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BIBLIOGRAPHICAL REVIEW ABOUT MINERAL NUTRITION AND FERTILIZATION OF PALM TREE (*Elaeis guineensis* Jacq.) AT PRODUCTION STAGE

KOUAME Konan[1*], CAMARA Brahima[3], KONE Boake[2], BALLO Koffi[2], SEKOU Diabate[2] and AKE Severin[3]

[1]Laboratoire de Physiologie Végétale, UFR Sciences Biologiques, Université Péléforo Gon Coulibaly, BP 1328 Korhogo, Côte d'Ivoire

[2]Centre National de Recherche Agronomique, Station de La Mé, 13 BP 989 Abidjan 13, Côte d'Ivoire

[3]Laboratoire de Physiologie Végétale, UFR Biosciences, Université Félix Houphouët-Boigny, 22 BP 582 Abidjan 22, Côte d'Ivoire

ABSTRACT

The stage of production preceding is characterized by the production of the palm plantation. During the exploitation, fertilization allows the palm tree to express its full potential for sustainable production. This work made it possible to take stock of the knowledge on the nutrition and the fertilization of the oil palm through the major production zones, and especially the consequences of the uncontrolled use of fertilizers on the environment. From the start of production, fertilization is driven by an annual intake of potassium, the dose of which is established by foliar diagnosis, used as the main method of studying the mineral nutrition. The doses applied vary according to the different production zones. For a necessary balance of all mineral elements, phosphate, nitrogen and magnesium fertilizers are applied to certain types of soil for a better expression of the production potential of the material used. The main stages of fertilizer application are: fertilizer selection, determination of doses, dates and methods of application. Fertilization makes it possible to obtain a surplus value at least equal to three times the expenditure granted when they are brought in quantity and balance. Because uncontrolled use of fertilizers acts dangerously on the environment, water, humans, soil and greatly reduces biodiversity. The cultivation of oil palms, with the advent of hybrids and a rational fertilization policy, can be a better tool for the development and improvement of the living standards of small rural farmers in the tropical world, the main component of the production chain.

Keywords: Mineral fertilization, palm tree, production stage, potassium, profitability

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1. INTRODUCTION

The 1st part of this bibliographical review was about the mineral nutrition and fertilization of the palm tree from the pre-nursery to the young tree stage. The plantation stage, generally, characterized by the production the fertilization is dominated by the quantity of potassium which measures vary from one region to another. In all the soil of tropical climate, potassium is the 1st factor that sets a limit to the output of palm nut bunches, and many studies point out important productivity gains, including potassium fertilizer supply even moderate in the system of palm tree based culture. They are the studies made by Rafflegeau (2008) in Cameroon, in Côte d'Ivoire by Ballo *et al.* (1994), Ballo (2009); in Malaya by Ng (1986); in Indonesia by Jamaluddin and Zulkifli (2005); in Brazil by Martin and Prioux (1972), Pachecco *et al*. (1985) and in Oceania by Breure (1982).

The results of these experiments allowed establishing the fertilization plan that permit to enhance the value of the soil reserve by taking into account the specific needs according to the weather conditions. The mineral fertilization, like that, is the main component of agriculture respect full of the environment because it increases the supply by avoiding the excess.

To keep the competitiveness of palm oil beyond world level, we must obtain a higher productivity thus a good mineral fertilization is necessary. It is vital to explore all the possibilities to reduce the fertilizer cost, and, permit a top efficiency of the fertilizer supplied. To reach this target, it is useful to have a better nutritious stability, of its main components and the working of its mechanism in different soil and environment. The researchers must be developed in the entire domain in which it is possible to save fertilizer or improve their efficiency namely: the choice of the fertilizers, the measures, the date and the method of spreading, the loss control, the soil preserving, the swallowing efficiency, the reduction of mineral export in the picking and the effects of the fertilizers use on the environment. This study aims to make the state of knowledge about nutrition and mineral fertilization of palm oil at the production stage, through all the key areas of culture. This paper presents various information for a comprehensive understanding of the issue that concerns us, namely: (i) changes in fertilizer programs in a growing area to another, (ii) the optimization of the supply of mineral fertilizers under oil palm cultivation, (iii) the negative effects of the uncontrolled application of mineral fertilizers on the environment and on human health.

2. STAGE OF PRODUCTION

This stage is characterized by the entry into production of the plantation. The economically productive phase of the oil palm starts three years after planting and lasts 20 to 30 years

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depending on the region and the plant material used (CNRA, 2006). To express its production potential, planting should be properly maintained and smoke.

Regarding the plant material used, 5 essential origins are used by breeders worldwide: Deli origin, La Mé origin, Pobé origin, Yangambi origin and Sibiti origin (Gascon and Berchoux, 1964). Mé, Pobé, Yangambi and Sibiti Origins are African and Asian Deli origin is. These origins according to these authors have different characteristics. For bunches production, the Deli is much less than each of the African origins and La Mé and Pobé origins differ from those of Sibiti and Yangambi by more bunches (Gascon and Berchoux, 1964). However, the average weight bunches is, cons, much higher among the Deli than among African origins, among which is much lower in the La Mé and Pobé origins (Gascon and Berchoux, 1964). These origins that have simultaneously the two varieties (*Dura* and *Tenera*) were used in the selection for the production of high-yielding hybrids popularized in all producing areas of oil palm.

