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Research Article

Improving mungbean growth in a semiarid dryland system with agricultural waste biochars and cattle manure

Roberto I.C.O. Taolin, Arnoldus Klau Berek*, Eduardus Y. Neonbeni, Syprianus Ceunfin, Origenes B. Kapitan, Maksimus Y. Seran

Center for Dryland Studies, Universitas Timor. Jl. Km 9, Kel. Sasi, Kec. Kota, Kefamenanu, TTU, NTT 85613

*corresponding author: b3r3kkl4u@gmail.com

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Abstract: Mungbean (*Vigna radiata* L.) productivity in dryland decreased recently due to the soil fertility degradation. The objective of this study was to evaluate the effect of biochar types and cattle manure rates on the growth of mungbean in semi-arid dark soil. The factorial completely randomized block design 3 x 5 with four replicates was set to arrange treatments for the field trial. Two biochars (rice husk and sawdust) at 10 t/ha in combination with four rates of cattle manure (1, 3, 5 and 10 t/ha) and control (without biochar and cattle manure) were applied to the soil, incubated for three weeks and then planted with mungbean cv. Fore Belu. The results revealed that additions of biochar and cattle manure increased soil moisture and soil electrical conductivity by 2-4% and 0.15-0.20, respectively; decreased soil temperature and bulk density by 1-2^{o}C and 0.2 g/cm^3, respectively; increased plant height, stem diameter, root length, total, shoot and root dry weights by 4 cm, 0.1 cm, 5 cm, 7 g, 0.9 g and 6 g, respectively, compared to the control. The best growth of mungbean was obtained from the additions of sawdust biochar at 10 t/ha and cattle manure at 3 t/ha.

Keywords: *biochar, cattle manure, mungbean, rice husk, sawdust*

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Introduction

The East Nusa Tenggara province is covered almost all by the climatic drylands (more than 3 billion ha out of 4.8 billion ha); thus the agriculture system was dominated by the dryland farming system (BPS NTT, 2017). Mungbean is one of the legumes crop cultivated by dry farmers such as in Malaka district, West Timor. This legume is being sequentially planted with maize in Malaka in particular (maize is planted first followed by mungbean). However, mungbean productivity tends to decrease due to the soil fertility degradation. Most of the dryland farmers were not applied chemical fertilizer due to the high price or the availability of the fertilizer issue. To face with this problem, the application of soil amendments such as biochar or organic fertilizers such as cattle manure is required. Biochar, solid product of pyrolysis lignocellulosic or other feedstock, produced at 200-600^{o}C in a closed container with limited or no oxygen supply (Lehmann and Joseph, 2015). It contains high fixed carbon and to a lesser extent some plant nutrients. Biochar is a porous material thus it can improve soil structure (soil aggregation, soil bulk density, soil aeration) (Mukherjee and Lal, 2013; Burell et al., 2016), increase water and nutrient retention (Zheng et al., 2013; Liu et al., 2017; Haider et al., 2017), and soil microbial population and activity (Graber et al., 2010; Kolton et al., 2010). Application of biochar was also enhanced plant growth and productivity. Biochar, on one side, contains limited plant nutrients because many of volatile nutrients were lost during the pyrolysis process, besides wood feedstock were poor in nutrient content (Ding et al., 2016; Domingues et al., 2017). Organic fertilizers such as animal manures, on another side, are higher in nutrient content. However, there are limited research findings on the application of biochar and cattle manure for improving dryland soil and mungbean productivity in West Timor in particular. The objective of this research is to improve soil and mungbean productivity with an application of biochar in combination with cattle manure.

Materials and Methods

Biochars feedstock was collected from the Malaka district, dried, burned with Kontiki kiln at about 350-400^{o}C. Cattle manure was also collected from Malaka district, air, dried, sieved to pass through 4 mm sieve size, and stored before used. Mungbean seeds were collected from a local farmer, sorted and stored before used. The field trial was conducted in Lorotolus village, Wewiku subdistrict, Malaka district, East Nusa Tenggara Province, started from July to November 2017. The factorial randomized completely block design 3 x 5 with four replications were used for arranged the treatments combinations.

