International Journal of Design & Nature and Ecodynamics
Vol. 18, No. 5, October, 2023, pp. 1273-1278
Journal homepage: http://iieta.org/journals/ijdne

Effectiveness of Peanut Green Manure on Root Growth and Corn Yield in Alfisol Soil

Maria Theresia Sri Budiastuti[1], Desy Setyaningrum[2*], Djoko Purnomo[1], Fauzan Wahidurromdloni[1], Supriyono[1], Bambang Pujiasmanto[1]

[1] Department of Agrotechnology, Faculty of Agriculture, Universitas Sebelas Maret, Surakarta 57126, Indonesia
[2] Department of Agribusiness, Vocational School, Universitas Sebelas Maret, Surakarta 57126, Indonesia

Corresponding Author Email: desy_setyaningrum@staff.uns.ac.id

https://doi.org/10.18280/ijdne.180530

Received: 23 July 2023
Revised: 18 September 2023
Accepted: 8 October 2023
Available online: 31 October 2023

Keywords:
zea mays, arachis hypogaea, nutrient uptake, soil quality, inorganic fertilizer, organic fertilizer

ABSTRACT

Addressing constraints associated with the low nutrient content of Alfisols used in agricultural practices, this study explored the potential of organic fertilizers in improving soil quality, health, and nutrient compositions. Specifically, the research examined the cultivation of corn on Alfisols supplemented with organic fertilizers, an approach aimed at addressing the growing demand for corn in Indonesia. Conducted from April 2022 to February 2023 at coordinates 07°38'07.04" S 110°57'00.7"E, this experimental study was structured according to a Randomized Complete Block Design with a single-factor treatment, consisting of six distinct doses of peanut green manure. The experiment was conducted with the following treatments: P0, which involved the use of inorganic fertilizer; P1, with the application of 2.5 tons/ha of peanut green manure; P2, with 5 tons/ha; P3, with 7.5 tons/ha; P4, with 10 tons/ha; P5, with 12.5 tons/ha. Each treatment was replicated thrice, yielding a total of 18 experimental units, each composed of 16 plants. The experimental plots were maintained within an area of 300 cm x 80 cm, with a planting distance of 100 cm × 50 cm. Data were subjected to an analysis of variance (ANOVA) at a 5% level, followed by Duncan's Multiple Range Test, also at a 5% level. A correlation analysis was performed to discern the relationships between the variables. The application of peanut green manure exhibited no significant differences in all variables, excluding root length. The longest root length (26.57 cm) was observed in treatments involving inorganic fertilizers compared to those with peanut green manure. However, the root length exhibited a significant difference in response to various doses of peanut green manure. This investigation underscores the importance of cultivating corn on Alfisol soils, considering the increasing food demand and the decreasing availability of optimal lands for cultivation. The utilization of Alfisol soils could provide a viable solution to these challenges.

1. INTRODUCTION

Soil nutrients play a pivotal role in agricultural cultivation, with their availability governed by both dynamic and inherent factors. While dynamic factors, such as fertilization, irrigation, and soil management, can be manipulated, inherent factors are dictated by the soil's parent materials, thus influencing soil orders [1]. Alfisols, one of the soil orders prevalent in Indonesia, hold significant potential for agricultural utilization owing to their extensive distribution, which covers an area of 12,749,000 hectares [2] and accounts for 10% of the world's land area [3]. Despite their potential, the use of Alfisols as agricultural land presents challenges, particularly due to their low nutrient content [4], which adversely affects plant quality.

Efforts to enhance the fertility of Alfisols have often involved both organic and inorganic fertilization methods [5]. Inorganic fertilizers, despite supplying essential nutrients to plants, do not contribute to overall soil health and can result in a reduction of microbial activity and soil organic matter content. Conversely, the application of organic fertilizer improves soil health by introducing organic matter and providing sustenance for beneficial soil microorganisms [6, 7], thereby enhancing the soil structure and nutrient cycling in Alfisol. Furthermore, inorganic fertilizers can lead to nutrient imbalance in the soil and, in extreme cases, soil pollution [8]. Organic fertilizers, releasing nutrients at a slower pace, help maintain soil nutrient balance and cater to the nutrient requirements of plants [9]. Additionally, the production and use of inorganic fertilizers have been associated with environmental impact, such as energy consumption, greenhouse gas emissions, and water pollution due to nutrient overload [10, 11]. Organic fertilizers, on the other hand, are generally more environmentally friendly, minimizing carbon emissions due to fertilizer production and use, and mitigating water pollution risks [12].

