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Combination of Liquid Organic and Chemical Fertilizer on Corn and Soybean Using Intercropping in Ultisols

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***Abstract*–Soybean intercropping has been done a lot. Growth rate, dry matter yield, and N, P, and K nutrient uptake are determined by soil fertility conditions as a plant growth medium. One of the ways to support the growth and yield of maize-soybean plants grown in intercropping is to use liquid organic fertilizers made from landfill leachate combined with chemical fertilizers. This study aimed to determine the ability of liquid organic fertilizer to support the growth and yield of corn-soybean plants planted in intercropping in the field in combination with chemical fertilizers. The materials to be used in this study were Ultisol soil, liquid organic fertilizer, Urea (N), T.S.P. (P), KCl (K), dolomite, sweet corn seed var. Nusa 1 and soybean var. Anjosmoro. This study used an experimental method with a randomized block design. The treatments were A = 4% LOF + 0 NPK, B = 4% LOF + 1/5 NPK, C = 4% LOF + 2/5 NPK, D = 4% LOF + 3/5 NPK, E = 4% LOF + 4/5 NPK, and F = 4% LOF + 1 NPK. The results showed that the giving of LOF combined with N.P.K. affected plant height, leaf area, plant stover weight, soybean cob/seed weight, absorption of nutrients N, P, K, metal content of Pb, Cd, Cu and Cr and N.K.L. in corn and soybean crops. The best 4% LOF + 2/5 NPK treatment for soybeans and the best 4% LOF + 3/5 NPK treatment for corn plants.**

***Keywords*— Competitiveness; intercropping; corn; soybean; organic fertiliser; combination.**

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I. INTRODUCTION

Ultisol is one of the widest soils in Indonesia. This land has some characteristics, such as low fertility inhibiting root growth and translocation of nutrients to the top of the plant, especially elements N, P, K, Ca, and Mg [1]. Another characteristic is high soil acidity. In [2], plants become poisoned by Al and Mn due to soil acidity. Reduced availability of calcium, magnesium, phosphorus, and molybdenum are elements in the soil solution. So, plant growth is stunted, and plant production decreases due to low soil organic matter content [3].

Increasing the productivity of ultisols is an important thing to do so that plants can grow well. Many ways have been done to improve this condition. Some of them are the provision of biochar, lime, and ash [4], fertilization [5], application of organic fertilizer [6], microbial fertilizers [7], application of organic fertilizers, and chemical/inorganic fertilizers [8].

The high amount of soil amendments needed, their limited availability, and the high cost mean that the above methods are still not optimally applied in the field. For this reason, it is necessary to research alternative fertilizer-based materials that are more easily available, in large quantities and at affordable prices, so their use can be applied on a larger scale, such as using landfill leachate as liquid organic fertilizer (LOF).

Based on the literature study results, there has not been much research on using landfill leachate as a liquid fertilizer ingredient. According to research by [9], using landfill leachate as liquid fertilizer with humic improvement can increase plant height and fresh weight of green bean plants by 54.7% and 121.4%. [10], recovery of macronutrients N and P in landfill leachate.

Leachate is liquid from landfill solid waste which is affected by humidity at the landfill site and is caused by chemical and physical reactions [11]. According to [12], leachate is a highly dissolved organic compound, inorganic compounds, suspended solids, and heavy metals. The high content of heavy metals in leachate can be damaging and dangerous if given directly to plants. According to [13], heavy metals cause damage to chlorophyll pigments, inhibit nutrient absorption, and damage plant physiological processes. So before leachate is used as liquid fertilizer, the metal content in the leachate needs to be reduced to a safe level for plants; one way is using biochar as an adsorbent.

Biochar is a solid material that is processed by pyrolysis [14]. Using biochar in agriculture improves soil, especially in preventing the solubility of heavy metals. According to [15], applying biochar in the soil can suppress the phytotoxicity and bioavailability of heavy metals. While in [16] and [17], applying 5% dry-weight of biochar to the soil can reduce the availability of toxic heavy metals.

It has been found in using biochar to reduce heavy metals in leachate. One of the studies conducted by [18], with the results using biochar with a size of 140 mesh with a contact time of 3 hours, can reduce levels of Cd by 82.2%. Pb 64.1% and added by [19], using 40 ml of landfill leachate LOF on soybeans, is the best liquid fertilizer concentration for plant growth and yields in greenhouses.