The first improvement based exclusively on mass selection (*Dura* x P*isifera*) gave *Tenera,* which launched the real market oil palm improved seeds worldwide. Subsequently, a multitude of inter-specific crosses between *Elaeis guineensis* and *Elaeis oleifera* (Latin American origin) and intra-specific were the subject of several studies (Cochard *et al*., 2001). They helped to make available to the producer countries of oil palm varieties with high yield and large agro-ecological adaptability.

To avoid that the vegetal material must be an obstacle, we must use the selected seed from the official station of production (Cochard *et al.*, 2001; Bakoumé *et al.*, 2006).

When exploiting a palm grove, the fertilization allows the specific production potential of the vegetal material to express itself for a long time. At the stage of production, it is the only mean to keep at the same time an optimum mineral situation of supplying or make up for a critical situation (Rafflegeau, 2008). This pattern also reflects a surge in fertilizer production phase on any plant material positively affects vigor and allows the expression of its intrinsic characteristics that have a direct impact on the production of components (number of bunch and average bunch weight) (Rodrigues *et al.,* 1997; Dubos *et al*., 1999; Corley and Tinker, 2003).

Upon entry into production of the palm, fertilization is controlled by annual monitoring of mineral nutrition palm trees by foliar diagnosis (Caliman *et al.,* 1994). Potassium is the most important nutrient in the production of oil palm (Ochs *et al.,* 1991; Rafflegeau, 2008). The objective of a high yield of number and weight of the bunch cannot be achieved without an adequate supply of this nutrient. On every continent, it has been known for long that it is important to monitor potassium nutrition palm production to reach the maximum performance

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(Ochs, 1965; Ruer, 1966; Anon, 1968; Bachy, 1969; Pacheco *et al.,* 1985; Hornus *et al*., 1987; Anon., 1992).

However during fertilization, a proper balance between all the elements becomes very important to achieve the highest returns. Depending on different soils, climates, growing techniques and planting materials, fertilizer suitable scales are needed to achieve a good nutritional balance (Ng, 1977; Barral *et al*., 2004). This is important for nitrogen and potassium. Poor nitrogen nutrition can induce a depressive effect on production, while in equilibrium these two elements lead to positive interaction (Ollagnier *et al*., 1983). However, there can be no question of any mention fertilizer formulas used in the world, because of the multiplicity of cases. However, include a number of specific cases from which it is possible to evaluate the biggest global trends (Ollagnier *et al.,* 1970).

In South and Latin America's countries, the potassium needs is dominant at the full grown age. The magnesia and the baron step in according to the needs (Pacheco *et al.,* 1985; Tampubolon *et al*., 1990).

In Brazil, on the vertisols, characterized by their clay content and a lack of nitrogen due to asphyxia, the potassium chloride and the sulphate of ammonium are supplied to the measures of 1200 g and 750 to 1500 g respectively per tree and per year (Lauzeral, 1980; Pacheco *et al*., 1985).

On the Latosols of Brazil, deprived of phosphorus, 500 g of urea, 1500 g of superphosphate triple, 1500 g of potassium chloride, 750 g of kieserite and 75 g of borax are supplied per plant and per year was bring as mineral fertilizer (Lauzeral, 1980).

On the recent alluvium of Colombia, rich soil in absorptive complex unbalanced of high calcium pressure and a lack of chlorine, the supply of mineral fertilizer are composed of potassium chloride (in a measure of 1250 g), of kieserite (in a measure of 650 g), of urea (in a measure of 250 g) and of borax (in a measure of 75 g) per plant and per year (Ollagnier *et al*., 1970; Lauzeral, 1980).

On the volcanic soils of the Equator, rich in mineral elements but with a bit lack in nitrogen and magnesium, the mineral fertilizer generally supplied in the palm grove is composed of 1500 g of urea, 750 g to 1000 g of kieserite and 75 g of borax per plant and per year (Lauzeral, 1980).

In Peru, on the rich alluvium deprived of magnesium, only the potassium chloride is supplied to the measure of 500 g per plant and per year (Daniel and Ochs, 1975).

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In Africa, there are two trends; one is mainly potassium in the western part and the other potassium and magnesium in the equatorial area (Ochs *et al*., 1991; Ballo *et al*., 1994).

In Côte d'Ivoire, desaturated ferrallitic soil on tertiary sand of old forest or poor in potassium, only the potassium chloride is supplied to the palm grove regarding to the measure from 1000 to 1500 g per plant and per year. On the contrary, on the old savannah, the potassium chloride is supplied to measure from 1500 to 2000 g per plant and per year (Ollagnier *et al*., 1970; Ollagnier et Ochs, 1981; Ollagnier *et al*., 1987; CNRA, 2006).

In Nigeria, on the acid soil poor in potassium, 2300 g of potassium chloride per tree and per year is necessary for mineral fertilizer of the oil palm in production (Ollagnier *et al*., 1987).

In Cameroon, on ferrallitic soil, the plantations at the production stage receive an annual supply of potassium chloride and of kieserite in the respective measure from 1000 to 2500 g and of 500 g per plant and per year (Rafflegeau, 2002; Rafflegeau, 2008).

In Congo, on the Latosols at the beginning of the production stage, the supply contain superphosphate triple in a measure between 750 to 1000 g, 500 g of ammonium sulphate in addition to the potassium chloride in a measure between 700 and 1000 g per plant and per year (Dubos *et al*., 1999).

