The effect of biochar application and number of shoots on the growth of ratoon sorghum in vertisol soil

Vidi Mercyana², Samanhudi¹,²,³,⁴, Puji Harsono¹,²,³

¹ Department of Agrotechnology, Faculty of Agriculture, Universitas Sebelas Maret (UNS), Jl. Ir. Sutami 36A, Kentingan, Surakarta, 57126, Central Java, Indonesia
² Magister Program of Agronomy, Faculty of Agriculture, Universitas Sebelas Maret (UNS), Jl. Ir. Sutami 36A, Surakarta, 57126, Central Java, Indonesia
³ Doctoral Program of Agricultural Science, Faculty of Agriculture, Universitas Sebelas Maret (UNS), Jl. Ir. Sutami 36A, Surakarta, Central Java, Indonesia
⁴ Center for Research and Development of Biotechnology and Biodiversity, Universitas Sebelas Maret (UNS), Jl. Ir. Sutami 36A, Kentingan, Surakarta, 57126, Central Java, Indonesia

Email: vidimercyana@gmail.com

Abstract. Sorghum (Sorghum bicolor (L.)) is one of the potential commodities that can be developed to support food and energy diversification programs in Indonesia. It has the advantage that one of them can be ratoon. However, the yield of ratoon is lower than that of the main crop. The research on ratoon sorghum was carried out in vertisol soil. This aims of the study to determine the interaction between biochar application and number of shoots on the growth of ratoon sorghum in vertisol soil, to obtain the right dose of biochar and to get the appropriate number of shoots to increase the yield of ratoon sorghum. The study was arranged in a factorial manner using a Completely Randomized Block Design (CRBD). The treatment factors were biochar (without biochar, 2.5 tons/ha, 5 tons/ha and 7.5 tons/ha), and the number of shoots (1 shoot, 2 shoots, 3 shoots, and 4 shoots) at the 5% level. The results showed that there was no interaction between biochar treatment and the number of shoots on the variable of panicle sorghum, weight of fresh stover, and weight of dry stover. The results showed an interaction on the variable of plants height observation. Provides growth results that are not significantly different in the parameters of plant height, panicle length and panicle weight. Gives significantly different results in panicle length, weight of fresh stover, and weight of dry stover. The number of 1 shoots produced the highest growth for all observed variables.

1. Introduction
Sorghum (Sorghum bicolor (L.)) is one of the potential commodities that can be developed to support food and energy diversification programs in Indonesia. Sorghum can be cultivated further (ratoon). The problem in ratoon sorghum is that the productivity of ratoon sorghum is still low. The yield of sorghum ratoon seeds has not yet reached optimal results [1]. Yield of ratoon sorghum compared to sorghum grown from seeds has decreased yield [2]. The main causes of low yield productivity include
poor quality seeds, environmental factors, lack of nutrients, pests diseases and less optimal plant maintenance. It is necessary to improve the management of a better cropping system [3].

The land used is vertisol soil. Vertisol soil is a soil that is dark gray to black in color, has a clay texture and has fractures that can periodically open and close [4]. Naturally, the fertility of Vertisol soil is low. [5] showed that the vertisol soil was classified as less fertile. One of the factors that affect plant growth and production is soil quality. Therefore, it needs effort to increase the productivity of vertisol soil. One of the solution is to addition organic fertilizer [4].

The use of biochar is one option as a source of organic matter in soil management. Aims to restore and improve the fertility quality of degraded or critical soils. Biochar is bio charcoal that functions as a soil enhancer to improve the physical, chemical and biological properties of the soil. Biochar in the soil is also useful as a habitat for fungi and other soil microbes so that it can increase soil biological fertility [6]. The role of biochar for improving soil properties, increasing soil pH [7]; [8], improve the electrical conductivity of the soil [9], increase the cation exchange capacity of the soil [10]; [11], increasing the ability of the soil to bind water [12]; [13] and increase the population and activity of beneficial microbes in the soil [14], so that it can increase the plant productivity further.

The problem faced is that there is no known use of biochar that can increase yields for the ratoon sorghum system on vertisol soils. Then the number of new shoots that grow on ratoon sorghum also affects the yield of the plant. The number of shoot and primary crop harvest in different age also influence bioethanol production in sorghum plant [15]. Increased production of ratoon sorghum can also be seen from the number of shoots that grow after the plant is pruned. The use of the number of shoots has an effect on the yield obtained from the ratoon sorghum system. So this research needs to be done to determine the use of wood charcoal biochar and the number of shoots.

The purpose of this study was to determine the effect of using wood charcoal biochar and the number of different shoots that could increase the productivity of ratoon sorghum on vertisol soil.

