Malays. J. Bioeng. Technol. Vol. 1, (2024): 41-47
https://doi.org/10.70464/mjbet.v1i1.1302

MALAYSIAN JOURNAL OF BIOENGINEERING AND TECHNOLOGY

MJBeT Malaysian Journal of Bioengineering and Technology

Enhancing Roselle Growth and Yield through Planting Density and Fertilization Strategies: A Study on BRIS Soil Area

Che Hanis Omar[1], Nor Izaida Ibrahim[1,2,*], Sitti Fatimah Mhd Ramle[1,2], Syafinie Abdul Majid[3], Noor Janatun Naim Jemali[3]

[1]*Department of Forest Resources Technology, Faculty of Bioengineering and Technology, Universiti Malaysia Kelantan, 17600, Jeli, Kelantan, Malaysia*

[2]*Tropical Wood and Biomass Research Group, Faculty of Bioengineering and Technology, Universiti Malaysia Kelantan, Jeli Campus, 17600 Jeli, Kelantan, Malaysia.*

[3]*Department of Natural Resources and Sustainability, Faculty of Earth Science, Universiti Malaysia Kelantan, 17600, Jeli, Kelantan, Malaysia,*

**Corresponding author: izaida.i@umk.edu.my*

ARTICLE INFO

Received: 31 March 2024
Accepted: 20 May 2024
Online: 21 June 2024
eISSN: 3036-017X

ABSTRACT

Optimizing planting density and fertilization practices are crucial factors influencing the micro-environment of agricultural fields, thereby profoundly impacting the growth, development, and yield formation of Roselle plants. This study investigates the combined effects of planting density and *Sesbania grandiflora* integration on nitrogen dynamics within the BRIS soil area, aiming to enhance Roselle growth and yield. Employing a randomized complete block design (RCBD), three fertilizer treatments—control, green manure, and organic fertilizer—were implemented. Nitrogen content was analyzed using the Kjeldahl method, while phosphorus and potassium contents were determined via UV spectrometry and atomic absorption spectrophotometry, respectively. Within an agroforestry model employing a spacing of 20 cm between plants, results revealed that Roselle plants treated with organic fertilizer exhibited higher nitrogen (N: 3.54 %), phosphorus (P: 0.54 %), and potassium (K: 1.61 %) content in their leaves, and similarly in their roots (N: 1.93%, P: 0.45%, K: 2.11%). However, soil analysis indicated that green manure fertilizer treatment led to higher nitrogen (0.11 %), phosphorus (44.67 %), and potassium (0.17 %) content within the BRIS soil. In conclusion, the green manure fertilizer treatment demonstrated a propensity to enhance nitrogen dynamics within the poorly structured BRIS soil, thereby promoting growth and development. Conversely, the integration of *Sesbania grandiflora* along with suitable plant spacing appeared instrumental in sustaining Roselle yield productivity. This research sheds light on the interplay between planting density, fertilizer strategies, and soil dynamics, providing valuable insights for optimizing Roselle cultivation practices in similar agroecological contexts.

Keywords: Intercropping; Nitrogen; Phosphorus; Sesbania grandiflora; Potassium

1. Introduction

Intercropping involves planting two or more crops in the same field at the same time and is an effective strategy for promoting agricultural diversification and sustainability [1]. However, intercropping has challenges, such as competition for water, light, and nutrients, which can result in reduced yields and suboptimal growth. Despite these difficulties, intercropping systems have been shown to improve soil health by reducing erosion, enhancing fertility, and offering farmers the opportunity to diversify their income streams [2]. One of the key aspects of intercropping systems is the incorporation of leguminous crops, which are widely recognized for their capacity to enhance soil fertility at a low cost. Legumes contribute to soil fertility directly by forming symbiotic relationships with nitrogen-fixing bacteria, in which nitrogen is fixed, and indirectly through processes such as root exudation and mycorrhizal associations, as noted by Kebede [3]. The fixing of nitrogen benefits not only the legume itself but also enriches the soil nitrogen levels, subject to the proportion of nitrogen fixed by the legume [4].

