Growth And Soils Chemicals Properties By Planting Asystasia Gangetica (L.) T. Anderson As Cover Crop

Yenni Asbur, Yayuk Purwaningrum, Mindalisma

Abstract: Cover crops have positive effect on agroecosystems to protect soil from erosion and nutrients loss, increasing soil fertility, organic matter, soil carbon stocks, availability of soil water, suppress weed, and provide nutrients through residues decomposition. This study aimed to evaluate growth of Asystasia gangetica (L.) T. Anderson in shade and without shade conditions, and to study the benefits of A. gangetica as a cover crop to improve soil chemical properties. The experiment was conducted in an experiment field, Faculty of Agriculture, Universitas Islam Sumatera Utara, Gedung Johor Medan, Indonesia. The results showed that the growth of A. gangetica as a cover crop was not affected by shade. Soil organic carbon (C-organic), total nitrogen (N-total), available and total potassium (K-available and K-total) were significantly higher in the soil planted A. gangetica as cover crop respectively by 10.64%, 29.41%, 11.54%, and 7.49% than in the soil without cover crops.

Index Terms: Shade, C-organic, N-total, available P and K.

1. INTRODUCTION

AWARENESS of environmental sustainability has begun to revive the use of cover crops. Although the use of cover crops has been practiced for centuries, nowadays the use of cover crops has been replaced by widespread use of fertilizers and herbicides [1]. Cover crops have a positive effect on agroecosystems [2]. Cover crops are planted to protect soil from erosion and nutrients loss through leaching and surface runoff [3], [4], improving quality and soil fertility [5], [6], [7], increasing organic matter and soil carbon stocks [8], [9], increasing soil water availability during the dry season [10], suppressing weed [11], and providing nutrients through residual decomposition [12]. In the last decades, the diversity of cover crops in Indonesia, especially in North Sumatra has been decreasing. Cover crops commonly used in North Sumatra is family of legumes. Cover crops are generally less tolerant to shade, thus more tolerant types is needed. Asystasia gangetica (L.) T. Anderson is one of potential perennial weeds to be used as cover crop and may be able to grow both in shade and without shade. Asbur et al. [3] showed that A. gangetica was able to grow well on 5-year-old of palm oil stand with high sunlight intensity and 17 years old with low sunlight intensity. Some research finding also indicate that A. gangetica grows well andland coverage rapidly [6], [7], able to reduce erosion and NPK nutrient loss in the soil [3], produce organic matter and as soil carbon stocks [8], increasing water availability in the dry season [10], increasing NPK availability in the soil through its nutrient balance [5], [6], and able to improve soil chemical properties [7] in mature oil palm plantations.

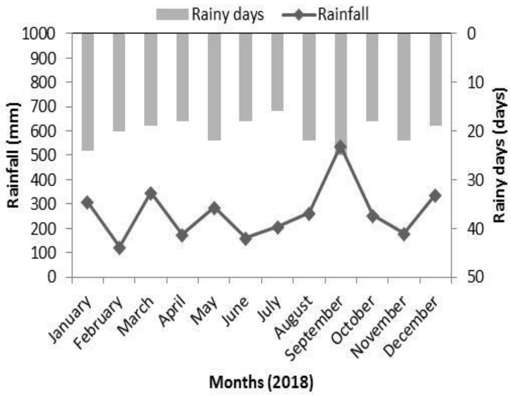
However, farmers have little knowledge about the growth of A. gangetica as cover crop in Indonesia and still regard A. gangetica as a weed and must be controlled. Due to the reasons, the study aims: (1) to study the growth of A. gangetica in shade and without shade condition, and (2) to study the benefits of A. gangetica as cover crop to improve soil chemical properties.

2 MATERIALS AND METHODS

2.1 Site Description and Experimental Design

The experiment was conducted in an experiment field at Faculty of Agriculture, Universitas Islam Sumatera Utara, Gedung Johor Medan, Indonesia. The experimental plot is laid on 2º27'00"-2º47'00" S and 98º35'00"-98º44'00" E, and the elevation is 25 m above sea level. The analysis of plants tissue and soil chemical properties was conducted in Soil Laboratory, Indonesian Oil Palm Research Institute, Medan, North Sumatera, Indonesia. The area has an average annual precipitation of 265.83 mm that ranges between 108-590 mm (Fig. 1), an average annual temperature of 22.1-31.3 °C (Fig. 1). The chemical characteristics of the experimental plot 0-10 cm depth were analyzed, showing that it is a soil with a low pH, organic matter, available phosphor (P-available), and K-available (Table 1). The soil is classified as Ultisols.

