第 55 卷 第 3 期 农 业 机 械 学 报 Vol. 55 No. 3
2024 年 3 月 **Transactions of the Chinese Society of Agricultural Machinery** Mar. 2024

Research article
Crop production: grains, legumes, fruits, vegetables, flowers, cotton: Sustainable agriculture
DOI：10.62321/issn.1000-1298.2024.03.05

Effect of Liquid Organic Fertilizer (LOF) on the Growth, Yield, and Economics of Maize (*Zea Mays* L.) in South Sulawesi, Indonesia

Idaryani[1], Andi Yulyani Fadwiwati[2], Syuryawati[2], Sri Bananiek[2], Muslimin[2], Emi Budiyati[3], Paesal[1], Warda[3], Meksy Dianawati[3], Amisnaipa[3], Emi Sugiartini[3], Imran[3], Sunanto[2], Heppy Suci Wulanningtyas[1], Andi Apriany Fatmawaty[4], Lis Yapanto[5]

(1. Research Center for Food Crops, Research Organization for Agriculture and Food, National Research and Innovation Agency (BRIN), Jl. Raya Jakarta-Bogor, Km 46, Cibinong, Bogor, West Java, Indonesia; 2. Research Center for Behavioral and Circular Economics, Research Organization for Governance, Economy, and Community Welfare, National Research and Innovation Agency (BRIN), Jl. Gatot Subroto, No. 10, Jakarta Selatan, Indonesia; 3. Research Center for Horticultural and Estate Crops, National Research and Innovation Agency (BRIN), Jl. Raya Jakarta-Bogor, Km 46, Cibinong, Bogor, West Java, Indonesia; 4. Department of Agroecotechnology, Faculty of Agriculture, University of Sultan Ageng Tirtayasa, Indonesia; 5. Faculty of Fishery and Marine Science, Gorontalo State University, Gorontalo, Indonesia)

Abstract: Maize is a cereal commodity with high economic value. However, in South Sulawesi, maize productivity is very low compared with the average national productivity, which is mainly attributed to poor soil fertility. This study determined the effect of liquid organic fertilizer on the growth and yield of maize. Therefore, a field experiment was conducted at Maros Regency, South Sulawesi, Indonesia, in February-June 2022. Treatments involving nine rates of liquid organic fertilizer (LOF) were tested in the RCBD arrangement with three replications. The results showed that the use of liquid organic fertilizer had a significant effect on the growth parameters and yield of maize. The highest yield (6.322 kg ha^{-1}) was obtained using 6000-ml ha^{-1} liquid organic fertilizer combined with 225-kg ha^{-1} urea. Economically, it can provide a higher profit, with an MBCR ratio of 1.78.
Keywords: liquid organic fertilizer; maize; economics

液体有机肥(洛夫)对印度尼西亚南苏拉威西省玉米(玉米·梅斯·L.)生

Received: January 16, 2024 / Revised: February 10, 2024 / Accepted: March 13, 2024 / Published: March 29, 2024
Fund projects: PT Maharaja Multi Sinergi
About the authors: Idaryani, Research Center for Food Crops, Research Organization for Agriculture and Food, National Research and Innovation Agency (BRIN), Cibinong, Bogor, West Java, Indonesia; Andi Yulyani Fadwiwati, Syuryawati, Sri Bananiek, Muslimin, Research Center for Behavioral and Circular Economics, Research Organization for Governance, Economy, and Community Welfare, National Research and Innovation Agency (BRIN), Jakarta Selatan, Indonesia; Emi Budiyati, Research Center for Horticultural and Estate Crops, National Research and Innovation Agency (BRIN), Cibinong, Bogor, West Java, Indonesia; Paesal, Research Center for Food Crops, Research Organization for Agriculture and Food, National Research and Innovation Agency (BRIN), Cibinong, Bogor, West Java, Indonesia; Warda, Meksy Dianawati, Amisnaipa, Emi Sugiartini, Imran, Research Center for Horticultural and Estate Crops, National Research and Innovation Agency (BRIN), Cibinong, Bogor, West Java, Indonesia; Sunanto, Research Center for Behavioral and Circular Economics, Research Organization for Governance, Economy, and Community Welfare, National Research and Innovation Agency (BRIN), Jakarta Selatan, Indonesia; Heppy Suci Wulanningtyas, Research Center for Food Crops, Research Organization for Agriculture and Food, National Research and Innovation Agency (BRIN), Cibinong, Bogor, West Java, Indonesia; Andi Apriany Fatmawaty, Department of Agroecotechnology, Faculty of Agriculture, University of Sultan Ageng Tirtayasa, Indonesia; Lis Yapanto, Faculty of Fishery and Marine Science, Gorontalo State University, Gorontalo, Indonesia

长、产量和经济的影响

Idaryani[1], Andi Yulyani Fadwiwati[2], Syuryawati[2], Sri Bananiek[2], Muslimin[2], Emi Budiyati[3], Paesal[1], Warda[3], Meksy Dianawati[3], Amisnaipa[3], Emi Sugiartini[3], Imran[3], Sunanto[2], Heppy Suci Wulanningtyas[1], Andi Apriany Fatmawaty[4], Lis Yapanto[5]

(1. 粮食作物研究中心，农业和食品研究组织，国家研究和创新局(布林)，Jl。雅加达-茂物拉亚, 茨比农46公里, 茂物, 西爪哇, 印度尼西亚

2. 行为和循环经济学研究中心，治理、经济和社区福利研究组织，国家研究和创新局(布林)，Jl。加托·苏布罗托，10号，雅加达南区，印度尼西亚

3. 国家研究和创新局(布林)园艺和种植作物研究中心，Jl。雅加达拉亚-茂物, 茨比农46公里, 茂物, 西爪哇, 印度尼西亚

4. 印度尼西亚阿让蒂尔塔亚萨苏丹大学农学院农业生态技术系

5. 哥伦打洛州立大学渔业与海洋科学学院，哥伦打洛，印度尼西亚)

摘要:

玉米是一种具有较高经济价值的谷物商品。然而，在南苏拉威西省，玉米生产力与全国平均生产力相比非常低，这主要归因于土壤肥力较差。本研究确定了液体有机肥对玉米生长和产量的影响。因此，我们于2022年2月至6月在印度尼西亚南苏拉威西岛马罗斯县进行了一项田间试验。在中央商务区安排中对涉及9种液体有机肥(洛夫)比例的处理进行了3次重复测试。结果表明，施用液体有机肥对玉米生长参数和产量有显着影响。使用6000毫升哈-1液体有机肥与225公斤哈-1尿素结合使用获得了最高产量（6.322公斤哈-1）。经济上可以提供较高的利润，MBCR率为1.78。

关键词：液体有机肥；玉米; 经济学

1 Introduction

Maize (*Zea mays* L.) is a commodity crop that has particular significance after rice in Indonesia. Maize plays a crucial role beyond being a food and feed source. It is increasingly utilized as an energy source and raw material in various industries, with its demand steadily rising each year. Therefore, the opportunity to increase domestic corn production is still wide open, both through increasing productivity and expanding the planting area [1]. Low soil fertility is one of the factors causing low maize productivity at the farmer level [2]. Low inputs in agriculture are a major cause of low and declining yields in many countries south of the Sahara [3]. One of the determining factors in the success of corn cultivation is the application of fertilizer to adequately supply the necessary nutrients for plant growth. Agricultural businesses that rely on chemicals, such as inorganic fertilizers and chemical pesticides, have caused numerous negative and harmful impacts on humans, the environment, and all living organisms. These chemicals have been used in the past and continue to be used today, leading to detrimental consequences. Excessive use of inorganic fertilizers causes environmental damage and increases sensitivity to pests and diseases due to an excess supply of nitrogen [4]. The build-up of chemical fertilizers in the soil results in excessive nitrate accumulation in plants. Furthermore, inorganic fertilizers are expensive and their use may not be economically justifiable, especially for poor smallholder farmers who mainly practice subsistence farming.

A potential way to reduce the impact of environmental damage due to the excessive use of inorganic fertilizers is by practicing organic farming [5,6]. Organic fertilizers can improve soil health, increase water holding capacity, cause high cation exchange capacity, and are suitable for growing beneficial microorganisms [7,8]. Organic fertilizer is produced from decomposed plants, animal manure, or other organic waste materials. It is formulated in solid or liquid form, enhanced with minerals and microbial substances. This type of fertilizer is beneficial for enhancing soil nutrient levels and organic matter content, thereby improving soil quality [9]. Some organic fertilizers contain macro- and micronutrients, vitamins, growth-promoting factors indole-3-acetic acid (IAA), gibberellic acid (GA), and beneficial microorganisms [10] and can increase crop yields similarly to inorganic fertilizers [11].

Organic fertilizers are effective in increasing environmental sustainability and plant growth after long-term use; however, some previous studies have focused mainly on solid organic matter, such as straw and manure. Currently, many types of organic fertilizers are being marketed, and the use of organic fertilizers is a government program promoted to realize a sustainable agricultural program. Various organic fertilizers that are marketed have different nutrient contents; therefore, they will have different effects on plants. Compared with solid organic fertilizers, liquid organic fertilizers contain soluble nutrients that can preserve soil and plant health [12]. In addition, it can also increase the efficiency of nutrient use and reduce the risk of nutrient loss [13,14]. Another benefit is that special compounds in liquid organic fertilizers, such as chitin, humid and fulvic acids, and other biopolymers, can be biostimulants for plants [15,16].

Liquid organic fertilizer is an environmentally friendly fertilizer developed from botanical extracts into a liquid that is easily absorbed in a soluble state and usually enriched with nutritional elements that promote healthy plant growth and development [17]. Liquid organic fertilizer is excellent for the growth of various crops including maize, sorghum, rice, sweet potato, cassava, potato, soybean, cowpea, mango, papaya, and oil palm. The effective application of foliar fertilizer is determined by the plant type, fertilizer form, concentration, application frequency, and plant growth stage [18]. Leaf application is effective in supporting the growth and yield of corn plants [19]. Previous research has concluded that the quality of the LOF, namely the nutritional composition, is determined by the type of raw material, decomposing microorganisms, and the production process [20]. Organic vegetable production is a systems approach, where the production is intentionally designed to promote biodiversity, biological cycles, and soil biological activity. The purpose of this study was to determine the effect of liquid organic fertilizer (LOF) on the growth, yield, and economy of maize.

2 Materials and Methods

2.1 Experimental Site

The research was conducted in February-June 2022 in Moncongloe District, Maros Regency, South Sulawesi, Indonesia. The research location is at coordinates 5.^{00} south latitude and 119.^{30} east longitude, with an altitude of 10-122 m above sea level. This area experiences an average monthly rainfall of 347 mm and approximately 16 rainy days per month.

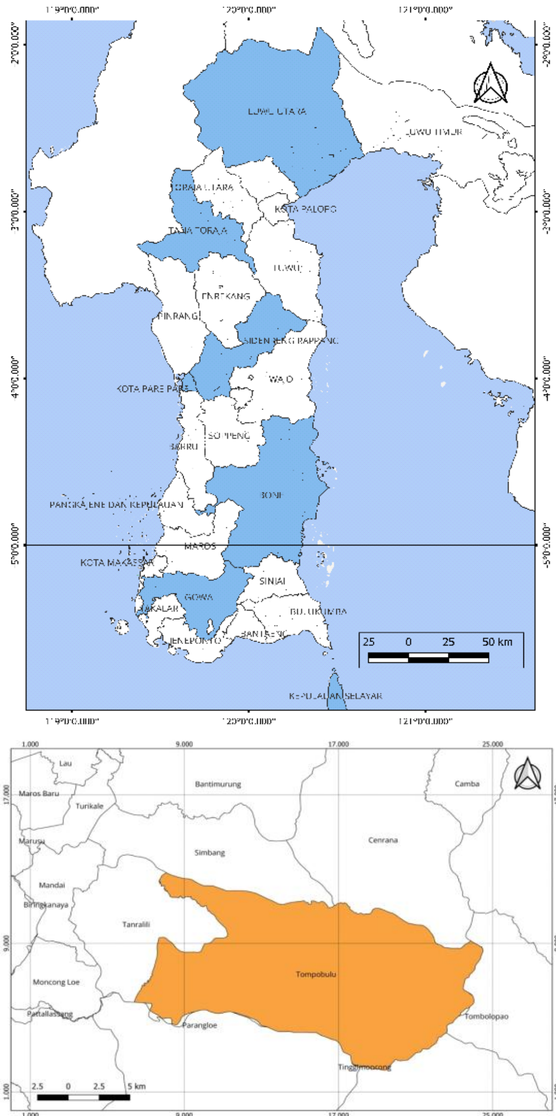

Fig. 1 Map of the study area (The authors)