Optimal spacing is crucial for crop production to balance cooperation between plants and minimize competition for essential growth factors, such as nutrients, sunlight, water, and gases [5]. Studies on Roselle crops have highlighted the significant impact of plant density on biomass, yield, and economic viability [6]. BRIS soil, with its well-aerated and deep rooting zone, is an excellent substrate for Roselle cultivation. Nevertheless, determining the optimal plant density for maximizing yield depends on factors such as genotype and geographical location [7]. Given the importance of understanding the relationship between planting density and nitrogen dynamics in the intercropping of *Sesbania grandiflora* with Roselle in BRIS soil, this study aims to assess the effects of different planting densities on Roselle biomass, yield, and nutrient uptake, evaluate the efficacy of various fertilization strategies, including organic fertiliser and green manure, on Roselle growth and soil nutrient levels, and investigate the potential synergistic benefits of intercropping Roselle with *Sesbania grandiflora* on soil fertility and crop productivity in BRIS soil. Based on these objectives, hypotheses propose that increasing planting density will lead to higher Roselle biomass and yield due to reduced competition for resources and improved light interception, and application of organic fertiliser and green manure will enhance soil fertility and nutrient availability, resulting in improved Roselle growth and yield, and intercropping Roselle with *Sesbania grandiflora* will promote nitrogen fixation, improve soil structure, and increase nutrient uptake, thereby enhancing overall crop productivity and soil health, ultimately contributing to our understanding of sustainable agricultural practices and providing practical recommendations for optimising Roselle cultivation in BRIS soil and similar agroecological contexts.

2. Materials and Methods

2.1 Site Preparation

The selected site was at Kampung Mujur, Bachok (5.958 ˚ N latitudes and 102.427 E longitudes). The site area was 15 m x 22.5 m. The soil was cultivated, and then the land was plowing and harrowing. The site was then laid out to the required plot size of 9m × 0.8 m each. There were 3 beds for one treatment fertilizer. Initially, *Sesbania grandiflora* was planted for 3 weeks, followed by the Roselle.

2.2 Integrated Planting

The experimental design was a randomized completed block with three treatments of fertilizer consisting of control treatment (no fertilizer), organic fertilizer treatment, and green manure fertilizer treatment. The *Sesbania grandiflora* leaves were used as a green manure fertilizer. Consequently, 10 tons/ha of organic fertilizer was applied to improve its capacity for water retention [8] which same as green manure fertilizer. Plots' size was 9 m × 0.8 m each. Intercropping plots had an average of 10 trees of *Sesbania grandiflora* per plot. Plant holes were manually dug with a hoe at a spacing of 20 cm between plants. Two to three seeds of Roselle were planted per hole at a depth of 0- 2 cm.

eISSN Number: 3036-017X

2.3 Plant Analysis

Air dry the roots until it is dry before putting them in an oven and oven them until they are dried at 50 – 70℃. Then, weighed the Roselle plant parts in terms of dry weight and recorded their reading. The dry weight reading is essential for calculating the plant nutrient uptake. Next, the samples were blended using a blender and kept in sealed zipper bags. The total cations, such as Potassium (K), were determined using AAS. Phosphorus was determined using a UV spectrophotometer after blue color development. Nitrogen was determined using the Kjeldahl method [9].

2.4 Soil analysis

Soil samples were collected randomly in each row at a depth of 0-20 cm by using Auger. The samples had been air-dried at 60 ˚c for 24 hours in the laboratory. The determination of nitrogen was proposed by Johan Kjeldahl in 1883 [9]. The value of phosphorus concentration was determined using a UV spectrophotometer. Soil cations (mainly Ca, Mg, K) were held in an exchangeable form on the surface of the soil particles, those that can be exchanged by a cation of an added salt. These values are very much dependent on the chemical and mineralogical makeup of the soil. K, Ca, and Mg were determined using an atomic absorption spectrophotometer (AAS).

