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RESEARCH PAPER

Study of the use of NPK fertilizer complexes in root and vegetative improvement of the C1001F category of oil palm (*Elaeis guineensis Jacq.*) In times of water deficit

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Abstract

The cultivation of oil palm in areas of average rainfall requires the search for categories capable of carrying out their cycle in these areas but also fertilizer complexes capable of supporting the root and vegetative development of plants. These fertilizer complexes must improve the tolerance of the oil palm in the middle of a deficit by allowing it to have a good root and vegetative adaptation. The root behavior and vegetative growth of the C1001F category when using three NPK treatment were evaluated during periods of water deficit. The test material, carried out at the Me station, consists of 162 6-month-old plants. The experimental design is a Fisher block of two factors at three different levels : NPK fertilizers (3 level) and water intake (3 level) for 45 days in the greenhouse. The control water value of 690 ml is the daily capacity of water supply to a 6 month old nursery plant. Water deficits are obtained by the gradual reduction of the control value : 690ml (100%), 520ml (75%), 345ml (50%). The parameters studied were assigned to each water level and NPK intake. The decrease in the values by the effect of water deficit of the number of primary roots, the length of the root, the height of the plants and the circumference at the collar of the plants were average under NPK_{122222} "reference control", very high under the control absolute "without contribution of NPK" and weak under the contribution of NPK_{151515}. The values of the parameters of the plants under NPK_{151515} kept a constant rise on the values of the two other treatments. The analysis of the variations of the parameter values shows that the NPK_{151515} treatment improves the tolerance of the palm tree through good root and vegetative development of the plants more than the other two treatments. This study distinguishes NPK_{151515} as the complex more improving tolerance of category C1001F to water deficit.

Keywords: Elaeis guineensis, water deficit, tolerance, NPK fertilizer complex, root, elongation, height, collar circumference

Introduction

The demand for palm products remains very high so that the supply cannot keep up with demand. The increase in palm oil production becomes a necessity to meet demand. One of the ways recommended to increase the production of palm oil is to increase the cultivable area of the oil palm by exploiting areas with average rainfall (water deficit). The main climatic factor limiting the expansion of palm cultivation in certain agricultural regions is the lack of water or insufficient rain. Water is the factor of the environment which optimizes more the vegetative potential and the production potential of the oil palm. Water supply is the main factor limiting the yield of oil palm, Kallarackal and al, (2004). Authors such as Devuyst, (1948) ; Surre, (1968) ; Nguettia and al, (1995) ; Quencez, (1996) ; have shown the influence of water deficit on the vegetative and productive cycle of the plant. The palm tree for its satisfaction in water needs 1800 to 2400 mm of water per year well distributed in the year, Dufour and al, (1988). Lack of water due to low rainfall or long dryness, has a negative effect on plant growth, sex ratio, increased abortion rate of female inflorescences, increased number of male inflorescence, Caliman, (1992) ; Corley and Tinker, (2003) and therefore the significant drop in production. It therefore becomes necessary to look for categories of palm capable of carrying out their vegetative and productive cycle in areas of water deficits Gogoue et al, (2018) ; but also to determine fertilizer complexes supporting the growth of these categories in these areas by good root development and thus improving their tolerance; Huang B. and H. Gao, (2000).

The architecture of the oil palm root system plays an important role in drought tolerance, thanks to the mobilization of water and mineral salts, Nodichao L. (1997). Cornaire et al. (1994) reported that drought tolerant oil palm crosses have a more developed root system than that of sensitive crosses. Palms with a developed root system have a morphological advantage for the mobilization of minerals. Thus the root system, by the different functions it performs, is an essential compartment for plant life. It is, in fact, directly responsible for the supply of water and mineral salts to the whole plant. In addition to its role in anchoring Coutts, (1983) ; it also participates in the storage of assimilates and in hormonal regulation within the plant, Fitter, (1991). Although the oil palm, Elaeis guineensis Jacq., has been cultivated since the beginning of the century for its high oil production, knowledge concerning its root system remains very fragmentary, Ruer P., (1967a). The lack or excess of nutrients can cause deficiencies or toxicities, which are generally detrimental to the plant and planting, Ollagnier and Ochs, (1972). Thus the need to study the behavior of the roots and the possibilities of improving their adaptation and their tolerance by contributions of fertilizer complexes in an environment which can be little favorable to their development becomes a priority, Jourdan Cl, Rey H., (1996) ; Nodichao and al., (2008).