In Asia on the contrary, it's added to the potassium dominance some needs in phosphorus and magnesia (Ng and Tan, 1974; Ummar *et al*., 1976).

On the andic ferralitic soil or on tertiary sediment of Indonesia, poor in potassium (Fallavier and Olivin, 1988), the plantation at the production stage receive an annual supply of potassium chloride in a measure from 1500 to 2500 g and rock phosphate in a measure of 2000 g per plant and per year (Ng, 1986; Tampubolon *et al*., 1990).

In Malaya, on the rich alluvial soil with an absorptive unbalanced complex, 3000 g of potassium chloride, 500 g of kieserite and 1500 g of natural phosphate are necessary to realize the scale of the fertilizer under the palm grove at the production stage (Ng, 1986). In sum, it is vain to deduce a universal formula because many climatic and soil factors play a major role.

The potassium is the most recommended element to produce palm tree and its reserves vary according to the type of soil (Ummar *et al*., 1976). The potassium intervenes in many physiological functions of the palm tree. This element is absorbed by the plant in its ionic form K^+. It intervenes in the translocation of sugar, in the formation of starch, in the metabolism of proteins, in the ionic and osmotic regulation as well as in the opening and closing process of the stomates (Manciot *et al*., 1979; Elalaoui, 2007). The sensitivity of these mechanisms is assigned

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in case of potassium deficiency. The closing takes longer to occur and it is not complete. Water is lost while photosynthesis is no longer active. Therefore, a rational potassium fertilization is required to improve the efficiency of water if soil moisture deficit (Martin-Prevel, 1984). Potassium is needed for many enzymatic functions and for the metabolism of proteins and carbohydrates.

Potassium is the most abundant cation in the cytoplasm of cells. It balances the mobile anions in vacuole and mobile anions in xylem and phloem (Fujiwara, 1975). In addition, it is involved in the accumulation of organic acids in the plant (Ollagnier *et al*., 1977).

The importance of the potassium on the production of palm tree was widely proved by Ochs *et al*. (1991). According these authors, the increase or relative lost of the production when the content in foliar (F17) of potassium increases or diminishes of 0.1 % represents about 5 % of the maximum of the production authorized by the other ecological factors. Due to its influence of the absorption of the nitrogen and phosphorus, the potassium intervenes directly on the growth of the palm tree (Tan, 1973; Fallavier and Olivin, 1988).

The ferrallitic soils of South Africa are poor in potassium, but it has the advantage to react quickly at the slightest request and allow with the foliar diagnosis (FD), to control the nutrition accurately. On these soils, the gradual fall of the content due to the age is easily stopped by the potassium fertilizer which permits to make a profit of 5 % between a content of 0.9 and 1 % of dry matter and more than 10 % beyond (Ollagnier and Ochs, 1981; Fallavier and Olivin, 1988).

In Indonesia, on the liparitic soils (volcanic soil or alluvial soils), the content in potassium diminish slowly from 0.9 to 0.8 % of dry matter between 12 and 20 years. The supply of potassium has no significant effect on the foliar content and on the yield. The increase of the yield is due to other treatments (phosphoric) (Ollagnier and Ochs, 1981).

In Malaya, Foster and Goh (1976), in experimentation on the alluvial or volcanic soils, deduced that the potassium must be involved in the combination of the most profitable fertilizer for the palm tree.

In Colombia, on alluvial soils, the problem of potassium nutrition is superimposed on a chlorine deficiency. The KCl intake corrects the deficiency and chlorine with a production gain of about 10 % (Lauzeral 1980; Ollagnier and Ochs 1981). Plant cells have a high permeability to the K. This explains the preferential uptake of K^+ oil palm relative to Ca^{2+}, even at a much lower concentration. This is true for desaturated lateritic soils (Benin, Côte d'Ivoire and Sumatra) where KCl flows easily increase foliar K levels (Ollagnier, 1987).

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The needs of potassium in oil palm are combined often with poor soils affected by climate requirements condemn to be grown (Ng, 1977). Potassium deficiencies relevant to all growing areas of the tropical world (IRHO, 1992). They result both of the importance of exports and poverty ferrallitic desaturated derived from granites, sandstones, sedimentary sands that are very low in potassium. Potassium deficiency can also be enhanced by the contribution of mineral fertilizers containing antagonistic elements like calcium content in phosphate fertilizer and magnesium (IRHO, 1992).

The phosphorus export concerning the palm tree is weak. It represents tenth of the potassium or nitrogen export (Pacheco *et al*., 1985). However, the phosphorus plays an important role in the development and of the palm tree production. It intervenes in the regeneration of the triphosphoric adenosine acid, in the composition of phosphoproteins, in the development of the system of roots, in the rigidity of the plant, in transfer of energy and in the metabolism of the proteins (Martin and Prioux, 1972; Pacheco *et al*., 1985; Aïssa, 2010). According to Moughli (2000), soils made to release phosphate fertilizer phosphorus as $H_2PO_4^-$, HPO_4^{2-}, and PO_4^{3-}. Some of these anions are absorbed by the roots. Another part reacts with cations such as calcium in a basic soil, iron and acid soil aluminum to form minerals that are sparingly soluble and therefore less available to plants.