2. Materials and Methods
The study was conducted at the experimental farm in Sukoharjo Regency from January to April 2021. Research materials include sorghum that has been harvested at the time of planting 1, biochar wood charcoal, urea fertilizer, combination label. The research tools used include tugal, meter, caliper, handrefractometer, stationery. Wood charcoal biochar that is used as a result of incomplete combustion (pyrolysis) is weighed according to the required treatment sample, then fills the sorghum planting area in a circle and spreads the biochar by immersing it in the soil and covering it with soil. The study land use vertisol soil. Vertisol soils have constraints on their physical properties which are generally heavy clay textures, have the property of expanding when exposed to water and shrinking when water shortages, low water infiltration rates and slow drainage.

The environmental design used was a factorial Completely Randomized Block Design (CRBD) with 2 treatment factors, they are biochar (without biochar, 2.5 tons/ha, 5 tons/ha and 7.5 tons/ha) and the number of shoots (1 shoot, 2 shoots, 3 shoots, and 4 shoots). The variables observed included plant height, panicle length, panicle weight, weight of plant fresh stover, and weight of plant dry stover. The data obtained were analyzed by Anova test at a 95% confidence level. If there is a significant difference, it is continued with the Duncan Multiple Range Test (DMRT) of 5% level.

3. Results and Discussion
3.1. Plant height
The results of the analysis of variance showed that there was an interaction between the application of biochar and the number of different shoots in plant height of the ratoon sorghum. However, the results of the biochar application and the number of shoot which is used give no significant effect in the height of sorghum plants (Table 1 and Table 2). The biochar treatment given to the 5 ton/ha biochar application resulted in the best ratoon sorghum plant height growth among the four tested biochar applications. The high yield of sorghum ratoon was 147.21 cm. This is because with the addition of
biochar into vertisol soil, nutrients for plant growth will be more available during the vegetative period because nutrients are not lost or leached by water, so plants are able to grow well and produce good plant height. Biochar is useful as a habitat for fungi and other soil microbes so that it can increase soil biological fertility [6]. The quantity and quality of biochar used is also influenced by the type of raw material from biochar [16]. The growth of ratoon sorghum plant height is relatively stable. Plants can grow well if their water needs are met in the right amount and time, as well as sufficient nutrients, CO2, temperature and sunlight. The availability of nutrients for plants will be able to increase plant growth because these nutrients an important role in the photosynthesis process [17].

Table 1. The effect of biochar application on plant height of ratoon sorghum in vertisol soil

| Biochar          | Plant height (cm) |
|------------------|-------------------|
| B1 (without biochar) | 143.42 a         |
| B2 (2.5 tons/ha)   | 145.17 a         |
| B3 (5 tons/ha)     | 147.21 a         |
| B4 (7.5 tons/ha)   | 140.29 a         |
| Average           | 144.02           |

Note: Numbers followed by the same letter show that there is no significant difference in DMRT at the 5% level.

Table 2. The effect of number of shoots on plant height of ratoon sorghum in vertisol soil

| Treatment of number of shoots | Plant height (cm) |
|-------------------------------|-------------------|
| T1 (1 Shoot)                  | 147.85 a          |
| T2 (2 Shoots)                 | 144.49 a          |
| T3 (3 Shoots)                 | 139.84 a          |
| T4 (4 Shoots)                 | 143.92 a          |
| Average                       | 144.02            |

Note: Numbers followed by the same letter that there is no significant difference in DMRT at the 5% level.

In the treatment of the number of shoots, the highest sorghum plant height at the number of 1 shoot was 147.85 cm. Plant height is influenced by number of shoots growing as well, less it grow, so the plant is higher. Because of absorbed sunlight is much if less shoot density and photosynthesis process run optimally. The more plant population tends to increase the competition between plants in one clump and another, which affects growth and production. In this condition, the competition is getting bigger in get the growth factors, which are needed in photosynthetic activity, thus affects the plant's metabolic process [18].

3.2. Sorghum panicle

The weight of panicle has the highest correlation with the weight seed per plant [19]. The difference in panicle length tends to be related to the number of main stem segments, having a longer panicle length also has more number of internodes, and vice versa. The panicle length of a cultivar is influenced by genetics and where to grow plants [20]. The results of the analysis of variance showed that there was no interaction between the application of biochar and the number of different shoots in panicle length and panicle weight (Table 3 and Table 4). Based on table 3 shows the results that the application of biochar and the number of shoots given were not significantly different in panicle length and panicle weight. The highest panicle length was obtained in the treatment of 5 tons/ha biochar at 19.76 cm and the lowest at 7.5 tons/ha biochar at 18.32 cm. The highest panicle weight in the treatment of 7.5 tons/ha biochar was 20.96 and the lowest without biochar was 16.46.