- *Yenni Asbur, Yayuk Purwaningrum, Mindalisma is lecturer at the Department of Agrotechnology, Faculty of Agriculture, Universitas Islam Sumatera Utara, Jln. Karyawisata Gedung Johor, Medan 20144, Indonesia. E-mail: yenni.asbur@fp.uisu.ac.id; yayuk.purwaningrum@fp.uisu.ac.id; mindalisma@fp.uisu.ac.id*
- *Corresponding Author: Yenni Asbur. E-mail: yenni.asbur@fp.uisu.ac.id*



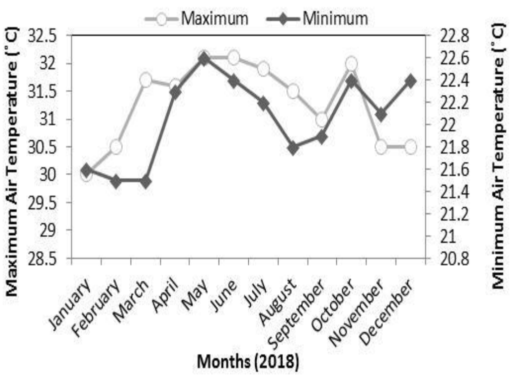


TABLE 1
CHARACTERISTICS OF THE SOIL ON STUDY SITE

Description	Value
Depth	0-10 cm
pH (H_2O)	5.21
C-organic	1.43%
N-total	0.19%
P-available	13.84 mg/kg
P-total	222.85 mg/kg
K-available	30.44 mg/kg
K-total	278.68 mg/kg

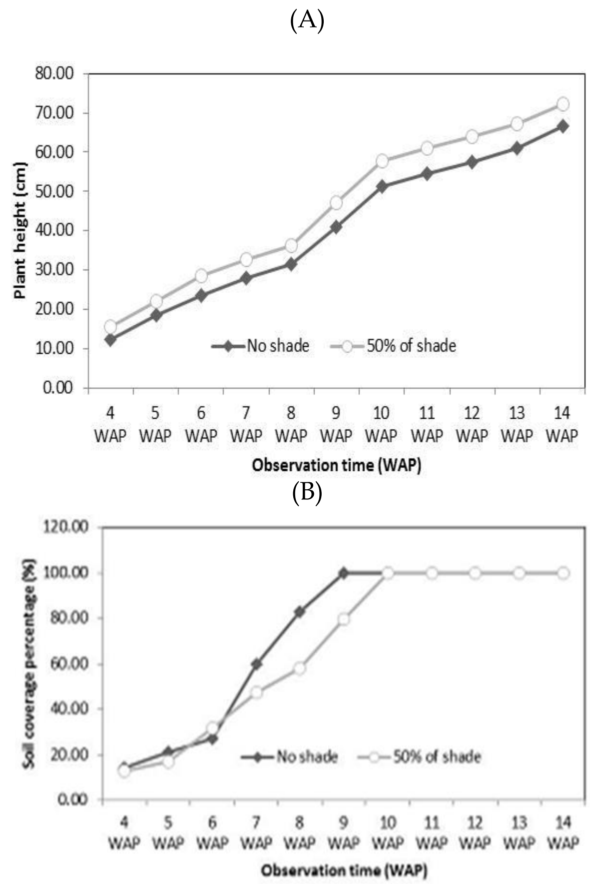
Experimental design in all experiments was a randomized complete block design with six replications and a plot size of 2 m x 2 m. The study consisted of two experiments. The first experiment was conducted in February 2018 to May 2018 to determine the growth of A. gangetica in shade and without shade. The second experiment was carried out in July 2018 to December 2018 to determine the ability of A. gangetica as cover crop for soil chemical properties. A. gangetica are planted on plant spacing of 20 cm x 20 cm, according to previous studies [6]. Planting of A. gangetica is using stem cuttings measuring 15 cm or two segments derived from the PT PP Lonsum oil palm plantation. The shade used is paranet 50%. No fertilizers were applied in the experiments. The growth of A. gangetica observed was plant height, soil coverage percentage, crop growth rate, and plant dry weight.