Organic fertilizers encompass a wide range, including compost [13], animal manure [14], and green waste [15]. Peanut residue, a type of green fertilizer, can be utilized as a soil amendment to bolster growth and yield [16]. Being a legume, peanuts can engage in a symbiotic relationship with microorganisms, potentially enhancing microbial activity in Alfisol when added as fertilizer [17]. Moreover, peanuts contain flavonoids, which attract nitrogen-fixing bacteria [18]. The high nitrogen content in peanut fertilizer supports plant growth and yield [16], and its addition can increase the soil's organic matter content, promoting water and nutrient retention

[19].

Alfisols can accommodate a range of agricultural activities, including corn farming. A versatile crop, corn can thrive in various soil types, including dune regosol, grumusol, latosol, Mediterranean, and Alfisol soils [20, 21]. With high economic value and versatility as a raw material in food, animal feed, biofuel, and other industries [22], corn demand outstrips its production in Indonesia, as evidenced by a 25.49% increase in corn imports in 2019 compared to 2018 [23]. Cultivating corn on Alfisol soil supplemented with peanut fertilizer presents a potential solution to this shortfall. Previous studies have demonstrated the positive impact of organic fertilizer on corn yields in Alfisol soils [24], with a combination of inorganic fertilizer and 10 tons/ha of organic fertilizer yielding up to 12.7 tons/ha of corn [25]. Similarly, the addition of green manure to inorganic fertilizer increased corn yields by 105% compared to inorganic fertilizer alone [26]. However, research on the application of peanut fertilizer to corn in Alfisol soil remains limited, underscoring the need for further investigation. This study aims to assess the effectiveness of peanut green fertilizer on corn's root growth and yield in Alfisol soil.

2. MATERIALS AND METHODS

This research was conducted from April 2022 to February 2023 in Bakaran, Sukosari, Jumantono District, Karanganyar Regency, Central Java. The coordinates are latitude (07°38'07.04") and longitude (110°57'00.7"), with an elevation of 181 meters above sea level. Land preparation begins with measuring the needs of the experimental plot, plowing the soil, and making 18 plots measuring 300 cm × 80 cm. The corn planting distance is 100 cm × 50 cm. The essential fertilizer used is 2.6 kg of cow dung/plot. The seeds used in this research were the Pertiwi 3 variety. Fill each planting hole with two corn seeds to a 3-5 cm depth. Fertilization was carried out three times: the first fertilization was carried out at the beginning of planting, the second fertilization was carried out three weeks after planting corn, and the third was carried out six weeks after planting corn.

The study is experimental research with a Randomized Complete Block Design with one factor. The treatment factor consists of peanut green manure with 6 levels of dosage, namely; P0 = Inorganic Fertilizer (Urea 84 g, SP36 30 g, KCL 24 g); P1 = 0.7 kg/plot = 2.5 tons/ha; P2 = 1.4 kg/plot = 5 tons/ha; P3 = 2.1 kg/plot = 7.5 tons/ha; P4 = 2.8 kg/plot = 10 tons/ha; P5 = 3.5 kg/plot = 12.5 tons/ha. Each experiment was repeated three times, resulting in 18 experimental units. Each experimental unit consists of 16 plants. The size of the experimental plot was 300 cm × 80 cm with a planting distance of 100 cm × 50 cm. The variables observed in this study are plant height, number of leaves, root length, root dry weight, shoot dry weight, cob weight without husk, weight of 100 seeds, number of cobs per plot, and NPK uptake. The data obtained from the observations were analyzed using analysis of variance (ANOVA) with a significance level of 5%. If a significant difference is found, it will be followed by Duncan's Multiple Range Test (DMRT) with a significance level of 5% and correlation analysis to determine the relationship between variables.

The observation results on the research site showed that the highest environmental temperature was 39.8℃, while the lowest was 24℃. The average environmental temperature on the research site was 28.57℃. The required air temperature for corn plants to thrive well ranges from 21 to 28℃ [27]. The highest air humidity was 95%, while the lowest was 51%. The average air humidity on the research site was 78.57%. The ideal air humidity for corn plants ranges from 70 to 85% [28]. The soil analysis used was Kjeldahl, Olsen, determination of P and K of 25% HCl extract, and determination of organic carbon in accordance with the provisions of the Soil Research Institute [29]. The chemical analysis of Alfisols in the Jumantono area shows that the soil has the following total nutrient content: 0.29% total N, 274.24 ppm total P, 0.20% total K, 1.45% organic C, and a C/N ratio of 5. The soil also contains 2.5% organic matter. The soil pH is classified as acidic at 5.26 [2]. On the other hand, the analysis of peanut green manure shows that the fertilizer contains the following total nutrient content: 2.26% total N, 0.26% total P, 1.13% total K, 25.96% organic C, and a C/N ratio of 11.49. The pH of the green manure is slightly acidic at 6.34.

