International Journal of Design & Nature and Ecodynamics
Vol. 16, No. 1, January, 2021, pp. 61-67
Journal homepage: http://iieta.org/journals/ijdne

Effect of Doses of Green Manure from Different Sources on Growth and Yield of Maize in Dryland

Idham Idham*, Salapu Pagiu, Sri Anjar Lasmini, Burhanuddin Haji Nasir

Faculty of Agriculture, Tadulako University, City of Palu 94118, Indonesia

Corresponding Author Email: idhamfaperta@gmail.com

https://doi.org/10.18280/ijdne.160108

Received: 7 December 2020
Accepted: 1 February 2021

Keywords:
leguminoceae, organic fertilizer, Zea mays

ABSTRACT

Dryland has low soil fertility. Efforts that can be made to improve soil fertility are fertilizer technologies such as green manure compost. The aim of this study was to determine the type and dose of green manure to increase the growth, production and nutrient uptake of maize in the dryland. The research was conducted in Sidera Village Sigi Biromaru District, Sigi Regency, Central Sulawesi from June to December 2018. The research used a factorial randomized block design. The first factor is the type of green manure consisting of three levels, namely mungbean green manure (K1), peanut green manure (K2) and *Centrosema pubescens* green manure (K3). The second factor is the dose of green manure which consists of three levels, namely 5 t. ha^{-1} (D1), 7.5 t. ha^{-1} (D2) and 10 t. ha^{-1} (D3). Thus, there are 9 treatment combinations, each treatment consisting of 3 replications so that there are 27 experimental units. Data were analyzed statistically using the F test and if significantly different it was followed by the least significant difference (LSD) Fisher's test, P-value 0.05. These results showed that the types and dose of green manure increase the growth and yield of maize, namely leaf area, stem diameter, cob length, the weight of 100 dry shelled seeds, and production per hectare of the dry weight of corn shelled. The highest nutrient uptake and maize production were obtained in the application of *C. pubescens* green manure at a dose of 10 t. ha^{-1}, namely nitrogen uptake of 7.68%, phosphorus of 0.39%, potassium of 0.09% and yield of 6.44 t. ha^{-1}.

1. INTRODUCTION

Maize (*Zea mays* L.) is an important cereal crop and has a strategic role in the economy in Indonesia. Maize is the main food commodity after rice. Maize plants are quite high because of its multipurpose function as a source of food, feed, and industrial raw materials. Maize contains fiber (72%), protein (10%), and energy (365 kcal 100 g^{-1}), and low in fat (4%). Maize can be processed into food ingredients such as oil, alcohol, and sweetened starch [1].

Maize production in Central Sulawesi in 2018 reached 4.13 t. ha^{-1}, still low compared to national production, which reached 5.24 t. ha^{-1} [2]. The low production is caused by being planted in dryland where fertility is very low due to the continuous use of inorganic fertilizers. The use of inorganic fertilizers continuously without being balanced with organic fertilizers can reduce their ability to bind nutrients, so that their effectiveness and efficiency decrease due to leaching and fixation, and can interfere with the physical properties of the soil which ultimately affect plant growth and production [3].

Integrated nutrient management is an integral part of sustainable agriculture to meet human needs without destroying the environment and conserving land resources. Including integrated nutrient management is a combination of organic and inorganic fertilizers. According to Aziz et al. [4], combined the use of inorganic and organic fertilizers is a good and practical technique to maintain soil fertility and productivity. Furthermore, Schoebitz and Vidal [5] suggest that the integration of the use of inorganic fertilizers with organic fertilizers increases the efficiency of chemical fertilizers while reducing nutrient loss. Sources of organic material can be compost, green manure, manure, crop residues, livestock waste, industrial waste that uses agricultural materials, and organic waste.

Efforts to increase soil productivity can be done by increasing organic matter. Organic matter plays an important role as a trigger for soil fertility through soil biological activities, thus encouraging improvements in physical, chemical and biological properties of soil [6]. Increasing soil organic matter can be done by adding ameliorants to the soil. Ameliorants are substances that can increase soil fertility by improving soil physical and chemical properties. Green fertilizers include ameliorants that can add soil organic matter [7].

Green manure is a source of organic material derived from plant material or in the form of unrefined crop residues. Generally, plants used as green manure have high N content. The plant material can be immersed while it is still green or immediately after composting [8].