This study aims to determine the effect of a combination of LOF from leachate landfill and N.P.K. fertilizers on corn and soybean intercropping growth and yield in the Ultisols. The use of LOF is one way to increase the efficiency of nutrient absorption. Sufficient water content has a significant relationship with the level of nutrient availability. According to [20], applying liquid organic fertilizer derived from waste can reduce the use of urea fertilizer with the same yield and nitrogen absorption. In [21], it is said that using LOF can increase soil nutrient content and improve the diversity of soil microorganisms.

Intercropping cultivation is planting two or more plants simultaneously and on the same land [22]. The research results by [23] suggested that maize and beans grown in intercropping showed higher yield stability and better system efficiency in all environments than monocultures. [24] suggested that the intercropping system causes interactions in the plants' root area, resulting in increased uptake of nitrogen and phosphorus nutrients. Corn cultivation is widely practiced in various places in the world. Humans use corn crops for carbohydrates, animal feed, and industrial raw materials. [25]. Corn is an important crop after wheat and rice. In the intercropping system, corn is widely used as the main crop. [26].

Soybean is a legume from the leguminous family. Soybean is rich in protein content, and planting soybeans can increase soil fertility [27]. One of the advantages of soybean plants is the ability to fix nitrogen from the air to the soil. This condition helps in reducing the use of chemical fertilizers. Legume plants can fix nitrogen from the air throughout the growing season by 50 - 200 kg N/ha/year. [28].

II. Materials and Methods

The materials to be used in this study were Ultisol soil, liquid organic fertilizer (LOF), Urea (N) fertilizer, T.S.P. (P), KCl (K), dolomite, sweet corn seed var. Nusa 1 and soybean var. Anjosmoro. The tools used include hoes, buckets, analytical scales, tape measure, I.C.P. (Inductively Coupled Plasma), stationery, and labor tools.

In addition, the design used was a randomized block design with 1 factor with six treatments and four groups, so 24 experimental plots were obtained. The treatment is as follows: A = 4% LOF + 0 N.P.K., B = 4% LOF + 1/5 NPK, C = 4% LOF + 2/5 NPK, D = 4% LOF + 3/5 NPK, E = 4 % LOF + 4/5 NPK, and F = 4% LOF + 1 N.P.K. (The use of LOF concentrations and their manufacture is based on the research results by [19]. The use of LOF is expected to reduce the use of N.P.K. fertilizers.

The land used is cleared of plants and plant residue. The soil is tilled with a hoe to a depth of 20 cm until it is suitable for growing corn and soybeans. Then, the land is plotted with the size (2 x 3) m of 24 plots. Each plot was given dolomite lime 1.1 tons/ha or 660 g/plot equivalent to 2 x Al-dd with Al-dd 0.3 me/100 g. The soil is left for two weeks before planting. Fertiliser application of N, P, K is given partly at the beginning of planting and partly at the age of 45 H.S.T. The dose of fertilizer given to corn plants is 450 kg/ha of urea, 125 kg of T.S.P./ha, and 100 kg of KCl/ha. Soybean plants are given 100 kg of urea/ha, 75 kg of T.S.P./ha, and 100 kg of KCl/ha [29].

Then, two corn seeds were planted per hole with a spacing of 40 cm in rows and 75 cm between rows. Similarly, soybean plants planted as many as two seeds per planting hole. After one week, the selection is made, and only one plant that grows better is maintained. Corn plants are intercropped with soybean plants. Between 2 rows of corn plants, there is 1 row of soybean plants with a distance of 37.5 cm between rows, and the distance between soybean plants in the row is 20 cm. One subplot has four rows of corn plants and three rows of soybean plants.

Plant maintenance includes watering, weeding, and hilling. Watering is done two times a day. Weeding and hilling are carried out after the soybean plants are one month old and routinely carried out the following month. Hoarding ensures the plant roots remain entirely in the soil so optimal roots absorb nutrients.

Observations on soybean plants included plant height, leaf area index, biomass weight, seed weight, and yield per hectare. At the same time, observations for corn plants include plant height, leaf area index, biomass weight, and net cob weight. Plant tissue analysis includes the nutrient content of N, P, and K and the metal content of Cd^{2+}, Cr^{3+}, Cu^{2+}, and Pb^{2+} in plant seeds. Data obtained from observations of plant growth were analyzed based on the F test. If the analysis had a significant effect, proceed with the D.N.M.R.T. test at the 5% level.

