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Changes in Some Soil Chemical Properties of Ultisol Applied by Mulch from Empty Fruit Bunches in an Oil Palm Plantation

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ABSTRACT

Changes in Some Soil Chemical Properties of Ultisol Applied by Mulch from Empty Fruit Bunches in an Oil Palm Plantation (D Budianta, AYA Wiralaga, and W Lestari): Objective of this research was to study the effect of empty fruit bunches (EFB) applied as mulching on some soil chemical properties of Ultisol in an Oil Palm Plantation**.** This field experiment was conducted in PT. Sampoerna Agro Tbk Plantation Mesuji, Ogan Komering Ilir of South Sumatra Province at blocks of 22/A, 23/B, 27/C, 33/, 12/A, 12/B, 24/D, 12/C, 00/C, 24/A, 24/B, 10/B, 02/C, 02/D, 11/C, 11/D, 10/A, 10/C, 11/A, and 24/C. The treatment was EFB dosage which are without EFB (control), 40 Mg ha^{-1} of EFB applied only once for a year, 80 Mg ha^{-1} of EFB applied twice for 2 years, 120 Mg EFB/ha applied three times for 3 years, and 160 Mg ha^{-1} of EFB applied four times for 4 years. The rate of EFB application was 40 Mg ha^{-1} per year. Every treatment was replicated 4 times, thus total of experiment was 20 units. Soil samples were taken in two differences of deepness which were 0-20 cm and 20-40 cm, respectively. Soil variables observed were soil pH, organic C, cation exchange capacity (CEC), total N, P availability, exchangeable K and Mg, Al and Fe. The results showed that application of EFB had significantly effect on some soil chemical properties such as soil pH and Mg exchangeable Mg for 0-20 cm and total N for 20-40 cm deepness. Meanwhile application of EFB did not have siginificant effects on total organic C, CEC, P-Bray I, exchangeable K, exchangeabile Al and Fe. It was also shown that some soil chemical properties were generally higher in top soil layer than sub soil layer, except for CEC, P and exchangeable Al.

Keywords: Empty fruit bunches (EFB), mulch, oil palm plantation, soil nutrient, Ultisol

INTRODUCTION

Oil palm (*Elaeis guineensis* Jacq.) is one of mainstay crop of estate in Indonesia, because the yield from this crop has an economic prospect to increase income of farmers and to generate national revenue. To succeed the growth of oil palm, it is needed to increase crop productivity through improving soil quality. Soil condition that is required by oil palm growth are nutrient supply, crumb of soil structure, deep of solum, and no other limiting factor such as duripan or fragipan. One of efforts which can be implemented to improve and to maintain soil fertility for oil palm growth is by applying organic and anorganic fertilizers. One of organic fertilizers that can be used for nutrient supply is empty fruit bunches (EFB) as byproduct of oil palm processing to become *crude palm oil* (CPO) with content of EFB about 20% per one ton of Fresh Fruit Bunches (FFB) proccesed. The EFB has good potential to improve soil physical, chemical and soil biology (Zaharah and Lim 2000; Sutarta *et al*. 2002; Lim and Zaharah 2002) and EFB has also contained some macronutrient essential such as 0.44% N, 0.144%P, 2.24% K, 0.36% Mg and 0.36% Ca (Menon *et al*. 2003) that can be uptaken by oil palm crop. If FFB production is around 25 Mg ha^{-1} per year, thus it can be resulted about 5 Mg ha^{-1} of EFB. The EFB can be incorporated to the soil as organic material source with the rate of 40 Mg ha^{-1} year^{-1} and particularly applied to the poor soil with low content of organic material. From this point of view, this organic material will reduce the application of convention fertilizers (Sutarta *et al*. 2002).

The oil palm plantation which is cultivated in Indonesia, generally has low soil fertility, such as

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Ultisol. Ultisol has a widely distribution covering about 25% from total land of Indonesia. Therefore, this soil has an important role in developing oil palm plantation in Indonesia. All type of soils are almost used to cultivate oil palm plantation, especially at out side of Java, except the soil has contraint for climate and relief (Koedadiri *et al*. 1999). Soil chemical properties has important role to characterize soil fertility, for examples organic matter, nutrient and soil pH. The availability of nutrients are affected by several factors such as soil pH that can influence nutrient availability. Hence, the addition of nutrient should be considered about kind of nutrient and other soil chemical properties, thus the nutrient can be absorbed by crop (Harahap *et al*. 2000).