Rice husk and sawdust biochars at 10 t/ha were applied in combination 4 rates of cattle manure (1, 3, 5, and 10 t/ha). Treatment without biochar or cattle manure was applied as the control. Biochars and cattle manure were mixed thoroughly with soil, watered, incubated for 3 weeks and then planted with mungbean cv. Fore Belu (a local mungbean). Soil properties changes and the growth of mungbean were measured and recorded until the maximum vegetative stage. Soil samples were collected before planting from each treatment/plot, air dried, grounded, sieve to pass through 2 mm sieve, and store before analysis. Soil pH and electrical conductivity (EC) were measured using a pH/EC meter from a mixture of soil and deionized water with the ratio of 1:1.

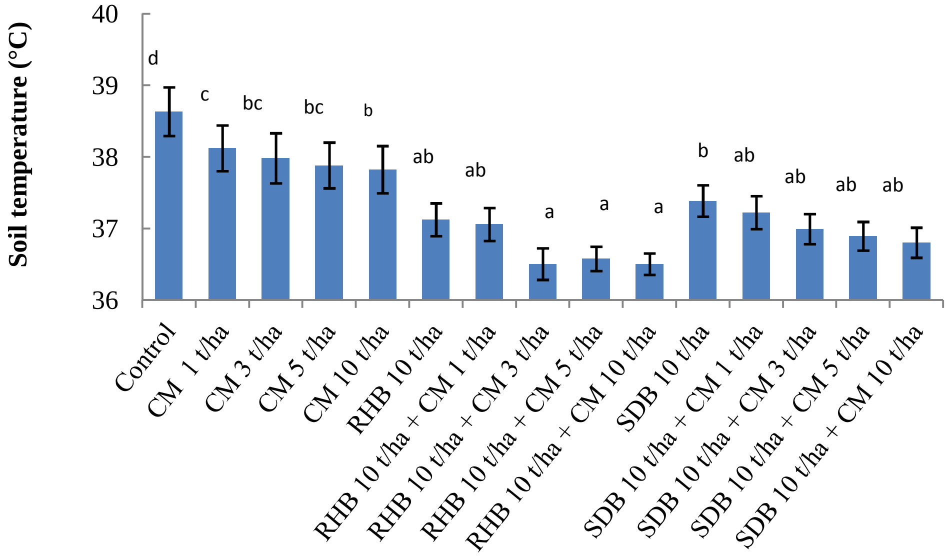
Soil moisture was measured using a gravimetric method. Soil temperature was measured in the field using an electrical soil thermometer. Soil bulk density was measured with the clod method (Black, 1986). Mungbean samples were collected five crops from each plot. Plant shoot and root were separated, and then washed three times with tap water. Plant fresh weights were measured before dried. Plant dry weights were measured after dried at 80^{o}C for 48 hours. Mungbean nodules were calculated after the nodules removed from the roots and washed three times with tap water. All data were analysed using the analysis of variance factorial of randomized completely block design. To compare the mean among treatments the new Duncan multiple range test at 5% was applied. All data analyses were running with SAS software 9.2 versions.

Results and Discussion

Soil properties changes and the growth mungbean resulted from the additions of biochars and cattle manures were presented in Tables 1 and 2, and Figures 1-6. Soil temperature was significantly ($P<0.05$) decreased by added biochars and cattle manures. The lowest temperature was resulted from the addition of rice husk biochar and cattle manure at 3 t/ha (Figure 1) although it was not significantly different to the rice husk biochar in combination with cattle manure at 5 or 10 t/ha.