The land equivalent ratio or LER can calculate land efficiency in intercropping planting corn and soybeans. Intercropping of corn and soybeans is more efficient if the land equivalent ratio (LER) > 1. The resulting increase in land production is calculated using the following formula [30]:

$$LER = \frac{Y_1}{M_1} + \frac{Y_2}{M_2} \quad (1)$$

Information:

Y_1 = Yield of plant type A planted in intercropping
Y_2 = Yield of plant type B planted in intercropping
M_1 = Yield of plant type A grown in monoculture
M_2 = Yield of plant type B grown in monoculture

III. Results and Discussion

A. Corn Plants

1) Plant Growth: Based on the analysis of variance, it was found that applying a combination of LOF and N.P.K. fertilizers to corn plants showed significantly different results for plant height and leaf area. At the same time, biomass weights were very significantly different.

TABLE I
COMBINATION OF LANDFILL LEACHATE LOF AND N.P.K. FERTILIZERS ON THE GROWTH OF CORN PLANTS IN THE FIELD

Treatment	Observation		
	height plant (cm)	leaf area (cm^2)	Biomass weight (g)
A (4% LOF + 0 NPK)	146.2 a	3312.19 a	163.65 a
B (4% LOF + 1/5 NPK)	158.84 ab	3645.55 a	199.14 ab
C (4% LOF + 2/5 NPK)	169.29 b	4179.15 a	236.80 bc
D (4% LOF + 3/5 NPK)	175.56 b	5239.17 b	263.31 c
E (4% LOF + 4/5 NPK)	167.00 b	4129.45 a	229.35 bc
F (4% LOF + 1 NPK)	158.35 ab	4106.48 a	224.59 bc
CD (%)	7.38	15.09	13.95

Note: Numbers followed by the same lowercase letter in the same column are not significantly different according to the 5% D.M.R.T. follow-up test

Table 1 shows that the results of observations on plant growth showed a significant difference. The best plant height was seen in the 4% LOF + 1/5 NPK treatment, which was not significantly different from other treatments, where there was an increase in plant height of 12.64 cm (8.6%) compared to treatment A. The best leaf area was in treatment D (4% LOF + 3/5 NPK), with an increase of 1926.98 cm^2 (58.2%) compared to treatment A. At the same time, the best biomass weight was in treatment C (4% P.O.C. + 2/5 NPK), with an increase of 73.15 g (44.7%) compared to treatment A. This is presumably due to the intercropping of corn and soybeans, causing nitrogen fixed by soybean plants to increase soil nitrogen content so that corn plants can utilize it. In [24], soybean is a plant that can fix nitrogen from the air to fulfill the nitrogen needs of corn plants. According to [31], intercropping corn and soybeans is beneficial because of corn plants' high nitrogen utilization efficiency. The provision of LOF applications combined with N.P.K. fertilizers can increase the availability of nutrients plants need to grow well. Combining organic and synthetic fertilizers can increase plant growth [32]. Combining 15 tonnes/ha of organic waste and synthetic fertilizers can increase shoot weight by 261%.

2) Corn Cob Weight: The analysis of variance showed that the combined application of LOF and N.P.K. fertilizers differed significantly for the weight of the ears/plant, the weight of the ears/plot, and the weight of the ears/hectare. Table 2 shows that the combination of LOF and N.P.K. fertilizers significantly affects the weight of corn cobs per plant, plot, and hectare. Treatment A (4% LOF + 0 N.P.K.) had the lowest cob weight, which differed from the other treatments. The best results for cob/plant weight per plot and hectare were shown in treatment D (4% LOF + 3/5 NPK) with successive increases of 60.12 g (65.9%), 1.2 kg (65.9%), 6%), and 2.01 tonnes (66.1%) compared to treatment A. The results of this plant can not be separated from the adequacy of nutrients, especially nitrogen. The level of nitrogen availability and uptake has the most dominant role in plant yields [33]. Nitrogen deficiency can inhibit energy formation, affecting plant growth and yield [34], [35]. The presence of microorganisms in LOF benefits plants because it can improve plant growth. In [36], *Azospirillum brasilense* inoculated into corn seeds could stimulate plant growth and increase nitrogen use efficiency. In [37], it is stated that the presence of bacteria plays an important role in the soil-root relationship, affecting production. Treatment D (4% LOF + 3/5 NPK) was the best treatment with the highest cob weight, which was different from other treatments. The combination of organic and synthetic N fertilizers reduced nitrogen loss due to leaching [38]. In [39], combining organic matter with N.P.K. fertilizer gave better results than other treatments.

