PAPER • OPEN ACCESS

Application of manures reduces inorganic fertilizers requirement for maize grown in a sandy soil

IOP Conf. Series: Earth and Environmental Science **913** (2021) 012001 doi:10.1088/1755-1315/913/1/012001

Application of manures reduces inorganic fertilizers requirement for maize grown in a sandy soil

G A A P Kreshnadhi[1], I K D Jaya*[1,2], B B Santoso[2], W Wangiyana[1,2], H Suheri[1,2]

[1]Dryland Agriculture Study Program, Postgraduate University of Mataram
[2]Agroecotechnology Study Program, Faculty of Agriculture University of Mataram

*Corresponding author: ikdjaya@unram.ac.id

Abstract. The use of inorganic fertilizers with high doses is not recommended in the sustainable maize production program. The present study aimed to evaluate soil chemical properties and growth of maize plants treated with several types of manure to reduce the use of chemical fertilizers in sandy soil. An experiment was conducted in dryland with pumped deep-well water in Gumantar Village, North Lombok Regency, from May to July 2021. There were three types of manure tested: cow, poultry, and goat manures (20 ton/ha) treated with and without BeKa decomposer. All the manure treatments received 75% of chemical fertilizers applied in the control treatment (500 kg of urea and 380 kg/ha of NPK Phonska). The treatments were arranged in a randomized block design with three replicates. The results showed that the poultry manure treatments, with and without decomposer, increased soil pH significantly. This increase improved soil chemical properties, such as available P and K. Plant height, stem diameter, leaf area index at silking, and total N in leaf tissue, were not significantly different among the treatments. These results showed that the application of manures, with or without decomposer, could substitute 25% of the inorganic fertilizers needed by maize plants grown in sandy soil.

1. Introduction

Drylands in West Nusa Tenggara (WNT) are spread over the northern part and southern part of the island of Lombok, and the southern part of East Lombok, as well as most of the parts of the island of Sumbawa. Farmers in the dryland areas generally grow maize as the main crop [1]. Statistical data also show that 71.4% of maize in Indonesia is produced from non-rice field lands with national productivity of around 5.47 ton/ha [2]. Mulyani and Mamat [3] reported that the yield of maize harvested from drylands in WNT was about 5.3 ton/ha, which is much lower than the genetic potential of most hybrid varieties of around 9.0 ton/ha. However, based on research conducted by Jaya et al. [4], maize yields in the dryland of North Lombok can be as high as 8.2 to 9.7 ton/ha. This high yield was achieved due to the increased application of inorganic fertilizers, consisting of 500 kg/ha urea and 380 kg/ha Phonska, into the soil and with a crop population density that can maximize the sunlight interception by their canopy.

Continuous applications in high rates of inorganic fertilizers can degrades the physical, chemical, and biological properties of the soil and can lead to the decline in soil fertility and in the quality of the environment [5, 6]. Due to the potential hazard of the long-term inorganic fertilizer applications, some prevention measures are needed, such as improving the soil organic matter by adding organic materials to improve soil health [7]. The application of organic matter and or organic fertilizer helps improve the physical, chemical, and biological properties of the soil, thereby increasing the availability of nutrients for plants [8.]. Previous studies showed that applications of organic materials from green manure and organic fertilizer that contained microbes (bio-fertilizer) improved soil properties and growth of maize plant and resulted in a reduced requirement of inorganic fertilizers by the plant [9; 10]. Other study results show that applying manure to the soil can improve aeration and infiltration of rainwater and irrigation, improve soil structure, increase soil porosity and increase the activity of soil microorganisms [8, 11, 12]. Soil microorganisms play a role in the process of nutrient recycling and mineralization [8]. Manure application was also reported to replace the role of nitrogen fertilizer while still maintaining adequate plant growth [13]. All those practices aimed to sustain land productivity by improving soil health.