3. RESULTS AND DISCUSSION

3.1 Corn growth

The research results indicate that the application of different doses of peanut green manure has not been effective in increasing the height of corn plants (Table 1). The tallest plants were obtained from the application of 12.5 tons/ha of peanut green manure. This application resulted in a 115% increase in plant height compared to the inorganic fertilizer application. Peanut green manure has a high nitrogen content, which optimally supports corn growth [30]. The use of peanut green manure can enhance nutrient content in the soil, providing sufficient nutrients to support corn growth [31].

Table 1. Corn growth on Alfisol soil

Fertilizer Dosage	Plant Height (cm)	Number of Leaves (strands)	Root Length (cm)
P0	151.58	11.17	26.57a
P1	143.38	10.33	23.40ab
P2	141.67	10.33	18.30bc
P3	170.65	11.17	14.33c
P4	145.80	10.50	21.73ab
P5	174.60	12.17	21.47ab
Sig	1.39	1.79	0.48

Notes: 1. numbers followed by different letters in one column show a significant difference in DMRT (α = 0.05). 2. P0: Inorganic Fertilizer (Urea 84 g, SP36 30 g, KCL 24 g); P1: 2.5 tons/ha; P2: 5 tons/ha; P3: 7.5 tons/ha; P4: 10 tons/ha; P5: 12.5 tons/ha.

The application of various doses of peanut green manure has not resulted in a significant effect on the number of corn leaves (Table 1). The growth and development of corn leaves are influenced by appropriate environmental conditions, such as the availability of nutrients in the soil. Soils with high nitrogen content can support corn growth and leaf formation [32]. The application of 12.5 tons/ha of peanut green manure resulted in the highest number of leaves, which was 12.17 leaves. This is due to the high nitrogen content in peanut green manure, which improves the condition of less fertile soil and provides nitrogen for the corn plants [16].

The length of corn roots in the application of various doses of peanut green manure shows significant values (Table 1). Inorganic fertilizers resulted in the longest root length compared to the application of peanut green manure. Corn roots have the ability to adapt to various conditions. Fertilization can improve soil structure, such as the level of soil porosity, thus encouraging roots to penetrate the soil [33]. Improvement in soil structure will be higher with organic fertilizer than inorganic fertilizer. However, this organic fertilizer has slow-release properties in improving soil quality [34].

Table 2. Dry weight of corn on Alfisols

Fertilizer Dosage	Canopy Dry Weight (g)	Root Dry Weight (g)
P0	35.12	44.12
P1	23.64	11.60
P2	29.68	35.01
P3	39.64	12.56
P4	31.68	14.40
P5	50.80	37.86
Sig	1.28	1.58

Notes: 1. numbers followed by different letters in one column show a significant difference in DMRT (α = 0.05). 2. P0: Inorganic Fertilizer (Urea 84 g, SP36 30 g, KCL 24 g); P1: 2.5 tons/ha; P2: 5 tons/ha; P3: 7.5 tons/ha; P4: 10 tons/ha; P5: 12.5 tons/ha.

The application of various doses of peanut green manure resulted in non-significant differences in shoot dry weight, except for the dose of 12.5 tons/ha, which increased shoot dry weight by 144% compared to inorganic fertilizer (Table 2). The higher doses of peanut green manure can improve the quality of low Alfisols [35]. Additionally, peanut green manure contains a variety of nutrients [36]. The addition of various nutrients from peanut green manure to the soil will provide nutrition for corn plants. Nutrient-rich soil can support the process of photosynthesis and increase the assimilates produced [37]. Abundant assimilates will be utilized for growth, resulting in a higher shoot dry weight [38].

The research results indicate that the application of various doses of fertilizer did not provide significant results in terms of root dry weight (Table 2). The inorganic fertilizer treatment resulted in the highest root dry weight, which was 44.12 grams. The application of various doses of peanut green manure has not been able to support the growth of the corn root system. Limited nutrient availability causes the corn roots to grow sub-optimally [39]. Roots require a healthy soil condition and sufficient nutrients to grow optimally in Alfisols.

3.2 Corn yield

Table 3. Corn yields on Alfisols

Fertilizer Dosage	Cobs Weight Without Husks (g)	Weight of 100 Seeds (g)	Number of Cobs per Plot
P0	52.73	18.59	7.00
P1	67.28	24.13	7.00
P2	65.74	23.11	6.00
P3	106.96	21.81	9.33
P4	54.34	23.04	9.00
P5	78.52	22.90	7.33
Sig	1.13	0.81	1.60

Notes: 1. numbers followed by different letters in one column show a significant difference in DMRT (α = 0.05). 2. P0: Inorganic Fertilizer (Urea 84 g, SP36 30 g, KCL 24 g); P1: 2.5 tons/ha; P2: 5 tons/ha; P3: 7.5 tons/ha; P4: 10 tons/ha; P5: 12.5 tons/ha.