For Pacheco *et al*. (1985), the application of phosphate fertilizers allows palm oil to double production regimes on phosphorus-poor soils (including latosols of Brazil). This gain comes to 2/3 of the increase in the number of bunches and for 1/3 of their average weight. The phosphate fertilizer makes it possible to double yields in young age and almost quadruple to 10 years (with an intake of 1000 to 1500 g per foot per year) on latosols of Brazil and recent alluvial soils of Colombia.

The deficiency in phosphorus is met on the volcanic soil of the North of Sumatra (Indonesia) and in the sedimentary Amazon basin (Brazil) (Pacheco *et al*., 1985). But, it exist some deficiency in Africa, on Precambrian soils (old base) and the quaternary sand of Côte d'Ivoire coastline and West Africa (Hornus *et al*., 1987; Caliman *et al*., 1994). It records the best answers to the phosphate fertilizers on these soils with the lowest phosphorus levels (Manciot *et al*., 1979; Hornus *et al*., 1987; Caliman *et al*., 1994). The correction of the lack in phosphorus, on the tertiary sand turn the yield from 12 to 20 tone of bunches par ha and per year, with the optimal measures (which vary between 150 and 450 kg/ha/year) of superphosphate triple (Foster and Goh, 1976). The absorption of phosphorus is highly related with the one the nitrogen. Consequently, the improvement of the vegetative growth caused by the application of phosphate enriched fertilizers can attributed to its indirect influence on the content in nitrogen of tissue (Manciot *et al*., 1979; Ollagnier and Ochs, 1981).

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According Prevot and Ollagnier (1959) and Ollagnier *et al*. (1970), the P and N are components of plant proteins according to proportions that must be constants for the same organ. If N increases or decreases, proteins can have a normal composition that if the P content increases or decreases in parallel. Otherwise, the plant no longer normally synthesizes its proteins and the nitrogen is present in soluble form.

The nitrogen is the 1st of the exportations rank. The response to the nitrogenous fertilizer is less frequent at the full-grown age (Ochs and Ollagnier, 1977). We observe many effects of the nitrogenous fertilizer on the color and the vegetative growth of the sprout but that effects disappear at the production stage (Hornus *et al*., 1987; Caliman *et al*., 1994). This lack of response is due to the rapid mineralization of the organic matter, the supply covered up by the rain and the symbiotically fixation of the atmospheric nitrogen by the front plant. Yet, out of hundred known experiments about thirty respond to the nitrogenous fertilizer. These responses intervene especially in Malaya and in Indonesia (Ummar *et al*., 1976).

In Malaya, out of the experiment studied by Foster and Goh (1976), the nitrogenous fertilizer intervenes seven times out of twenty in the formula of optimal fertilizer. In Indonesia on the contrary, on the liparitic soils, richer in nitrogenous, the response to the nitrogenous fertilization is more important (Ummar *et al*., 1976).

Rosenquist (1962) and Tan (1973) found that increasing nitrogen application; we get a higher leaf emission rate and a greater number of leaves in the crown. For Ollagnier *et al.* (1970) and Achuthman and Sreedharan (1983), the application of nitrogen increases the foliar content of phosphorus and potassium with the result, improved performance. The absorption of nitrogen is highly significant in relation to that of phosphorus thus improving vegetative growth due to the application of phosphate fertilizers can be attributed to its indirect influence on the N content of the tissue (Manciot *et al*., 1979; Ollagnier and Ochs 1981).

The responses to the nitrogenous fertilizer in West Africa and South American are rare and correspond to the intervention of minor factors like erosion, hydromorphy of the soils and the competition of harmful adventitious like *Imperata* (Ollagnier and Ochs, 1981; Pacheco *et al*., 1985). Ultimately, nitrogen fertilizers do not play a sufficiently important role in the production of palm oil but on the other hand, in deficit situations, the effectiveness and efficiency of these fertilizers can be very high. The dose levels used, expressed as ammonium sulfate range from 150 to 750 kg per hand per year (Ochs and Ollagnier, 1977).

Nitrogen deficiency appears to be relatively rare in adult palm (Bachy, 1968; Hornus *et al*., 1987). In case of deficiency before using mineral fertilizer, we must check accurately if there are

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those minor factors (Ollagnier and Ochs, 1973). By eliminating those indirect causes we can improve the nitrogenous nutrition economically.

In West Africa, the agro industries don't supply nitrogen to the palm grove at the production stage (Hornus *et al*., 1987; Caliman *et al*., 1994), by contrast with what happens in South-east Asia (Pacheco *et al*., 1985; Tampubolon *et al*., 1990; Anon, 1992; Rodrigues *et al*., 1997; Caliman *et al*., 2007).

Margat *et al*. (1979) indicate that we commit errors on the alluvial and volcanic soils by always attributing the responses of potassium chloride to the only element potassium, since the ignorance of the deficiency in chlorine lead to lots of several hundred of kilos of oil per ha. Uexkull (1985) showed that the importance of the chloride nutrition comes from the existence of the double action on the leaves. The application of chloride fertilizer increases the level of Cl^- of the leaf as well as the Ca^{2+} and by antagonism; the Ca^{2+} reduces the content of the foliar in K^+. Thus, chlorine plays a central role in the physiology of the plant. It acts as a coenzyme and accelerates photosynthesis (Fujiwara, 1975). Carbohydrate metabolism, reduction of soluble sugars and starch accumulation are in the chlorine dependence (Ollagnier *et al*., 1977).