2.2 Soil Sample Collection and Chemical Analysis
Soil chemical analysis was performed before and after the experiment. Soil sample were taken composite from five sampling site on topsoil as deep as 0-10 cm using a soil drill. Soil samples were placed in clip-locked plastic bags and transferred to the Indonesian Palm Oil Research Institute (PPKS) laboratory in Medan, North Sumatera, Indonesia. Organic carbon was determined by dry combustion method using Vario Macro Elemental Analyzer (CNS Version; Elementar, Hanau, Germany). Analysis of total N was performed using the Kjeldahl digestion metho, while analysis of P-available and K-available was using Bray method 1. Total P and K were analyzed using extract HCl 25% with spectrophotometer (manufactured by Techtron 'Pty. Ltd., Melbourne, Australia). Soil pH was measured using deionized water with a 1:5 (soil:water ratio).

2.3 Statistical Analysis
Differences in growth of A. gangetica and soil chemical properties were tested by analyses of variance. Pairwise differences were subsequently tested by the LSD tests. The SAS procedure GLM [13] was used for the calculations.

3 RESULTS AND DISCUSSION

3.1 Growth of Asystasia gangetica (L.) T. Anderson
Statistical analysis showed that shade had no significant effect ($p < 0.05$) on the growth of I. However, the plant height of A. gangetica is higher in shade treatment than without shade (Fig. 2A). This is due to low sunlight reception by plants in shade conditions. Low light intensity will cause etiolation symptoms, triggered by auxin hormone activity. The canopy part that is exposed to light will grow slowly because auxin work is inhibited by light. In contrary, the canopy part that is not exposed to light is growing very fast because auxin work is not inhibited. Such condition makes the canopy (apical) experience the most active growth so that the plants grow searching more light for better photosynthesis [14] (Handriawan et al., 2016). Ajmi et al. [15] shows that although shade has no significant effect on plant height, but plant height is higher in shaded conditions. However, Fauzi et al. [16] showed that shade significantly affect the height of M. bracteta, where the height was lower in shaded conditions. The percentage of soil coverage by A. gangetica is also not affected by shade (Fig. 2B). Asbur et al. [3] showed that there is no significant difference in soil coverage percentage by A. gangetica in high and low light conditions. According to Brust et al. [2], soil coverage by cover crops is influenced by many factors, such as environment, cultivation techniques, and plant genotypes. However, some research found that generally soil coverage is more influenced by plant genotypes [2]. Crop growth rates of A. gangetica were not significantly affected by shade (Table 2). This shows that A. gangetica is able to grow and metabolize well in full and low sunlight conditions. However, crop growth rates without shade are faster than with shade. Lower crop growth rate of A. gangetica in shade treatment was caused by reduced photosynthesis due to low light intensity received in shaded conditions. Sundari et al. [17] showed that the crop growth rate of soybean is faster in conditions without shade compared to shaded. Crop growth rates of A. gangetica were faster in the age of 8 WAP (weeks after planting) and 12 WAP compared to 12 WAP and 16 WAP, both in conditions without shade and with shade. Crop growth rate of A. gangetica showed a sigmoid growth pattern, which is experiencing a rapid growth phase at the beginning and then decline because enter in the stationary phase (slow growth) [18].



WAP: Week After Planting

Fig. 2. Increasing plant height (A) and soil coverage percentage (B) of Asystasia gangetica by shade.

Plants dry weight is the net result of CO_2 assimilation carried out during plant growth and development [18]. Shade also had no significant effect ($p < 0.05$) on canopy and root dry weight of A. gangetica (Fig. 3). Asbur et al. [3] showed that canopy and root dry weight of A. gangetica were not affected by sunlight intensity but more influenced by plant spacing. In contrast, Ajmi et al. [15] in olive, and Artru et al. [19] in sugar beet showed that the dry weight is affected by shade.

TABLE 2

GROWTH RATE OF A. gangetica BY SHADE

Treatments	Observation time (WAP)	
	8 and 12 WAP	12 and 16 WAP
	………………..(g/days)……………….	
No shade	2.20	0.72
50% of shade	0.90	0.38

WAP: Weeks after planting.

No letters in the same column indicate not significant differences according to LSD test ($P < 0.05$).