2.2 Experimental Design and Treatments

The experimental area was 50 m x 20 m, and the plots were made measuring 5 x 6 m. The boundaries of the plots between treatments were made with channels measuring 20 cm deep and 50 cm wide, while the limit for replications was 100 cm. The field experiments were arranged in a randomized block design (RAK = randomized complete block design) with nine types of treatment and repeated three times.

The treatments tried were several levels of LOF combined with inorganic fertilizers. The complete treatment arrangement is presented in Tab. 1.

Tab. 1 LOF application to maize in Maros Regency, South Sulawesi (The authors)

		Fertilizer Dosage				
Treatment	Symbol	Urea	ZA	SP-36	KCl	LOF
		kg ha^{-1}				ml ha^{-1}
Without fertilizer (control)	P0	0	0	0	0	0
Based on the recommendation	P1	300	100	100	50	0
75% LOF	P2	0	0	0	0	4500
100% LOF	P3	0	0	0	0	6000
150% LOF	P4	0	0	0	0	9000
100% LOF + 100% urea	P5	300	0	0	0	6000
75% LOF + 100% urea	P6	300	0	0	0	4500
100% LOF + 75% urea	P7	225	0	0	0	6000
100% LOF + 50% urea	P8	150	0	0	0	6000

2.3 Agronomic Practices

The land preparation field was cleared and plowed with a tractor and leveled manually with a hoe. The field was laid out according to the experimental design. Planting was carried out individually, with spacing of 70 x 20 cm (1 seed/hole). The depth of the hole was 3 cm. The hole was then filled with loose soil, ensuring it was evenly distributed to promote consistent germination rates and avoid any disparities in growth. The maize variety used was Provit A1.

Urea fertilizer was applied twice, namely at the first fertilization when the plant was 10 days after planting (DAP) and the second fertilization when the plant was 18 DAP. Meanwhile, SP-36, ZA, and KCl fertilization were given at the time of the first fertilization. Urea, SP-36, ZA, and KCl fertilizers were applied by adding 3-5 cm to the side of the planting hole. LOF application is carried out every 7 days as much as 8 times (2 months) by pouring and spraying all parts of the plant. Hand-weeding was performed at 3-week intervals, starting from 3 WAS. The weeded weeds were allowed to decompose in the field.

2.4 Data Collection

2.4.1 Soil Sampling and Analysis

At a depth of 30 cm for each treatment, core samplers were used to accumulate soil samples. The soil samples were analyzed to determine pH and the contents of organic C and the minerals N, P, and K. The soil samples were extracted with 1 M KCl, followed by steam distillation extraction to determine the mineral N content [21]. Extracting 0.5 M sodium bicarbonate ($NaHCO_3$; pH = 8.5; 1:20: soil/extractant) was used to determine the amount of P in the soil samples [22]. The concentration of P in the extract can be measured colorimetrically [23]. The existing K in the soil samples was extracted with 1 N ammonium acetate (NH_4OAc, pH = 7.0) [30].

2.4.2 Phenological and Growth Parameters of Maize

The time to tasseling was determined by counting the number of days from sowing until 80% of the plants in the net plot area developed tassels.

The number of days to silking was determined by counting the days from sowing until 80% of the plants in the net plot area developed silks.

Plant height (cm) was measured using a measuring tape; the height of five tagged plants selected randomly in each net plot was measured from the ground level to the last flag leaf at 35, 50, and 65 DAP, and their means were determined.

The number of leaves per plant was recorded from five randomly selected plants that were tagged; the plant samples in each net plot were counted at 35, 50, and 65 DAP, and their mean was determined.

Cob length was calculated by measuring the mean length of five samples from each plant using a ruler.

The mean cob diameter of five samples from each plant was determined using vernier calipers.

The cob weight from each plot was determined using a scale.

The cob weight without cornhusk from each plot was determined using the scale.

The number of rows per cob was determined by sampling five randomly selected and tagged plants.

The number of seeds per row was determined by sampling five randomly selected and tagged plants.

Hundred kernel weight (g) was determined by counting 100 seeds from a bulk of shelled grains from a net plot and weighing them using a sensitive balance. The weight was then adjusted to a moisture level of 12.5%.

Grain yield (kg ha^{-1}): The central rows of each plot were harvested, sun-dried, threshed, cleaned, and weighed using a sensitive balance, and the yield was adjusted to 12.5% moisture content before estimating the hectare base yield.

2.4.3 Data Statistical Analysis

Data collected on various growth, yield, and yield components were subjected to analysis of variance (ANOVA) using the Statistical Analysis System software (SAS, Version 9.1), and mean separation was performed using the least significant difference (LSD) test at 5% level of significance when the analysis of variance indicated the presence of significant differences.

2.4.4 Economic Analysis

The economic effectiveness test of fertilizers is used to determine whether the fertilizers used have good economic value. If the value produced is more than one, the tested fertilizer has an excellent economic value [24].