The detection of fertilizer complexes having the capacity to support root development and plant growth in times of water deficit and therefore improving the tolerance of oil palm becomes essential. NPK is one of the fertilizer complexes used in the fertilization of palm, whose compound elements have an impact on the tolerance of oil palm in times of water stress. Nitrogen (N), involved in the growth process, is involved in the synthesis of proteins, chlorophyll and other major compounds which are determining factors in plant metabolism. Phosphorus (P) is an energy transporter both in photosynthesis and in the degradation of carbohydrates, Pellerin S. and al., (2000). It promotes root development in particular and intervenes in maturation, Anghinoni I. and S. A. Barber., (1980). Potassium (K) plays an essential role as activator of several enzymes. It plays an important role in the transport of sugars and increases photosynthesis. It intervenes in the synthesis of glucoses and proteins, Quencez P. and G. de Taffin., (1981). Potassium is thus involved in increasing resistance to drought and diseases, Egilla J. N., and al, (2001). The study of the root improvement of the oil palm by the use of NPK complex of fertilizers in the greenhouse (control of external climatic factors and accuracy of the values to be obtained) will allow on the one hand to highlight the level of stimulation root growth in times of water deficit, but also to determine the most effective NPK complex fertilizer formula allowing good root development and therefore an improvement in the palm's tolerance to water deficit.

The study will thus allow to assess the role of NPK complexes in plant growth and also to highlight which NPK complex ($NPK_{12\text{-}22\text{-}22}$, $NPK_{15\text{-}15\text{-}15}$) supports root development and growth more plants of category C1001F of oil palm in the middle of a water deficit.

Materials and Methods

Study site

The test was carried out in a greenhouse on the Me station of the national center for agricultural research (NCAR), located 30 km from Abidjan in Côte d'Ivoire. The greenhouse allows us to maintain the water deficit as the only stressor while setting up normal growing conditions for the plant. A humidity sensor in the greenhouse made it possible to establish favorable temperature and humidity conditions for palm cultivation (an average hourly temperature between 27 ° and 35 ° C and a humidity fluctuating between 80% at night and 50% mid-day). These conditions are adequate for palm cultivation, J.C Jacquemard (1995), Quencez P. (1996).

Plant material

The plant material of the study is 162 plants of the category of palm oil C1001F of 6 months. This category is obtained by artificial fertilization on the Me station. It has a high genotype number. It is characterized in the field by a high production yield. It is very popular for the creation of oil palm plantations. The category C1001F has the particularity of being tolerant to Fusarium wilt, Duarand-Gasselin et al, (2000) ; Diabate S. (2009). The seedlings obtained after 3 months of pre-nursery were transplanted in the nursery in black polyethylene bags 25cm high by 20cm in diameter, perforated with 20 holes at the base and filled with 10000g of soil. Thus after 3 months in the nursery, at 6 months from the plants, 162 plants of C1001F were selected according to the selection criteria in the nursery and the homogeneity to be subjected to different water and NPK complex treatment for 45 days in the greenhouse (figure 1).

Figure 1: General view of the experimental device inside the greenhouse

Determination of various water treatments

The experiment focused on three water regimes : A water control maintained at the daily need for water from a 6-month-old plant, IRHO (1983), and two stressed treatments. In our case, the water requirement for 6-month-old plants is around 17.25mm or 690ml of water (17.25mm * 1000ml / 25mm), IRHO (1983). The two stressed treatments observed below are obtained by gradual reduction in the value of the control treatment (Table 1).

Table 1 : Value of the various water treatments

Water treatment	Value in (%) of water treatments	Value in (ml) of water treatments
Control treatment	100%	690 ml
Stressed treatment 1	75%	520 ml
Stressed treatment 2	50%	345 ml

The water supply was done manually using graduated containers. The gradual watering cycle lasted 45 days. To avoid water loss, each seedling was placed on a bowl which collected the water lost during watering and this water was then poured back into the palm bag.