3.2 Effect of Asystasia gangetica (L.) T. Anderson as Cover Crops on Soil Chemical Properties

Based on the results of the first experiment which showed that A. gangetica growth was not affected by shade, then in the second experiment, the effect of A. gangetica as cover crop on soil chemical properties was tested using a non-factorial randomized block design with six replications with cover crops as treatment, namely without and with cover crops. Based on average, soil chemical properties at the study site is acidic, and had low C-organic, N-total, P-available, and K-available. Syahputra et al. [20] showed that Ultisol soil has soil acidity problems, low organic matter, low macro nutrients, and has very low availability of P and K. Statistical analysis showed that cover crops have no significant effect ($p < 0.05$) on soil pH, but have a significant effect on other soil chemical properties such as C-organic, N-total, P-available, P-total, K-available, and K-total. In general, soil pH decreases at a soil depth of 0-10 cm after treatment of cover crops. Soil pH at the study site before treatment ranged from 5.20-5.22 and decreased after treatment to 5.08-5.09 (Table 3). This is due to high rainfall during the study, ranging from 124-347 mm/month (Fig. 1). According to Lindtner et al. [21], high rainfall causes high levels of nutrient leaching especially bases that make soil become acidic with low base saturation. Changes in soil pH are also influenced by plant species such mechanism is based on the release of H^+ or OH^- in soil solutions by plant roots to maintain intracellular pH. Plants that use ammonium will reduce soil pH, while plants that use nitrates tend to increase soil pH (Yé et al., 2017).

TABLE 3

SOILS CHEMICALS PROPERTIES BEFORE AND AFTER TREATMENTS COVER CROP

Soil chemicals properties	No cover crop	A. gangetica
	Before treatments cover crop	
pH (H_2O)	5.22	5.20
C-organic (%)	1.44	1.44
N-total (%)	0.19	0.19
P-available (mg/kg)	13.84	13.83
P-total (mg/kg)	222.85	222.86
K-available (mg/kg)	30.44	30.43
K-total (mg/kg)	278.66	278.69
	After treatments cover crop	
pH (H_2O)	5.08	5.09
C-organic (%)	1.41b	1.56a
N-total (%)	0.17b	0.22a
P-available (mg/kg)	11.89b	12.74a
P-total (mg/kg)	108.66b	122.16a
K-available (mg/kg)	51.03b	61.10a
K-total (mg/kg)	328.87a	370.94a

Distinct letters in the column indicate significant differences according to LSD test ($P \leq 0.05$).

Cover crops have significant effect ($p < 0.05$) on soil C-organic (Table 3). In soil with A. gangetica as cover crops there was an increase in soil C-organic after treatment namely from 1.44% to 1.56%, whereas without cover crops there was a decrease in soil C-organic namely from 1.44% to 1.41%. Yé et al. [22] showed an increase in soil C-organic after planted with perennial herbaceous cover crops. Similarly, [8], [7], Guzmán et al. [23] showed an increase in soil C-organic by the presence of cover crops. This is because biomass from cover crops has important role in increasing soil C-organic content, mainly through organic changes in plant biomass which represent 11%-16% of the total C increase in soil [24]. N-total content describes the content of all nitrogen present in the soil, both in available and unavailable forms because it still fuses as an organic compound [25]. Cover crops have significant effect ($p < 0.05$) on soil N-total. N-total is higher in the soil planted with cover crops A. gangetica compared to without cover crops (Table 3). Lindtner et al. [21] showed that soil N-total is higher in soil with surface vegetation compared to without vegetation, because the presence of cover crops will reduce erosion which causes nutrient loss during rain. Asbur et al. [3] also showed that the use of A. gangetica as cover crops capable to minimize loss of soil N-total by 93.4% compared to soil without cover crops during rain. Furthermore, Kuotsu et al. [26] stated that rapid decomposition of cover crops and incorporation of cover crop residues will increase soil N content. Accordingly, Asbur and Purwaningrum [12] showed that A. gangetica was rapidly decomposed, which was decomposed within 30 days by 92% and releasing N-total by 94%. Low N-total of soil without cover crops may be caused by very low nutrient translocation to underground layers from the soil surface [27]. In addition, it is also caused by loss of high amount of N in the rainy season on soil without cover crops due to high erosion [3]. Cover crops also had significant effect ($p < 0.05$) on P-available and P-total (Table 3). However, there was a decrease in P-available and P-total after treatment (Table 3). This is due to a decrease in soil pH after treatment. According to Chapin III et al. [28], P-available is strongly influenced by soil pH. On acidic pH (low), P-available will also decrease because in acidic soils, P will be fixed by Al [29]. This finding is confirmed by Welch et al. [30] which showed a decrease in P-available due to decrease in pH. Higher P-available and P-total on soil with A. gangetica as cover crop can be caused by higher temperatures and high rainfall (Fig. 2) during the study thus able to increase plant biomass and reduce soil erosion [24]. Similarly, Asbur et al. [3] showed that soil with A. gangetica as cover crop was able to reduce erosion by 54.7% compared to soil without cover crops. Murtilaksono et al. [4] also showed that the use of cover crops can reduce soil erosion by 95.9%. K-available and K-total is significantly higher in soil with cover crops compared to without cover crops (Table 3). According to Prasat et al. [31], higher K-available and K-total in soil with cover crops is due to decomposition of residual cover crops in the soil. Similarly, Asbur et al. [5], [6], [7], Asbur and Purwaningrum [12] also showed an increase in the availability of K due to recycling of plant residues. According to Asbur et al. [5}, [6], K-available and K-total are relatively higher in soil with cover crops A. gangetica compared to without cover crops caused by recycling K through cover crops biomass. Furthermore, Crusciol et al. [32] stated that cover crops have great potential for absorption and accumulation of K which is returned to the soil after drying.