The research results indicate that the application of various doses of peanut green manure did not provide significant results in terms of cob weight without husk (Table 3). However, all doses of peanut green manure increased the cob weight without husk compared to inorganic fertilizer. The increase in cob weight without husk proves that the application of peanut green manure can add nutrients to the Alfisols. The addition of nutrients to the soil can support corn growth, thereby increasing the cob weight without husk [40].

The research results indicate that the application of various doses of peanut green manure did not provide significant results in terms of the weight of one hundred seeds (Table 3). However, the application of peanut green manure at all doses successfully increased the weight of one hundred corn seeds. Seed formation is supported by the availability of nutrients [41]. Adequate phosphorus availability can support seed formation and improve seed quality [42]. The improved seed quality is indicated by the higher weight of one hundred seeds.

The application of various doses of peanut green manure has not provided significant results in terms of the number of cobs per plot. The highest number of cobs per plot was obtained from the application of 7.5 tons/ha of peanut green manure. The treatments with inorganic fertilizer and 2.5 tons/ha of peanut green manure resulted in the lowest number of cobs per plot, which was 7 cobs. This proves that the application of peanut green manure can replace inorganic fertilizer in supporting the formation of corn cobs. Green manure contains high levels of phosphorus and potassium, which can support corn growth and cob formation [43].

3.3 Nutrient uptake

The application of various doses of peanut green manure has not provided significant results in terms of nitrogen, phosphorus, and potassium uptake in corn plants. The highest nitrogen uptake was obtained from the application of inorganic fertilizer, which was 87.22 grams (Table 4). This is because inorganic fertilizer has the highest nitrogen content, which increases the availability of nitrogen in Alfisols. The increased availability of nitrogen in the soil supports higher nitrogen uptake in corn plants [44].

Table 4. Nutrient uptake of corn on Alfisol soil

Fertilizer Dosage	Nitrogen Uptake (g)	Phosphate Uptake (g)	Potassium Uptake (g)
P0	87.22	12.34	99.48
P1	32.92	2.02	55.94
P2	59.68	3.11	90.96
P3	33.42	1.30	39.78
P4	54.97	4.29	95.36
P5	74.27	4.57	101.57
Sig	1.41	6.34	0.88

Notes: 1. numbers followed by different letters in one column show a significant difference in DMRT (α = 0.05). 2. P0: Inorganic Fertilizer (Urea 84 g, SP36 30 g, KCL 24 g); P1: 2.5 tons/ha; P2: 5 tons/ha; P3: 7.5 tons/ha; P4: 10 tons/ha; P5: 12.5 tons/ha.

The application of inorganic fertilizer resulted in the highest phosphorus uptake, which was 12.34 grams. Inorganic fertilizers contain a high source of phosphorus, which can support phosphorus availability in Alfisols [45]. Acidic Alfisols tend to bind phosphorus, so the application of peanut green manure has not been able to provide phosphorus as effectively as inorganic fertilizer [46]. The longer roots in the inorganic fertilizer treatment also support phosphorus uptake.

Longer roots will expand the absorption area [47].

The highest potassium uptake was obtained from the application of 12.5 tons/ha of peanut green manure. The application of peanut green manure can improve the condition of acidic soil and increase potassium availability in Alfisols. High potassium availability can support nutrient uptake, leading to an increased accumulation of potassium in plants [48].

3.4 Correlation between variables

The height of the plants and the number of leaves show a positive correlation with shoot dry weight (Table 5). An increased number of leaves leads to an increase in photosynthesis activity. The enhanced photosynthesis activity results in more assimilates being produced, leading to an increase in shoot dry weight in corn plants [49]. Taller plants indicate that a significant portion of the assimilates is allocated for growth. This leads to an increase in shoot dry weight due to optimal stem formation in the plants [50].

The root dry weight shows a positive correlation with nitrogen uptake (Table 5). Higher root dry weight indicates more optimal root growth. Optimal root growth allows roots to penetrate deeper into the soil and extend further from the plant, thereby expanding the area for nutrient absorption [51]. Peanut green manure is a fertilizer derived from leguminosae plants, which contain a lot of nitrogen. Fertilizer derived from organic materials also contains organic carbon, which can improve soil structure. Application of peanut green fertilizer can increase soil porosity so that roots can easily penetrate the soil so that root growth will be high. Higher root growth will cause higher nutrient absorption. Nitrogen uptake correlates positively with phosphorus and potassium uptake. The application of peanut green manure can provide various nutrients, leading to an increase in nutrient availability in Alfisols. The improved nutrient availability in Alfisols can support nitrogen, phosphorus, and potassium uptake [52]. Phosphorus uptake shows a positive correlation with the weight of one hundred seeds. Increased phosphorus uptake can support seed formation, thereby enhancing the quality of corn seeds [53].