2.5 Data analysis

The statistical analysis of the data was performed using the variance method (ANOVA), using a statistical package program SPSS (Version 24), and differences in mean among treatments were determined by Tukey's test. Results were considered significant at $P \leq 0.05$.

3. Results and Discussion

3.1 Plants Analysis

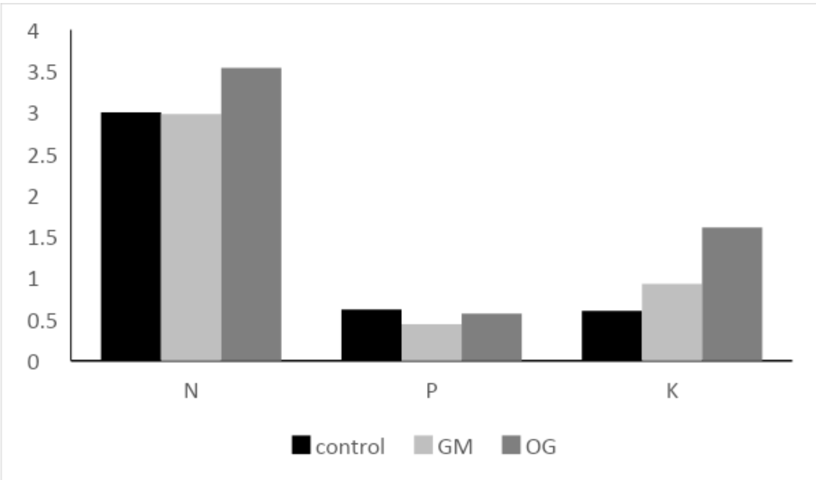

Fig. 1: The graph of the N, P, and K content of leaves

The graph in Fig.1 illustrates the nitrogen (N), phosphorus (P), and potassium (K) contents in the leaves. Notably, the N content peaked at 3.54 % under the organic fertilizer treatment, the P content reached 0.57 %, and the K content increased to 1.61 % under the same treatment. This trend highlights the multifaceted benefits of organic fertilizers, which not only enrich the soil with essential nutrients but also stimulate leaf growth beyond just nitrogen availability. The nitrogen content in organic fertilizers plays a crucial role in enhancing the vegetative vigor of crops, ensuring robust and healthy plant growth. Additionally, the chlorophyll content in Roselle leaves served as a proxy for the nutrient absorption capacity of the plant from the soil, reflecting the physical manifestation of Roselle's overall performance.

The graph in Fig.2 shows the nitrogen (N), phosphorus (P), and potassium (K) contents in Roselle roots within the field area. The organic fertilizer treatment demonstrated clear superiority, with a notable increase of 38 % in N content (1.93 % N), 27 % in P content (0.45 % P), and 38 % in K content (2.11 % K) compared to the control treatment. The analysis of Roselle plants revealed significant variations in nutrient content across different fertilizer treatments. The nitrogen (N), phosphorus (P), and potassium (K) contents in Roselle leaves and roots are illustrated in (Fig. 1 and Fig. 2), respectively. Notably, the organic fertilizer treatment resulted in substantial increases in N, P, and K content compared to the control and green manure treatments. These findings align with previous studies highlighting the efficacy of organic fertilizers in enhancing soil fertility and promoting nutrient uptake in plants ([10];[11]). The effectiveness of organic fertilizers in enhancing soil fertility, promoting root growth, and fostering biologically active conditions is evident. According to earlier studies [12], this improvement can be attributed to the organic matter found in these fertilizers, which is essential as a substrate for microbial activity. This is especially true in processes like mineralization.

