ha, except leaf number (Table 1). Number of soybean leaf increased by 18.1% and 31.6% for buffalo manure 5 t/ha and 10 t/ha, respectively, compared to the control. Buffalo manure at the rate of 10 t/ha significantly increased branch number ($P = 0.014$), filled pods per plant ($P = 0.001$), 100 seed weight ($P = 0.003$), seed yield ($P = 0.002$) and plant biomass production ($P = 0.003$) by 40.65%, 32.55%, 5.93%, 36.24% and 35.17%, respectively, compared to the controls.

Overall, biochar at the rate of 3 t/ha significantly increased growth and yield of soybean compared to the controls, but, in general, no differences observed between the 3 t/ha biochar and 6 t/ha (Table 1). Soybean leaf number did not differ between control (20.07 leaves) and the 3 t/ha biochar (21.85 leaves), but biochar with 6 t/ha significantly increased leaf number by 14.81% compared to the control. Number of branches increased by 12.74% and 25.66% for 3 t/ha and 6 t/ha biochar, respectively, compared to the control ($P < .001$). Application of 3 t/ha biochar increased filled pods per plant by 10.64% compared to the control ($P < .001$). Number of seeds per pod did not differ between the control and 3 t/ha biochar. However, adding 6 t/ha biochar significantly increased seeds per pod by 5.74% compared to the control ($P = 0.037$). Biochar with 3 t/ha increased 100 seed weight by 1.70% compared to the control ($P = 0.013$). Adding 3 t/ha biochar significantly increased seed yield, plant biomass and harvest index by 10.47% ($P < .001$), 7.51% ($P = 0.005$), and 2.94% ($P < .001$), respectively, compared to the controls.

Table 1: Average number of soybean leaves, branches and filled pods per plant, and seeds per pod, 100 seed weight, seed yield, total biomass production and harvest index (HI).

Treatments	Leaf number	Branch number	Filled pod/plant	Seeds/pod	100 seed weight (gr)	Seed yield (t/ha)	Plant biomass (t/ha)	HI (%)
Buffalo manure								
K0 (control)	17.78 A	2.00 A	29.36 A	2.31 A	12.53 A	1.39 A	3.17 A	44.09 A
K1 (5 t/ha)	21.70 B	2.52 A	33.07 A	2.33 A	12.76 A	1.52 A	3.43 A	44.37 A
K2 (10 t/ha)	26.00 C	3.37 B	43.53 B	2.44 A	13.32 B	2.18 B	4.89 B	44.49 A
l.s.d.0.05	2.693	0.697	4.090	0.131	0.275	0.240	0.608	2.643
Biochar								
B0 (Control)	20.07 a	2.26 a	32.09 a	2.30 a	12.70 a	1.54 a	3.57 a	43.28 a
B1 (3 t/ha)	21.85 ab	2.59 b	35.91 b	2.33 a	12.92 b	1.72 b	3.86 b	44.59 b
B2 (6 t/ha)	23.56 b	3.04 c	38.00 b	2.44 b	12.99 b	1.83 b	4.08 b	45.10 b
l.s.d.0.05	1.938	0.2952	2.465	0.109	0.1820	0.121	0.265	0.631

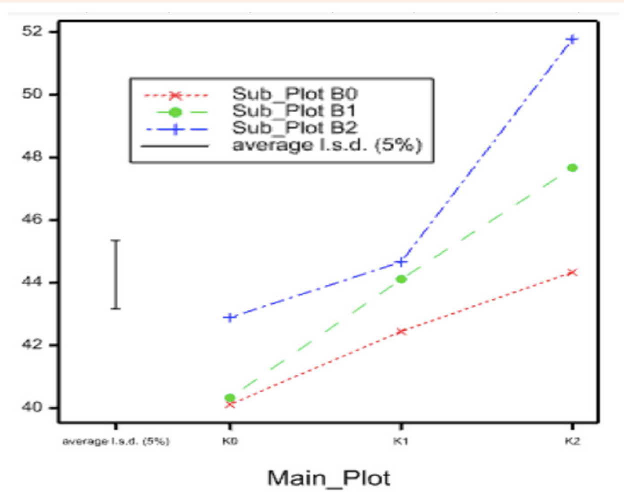

Figure 3: Buffalo manure x biochar interaction for plant height (P = 0.021).

Discussion

This is the first study to identify the appropriate dose of buffalo manure and biochar on growth and yield of soybean particularly on the southeast coast of Timor-Leste. The research site is one of the agriculture potentials in the country, however it is in remote areas where farmers are rarely accessed to technology interventions. The research was conducted on a livestock farmland where nearby community are easily accessed to the site. Thus, the additional objective of the research was to demonstrate the use of organic materials of buffalo manure and biochar for production of soybean to local community.

The experimental site was acidic clay loam soil. The application of biochar significantly improved soil pH measured at the maximum growth of soybean plant. This result consistent with a review that the application of biochar can improves soil pH that enhances the availability of essential plant nutrients such as N, P, K, Ca, Mg and Mo [16].