The addition of bacteria as decomposers into the manures can also help speed up the decomposition process of the organic matters [14]. One of the commercial decomposers available in Indonesian markets is BeKa. BeKa is claimed to be rich in carbon and contains macronutrients (N, P, K) and micronutrients (Ca, Mg, Si, Fe, Mn, Mo, B, Cl, Zn, and Cu), humic acid, sulfuric acid. A consortium of microorganisms comprising *Trichoderma* sp., *Bacillus* sp. and *Streptomyces* sp. are also contained in the product. decomposers. All those constituents can help increase the cation exchange capacity (CEC) and water holding capacity the soil and produce growth regulators and provide protection against plant pathogens [15]. This study aimed to evaluate the effectiveness of manure application combined with BeKa decomposer in reducing the inorganic fertilizer application for maize crops. The focus of this study was at the role of manures and BeKa decomposers in affecting soil chemical properties and the growth of maize in a predominantly sandy dryland soil.

2. Materials and methods

2.1. Sampling location and treatments

A field experiment was carried out from May 2021 to July 2021 in Gumantar Village, Kayangan District, North Lombok Regency, Indonesia. The soil texture in the experimental field is predomenantly sandy with 93% sand fraction and 7% silt. There were three types of manures tested, namely: cow manure, goat manure, and poultry manure, either as individual or in combination with BeKa decomposer. All the manure treatments received only 75% of prescribed rate inorganic fertilizer (375 kg/ha urea +280 kg/ha Phonska). A treatment with 100% prescribed rate of inorganic fertilizers was also included as the control treatment. The prescribed rate of inorganic fertilizers for the experimental area consists of 500 kg/ha urea and 380 kg/ha NPK (15-15-15) Phonska [16]. The whole treatments in this study were as follows: (A). 100% of inorganic fertilizer as control; (B). 75% inorganic fertilizer + cow manure; (C). 75% inorganic fertilizer + goat manure; (D). 75% inorganic fertilizer + poultry manure; (E). 75% inorganic fertilizer + cow manure + BeKa; (F). 75% inorganic fertilizer + goat manure + BeKa; and (G). 75% inorganic fertilizer + poultry manure + BeKa. The dose for each type of manure was 20 ton/ha, while the BeKa concentration was 0.2%.

Manures were applied soon after soil preparation and treatment plot formation. The manures were evenly mixed with the soil in each treatment plot and then were incubated for three weeks. Inorganic fertilizers were applied three times, namely at planting, 35 days after planting (DAP), and 56 DAP. For the control treatment, the application dose for each fertilizer was 150 kg/ha urea and 190 kg/ha Phonska, while the other treatments received 75% of that dose. At 35 DAP, the control treatment received 200 kg/ha urea and 190 kg/ha Phonska. The other treatments also received 75% of the doses applied in the control treatment. The rest of the urea fertilizer dose was applied at 56 DAP when the plants entered the silking stage.

2.2. Crop culture and management

Maize seeds (NK007) were planted in a double row planting pattern in a 5.0 x 3.5 m^2 treatment plot. The spacing for the double planting pattern was as follows: inside the double row was 35 x 20 cm^2 while the distance between the double row was 70 cm. There were 150 plants in two double rows and two-single rows (as border crops) in each treatment plot with this planting pattern. During the establishment of the crop, watering was conducted at least once in four days, depending on the crop's condition. The water for the crops was pumped from a deep well located nearby the experimental site.