The external factors such as nutrients, water, temperature, humidity, and light also respond differently to the characteristics of a plant. The increased absorption of nutrients causes the metabolic process to run optimally which will increase the formation of protein, carbohydrates and starch which
will be translocated to food reserves, namely panicles, as a result the panicles formed have a more weight [21].
Table 3. The effect of biochar application on panicle length and weight of ratoon sorghum in vertisol soil

| Biochar       | Panicle length (cm) | Panicle weight (g) |
|---------------|---------------------|--------------------|
| B1 (without biochar) | 19.00 a        | 16.46 a            |
| B2 (2.5 tons/ha)    | 19.46 a          | 19.48 a            |
| B3 (5 tons/ha)      | 19.76 a          | 17.80 a            |
| B4 (7.5 tons/ha)    | 18.32 a          | 20.96 a            |
| **Average**        | 19.14            | 18.67              |

Note: Numbers followed by the same letter in the same column show that there is no significant difference in DMRT at the 5% level.

Table 4. The effect of different number of shoots on panicle length and weight of ratoon sorghum in vertisol soil

| Number of shoots | Panicle length (cm) | Panicle weight (g) |
|------------------|---------------------|--------------------|
| T1 (1 Shoot)    | 22.47 b             | 20.78 a            |
| T2 (2 Shoots)   | 18.25 a             | 17.98 a            |
| T3 (3 Shoots)   | 17.82 a             | 17.96 a            |
| T4 (4 Shoots)   | 17.99 a             | 17.98 a            |
| **Average**     | 19.14               | 18.67              |

Note: Numbers followed by the same letter in the same column show that there is no significant difference in DMRT at the 5% level.

While the number of shoots treatment gave significantly different results on the panicle length of ratoon sorghum (Table 4). The panicle length yield of 3 shoots was significantly different from the yield of 1 shoot. The highest yield was obtained in 1 shoot with a panicle length of 22.47 cm and a panicle weight of 20.78 g. According to [22] stated that nutrients, water and light greatly affect metabolism in the development of flowers and seeds in plants. The panicle length is influenced by the genetic factors of each variety and the adaptability of the variety to the plant growing environment.

3.3. Weight of plant fresh stover

The weight of plant fresh stover is an indicator that shows the level of uptake of water and nutrients by plants for metabolism and is a combination of the development and increase of plant tissue such as number of leaves, leaf area, root length and plant height. The results of the analysis showed that there was no interaction between biochar application factors and the number of different shoots. Based on the Table 5 shows the results that the application of biochar given was not significantly different in the weight of fresh stover ratoon sorghum. The highest yield on the weight of plant fresh stover was produced with the use of 2.5 tons/ha biochar of 667.67 g and the lowest yield on the use of 5 tons/ha biochar.

Table 5. The effect of biochar application on fresh weight of ratoon sorghum in vertisol soil

| Biochar       | Weight of plant fresh stover (g) |
|---------------|----------------------------------|
| B1 (without biochar) | 620.67 a               |
| B2 (2.5 tons/ha)    | 667.67 a               |
| B3 (5 tons/ha)      | 578.33 a               |
| B4 (7.5 tons/ha)    | 626.92 a               |
| **Average**        | 623.39                |

Note: Numbers followed by the same letter show that there is no significant difference in DMRT at the 5% level.
Table 6. The effect of different number of shoots on fresh weight of ratoon sorghum stover in vertisol soil

| Number of Shoots | Weight of plant fresh stover (g) |
|------------------|----------------------------------|
| T1 (1 Shoot)     | 787.92 b                         |
| T2 (2 Shoots)    | 673.17 ab                        |
| T3 (3 Shoots)    | 555.08 ab                        |
| T4 (4 Shoots)    | 477.42 a                         |
| Average          | 623.39                           |

Note: Numbers followed by the same letter show that there is no significant difference in DMRT at the 5% level.

Based on the Table 6, the number of shoots treatment gave significantly different results on the weight of fresh stover ratoon sorghum. The highest weight of fresh stover on 1 shoot was 787.92 g. According to [23] states that the one seed planting per hole causes not competitive growing so that the plants more freely in nutrient and water absorption and also can absorb enough sunlight for photosynthesis process.