TABLE II
COMBINATION OF LANDFILL LEACHATE OF LOF AND N.P.K. FERTILIZERS ON THE WEIGHT OF CORN COBS IN THE FIELD

Treatment	Cob weight		
	/plant (g)	/plot (kg)	/hectare (ton)
A (4% LOF + 0 NPK)	91.28 a	1.83 a	3.04 a
B (4% LOF + 1/5 NPK)	121.54 b	2.43 b	4.05 b
C (4% LOF + 2/5 NPK)	124.61 cb	2.49 cb	4.15 bc
D (4% LOF + 3/5 NPK)	151.41 e	3.03 e	5.05 e
E (4% LOF + 4/5 NPK)	130.05 d	2.60 d	4.33 d
F (4% LOF + 1 NPK)	127.70 cd	2.55 cd	4.26 cd
CD (%)	1.76	1.76	1.76

Note: Numbers followed by the same lowercase letter in the same column are not significantly different according to the 5% D.M.R.T. follow-up test paragraphs must be indented. All paragraphs must be justified, i.e., both left-justified and right-justified.

The corn and soybean intercropping system results in better plant growth. In [24], corn-soy intercropping system led to interactions between corn and soybeans in increasing soil nutrients and nitrogen and phosphorus uptake. N uptake increased by 2.4% compared to monoculture. According to [40], using nitrogen in corn-soybean intercropping increased efficiency by 105.1% compared to monoculture maize. In addition, applying *Azotobacter*, *Azospirillum*, *Bacillus*, and *Pseudomonas fluorescent* bacteria into landfill leachate LOF also helps increase nutrient availability and crop yields. According to [41], microorganisms *Azospirillum*, *Azotobacter*, *Bacillus* and *Pseudomonas* can increase nutrient availability and absorption, plant growth, and crop production. *Azospirillum* inoculant applied to the soil could increase soil fertility and maize production [42].

3) Elemental Absorption: Based on the analysis of variance, it was found that the combination of landfill leachate LOF and N.P.K. fertilizer had a very significant effect on the uptake of N, P, and K nutrients from corn plants. Table 3 shows that the combination of landfill leachate LOF and N.P.K. fertilizer on the nitrogen content in plant tissue treatment A (4% LOF + 0 N.P.K.) significantly differed. Treatment B (4% LOF + 1/5 NPK) was not significantly different from treatment F (4% LOF + 1 N.P.K.).

TABLE III
COMBINATION OF P.O.C. LEACHATE T.P.A. AND N.P.K. FERTILISER ON THE UPTAKE OF ELEMENTS N, P, AND K (%) IN MAISE PLANT TISSUE IN THE FIELD

Treatment	Elemental content (%)		
	N	P	K
A (4% LOF + 0 NPK)	0.63 a	0.20 a	0.43 a
B (4% LOF + 1/5 NPK)	1.61 b	0.22 b	0.46 ab
C (4% LOF + 2/5 NPK)	2.86 d	0.28 d	0.53 c
D (4% LOF + 3/5 NPK)	3.02 e	0.37 e	0.58 d
E (4% LOF + 4/5 NPK)	1.88 c	0.26 c	0.51 bc
F (4% LOF + 1 NPK)	1.63 b	0.28 d	0.52 c
CD (%)	1.86	5.40	5.68

Note: Numbers followed by the same lowercase letter in the same column are not significantly different according to the 5% D.M.R.T. follow-up test

Treatment A (4% LOF + 0 N.P.K.) was the treatment with the lowest nitrogen uptake in corn plants of 0.63%, while treatment D (4% LOF + 3/5 NPK) was the best treatment with nitrogen uptake of 3.02% with an increase in uptake of 2.39%. Increasing the application of the combination of landfill leachate LOF + N.P.K. fertilizer in E and F treatments, on the other hand, decreased the nitrogen content absorbed by plants. This is presumably because the amount of nutrients given to plants has exceeded the balance of nutrients. This causes excess nutrients to affect the availability and absorption of other nutrients. In [43], it is suggested that applying nutrients in the right amount can increase crop yields. However, giving excess nutrients will reduce crop yields. Excess potassium fertiliser would affect the absorption of microelements such as boron [44].

Likewise, for plant P and K uptake, the best treatment is 4% LOF + 3/5 NPK (D) with values of 0.37% and 0.58%, respectively, with an increase of 0.17 and 0.15 or an increase in absorption of 85% and 34.88% when compared to treatment without N.P.K. fertiliser (A). The combination of using landfill leachate LOF and N.P.K. fertiliser in treatment D showed that there was a balance of nutrients for plants. This aligns with the study of [45], where the highest nitrogen uptake was shown in the 1 LOF + ¾ N.P.K. treatment.