2.3. Measurements and data analysis

Soil sampling for analysis of soil chemical properties was conducted just before planting (3 weeks after the incubation of manure treatments). Soil samples (of around 0.5 kg) were taken from the middle of each treatment plot at a depth of 5 cm. The samples were then taken to the Laboratory of Soil, Fertilizer and Water, Indonesian Agency for Agricultural Research and Development, West Nusa Tenggara. The soil parameters measured were soil texture, soil pH (H_2O, electrometry), C-organic (Walkey and Black), nitrogen total (Kjeldahl), available phosphorus (Morgan Wolf), and available potassium (Morgan Wolf). The analysis of soil cation exchange capacity (ammonium acetate) and nitrogen total in leaf tissue (Kjeldahl) were conducted at Soil Chemical Laboratory, Faculty of Agriculture University of Mataram. Three leaves from each treatment (the third leaf down from the flag leaf) were taken at 56 DAP before the third fertilizer application to measure the total nitrogen in leaf tissue. Soil samples for the bacteria population were taken from each treatment plot. Approximately 250 g of soil was taken from the rhizosphere (approximately up to 3 cm in depth) in each plot in the morning at 60 DAP. The soil samples were then taken to the Health Laboratory for Testing and Calibration, Public Health Office, West Nusa Tenggara.

Plant growth parameters measured were plant height, number of green leaves, stem diameter, and leaves area index. All measurements were conducted at anthesis (when the male flowers appear), 56 DAP. All collected data were analysed using analysis of variance at 95% confidence interval using Minitab statistical package. Further tests using Duncan's Multiple Range Test (DMRT) at 95% confidence interval were performed for the treatments' significantly affected parameters.

3. Results and discussion

The maize seeds (NK007 produced by Syngenta) were planted on the 9th of May 2021, and the crops received very little rain during the growth period. There was a total of 24 mm of rainfall with two rainy days recorded from planting to the final measurement at 60 DAP. The rest of the water requirements by the crops was supplied from a deep-well pump nearby. The maximum and minimum temperatures during the experiments were 35°C and 20ºC, respectively. The maize crops grew well, but there was pests (*Spodoptera frugiperda*) attack at 42 DAP, and therefore, tetraniliprole 200 g/l was applied twice, at 42 and 49 DAP.

Table 1. Effect of cow manure (CM), goat manure (GM) and poultry manure (PM) treatments, with and without BeKa decomposer on soil pH, C-organic, N total, and cation exchange capacity (CEC).

Treatments	Variable measured			
	pH	C-organic (%)	N total (%)	CEC (me/%)
A (100% IF)	6.33 ab*	1.15 a	0.06 ab	8.55 a
B (75% IF + CM)	6.22 a	0.98 a	0.07 ab	8.49 a
C (75% IF + GM)	6.07 a	1.35 ab	0.11 b	8.82 a
D (75% IF + PM)	6.77 bc	1.38 ab	0.06 ab	8.42 a
E (75% IF + CM + BeKa)	6.37 abc	1.05 a	0.04 a	9.63 a
F (75% IF + GM + BeKa)	6.34 ab	1.38 ab	0.04 ab	8.63 a
G (75% IF + PM + BeKa)	6.82 c	1.83 b	0.05 ab	8.67 a

*Values in the same column followed by the same letter are not significantly different.

Analysis of variance results showed that soil chemical properties were affected by manures and BeKa decomposer application except for cation exchange capacity (CEC), as shown in table 1 and table 2. Poultry manure increased soil pH more than goat manure but relatively the same as pH of the soil treated with cow manure. An earlier study by Naramabuye and Haynes [17] showed the same trend that poultry manure increased soil pH more than other sources of manures. The application of $CaCO_3$ as a base in the poultry industry was considered the main reason for the high pH value in the poultry manure treatment. Further increase in soil pH was recorded when the manures were treated with BeKa decomposer. This result is obvious since high microbes' activities during carbon mineralization of the manures can increase pH value [18].

Poultry manure with BeKa decomposer improved soil organic carbon better than cow manure, with or without decomposer and the control treatment. No significant difference was observed between poultry manure and goat manure (Table 1). A previous study showed that poultry manure had the highest organic matter property, followed by goat and cow manure [19]. The high organic matter content in poultry manure contributed to the high C-organic in the soil. In terms of nitrogen total in soil, goat manure treatment without decomposer produced the highest value and was significantly different from those treated with BeKa decomposer treatments. The nitrogen total in the soil was low in all manure treatments treated with BeKa decomposer. The microbes in the decomposer might have used a lot of nitrogen during the decomposition process, as previously reported by Korsaeth et al. [20].