Green manure acts as a source and buffer of nutrients through the process of decomposition and its role in providing soil organic matter and soil microorganisms. Besides, the application of green manure can increase the content of organic matter and nutrients in the soil, resulting in improved soil physical, chemical and biological properties, and increased soil productivity and soil resistance to erosion [9].

This organic matter has an important role in increasing the efficiency of fertilizer use. The application of green manure can improve soil physical properties, including soil volume weight, total soil pore space, soil aeration pores, and available groundwater [10].

Several types of plants that can be used as green manure are plants included in the leguminoceae class such as mungbean, peanut and *Centrosema pubescens* which have been processed into compost. Leguminoceae plant waste has a high potential for restoring soil fertility [11]. Leguminoceae contain flavonoid compounds that can attract nitrogen-fixing bacteria, marked by nodules on the roots so that leguminoceae waste can be used as a raw material for composting because it has the advantage of containing nitrogen-fixing bacteria and chemo-attraction [11].

According to Khan et al. [12], peanut straw waste contains lower crude fiber than rice straw and contains higher protein. Nutritional content of groundnut straw, among others; 14.7% protein, 1.5% calcium, and 8.20% phosphorus. Mungbean straw waste has a high potassium content.

The use of green manure in crop cultivation has been widely reported by several researchers such as rice [13, 14], maize [15, 16] okra [17], tomatoes [18] and wheat [19]. Besides having a role in increasing yield, it also reduces the use of chemical fertilizers [19-21], increases soil microbial activity [22, 23], biological and chemical properties of soil [24-27], and strengthened the abundance of soil microbes [28].

Research on the use of integrated compost derived from various types of green manure compost such as mungbean, peanuts, and *C. pubescens* on the growth and production of maize is still lacking, so it is interesting to study. This research can provide information about green manure from the waste sources of mungbean, peanut, and *C. pubescens* and its role in improving soil quality and maize yields. The aim of this study was to determine the effectiveness of the types and doses of mungbean green manure, peanut green manure, and *C. pubescens* green manure on the growth, production and nutrient uptake of maize in the dryland.

2. MATERIALS AND METHODS

2.1 Location of the experiment

The research was conducted in Sidera Village (1°0.37 "South Latitude 119° 56" East Longitude), Sigi Biromaru District, Sigi Regency, Central Sulawesi with an altitude of 239 meters above sea level. The research was conducted from June to December 2018 with an average daily temperature of 28-31°C and soil moisture of 60-64%. Plant tissue analysis was carried out at the Laboratory of Soil Science, Faculty of Agriculture, Tadulako University, Palu, Central Sulawesi.

2.2 Experimental design and treatment

This study used a factorial randomized block design (RBD). The first factor is the type of green manure consisting of three levels, namely mungbean green manure (K1), peanut green manure (K2) and *Centrosema pubescens* green manure (K3). The second factor is the dose of green manure which consists of three levels, namely 5 t. ha^{-1} (D1), 7.5 t. ha^{-1} (D2), and 10 t. ha^{-1} (D3). Thus there are 9 treatment combinations, each treatment consisting of 3 replications so that there are 27 experimental units.

2.3 Preparation of land

Land preparation is carried out by cultivating land using tractors and hoes. Soil processing is done 1 week before planting. After processing, then made beds with a size of 3.5 m x 2.75 m as many as 27 beds.

2.4 Preparation of green manure compost

Preparation of green manure compost begins with preparing the materials and equipment used, consisting of 800 kg of straw waste (mungbean, peanuts, and *C. pubescent*), sufficient water, bucket, black plastic, hoe and shovel.

The stages of composting are as follows: decomposer microbes are dissolved in 250 liters of water. The waste of each plant is chopped then doused with a decomposer solution that has been prepared. Watering is done slowly until the water content of the dough reaches 30%. Furthermore, the dough is spread 30-40 cm high in a dry place / on the floor. The dough is covered with a tarp.

During fermentation, the temperature is maintained at 40–50°C. If the temperature exceeds 50°C, the cover is opened, then turned or stirred to allow air to enter, and then closed again.

The fermentation process takes from 3-4 weeks. Finished compost is characterized by a pleasant odor such as the aroma of tape and a layer of white, brownish, or blackish mushrooms, and the compost is no longer hot.

2.5 Application of green manure

Mungbean green manure (K1), peanut green manure (K2) and green manure *C. pubescens* (K3) were given 3 days before planting by being spread evenly over the entire surface of the plot and then mixed. The doses of green manure are 5; 7.5; and 10 t. ha^{-1}, respectively.

