EFFECT OF COMBINATION OF EMPTY FRUIT BUNCH COMPOST AND CHEMICAL FERTILIZER ON SOIL AND LEAF NUTRIENTS, LEAF AREA AND YIELD PRODUCTION IN SMALLHOLDER OIL PALM (*ELAIES GUNINEENSIS*) CULTIVATION

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ABSTRACT

Good sustainability practices are major challenges in smallholder oil palm cultivation. This study examined the combination of empty fruit bunch (EFB) compost and chemical fertilizer application to address the continual chemical fertilizer application associated with environmental degradation. The study used a Randomized Complete Block Design with five treatments replicated four times in a smallholder farm in Sarawak. The treatments were: T1 (EFB Compost), T2 (EFB Compost + Korn-kali), T3 (Korn-Kali), T4 (NPK), and T% (EFB Compost + NPK). At Month 9, the soil total N was highest in T1 (0.43%) and lowest in T3 (0.34%). This trend was also observed in plant N (0.70 – 1.23 %). Soil available P was lowest in T3 (13.80 mg kg-1), with T4 and T5 the highest (15.90 mg kg-1). Similarly, plant P was lowest in T3 (0.14%); however, T5 was the highest (0.33 %). There were significant differences in both the soil available P and plant P as ANOVA indicated p<0.00. Soil K was lowest in T3 (0.55 cmolc kg-1) while highest in T1 (0.65 cmolc kg-1). Plant K was also lowest in T3 (1.30 %), while T4 was highest (1.83%). Both soils available P and plant P showed significant differences with ANOVA indicating p<0.00. However, T2 and T5 produced higher leaf area at 1900 cm2 and 2100 cm2, and average bunch weight at 20.1 kg and 10.1 kg respectively, significantly different from single fertilizer application. The study concluded that the combination of EFB compost and chemical fertilizer could be adopted as mitigation to reduce chemical fertilizers application.

Key words: *Elaies guinensis*, EFB compost, Korn-kali fertilizer, NPK fertilizer, smallholder.

INTRODUCTION

Currently, Malaysian oil palm industry has become one of the main contributors to the Gross Domestic Product (GDP), foreign exchange earnings and employment opportunity. This is due to the global population and oil consumption for food product and industrial purposes. Among the world's major oil palm producers, Indonesia and Malaysia provide 85 of the total production of palm oil and export globally to China, India and European Union (Ferdous Alam et al., 2015). Malaysia was globally renowned as a main producer of oil palm in year 1966 and 1971 respectively (Rasiah and Shahrin, 2014). After this period, it faced major fluctuation and overtaken by Indonesia in year 2008 and 2010 respectively (Rizwan and Rahuman, 2014).

With growing demand and less availability of soil for oil palm plantation, smallholder have been increasing practiced the used of inorganic fertilizer to enhance the oil palm production. However, the excessive used of nitrogen fertilizer can have undesirable effects including an increasing in greenhouse gas (GHG) emission which is a global warming potential, increasing soil acidity and reducing non-renewable fossil fuels such as natural gas. While, an excessive use of phosphorus can contribute to the contamination of water quality, particularly through eutrophication. Without a knowledge of the soil characteristics, environment and other factors needed for better fertilizer management, the program of the fertilizer application can also lead to high cost of production and increase the loss of plantation availability. According to Comte et al. (2012), the cost of fertilizers is approximately 25% of the overall cost of production and it represents 50-70% of the operating costs in the field. Therefore, it is important to understand the effect of inorganic fertilizers beyond their effects on oil palm production to achieve a balance life between human and environment.