The corn and soybean intercropping system also plays a role in influencing better plant growth. [24] suggested that corn and soybean intercropping could increase nitrogen uptake by 2.4% compared to monoculture cropping systems. According to [46], using nitrogen in corn-soy intercropping increased efficiency by 105.1% compared to corn grown in monoculture. In [47], it is stated that intercropping corn with soybeans increased P uptake by corn.

Applying a combination of landfill leachate and N.P.K. fertiliser showed good growth and yield of corn plants. The role of microorganisms present in the landfill leachate LOF influences. The presence of microorganisms helps plants increase nutrient availability and uptake, thereby increasing crop yields. P. fluorescens bacteria could increase soil P solubility and produce I.A.A. hormones [48]. In [49], it is concluded that Bacillus can dissolve P and K in large quantities.

4) Metal Content in Corn Cobs: Based on variance, it was found that the combination application of landfill leachate LOF + N.P.K. fertiliser had a very significant effect on the uptake of Pb, Cd, Cu, and Cr elements in plant cobs. Optimal Pb content was found in treatment D (4% LOF + 3/5 NPK), which was not different from treatments E and F showing an increase of 0.012 (23%), optimal Cd content in treatment E (4% LOF + 4/5 NPK) which was not different from treatment F with an increase of 0.006 (16.7%), and the highest Cu and Cr content in treatment F (4% LOF + 1 N.P.K.) with a successive increase of 0.18 (72%) and 0. 22 (100%) compared to treatment A.

TABLE IV
COMBINATION OF LANDFILL LEACHATE OF LOF AND N.P.K. FERTILISERS ON THE UPTAKE OF PB, CD, CU, AND CR (PPM) ELEMENTS IN CORN COBS IN THE FIELD

Treatment	Metal Content (ppm)			
	Pb	Cd	Cu	Cr
A (4% LOF + 0 NPK)	0.052 b	0.036 d	0.25 e	0.22 e
B (4% LOF + 1/5 NPK)	0.053 b	0.038 c	0.30 d	0.23 e
C (4% LOF + 2/5 NPK)	0.054 b	0.039 c	0.33 c	0.24 d
D (4% LOF + 3/5 NPK)	0.064 a	0.041 b	0.35 bc	0.34 c
E (4% LOF + 4/5 NPK)	0.065 a	0.042 ab	0.37 b	0.42 b
F (4% LOF + 1 NPK)	0.066 a	0.043 a	0.43 a	0.44 a
CD (%)	2.56	2.20	4.29	2.57

Note: Numbers followed by the same lowercase letter in the same column are not significantly different according to the 5% D.M.R.T. follow-up test

The metal content influences the increase in metal in fruit in LOF and the soil. The Pb, Cd, Cu and Cr contents in LOF were 4.68 ppm, 0.42 ppm, 3.48 ppm and 4.22 ppm, respectively. At the same time, the metal content contained in the soil is 1.08 ppm Pb, 8.12 ppm Cd, 2.67 ppm Cu, and 3.24 ppm Cr. However, the metal content in corn cobs is still below the permissible threshold. According to [50] B.P.O.M. (2018), the safe limit for Pb in seeds is 0.2 ppm and 0.05 ppm for Cd. According to [51], S.N.I. (2009), the secure content of Cu and Cr in corn kernels is one ppm.

Excess heavy metal content in plant tissue can interfere with and inhibit plant growth. [52] suggested that the symptoms of Cd poisoning plants were chlorosis and stunted plant growth. Furthermore, in [53], it is concluded that increased Cd in the soil increased Cd uptake, reduced root length, reduced root nodules formed, and reduced plant biomass. In [54], it is stated that lead absorbed by plants will affect metabolism, photosynthetic activity, and plant growth processes. Excessive lead accumulation in plants can reduce root growth by up to 42%.

The content of the elements Pb, Cd, Cu, and Cr contained in plant tissues is below the permissible threshold due to the role of microorganisms. Microorganisms inhibit the uptake of these elements so they do not enter plant tissue. In [55], it is concluded that bacteria can convert metals into forms that are not available to plants to reduce the toxic effect on plants. [56] suggested that injection of Bacillus sp bacteria positively increased plant root and shoot biomass and reduced metal content in plant tissue.

B. Soybean Plants

1) Plant Growth: The analysis of variance found that the combination of landfill leachate LOF and N.P.K. fertiliser significantly differed in plant height, stem diameter, and leaf area. While the combination of landfill leachate LOF and N.P.K. fertilisers significantly differs from the soybean plant's weight. Table 5 shows that applying a combination of landfill leachate LOF and chemical fertilisers affected plant height, leaf area and biomass weight of soybean plants.