Economic effectiveness of fertilizers = P/C

P - price of grain (Rp. kg -1)

Q - dry grain yield (tons ha-1)

C - expenses including the purchase of fertilizer (Rp. ha-1)

3 Results

3.1 Physical and Chemical Properties of Soil at the Experimental Site

Tab. 2 Soil properties before fertilization (The authors)

Parameters	Value
Texture	
Sand (%)	44
Silk (%)	35
Clay (%)	21
Chemical properties	
pH	5.04
Organic matter (%)	2.69
Total N (g kg^{i1})	0.15
Available P (mg kg^{i1})	16
CEC (cmolc kg^{i1})	17.26

3.2 Number of Days to Tasseling

The application of LOF in all doses, whether combined with single fertilizer urea ha^{-1} or without urea, had a significant effect on the number of days to tasseling. The test results revealed that the shortest time to tasseling was 83.65 days, while the longest was 115.23 days. These results were observed with 6000 ml ha^{-1} of LOF combined with 225 kg ha^{-1} of urea fertilizer (P7) and without fertilizer (control) (P0) (Tab. 3).

Tab. 3 Mean number of days to tasseling and number of days to silking of maize (*Zea mays*) influenced by LOF (The authors)

Treatment	Number of days to tasseling	Number of days to silking
P0	115.23^{a}	123.17^{a}
P1	88.12^{bc}	115.21^{b}
P2	96.52^{bc}	111.29^{b}
P3	100.12^{bc}	113.56^{b}
P4	101.15^{bc}	111.10^{b}
P5	105.10^{bc}	113.05^{b}
P6	88.16^{bc}	113.41^{b}
P7	83.65^{c}	110.65^{b}
P8	98.82^{bc}	112.24^{b}

Note: The means in the column within a parameter followed by the same letter(s) are not significantly different at a 5% level of significance.

3.3 Number of Days to Silking

The application of LOF in all doses, whether combined with single fertilizer urea ha^{-1} or without urea, had a significant effect on the number of days to silking in this experiment. Accordingly, a higher number of days to silking (123.17) was associated with the application of 6000 ml ha^{-1} of LOF combined with 225 kg ha^{-1} of urea fertilizer (P7), while a lower number of days to silking (110.05) was noted in the control group (P0) without fertilizer (Tab. 3).

3.4 Plant Height

The mean plant height of maize influenced by LOF is presented in Tab. 4. The average growth stages indicate that the combination of 6000 ml ha^{-1} of LOF and 225 kg ha^{-1} of urea fertilizer (P7) resulted in the tallest plant measuring 76 cm at 35 DAP, while the lowest plant height was observed with 4500 ml ha^{-1} (P2). At 50 and 65 DAP, the tallest plant was obtained with 6000 ml ha^{-1} of LOF combined with 150 kg ha^{-1} of urea fertilizer and 6000 ml ha^{-1} of LOF combined with 300 kg ha^{-1} of urea fertilizer (P6) with 123.5 and 169.1 cm, respectively.

Tab. 4 Mean plant height of maize (*Zea mays*) influenced by LOF (The authors)

Treatment	Plant height (cm)		
	35 DAP	50 DAP	65 DAP
P0	65.9^{ab}	79.7^{a}	124.5^{a}
P1	71.7^{b}	99.4^{ab}	149.6^{ab}
P2	52.6^{a}	81.5^{a}	149.9^{ab}
P3	59.6^{a}	87.3^{a}	166.7^{b}
P4	57.7^{a}	92.9^{ab}	154.5^{b}

Continuation of Tab. 4

P5	75.3 b	109.5 b	169.1 b
P6	75.8 b	117.0 b	168.8 b
P7	76.0 b	122.3 c	166.3 b
P8	74.1 b	123.5 c	166.1 b

Note: The means in the column within a parameter followed by the same letter(s) are not significantly different at a 5% level of significance.

3.5 Number of Leaves per Plant

The mean number of leaves per plant of maize influenced by LOF is presented in Tab. 5. The mean growth stages show that LOF 4500 ml ha^{-1} combined with urea fertilizer 300 kg ha^{-1} resulted in the highest number of leaves at 35 DAP with 7.7 leaves per plant. At 50 DAP, the LOF 6000 ml ha^{-1} combined with 225 kg ha^{-1} of urea fertilizer yielded the highest number of leaves (9.6) per plant, and at 65 DAP, the LOF 6000 ml ha^{-1} combined with 150 kg ha^{-1} of urea fertilizer provided the highest number of leaves (9.8) per plant.

Tab. 5 Mean number of leaves per plant of maize (*Zea mays*) influenced by LOF (The authors)

Treatment	Number of leaves		
	35 DAP	50 DAP	65 DAP
P0	5.9 a	7.0 ns	7.0 a
P1	6.9 ab	8.5	7.5 a
P2	5.8 a	7.5	7.8 a
P3	6.0 a	7.8	8.0 ab
P4	5.7 a	8.1	8.3 ab
P5	7.1ab	8.3	8.5 ab
P6	7.7 b	8.7	8.7 ab
P7	7.3 ab	9.6	9.5 b
P8	7.3 ab	9.5	9.8 b

Note: The means in the column within a parameter followed by the same letter(s) are not significantly different at a 5% level of significance.

3.6 Cob Length

The mean cob length of maize influenced by LOF is presented in Tab. 6. LOF 6000 ml ha^{-1} combined with urea fertilizer 225 kg ha^{-1} resulted in the highest cob length of 24.24 cm. In contrast, the control group, which did not receive fertilizer, had the lowest cob length of 20.33 cm.

Tab. 6 Mean cob length, diameter, and weight of maize (*Zea mays*) influenced by LOF (The authors)

Treatment	Cob length (cm)	Cob diameter (mm)	Cob weight (kg)
P0	20.33 a	17.90 a	5.83 a
P1	23.09 bc	19.95	13.17 b
P2	21.19 b	18.76	11.60 b
P3	22.48 b	20.14	13.03 b
P4	23.33 bc	19.86	13.20 b
P5	23.19 bc	20.43	14.00 b
P6	22.62 b	20.19	14.47 b
P7	24.24 c	21.19	15.97 b
P8	23.67 bc	20.81	14.73 b

Note: The means in the column within a parameter followed by the same letter(s) are not significantly different at a 5% level of significance.