2.6 Preparation of seeds

The seeds used are local varieties. Soak the seeds in warm water for 1 day so that the skins soften so that germination can accelerate and get vigorous seeds

2.7 Planting

Seedlings are planted at a spacing of 70 x 20 cm, with 2 seeds per hole. The planting hole is made with a depth of 5 cm.

2.8 Maintenance

Plant maintenance that is carried out includes watering, replanting, thinning, weeding, planting, and fertilizing. Watering is done every day in the morning at 08.00 and evening at 16.00 unless it rains. Watering twice a day is intended so that the maize plant does not experience drought considering the conditions around the study have an extreme temperature. Stitching/inserting is done to replace plants that do not grow, done when the plants are 1 week after planting.

Thinning is done simultaneously with insertion by leaving one plant per hole. Weeding is carried out in conjunction with observing plant growth by pulling out weeds that grow around the plants that can inhibit plant growth, at the same time planting is done to strengthen the position of the stems and cover the roots that have sprung up above the soil surface.

2.9 Evaluated variables

Leaf area (cm^2), observed when male flowers had come out ± 75%, and measured on the seventh leaf using a portable leaf area meter.

Stem diameter (cm) was observed at 7 weeks after planting and measured at 5 cm above the surface of the land using calipers.

Cob length (cm), measured from the base of the cob to the tip of the cob containing the seeds after the shells are peeled.

The weight of 100 seeds is taken randomly then weighed, and the production of dry shells is dried in the sun.

The chemical properties of the soil observed include total-N, P and K uptake on maize leaves.

2.10 Statistical analysis

The data obtained were statistically analyzed using the F test, if it showed significantly different results, followed by the least significant difference (LSD) Fisher's test, P-value 0.05.

3. RESULTS

3.1 Leaf area per plant

There was no significant effect of the interaction of the type and a dose of green manure on leaf area per plant. However, a single factor in the type and a dose of green manure had a significant effect on the leaf area. The results of the Fisher's least significant difference test at P-value 0.05 (Table 1) indicate that the application *C. pubescens* green manure (K3) produced higher leaf area (922.37 cm^2) and was significantly different from mungbean green manure (804.39 cm^2) but not significant from peanut green manure (848.61cm^2). Furthermore, the green manure dose of 10 t ha^{-1} (D3) was significantly different compared to a dose of 5 t ha^{-1} (D1) and 7.5 t ha^{-1} (D2).

3.2 Stem diameter

There was no significant effect of the interaction of the type and dose of green manure on the stem diameter of maize.

A single factor in the type and a dose of green manure had a significant effect on the stem diameter of maize. The results of the Fisher's test at P-value 0.05 (Table 1) showed that *C. pubescens* green manure (K3) produced the largest stem diameter (3.22 cm) and was significantly different from mungbean green manure (2.75 cm) and peanut green manure (2.45 cm). Furthermore, the green manure dose of 10 t. ha^{-1} (D3) was significantly different from other doses.

Table 1. Leaf area and stem diameter of maize plants at the age of 7 weeks after planting on various types and a dose of green manure

Treatment	leaf area (cm^2)	stem diameter (cm)
Green manure		
K1	804.39 b	2.75 b
K2	848.61 ab	2.45 b
K3	922.37 a	3.22 a
Fisher's test P-value 0.05	77.72	0.35
Dose (t ha^{-1})		
D1	754.02 z	2.27 z
D2	853.64 y	2.62 y
D3	967.70 x	3.53 x
Fisher's test P-value 0.05	77.72	0.35
Interaction between treatments	(-)	(-)

Note: Means followed by the same letters in the same columns are not significantly different at 5% level of probability by LSD. K1 (mungbean green manure); K2 (peanut green manure); K3 (*C. pubescens* green manure); D1 (dose of 5 t.ha^{-1}); D2 (7.5 t. ha^{-1}); D3 (10 t. ha^{-1})

3.3 Cob length

The type and dose of green manure had a significant effect on the length of corn cobs, but the treatment interactions had no significant effect. The type of green manure of *C. pubescens* (K3) in Fisher's test at P-value 0.05 (Table 2) indicated that the cob length was higher (13.95 cm) but not significantly different from mungbean green manure (13.31cm) and peanut green manure (13.50 cm). The green manure dose of 10 t. ha^{-1} (D3) was significantly different from a dose of 5 t. ha^{-1} (D1) but was not significantly different from the green manure a dose of 7.5 t. ha^{-1} (D2).