Table 5. Correlation between observation variables

	TT	**JD**	**AP**	**BKA**	**BKT**	**BTTB**	**B100**	**JTP**	**N**	**P**	**K**
TT	1										
JD	0.696	1									
AP	-0.317	-0.693	1								
BKA	0.138	0.496	-0.602	1							
BKT	0.914*	0.837*	-0.378	0.422	1						
BTTB	0.726	0.387	-0.207	-0.338	0.436	1					
B100	-0.198	-0.156	0.605	-0.579	-0.227	0.161	1				
JTP	0.444	0.087	0.093	-0.618	0.238	0.453	-0.012	1			
N	0.097	0.418	-0.453	0.916*	0.426	-0.534	-0.632	-0.401	1		
P	-0.072	0.014	-0.336	0.721	0.125	-0.595	-0.856*	-0.266	.853*	1	
K	-0.144	0.346	-0.209	0.730	0.262	-0.715	-0.249	-0.409	.878*	0.622	1

Notes: 1. TT (plant height), AP (root length), BKA (root dry weight), BKT (shoot dry weight), BTTB (cob weight without plant husk), B100 (100 seed weight), JTP (number of cobs per plot), N (N uptake), P (P uptake), K (K uptake). 2. *: 99% significance, **: 95% significan

4. CONCLUSIONS

Peanut green fertilizer affects corn growth and yields the same as inorganic fertilizer. The dose of peanut green fertilizer plays a role in root length growth. The longest roots produced by the application of chemical fertilizer were 26.57 cm. The application of peanut green fertilizer at a dose of 12.5 tons/ha is the best dose to support the growth and yield of corn on Alfisol soil. Root growth has a positive correlation with nutrient uptake. Peanut green manure can be used as a natural fertilizer supporting growth, plant yields, and soil quality. Peanut green manure can be used to support integrated and sustainable agriculture.

REFERENCES

[1] Fajeriana, N., Gafur, M.A.A. (2023). Status hara tanah alfisol sebelum tanam dan setelah panen sebagai media tanam melon dengan pemupukan bioboost. Jurnal Penelitian Pertanian Terapan, 23(74): 73-80. https://doi.org/10.25181/jppt.v23i1.2278

[2] Supriyono, S., Nurmalasari, A.I., Sulistyo, T.D., Fatimah, S. (2022). Efektivitas pupuk hayati terhadap pertumbuhan dan hasil jagung hibrida di tanah alfisol. Agrotechnology Research Journal, 6(1): 1. https://doi.org/10.20961/agrotechresj.v6i1.44992

[3] Wawan, E.S., Ummah, R., Wiyatiningsih, S. (2022). Evaluasi Kemampuan Lahan pada Lahan Tanaman Cengkeh dan Kakao Menuju Pertanian Berkelanjutan. Agrifor: Jurnal Ilmu Pertanian dan Kehutanan, 21(1): 111-122. https://doi.org/10.31293/agrifor.v21i1.5926

[4] Adekiya, A.O., Olaniran, A.F., Adenusi, T.T., Aremu, C., Ejue, W.S., Iranloye, Y.M., Olayanju, A. (2020). Effects of cow dung and wood biochars and green manure on soil fertility and tiger nut (Cyperus esculentus L.) performance on a savanna Alfisol. Scientific Reports, 10(1): 21021. https://doi.org/10.1038/s41598-020-78194-5

[5] Sosina Adebola, O., Adeyemo Adebayo, J., Awodun Moses, A., Ojeniyi Stephen, O. (2018). Comparative effect of poultry manure, ash and NPK fertilizer on soil chemical properties and trifoliate yam (Dioscorea dumetorum) performance in an alfisol of southwestern Nigeria. International J. Advances in Scientific Research and Engineering, 4(12): 125–130. https://doi.org/10.31695/ijasre.2018.33003

[6] Han, J., Dong, Y., Zhang, M. (2021). Chemical fertilizer reduction with organic fertilizer effectively improve soil fertility and microbial community from newly cultivated

land in the Loess Plateau of China. Applied Soil Ecology, 165: 103966. https://doi.org/10.1016/j.apsoil.2021.103966

[7] Liu, Y., Lv, Z., Hou, H., Lan, X., Ji, J., Liu, X. (2021). Long-term effects of combination of organic and inorganic fertilizer on soil properties and microorganisms in a Quaternary Red Clay. Plos One, 16(12): e0261387. https://doi.org/10.1371/journal.pone.0261387

[8] Nadarajan, S., Sukumaran, S. (2021). Chemistry and toxicology behind chemical fertilizers. In Controlled Release Fertilizers for Sustainable Agriculture, 195-229. https://doi.org/10.1016/b978-0-12-819555-0.00012-1