3.7 Cob Diameter

The mean cob diameter of maize influenced by LOF is presented in Tab. 6. LOF 6000 ml ha^{-1} combined with urea fertilizer 225 kg ha^{-1} resulted in the highest cob diameter of 21.19 mm. In contrast, the control group, which did not receive fertilizer, had the lowest cob diameter of 17.90 mm.

3.8 Cob Weight

The mean cob weight of maize influenced by LOF is presented in Tab. 6. LOF 6000 ml ha^{-1} combined with urea fertilizer 225 kg ha^{-1} resulted in the highest cob weight of 15.97 kg; the control group, which did not receive fertilizer, had a cob weight of 5.83 kg.

3.9 Cob Weight without Cornhusk

The highest cob weight without cornhusk (14.77 kg) was recorded with LOF 6000 ml ha^{-1} combined with urea fertilizer 225 kg ha^{-1}, and the lowest (4.30 kg) was recorded without fertilizer (Tab. 7).

Tab. 7 Mean cob weight without cornhusk, number of rows per cob, and number of seeds per row of maize (*Zea mays*) influenced by LOF (The authors)

Treatment	Cob weight without cornhusk (kg)	Number of rows per cob	Number of seeds per row
P0	4.30 a	11.76 a	231.57 a
P1	11.93 b	13.14 b	382.99 b
P2	10.77 b	12.33 b	368.48 b
P3	11.53 b	12.62 b	370.67 b
P4	11.47 b	12.81 b	383.19 b
P5	12.80 b	12.95 b	440.24 b
P6	13.27 b	13.48 bc	412.28 b
P7	14.77 b	14.24 c	479.10 b
P8	13.53 b	13.81 bc	400.28 b

Note: The means in the column within a parameter followed by the same letter(s) are not significantly different at a 5% level of significance.

3.10 Number of Rows per Cob

The highest mean number of rows per cob (14.24) was recorded with LOF 6000 ml ha^{-1} combined with urea fertilizer 225 kg ha^{-1}. The lowest mean number of rows per cob (11.76) was recorded without fertilizer (Tab. 7).

3.11 Number of Seeds per Row

The highest mean number of seeds per row (479.10) was recorded with LOF 6000 ml ha^{-1} combined with urea fertilizer 225 kg ha^{-1}. The lowest mean number of seeds per row (231.57) was recorded without fertilizer (Tab. 7).

3.12 Hundred Kernel Weight (g) and Grain Yield (kg ha^{-1})

In terms of hundred kernel weight, treatment with LOF 6000 ml ha^{-1} combined with urea fertilizer 225 kg ha^{-1} gave the highest yield (30.5) compared to other treatments. The lowest results were obtained without fertilization (24.4 g). Likewise, regarding plant yields, the highest grain yield (6.32 kg ha^{-1}) was obtained with LOF 6000 ml ha^{-1} combined with urea fertilizer 225 kg ha^{-1}, and the lowest (3,92 kg ha^{-1}) was obtained without fertilization (Tab. 8).

Tab. 8 Mean hundred kernel weight and grain yield of maize (*Zea mays*) influenced by LOF (The authors)

Treatment	Hundred kernel weight (g)	Grain yield (kg ha^{-1})
P0	24.4 ^{a}	3.922,2 ^{a}
P1	30.0 ^{b}	4.388,9 ^{bc}
P2	26.5 ^{b}	3.870,1 ^{b}
P3	29.3 ^{b}	3.977,8 ^{b}
P4	29.2 ^{b}	4.333,3 ^{bc}
P5	29.7 ^{b}	4.897,8 ^{bc}
P6	30.0 ^{b}	4.822,2 ^{bc}
P7	30.5 ^{b}	6.322,3 ^{c}
P8	30.3 ^{b}	4.744,4 ^{bc}

Note: The means in the column within a parameter followed by the same letter(s) are not significantly different at a 5% level of significance.

3.13 Economic Analysis

The economic analysis is performed by calculating the ratio of income to expenses, which includes the cost of fertilizer. After analyzing the impact of economic challenges, it was determined that LOF 6000 ml ha^{-1} combined with 225 kg ha^{-1} of urea yielded the highest effectiveness test value, although other treatments were also feasible for corn farming because all treatments had a fertilization effectiveness test value > 1. The same results were obtained from [25]. The MBCR of all plots compared with controls ranged from 2.15 to 2.78, which is higher than the allowable limit (2.00).

4 Discussion

The soil texture at the research site is dusty clay. The high sand content of the soil can be attributed to the high quartz content of the material [26]. The acidic nature of the soil at that location can be seen from the marked leaching of exchangeable bases due to high rainfall associated with the environment and organic matter [27]. Low organic matter status caused by organic matter decomposition due to high solar radiation and humidity, which supports optimal microbial activity in the soil, can also be associated with straw burning, which tends to deplete the organic matter accumulated in the soil [28]. Low levels of total nitrogen can be caused by high temperatures. It could also be associated with the leaching of nitrates by heavy rains prevalent in the environment [29]. In general, this agrees with the findings of [30], who reported that historical land use and cultural practices affect soil conditions and crop productivity.

The use of LOF 6000 ml ha^{-1} combined with urea 225 kg ha^{-1} can significantly shorten the number of days to tasseling and silking. Chimdessa [31] reported that nitrogen application resulted in an increase in growth rates during both the tasseling and silking stages of the plant. The higher the nitrogen content applied, the faster tasseling and silking due to the rapid growth. Bakala [32] and Microsoft Corporation [33] also showed that tasseling and silking of maize were significantly affected by the application of liquid organic fertilizer. Galal et al. [34] said that liquid organic fertilizers act as substrates for microorganisms that help in the biological stimulation of growth, increase vitality, and plant vigor, and decrease crop yields for the right period. Fisinin et al. [35] stated that liquid fertilizers promote healthy plant growth and development. This is also consistent with the findings of [36] and [37], who reported positive responses of some plants to the application of biofertilizers.