NPK complex fertilizer formulas and their application rate

The two NPK fertilizer formulas used in our study are $N_{12}P_{22}K_{22}$ and $N_{15}P_{15}K_{15}$. Their application to 6-month-old plants is made every fortnight in a dose of 5 grams. For each level of water deficit, three levels for measuring the effects of complex fertilizers on the plants were implemented: a block of plants without NPK input (absolute control), a block of plants subjected to the complex fertilizer $N_{12}P_{22}K_{22}$ and a block of plants subjected to the $N_{15}P_{15}K_{15}$ complex fertilizer. The values of plants without NPK input (absolute control) will be compared with those subjected to $N_{12}P_{22}K_{22}$ (reference control) and those subjected to $N_{15}P_{15}K_{15}$.

Experimental apparatus

The experimental device is a Fisher block with 3 randomized repetitions allowing the study of two variable factors at three different levels : NPK complexes (three levels of NPK intake) and water treatments (three levels of fluid intake). The crossing of the two variable factors (Water treatment and NPK fertilizer treatment) gives an experimental unit. Each repetition is made up of 9 experimental units. Each experimental unit consists of 6 plants (Figure 2).

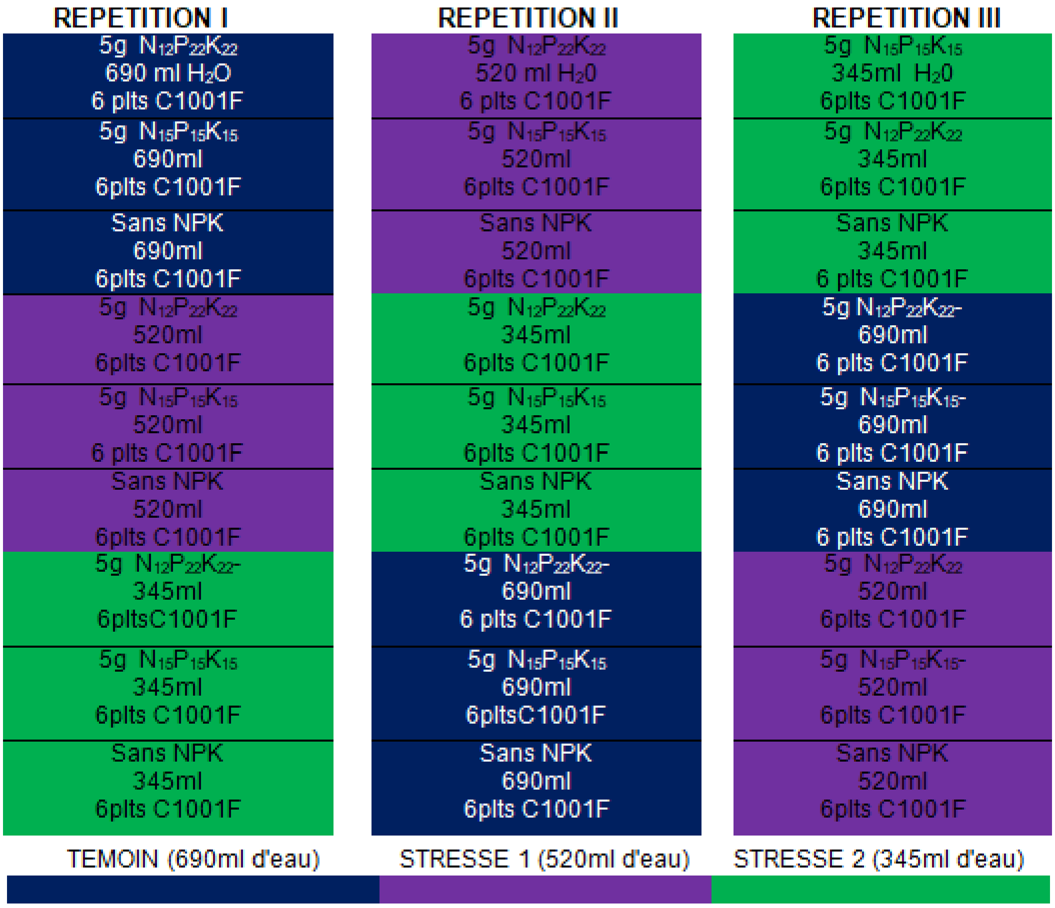

Figure 2: 45 days trial experimental setup

Morphological observations

All of the morphological observations, after 45 days of application of water treatments and fertilizer application, focused on plants aged 225 days. At this stage, each plant had at least 7 to 8 lanceolate leaves that were well open. The morphological parameters retained for our study are the number of primary roots emitted, the length of the roots, the height of the plant and the circumference at the collar. These parameters were chosen for their fairly good correlation with water deficit, Maillard G, and al, (1974) ; Adjahoussou D.F. (1983) ; Nouÿ B. et al, (1999) ; Davies W. J. and M. A. Bacon. (2003)