Table 2. The length of the cob, the weight of 100 seeds and the yield dry weight of maize per hectare, on various types and a dose of green manure

Treatment	cob length (cm)	weight 100 seeds (g)	yield dry weight (t. ha^{-1})
Green manure			
K1	13.31 a	24.71 b	5.69 b
K2	13.50 a	27.03 a	5.83 ab
K3	13.95 a	27.60 a	6.44 a
Fisher's test P-value 0.05	0.93	2.22	0.55
Dose (t ha^{-1})			
D1	12.68 y	25.16 y	5.61 y
D2	13.68 x	25.89 y	5.92 xy
D3	14.40 x	28.29 x	6.44 x
Fisher's test P-value 0.05	0.93	2.22	0.55
Interaction between treatments	(-)	(-)	(-)

Note: Means followed by the same letters in the same columns are not significantly different at 5% level of probability by LSD. K1 (mungbean green manure); K2 (peanut green manure); K3 (*C. pubescens* green manure); D1 (dose of 5 t.ha^{-1}); D2 (7.5 t. ha^{-1}); D3 (10 t. ha^{-1})

3.4 Weights 100 seeds

Increasing the dose of green manure increases the weight of 100 seeds of maize. The results of the Fisher's least significant difference test at P-value 0.05 (Table 2) indicate that the application *C. pubescens* green manure (K3) produced higher weights 100 seeds (27.60 g) and was significantly different from mungbean green manure (24.71 g) but not significant from peanut green manure (27.03 g). Green manure dose of 10 t. ha^{-1} produced the highest weight of 100 seeds (28.29 g) and was significantly different from other doses.

3.5 Yield dry weight

The highest of dry weight of maize seeds per hectare was in *C. pubescens* green manure (K3) which was 6.44 t.ha^{-1} significantly different in Fisher's test at P-value 0.05 with the mungbean green manure (5.69 t. ha^{-1}), but not different from the peanut green manure (5.83 t. ha^{-1}). The doses of *C. pubescens* green manure of 10 t.ha^{-1} also produces the highest yield dry weight of maize per hectare and is different from the dose of 5 t. ha^{-1} but not significantly different from the dose of 7.5 t. ha^{-1} (Table 2).

4. DISCUSSION

The results of statistical analysis showed that there was no significant interaction effect between the type (K) and dose (D) of green manure on the growth and yield of maize. However, the single factor type and a dose of green manure had a significant effect on growth variables (leaf area and stem diameter) and crop yield (cob length, 100 seeds weight, and yield dry weight per hectare). This shows that a single treatment type and a dose of green manure have their respective effects on the observed variables.

The use of green manure *C. pubescens* and green manure dose of 10 t. ha^{-1} can increase leaf area, stem diameter and length of cobs (Table 1). Green manure *C. pubescens* can provide nutrients for the growth of maize plants faster than other green fertilizers, as well as the effect of synchronization between the time of the release of N-minerals and the time the plants need these nutrients. Biomass *C. pubescens* can release more nitrogen minerals when compared to other legume biomass, this has a major effect on N uptake by maize plants, this causes vegetative growth to take place well, resulting in large numbers of leaves and an impact on increasing leaf area. Large leaf areas can receive more sunlight. The absorption of sunlight by plant leaves is an important factor that determines photosynthesis resulting in assimilation for fruit formation. This is consistent with Xie et al. [20], nitrogen is a very important element for plant growth. Nitrogen is an important part of proteins, protoplasm, enzymes and biological catalyst agents that accelerate life processes. Nitrogen is also part of the nucleoproteins, amino acids, amines, sugar acids, polypeptides, and organic compounds in plants. Nitrogen also plays a role as a constituent of chlorophyll which causes green leaves which play an important role in the photosynthesis process.

Sunlight absorbed by the plant canopy is proportional to the total area covered by the plant canopy [29]. Wider leaves tend to absorb more sunlight than narrower leaves [30]. Furthermore, it was stated that the size of the leaf distribution and the angle of the plant canopy determine the absorption and distribution of sunlight so that it affects photosynthesis and plant yield. According to Stewart et al. [31], the spread of leaves on the crown causes the light received by each leaf to be different. The closer to the surface, the less light the leaves receive.

The green manure *C. pubescens* also increased maize yield (Table 2). Application of organic fertilizers such as green manure can increase drainage pores and aeration pores due to the availability of sufficient O_2, causing wider roots so that the volume of plant roots increases [11]. Furthermore, improving the physical properties of the soil, the roots will develop well so that growth and production also increase [32].