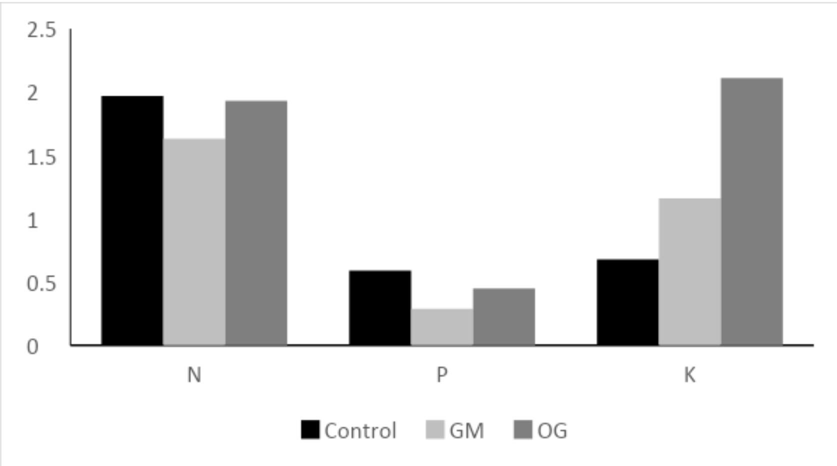

Fig. 2: The graph of the N, P, and K content of the root

The comprehensive examination of the leaves and roots of plants treated with organic fertilizer revealed a significant rise in nitrogen (N), phosphorus (P), and potassium (K) uptake, potentially attributable to the synergistic effects of intercropping Roselle with *Sesbania grandiflora*. This phenomenon underscores the efficacy of organic fertilizers in enhancing the physical attributes of BRIS soils and fostering microbial activity, ultimately leading to the production of organic acids, as elucidated by Youssef et al. [10]. These organic acids, in turn, amplify the auxin-mediated promotive effect on plant growth, as demonstrated by Norhayati et al. [11]. Furthermore, the observed increases in nutrient content under organic fertilizer treatment underscore the importance of sustainable fertilization practices in optimizing crop growth and yield. The higher nutrient uptake in Roselle plants treated with organic fertilizer may be attributed to the presence of organic matter, which serves as a substrate for microbial activity and promotes nutrient release in the soil [13]. These findings are consistent with the notion that organic fertilizers contribute to improved soil structure and biological activity, ultimately enhancing plant nutrient availability and growth [14].

These findings are further corroborated by El-Sherif and Sarwat, who highlighted a significant increase in the number of Roselle fruits upon the incorporation of organic waste into sandy soil [15]. Organic manures significantly enhance plant yield by enabling plants to accumulate essential nutrients in their storage and economically valuable parts. Additionally, intercropping systems effectively boost plant survival, growth, and the uptake of critical nutrients such as nitrogen (N), phosphorus (P), and potassium (K) [16]. Studies in agroforestry, such as those by Chifflot et al., have consistently reported the positive impacts of intercropping tree species with crops compared to monoculture. This practice facilitates improved tree mineral nutrition and accelerates tree growth and harvest [17].

Thus, integrating Roselle plants with *Sesbania grandiflora*, coupled with applying organic fertilizers, provides a holistic approach to meeting the nutritional requirements of Roselle plants without compromising environmental

eISSN Number: 3036-017X

integrity. This integrated approach ensures enhanced nutrient uptake by plants traversing the Roselle root zone, promotes sustainable agricultural practices, and mitigates adverse environmental impacts.

3.2 Soil Analysis

The mean nitrogen (N) content within the BRIS soil before and after fertilizer application is presented in Fig.3. Notably, the N content remained higher under the green manure fertilizer treatment, experiencing only a marginal decrease of 0.02 %, from 0.13 % to 0.11 %, post-application. This phenomenon can be attributed to the inherent nutrient richness of manure, which serves as a potent source for crop production. Additionally, the risk of nitrogen leaching from the root zone into the groundwater necessitates efficient nitrogen management. The effectiveness of green manure in nitrogen (N) uptake is mainly dependent on the development of a robust root system that can efficiently access the available nitrogen in the soil [18].