Parameter number of primary root emitted

Primary roots are important in the development of the plant, Tailliez B. (1971). The number of primary roots on a foot is an important criterion in the evaluation of the effect of NPK complex fertilizers in the root development of plants in times of water deficit. The appearance of primary roots can be slowed down or stopped by the effect of water reduction, Davies W. J. and M. A. Bacon. (2003), Kolek J. and V. Kozinka., (1992), but adding NPK complex fertilizers can improve the tolerance of primary roots. Determining the number of primary roots of plants under water deficit and with fertilizer supply therefore remains a very important parameter to assess the effect of NPK fertilizers during periods of water deficit on root development, Ognalaga M. and al (2017). For the determination of the number of primary roots, a manual count was carried out on each plant removed from the bag (figure 3).

Root length parameter

Oil palm for good vegetative development must have good root elongation to capture the necessary nutrients, Jourdan C. and H. Rey. (1997a). In times of water deficit, water stress can stop root elongation, preventing the roots from getting the nutrients they need for their proper functioning, Sun and al, (2011), Ryser P., (2006). There is atrophy of the roots and even death due to the effect of the high soil temperature and the lack of water, Maillard G., and al. (1974) ; Nouÿ B. and al. (1999). But certain complex fertilizers have the capacity to improve the growth and elongation of these roots in times of water deficit, Anghinoni I. and S. A. Barber., (1980). This allows tolerance of the roots in the middle of a water deficit. Measuring the level of root elongation in times of water deficit when using NPK complex fertilizers is a good indicator for evaluating the effects of NPK complex fertilizers on the root development of the plant in times of water stress. For the measurement of the length of the roots of the plant, a rule (Stainless steel ruler, Westcott 60cm/24, from firm Staples, Canada) was used according to conventional measurement standards (figure 3), www.metrologie-francaise.fr

Plant height parameter

The height growth of the oil palm is characterized by a good mineral and water supply, Jacquemard J.C., (1980). The water deficit has an impact on the height growth of the plants. In times of water stress, the palm tree tends to reduce or stop its growth in height. For the most tolerant, this period is characterized by slow growth, while in the susceptible, we observe a stunting of the plant and its death, Reis de Carvalho C. (1991) ; Cornaire B. and al. (1994). The contribution of certain complex fertilizers has the capacity to support the growth of plants in general and of palm in particular in times of water deficit, Egilla JN, and al, (2001). Measuring the level of growth in height of the plant in period of water deficit when using NPK complex fertilizers is a direct indicator for assessing the effects of NPK complex fertilizers on plant development during periods of water deficit, Cao and al, (2011), Ognalaga M. and al (2017). For the measurement of the height of the plant, a ruler (Stainless steel ruler, Westcott 60cm/24, from firm Staples, Canada) was used according to conventional measurement standards (figure 3), www.metrologie-francaise.fr.

Neck circumference setting

The circumference at the collar is the index of vigor of the development at the base of the oil palm. The diameter at the base of the palm tree tends to widen in times of water satisfaction and good mineral nutrition, Adam J. (1910), Jacquemard JC, (1995). But in times of water deficit, or mineral deficiency, the collar of the palm develops weakly and this can lead to a significant growth retardation of the oil palm, Nouÿ B. et al. (1999). The value of the circumference at the neck of C1001F plants during periods of water deficit and with the use of NPK complex fertilizers is a good indicator to assess the effect of NPK complexes on the development of the palm neck circumference of plants, Sun et al, (2011). For the determination of the circumference at the collar, the caliper (Mitutoyo Digital Calliper, Kanagawa, Japan) was used, (figure 3), www.metrologie-francaise.fr.