TABLE V
COMBINATION OF LANDFILL LEACHATE LOF AND N.P.K. FERTILIZERS ON THE GROWTH OF SOYBEAN PLANTS IN THE FIELD

Treatment	Observation		
	height plant (cm)	leaf area (cm²)	Biomass weight (g)
A (4% LOF + 0 NPK)	34.44 a	1632.93 a	28.17 a
B (4% LOF + 1/5 NPK)	39.44 ab	2312.97 b	30.33 a
C (4% LOF + 2/5 NPK)	42.88 ab	2331.67 b	30.72 a
D (4% LOF + 3/5 NPK)	51.88 c	3044.23 c	37.94 b
E (4% LOF + 4/5 NPK)	46.94 bc	2633.69 bc	31.33 a
F (4% LOF + 1 NPK)	44.94 bc	2419.42 b	33.36 ab
CD (%)	11.8	14.07	11.3

Note: Numbers followed by the same lowercase letter in the same column are not significantly different according to the 5% D.M.R.T. follow-up test

The best combination of landfill leachate LOF and N.P.K. fertilisers for plant height, leaf area, and biomass weight was best in the 4% LOF + 3/5 NPK (D) treatment with a successive increase of 17.44 cm (50.6%), 1,411.3cm2 (86.4%), and 9.77 g (34.7%). The best growth of soybean plants in treatment D is thought to be caused by the optimal nitrogen nutrient content in treatment D. According to [43], nutrients given to plants in sufficient quantities and at the right time will provide optimal plant growth and development.

In addition to being obtained from fertilisation, plant nitrogen needs are also obtained from N fixation carried out by plants. According to [57], the contribution of nitrogen from focus ranges from 45 – 56% of total plant N uptake. [58] suggested that plant growth and nitrogen requirements of soybean plants are strongly influenced by nitrogen fixation. Furthermore, in [59], legume plants added nitrogen fixation positively contributes to nitrogen balance. In addition, the nutrient content contained in P.O.C.plants supports plant growth. Using liquid organic fertilizer can increase plant growth and nutrients [60].

2) Soybean Seed Weight: The variance analysis results for the combination of landfill leachate LOF and N.P.K. fertilizers significantly affected seed/plant weight, seed weight/plot, and seed weight/hectare in soybean plants. The combination of landfill leachate LOF and chemical fertilizers gave the best results in treatment C (4% LOF + 2/5 NPK) for yield per plant, plot, and hectare. The increase in crop yield aligns with the increase in nutrients supplied to the plants.

TABLE VI
COMBINATION OF LANDFILL LEACHATE OF LOF AND N.P.K. FERTILIZERS ON THE WEIGHT OF SOYBEAN SEEDS IN THE FIELD

Treatment	Soybean seed weight		
	/plant (g)	/plot (kg)	/hectare (ton)
A (4% LOF + 0 NPK)	19.76 a	0.54 a	0.89 a
B (4% LOF + 1/5 NPK)	21.34 ab	0.58 ab	0.96 ab
C (4% LOF + 2/5 NPK)	26.40 bc	0.71 bc	1.19 bc
D (4% LOF + 3/5 NPK)	27.98 c	0.76 c	1.26 c
E (4% LOF + 4/5 NPK)	26.08 bc	0.70 bc	1.18 bc
F (4% LOF + 1 NPK)	25.65 bc	0.69 bc	1.16 bc
CD (%)	13.59	13.74	13.5

Note: Numbers followed by the same lowercase letter in the same column are not significantly different according to the 5% D.M.R.T. follow-up test

Increasing the nutrients given can increase the availability and absorption of nutrients to increase the production of plants. [61] suggested that increasing the amount of nutrients added to the soil will increase the nutrients plants absorb. Increasing the nutrients absorbed by plants will affect the physiological activity of plants, and eventually, plant growth will increase. According to [62], nutrient adequacy can increase plant growth and affect seed formation.