Plant growth can be used as an indicator to learn more about plant characteristics concerning yield. The application of LOF in all doses, whether combined with single fertilizer urea ha^{-1} or without urea, had a significant effect on increasing maize plant height at the age of 35, 50, and 65 DAP.

During vegetative growth, most nutrients are used for cell growth compared with other plant functions such as the reproductive phase, which includes grain filling. Moreover, in the later stages of plant development, the rate of photosynthesis decreases because of a decrease in chlorophyll activity, which signals the plant to use most of its energy in grain development for reproduction and survival [38]. For maximum height growth, LOF combined with Urea fertilizer is the best, although it is not the best attribute for maize survival because maize is susceptible to wind-induced fall [39].

Application of LOF with urea fertilizer can increase the growth and yield of maize. As reported by [40–42], the use of LOF can increase the yield of *Brassica juncea*. Likewise, the results reported by [43] showed that yields of COBLN 9003 sugarcane cultivars were significantly higher with LOF than without it. This is influenced by macro- and microelements in fertilizers to increase crop yields.

5 Conclusion

Based on the research results, it can be concluded that LOF 6000 ml ha^{-1} combined with urea fertilizer 225 kg ha^{-1} produces the best results in terms of tasseling and silking time. This combination has been shown to significantly enhance crop yield and boost the income of corn farmers in agricultural areas with similar ecological conditions.

Acknowledgments

The authors sincerely thank PT Maharaja Multi Sinergi for funding this research, which aimed to test the effectiveness of fertilizers. Additionally, we would like to extend our appreciation to the farmers who prepared land sites for trials.

References

参 考 文 献

[1] DIRECTORATE OF CEREAL CULTIVATION. Teknologi Budidaya Jagung. Direktorat Jenderal Tanaman Pangan, 2013.

[2] ZUBACHTIRODIN, SUGIHARTO B, MULYONO, et al. Teknologi Budidaya Jagung. Jakarta: Direktorat Jenderal Tanaman Pangan, 2011.

[3] SIMPSON K. Fertilizers and manures. London: Longman, 1986.

[4] CHEN J H. The combined use of chemical and organic fertilizers and/or biofertilizer for crop growth and soil fertility. In: Proceedings of the International Workshop on Sustained Management of the Soil-Rhizosphere System for Efficient Crop Production and Fertilizer Use, 16–20 October 2006; Bangkok: Land Development Department, 2006: 1–11.

[5] AKSOY U. Ecological farming. II. In: Proceedings of the Ecological Farming Symposium, 14–16 December 2001; Antalya, 2001.

[6] CHOWDHURY R. Effects of chemical fertilizers on the surrounding environment and the alternative to the chemical fertilizers. IES-ENVIS Newsl, 2004, 7, 4–5.

[7] BULLUCK III L R, BROSIUS M, EVANYLO G K, et al. Organic and synthetic fertility amendments influence soil microbial, physical and chemical properties on organic and conventional farms. Applied Soil Ecology, 2002, 19(2), 147–160.

[8] OYEWOLE C I, OPALUWA H, OMALE R. Response of tomato (Lycopersicon esculentum): growth and yield, to rates of mineral and poultry manure application in the Guinea savanna agro-ecological zone in Nigeria. Journal of Biology, Agriculture and Healthcare, 2012, 2(2), 44–56.

[9] KEMENTERIAN PERTANIAN. *Peraturan Menteri Pertanian Nomor 70/Peraturan Menteri Pertanian Republik Indonesia/SR.140/10/2011 Tentang Pupuk Organik, Pupuk Hayati dan Pembenah Tanah*, 2011.

[10] SREENIVASA M N, NAGARAJ M N, BHAT S N. Beejamruth: a source for beneficial bacteria. Karnataka Journal of Agricultural Sciences, 2010, 17(3), 72–77.

[11] BULLUCK L R, RISTAINO J B. Effect of synthetic and organic soil fertility amendments on southern blight, soil microbial communities, and yield of processing tomatoes. Phytopathology, 2002, 92, 181–189.

[12] GUNGULA D T, TOGUN A O, KLING J G. The influence of N rates on maize leaf number and senescence in Nigeria. World Journal of Agricultural Sciences, 2005, 1(1), 1–5.

[13] TONFACK L B, BERNADAC A, YOUMBI E, et al. Impact of organic and inorganic fertilizers on tomato vigor, yield and fruit composition under tropical andosol soil conditions. Fruits, 2009, 64(3), 167–177.

[14] BEECHER C W. Cancer preventive properties of varieties of Brassica oleracea: a review. The American Journal of Clinical Nutrition, 1994, 59(5), 1166S–1170S.

[15] FOOD AND AGRICULTURE ORGANIZATION. Production yearbook. Rome: Food and Agriculture Organization of the United Nations, 2012.

[16] BAHADUR A, SINGH J, SINGH K P. Response of cabbage to organic manures and biofertilizers. Indian Journal of Horticulture, 2004, 61(3), 278–279.

[17] MIAH M U M, JAHIRUDDIN M, ISLAM M F, et al. Fertilizer recommendation guide. Dhaka: Bangladesh Agricultural Research Council, 2012.

[18] DAMBARA A K, GREEN PLANET INTERNATIONAL. Evaluation of power plant TM liquid fertilizer for potato production in Plateau State, Nigeria. Jos: National Root Crop Research Institute,