Process for measuring plant parameter values

For the measurement of the parameter values, the plants were removed from the nursery sachets which were heavily wet. The roots of the plants were washed in water to remove all the cover soil. Then the plants were put in cloth to absorb the rinsing water. After that, the values of the different parameters were measured on the plants (Figure 3).

Figure 3: General view of the measurement of the different parameters : 1: Counting number of primary roots, 2: Measuring the height of the plants, 3: Measuring the length of the root, 4: Measuring the circumference at the collar

Statistical data processing

The statistical analyzes were carried out with the software Statistics version 7.1. The marginal means, the standard deviations, the basic deviations of the analyzes and the profile diagrams were obtained by the method of descriptive statistics. Anova followed by the Newman-Keuls means comparaison test determined the significant impact of means. The differences between treatments were considered statistically significant at the 5% level

Results and Discussion

Results

Wilting of plants after 45 days of water treatment and fertilizer application

The wilting of the plants after 45 days of testing, characterized by yellowing of the leaves, was visible in the plants subjected to the water deficit of 345 ml. The yellowing of the leaves of the plants was very high in plants without NPK input and low in plants with NPK complexes. The determination of the percentage of yellowing was done mainly by counting the number of yellowing leaves on a palm plant. In plants without NPK supply, it is around 4 to 6 leaves, but in plants with NPK supply, it is 2 to 3 leaves. (Table 2, Figure 4).

Table 2: Percentage of yellowing of leaves on a plant after 45 days

% of yellowing / Treatments	Treatments Water level of wilting of plants (345ml)		
	Repetition 1	Repetition 2	Repetition 3
Without NPK	70%	70%	70%
NPK $_{12\ 22\ 22}$	30%	30%	30%
NPK $_{15\ 15\ 15}$	30%	30%	30%

Figure 4: State of wilting plants without NPK (1 and 2) and with NPK (3) during periods of water deficit (345ml)

Evaluation of the effect of NPK complex fertilizers on the number of primary roots emitted from C1001F in the different levels of water deficit during the 45 day trial

Table 3: Descriptive data of the general marginal means of the values of the parameter number of primary roots emitted recorded in the 3 repetitions during the 45 days of test and the margins of deviation (%) according to control

Average number of primary roots emitted by water level according to treatments and the margins of deviations in% according to the absolute control during the 45 days of testing			
Water level / Treatments	690ml (Water control)	520ml	345ml
Without NPK (absolute control)	8,33±3	8,08±2,90	7,94 ±2,85
Absolute control in %	100%	100%	100%
NPK 12 22 22	10,16±5	9±4,50	8,5±4
Margins of deviations	+21%	+11%	+6%
NPK 15 15 15	9,65±4,30	9,83±4,10	8,83±4
Margins of deviations	+16%	+21%	+10%

The descriptive evaluation of the effect of NPK treatments on the average number of primary roots emitted within each water level shows that in the state of normal water satisfaction of plants, without stress (690 ml), the effect of the NPK_{122222} complex (reference control) is significant on the increase in the number of primary roots (Table 3, Figure 5). Plants receiving this complex have the highest number of primary roots emitted, it exceeds the value of the absolute control by 21% and remains slightly higher than that of the NPK_{151515} complex by 5%. At the first level of water deficit (520ml), the number of primary roots is high in plants under the supply of NPK_{151515} fertilizer, it exceeds by 21% the value of the absolute control. It remains significantly higher by + 10% than the reference fertilizer NPK_{122222} (Table 3, Figure 5). At the second level of water deficit, the number of primary roots remains high with the addition of the NPK_{151515} fertilizer, which exceeds by 10% the value of the absolute control and by 4%, the value of the reference control (6%), (table 3, figure 5).