Soil cation exchange capacity (CEC) was not significantly different among the treatments. All of the CEC values were considered very low, typical of sandy soil [21]. The application of manure into the sandy soil in a short period could not improve the soil CEC. The low CEC value means that the soil requires many nutrients to support good growth of crops, and the applied nutrients easily leech during the rainy season [21].

Table 2. Effect of cow manure (CM), goat manure (GM) and poultry manure (PM) treatments, with and without BeKa decomposer on soil available P, K, bacteria colony, and N total in leaf tissue.

Treatments	Variable measured			
	P avail. (ppm)	K avail. (ppm)	Bac. colony (colony/g)	N tissue (%)
A (100% IF)	4.00 a*	59.21 a	1.36×10^6 a	2.60 ab
B (75% IF + CM)	10.49 a	65.98 ab	1.96×10^6 a	2.62 abc
C (75% IF + GM)	13.93 a	66.66 abc	1.92×10^6 a	2.82 bc
D (75% IF + PM)	36.34 ab	91.17 c	1.48×10^6 a	2.55 a
E (75% IF + CM + BeKa)	8.80 a	65.42 ab	1.30×10^6 a	2.89 c
F (75% IF + GM + BeKa)	21.87 ab	68.88 abc	2.05×10^6 a	2.88 bc
G (75% IF + PM + BeKa)	44.50 b	88.68 bc	1.49×10^6 a	2.63 abc

*Values in the same column followed by the same letter are not significantly different.

The available soil P was recorded the highest in poultry manure treatments, either with or without BeKa decomposer (Table 2). Low soil available P was recorded in control, cow manure, and goat manure treatments but the available P in the soil with goat manure treatment plus BeKa was relatively the same as that in poultry manure treatment. These data trends show that P's availability from poultry and goat manure slightly improved with the decomposer application but not showing a significant difference. The higher available P in soil treated with poultry and goat manure is due to the higher P content in those two manures than in cow manure [19]. The trend of soil available K was somewhat similar to that of the soil available P even though Azeez and van Averbeke [19] show that goat manure contains more P than K. Still, that data show the total nutrients content, not the available one.

A slight increase was recorded in the total colony of bacteria in the manure-treated soil, but the increase was not significantly different from the control treatment (Table 2). Some studies suggest that manure application improves soil microbes' population because the organic matter in the manures is a food source of the microbes [22]. Later study shows that microbe population, especially in sandy soil, improves after a long-term application of manures [23]. The non-significant difference in the bacteria population in all treatments compared to the control treatment might be due to the short time from manure application to the bacteria counting time.

The highest total nitrogen content in the leaf tissue was recorded in 75% inorganic fertilizer + cow manure treatment combined with BeKa decomposer. It was not significantly different from other treatments except with control and 75% inorganic fertilizer + poultry manure treatment (Table 2). It seems that the availability of nitrogen from cow and goat manures was faster than the one from poultry manure. The addition of BeKa decomposer appeared to speed up the nitrogen availability from poultry manure to make the total nitrogen in the maize leaf tissue was not significantly different from other manure treatments. This result is promising because the nitrogen from cow, goat, and poultry manures could replace 25% of nitrogen requirement from chemical fertilizers (urea and NPK Phonska).

Table 3 shows that maize plant growth parameters (plant height, stem diameter, and leaf area index) at 56 DAP in the 25% fewer inorganic fertilizers treatments were not significantly different from the control treatment (100% inorganic fertilizer treatment). These results show that manure can replace 25% of nutrients from inorganic fertilizer for maize grown in sandy soil with a dryland environment. The number of green leaves in 75% inorganic fertilizer + poultry manure treatment combined with BeKa decomposer was higher than in the control treatment (100% inorganic fertilizer), indicating that nutrients absorption was better in this treatment. The high value of soil organic carbon and high values in P and K availability in the soil with poultry manure treated with BeKa + 75% inorganic fertilizer also contributed to this result.