4 CONCLUSIONS

Asystasia gangetica is a plant that can grow both in shade and without shade. The use of A. gangetica as cover crop increased soil C-organic, N-total, P-available, P-total, K-available and K-total mainly by organic changes in plant biomass. Under cover crop treatment, soil chemicals properties can be improved compared to soil without cover crops. This indicates that A. gangetica caused more nutrients to be retained in the soil solution and solid phase compared to without cover crop treatment.

ACKNOWLEDGMENTS

The research was funded by the Ministry of Research, Technology and Higher Education, the Republic of Indonesia through National Competitive Grant Research, Ministry of Research, Technology and Higher Education (Grant ID No. 0045/E3/LL/2018 and No. 58/I/LP-UISU/V/2018)

REFERENCES

[1] M. Parlak and A.Ö. Parlak, “Measurement of Splash Erosion in Different Cover Crops,” Turkish Journal Field Crops, vol. 15, no. 2, pp. 169-173, 2010.

[2] J. Brust, W. Claupein and R. Gerhards, “Growth and Weed Suppression Ability of Common and New Cover Crops in Germany,” Crop Protection, vol. 63, pp. 1-8, 2014, http://dx.doi.org/10.1016/j.cropro.2014.04.022.

[3] Y. Asbur, S. Yahya, K. Murtilaksono, Sudradjat and E.S Sutarta, E.S. “The Roles of Asystasia gangetica (L.) T. Anderson and Ridge Terrace in Reducing Soil Erosion and Nutrient Losses in Oil Palm Plantation in South Lampung, Indonesia,” Journal of Tropical Crop Science, vol. 3, no. 2, pp. 49-55, 2016.

[4] K. Murtilaksono, M. Ariyanti, Y. Asbur, H.H. Siregar, E.S. Sutarta, S. Yahya, Sudradjat, Suwarto, Suroso and M.A. Yusuf, “Surface Runoff and Soil Erosion in Oil Palm Plantation of Management Unit of Rejosari, PT Perkebunan Nusantara VII, Lampung,” IOP Conf. Series: Earth and Environmental Science, vol. 196, pp. 1-5, 2018, doi :10.1088/1755-1315/196/1/012002.

[5] Y. Asbur, S. Yahya, K. Murtilaksono, Sudradjat and E.S. Sutarta, “The Role of Cover Crop in Nutrient Balance of N, P, and K in Mature Oil Palm Plantation in South Lampung,” Jurnal Penelitian Kelapa Sawit, vol. 23, no. 2, pp. 53-60, 2015.

[6] Y. Asbur, Y. Purwaningrum and M. Ariyanti, “Growth and Nutrient Balance of Asystasia gangetica (L.) T. Anderson as Cover Crop for Mature Oil Palm (Elaeis guineensis Jacq.) Plantations,” Chilean Journal of Agricultural Research, vol. 78, no. 4, pp. 486-494, 2018a, doi:10.4067/S0718-58392018000400486.