Prasetyo dan Suryadikarta (2006) reported that soil fertility of Ultisol is generally accumulated in thin upper layer or A layer containing low organic material. Essential macroelements such as P and K which are often in deficiency condition, low soil pH and high Al saturation are the characterization of Ultisol that is limiting plant growth (Budianta 2001). Due to low of soil fertility of the Ultisol, it is required an effort to improve the fertility of Ultisol through increasing soil pH and nutrient supply, and decreasing Al toxicity by adding empty fruit bunches (EFB). For that purpose, this research was conducted to study the effect of fresh EFB applied in surface soil as soil mulching on some soil chemical properties of Ultisol in oil palm plantation.

MATERIALS AND METHODS

Study Site

This research was a field experiment which was conducted in an Oil Palm Plantation of PT. Sampoerna Agro Tbk, Mesuji estate in Blocks of 22/A, 23/B, 27/C, 33/, 12/A, 12/B, 24/D, 12/C, 00/C, 24/A, 24/B, 10/B, 02/C, 02/D, 11/C, 11/D, 10/A, 10/C, 11/A and 24/C located in Mesuji District, Ogan Komering Ilir Regency of South Sumatra province.

Research Design

Material used in this experiment was Empty Fruit Bunch (EFB) as byproduct of Oil Palm processing to become *Crude Palm Oil* (CPO). Meanwhile, the equipment used were auger, plastic bag, etc and some laboratory equipment. This field experiment was done using one factor only which are EFB with a rate of 40 Mg ha^{-1} year^{-1}. The level of treatments were A0 without EFB (as control), A1 (only once application of EFB amounting to 40 Mg ha^{-1} for 1 year application), A2 (2 times of EFB application with the rate of 80 Mg ha^{-1} for 2 years application with the rate of 40 Mg ha^{-1} year^{-1}), A3 (3 times of EFB application at 120 Mg ha^{-1} for 3 years), and A4 (4 times of EFB application at 160 Mg ha^{-1} for 4 years (Table 1).

The EFB which was applied was not chopped and was not decomposed in advance. Every treatment was replicated 4 times, thus the total experiment was 20 experiment units. The EFB was applied at soil surface as soil mulching in between of oil palm trees. Soil samplings were collected only once in the same time, but in difference of duration EFB application.

Soil Analysis

Soil chemical variables observed were soil pH (potensiometric method), C-organic (Walkley and Black method), cation exchange capacity (NH_4OAc pH 7.0 method), and N (Kjeldahl method), P (Bray-I method), K, Mg, Fe and Al (NH_4OAC, pH 7.0 method).

Statistical Analysis

To determine the effect of treatment on soil chemical properties, data was tested by statistical analysis using analysis of variance and then continued the advance analysis using *Duncan Multiple Range Test* (DMRT) at 5% to examine the difference of each treatment.

RESULTS AND DISCUSSION

Briefly General Condition of Experimental Site

The experimental site was located in Oil Palm Plantation belonged to PT. Sampoerna Agro Tbk placed in Mesuji District, Ogan Komering Ilir (OKI)

Table 1. Experimental block and location of the soil samplings after soil treatment.

Treatment	Block/planting year (As replication)
A0	22/A, 23/B, 27/C, 33
A1	12/A, 12/B, 24/A/95, 24/B/95
A2	00/C, 24/A/89, 24/B/89, 10/B
A3	02/C, 02/D, 11/C, 11/D
A4	10/A, 10/C, 11/A, 24/C

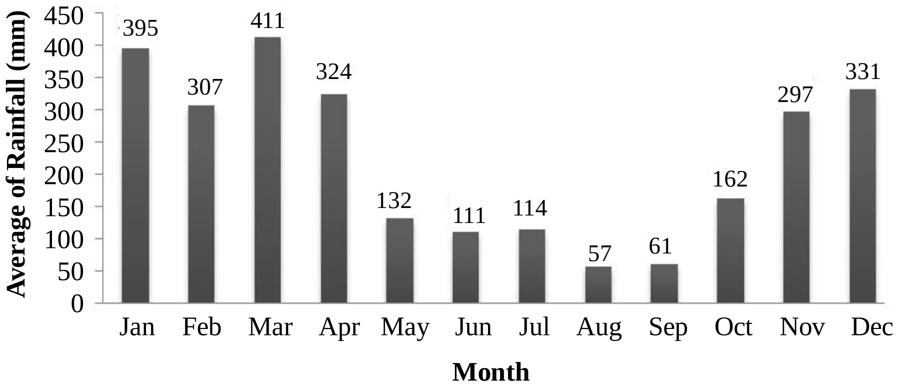

Figure 1. Average of rainfall during 8 years (2000-2007).