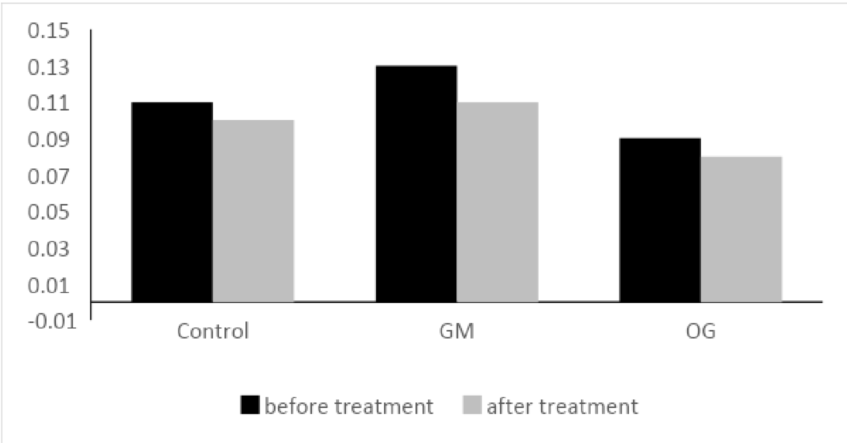

Fig. 3: Nitrogen (N) content of the soil

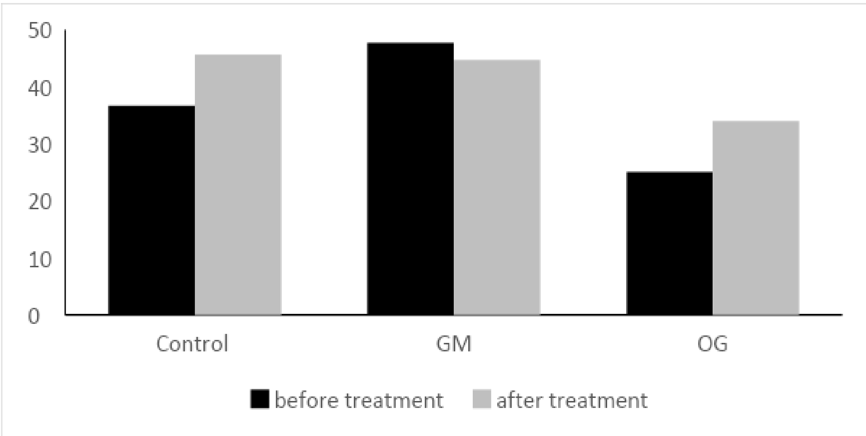

Fig. 4: Phosphorus (P) content of the soil

The average Phosphorus (P) content within the BRIS soil in the field area integrated with *Sesbania grandiflora* is depicted in Fig. 4. Notably, the P content peaked under the green manure fertilizer treatment, albeit experiencing a modest decline of 3 % from 47.67 % to 44.67 % post-application. This trend is likely attributable to the organic matter present in green manure leaves, which harbors a myriad of nutrients essential for crop growth and contributes to improving soil texture and nutritional status. As articulated by Hou et al. (2013), green manure has the potential to enhance soil water and nutrient retention capacity, particularly in addressing the deficiencies of sandy soils [19].

Moreover, cropping systems incorporating legumes as green manure have proved particularly efficient, as the nitrogen input to the soil correlates directly with the amount of nitrogen fixed by leguminous plants.

The Potassium (K) content within the BRIS soil before and after fertilizer application is shown in Fig. 5. Once again, the K content remained high under the green manure fertilizer treatment, experiencing a minor reduction of 0.02 % from 0.19 % to 0.17 % post-application. The elevated potassium levels attributed to green manure can be attributed to the extensive root system of green manure plants, which contributes to improving the physical conditions of the soil. Moreover, the high organic matter content of green manure, which includes nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg), ensures the release of essential nutrients into the soil upon decomposition [14]. The soil analysis results shown in (Fig. 3, Fig. 4, and Fig. 5) highlight the changes in nitrogen (N), phosphorus (P), and potassium (K) content in BRIS soil before and after fertilizer application. The green manure fertilizer treatment resulted in higher nutrient levels, demonstrating its effectiveness in enhancing soil fertility and nutrient availability. These findings are in line with previous studies demonstrating the beneficial effects of green manure in improving soil nutrient status and promoting sustainable agricultural practices [20,21].