Nutrient uptake does not occur if nutrient levels in the soil are low. The use of a dose of 10 t. ha^{-1} with green manure *C. pubescens* immersed in the soil has contributed sufficient nutrients to the soil so that it can be absorbed by plants. This can be seen from the total N uptake of 7.68%, phosphorus of 0.39% and potassium of 0.09% greater than other treatments (Table 3). This is by Islam et al. [33] that the application of green manure with the right dose can increase organic matter and nutrients, especially total nitrogen, total carbon, soil cation exchange capacity, and soil porosity, and can reduce soil density. The organic matter from the green manure prevents the leaching of nutrients through the metal-organic complex bonds. Organic matter supplies N and S and half P which is absorbed by green manure [9]. Also, green manure can supply N around 30-60 kg per year. The cumulative effect of using sustainable green manures not only on N supply but also increases the content of organic matter and other trace elements, replacing phosphates and micro-elements that are mobilized.

The high nutrient uptake in green manure of *C. pubescens* (Table 3) indicates that green manure *C. pubescens* can be used as an alternative to organic fertilizers in maize cultivation. The application of green manure *C. pubescens* can release N quickly at the beginning of the planting period where at that time the need for N plants is less when compared to the release of N. Therefore, green manure from legumes can maintain the N nutrient content in the soil when compared to Application of compost or other inorganic fertilizers which are easier to lose at the end of the planting period. According to Naveed et al. [34] organic fertilizers affect nutrient uptake from the soil, improve product quality, and act as a good fertilizer.

The improvement of soil fertility status with the application of green manure was associated with increased maize yield (Table 2). The positive response of maize crops to green manure application in this study is consistent with previous reports in other tropical areas [15]. According to Sumiati and Gunawan [35], the high grain yield was caused by the division of the total dry matter into high seeds.

Kresnatita and Santoso [36] reported that high levels of N in the leaves are capable of high photosynthesis, which results in high yields of maize. This is also consistent with what was reported by Grüter et al. [37] and [38] that the application of green manure increased the N content of wheat and maize crops.

Application of mungbean green manure, peanut green manure, and *C. pubescens* green manure; 5; 7.5; and 10 t. ha^{-1} has been able to increase nutrient content in the soil. The use of green manure *C. pubescens* with a dose of 10 t. ha^{-1} significantly (P-value 0.05) influenced most of the observed variables (stem diameter, leaf area, the weight of 100 seeds, and yield dry weight per hectare) of maize. Similar results were reported by Mandal et al. [24], that the addition of green manure with *Sesbania aculeata* increased soil organic matter resulting in better soil aggregation, reduced rainfall density and improved water flow characteristics, which in turn increased rice plant growth.

The use of green manure in crop cultivation has the advantage of high organic matter content and low pollution with less investment [39, 40]. Green manure also stimulates soil fungal activity and provides a suitable environment for stabilizing soil enzymes [23], as well as increasing the growth and yield of shallots in dryland [27]. Thus the use of green manure will help farmers increase maize production and maintain soil health [41-43].

Table 3. Absorption of nutrients in the leaves of maize plants

Nutrients (%)	Uptake								
	K1D1	**K1D2**	**K1D3**	**K2D1**	**K2D2**	**K2D3**	**K3D1**	**K3D2**	**K3D3**
N–total	1.05	2.19	3.40	1.75	3.68	7.64	2.58	6.40	7.68
Phosphorus	0.33	0.34	0.35	0.33	0.37	0.38	0.35	0.36	0.39
Potassium	0.06	0.08	0.08	0.07	0.08	0.08	0.08	0.08	0.09

Source: Laboratory of Soil Science, Faculty of Agriculture, Tadulako University, Indonesia
K1 (mungbean green manure); K2 (peanut green manure); K3 (*C. pubescens* green manure); D1 (dose of 5 t.ha^{-1}); D2 (7.5 t. ha^{-1}); D3 (10 t. ha^{-1})

5. CONCLUSION

Types and doses of green manure increase the growth and yield of maize, namely stem diameter, leaf area, cob length, the weight of 100 dry shelled seeds, and production per hectare of dry maize shelled. The highest nutrient uptake and maize production were obtained in the application of *C. pubescens* green manure at a dose of 10 t.ha^{-1}, namely nitrogen uptake of 7.68%, phosphorus of 0.39%, potassium of 0.09% and yield of 6.44 t. ha^{-1}.