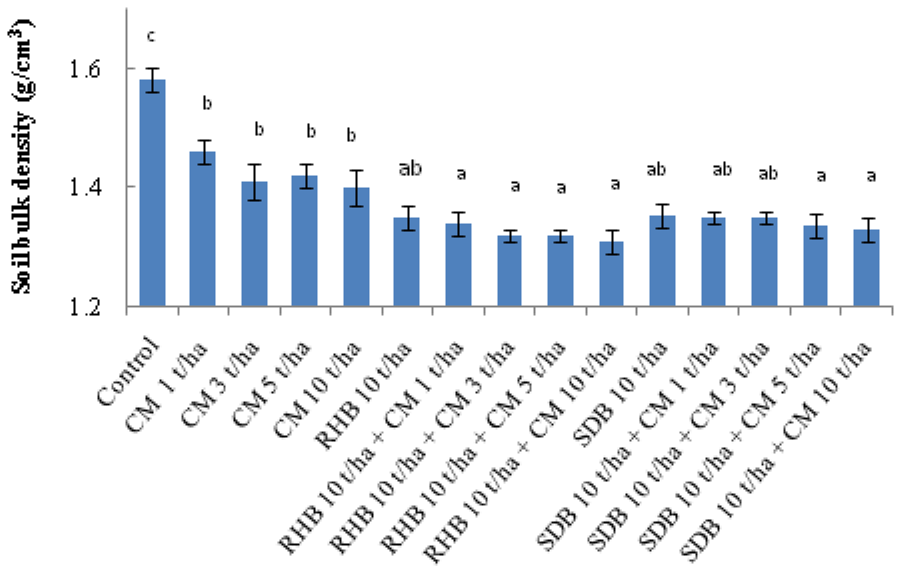
The decreasing of soil temperature by added biochar was likely due to declining of heat conductance, and reflectance resulted from the decreasing of soil bulk density and increasing of soil moisture content (Zhang et al., 2012). Application of rice-husk biochars in combination with cattle manures was also significantly ($P<0.05$) decreased soil bulk density compared to the control and cattle manure alone (Figure 2). Similar results were reported by Artiola et al. (2012), Basso et al. (2013), Bruun et al. (2014), and Igalavithana et al. (2017). Soil moisture content was significantly ($P<0.05$) increased by added biochars and cattle manures (Figure 3). Increasing soil moisture content by added biochars was due to the improving soil water holding capacity resulted from the increasing volumetric soil pores, soil specific surface areas and other physical properties by added biochars and cattle manures (Novak et al., 2009; Basso et al., 2013; Bantley et al., 2015; Yu et al., 2017). Soil pH ranged from 7.3 to 7.6. It was not significantly affected by added biochars and cattle manures because of the short range of original soil pH (7.4) and biochars pH (7.5-7.8).

Soil electrical conductivity (EC) was significantly ($P<0.05$) increased by added biochars and cattle manures (Table 1). It was increased from 1.009 to 1.225 dS/m. The highest EC was obtained from the added sawdust biochar 10 t/ha and cattle manure 10 t/ha, although it was not significantly different from other added biochars and cattle manures. The similar result was also reported by Chintala et al. (2013). Soil pH was not significantly ($P>0.05$) affected by added biochars and cattle manures. This could be related to the fact that biochars pH were 7.5-7.8 and the original soil pH was 7.4. Soil EC was significantly ($P<0.05$) increased by added biochars and cattle manures (Table 1). The increasing of soil EC was likely attributed to the increasing basic cations from the added biochars and cattle manures.



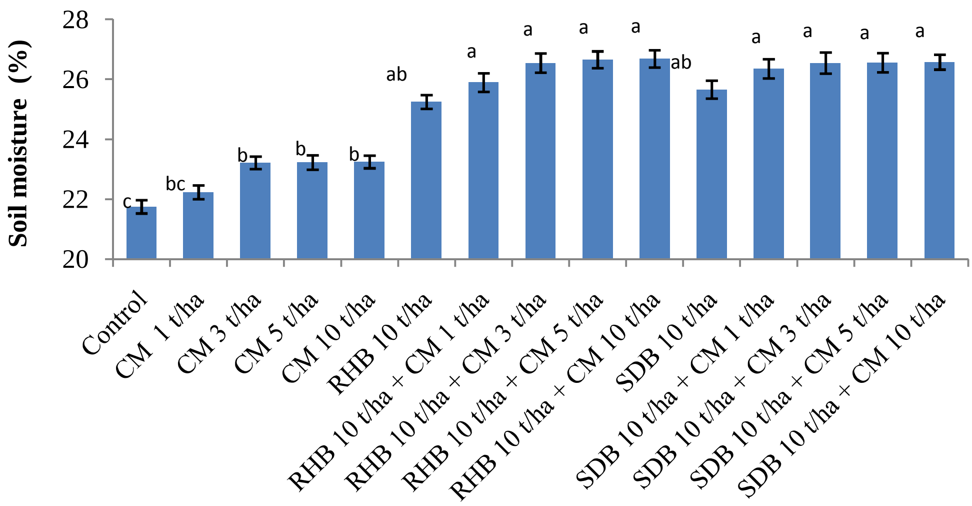
Note: CM = cattle manure, RHB = ricehusk biochar, SDB = sawdust biochar. Bars with the same letter(s) were not significantly different based on the DMRT test at 5%.