Experiments carry out in Colombia (Ollagnier and Ochs, 1971), in Philippines (Uexkull, 1972; Magat *et al*., 1975; Margate *et al.,* 1979; Ognis *et al*., 1979), in Côte d'Ivoire (Ollagnier *et al.*, 1976), in Indonesia (Ummar *et al*., 1976 and Ollagnier *et al*., 1983) and in Peru (Daniel *et al*., 1975) have shown that the application of KCl induced increased yield and concentrations of Ca^{2+} and Cl^-, but a reduction in K^+ content in the leaves.

For Bové *et al.* (1963), traces of Cl^- are necessary for the evolution of oxygen in the photosynthesis. According Terry (1977), Cl^- deficiency reduces the rate of multiplication of the cells in the leaves, resulting in a decrease in growth and leaf area. Only traces of chlorine would be needed in establishing this function. Uexkull (1972) showed that Cl was involved in water conservation. Foster and Goh (1976) analyzed the leaves of oil palm and found that the guard cells lack chloroplasts and starch. This indicates that the oil palm needs a Cl adequate intake for stomata opening.

Concerning the magnesium, it is important in most of the vital function of the plant. It takes part to the formation and to the set of sugar reserve, carbohydrate and vitamins (Fallavier and Olivin, 1988). The availability of magnesium depends on the mineralogy of clay. The montmorillonite soils are generally richer and well plugged than the kaolinite one (Foster and Goh, 1976; Ng, 1977).

According to Eschbach (1980), the boron is the most important trace element for the palm tree. It plays an essential role in the migration and the use the assimilation product, in the absorption of

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potassium, of phosphorus and magnesium. The manure nitrogen and phosphate promoting growth, increasing the boron needs in oil palm (Turner, 1981). The lack of boron can be corrected by supply or spraying the soil with the foliar of borax which contains between 36 and 65 % of boron (Ollagnier et Valverde, 1968; Elalaoui, 2007).

Iron is a trace element which is necessary in great quantity (Eschbach, 1980). Iron is a component of many hem enzymes. The hem is a complex which constitutes the prosthetic group of many enzymes of the Krebs cycle (catalase, peroxydase, succino-deshydrogenase). The iron plays an essential role in the standard working of the metabolic responses (photosynthesis, breathing) (Eschbach, 1980).

The lack of iron is essentially due to the problem of availability. This reduces because of a bad drainage (iron becoming ferrous), of an increase of pH or the acid soil, rich in phosphorus and other heavy metals which stop the iron and become less assimilated (Krauskoff, 1972; Eschbach, 1980; Manciot *et al*., 1980). The sulphate of iron is used to correct the lack of iron. The numerous experiments worldwide have shown that all the minerals may be useful at one time or another, to a location or to another, due to the extreme heterogeneity of mineral nutrition in space and in time. This is insurance that must be paid to ensure the homogeneity of future planting.

3. FERTILIZATION PRACTICE

Once the lack is detected, we choose the fertilizer by determination the necessary measures according to the acuteness of the lack and the age of the tree. The lacks are point out by the foliar analysis or the soil analysis (Ochs and Olivin, 1975; Ollagnier *et al*., 1987; de Taffin and Rognon, 1991).

Most of the time, the lacks are numerous and their correction require the application of several mineral elements. Although, the fertilizer components do not always correspond to the needs of the palm tree, it's proved for example that moreover the potassium lack correction, the potassium chloride can limit the chloride deficiency (ferralitic soil of Côte d'Ivoire) since the ammonium chloride fill an half part of the lack in chlorine or in nitrogen (andic ferralitic soil of Asia) (Ollagnier *et al*., 1970). The fertilization study is useful if they don't lead to the definition of the rule of the practice on which the farmer can rely on to design a rational policy of mineral fertilization. The top concern, the choice of the fertilizer that is closely related to agronomic and financial requirements, then come the concepts of dose, evolution of these doses by age and needs of the plant and, finally, mode Application (manual or mechanical) withholding formulas.

3.1 Fertilization rules to follow

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The quantities of fertilization to be used depend on the number planted trees. The farmer must regularly update the inventory of its trees per year of planting. According to the recommendations and the measures per tree, the farmer can exactly work out the needs of the campaign.

Some metallic box of recovery can be used. The level corresponding to the measure is marked on the measure box and then cut off at the level of this mark. By this way, the content of the box corresponds to the measure of the fertilizer for which it has been made thus it is necessary to condition as much box as the fertilizer measures. Before the application of the fertilizer, the circles are cleaned so that the fertilizer can be useful to the palm tree. The fertilizer is spread evenly on the full surface of the circle. For young palms, the round is of variable size; its radius is determined by the ground projection of the horizontal fins. For older trees, the spreading range is 2 to 2.5 meters (Ollagnier *et al*., 1970; Jacquemard, 1995). Sometimes, we must apply several simple fertilizers, the urea, the potassium chloride and sulphate of magnesium for example. It's possible to mix before on a clean cemented area. It is also possible performer layers of which one for each type of fertilizer. This option is easiest and implies less risk of errors because some fertilizers can't be mixed up. We fill the bucket which permits to carry things, with the product to spread along the palm tree line. It is enough to take in the bucket one or several measure box at the level of each tree to spread the content carefully. Besides these general rules, it must also proceed with the pruning of palm oil in order to facilitate the movement and harvesting regimes.