REFERENCES

[1] Ranum, P., Peña-Rosas, J.P., Garcia-Casal, M.N. (2014). Global maize production, utilization, and consumption. Annals of the New York Academy of Sciences, 1312(1): 105-112. https://doi.org/10.1111/nyas.12396

[2] Central Bureau of Statistics of Central Sulawesi. (2019). Sulawesi Tengah Province in figures 2019. Harvested area, production, and productivity of maize and soybean by regency/municipality in Sulawesi Tengah Province, 2018. BPS-Statistics of Sulawesi Tengah Province. 303 p. (in Indonesia).

[3] Hepperly, P., Lotter, D., Ulsh, C.Z., Seidel, R., Reider, C. (2009). Compost, manure and synthetic fertilizer influences crop yields, soil properties, nitrate leaching and crop nutrient content. Compost Science & Utilization, 17(2): 117-126. https://doi.org/10.1080/1065657X.2009.10702410

[4] Aziz, T., Ullah, S., Sattar, A., Nasim, M., Farooq, M., Khan, M.M. (2010). Nutrient availability and maize (*Zea mays*) growth in soil amended with organic manures. International Journal of Agriculture & Biology, 12(4): 621-624. https://doi.org/10.1016/j.compag.2010.03.005

[5] Schoebitz, M., Vidal, G. (2016). Microbial consortium and pig slurry to improve chemical properties of degraded soil and nutrient plant uptake. Journal of Soil Science and Plant Nutrition, 16(1): 226-236. https://doi.org/10.4067/S0718-95162016005000018

[6] Ziblim, A., Paul, G.S., Timothy, K.A. (2013). Assessing soil amendment potentials of *Mucuna pruriens* and *Crotalaria juncea* when used as fallow crops. Journal of Soil Science and Environmental Management, 4(2): 28–34. https://doi.org/10.5897/JSSEM12.064

[7] Septyani, I.A.P., Yasin, S., Gusmini, G. (2019). Utilization of sugarcane filter press mud compost as organic fertilizer for improving chemical properties of ultisols and oil palm seedlings. Tropical and Subtropical Agroecosystems, 22: 647-653.

[8] Dabin, Z., Pengwei, Y., Na, Z., Changwei, Y., Weidong, C., Yajun, G. (2016). Contribution of green manure legumes to nitrogen dynamics in traditional winter wheat cropping system in the Loess Plateau of China. European Journal of Agronomy, 72: 47-55. https://doi.org/10.1016/j.eja.2015.09.012

[9] Rayns, F., Rosenfeld, A., Organic, G. (2010). Green manures – effects on soil nutrient management and soil physical and biological properties. Horticulture Development Company, 1-8.

[10] Sultani, M.I., Gill, M.A., Anwar, M.M., Athar, M. (2007). Evaluation of soil physical properties as influenced by various green manuring legumes and phosphorus fertilization under rain fed conditions. International Journal of Environmental Science & Technology, 4(1): 109-118. https://doi.org/10.1007/BF03325968

[11] Corti, G., Weindorf, D.C., Fernández Sanjurjo, M.J., Cacovean, H. (2012). Use of waste materials to improve soil fertility and increase crop quality and quantity. Applied and Environmental Soil Science, 2012: 1-2. https://doi.org/10.1155/2012/204914

[12] Khan, M.T., Khan, N.A., Bezabih, M., Qureshi, M.S., Rahman, A. (2013). The nutritional value of peanut hay (*Arachis hypogaea* L.) as an alternate forage source for sheep. Tropical Animal Health and Production, 45(3): 849-853. https://doi.org/10.1007/s11250-012-0297-8

[13] Yao, Y., Zhang, M., Tian, Y., Zhao, M., Zhang, B., Zhao, M., Yin, B. (2017). Duckweed (*Spirodela polyrhiza*) as green manure for increasing yield and reducing nitrogen loss in rice production. Field Crops Research, 214: 273-282. https://doi.org/10.1016/j.fcr.2017.09.021

[14] Winarni, M., Yudono, P., Indradewa, D., Sunarminto, B. (2016). Application of perennial legume green manures to improve growth and yield of organic lowland rice. Journal of Degraded and Mining Lands Management, 4(1): 681-687. https://doi.org/10.15243/jdmlm.2016.041.681

[15] Yamato, M., Okimori, Y., Wibowo, I.F., Anshori, S., Ogawa, M. (2006). Effects of the application of charred bark of *Acacia mangium* on the yield of maize, cowpea and peanut, and soil chemical properties in South Sumatra, Indonesia. Soil Science and Plant Nutrition, 52(4): 489-495. https://doi.org/10.1111/j.1747-0765.2006.00065.x