Nowadays, the sustainability practices in oil palm plantation are an important global issue. In year 2020, mandatory implementation of the Malaysian Sustainable Palm Oil (MSPO) certification in oil palm plantations was imposed for smallholders to ensure the sustainability of the oil palm industry. Then, the introduction of United Nations Sustainable Development Goals (SDGs) specifically SDG 1 and SDG 12 were focused on maximizing economic benefits and reducing environmental impacts. These has resulted on the highlight of the best management practices in oil palm plantation. Best management practices (BMP) are important in order to boost economic yield with steps ensuring the estate and field practices complying with all standard and fertilizer guidelines as Heffer et al. (2015) literate the 4R or the "four rights; right source, right rate, right time and right place. In addition, latest and extensive information on the new system or technologies about fertilizer management has to be introduced and provided training (Woittiez et al., 2018). Rhebergen, (2012) advised that, before enforcing site-specific BMPs, planters should track and evaluate environmental conditions. Productivity in established oil palms can be improved if properly implemented under site-specific conditions. Need-based' fertilizer use for the effective use of nutrients is focused on the use of appropriate nutrients requiring preventive and corrective measures to effectively manage nutrients, improve soil resource base and increase the viability of oil production. However, majority of smallholder farmers do not adopt an ecological intensification mechanism intended to guide decision-makers in defining key productivity-enhancing constraints by quantifying specific output indices and analyzing the data collected. They are not able to follow BMPs as they are not equipped with the skills and tools and dependent on extension services.

The usage of organic fertilizer can be implemented to enhance the smallholder with the best management practices. EFB is the residue that has been left after the fresh fruit bunches (FFB) of oil palm have been processed in a mill and it can be used as organic fertilizer. The use of EFB at 37.5 t/ha per year in oil palm plantation has shown a positive impact as it significantly increases the yield of oil palm, improves the nutrient content of K, Ca and Mg as well as the acidity of soil (Asy Syura and Tsan, 2007). The efficient use of EFB for long term can help the smallholder to use their field until the next generation, reduce the cost of improving soil condition using chemical fertilizers and have high yield per hectare.

This study, therefore examined the combination of empty fruit bunch (EFB) compost and chemical fertilizer application to address the continual chemical fertilizer application associated with environmental degradation.

MATERIALS AND METHODS

Study Site and Experimental Design

The experiment was carried out in a smallholder farm in Kampung Telagus, Melikin, Serian, Sarawak. Melikin, is located at 1˚ 2' N and 110˚ 40' E at 10th mile, Serian-Simanggang Road in Upper Sadong District. The soil type in Melikin is a Grey-White Podzolic. Grey-White Podzolic consists of three families such as SARATOK, BANDANG and KERAIT as stated in Table 1.

Table 1: Families of Grey-White Podzolic Soils

Particle-size class	Family
Coarse loamy or coarse silty, or contrasting texture where the upper 50 cm is coarse loamy or coarse silty	SARATOK
Fine loamy or fine silty, or contrasting texture where the upper 50 cm is fine loamy or fine silty	BANDANG
Clayey; or contrasting texture where the KERAIT upper 50cm is clayey	KERAIT

Source: Teng (2004)

The topography of study site is broken hilly terrain. Thus, it has good external drainage and suitable for secondary growth. The site is located near top of hill, slope approximately with 10 degrees. Climatic conditions and rainfall of the study sites from year 2014 until 2018 were stated in Table 2.

Table 2: Climatic Conditions and Rainfall from Year 2014 to 2018

Year	Mean Temperature		Rainfall	
	Min	Max	Total (mm)	No. of Days
2014	23.7	32.2	3,692.9	221
2015	23.9	32.0	4,545.5	223
2016	24.0	32.5	5,423.0	265
2017	23.8	32.3	3,823.2	252
2018	23.8	32.3	3,864.6	249

Source: Department of Statistics Malaysia (2019)

The study area covered 5.17 hectares with five years old of oil palm. The fertiliser used in the farm was Korn-Kali+B for the last two years. Korn-kali+B is a granular fertiliser with 40% potassium Oxide, 6% Magnesium Oxide and 4% Sulphur + 0.8% Boric Oxide. A Randomized Complete Block Design (RCBD) was used with (five treatments replicated three times. The five fertilizer treatments included:

T1: EFB Compost
T2: EFB Compost + Korn-Kali+B
T3: Korn-Kali+B
T4: NPK
T5: EFB + NPK

Detailed fertilizer treatments and equivalent nutrient supply of N, P and K are shown in Table 3. The application of fertilizers was carried out two times a year (January and June) and the sample collections were done after three months of fertilizer application (March and September). This research was carried out for two years.

Table 3: Fertilizer Application

Treatment	Nutrient Supply kg/tree/year			Total Fertilizer (kg/tree/application
	N	P	K	
2014	23.7	32.2	3,692.9	221
2015	23.9	32.0	4,545.5	223
2016	24.0	32.5	5,423.0	265
2017	23.8	32.3	3,823.2	252
2018	23.8	32.3	3,864.6	249

The application rate was determined based on the practices done by the smallholder and oil palm plantation company in Kampung Telagus, Melikin, Serian. The fertilizer was then spread around the palm circles as shown in Figure 1.