[9] Shaji, H., Chandran, V., Mathew, L. (2021). Organic fertilizers as a route to controlled release of nutrients. In Controlled release fertilizers for sustainable agriculture, 231-245. https://doi.org/10.1016/b978-0-12-819555-0.00013-3

[10] Abbas, A., Waseem, M., Ahmad, R., Khan, K.A., Zhao, C., Zhu, J. (2022). Sensitivity analysis of greenhouse gas emissions at farm level: Case study of grain and cash crops. Environmental Science and Pollution Research, 29(54): 82559-82573. https://doi.org/10.1007/s11356-022-21560-9

[11] Wu, H., MacDonald, G.K., Galloway, J.N., Zhang, L., Gao, L., Yang, L., Yang, J.X., Li, X.L., Li, H.R., Yang, T. (2021). The influence of crop and chemical fertilizer combinations on greenhouse gas emissions: A partial life-cycle assessment of fertilizer production and use in China. Resources, Conservation and Recycling, 168: 105303. https://doi.org/10.1016/j.resconrec.2020.105303

[12] Zahoor, I., Mushtaq, A. (2023). Water pollution from agricultural activities: A critical global review. Zahoor and Mushtaq, 23: 164-176.

[13] Waqas, M., Hashim, S., Humphries, U.W., Ahmad, S., Noor, R., Shoaib, M., Naseem, A., Hlaing, P.T., Lin, H.A. (2023). Composting processes for agricultural waste management: A comprehensive review. Processes, 11(3): 731. https://doi.org/10.3390/pr11030731

[14] Ren, K., Sun, Y., Zou, H., Li, D., Lu, C., Duan, Y., Zhang, W. (2023). Effect of replacing synthetic nitrogen fertilizer with animal manure on grain yield and nitrogen use efficiency in China: A meta-analysis. Frontiers in Plant Science, 14: 1153235. https://doi.org/10.3389/fpls.2023.1153235

[15] Naz, A., Rebi, A., Naz, R., et al. (2023). Impact of green manuring on health of low fertility calcareous soils. Land, 12(3): 546. https://doi.org/10.3390/land12030546

[16] Budiastuti, M.T.S., Purnomo, D., Pujiasmanto, B., Wahidurromdloni, F., Setyaningrum, D. (2023). Soybean Response to Organic Fertilizer Types in Pine Stand-Based Agroforestry System. In IOP Conference Series: Earth and Environmental Science, 1165(1): 012040. https://doi.org/10.1088/1755-1315/1165/1/012040

[17] Lai, H., Gao, F., Su, H., Zheng, P., Li, Y., Yao, H. (2022). Nitrogen distribution and soil microbial community characteristics in a legume–cereal intercropping system: A review. Agronomy, 12(8): 1900. https://doi.org/10.3390/agronomy12081900

[18] Dong, Q., Zhao, X., Zhou, D., Liu, Z., Shi, X., Yuan, Y., et al. (2022). Maize and peanut intercropping improves the nitrogen accumulation and yield per plant of maize by promoting the secretion of flavonoids and abundance of Bradyrhizobium in rhizosphere. Frontiers in Plant Science, 13: 957336. https://doi.org/10.3389/fpls.2022.957336

[19] Sun, Y., Xiong, X., He, M., Xu, Z., Hou, D., Zhang, W., Sik Ok, Y., Rinklebe, J., Wang, L.L., Tsang, D.C. (2021). Roles of biochar-derived dissolved organic matter in soil amendment and environmental remediation: A critical review. Chemical Engineering Journal, 424: 130387. https://doi.org/10.1016/j.cej.2021.130387

[20] Genesiska, G., Mulyono, M., Yufantari, A.I. (2021). The effect of soil type on the growth and yield of corn (*Zea mays* L.) varieties of Pulut Sulawesi. PLANTROPICA: Journal of Agricultural Science, 5(2): 107-117.

[21] Lovitna, G., Nuraini, Y., Istiqomah, N. (2021). Effect of application of phosphate solubilizing bacteria and inorganic phosphate fertilizer on the population of phosphate solubilizing bacteria, available P, and corn yields on alfisol. Journal of Land and Land Resources, 8(2): 437-449. https://doi.org/10.21776/ub.jtsl.2021.008.2.15

[22] Panikkai, S., Nurmalina, R., Mulatsih, S., Purwati, H. (2017). Analysis of national corn availability towards self-sufficiency using a dynamic model approach. Agricultural Informatics, 26(1): 41-48.

[23] Pertanian, S.J.K. (2020). Outlook Jagung Komoditas Pertanian Subsektor Tanaman Pangan [Outlook for corn, an agricultural commodity in the food crop subsector]. Pusat Data dan Sistem Informasi Pertanian, Jakarta.