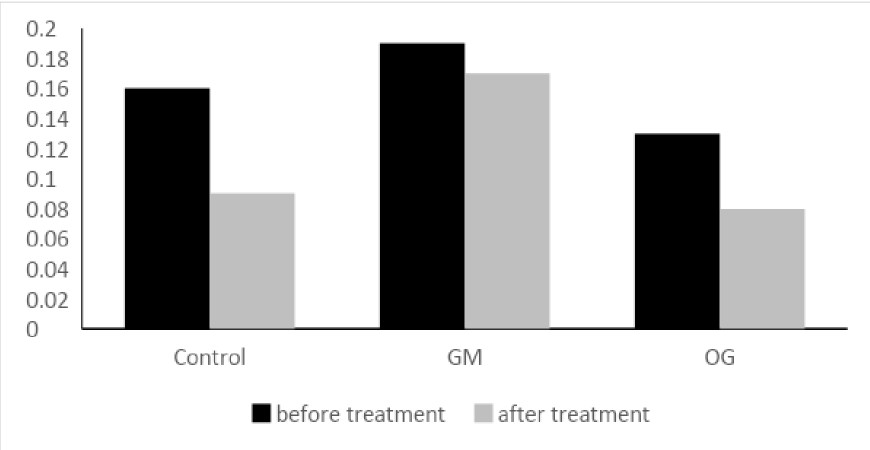

Fig. 5: Potassium (K) content of the soil

4. Conclusion

According to this study, using green manure fertilizer led to higher levels of nitrogen, phosphorus, and potassium. This is due to incorporating *Sesbania grandiflora*, a plant known for its rich nutrient profile, into the soil. Implementing an alley cropping system also helped enhance soil fertility by reducing the need for chemical inputs. The spacing between plants had a significant impact on different crop parameters, such as fresh weight per fruit and the growth of 137 seeds. Understanding the relationship between yield and various growth components at different planting densities is crucial. This knowledge helps optimize plant density to maximize roselle yields. Moreover, the study found that Roselle thrived when planted alongside *Sesbania grandiflora*. The open canopy of *Sesbania grandiflora* allows ample sunlight to penetrate, creating favorable conditions for the continued growth of Roselle plants. Highlight the advantages of intercropping Roselle with *Sesbania grandiflora*, as observed in the study. Recommend integrating *Sesbania grandiflora* into Roselle cultivation systems to enhance soil fertility through nitrogen fixation and to provide additional benefits such as weed suppression and pest control. Emphasize the importance of selecting suitable companion crops that complement Roselle's growth and contribute to overall agroecosystem resilience.

eISSN Number: 3036-017X

Acknowledgment

We gratefully thank the Forest Resource Technology Programme, Faculty of Bioengineering and Technology, Universiti Malaysia Kelantan, Jeli Campus, Malaysia, for their help in securing a place for the current research and for providing all the facilities and amenities. Special thanks go to the Ministry of Higher Education (MOHE) for giving research funding under the Fundamental Research Grants Scheme (FRGS), project code FRGS/1/2015/WAB07/UMK/03/1, that enables the financial support of this research.