3.2 Spreading date

Many experiment made in the world showed the importance of the choice for the mineral fertilizer application date which efficiency depends on the maximum of rain. If the dry season is not to be retained, the strong rain of the rainy season is having the disadvantage to leach out the supplied elements (Ollagnier *et al*., 1970; Ollagnier and Ochs, 1981; Tailliez, 1982). The most favorable period is the one which profits of enough rain to make easier the absorption all the mineral elements. The IRHO has sought to investigate the effect of spreading fractional compared to single applications at different times of the year

In West Africa, where there are two rainy seasons the young palm grove are fertilized at beginning of each rainy season (April and August). The older plantations receive the fertilizer only in August (before the short rainy season) (de Taffin and Ochs, 1973; Ollagnier and Ochs, 1981).

In South America, where the rains are abundant, the appropriate period to spread the fertilizer are the months of December and January which indicate the end of long rainy season (January to April) (Pacheco *et al*., 1985).

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In South East Asia on the contrary, the rainy season is long (September to July) oblige to spread the fertilizer in July or in August which correspond to the dry season comparatively (Ollagnier and Ochs, 1981; Tailliez, 1982).

3.3 Direction for spreading

Studies by IRHO define the rules for manual fertilization of palm groves. The conclusions have been drawn from the application tests KCl in a ring around the stem which has doubled the production of palm schemes per tree and per year.

The radius of the circle of spreading depends on the age (from one meter to one year and the increase is of 0.5 each year till 5 years) (Ollagnier *et al*., 1970). This practice concentrates the fertilizer at the trunk bottom.

Ruer (1967) and Jourdan and Rey (1997), studies, helped to better know the distribution of the root system of oil palm in the ground. Palm oil comprises essentially two broad categories of roots:

- ✓ inking roots sinking almost vertically and deeply in the soil which role is only physic,
- ✓ surface roots occupying the layer from 0 to 50 cm which bring offshoot leading to thin roots with white end.

These are offshoot of IV order and the white end of these roots play the role of root hairs (Ruer, 1967; Ballo *et al*., 1994). Root distribution in the horizontal plane is the essential factor of choosing a method of application. The roots concentration on the surface diminishes gradually when we go far from the trunk, but the wide extension go together with the ageing process of the trees (Dufrène, 1989; Jourdan, 1995).

This way of root extension leads during the sprout period to the concentration of the fertilizer around the young plant, where the roots are numerous.

The need to seek a more economical mode of application led Broeshart (1959), Ruer (1967) and Ollagnier and Ochs (1981) to adopt a method of application. For them, the mechanical application in spacing from the age of 5 to 6 years is more favorable to the economy of the mineral fertilizer that spreading manual when interlining contains at least one third of roots present in the round. However, the mechanical application from 5 to 6 years faces a disadvantage. The decumbent fins obstruct the progress of gear and can be torn, which may injure the trees and promote parasite development (Ollagnier and Ochs 1981).

4. PROFITABILITY OF THE FERTILIZATION

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All fertilization studies have shown that fertilization of oil palm provides increased yields when nutritional status is not optimal (Daniel and Ochs, 1975; Ollagnier and Renard, 1976; Margate *et al*., 1979; Ollagnier and Ochs, 1981; Tailliez 1982; Ballo *et al*., 1994).

The correction of a nitrogen deficiency can increase yields by over 50 %. In some parts of west Africa (Ochs *et al*., 1991; Ballo *et al*., 1994) and of South Asia (Pacheco *et al*., 1985), the correction of the potassium deficiency causes a significant gain over 50 %, as it doubles the production of palm schemes/ha on the poorest soils. P fertilization on the poorest soils phosphorus is efficient and induces gains exceeding 40 %. On soils of Sumatra, phosphorus poor, the simultaneous supply of urea and triple superphosphate increased the average production of 12.5 to 22 tons of bunches per ha and per year (Tampubolon *et al*., 1990).

The spectacular results obtained from the use of a chlorinated allow manure production increases above 60 %, leave auguring well the profitability of chloride fertilizer (Daniel et Ochs, 1975). In multiple combinations, magnesium is likely to bring more than 40 % increases (Eschbach, 1980). Without iron, palms of the atolls have paltry productions, the injection of a double iron salt production but in association with manganese and nitrogen yields are tripled. Preventive action on a young palm borate fertilizer avoids the appearance of distortions detrimental to the entry into fruiting planting. This delay causes significant financial loss given the modest cost of the corresponding fertilizer, which avoids these drawbacks (Eschbach, 1980).

The level of profitability of fertilization depends on raw material costs. Fertilization problems are to define the level of profitability due to the increase in production since the planter must be paid for the effort he provided and the expenditure incurred. Coomans and Ochs (1976), working on Ivorian coconut, note that with the popularized material, the use of a fertilizer containing the three elements P, K and Mg increases variable costs of 13,500 to 70,500 FCFA per ha and per year to adulthood, but increased the value of the gross proceeds of 53,500 to 180,000 CFA, ensuring an increase in gross margin of 40,000 to 109,000 CFA francs. Net income for the fertilizer operation is more than 69 000 CFA. Fertilization brings significant added value which the value/cost of fertilizer is greater than 2. This is the threshold generally used to account for the variability of the database. In 1977, Ochs and Ollagnier confirms that profitability in the oil palm by referring to various authors where the value/cost ratio ranges from 2.5 to 3.6 and even to 8.7 on the hybrid plant material with all due investments the manure.