Regency of South Sumatra Province. The oil palm plantation has administratively covered about 2.283 ha, and the boundaries are as follows: the boundary of North side is Pedamaran District, the South is Lampung Province, the West is Lempuing and the East is Pampangan District.

The annual rainfall (recorded in milimeter) during 8 years from 2000-2007 showed that the low rainfall was situated from May until October. Meanwhile the high rainfall was occurred from September until April. The rainfall fluctuation during 8 years was presented in Figure 1. From Figure 1, it is shown that the high rainfall was occurred in March with value of 411 mm. From this point of view, it is expected that EFB decomposition is effective, because the water supply is more enough to support the organic matter decomposition. Manwhile, the EFB decomposition will be slow in condition of low water. This condition will be occurred in August with value of rainfall amounting to 57 mm. In this regard, the soil with dry condition, organic material derived from EFB will be decomposed slowly, thus the availability of nutrient for plant growth is also small.

Soil Quality

Data of soil chemical properties of oil palm plantation which were used for field experiments was presented in Table 2. The data were obtained from soil sampling collected from two differences of soil depth which were 0-20 cm and 20-40 cm respectively. The soil chemical variables observed consisted of soil pH, organic C, N, P, K, Mg, cation exchange capacity (CEC), Al and Fe. The results showed that Ultisol has low pH with value of 5.42 at top soil layer (0-20 cm) and soil pH decreased about 0.46 unit to become 4.96 at sub soil layer (20-40 cm).

Content of organic Carbon (C) of this soil was very low up to moderate with value of 2.05% at top soil layer (0-20 cm) and lowered to 0.7% at sub soil layer (20-40 cm). This indicated that Ultisol did not show organic C translocation to deeper soil layer. Meanwhile, soil CEC content was low with value of

Table 2. Some soil chemical properties in experimental site.

Variables	Average	Note	Average	Note
	0-20 cm		20-40 cm	
C-Organic (%)	2.05	Moderate	0.70	Low
pH H_2O	5.42	Acidic	4.96	Acidic
CEC (cmol(+) kg^{-1})	12.84	Low	14.32	Low
N-total (%)	0.18	Low	0.07	Very low
P_2O_5 Bray-I ($\mu g\ g^{-1}$)	6.74	Very low	10.43	Low
Exch-K (cmol(+) kg^{-1})	1.71	Very high	0.61	High
Exch-Mg (cmol(+) kg^{-1})	0.36	Very low	0.35	Very low
Exch-Al (cmol(+) kg^{-1})	1.67	-	2.58	-
Exch-Fe ($\mu g\ g^{-1}$)	1.25	-	0.48	-

12.84 cmol(+) kg^{-1} at top soil layer and the CEC increased up to 14.32 cmol(+) kg^{-1} at sub soil layer. The increasing of CEC in deeper soil layer was suggested not caused by the organic C content, but it was likely caused to by clay content (although the clay content was not analyzed). In this case, Ultisol has generally argillation process (Argillic horison in B layer). The argillation process will be occurred by increasing clay content in deeper soil layer.

Soil content of N, P, and Mg were low until very low and they were lowering up to deeper soil layer (20-40 cm), except for K (Table 2). Due to low of organic C and nutrient content in Ultisol, addition of organic materials were neccesary. The beneficial efect of organic material was as nutrient sources, and it can also improve soil physic, soil chemistry and soil biology, however, in this research, it was only focused on soil chemistry and the application of organic material derived from EFB were given in soil surface only as soil mulching. Except for Al, Fe in sub soil layer was lower than Fe in top soil layer. This fact showed that Al is more mobile compared to Fe, and the exchangeability of Al is often used for soil acidity indicator and it is also used for lime requirement (Budianta and Vanderdeelen 1998). By increasing the soil acidity, the Al content was likely to be higher. In this Ultisol, it was shown that sub soil layer (20-40 cm) has higher Al content with value of 2.58 cmol (+) kg^{-1} than to the top soil layer (0-20 cm) amounting to 1.67 cmol(+) kg^{-1} which was also low pH in the sub soil layer (Table 2).