2003.
[19] HAYTOVA D. A review of foliar fertilization of some vegetables crops. Annual Research & Review in Biology, 2013, 3(4), 455–465.
[20] AMANULLAH, KAKAR K M, KHAN A, et al. Growth and yield response of maize (Zea mays L.) to foliar NPK-fertilizers under moisture stress condition. Soil & Environment, 2014, 33(2), 116–123.
[21] CURTIN D, WRIGHT C E, BEARE M H, et al. Hot water-extractable nitrogen as an indicator of soil nitrogen availability. Soil Science Society of America Journal, 2006, 70(5), 1512–1521.
[22] SANTI C, CERTINI G, D'ACQUI L P. Direct determination of organic carbon by dry combustion in soils with carbonates. Communications in Soil Science and Plant Analysis, 2006, 37(1-2), 155–162.
[23] HANSEN B. Determination of nitrogen as elementary N, an alternative to Kjeldahl. Acta Agriculturae Scandinavica, 1989, 39(2), 113–118.
[24] ISLAM M N, SAHA P K, ISLAM S. Determination of optimum and economic doses of fertilizers for rice production in saline and charlands ecosystem. Bangladesh Journal of Agricultural Research, 2017, 42(3), 521–529.
[25] BRUST G, EGEL D S, MAYNARD E T. Organic vegetable production. Purdue University Cooperative Extension Service, 2003, Bulletin 316.
[26] BRADY C, WEILS R R. Nature and properties of soil. 12th ed. New Delhi: Prentice Hall, 1999.
[27] ESU I E. Pedological characterization of soils of alluvial complex of Nigeria. In: Ibadan. Pedological handbook, 2001: 171–190.
[28] LANDOR J R. Booker tropical soil manual: a handbook for soil survey and agricultural land evaluation in the tropics and subtropics. London: Routledge, 1991.
[29] NNAJI G U, ASADU C L A, MBAGWU J S C. Evaluation of physico-chemical properties of soils under selected agricultural land utilization types. Agro-Science, 2002, 3(1), 27–33.
[30] RAI K D. The response of maize following sorghum to fertilisers and foliar spray of zinc sulphate at Tozi, Sudan. Indian Journal of Agronomy, 1961, 5(1), 176–187.
[31] CHIMDESSA D. Blended fertilizers effects on maize yield and yield components of Western Oromia, Ethiopia. Agriculture, Forestry and Fisheries, 2016, 9(1), 151–162.
[32] BAKALA A. Soil characterization and response of maize (Zea mays L.) to application of blended fertilizer types and rates in Asossa district, Western Ethiopia. Master’s thesis, Haramaya University, 2018.
[33] MICROSOFT CORPORATION. Organic farming: encarta encyclopedia, 2003, 99, 1–4.
[34] GALAL Y, EL-GHANDOUR I, ALY S, et al. Non-isotopic method for the quantification of biological nitrogen fixation and wheat production under field conditions. Biology and Fertility of Soils, 2000, 32, 47–51.
[35] FISININ V I, ARKHIPCHENKO I A, POPOVA E V, et al. Microbe fertilizers with polyfunctional properties - production with the use of fowl manure. Russian Agricultural Sciences, 1999, 4, 20–25.
[36] HEDGE D M, DWIVEDI B A, BABU S N S. Bio-fertilizer for cereal production in India - a review. Indian Journal of Science, 1999, 69, 73–83.
[37] HENAO J, BAANANTE C A. Estimating rates of nutrient depletion in soils of agricultural lands of Africa. Muscle Shoals, AL: International Fertilizer Development Center, 1999, Volume 48.
[38] EFTHIMIADOU A, BILALIS D, KARKANIS A, et al. Combined organic/inorganic fertilization enhance soil quality and increased yield, photosynthesis and sustainability of sweet maize crop. Australian Journal of Crop Science, 2010, 4(9), 722–729.
[39] CHAUHAN D R, PARODA S, KATARIA O P, et al. Response of Indian mustard (Brassica juncea) to biofertilizers and nitrogen. Industrial Journal of Agronomy, 1995, 40(1), 86–90.
[40] MEHTA A C, MALAVIA D D, KANERIA B B, et al. Effect of phosphatic bio-fertilizers in conjunction with organic and inorganic fertilizers on growth and yield of groundnut (Arachis hypogaea). Indian Journal of Agronomy, 1995, 40(4), 709–710.
[41] SNEHAL JOSHI S J, ZENDE N A. Biofertilizers and organic manures in sugarcane spaced transplanting method (Var. Co 7527). In: Proceedings of the 60th Annual Convention of the Sugar Technologists’ Association of India, 19–21 September 1998; New Delhi: Sugar Technologists’ Association of India, 1998: 105–113.
[42] BURAGOHAIN S K. Efficacy of biofertilizers with varying levels of N on growth, yield and quality of sugarcane (Saccharum officinarum L.). Indian Sugar, 2000, 49(10), 847–850.
[43] ZODAPE S T. Seaweeds as bio-fertilizer. Journal of Scientific Industrial Research, 2001, 60(56), 378–382.

[1] 谷物种植局。布迪达亚贾贡技术。总监詹德拉尔·塔纳曼·潘甘，2013年。

[2] ZUBACHTIRODIN、SUGIHARTO B、MULYONO 等人。布迪达亚贾贡技术。雅加达：总监詹德拉尔·塔纳曼·潘甘，2011年。

[3] SIMPSON K. 肥料和粪肥。伦敦：朗文，1986年。

[4] 陈建华. 化学肥料与有机肥料和/或生物肥料的结合使用促进作物生长和土壤肥力。见：土壤-根际系统可持续管理促进作物生产和化肥高效利用国际研讨会论文集，2006年10月16-20日；曼谷：土地开发部，2006年：1-11。

[5] AKSOY U. 生态农业。二. 见：生态农业研讨会论文集，2001年12月14-16日；安塔利亚，2001年。

[6] CHOWDHURY R. 化肥对周围环境的影响及化肥的替代品。IES-英威斯新闻l，2004年，7，4-5。

[7] BULLUCK III L R、BROSIUS M、EVANYLO G K 等人。有机和合成肥力改良剂会影响有机农场和传统农场的土壤微生物、物理和化学特性。应用土壤生态学，2002，19（2），147-160。

[8] OYEWOLE C I，OPALUWA H，OMALE R。番茄（番茄）的响应：生长和产量，对尼日利亚几内亚稀树草原农业生态区矿物和家禽粪便施用率的影响。生物学、农业和医疗保健杂志，2012，2(2)，44–56。