Nationally, the yield increases due to fertilization have the advantage of limiting oil imports, saving as many currencies. The rise in energy costs and the appreciation of oil prices at global level have a significant impact on the cost of fertilizers (Coomans and Ochs 1976). However, the world is aware of the requirement to increase the mass of agricultural products to meet the demand, itself closely with the increase in population and the rise of living standards.

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Fertilization is for this reason, a great way to improve productivity and thus to meet the growing demand of fats in the world, especially by people in developing countries.

For some countries, a good fertilizer policy based on scientific results allows them to spend a period of scarcity than opulence and see the future with greater serenity.

5. ADVERSE EFFECTS OF FERTILIZERS ON THE ENVIRONMENT

If the beneficial effects of fertilizer are well established, their use poses serious problems for the environment and human and animal health. Fertilizers are a source of nutrients that ensures the plant growth and disease resistance. Excessive fertilization or clumsy by farmers results in the pollution of water by a high concentration of nitrates and phosphates (Capowiez, 2009).

The environmental protection and food security are now two major concerns in developed countries. For the indiscriminate use of fertilizers can have a negative impact on the environment and on humans.

5.1 Effects on human

First, humans can suffer fertilizers either directly or indirectly. Most affected by the direct damage are obviously farmers. In its collective expert report, Inserm (2013) notes that epidemiological studies have identified relationships between the occurrence of certain diseases (Parkinson's disease, cancer, leukemia) and exposure to mineral fertilizers.

The indirect damage caused fertilizers affect us all. Indeed, during infiltration into the soil, nitrates make the ground water undrinkable. The danger here is poisoning by consumption and accumulation of dangerous elements for humans (nitrates, nitrogen). The consumption of animals poisoned by these elements is an additional hazard for humans. The intensive use of nitrogen fertilizers can also cause ecological disasters can be fatal for humans (Daujat *et al*., 2016).

The main dangers of chemical or inorganic fertilizers are nitrogen compounds, which are most fertilizers. Nitrogenous components are nitrate (NO_3), ammonium (NH_4, usually in the form of NH_4NO_3 ammonium nitrate) and urea. Ammonia (NH_3) is from fertilizers containing ammonium nitrate, and which exhaled gas. This clear product is highly toxic to those working with the fertilizer. Inhalation causes irritation of the nose, throat and lungs.

The human body is capable of transforming ammonia (very toxic) in urea (less toxic). However, if the continuous exposure, the liver is saturated by ammonia, which causes poisoning or can reach the brain and cause damage. Ingesting nitrates can cause conversion to nitrite (NO_2). The latter react with hemoglobin and limit the absorption of oxygen by the body, especially in

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infants, who can die from the disease Methaemoglobinaemia acquired (or blue-baby syndrome). Nitrate fertilizers can also cause or increase the risk of developing bladder cancer.

5.2 Environmental consequences

To promote the quality and growth of his crop, a farmer is now forced to use mineral fertilizers because their prices are lower than other types of fertilizers. In addition, they increase the yield per hectare, far more than any other fertilizer. Their nitrogen content, nitrate and potassium is very high, so they can feed the plants to their maximum absorption capacity. The plant absorbs 89 % of the nutrients needed for growth, but the remaining 11 % do not reach the plant and have destructive effects on the biotope. Environmental externalities generated by the use of inorganic fertilizers are of four types: water pollution, air pollution, soil pollution, damage to biodiversity.

5.3 Air pollution

Air pollution is caused by the accidental discharge of various substances into the atmosphere as NO_2 (nitrogen dioxide), NH_4 (methane) and CO_2 (carbon dioxide) resulting from intensive agriculture. Atmospheric pollution can be summarized:

• acid rain resulting from ammonia volatilization from spreading some nitrogen fertilizer urea or ammonia. Emissions of nitrogen fertilizers in the air result in ammonia, a precursor of fine and ultrafine particles in the atmosphere, and nitrogen oxides (NO_x), which pollute the atmosphere (Marcus and Simon, 2015).

• emissions of greenhouse consecutive use of nitrogen fertilizers. The impact of the use of nitrogen fertilizers on climate change is due to the emission of nitrous oxide (N_2O), a greenhouse gas, which has a contribution to the hole in the ozone layer (Aubert, 2012). This form of pollution is largely responsible for climate changes such as heat waves and largest monsoons.

5.4 Water pollution

Contamination of surface and deep waters by nitrates is mainly due to the massive use of fertilizers in intensive agriculture (Levallois and Phaneuf, 1994; Chartrand *et al*., 1999). These substances have high acute and chronic toxicity to humans and animals. They are transformed into nitrites which are known for their potent carcinogen in humans. Once groundwater contaminated with these toxic, it is difficult or impossible to decontaminate. The rivers and streams are fed by groundwater can be polluted.

Nitrates and phosphates cause the proliferation of aquatic plants. When they die, their decomposition consumes oxygen in the water, causing the death of most animals: the

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eutrophication. This pollution affects the final several ecosystems: the seas, oceans, rivers and forests.

5.5 Soils pollution

The farmer corrects the chemical soil fertility through mineral fertilization. In promoting increased crop production, fertilizers allow a greater return of organic residues in soil, source of humus. The maintenance of soil fertility also involves contributions of minerals, particularly phosphorus, potassium and magnesium, which are offset export crops. The plant absorbs much of the elements necessary for growth. Items that are not absorbed are harmful to the entire ecosystem surrounding the plant, reducing the amount of microorganisms (bacteria, fungi) in soil, which are essential for plant growth. This destruction result in addictive fertilizers.