Empty Fruit Bunches Characterization

Result of Empty Fruit Bunches (EFB) analyses which was used for field experiment is presented in Table 3. As shown in Table 3 that N, P, K, and Mg of EFB were in low criteria, except for organic C content was very high and FEB also had high moisture content. The high content of organic C, mening that the EFB has a good potential as a soil organic material source.

Table 3 showed that EFB material which was applied in Oil Palm Plantation has neutral acidity (pH 6.25) it means that EFB has not decomposed yet. Thus, during pH mesurement it was only soil water detection, because EFB was still in fresh form. The undecomposed EFB can be shown by a low content of N, P, K and Mg, and high ratio of C/N (34.04). Kalium content of EFB was low compared to the result of Mennon *et al.* (2003), that K content was 2.24%. Meanwhile, N, P, Mg and Ca were 0.44%, 0.144%, 0.36%, and 0.36%, respectively.

Tabel 3. EFB characterization used for field experiment.

Variables	Value
N-total (%)	1.10
P-Bray 1 (μ g g^{-1})	0.67
K (cmol(+) kg^{-1})	0.73
pH H_2O	6.25
Mg (cmol(+) kg^{-1})	0.15
C-Organik (%)	36.83
C/N ratio	34.04
Moisture content (%)	73.40

Effect of EFB Application on Some Soil Chemical Properties

Organic C Content and Soil Acidity

Results of organic C and soil pH are presented in Table 4. It is showed that at soil depth of 0-20 cm and 20-40 cm, application of EFB has no significant effect on organic C content in soil. At soil depth of 20-40 cm, organic C content decreased both on control and soil treatments in the range of 65-70%, however, organic C content was likely to raise when EFB application was increased. This is due to the application of EFB was only placed in soil surface as a soil mulching in between of palm trees and it was not incorporated into the soil. Thus it has no effect to the organic C content in soil, but the content of organic C was likely to increase by increasing EFB application. Table 4 also showed that there was no organic C translocation to the deeper soil (20-40 cm) for all EFB application.

Since increasing organic C in soil caused by EFB application, EFB can be potential to supply organic C in soil, but it is needed time to release carbon to the soil or EFB is required to decompose prior to be used it. According to Lim and Zaharah (2000), EFB can be used as an organic mulch on young and/or old oil palm crop.

Furthermore, application of EFB affected soil pH on top soil layer of 0-20 cm. It is because EFB application on soil surface can give soil reduction (anaerobic). The reduction condition can reduce cations from high valence to lower valence for example ferri becoming ferro, mangani to mangano and resulting hidroksil ion. Hidroksil ion which was

Table 4. Effect of EFB application on content of organic C and soil pH.

EFB application	0-20 cm		20-40 cm	
	C-org^{ns} (%)	pH	C-org^{ns} (%)	pH
Control	1.53	4.74 a	0.54	4.94 a
1 times for 1 year	1.65	5.25 ab	0.67	4.72 a
2 times for 2 years	2.06	5.41 ab	0.71	5.26 a
3 times for 3 years	2.35	5.85 b	0.80	4.87 a
4 times for 4 years	2.64	5.85 b	0.80	5.00 a

Note: ns= non significance different and values fllowed by same letter showed no significance different according to DMRT 5% test.

released, caused soil pH becoming more alkaline (Asghar dan Kanehiro 1980; Hue and Amien 1989; Pocknee and Sumner 1994; Budianta 1999).

From Table 4, it is also shown that soil pH on top soil layer (0-20 cm) was likely to increase as increasing the rate of EFB. Application of EFB at 120 Mg ha^{-1} applied for 3 years continuesly and applied at 40 Mg ha^{-1} each year showed increasing soil pH compared to control plot without EFB and/or at lower rate of EFB application. Changes on soil pH was 1.1 unit compared to control plot. However, increasing the EFB rates did not show any significant difference on soil pH change.