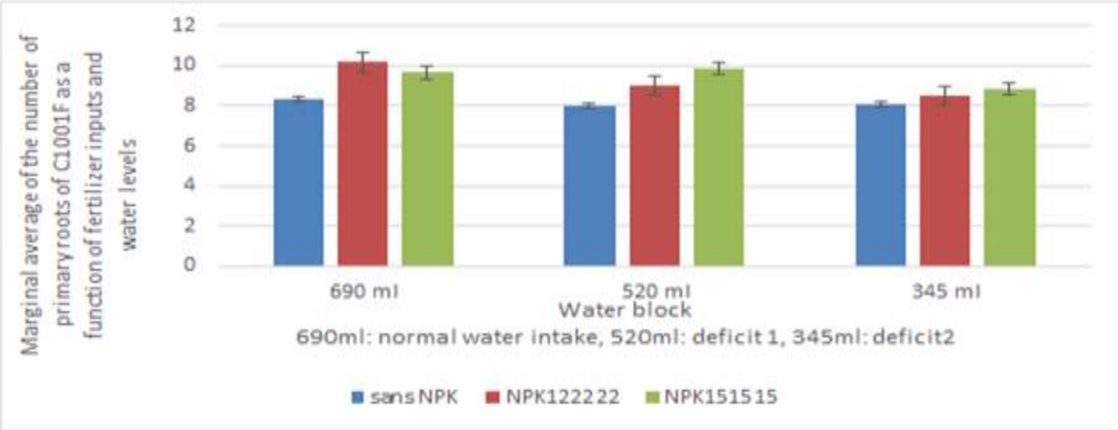

Figure 5: Evolution of the marginal average of the number of primary roots in category C1001F as a function of the water blocks and fertilizer inputs

Table 4: Statistical evaluation of the effect of NPK_{122222} and NPK_{151515} treatments on the average number of primary roots emitted at different water levels according to the control treatment without NPK

Average number Root Primary Issued / Treatments	Average number of primary roots issued at 690ml		Average number of primary roots issued at 520 ml		Average number of primary roots issued at 345ml	
Without NPK	Without NPK	8,33b±3	Without NPK	8,08b±2,9	Without NPK	7,94a±2,85
NPK_{122222}	NPK_{151515}	9,66a±5	NPK_{122222}	9a±4,50	NPK_{122222}	8,50a±4
NPK_{151515}	NPK_{122222}	10,16a±4,3	NPK_{151515}	9,83a±4,10	NPK_{151515}	8,83a±4

The numbers followed by different letters are significantly different at 5% risk

At normal water intake (690ml), the value of the average number of primary roots varies with the treatments. Statistical evaluation of the values of treatments NPK_{122222} and NPK_{151515} and that of the control treatment Without NPK, shows that the variations in values are statistically significant. The contribution of NPK treatments to this level of deficit has a significant impact on the increase in the number of primary roots emitted. With a water deficit of 520ml, the value of the average number of primary roots varies with the treatments. The statistical evaluation shows that the values of the NPK treatments and that of the control treatment Without NPK are significant. The contribution of NPK treatments to this level of deficit has a significant impact on the increase in the number of primary roots emitted. With a water deficit of 345ml, the value of the average number of primary roots varies with the treatments. The statistical evaluation of the values of the NPK treatments and of the value of the control treatment Without NPK shows that the variations in the values are not significant. The contribution of NPK treatments to this level of deficit has no significant impact on the increase in the number of primary roots emitted.

Evaluation of the effect of complex NPK fertilizers on the length of the roots of C1001F plants in the different levels of water deficit during the 45 days of testing

Table 5 : General marginal average of the length of the roots and the variations of the margins of deviations in % as a function of the absolute control in each water level

Average of the length of the roots(cm) by water level according to treatments and the margins of deviations in % according to controls during the 45 days of testing			
Water level / Treatments NPK	690ml (Water control)	520ml	345 ml
Without NPK (absolute control)	37,62±6,50	37,16±6,20	31,25±6
Absolute control in %	100%	100%	100%
NPK 12 22 22	34,75±7	39,54 ±8	32±6,90
Margins of deviations	-8%	+6%	+2%
NPK 15 15 15	33,16±8,20	42,24 ±10	33±9
Margins of deviations	-12%	+14%	+5%

The descriptive evaluation of the effect of NPK treatments on the average length of roots within each water level shows that in the state of normal water satisfaction of the plants (690 ml), the effect of the NPK complex on the elongation of the roots is insignificant compared to the absolute control. It is -8% lower in plants receiving NPK_{122222} and -12% lower in plants receiving NPK_{151515} compared to the value of the absolute control (without NPK) (Table 4, Figure 6). At the first level of water deficit (520ml), the elongation of the roots is high in plants under the supply of fertilizer NPK_{151515}, it exceeds by 14% the value of the absolute control and remains 7% higher than the reference control NPK_{122222}, which record a margin of +6 more than the absolute control (Table 4, Figure 6). At the second level of water deficit, water stress becomes severe. Plants supplied with NPK151515 complex have the highest elongation which exceeds by 5% the value of the absolute control and by 3% that of NPK_{122222} whose value is greater than the absolute control by 2% (Table 5, Figure 6).