Figure 1: Application of fertilizer at the canopy edge of the oil palm

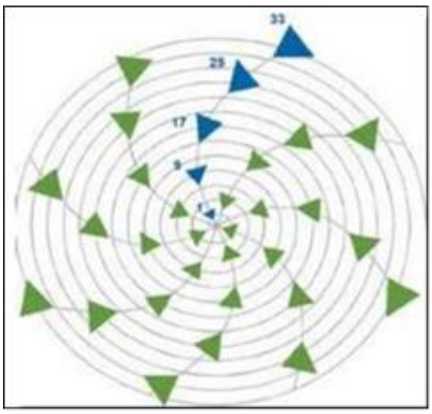
Soil Sampling

At each sampling palm, there were three collections at 0-10 cm depth, 10-20 cm depth and 20-30 cm depth using an auger at the two sampling points. Preliminary analysis indicated that the three soil minerals N, P and K of soil samples from the two sampling points were not significant. Therefore, the soil samples from the same sampling palm were combined into a composite sample. The composite soil samples were air-dried and grounded for analysis of total N concentration, extractable P and concentration of exchangeable cation K using CHNS Elemental Analyzer, Bray II method and USEPA method 3050B Acid Digestion of Sediments, Sludges and Soils respectively. Two analyses were conducted at three months after first fertilizer application and after the fourth and final fertilizer application.

Leaf Sampling

Frond 17 was used for leaf analyses and its identification is shown in Figure 2 (Rankine and Fairhurst, 1999). The samples were taken in the morning and twelve leaflets were cut from the frond.

Figure 2: Palm frond spiral indicating location frond 17 (Fairhust and Hardter, 2003)



Leaf Area

Six leaflets of the Frond 17 from each palm were cut into sections to fit an A4 size paper before being placed inside a transparency file, scanned and saved as JPEG images. It is essential to ensure that the image was taken parallel to the surface where the leaf segments were located so that a fixed distance was maintained so that the scale factors would be the same for all images. The scanned image was then uploaded to the 2017 version of AutoCAD software as shown in Figure 3.

Once the image was in the workspace of the AutoCAD software, the image was sized to its actual scale, and a continuous line was plotted around the leave using the POLYLINE command to form a closed object. The area of the object would have been calculated.

Figure 3: Uploading the image of the oil palm leaf saved in JPEG format into the AutoCAD

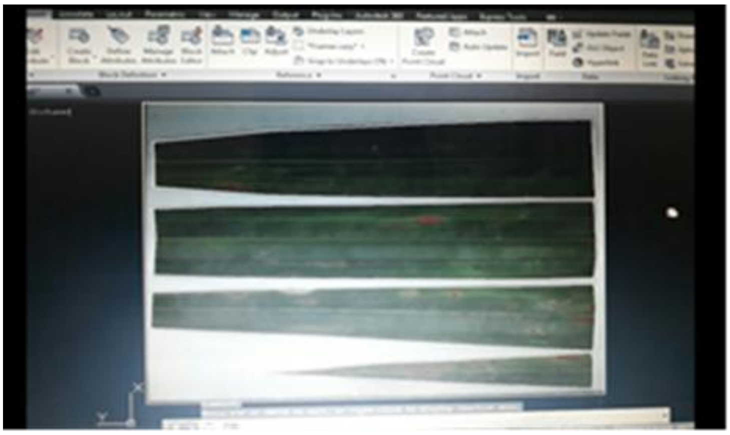


Table 4 shows the steps to process the image in AutoCAD software version 2017.

Table 4: Steps of Measuring Leaf Area Using AutoCAD

Steps	Description of action	Command		
		N	P	K
1	The image should be attached in AutoCAD work	In ordinary way		
2	Knowing the dimension before scaling the image	In ordinary way		
3	Scaling the image to real scale	Scale		Enter
4	Selecting the image to specify scale factor	R	Enter	Enter
5	Specify the new length of the object based on the actual size of the biggest width of leaf			Enter
6	Ensure the length of leaf is same	Dist		Enter
7	Drawing a close line around the leaves	Pline		Enter
8	Knowing the area of the leaf image by selecting the line of the leaves	Area	Enter	Double Enter

Figure 4 shows the process measuring the leaf area oil palm using the AutoCAD software.