Coupled with poor drainage, the intensive use of fertilizers risk salinization over-watered areas, causing sterilization, soil acidification and their desertification. This situation led to lower fertility of these soils and increased risk of leaching of heavy metals (Aubert, 2012).

5.6 Damage to biodiversity

The Water pollution by nitrogen fertilizers impact wildlife, very sensitive to the slightest change in its habitat. We note in particular the feminization of certain species of fish and amphibians. The high concentration of nutrients in the water can cause eutrophication, resulting in an uncontrolled growth of algae. It is developed in coastal waters, with many negative consequences for biodiversity, such as the development of plants or undesirable or toxic bacteria (cyanobacteria, phytoplankton), suffocation of fish and impoverishment of the environment animal and plant species (Klein *et al.,* 2007).

6. FIGHT AGAINST POLLUTION GENERATED BY FERTILIZERS

The best way to avoid the presence of harmful substances in mineral fertilizers is the development and implementation of an appropriate regulatory framework for the production and the trade in fertilizers. The laws and their implementing legislation and awareness campaigns at the location of producers and distributors of agricultural inputs will prevent toxic products are found in fertilizers by ignorance, negligence or fraud.

Choosing the right fertilizer, rate, time and method of application must be consistent with the dietary needs of the plant, the amount of nutrients already available in the soil texture, depth, slope and hydrodynamic properties. We must therefore promote soil analyzes for the establishment of fertilizer plans. The amount and distribution of rainfall should also be taken into account in the management of fertilizer to avoid excessive nitrogen and phosphorus leakage to

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groundwater and surface water. In order to avoid environmental damage and human health, arising from inappropriate management of fertilizers, agricultural research and extension services should work in synergy with the environmental protection agencies. They will together develop appropriate technologies for each agricultural speculation in every soil and agro-ecological zone, and advocate for legislation that regulates the production and trade of fertilizers.

7. CODE OF GOOD FERTILIZATION PRACTICES

A number of measures have been identified to reduce the risk of leakage of fertilizer applied. These rules relating to soil, climate and crop sequences were enacted as a code of good fertilization practice.

1 - Avoid spreading fertilizer during periods of high leaching and on soils with plant cover does not allow to absorb When applied elements. Periods or spreading is inappropriate are defined according to the types of fertilizers. These periods correspond to the major rainy seasons.

2 - We must realize the land application of fertilizer to steeply sloping so that runoff outside the leach field is removed. The direction of crop establishment, the location of grass strips, hedgerows or talus slope down must be respected.

3 - Avoid spreading fertilizer to water-saturated, flooded, frozen or snow-covered aggravating the risk of subsequent runoff.

4 - It is also spread fertilizer respecting minimum distances from surface water and taking into account the types of fertilizers.

5 - We must balance the foreseeable needs of culture and supplies of minerals from the soil and fertilization. We must therefore divide the contributions in order to best meet the needs of crops at different stages of development, and ensure consistency of application of the dose determined by monitoring the hardware setting.

6 - We must realize forward-fertilization plans for the plot and keep a notebook spreading fertilizer by specifying culture, spreading dates, volumes and quantities of manure from all backgrounds.

8. CONCLUSION

To increase its competitiveness and maintain its leading position vis-à-vis other vegetable oils, palm oil industry needs to increase productivity while reducing costs. Such as cost, the mineral fertilizer is the most important variable for greater efficiency in the use should be sought.

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Fertilization plays an important role in the growth and production of palm schemes. Potash fertilizers are most useful away for adult trees. During operation of a palm grove, fertilization allows the production potential established in juvenile phase, to express them sustainably. From the start of production, it is indeed the only possible means of action to maintain mineral nutrition situation at the optimum or catch a deficiency situation. This pattern also reflects a fertilizer production stage on any plant material positively affects its force but does not fundamentally change its intrinsic characteristics that have a strong and direct impact on the yield components.

The reconciliation of the results from several experiments in Ivory Coast, Cameroon, South-east Asia, America and Oceania has highlighted some very general characteristics about the fertilization of the oil palm. It is not possible to replace a method happening all the classic method of establishing manuring programs tailored to each situation. Based on the experimental results, we can use this information as a guide for establishing mineral fertilizer programs. These methods of management of mineral nutrition of plantations can afford to make very significant fertilizer savings without reducing the production potential. These savings are particularly sensitive in Southeast Asia where it was customary to bring heavy and complete fertilizers (up to 8 kg KCl per tree and per year) for the sake of compensating exports and maintain the potential production regardless of leaching losses. The doses used may exceed the export needs of the crop.

The soils used for oil palm cultivation are usually very poor in assimilable minerals and feeding should have the effect of increasing the concentration of the soil solution elements to achieve a sufficient level of absorption. The doses are in this case higher than those that allow a simple restitution of exports.

Progress in research for over fifty years lead to an understanding of agronomic culture of oil palm issues. Prospecting by foliar diagnosis (FD), combined with a good knowledge of soils, is an excellent means of investigation to take stock of mineral nutrition. The results achieved must be sent to farmers through extension that provides simultaneously liaison with organizations responsible farm management.

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