[24] Gao, C., El-Sawah, A.M., Ali, D.F.I., Alhaj Hamoud, Y., Shaghaleh, H., Sheteiwy, M.S. (2020). The integration of bio and organic fertilizers improve plant growth, grain yield, quality and metabolism of hybrid maize (Zea mays L.). Agronomy, 10(3): 319. https://doi.org/10.3390/agronomy10030319

[25] Syamsiyah, J., Herdiyansyah, G., Hartati, S., Suntoro, S., Widijanto, H., Larasati, I., Aisyah, N. (2023). The effect of substitution of chemical fertilizer with organic fertilizer on the chemical properties and productivity of corn in Alfisol Jumantono. Journal of Soil and Land Resources, 10(1): 57-64. https://doi.org/10.21776/ub.jtsl.2023.010.1.6

[26] Bharti, J., Manjhi, R.P., Thakur, R., Karmakar, S., Singh, C.S., Mahapatra, P., Kumari, M., Kumar, R. (2022). Productivity of maize and wheat influenced by long term application of fertilizer and manure under maize-wheat system in alfisol of Jharkhand. The Pharma Innovation Journal, 11(11): 1402–1405.

[27] Herlina, N., Prasetyorini, A. (2020). The influence of climate change on the planting season and productivity of corn (Zea mays L.) in Malang Regency. Indonesian Journal of Agricultural Sciences, 25(1): 118-128. https://doi.org/10.18343/jipi.25.1.118

[28] Stefanie, C., Nurjani, N., Basuni, B. (2023). The use of chicken egg shell flour and NPK fertilizer on the growth and yield of pulut corn on peat soil. Equator Agricultural Science Journal, 12(1): 55-63. https://doi.org/10.26418/jspe.v12i1.60409

[29] Eviati, S., Sulaeman, M. (2009). Analisis kimia tanah, tanaman, air, dan pupuk [Chemical analysis of soil, plants, water, and fertilizer]. Soil Research Institute. Bogor.

[30] Idham, I., Pagiu, S., Lasmini, S.A., Nasir, B.H. (2021). Effect of doses of green manure from different sources on growth and yield of maize in dryland. International