Figure 4: Measuring leaf area using Autodesk AutoCAD software Version 2017

Yield of Fresh Fruit Bunch

The number of Fresh Fruit Bunch (FFB) were harvested and recorded. The harvested bunch were selected when the bunch colour change to intense orange and have three fruitlets on the ground as shown in Figure 5.

Figure 5: Harvested Fresh Fruit Bunch

The FFB were weighed using the weighing scale within 24 hours after harvesting to reduce the amount of Free Fatty Acid (FFA). The average bunch weight (ABW) was calculated using the formula shown in Equation 1:

$$\text{ABW (kg)} = \frac{\text{Weight of FFB (kg)}}{\text{No. of FFB}}$$

Leaf Nutrients Content

The samples were oven-dried at 105°C for 24 hours, grounded and sieved, before laboratory analysis to determine concentrations of N, P and K in these vegetative tissues. The concentration of N in vegetative tissue was determined using CHNS Elemental Analyzer, P using Bray (II) extraction method described by Seraphina and Chan (2018) and determined using UV-Vis Spectrophotometer Lambda 35 at 660 nm wavelength and K by atomic absorption spectroscopy.

Statistical Analysis

The data was statistically analysed using IBM SPSS 22 for data collected three months after first application and third applications of treatments. Two-way analysis of variance and Tukey Multiple Comparison of Test were used to determine the significant differences in the measured parameters based on α at 0.05.

RESULTS AND DISCUSSION

Soil Nutrient Level

Table 5 shows the soil nutrient level three months after the first application and third applications of treatments.

Table 5: Soil Nutrient Level After First Application and Third Application of Treatments

Steps	Nitrogen (%) Collection		Phosphorus (%) Collection		Potassium (cmol, kg^{-1}) Collection	
	1st	3rd	1st	3rd	1st	3rd
1	0.38	0.43	14.30^{ab}	15.30^{ab}	0.54^{ab}	0.65^{a}
2	0.33	0.38	13.40^{a}	14.60^{ac}	0.57^{b}	0.64^{ab}
3	0.32	0.34	13.20^{a}	13.80^{c}	0.58^{b}	0.55^{c}
4	0.35	0.37	15.10^{b}	15.90^{b}	0.51^{a}	0.64^{ab}
5	0.33	0.37	14.00^{ab}	15.90^{b}	0.50^{a}	0.59^{bc}
ANOVA p-value			0.00	0.00	0.00	0.00

Common letters indicate no significant differences based on Tukey Multiple Comparison of Means

After the first application, the soil N % from all the treatments ranged from 0.32% to 0.38%. Subsequently after the third application, the same pattern was also observed. The lowest N content in T2 and T3 was attributed to Korn-Kali+B which did not have N content in its formulation and also indicating that EFB compost had contributed the N content to the soil. There was an increase of N content from the first application to the after third application. No statistical analysis was conducted for N content as the determination was based on one composite samples from the four replicates of the five treatments. T1 indicated that EFB compost was able to retain the N content in the soil. According to Jouquet et al. (2011), EFB compost has plausible mechanism in retaining the nutrients in the growing media by surface adsorption and increased nutrient recovery. Bah et al. (2014) showed that the slow-release compound fertilizers reduced the runoff risks of nutrient loss possibly due to their slow-release properties. EFB has slow-release nutrient properties which depends on the microbial activities which was reported to take longer time to breakdown the binders as observed in chemical slow release or controlled release fertilizer by Ransom et al. (2020) thus indicating the N is still bounded in the organic matter of EFB. The lower N content in all the chemical fertiliser treatments is therefore due to some N losses due to leaching or runoff. This is pointed out by AlShamaileh et al. (2018) who stated that the major drawback of conventional fertilizer is their fast dissolution in soil relative to their absorptivity by plants, consequently, water runoff results in the loss of fertilizers materials and contamination of surrounding environment. The reduction of chemical fertilisers supplemented by EFB compost also has higher total N concentration. Santi et al. (2018) showed EFB compost could provide silicon available to the oil palm and the addition of 500 kg EFB compost/ha/year combined with 75% NPK fertilizer reduced 50% the need for the Silicon fertilizer (BioSilAc).