The Azospirillum, Azotobacter, Bacillus sp, and Pseudomonas fluorescent bacteria positively influence plant growth and development in LOF. So the combination of landfill leachate LOF and N.P.K. fertilizers showed an increase in soybean seed yield of 6.64 g (33.6%) per plant, 0.17 g (31.2%) per plot, and 0.3 g (33.7%) per hectare when compared to treatment A (LOF without N.P.K. fertilizers) and saves on the use of N.P.K. fertilizers. According to [63] and [64], applying bacteria to the soil can increase soil fertility and plant nutrition. Adequate nutrient availability can increase plant nutrient content and crop yields. Combining organic and synthetic fertilisers can increase soybean seed weight by 262% [32]. In [65], it is suggested that less than 70% synthetic fertiliser mixed with organic N fertiliser could increase vegetable yields. [66], concluded that using chemical fertilisers combined with a mixture of *Azospirillum lipoferum*, *Azotobacter chroococcum*, and *Bacillus* spp saved 50% of the use of chemical fertilisers. According to [67], substituting N fertiliser with sludge and animal manure can increase vegetable yields by 20.4%–35.3% compared to 100% application of N.

3) Elemental Absorption: Based on the analysis of variance, the combination of landfill leachate of LOF and N.P.K. fertiliser had a very significant effect on the percentage of the content of N, P, and K elements in soybean plants. Table 7 shows that the combination of landfill leachate of LOF and N.P.K. fertiliser increased the uptake of N, P, and K nutrients in soybean plants. The best treatment was at 4% LOF + 3/5 NPK (D) with a successive increase in absorption of 2.31 (278%), 0.12 (85.7%), and 0.27 (69%) compared to the other treatment A.

TABLE VII
COMBINATION OF LANDFILL LEACHATE OF LOF AND N.P.K. FERTILISER ON THE CONTENT OF ELEMENTS N, P, AND K (%) OF SOYBEAN PLANTS IN THE FIELD

Treatment	Elemental content (%)		
	N	P	K
A (4% LOF + 0 NPK)	0.83 a	0.14 a	0.39 a
B (4% LOF + 1/5 NPK)	1.11 b	0.17 b	0.47 b
C (4% LOF + 2/5 NPK)	2.42 e	0.24 d	0.58 d
D (4% LOF + 3/5 NPK)	3.14 f	0.26 e	0.66 e
E (4% LOF + 4/5 NPK)	2.05 d	0.20 c	0.52 c
F (4% LOF + 1 NPK)	1.79 c	0.18 b	0.52 c
CD (%)	5.73	8.33	2.86

Note: Numbers followed by the same lowercase letter in the same column are not significantly different according to the 5% D.M.R.T. follow-up test

The increased absorption of N, P, and K nutrients is in line with the increased availability of nutrients from LOF and N.P.K. fertilisers. The increase in nutrient uptake is also due to the role of microorganisms, which assist in nutrient solubility and absorption of nutrients from the soil solution. The nutrients absorbed by plants are primarily determined by the nutrient content found in the soil [68]. Combining inorganic and organic fertilizers can increase crop yields compared to using only one fertilizer [69]. Furthermore, microorganisms interacting with plant roots in symbiosis or free-living can increase plant nutrient absorption and crop yields [70].

4) Metal Content in Soybean Seeds: The results of the analysis of variance on the combination of landfill leachate of LOF and N.P.K. fertilizer showed a very significant effect on the percentage content of the elements Pb, Cd, Cu, and Cr in soybean seeds (Table 8). The combination of landfill leachate LOF and N.P.K. on the content of Pb, Cd, Cu, and Cr in soybean plants increased with increasing treatment given. The range of these elements in plant tissue increases from LOF and the soil and agricultural activities carried out] stated that the source of heavy metals in the ground comes from fertilization and excessive use of pesticides in agriculture [71].

TABLE VIII
COMBINATION OF LANDFILL LEACHATE LOF AND N.P.K. FERTILISER ON THE METAL CONTENT OF PB, CD, CU, AND CR (PPM) OF SOYBEAN PLANTS IN THE FIELD

Treatment	Metal Content (ppm)			
	Pb	Cd	Cu	Cr
A (4% LOF + 0 NPK)	0.048 e	0.031 e	0.35 d	0.37 d
B (4% LOF + 1/5 NPK)	0.050 d	0.034 d	0.37 c	0.39 c
C (4% LOF + 2/5 NPK)	0.051 d	0.037 c	0.39 b	0.40 c
D (4% LOF + 3/5 NPK)	0.054 c	0.039 b	0.41 b	0.42 b
E (4% LOF + 4/5 NPK)	0.060 b	0.040 b	0.42 a	0.43 ab
F (4% LOF + 1 NPK)	0.062 a	0.042 a	0.43 a	0.44 a
CD (%)	1.51	2.21	2.61	2.82

Note: Numbers followed by the same lowercase letter in the same column are not significantly different according to the 5% D.M.R.T. follow-up test

Based on statistical analysis, the highest percentage of Pb and Cd metals contained in treatment F (4% LOF + 1 N.P.K.) with an increase of 0.014 (29%) and 0.011 (35.5%). Cu and Cr metals in treatment E (4% LOF + 4/5 NPK) had an increase of 0.07 (20%) and 0.06 (16%) compared to treatment A (4% LOF + without N.P.K.). Increased metal content in plant tissues because the solubility of metals increases due to increased nitrogen fertilisation. This results in nitrogen accumulation around the roots, improving the soil's acidity. This result is in line with the research of [72], which stated that the solubility of Cd and Pb increased due to soil acidity caused by cumulative N fertilisation. So, the amount that goes into the plant also increases.