Figure 1. Soil temperature as affected by added biochars and cattle manures



Note: CM = cattle manure, RHB = ricehusk biochar, SDB = sawdust biochar. Bars with the same letter(s) were not significantly different based on the DMRT test at 5%

Figure 2. Soil bulk density as affected by added biochars and cattle manures



Note: CM = cattle manure, RHB = ricehusk biochar, SDB = sawdust biochar. Bars with the same letter(s) were not significantly different based on the DMRT test at 5%.

Figure 3. Soil moisture content as affected by added biochars and cattle manures

Table 1. Soil pH and EC as affected by added biochars and cattle manures

Treatments	**pH**		**EC (dS/m)**	
Control	7.4	a	1.009	b
Cattle manure 1 t/ha	7.5	a	1.125	ab
Cattle manure 3 t/ha	7.4	a	1.135	ab
Cattle manure 5 t/ha	7.4	a	1.174	ab
Cattle manure 10 t/ha	7.3	a	1.205	a
Rice husk biochar 10 t/ha	7.4	a	1.156	ab
Rice husk biochar 10 t/ha + cattle manure 1 t/ha	7.6	a	1.211	a
Rice husk biochar 10 t/ha + cattle manure 3 t/ha	7.3	a	1.235	a
Rice husk biochar 10 t/ha + cattle manure 5 t/ha	7.6	a	1.245	a
Rice husk biochar 10 t/ha + cattle manure 10 t/ha	7.5	a	1.054	b
Sawdust biochar 10 t/ha	7.6	a	1.145	ab
Sawdust biochar 10 t/ha + cattle manure 1 t/ha	7.5	a	1.201	a
Sawdust biochar 10 t/ha + cattle manure 3 t/ha	7.4	a	1.213	a
Sawdust biochar 10 t/ha + cattle manure 5 t/ha	7.4	a	1.222	a
Sawdust biochar 10 t/ha + cattle manure10 t/ha	7.3	a	1.225	a

Means followed by the same letter(s) were not significantly different base on the DMRT test at $\alpha = 5\%$

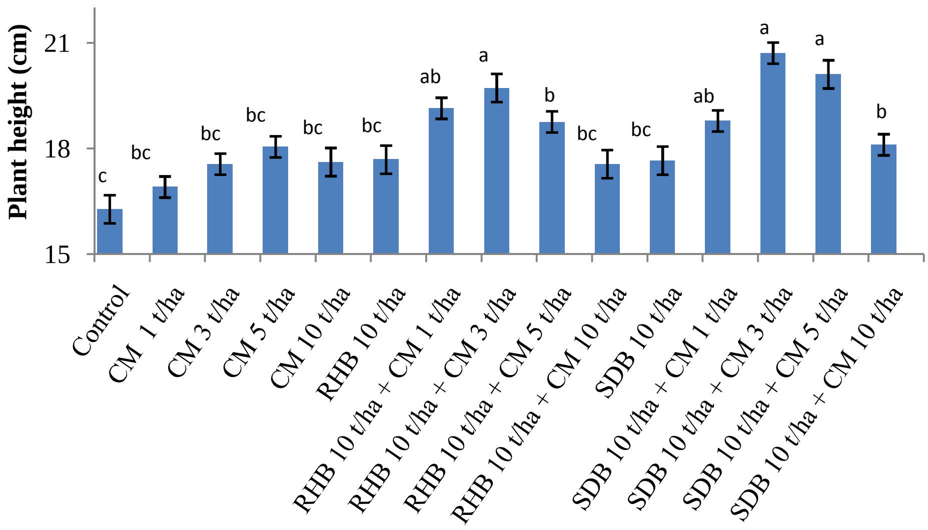
Additions of biochars and cattle manures increased the mungbean growth expressed in stem diameter, number of leaves, root and shoot dry weights, number of nodules (Table 2), plant height and total dry weights (Figure 4-6) compared to control or cattle manure alone. Increasing of mungbean steam diameter, number of leaves, plant height, root, shoot and total dry weight indicated that additions of biochars and cattle manures improve soil productivity. For example, mungbean stem diameter and plant height were increased 40% and 31%, respectively and mungbean root weight, root length, number of nodules were increased 210%, 22% and 181%, respectively resulted from the additions of sawdust biochar 10 t/ha and cattle manure 3 t/ha. This could be attributed to the improving of Vertisol soil productivity such as the decreasing of soil bulk density (Figure 2) and soil moisture content.