References

[1] Toker P, Canci H, Turhan I, Isci A, Scherzinger M, Kordrostami M, Yol E. The advantages of intercropping to improve productivity in food and forage production–a review. Plant Prod Sci, 2024;27(3):155-169.
[2] Rani M, Kaushik P, Bhayana S, Kapoor S. Impact of organic farming on soil health and nutritional quality of crops. J Saudi Soc Agric Sci, 2023;22(8):560-569.
[3] Kebede E. Contribution, Utilization, and Improvement of Legumes-Driven Biological Nitrogen Fixation in Agricultural Systems. Front Sustain Food Syst, 2021;5(Nov):1-18.
[4] Ladha JK, Peoples MB, Reddy PM, Biswas JC, Bennett A, Jat ML, Krupnik TJ. Biological nitrogen fixation and prospects for ecological intensification in cereal-based cropping systems. Field Crops Res, 2022;283:108541.
[5] El Naim AM, Khaliefa EH, Ibrahim KA, Ismaeil FM, Zaied MB. Growth and Yield of Roselle (Hibiscus sabdariffa L) as Influenced by Plant Population in Arid Tropic of Sudan under Rain-fed. Int J Agric For, 2012;2(3):88-91.
[6] Yirzagla J, Quandahor P, Amoako OA, Akologo LA, Lambon JB, Imoro AWM, Santo KG, Akanbelum OA. Yield of Roselle (Hibiscus sabdariffa L.) as Influenced by Manure and Nitrogen Fertilizer Application. Am J Plant Sci, 2023;14(5):599-612.
[7] Rahman MM, Hossain MM. Effect of Plant Population on Soybean Development and Production. Asian J Plant Sci, 2011;10:278-286.
[8] Atta S, Sarr B, Bakasso Y, Diallo AB, Lona I, Saadou M, Glew RH. Roselle (Hibiscus sabdariffa L.) yield and yield components in response to nitrogen fertilization in Niger. Indian J Agric Res, 2010;44(2):96-103.
[9] Kjeldahl J. New Method for the Determination of Nitrogen in Organic Bodies. J Anal Chem, 1883;22(1):366-382.
[10] Youssef A, Mady M, Ali M. Partial Substitution Of Chemical Fertilization Of Roselle Plant (Hibiscus Sabdariffa L.) By Organic Fertilization In Presence Of Ascorbic Acid. J Plant Prod, 2014;5(3):475-503.
[11] Norhayati Y, Ng WH, Adzemi MA. Effects of organic fertilizers on growth and yield of roselle (Hibiscus sabdariffa l.) on bris soil. Malaysian Appl Biol, 2019;48(1):177-184.
[12] Lazcano C, Zhu-Barker X, Decock C. Effects of organic fertilizers on the soil microorganisms responsible for n2o emissions: A review. Microorganisms, 2021;9(5):1-18.
[13] Besharati J, Shirmardi M, Meftahizadeh H, Dehestani Ardakani M, Ghorbanpour M. Changes in growth and quality performance of Roselle (Hibiscus sabdariffa L.) in response to soil amendments with hydrogel and compost under drought stress. South Afr J Bot, 2022;145:334-347.
[14] Adekiya AO, Agbede TM, Aboyeji CM, Dunsin O, Ugbe JO. Green manures and NPK fertilizer effects on soil properties, growth, yield, mineral and vitamin C composition of okra (Abelmoschus esculentus (L.) Moench). J Saudi Soc Agric Sci, 2019;18(2):218-223.
[15] El-Sherif M, Sarwat M. Physiological and chemical variation in producing Roselle plant by using some organic farmyard manure. World J Agric Sci, 2007;3(5):609-616.
[16] Khaitov B, Yun HJ, Lee Y, Ruziev F, Le TH, Umurzokov M, Bo Bo A, Cho KM, Park KW. Impact of organic manure on growth, nutrient content and yield of chili pepper under various temperature environments. Int J Environ Res Public Health, 2019;16(17):3031.
[17] Chifflot V, Bertoni G, Cabanettes A, Gavaland A. Beneficial effects of intercropping on the growth and nitrogen status of young wild cherry and hybrid walnut trees. Agrofor Syst, 2006;66(1):13-21.
[18] Lei B, Wang J, Yao H. Ecological and Environmental Benefits of Planting Green Manure in Paddy Fields. Agric, 2022;12(2):1-15.
[19] Hou Y, Hu X, Yan W, Zhang S, Niu L. Effect of organic fertilizers used in sandy soil on the growth of tomatoes. Agric Sci, 2013;4(5):31-34.
[20] Sujatha DV, Kavitha P, Naidu MVS. Influence of Green Manure and Potassium Nutrition on Soil Potassium Fractions and Yield of Rice Crop. Int J Curr Microbiol Appl Sci, 2017;6(11):13-23.
[21] Thorup-Kristensen K, Magid J, Jensen LS. Catch crops and green manures as biological tools in nitrogen management in temperate zones. Adv Agron, 2003;79:227-302.