C. *Land Equivalent Ratio (LER)*

The variance analysis found that the combination of landfill leachate LOF and N.P.K. fertilisers significantly affected the LER of maise and soybean plants grown by intercropping. Table 9 shows that the intercropping cropping pattern in treatment A (4% LOF + 0 N.P.K.) was the lowest treatment compared to all treatments. Land Equivalent Ratio (LER) for all treatments gave better results than monoculture planting. This is shown from LER > 1. The best LER was shown in treatment C (4% LOF + 2/5 NPK) with an increase of 0.57 (35.6%) compared to treatment A (4% LOF + without N.P.K.).

TABLE IX
LAND EQUIVALENT RATIO (LER) OF CORN AND SOYBEAN INTERCROPPING

Treatment	**LEV**
A (4% LOF + 0 NPK)	1.60 a
B (4% LOF + 1/5 NPK)	1.90 ab
C (4% LOF + 2/5 NPK)	2.17 bc
D (4% LOF + 3/5 NPK)	2.42 c
E (4% LOF + 4/5 NPK)	2.09 bc
F (4% LOF + 1 NPK)	2.11 bc
CD (%)	11.55

Note: Numbers followed by the same lowercase letter in the same column are not significantly different according to the 5% D.M.R.T. follow-up test

The results of [73] stated that the intercropping of hybrid corn (KSC301) with *Vicia villosa* L in the first and second years had the highest LOF, 1.37 and 1.53. These figures show that it would take 37% and 53% more land in monoculture plantings to achieve the same productivity as intercropping, respectively. In [74], the intercropping system has more significant benefits for land productivity, acquisition and use of N/P than monoculture.

The best Land Equivalent Ratio was found in treatment C (4% LOF + 2/5 NPK) of 2.17, meaning that the total productivity in intercropping obtained an advantage of 117% compared to the corn monoculture cropping system. Thus, in treatment C, an area of 2.17 ha was required to produce soybeans in a single crop. One of the high productivity of plants with intercropping systems compared to monoculture is the efficiency in utilising the intensity of solar radiation. This results in increased photosynthesis, followed by increased crop production. Intercropping corn and peanuts increases light power, thereby increasing plant photosynthesis compared to monoculture systems [75]. Intercropping systems can improve soil fertility and longer-term land use compared to monocultures [76]. According to [23], corn-bean intercropping provides higher yield stability and is more efficient than monoculture.

The land equity value with the intercropping system is better than monoculture due to the higher soil nutrient content, so nutrient absorption, especially nitrogen, phosphorus and potassium nutrients, is also more excellent. This is to the research of [24], which suggested that the corn-soy intercropping system increased the amount of total soil nitrogen and soil phosphorus availability. An increase in soil nutrients will increase the nutrient uptake of nitrogen, phosphorus, and potassium, respectively 24.4; 9.6; and 22.4% compared to planting in monoculture.

Treatment A gave LOF independently (without N.P.K. fertilisers) better results with an LER value of > 1. This shows that applying liquid organic fertiliser can support plant growth and yield. This is in line with the research of [60], which concluded that using liquid organic fertiliser can increase the growth and yield of *L. sicario* plants. However, further studies are needed to determine the ability of LOF to support plant growth to improve the results obtained. According to [77], the application of liquid organic fertiliser could increase the fresh weight of *L. sativa* plants close to the plant description

IV. CONCLUSION

The research concludes that liquid organic fertiliser made from leachate can support the growth of maise and soybean plants in intercropping. Using 4% leachate-based liquid fertiliser without a combination of chemical fertilisers shows LER > 1, which indicates that the leachate-based LOF can replace chemical fertilisers to support the growth and yield of corn and soybeans planted in intercropping. The best combination of LOF is made from landfill leachate and chemical fertilisers for corn plants in the 4% LOF + 3/5 NPK treatment and for soybean plants in the 4% LOF + 2/5 NPK treatment.

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