The treatment T4 indicated the highest P content. The application of EFB compost alone or combination with NPK had indicated there was also higher P in the soil after the first application with no significant differences from 100% NPK. As T3 did not have any P content in Korn-Kali+B, the P content was detected the lowest and a slight increase with no significant difference when the fertiliser was combined with EFB compost. The higher P content of T1 over T4 was attributed to EFB compost. There was no significant difference between T1 and T3. This pattern was similar in P content after the third application and in general there was higher accumulation of P content. Zulkifli and Tarmizi (2010) suggested that organic P was an important P pool which accumulated during dissolution of applied rock phosphate in soil amended with EFB and during the decomposition of EFB by microbial activity. This was explained by Cross and Schlesinger (1995) organic P compounds were thought to be associated with the positively-charged sites on organic matter and clay particles, or with cations in the soil solution and a source of plant-available P.

Treatments with Korn-kali indicated higher value of K after the first application. This could be attributed to the long-term effect of the application of Korn-Kali+B. The two treatments were not significantly different from T1 but significantly different from treatments with NPK with or without EFB compost. After the third application, the pattern of K content in the soil was reversed. The K content from T3 was significantly different from other treatments except T5 which was the combination of NPK and EFB compost. In contrast, T1 of EFB compost was significantly different from T5 while not significantly different from T2 and T4. The reduced K content in T3 in the fourth application from the first application was observed, whereas other treatments increased K content in soil. This could be attributed to either more efficient uptake by the plant or due to loss of K due to leaching. Tao et al. (2018) reported that reducing fertilizer rate resulted in higher nutrient use efficiency in K, compared to the standard treatment indicative of Korn-kali without N and P could have effective caused more K efficient uptake by the plant, thus the lower value of K in the soil. However, Haron et al. (2015) attributed lower exchangeable K as compared to the those integrated with organic fertiliser in the soil to leaching losses of K.

Nutrient Concentration in Vegetative Tissue

Table 6 shows the nutrient concentration in the vegetative tissue of oil palm after first application and third applications of treatments.

Table 6: Nutrient Concentration in vegetative Tissue Oil Palm After First Application and Third Applications of Treatments

Steps	Nitrogen (%) Collection		Phosphorus (%) Collection		Potassium (cmol, kg^{-1}) Collection	
	1st	3rd	1st	3rd	1st	3rd
1	0.62	1.23	0.28^{a}	0.25^{a}	1.17^{a}	1.34^{a}
2	0.72	0.98	0.17^{b}	0.20^{b}	1.66^{b}	1.72^{bc}
3	0.74	0.87	0.12^{c}	0.14^{c}	1.32^{c}	1.30^{a}
4	0.61	1.00	0.37^{d}	0.30^{d}	1.44^{d}	1.83^{b}
5	0.59	0.70	0.21^{e}	0.33^{e}	1.49^{d}	1.60^{c}
ANOVA p-value			0.00	0.00	0.00	0.00

Common letters indicate no significant differences based on Tukey Multiple Comparison of Means

In the first application, the higher percentage of N was recorded in T3 as compared to treatments with T4 and T1 alone. This pattern was not observed after the third application indicative of accumulative N with more applications in both periods, T5 had remained with the lowest percentage. The increasing N elements absorbed by the plant was due to the ability of soil to supply N for the plants. This is supported by Mengel et al. (2001) which stated that the formation of organic compound in plant tissues increased with the availability of plant absorption on the macronutrient that have been applied in soil with reference to Table 5. The beneficial effect of EFB compost was also reflected. Haron et al. (2018) contrasted in that a lower N content in the organic fertilizer was obtained in their study. However, this was explained that since that organic N needed to be transformed through mineralisation process to inorganic N before it could be taken up by the palm and immobilisation occurred if source of N was limited under which circumstances the microbes would consume the N first.

The P content in vegetative tissue was observed to be also dependent on the availability of P in the soil. The plant response to such availability was significantly reflected as in the availability in all other treatments as compared to T3 regardless of the period of the applications. Haron et al. (2018) indicated that only N content was the limiting factor which was also a contrast in this study.