Table 2.Mungbean growth as affected by added biochars and cattle manures

Treatments	**Stem diameter (cm)**	**Number of leaves (leave)**	**Number of nodules (nodule)**	**Root dry weight (g/plant)**	**Shoot dry weight (g/plant)**	**Shoot : root ratio**
Control	0.35 c	6 c	32 d	0.39 c	7.36 c	18.9 a
Cattle manure 1 t/ha	0.40 bc	7 b	50 c	0.49 c	8.46 b	17.3 a
Cattle manure 3 t/ha	0.42 bc	7 b	36 d	0.61 b	9.17 b	15.0 b
Cattle manure 5 t/ha	0.44 b	7 b	80 b	0.76 b	9.49 b	12.4 b
Cattle manure 10 t/ha	0.45 b	7 b	52 c	0.70 b	9.00 b	12.8 b
Rice husk biochar 10 t/ha	0.43 bc	7 b	58 c	0.62 b	8.51 b	13.8 b
Rice husk biochar 10 t/ha + cattle manure 1 t/ha	0.46 b	8 a	79 b	0.91 a	11.28 a	12.4 b
Rice husk biochar 10 t/ha + cattle manure 3 t/ha	0.48 a	8 a	80 b	1.19 a	12.11 a	10.1 c
Rice husk biochar 10 t/ha + cattle manure 5 t/ha	0.45 b	7 b	87 b	1.01 a	10.62 a	10.5 c
Rice husk biochar 10 t/ha + cattle manure 10 t/ha	0.44 b	7 b	62 c	0.92 a	9.68 b	10.5 c
Sawdust biochar 10 t/ha	0.45 b	7 b	58 c	0.71 b	8.54 b	12.0 b
Sawdust biochar 10 t/ha + cattle manure 1 t/ha	0.46 b	7 b	61 c	0.87 b	11.32 a	13.0 b
Sawdust biochar 10 t/ha + cattle manure 3 t/ha	0.49 a	8 a	90 a	1.21 a	12.93 a	10.7 c
Sawdust biochar 10 t/ha + cattle manure 5 t/ha	0.49 a	8 a	49 c	1.11 a	13.25 a	11.9 b
Sawdust biochar 10 t/ha + cattle manure 10 t/ha	0.47 a	7 b	58 c	0.89 b	10.61 a	11.9 b

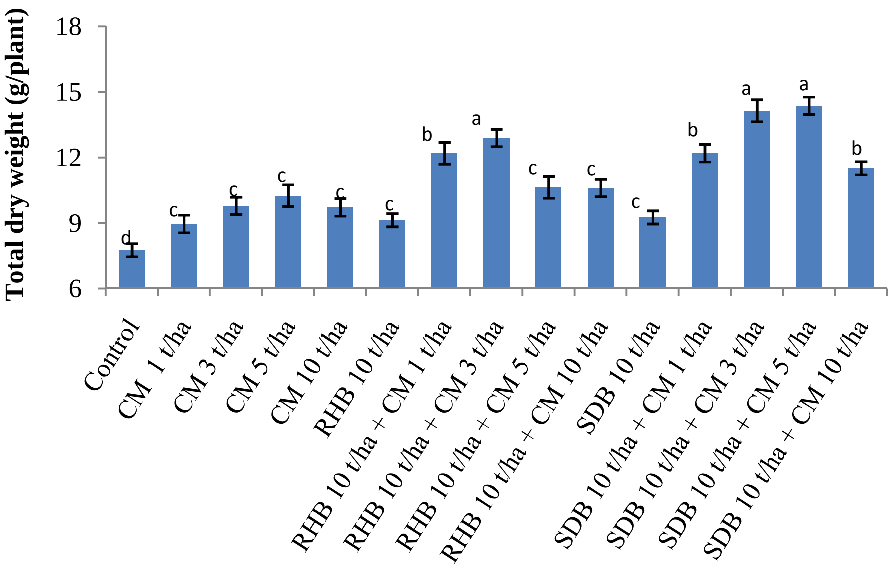
Means followed by the same letter(s) were not significantly different base on the DMRT test at $\alpha = 5\%$