The current study revealed no significant impact of buffalo manure and biochar on crop phenology. In general, crop phenology in the current study was consistent with a study on soybean [7], but it was earlier than another study on soybean [8].

Overall, there were no buffalo manure x biochar interaction observed except plant height (Figure 3). Treatment combination of buffalo manure with dose 10 t/ha and biochar with dose 6 t/ha had the highest plant height (51.78cm) followed by the treatment combination of buffalo manure with dose 10 t/ha and biochar with dose 3 t/ha (47.67cm) and the rests of treatment combinations were comparable and the shortest plant height was the control treatments. This result showed a positive mixing buffalo manure and biochar on soil nutrients and physics that improve plant height of soybean which was consistent with other studies on tomato [17], maize [18] and soybean [19]. The author [19] concluded that combined biochar and cow manure improved soil fertility and thus growth and yield of soybean.

The results, in general, showed an independent positive impact of buffalo manure and biochar on growth, development and yield of soybean. Overall, application of buffalo manure with dose 6 t/ha did not affect significantly on growth, development and yield of soybean (Table 1 & Figure 4). Except seeds per pod and harvest index, adding buffalo manure with dose 10 t/ha significantly increased growth and yield of soybean (Table 1 & Figures 4A & 4C) and this was consistent with other study showed significant impact of manures on growth and yield component of soybean varieties [20]. Similar result to the current study was also reported for different grain legumes treated with carbonized chicken manure [21].

Unlike buffalo manure, application of biochar with dose 3 t/ha significantly increased growth and development of soybean (Table 1 & Figures 3 & 4). Adding more biochar to 6 t/ha, in general, did not make a difference on soybean growth and yield suggesting that biochar with low rate of 3 t/ha can be recommended to increase production of soybean. This is particularly important for the local community where the availability of biochar materials particularly rice-husk are limited. Because of this reason, other previous studies on horticultural crops such as watermelon used a minimum level of 3 t/ha biochar to increase yield of water melon (unpublished data) to be feasible for farmers to adopt the technology. Soybean biomass production in the current study was comparable to other study on soybean [7], but the rate of increase (7.51%) with 3 t/ha biochar (Table 1 & Figure 4B) was less than a greenhouse study [22]. The seed yield in the current study was over 100% higher with 10 t/ha buffalo manure (Table 1 & Figure 4C) and 36% higher with 3 t/ha biochar (Table 1 & Figure 4D) compared to soybean yield in a study carried out on the northeast coast of Timor-Leste with irrigation supplement [8], but the yield was comparable to another study on soybean [7]. The application of 3 t/ha biochar in the current study increased seed yield by 11.49% and this was less than a greenhouse study treated with biochar (54% increased) [22]. Increased seed yield maybe associated with increased P availability [14] and thus P uptakes [21]. Harvest index in the current study was comparable to a study on soybean [7], but it was 34% higher than in study on soybean [8].

In general, buffalo manure has not commercialized in Timor-Leste, except chicken manure where it is currently sale for an approximately of USD 1/5 kg air dried weight. Similarly, rice-husk was not utilized until recently in 2018 when rice-husk biochar technology was first introduced to Timor-Leste. The demand on biochar has now increased and it is sale for USD 0.75 -1/kg biochar (personal communication to biochar users). These prices are relatively higher than its price in Indonesia which is below USD 0.50/kg biochar [23]. There is no study undertaken on the income generation for buffalo manure in crop production particularly in Timor-Leste. Studies on biochar, however, showed that application of biochar plus inorganic fertilizers N, P and K had positive impact on gross margin of tomato and cauliflower [24] and rock melon [25] suggesting potential use of biochar for crop production in Timor-Leste.

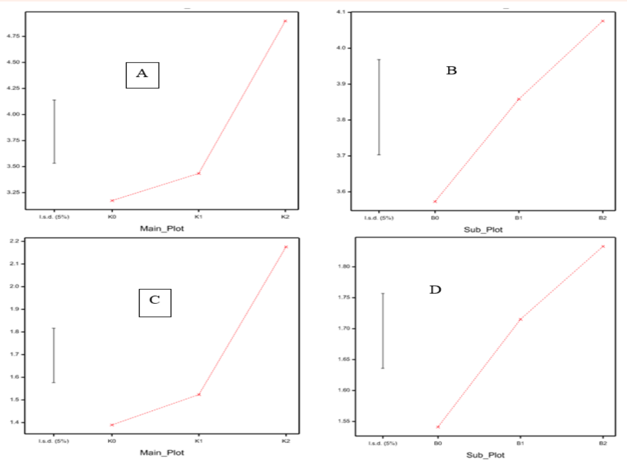

Figure 4: Biomass production (t/ha) with buffalo manure treatment (A) (P = 0.003) and Biochar treatment (B) (P = 0.005) and seed yield (t/ha) with buffalo manure treatment (C) (P = 0.002) and Biochar treatment (D) (P < .001).

Conclusion

This study revealed that buffalo manure with dose 10 t/ha and rice-husk biochar with dose 3t/ha should be applied to soil to increase growth and yield of soybean. Gross margin study on the use of buffalo manure and biochar for soybean production is recommended for future study.

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