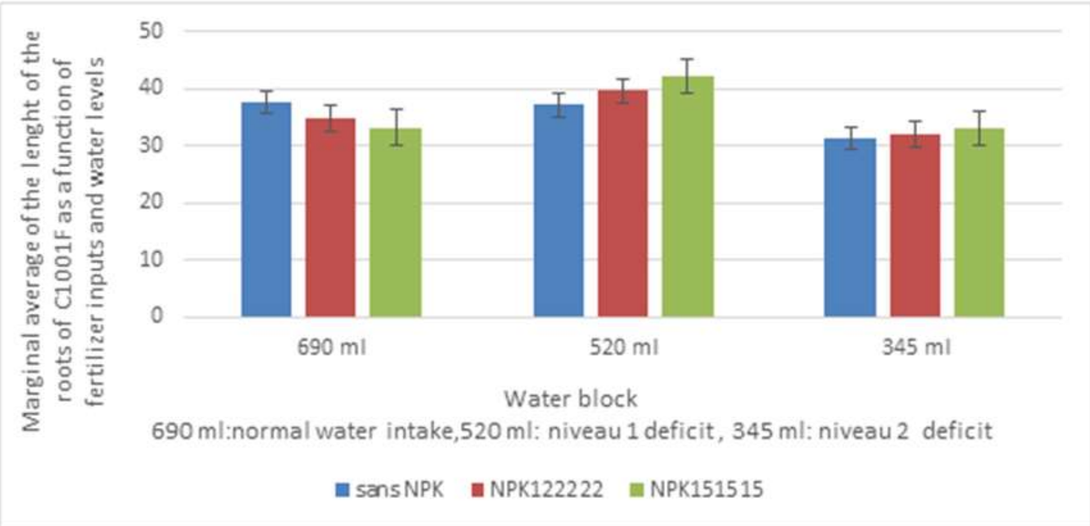

Figure 6 : Evolution of the length of the root of C1001F as a function of the water blocks and fertilizer inputs

Table 6: Statistical evaluation of the effect of NPK_{122222} and NPK_{151515} treatments on the average length of roots at different water levels depending on the treatment Without NPK

Length average of roots / Treatments	Average roots length at 690ml		Average root length at 520 ml		Average root length at 345ml	
Without NPK	NPK $_{151515}$	33,16a±8,20	Without NPK	37,16a±6,20	Without NPK	31,25a±6
NPK $_{122222}$	NPK$_{122222}$	34,75a±7	NPK $_{122222}$	39,54a±8	NPK $_{122222}$	32a±6,90
NPK $_{151515}$	Without NPK	37,62a±6,50	NPK $_{151515}$	42,24a±10	NPK $_{151515}$	33a±9

The numbers followed by different letters are significantly different at 5% risk

At the normal water intake of 690ml, the value of the average length of the roots varies in each treatment. The statistical evaluation of the values of the NPK treatments and of the value of the control treatment Without NPK shows that the variations in the values are not significant. The contribution of NPK treatments in normal water condition (690ml) has no significant impact on the root elongation of the plants. At the first level of water deficit, the value of the average length of the roots varies with the treatments. The statistical evaluation of the values of the NPK treatments and of the value of the control treatment Without NPK shows that the variations in the values are not significant. The contribution of NPK treatments to this deficit has no significant impact on the root elongation of the plants. At the second level of water deficit, the statistical evaluation shows that the variation in the values of the two NPK treatments and of the control treatment Without NPK are not significant. The contribution of NPK treatments to the water level of 345ml does not have a significant impact on the root elongation of the plants.