[7] Y. Asbur, R.D.H. Rambe, Y. Purwaningrum and D. Kusbiantoro, “Potensi Beberapa Gulma sebagai Tanaman Penutup Tanah di Perkebunan Kelapa Sawit Menghasilkan,” J. Pen. Kelapa Sawit, vol. 26, no. 3, pp. 113-128, 2018b.

[8] Y. Asbur and M. Ariyanti, “Peran Konservasi Tanah terhadap Cadangan Karbon Tanah, Bahan Organik, dan Pertumbuhan Kelapa Sawit (Elaeis guineensis Jacq.),” Jurnal Kultivasi, vol. 16, no. 3, pp. 402.411, 2017, http://dx.doi.org/10.24198/kltv.v16i3.14446.

[9] C. Hu, X. Xia, Y. Chen and X. Han, “Soil Carbon and Nitrogen Sequestration and Crop Growth as Influenced by Long-Term Application of Effective Microorganism Compost,” Chilean Journal of Agricultural Research, vol. 78, no. 1, pp. 13-22, 2018.

[10] M. Ariyanti, S. Mubarok and Y. Asbur, “Study of Asystasia gangetica (L.) T. Anderson as Cover Crop against Soil Water Content in Mature Oil Palm Plantation,” Journal of Agronomy, vol. 16, no. 4, pp. 154-159, 2017, doi: 10.3923/ja.2017.154.159.

[11] H.H. Blanco-Canqui, M.M. Claassen and D.R. Presley, “Summer Cover Crops Fix Nitrogen, Increase Crop Yield, and Improve Soil-Crop Relationships,” Agron. J., vol. 104, pp. 137-147, 2012, doi:10.2134/agronj2011.0240.