Table 3. Effect of cow manure (CM), goat manure (GM) and poultry manure (PM) treatments, with and without BeKa decomposer on maize plant growth variables at 56 DAT.

Treatments	Variable measured			
	Plant height (cm)	Green leaves number	Stem diameter (cm)	Leaf area index
A (100% IF)	175.7 a*	12.4 a	1.86 a	4.1 a
B (75% IF + CM)	183.5 a	12.5 ab	1.84 a	4.4 a
C (75% IF + GM)	191.9 a	13.1 ab	1.88 a	4.1 a
D (75% IF + PM)	187.4 a	13.1 ab	2.03 a	4.5 a
E (75% IF + CM + BeKa)	176.6 a	12.8 ab	1.75 a	4.3 a
F (75% IF + GM + BeKa)	174.6 a	12.7 ab	1.78 a	4.0 a
G (75% IF + PM + BeKa)	185.5 a	13.6 b	1.98 a	4.7 a

*Values in the same column followed by the same letter are not significantly different.

4. Conclusion

Manure's application improved chemical properties of sandy soil in a dryland environment. The improvement was mainly in pH, C-organic, available P and K but not in cation exchange capacity, bacteria population, and hardly in the total nitrogen. This improvement led to the similar maize growth performance between the maize plants treated with 100% inorganic fertilizer and those treated with 75% inorganic fertilizer plus manures. In the 75% inorganic fertilizers treatment plus poultry manure and BeKa decomposer, the number of green leaves was higher than the one in 100% inorganic fertilizers treatment. These results show that manure application can replace 25% of the inorganic fertilizers requirement for maize to grow in sandy soil. In the long run, the application of manures in maize cultivation is recommended to sustain the dryland soils productivity.

References

[1] Jaya IKD, Suheri H and Wangiyana W 2021 Can organic soil ameliorant and foliar organic fertilizer improve maize and reduce inorganic fertilizer input in a dryland semiarid? *IOP Conf. Ser.: Earth Environ. Sci.* **712** (2021). 012012. doi:10.1088/1755-1315/712/1/012012.

[2] Directorate of Food Crops, Horticulture, and Estate Crops Statistics 2020 *The 2020 Analysis of Maize and Soybean Productivity in Indonesia (The Results of Crop Cutting Survey)*. 110 p. ISBN : 978-602-438-425-8.

[3] Mulyani A and Mamat HS 2019 Pengelolaan lahan kering beriklim kering untuk pengembangan jagung di Nusa Tenggara *Jurnal Sumberdaya Lahan* **13** 41-52.

[4] Jaya IKD, Sudirman S and Sudika IW 2019 Light interception and yield of some maize varieties grown in a double-row pattern under different urea applications *IOP Conf. Ser.: Earth Environ. Sci.* **346** (2019) 012071. doi:10.1088/1755-1315/346/1/012071

[5] Savci S 2012 Investigation of effect of chemical fertilizers on environment *APCBEE Procedia* **1**: 287 – 292

[6] Bai Y-C, Chang Y-Y, Hussain M, Lu B, Zhang J-P, Song X-B, Lei X-S and Pei D 2020 Soil chemical and microbiological properties are changed by long-term chemical fertilizers that limit