The other result showed that soil pH on top soil layer (0-20 cm) was relatively higher than the sub soil layer (20-40 cm), except for control. It means that EFB applied as a soil mulching did not affect the soil pH on sub soil layer, although the rate of EFB was increased.

Cation Exchange Capacity

Resuts of CEC of Ultisol after applied EFB is presented in Table 5. Based on the result, it is shown that at both soil depth of 0-20 cm and 20-40 cm, application of EFB did not give any significant difference on soil CEC. The CEC values of both soil depth did not change. The high CEC with value of 16.38 cmol (+) kg^{-1} was found on EFB application on sub soil layer at 160 Mg ha^{-1} and applied for 4 years continuesly and the lowest one was found on control plot with CEC value of 11.59 cmol (+) kg^{-1} and it was also found on sub soil layer at 20-40 cm depth. The increasing of EFB application was likely insignificant to CEC. This is caused by EFB applied in undecomposed form and the application of EFB was only placed in soil surface without soil incorporated.

From Table 5, it is also shown that soil CEC on sub soil layer was higher than top soil. This is suggested that increasing CEC on sub soil layer was caused by the contribution of CEC derived from clay translocation to a deeper soil. It can be seen that CEC value on sub soil layer (20-40 cm) was likely to increase compared to the top soil layer and this phenomena did not have a correlation to the organic C content.This is because on soil deepth of 20-40 cm was suggested to be dominated by soil clay fraction. This datum is matched as reported by Seilsepour and Rashidi (2008) that the increasing of soil clay caused increasing of CEC and most of CEC was generally influenced by organic C in soil.

Tabel 5. Effect of EFB application on soil CEC.

EFB application	CEC (cmol(+) kg^{-1})^{ns}	
	0-20 cm	20-40 cm
Control	12.29	11.59
1 time for 1 year	11.75	13.81
2 times for 2 years	13.05	13.49
3 times for 3 years	13.87	16.32
4 times for 4 years	13.22	16.38

Note: ns = non significant.

Nitrogen and Phosphorus

Results of total Nitrogen (N) and availability of phosphorus (P) on soil applied by EFB can be seen on Table 6. Based on the results, it was shown that application of EFB had insignificantly effect on total N and availability of P at soil depth of 0-20 cm, meanwhile the application of EFB has significant effect on total N, but not for P availability on 20-40 cm soil depth.

Although EFB application did not give any significant effect on total N in soil, but the increasing rate of EFB application was likely to increase total N in soil. This is because the EFB which was added to

Table 6. Effect of EFB application on total N and P availability.

EFB Application	0-20 cm		20-40 cm	
	Total N (%)	P-avail (μ g g^{-1})^{ns}	Total N (%)	P- avail (μ g g^{-1})^{ns}
Control	0.13 a	6.32	0.05 a	11.18
1 time for 1 year	0.14 a	7.69	0.07 ab	10.56
2 times for 2 years	0.17 a	7.31	0.07 ab	11.24
3 times for 3 years	0.21 a	5.98	0.08 bc	8.50
4 times for 4 years	0.23 a	6.39	0.09 c	10.65

Note: ns= non significance different and values fllowed by same letter showed no significance different according to DMRT 5% test.

soil did not undergone completely decomposition, thus N supply derived from EFB can not be expected as N supply. For all soil depth, N total content on top soil (0-20 cm) was higher than sub soil layer (20-40 cm). This indicated that N did not translocate to a deeper soil.

Moreover, P availability on sub soil layer (20-40 cm) was likely to be higher than top soil (0-20 cm). This can be explained that P in acidic soil is generally not available due to bound by Fe, Mn or Al elements. Through clay translocation process, it is suggested that P together with clay moved to deeper soil, thus P in top soil is decreasing (Table 6). According to Budianta (1999), at acidic mineral soils with soil pH below 5, Al and Fe elements will adsorp P and forming unavailable Al-P and Fe-P forms.

Potassium and Magnesium

Soil macroelements which were analysed in this experiment were exchangable potassium (K) and magnesium (Mg). Both elements are required for oil palm growth. The result of exchangeable K and Mg analysis showed that application of EFB did not have any significant effect on exchangeable K for all soil layers, but it had effects on exchangeable Mg on top soil layer only (Table 7).