3.4. Weight of plant dry stover
The weight of plant dry stover is the organic material contained in the form of biomass, which reflects the energy capture by plants in the photosynthesis process. The higher the weight of the dry stover indicates that the photosynthesis process is going well. The results of the analysis showed that there was no interaction between biochar application factors and the number of shoots. Based on Table 7 showed the results that the application of biochar given was not significantly different in weight dry stover ratoon sorghum. Gives the highest yield on the application of 5 tons/ha biochar of 410.65 g, and the lowest yield on the treatment without biochar of 360.15 g.

Table 7. The effect of biochar application on weight of plant dry stover of ratoon sorghum in vertisol soil

| Biochar          | Weight of plant dry stover (g) |
|------------------|--------------------------------|
| B1 (without biochar) | 360.15 a                     |
| B2 (2.5 tons/ha)  | 390.42 a                      |
| B3 (5 tons/ha)    | 410.65 a                      |
| B4 (7.5 tons/ha)  | 377.69 a                      |
| Average           | 387.73                         |

Note: Numbers followed by the same letter show that there is no significant difference in DMRT at the 5% level.

Table 8. The effect of different number of shoots on weight of plant dry stover of ratoon sorghum in vertisol soil

| Number of Shoots | Weight of plant dry stover (g) |
|------------------|--------------------------------|
| T1 (1 Shoot)     | 233.31 b                       |
| T2 (2 Shoots)    | 180.82 ab                      |
| T3 (3 Shoots)    | 139.17 a                       |
| T4 (4 Shoots)    | 131.87 a                       |
| Average           | 171.29                         |

Note: Numbers followed by the same letter show that there is no significant difference in DMRT at 5% level.

Based on Table 8 shows the results that the treatment of the number of shoots gave significantly different results on the weight of dry stover ratoon sorghum. The yield of the number of 4 shoots...
was significantly different from the yield of the number of 1 shoots. The weight of dry stover in 1 shoots is 233.31 g and the weight of dry stover in 4 shoots is 131.87 g. In general, the number of 1 shoots had the highest average value for individual plants compared to ratoon sorghum plants with 2 shoots, 3 shoots and 4 shoots.

4. Conclusion
The results showed that there was no interaction between biochar application and the number of shoots on the variables observed as sorghum panicle, weight of fresh and dry stover. The results showed an interaction on the variable of plants height observation. The study resulted in the highest plant height in the application of 5 tons/ha biochar with 1 shoot. The highest yield for all variables was obtained in the number of 1 shoots of ratoon sorghum, this was because there was no competition for nutrients, sunlight, and water absorbed, so that the ratoon sorghum plant could grow optimally.

Acknowledgements
The authors are grateful to Universitas Sebelas Maret for funding this research through the scheme of Mandatory Research (Non APBN) UNS for the fiscal year 2021.

References
[1] Wiseman AJ., R.M. Kaminski, S.K. Riffell, K.J. Reinecke, and E.J. Larson. 2010. Ratoon grain sorghum and other seeds for waterfowl in sorghum croplands. Proceedings of the Annual Conference of Southeastern Association of Fish and Wildlife Agencies 64 106–111.
[2] Ardiyanti S.E., D. Sopandie, D. Wirnas, and Trikoesoemaningtyas. 2019. Ratoon productivity of sorghum breeding lines (Sorghum bicolor (L.) Moench). Earth and Environmental Science 399(1): 1-9.
[3] Subagio H., dan M. Aqil. 2013. Pengembangan produksi sorgum di Indonesia. Prosiding Seminar Nasional Inovasi Teknologi Pertanian p.199–214.
[4] Tae A. R., B.B. Konten, A. Semang, R. Wea, dan A.T. Lema. 2019. Kandungan mineral arbila (Phaseulus lunatus L.) sebagai pakan pada tanah vertisol dengan penambahan bokashi berbahan Chromolaena odorata dan feses sapi. Jurnal Ilmu Peternakan Terapan 2(2):63–68.
[5] Muzaiyanah S., A. Kristiono, dan S. Subandi. 2017. Pengaruh pupuk organik kaya hara santap Nm1 dan santap Nm2 terhadap pertumbuhan dan hasil kedelai pada tanah vertisol. Buletin Palawija 13(1), 74–82.
[6] Shalsabila F., S. Prijono, dan Z. Kusuma. 2017. Pengaruh aplikasi biochar kulit kakao terhadap kemantapan agregat dan produksi tanaman jagung pada Ultisol Lampung Timur. Jurnal Tanah dan Sumberdaya Lahan 4(1): 473–480.
[7] Berek A.K., S. Ceufin, R.I.C.O. Taoilin, E.Y. Neombeni, and M.J. Seran. 2016. Biochar and compost tea effect on the growth and yield of curly leave lettuce in a semiarid vertisol soil. Jurnal Floratek 12(2):111–114.
[8] Yuan J.H., and R. K. Xu. 2011. The amelioration effects of low temperature biochar generated from nine crop residues on an acidic ultisol. Soil Use and Management 27(1): 110–115.
[9] Chintala R., J Mollinedo, T.E. Schumacher, D.D. Malo, and J.L. Julson. 2014. Effect of biochar on chemical properties of acidic soil. Archives of Agronomy and Soil Science 60(3), 1–12.
[10] Hossain M. K., V. Streoz, K.Y. Chan, and P.F. Nelson. 2010. Agronomic properties of wastewater sludge biochar and bioavailability of metals in production of cherry tomato (Lycopersicon esculentum). Chemosphere 78(9), 1167–1171.
[11] Silber A., I. Levkovitch, and E.R. Graber. 2010. pH-dependent mineral release and surface properties of cornstraw biochar: Agronomic implications. *Environmental Science and Technology* 44(24): 9318–9323.