Journal of Design & Nature and Ecodynamics, 16(1): 61-67. https://doi.org/10.18280/ijdne.160108
[31] Jani, A., Mulvaney, M.J., Bashyal, M., Singh, H. (2019). Nitrogen contributions from peanut residues to subsequent crops. EDIS, 2. https://doi.org/10.32473/edis-ag431-2019
[32] Lin, Y., Watts, D.B., Kloepper, J.W., Adesemoye, A.O., Feng, Y. (2019). Effect of Plant growth-promoting rhizobacteria at various nitrogen rates on corn growth. Agricultural Sciences, 10(12): 1542-1565. https://doi.org/10.4236/as.2019.1012114
[33] Liu, Y.X., Sun, J.H., Zhang, F.F., Li, L. (2020). The plasticity of root distribution and nitrogen uptake contributes to recovery of maize growth at late growth stages in wheat/maize intercropping. Plant and Soil, 447: 39-53. https://doi.org/10.1007/s11104-019-04034-9
[34] Qin, L., Walk, T.C., Han, P., Chen, L., Zhang, S., Li, Y., Hu, X.J., Xie, L.H., Yang, Y., et al. (2019). Adaption of roots to nitrogen deficiency revealed by 3D quantification and proteomic analysis. Plant Physiology, 179(1): 329-347. https://doi.org/10.1104/pp.18.00716
[35] Ma, D., Yin, L., Ju, W., Li, X., Liu, X., Deng, X., Wang, S. (2021). Meta-analysis of green manure effects on soil properties and crop yield in northern China. Field Crops Research, 266: 108146. https://doi.org/10.1016/j.fcr.2021.108146
[36] dos Santos Marques, C.T., Gama, E.V.S., da Silva, F., Teles, S., Caiafa, A.N., Lucchese, A.M. (2018). Improvement of biomass and essential oil production of Lippia alba (Mill) NE Brown with green manures in succession. Industrial Crops and Products, 112: 113-118. https://doi.org/10.1016/j.indcrop.2017.10.065
[37] Mangaravite, J.C.S., Passos, R.R., Andrade, F.V., Burak, D.L., Mendonça, E.D.S. (2014). Phytomass production and nutrient accumulation by green manure species. Revista Ceres, 61: 732-739. https://doi.org/10.1590/0034-737X201461050017
[38] Cai, F., Zhang, Y., Mi, N., Ming, H., Zhang, S., Zhang, H., Zhao, X., Zhang, B. (2022). The effect of drought and sowing date on dry matter accumulation and partitioning in the above-ground organs of maize. Atmosphere, 13(5): 677. https://doi.org/10.3390/atmos13050677
[39] Wang, Y., Zhang, X., Chen, J., Chen, A., Wang, L., Guo, X., Niu, Y., Liu, S., Mi, G., Gao, Q. (2019). Reducing basal nitrogen rate to improve maize seedling growth, water and nitrogen use efficiencies under drought stress by optimizing root morphology and distribution. Agricultural Water Management, 212: 328-337. https://doi.org/10.1016/j.agwat.2018.09.010
[40] de Medeiros, E.V., Silva, A.O., Duda, G.P., dos Santos, U.J., de Souza Junior, A.J. (2019). The combination of Arachis pintoi green manure and natural phosphate improves maize growth, soil microbial community structure and enzymatic activities. Plant and soil, 435: 175-185. https://doi.org/10.1007/s11104-018-3887-z
[41] Aulia, S., Lukiwati, D.R., Fuskhah, E. (2021). Pengaruh Pupuk Kandang Plus Terhadap Pertumbuhan dan Produksi Jagung Manis di Purwodadi, Kabupaten Grobogan. Agrosains: Jurnal Penelitian Agronomi, 23(2): 99-104. https://doi.org/10.20961/agsjpa.v23i2.53874
[42] Javeed, H.M.R., Qamar, R., Rehman, A.U., Ali, M., Rehman, A., Farooq, M., et al. (2019). Improvement in soil characteristics of sandy loam soil and grain quality of spring maize by using phosphorus solublizing bacteria. Sustainability, 11(24): 7049. https://doi.org/10.3390/su11247049
[43] Ahmed, A., Aftab, S., Hussain, S., Nazir Cheema, H., Liu, W., Yang, F., Yang, W. (2020). Nutrient accumulation and distribution assessment in response to potassium application under maize–soybean intercropping system. Agronomy, 10(5): 725. https://doi.org/10.3390/agronomy10050725
[44] Geng, Y., Cao, G., Wang, L., Wang, S. (2019). Effects of equal chemical fertilizer substitutions with organic manure on yield, dry matter, and nitrogen uptake of spring maize and soil nitrogen distribution. PloS one, 14(7): e0219512. https://doi.org/10.1371/journal.pone.0219512
[45] Billah, M., Khan, M., Bano, A., Hassan, T.U., Munir, A., Gurmani, A.R. (2019). Phosphorus and phosphate solubilizing bacteria: Keys for sustainable agriculture. Geomicrobiology Journal, 36(10): 904-916. https://doi.org/10.1080/01490451.2019.1654043
[46] Penn, C.J., Camberato, J.J. (2019). A critical review on soil chemical processes that control how soil pH affects phosphorus availability to plants. Agriculture, 9(6): 120. https://doi.org/10.3390/agriculture9060120
[47] de Sousa, S.M., de Oliveira, C.A., Andrade, D.L., de Carvalho, C.G., Ribeiro, V.P., Pastina, M.M., ... & Gomes, E.A. (2021). Tropical Bacillus strains inoculation enhances maize root surface area, dry weight, nutrient uptake and grain yield. Journal of Plant Growth Regulation, 40(2): 867-877. https://doi.org/10.1007/s00344-020-10146-9
[48] Kandil, E.E., Abdelsalam, N.R., Mansour, M.A., Ali, H.M., Siddiqui, M.H. (2020). Potentials of organic manure and potassium forms on maize (Zea mays L.) growth and production. Scientific Reports, 10(1): 8752. https://doi.org/10.1038/s41598-020-65749-9
[49] Jiang, C., Zu, C., Lu, D., Zheng, Q., Shen, J., Wang, H., Li, D. (2017). Effect of exogenous selenium supply on photosynthesis, Na+ accumulation and antioxidative capacity of maize (Zea mays L.) under salinity stress. Scientific Reports, 7(1): 42039. https://doi.org/10.1038/srep42039
[50] Pradi-Vendruscolo, E., Seleguini, A. (2020). Effects of vitamin pre-sowing treatment on sweet maize seedlings irrigated with saline water. Acta Agronómica, 69(1): 20-25. https://doi.org/10.15446/acag.v69n1.67528
[51] Gao, J., Shi, J., Dong, S., Liu, P., Zhao, B., Zhang, J. (2017). Grain yield and root characteristics of summer maize (Zea mays L.) under shade stress conditions. Journal of agronomy and crop science, 203(6): 562-573. https://doi.org/10.1111/jac.12210
[52] Bornø, M.L., Müller-Stöver, D.S., Liu, F. (2019). Biochar properties and soil type drive the uptake of macro-and micronutrients in maize (Zea mays L.). Journal of Plant Nutrition and Soil Science, 182(2): 149-158. https://doi.org/10.1002/jpln.201800228
[53] Amanullah, Fahad, S. (2018). Integrated nutrient management in corn production: symbiosis for food security and grower’s income in arid and semiarid climates. in Corn - Production and Human Health in Changing Climate, InTech. https://doi.org/10.5772/intechopen.80995