[9]凯门特里亚佩塔尼安。关于有机肥料、生物肥料和土壤改良的第70号农业部长条例/印度尼西亚共和国农业部长条例/SR.140/10/2011，2011。

[10] SREENIVASA M N、NAGARAJ M N、BHAT S N. 比贾姆鲁斯：有益细菌的来源。卡纳塔克农业科学杂志，2010，17(3)，72–77。

[11] BULLUCK L R，RISTAINO J B. 合成和有机土壤肥力改良剂对白疫病、土壤微生物群落和加工番茄产量的影响。植物病理学，2002，92，181-189。

[12] GUNGULA D T，TOGUN A O，KLING J G。施氮量对尼日利亚玉米叶片数量和衰老的影响。世界农业科学杂志，2005年，1(1)，1-5。

[13] TONFACK LB，BERNADAC A，YOUMBI E 等人。有机和无机肥料对热带安多索土壤条件下番茄活力、产量和果实组成的影响。水果，2009，64(3)，167–177。

[14] BEECHER C W. 甘蓝品种的癌症预防特性：综述。美国临床营养学杂志，1994年，59(5)，1166S–1170S。

[15] 粮食及农业组织。生产年鉴. 罗马：联合国粮食及农业组织，2012年。

[16] BAHADUR A，SINGH J，SINGH K P。卷心菜对有机肥和生物肥料的反应。印度园艺杂志，2004年，61(3)，278–279。

[17] MIAH M U M、JAHIRUDDIN M、ISLAM M F 等。肥料推荐指南。达卡：孟加拉国农业研究委员会，2012年。

[18]丹巴拉·AK，绿色星球国际。尼日利亚高原州电厂TM液肥马铃薯生产评价。乔斯：国家块根作物研究所，2003年。

[19] HAYTOVA D. 一些蔬菜作物叶面施肥的综述。生物学年度研究与评论，2013，3(4)，455–465。

[20] AMANULLAH、KAKAR K M、KHAN A 等人。水分胁迫条件下玉米(玉米L.)对叶面氮磷钾肥料的生长和产量响应。土壤与环境，2014，33（2），116-123。

[21] CURTIN D、WRIGHT C E、BEARE M H 等人。热水可提取氮作为土壤氮有效性的指标。美国土壤科学学会杂志，2006，70(5)，1512–1521。

[22] SANTI C，CERTINI G，D'ACQUI L P。通过干燃烧直接测定碳酸盐土壤中的有机碳。土壤科学与植物分析通讯，2006，37(1-2)，155–162。

[23] HANSEN B.

氮元素氮的测定，凯氏定氮法的替代方案。斯堪的纳维亚农业学报，1989，39(2)，113–118。
[24] ISLAM M N，SAHA P K，ISLAM S。确定盐碱地和炭地生态系统中水稻生产肥料的最佳和经济剂量。孟加拉国农业研究杂志，2017 年，42(3)，521–529。
[25] BRUST G，EGEL D S，MAYNARD E T. 有机蔬菜生产。普渡大学合作推广服务，2003年，公告316。
[26] BRADY C，WEILS R R。土壤的性质和特性。第12版。新德里：普伦蒂斯·霍尔，1999。
[27] ESU I E. 尼日利亚冲积复合体土壤的土壤学特征。于：伊巴丹。土壤学手册，2001：171-190。
[28] LANDOR J R. 布克热带土壤手册：热带和亚热带土壤调查和农业用地评估手册。伦敦：劳特利奇，1991年。
[29] NNAJI GU，ASADU C L A，MBAGWU J S C。选定农业土地利用类型下土壤理化性质的评估。农业科学，2002，3(1)，27–33。
[30] RAI K D. 苏丹托兹高粱后玉米对肥料和叶面喷洒硫酸锌的反应。印度农学杂志，1961年，5(1)，176–187。
[31] CHIMDESSA D. 混合肥料对埃塞俄比亚西奥罗米亚州玉米产量和产量构成的影响。农林渔业，2016，9（1），151-162。
[32] BAKALA A. 埃塞俄比亚西部阿索萨地区玉米（玉米L.）的土壤特征和对混合肥料类型和施肥量的响应。硕士论文，原山大学，2018年。
[33] 微软公司。有机农业：百科全书，2003，99，1-4。
[34] GALAL Y，EL-GHANDOUR I，ALY S，等。田间条件下生物固氮和小麦产量定量的非同位素方法。土壤生物学和肥力，2000，32，47–51。
[35] FISININ VI、ARKHIPCHENKO I A、POPOVA E V 等。具有多功能特性的微生物肥料-使用鸡粪生产。俄罗斯农业科学，1999年，4，20-25。
[36] HEDGE DM、DWIVEDI B A、BABU S N S。印度谷物生产的生物肥料-评论。印度科学杂志，1999，69，73-83。
[37] HENAO J，BAANANTE CA。估算非洲农田土壤养分消耗率。阿拉巴马州马斯尔肖尔斯：国际肥料开发中心，1999年，第48卷。
[38] EFTHIMIADOU A、BILALIS D、KARKANIS A 等人。有机/无机复合施肥可提高土壤质量，提高甜玉米作物的产量、光合作用和可持续性。澳大利亚作物科学杂志，2010，4(9)，722–729。
[39] CHAUHAN DR、PARODA S、KATARIA O P 等人。印度芥菜（芥菜）对生物肥料和氮的反应。农学工业杂志，1995，40（1），86-90。
[40] MEHTA A C、MALAVIA D D、KANERIA B B 等。磷酸生物肥料与有机无机肥料配施对花生生长和产量的影响。印度农学杂志，1995，40(4)，709–710。
[41] SNEHAL JOSHI S J，ZENDE N A。甘蔗间隔移植方法中的生物肥料和有机肥（变种。钴7527）。载于：1998年9月19-21日印度糖技术专家协会第60届年会会议记录；新德里：印度糖技术专家协会，1998年：105-113。
[42] BURAGOHAIN SK。不同氮水平的生物肥料对甘蔗（甘蔗L.）生长、产量和质量的功效。印度糖业，2000，49(10)，847–850。
[43] ZODAPE ST. 海藻作为生物肥料。科学工业研究杂志，2001，60(56)，378–382。