[16] Yang, Y.J., Lei, T., Du, W., Liang, C.L., Li, H.D., Lv, J.L. (2020). Substituting chemical fertilizer nitrogen with organic manure and comparing their nitrogen use efficiency and winter wheat yield. The Journal of Agricultural Science, 158(4): 262-268. https://doi.org/10.1017/S0021859620000544

[17] Adekiya, A.O., Agbede, T.M., Aboyeji, C.M., Dunsin, O., Ugbe, J.O. (2019). Green manures and NPK fertilizer effects on soil properties, growth, yield, mineral and vitamin C composition of okra (*Abelmoschus esculentus* (L.) Moench). Journal of the Saudi Society of Agricultural Sciences, 18(2): 218-223. https://doi.org/10.1016/j.jssas.2017.05.005

[18] Adekiya, A.O. (2019). Green manures and poultry feather effects on soil characteristics, growth, yield, and mineral contents of tomato. Scientia Horticulturae, 257: 108721. https://doi.org/10.1016/j.scienta.2019.108721

[19] Li, Z., Zhang, R., Xia, S., Wang, L., Liu, C., Zhang, R., Liu, Y. (2019). Interactions between N, P and K fertilizers affect the environment and the yield and quality of satsumas. Global Ecology and Conservation, 19: e00663. https://doi.org/10.1016/j.gecco.2019.e00663

[20] Xie, Z., Tu, S., Shah, F., Xu, C., Chen, J., Han, D., Cao, W. (2016). Substitution of fertilizer-N by green manure improves the sustainability of yield in double-rice cropping system in south China. Field Crops Research, 188: 142-149. https://doi.org/10.1016/j.fcr.2016.01.006

[21] Yang, L., Bai, J.S., Liu, J., Zeng, N.H., Cao, W.D. (2018). Green manuring effect on changes of soil nitrogen fractions, maize growth, and nutrient uptake. Agronomy, 8(11): 261. https://doi.org/10.3390/agronomy8110261

[22] Elfstrand, S., Båth, B., Mårtensson, A. (2007). Influence of various forms of green manure amendment on soil microbial community composition, enzyme activity and nutrient levels in leek. Applied Soil Ecology, 36(1): 70-82. https://doi.org/10.1016/j.apsoil.2006.11.001

[23] Kataoka, R., Nagasaka, K., Tanaka, Y., Yamamura, H., Shinohara, S., Haramoto, E., Sakamoto, Y. (2017). Hairy vetch (*Vicia villosa*), as a green manure, increases fungal biomass, fungal community composition, and phosphatase activity in soil. Applied Soil Ecology, 117-118: 16-20. https://doi.org/10.1016/j.apsoil.2017.04.015

[24] Mandal, M., Chandran, R., Sencindiver, J. (2013). Amending subsoil with composted poultry litter-I: Effects on soil physical and chemical properties. Agronomy, 3(4): 657-669. https://doi.org/10.3390/agronomy3040657

[25] Sarwar, G., Schmeisky, H., Tahir, M.A., Iftikhar, Y., Sabah, N.U. (2010). Application of green compost for improvement in soil chemical properties and fertility status. The Journal of Animal & Plant Sciences, 20(4): 258-260.

[26] Carvalho, N.S., Oliveira, A.B.B., Pessoa, M.M.C., Neto, V.P.C., de Sousa, R.S., Coutinho, G. (2015). Short-term effect of different green manure on soil chemical and biological properties. African Journal of Agricultural Research., 10(43): 4076-4081. https://doi.org/10.5897/AJAR2015.9885

[27] Lasmini, S. A., Wahyudi, I., Rosmini, R., Nasir, B., Edy, N. (2019). Combined application of mulches and organic fertilizers enhance shallot production in dryland. Agronomy Research, 17(1): 165-175. https://doi.org/10.15159/AR.19.017

[28] Tong, J., Sun, X., Li, S., Qu, B., Wan, L. (2018). Reutilization of green waste as compost for soil improvement in the afforested land of the Beijing plain. Sustainability, 10(7): 2376. https://doi.org/10.3390/su10072376

[29] Slattery, R.A., VanLoocke, A., Bernacchi, C.J., Zhu, X.G., Ort, D.R. (2017). Photosynthesis, light use efficiency, and yield of reduced-chlorophyll soybean mutants in field conditions. Frontiers in Plant Science, 8(549): 1-19. https://doi.org/10.3389/fpls.2017.00549