[12] Y. Asbur and Y. Purwaningrum, "Decomposition and Release Rate of Asystasia gangetica (L.) T. Anderson Litter Nutrient using Litterbag Method," International Journal of Engineering & Technology, vol. 7, no. (2.5), pp. 116-119, 2018, doi: 10.14419/ijet.v7i2.5.21665.
[13] SAS Institute Inc., "SAS/STAT 9.2 User's Guide," SAS Inst. Inc., Cary, NC., 2009, https://doi.org/10.1111/j.1532-5415.2004.52225.x.
[14] A. Handriawan, D.W. Respatie and Tohari, "Pengaruh Intensitas Naungan terhadap Pertumbuhan dan Hasil Tiga Kultivar Kedelai (Glycine max (L.) Merrill) di Lahan Pasir Pantai Bugel, Kulon Progo," Vegetalika, vol. 5, no. 3, pp. 1-14, 2016.
[15] A. Ajmi, S. Vázquez, F. Morales, A. Chaari, H. El-Jendoubi, A. Abadía and A. Larbi, "Prolonged Artificial Shade Affects Morphological, Anatomical, Biochemical and Ecophysiological Behavior of Young Olive Trees (cv. Arbosana)," Scientia Horticulturae, vol. 241, pp. 275-284, 2018. https://doi.org/10.1016/j.scienta.2018.06.089.
[16] R. Fauzi, Meiriani and A. Barus, "Pengaruh Persentase Naungan terhadap Pertumbuhan Bibit Mucuna bracteata D.C. Asal Setek dengan Konsentrasi IAA yang Berbeda," Jurnal Agroekoteknologi, vol. 4, no. 3, pp. 2114-2126, 2016.
[17] T. Sundari, N. Nugrahaeni and G.W.A. Susanto, "Interaksi Genotipe x Lingkungan dan Stabilitas Hasil Biji Kedelai Toleran Naungan," J. Agron. Indonesia, vol. 44, no. 1, pp. 16-25, 2016, http://dx.doi.org/10.24831/jai.v44i1.12487.
[18] W.W. Larcher, "Physiological Plant Ecology: Ecophysiology and Stress of Function Groups," Edition: 4thPublisher: Springer-Verlag, 2003, doi: 10.1007/978-3-642-87851-0.
[19] S. Artru, L. Lassois, F. Vancutsem, B. Reubens and S. Garré, "Sugar Beet Development under Dynamic Shade Environments in Temperate Conditions," European Journal of Agronomy, vol. 97, pp. 38-47, 2018, https://doi.org/10.1016/j.eja.2018.04.011.
[20] E. Syahputra, Fauzi and Razali, "Karakteristik Sifat Kimia Sub Grup Tanah Ultisol di Beberapa Wilayah Sumatera Utara," Jurnal Agroekoteknologi, vol. 4, no. 1, pp. 1796-1803, 2015.
[21] P. Lindtner, E. Gömöryová, D. Gömöry, S. Stašiov and V. Kubovčík, "Development of Physico-Chemical and Biological Soil Properties on The European Ground Squirrel Mounds," Geoderma, vol. 339, pp. 85-93, 2019, https://doi.org/10.1016/j.geoderma.2018.12.043.
[22] L. Yé, J.C. Lata, D. Masse, H.B. Nacro, R. Kissou, N.H. Diallo and S. Barot, "Contrasted Effects of Annual and Perennial Grasses on Soil Chemical and Biological Characteristics of a Grazed Sudanian Savanna," Applied Soil Ecology, vol. 113, pp. 155–165, 2017, http://dx.doi.org/10.1016/j.apsoil.2017.02.003.
[23] G. Guzmán, J.M. Cabezas, R. Sánchez-Cuesta, Á. Lora, T. Bauer, P. Strauss, S. Winter, J.G. Zaller and J.A. Gómez, "A Field Evaluation of The Impact of Temporary Cover Crops on Soil Properties and Vegetation Communities in Southern Spain Vineyards. Agriculture," Ecosystems and Environment, vol. 272, pp. 135–145, 2019, https://doi.org/10.1016/j.agee.2018.11.010.
[24] A. Das, D. Lyngdoh, P.K. Ghosh, R. Lal, J. Layek and R.G. Idapuganti, "Tillage and Cropping Sequence Effect on Physico-chemical and Biological Properties of Soil in Eastern Himalayas, India," Soil & Tillage Research, vol. 180, pp. 182-193, 2018, https://doi.org/10.1016/j.still.2018.03.005.
[25] R. Manurung, J. Gunawan, R. Hazriani and J. Suharmoko, "Pemetaan Status Unsur Hara N, P dan K Tanah pada Perkebunan Kelapa Sawit di Lahan Gambut," Jurnal Pedon Tropika, vol. 3, no. 1, pp. 89-96, 2017.
[26] K. Kuotsu, A. Das, R. Lal, G.C. Munda, P.K. Ghosh and S.V. Ngachan, "Land Forming and Tillage Effects on Soil Properties and Productivity of Rainfed Groundnut (Arachis hypogaea L.) – Rapeseed (Brassica campestris L.) Cropping System in Northeastern India," Soil Till. Res., vol. 142, pp. 15-24, 2014, https://doi.org/10.1016/j.still.2014.04.008.
[27] D.J. Eldridge and W.G. Whitford, "Badger (Taxidea taxus) Disturbances Increase Soil Heterogeneity in a Degraded Shrub-Steppe Ecosystem," J. Arid Environ., vol. 73, pp. 66-73, 2009, https://doi.org/10.1016/j.jaridenv.2008.09.004.
[28] S.F. Chapin III, P.A. Matson and P.M. Vitousek, "Principles of Terrestrial Ecosystem Ecology," second edition Springer, 2011.
[29] R. Bunch, "Restoring the Soil. A Guide for Using Green Manure/Cover Crops to Improve the Food Security of Smallholder Farmers," Canadian Foodgrains Bank, Canada, 2012.
[30] R.Y. Welch, G.D. Behnke, A.S. Davis, J. Masiunas and M.B. Villamil, "Using Cover Crops in Headlands of Organic Grain Farms: Effects on Soil Properties, Weeds and Crop Yields," Agriculture, Ecosystems and Environment, vol. 216, pp. 322-332, 2016, http://dx.doi.org/10.1016/j.agee.2015.10.014.
[31] R.K. Prasad, Vipin-Kumar, B. Prasad and A.P. Singh, Long-term Effect of Crop Residues and Zinc Fertilizer on Crop Yield, Nutrient Uptake and Fertility Build-up under Rice Wheat Cropping Systems in Calciortents," J. Indian Soc. Soil Sci., vol. 58, no. 2, pp. 205-211, 2010.
[32] C.A.C. Crusciol, A.S. Nascente, E. Borghi, R.P. Soratto and P.O. Martins, "Improving Soil Fertility and Crop Yield in A Tropical Region with Palisadegrass Cover Crops," Agron J., vol. 107, no. 6, pp. 2271-2280, 2015, doi:10.2134/agronj14.0603

.