The increasing of mungbean stem diameter and plant height caused by an addition of biochar and compost was also reported by Wang et al. (2016). Xiang et al. (2017) based on a meta-analysis showed that addition of biochar increase root biomass, root length and number of nodules about 32%, 52%, and 25%, respectively. Sawdust biochar enhanced mungbean growth better than rice husk biochar, although there was no significantly different effect between them on soil physic-chemical properties. This could be attributed to the regulation of soil temperature and soil moisture contents that improving mungbean root growth. Chaudhary et al. (1985) showed that summer mung bean root density was higher when grown under the lower soil temperature (35-37^{o}C) in India. Kizito et al. (2015) was also reported that BET surface area, total pore volume and micropore volume of wood biochar was higher than the rice husk biochar.



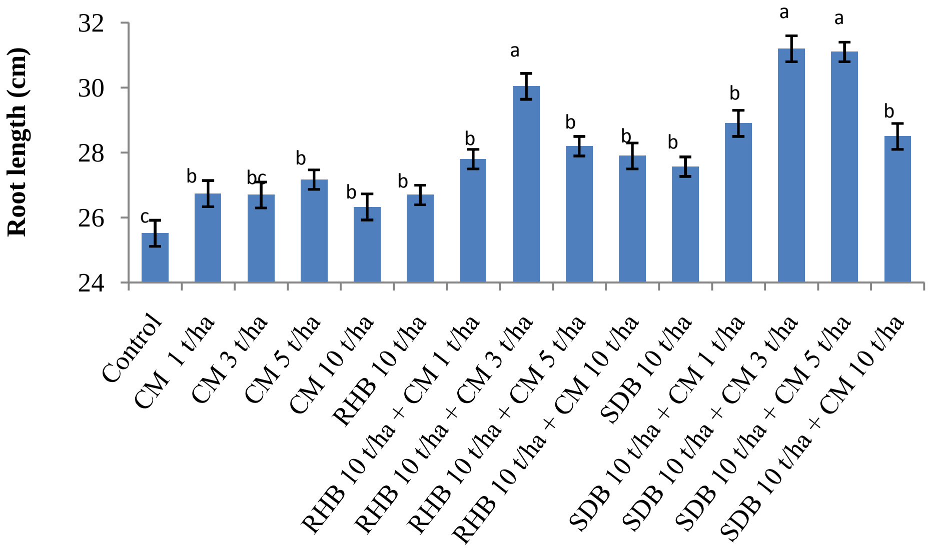
Note: CM = cattle manure, RHB = ricehusk biochar, SDB = sawdust biochar. Bars with the same letter(s) were not significantly different based on the DMRT test at 5%.

Figure 4. Mungbean height as affected by added biochars and cattle manures



Note: CM = cattle manure, RHB = ricehusk biochar, SDB = sawdust biochar. Bars with the same letter(s) were not significantly different based on the DMRT test at 5%.

Figure 5.Mungbean total dry weight as affected by added biochars and cattle manures



Note: CM = cattle manure, RHB = ricehusk biochar, SDB = sawdust biochar. Bars with the same letter(s) were not significantly different based on the DMRT test at 5%.

Figure 6.Mungbean root length as affected by added biochars and cattle manures

Conclusion

Mungbean growth in a semiarid Vertisol soil was enhanced by added biochars and cattle manures. Specifically, soil bulk density and temperature were decreased and soil moisture content was increased by added biochars and cattle manure compared to the control. As a result, mungbean grown at the biochar and cattle manure-amended soil were increased its stem diameter, height, shoot, root and total dry weights, and number of nodules. Sawdust biochar in combination with cattle manure improve the mungbean growth better than rice husk biochar, and the best growth of mungbean was obtained from the addition of sawdust biochar at 10 t/ha and cattle manure at 3 t/ha.

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