ecosystem functioning *Microorganisms* **8** 694; doi:10.3390/ microorganisms8050694
[7] Pataczek L, Zahir ZA, Ahmad M, Rani S, Nair R, Schaf-leitner R, Cadisch G and Hilger T 2018 Beans with benefits-the role of mungbean (*Vigna radiata*) in a changing environment. *Am. J. Plant Sci.* **9** 1577-600. https://doi.org/10.4236/ajps.2018.97115
[8] Aziz T, Ullah S, Sattar A, Nasim M, Farooq M and Khan MM 2010 Nutrient availability and maize (*Zea mays*) growth in soil amended with organic manures *Int J Agric Biol.* **12** 621–24.
[9] Jaya IKD, Sudirman, Sudika IW 2021 Mung bean cover crop improved soil organic carbon and maize yield in a semiarid area *IOP Conf. Ser.: Earth Environ. Sci*. **637** (2021) 012006. doi:10.1088/1755-1315/637/1/012006
[10] Jaya IKD, Sudirman, Sudika IW 2021 Application of Petrobio fertiliser in addition to inorganic fertiliser improved the growth of maize plants *ASM Sc. J*. **14** Special Issue 2 2021 for ICST2017 18-23.
[11] Singh VK, Dwivedi BS, Mishra RP, Shukla AK, Timsina J, Upadhyay PK, Shekhawat K, Majumdar K and Panwar AS 2019 Yields, soil health and farm profits under a rice-wheat system: long-term effect of fertilizers and organic manures applied alone and in combination *Agronomy* 2019, **9**, 1; doi:10.3390/agronomy9010001
[12] Rayne N and Aula L 2020 Livestock manure and the impacts on soil health: a review *Soil System* 2020, **4**, 64; doi:10.3390/soilsystems4040064
[13] Wang X, Yang Y, Zhao J, Nie J, Zang H, Zeng Z and Olesen JE 2020 Yield benefits from replacing chemical fertilizers with manure under water deficient conditions of the winter wheat – summer maize system in the North China Plain *Eur J Agron* **119** (2020) 126118. https://doi.org/10.1016/j.eja.2020.126118
[14] Said MI 2020 Livestock waste and its role in the composting process: A review. *IOP Conf. Ser.: Earth Environ. Sci*. **492** (2020) 012087. doi:10.1088/1755-1315/492/1/012087
[15] BeKa Dekomposer. https://www.acidatama.co.id. Accessed 5 September 2021.
[16] Ihwan K, Jaya, IKD and Sudika IW 2019 Effect of two different planting patterns on performance of four maize varieties under rainfed conditions**.** *AIP Conference Proceedings* **2199**, 040003 (2019); https://doi.org/10.1063/1.5141290
[17] Naramabuye FX and Haynes RJ 2006 Short-term effects of three animal manures on soil pH and Al solubility *AUST J SOIL RES* **44** 515–21.
[18] Carter DO and Tibbett M 2006 Microbial decomposition of skeletal muscle tissue (*Ovis aries*) in a sandy loam soil at different temperatures *Soil Biol. Biochem.* **38** 1139–1145. https://doi.org/10.1016/j.soilbio.2005.09.014
[19] Azeez JO, van Averbeke W, 2010. Nitrogen mineralization potential of three animal manures applied on a sandy clay loam soil. *Bioresour. Technol.* **101** 5645–51. doi:10.1016/j.biortech.2010.01.119
[20] Korsaeth A, Henriksen TM, Bakken, LR 2002 Temporal changes in mineralization and immobilization of N during degradation of plant material: implications for the plant N supply and nitrogen losses *Soil Biol. Biochem.* **34** 789-99. https://doi.org/10.1016/S0038-0717(02)00008
[21] Aprile F and Lorandi R 2012 Evaluation of cation exchange capacity (CEC) in tropical soils using four different analytical methods *J Agric Sci.* **4** 278-89. http://dx.doi.org/10.5539/jas.v4n6p278
[22] Doran JW and Zeiss MR 2000 Soil health and sustainability: managing the biotic component of soil quality *Appl. Soil Ecol.* **15** 3–11 https://doi.org/10.1016/S0929-1393(00)00067-6
[23] Ulrich A, Klimke G and Wirth S 2008 Diversity and activity of cellulose-decomposing bacteria, isolated from a sandy and a loamy soil after long-term manure application. *Microb Ecol* **55** 512–22 DOI 10.1007/s00248-007-9296-0.