Based on Table 7, exchangeable K on soil depth of 0-20 cm was higher than 20-40 cm depth. It means that exchangeable K was immobile and it can not be translocated to the deeper soil (20-40 cm). Beside that, the higher exchangeable of K on top soil layer might come from this organic matter, although it did not have significant effect.

The other result showed that application of EFB at 80 Mg ha^{-1} of EFB applied for 2 years (each year 40 Mg ha^{-1}) had a significant different compared to control plot by increasing Mg about 0.27 cmol(+) kg^{-1} (exceeding 100%). Meanwhile on 20-40 cm soil depth, application of EFB did not have any significant effect on exchangeable Mg in soil. However the exchangeable Mg in both of soil depth was still in low content, this was enfluenced by soil pH in acidic condition. At soil pH below than 6.0, the exchangeable Mg decreased quickly (Fauzi *et al.* 2002).

Table 7. Effect of EFB application on exchangeable K and Mg in soil.

EFB application	0-20 cm		20-40 cm	
	Exch-K (cmol(+) kg^{-1})^{ns}	Exch-Mg (cmol(+) kg^{-1})	Exch-K (cmol(+) kg^{-1})^{ns}	Exch-Mg (cmol(+) kg^{-1})
Control	1.66	0.17 a	0.40	0.35 a
1 time for 1 year	1.83	0.32 ab	0.48	0.36 a
2 times for 2 years	1.78	0.44 bc	0.68	0.32 a
3 times for 3 years	1.61	0.50 c	0.76	0.36 a
4 times for 4 years	1.67	0.39 bc	0.71	0.34 a

Note: ns = non significance different and values fllowed by same letter showed no significance different according to DMRT 5% test.

Table 8. Effect of EFB application on exchangeable of Al and Fe in soil.

EFB application	0-20 cm		20-40 cm	
	Exch-Al (cmol(+) kg^{-1})^{ns}	Exch-Fe ($\mu g\ g^{-1}$)^{ns}	Exch-Al (cmol(+) kg^{-1})^{ns}	Exch-Fe ($\mu g\ g^{-1}$)^{ns}
Control	0.97	1.93	1.49	1.76
1 time for 1 year	0.35	1.44	1.24	1.88
2 times for 2 years	0.10	1.17	0.68	1.63
3 times for 3 years	0.09	3.66	0.95	1.81
4 times for 4 years	0.19	3.95	1.00	1.37

Note: ns= non significance different.

Content of Amphoter Metals

The amphoter metals which were analysed are exchangeable Al and Fe in soil. Results of exchangeable Al and Fe in soil showed that application of EFB did not have any significant effect on two amphoter metals. This can be seen on two soil depths that the two amphoter metal were not affected by EFB application (Table 8). It means that application of fresh EFB was not effective to immobile exchangeable Al and Fe.

However from the two soil depths, it is seen that value of Al on 20-40 cm was higher than 0-20 cm, but it was not for exhangeable Fe. This has a relation to soil pH on sub soil layer that soil pH on the sub soil layer was likely to be lower (acidic) than the top soil. Many experts reported that low soil pH caused high Al and Fe solubility that can be fixing P solubility (Budianta 1999). High Al concentration in soil solution is also toxic for plant growth and it can be inhibiting root crop development.

Based on Table 8, it is also shown that highest Fe was found on 0-20 cm soil depth and addition of EFB at the rate of 160 Mg ha^{-1} applied for 4 years with value of 3.95 $\mu g\ g^{-1}$, and the lowest one was found at 80 Mg ha^{-1} of EFB with value of 1.17 g g^{-1} on 20-40 cm soil depth.

CONCLUSIONS

It is concluded that application of EFB applied as a soil mulching only affected soil pH and exchangeable Mg in top soil layer (0-20 cm), total N in sub soil layer (20-40 cm), and EFB did not have any significant effect on P, K and some soil properties such as organic C, CEC, Al and Fe. Some soil chemical properties observed on sub soil layer (20-40 cm) generally lower than top soil layer (0-20 cm), except for exchangeable Al, CEC and P availability.

It is suggested that EFB is required to be chopped and to be decomposed before applied to the land. Then, method for EFB application is not only placed on soil surface without soil cultivation, but it needs to be incorporated in the soil or EFB is placed to plant hole, thus nutrient rephlenished from EFB will be available to the arable layer.

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