[30] Sanchez-Martín, L., Meijide, A., Garcia-Torres, L., Vallejo, A. (2010). Combination of drip irrigation and organic fertilizer for mitigating emissions of nitrogen oxides in semiarid climate. Agriculture, Ecosystems & Environment, 137(1-2): 99-107. https://doi.org/10.1016/j.agee.2010.01.006

[31] Stewart, D.W., Costa, C., Dwyer, L.M., Smith, D.L., Hamilton, R.I., Ma, B.L. (2003). Canopy structure, light interception, and photosynthesis in maize. Agronomy Journal, 95(6): 1465-1474. https://doi.org/10.2134/agronj2003.1465

[32] Egbe, E.A., Fonge, B., Mokake, S.E., Besong, M., Fongod, A.N. (2012). The effects of green manure and NPK fertilizer on the growth and yield of maize (*Zea mays* L) in the mount Cameroon region. Agriculture and Biology Journal of North America, 3(3): 82-92. https://doi.org/10.5251/abjna.2012.3.3.82.92

[33] Islam, M., Hossain, M., Siddique, A., Rahman, M., Malika, M. (2015). Contribution of green manure incorporation in combination with nitrogen fertilizer in rice production. SAARC Journal of Agriculture, 12(2): 134-142. https://doi.org/10.3329/sja.v12i2.21925

[34] Naveed, M., Mehboob, I., Shaker, M., Hussain, M.B., Farooq, M. (2015). Biofertilizers in Pakistan: Initiatives and limitations. International Journal of Agriculture and Biology, 17(3): 411-420. https://doi.org/10.17957/IJAB/17.3.14.672

[35] Sumiati, E., Gunawan, O.S. (2007). The application of mycorrhizal bio-fertilizers to increase the efficiency of NPK nutrient uptake and its effect on yield and seed quality. Journal of Horticulture, 17(1): 34-42. (in Indonesia).

[36] Kresnatita, S., Santoso, M. (2013). Effects of organic manure on growth and yield of sweetcorn. Indonesian Green Technology Journal, 2(1): 8-17.

[37] Grüter, R., Costerousse, B., Bertoni, A., Mayer, J., Thonar, C., Frossard, E., Tandy, S. (2017). Green manure and long-term fertilization effects on soil zinc and cadmium availability and uptake by wheat (*Triticum aestivum* L.) at different growth stages. Science of The Total Environment, 599-600: 1330-1343. https://doi.org/10.1016/j.scitotenv.2017.05.070

[38] Bhatt, K., Bhattachan, B., Marahatta, S., Adhikari, J. (2019). Yield performance of maize (*Zea mays* L.) under different combinations of organic and inorganic nutrient management during spring at Rampur, Chitwan, Nepal. Acta Scientific Agriculture, 4(1): 120-127. https://doi.org/10.31080/ASAG.2020.04

[39] Järvis, J., Ivask, M., Nei, L., Kuu, A., Luud, A. (2016). Effect of green waste compost application on afforesta-tion success. Baltic Forestry, 22(1): 90-97.

[40] Tits, M., Elsen, A., Bries, J., Vandendriessche, H. (2014). Short-term and long-term effects of vegetable, fruit and garden waste compost applications in an arable crop rotation in Flanders. Plant and Soil., 376: 43-59. https://doi.org/10.1007/s11104-012-1318-0

[41] Bonilla, N., Gutiérrez-Barranquero, J., Vicente, A., Cazorla, F. (2012). Enhancing soil quality and plant health through suppressive organic amendments. Diversity, 4(4): 475-491. https://doi.org/10.3390/d4040475

[42] Lehman, R., Cambardella, C., Stott, D., Acosta-Martinez, V., Manter, D., Buyer, J., Maul, J.E., Smith, J.L., Collins, H.P., Halvorson, J.J., Kremer, R.J., Lundgren, J.G., Ducey, T.F., Jin, V.L., Karlen, D.L. (2015). Understanding and enhancing soil biological health: the solution for reversing soil degradation. Sustainability, 7(1): 988-1027. https://doi.org/10.3390/su7010988

[43] Wang, Y., Zhu, Y., Zhang, S., Wang, Y. (2018). What could promote farmers to replace chemical fertilizers with organic fertilizers? Journal of Cleaner Production, 199: 882-890. https://doi.org/10.1016/j.jclepro.2018.07.222