After the first application, the treatments with NPK with or without EFB compost recorded lower values of K content with only non-significant differences from T1. The treatments with Korn-Kali+B with or without recorded the higher values of K which however were also significantly different from T1. After the third application, there was a reduction in K concentration from 1.32% to 1.30% and the lowest in T3, only not significant from T4, while the other treatments showed the enhancement. The highest K concentration was recorded from the application of NPK only not significantly different from EFB Compost + Korn-Kali+B. Generally, the pattern showed the K content in the vegetative tissues depended on the availability of K concentration in the soil.

Leaf Area

Table 7 shows that leaf area recorded under the various treatments. After first application, there was significant difference as ANOVA obtained the p-value = 0.047. T1 recorded the highest mean leaf area of 1.737m2 which was significant different from T3 with the lowest leaf area of 1.504 m2. After the third application there were no significant differences as p = 0.328. However, T5 recorded highest mean leaf area while T3 still recorded the lowest mean leaf area. This indicated that nitrogen is the main nutrient for leaf production attributing the lowest N content in the vegetative tissue. Korn-Kali+B fertilizer only contained potassium, boron and magnesium only.

Table 7: Leaf Area After First Application and Third Applications of Treatments

Steps	Leaf Area (%) Collection	
	1st	3rd
1	1.737[a]	1.872
2	1.587[ab]	1.987
3	1.504[b]	1.813
4	1.640[ab]	1.917
5	1.637[ab]	2.153
ANOVA p-value	0.047	0.328

Common letters indicate no significant differences based on Tukey Multiple Comparison of Means

Yield

Table 8 show the yield of oil palm in terms of number of FFB weight of FFB and average bunch weight. As the harvest was erratic over each harvest with large variation, statistical analysis was not conducted.

Table 8: Yield Determined by Number of Fresh Fruit Bunch (FFB), Weight of FFB and Average Bunch Weight from Five Treatments Three Months After First and Third Applications

Treatment	FFB/Treatment		Weight/Treatment		ABW/Treatment	
	1st	3rd	1st	3rd	1st	3rd
T1	2	14	30.6	218.8	15.3	15.6
T2	7	18	62.6	362.0	8.9	20.1
T3	7	21	75.9	251.6	10.8	12.0
T4	3	22	30.9	273.0	10.3	12.4
T5	4	12	37.0	231.1	9.2	19.3

After the first application, the treatments of Korn-kali+B with or without EFB compost had produced the equivalent number and weight of FFB higher than the other treatments indicating the effect of K availability and also the low K accumulation in vegetative tissue. However, when the ABW was compared, T1 produced the heaviest. This pattern of ABW was not observed after the third application. The combination of NPK or Korn-kali+B with EFB compost showed better ABW with 20.1kg from T2 and 19.3kg from T5. But it did not match the N, P and K availability of soil and content in the vegetative tissue of the leaf contradicting Haron et al. (2018) who observed and stated that low FFB yield was in agreement with the low total soil N and leaf N. However, they observed that highest yield suggested efficient use of nutrients by integrating inorganic and organic fertilisers supported by Goenadi (1998). Similarly, Cezar (2004) also stated that the combination of organic fertilizer with chemical fertilizer can improved soil properties and increase oil palm productivity.

CONCLUSION

Combination of inorganic and organic fertilisers can increase the nutrient availability in the soil and thus the efficiency of uptake increasing yield of oil palm. This demonstrated by the better results of both soil and leaf nutrients, leaf area and the production of yield obtained from in the combination of NPK or Korn-kali+B with EFB compost. The EFB compost enhance the long-term retention of nutrients in the soil while the reduction of the chemical fertilizer reduced the loss through leaching before the nutrients can be uptake by the oil palm. This balanced strategy will be a mitigation measures in achieving SDG 12 towards sustainable management of oil palm.

The application of fully inorganic fertilizer can be reduced into half by combining EFB compost as organic fertilizer. Based on the application of EFB with Korn-Kali+B and EFB with NPK fertilizer, both average bunch weight (ABW) of fresh fruit bunch showed the better results as compared with the single application of inorganic fertilizer. This research concludes, the combination of inorganic fertilizer with organic fertilizer can be recommended as an alternative fertilizer application programme in smallholder oil palm cultivation. This alternative can enhance the income of smallholder, reduce the production cost and protect the environment from the excessive use of chemical fertilizer.

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