[12] Laird D. A., P. Fleming, D.D Davis, R. Horton, B. Wang, and D.L. Karlen. 2010. Impact of biochar amendments on the quality of a typical Midwestern agricultural soil. *Geoderma* 158(3–4): 443–449.

[13] Novak J. M., I. Lima, B. Xing, J.W. Gaskin, C. Steiner, K.C. Das, M. Ahmedna, D. Rehrah, D.W. Watts, and W.J. Busscher. 2009. Characterization of designer biochar produced at different temperatures and their effects on a loamy sand. *Annals of Environmental Science* 3:195-206.

[14] Graber E. R., Y.M. Harel, M. Kolton, E. Cytryn, A. Silber, D.R. David, L. Tsechansky, M. Borenshtein, and Y. Elad. 2010. Biochar impact on development and productivity of pepper and tomato grown in fertigated soilless media. *Plant and Soil* 337(1), 481–496.

[15] Da Rato Y.Y., S.A. Syaiful, M. Riadi, and M.B Pabendo. 2020. Produksi bioetanol ratun pertama sorgum manis varietas super-1 pada perbedaan jumlah tunas dan umur panen tanaman primer. *Jurnal Penelitian Pertanian Tanaman Pangan* 3(3): 159–164.

[16] Oni B. A., O. Oziegbe, and O.O Olawole. 2019. Significance of biochar application to the environment and economy. *Annals of Agricultural Sciences* 64(2):222–236.

[17] Ridwan T. A., N Sandiah, W Kurniawan. 2021. Efektivitas penggunaan arang hayati terhadap pertumbuhan mingguan tanaman sorgum (*Sorghum bicolor* L.) ratun pertama sebagai sumber hijauan pada tanah rawa. *Jurnal Ilmiah Peternakan Halu Oleo* 3(1):101-105.

[18] Nurhaliza A., Liman, A.K. Wijaya, and Muhtarudin. 2020. Pengaruh jumlah benih per lubang dan jarak tanam sorgum manis (*Sorghum bicolor* (L.) Moench) terhadap performa vegetatif pada ratun ketiga. *Journal of Research and Innovation of Animals* 4(2):71-78.

[19] Sulistyowati Y., D. Sopandi, S.W. Ardie, and S. Nugroho. 2017. Parameter genetik dan seleksi sorgum (*Sorghum bicolor* (L.) Moench) populasi F4 hasil Single Seed Descent (SSD). *Jurnal Biologi Indonesia* 12(2):175-184.

[20] Khasanah M., A. Rasyad, E. Zuhry, and J.L. Darwis. 2016. Yield potential for some cultivars of sorgum (*Sorghum bicolor* (L.) Moench) in different planting spac. *Jurnal Faperta* 3(2): 71-13.

[21] Sihaloho A. N. and R. Situmeang. 2021. Respon pertumbuhan dan daya hasil sorgum (*Sorghum bicolor* [L] Moench) dengan pemberian pupuk fosfor di lahan masam Kabupaten Simalungun. *Jurnal Agrin* 25 (1): 1-9

[22] Siswanto S.E., and E. Zuhry. 2017. Komponen hasil dan kandungan karbohidrat empat kultivar sorgum (*Sorghum bicolor* (L.) Moench) dengan jarak tanam yang berbeda. *Journal Faperta* 4(1):1-13.

[23] Nurhaliza A., L. Liman., A.K. Wijaya, and M. Muhtarudin. 2020. Pengaruh jumlah benih per lubang dan jarak tanam sorgum manis (*Sorghum bicolor* (L.) Moench) terhadap peforma vegetatif pada ratun ketiga. *Journal of Research and Innovation of Animals* 4(2):71–78.