Evaluation of the effect of NPK complex fertilizers on the height of C1001F plants in the different levels of water deficit during the 45 days of testing

Table 7: General marginal average of the height of the plants and the variations in the margins of deviations in % as a function of the absolute control in each water level during the test

Average height of plants (cm) by water level according to treatments and the margins of deviations in %, according to controls during the 45 days of testing			
Water level / Treatments NPK	690ml (Water control)	520ml	345 ml
Without NPK (absolute control)	41,33±8,40	39,95±8,20	38,58±8,05
Absolute control in %	100%	100%	100%
NPK 12 22 22	42,91±10,70	47,49±11,60	41,25±10,50
Margins of deviations	+4%	+19%	+7%
NPK 15 15 15	46,83±9,45	47,5±10	45±9
Margins of deviations	+13%	+19%	+15%

The descriptive evaluation of the effect of NPK treatments on the average height of the plants within each water level shows that in the state of normal water satisfaction of the plants (690 ml), the effect of NPK fertilizers on the height of the plants is significant, in particular for the plants under the NPK$_{151515}$ complex which increases the height of the plants by + 13% more than the absolute control. The plants under NPK$_{122222}$ raised the height of the plants by 4% more than the absolute control, (Table 7, Figure 7). At the first level of water deficit (520ml), the height of the plants remains maintained and high in the plants under the contribution of the two NPK complexes by 19% more than those under the absolute control, (Table 7, Figure 7). At the second level of water deficit, or water stress is severe, the height of the plants remains high in plants with NPK fertilizer, especially plants with NPK$_{151515}$ which promotes an increase of 15% more than the value of the absolute control. The value of the height under the NPK151515 remains 8% higher than that under the NPK$_{122222}$, (table 7, figure 7).

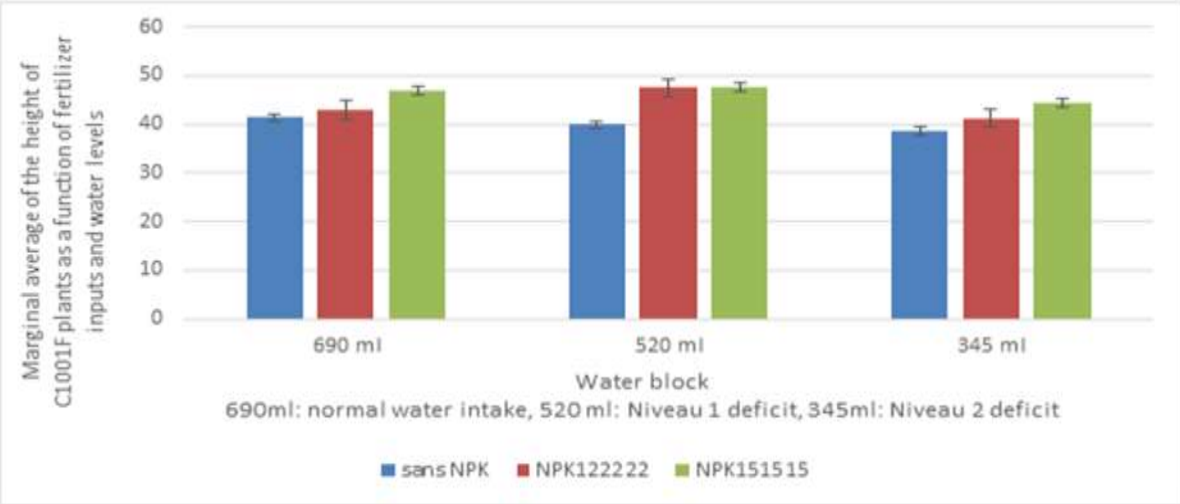

Figure 7 : Evolution of the height of C1001F plants as a function of the water blocks and fertilizer inputs

Table 8: Statistical evaluation of the effect of NPK_{122222} and NPK_{151515} treatments on the average height of plants as a function of the control treatment Without NPK at different water levels

Height average plants / Treatments	Average plant height at 690ml		Average plant height at 520ml		Average plant height at 345ml	
Without NPK	Without NPK	41,33 b±8,40	Without NPK	39,95b±8,2	Without NPK	38,5a±8,05
NPK 122222	NPK 122222	42,91b±10,70	NPK 151515	47,5a±11,6	NPK 122222	41,25b±10,50
NPK 151515	NPK 151515	46,83a±9,45	NPK 122222	47,50a±10	NPK 151515	45c±9

The numbers followed by different letters are significantly different at 5% risk

At the normal water supply of 690ml, the value of the average height of the plants varies with the treatments. The statistical evaluation of the values of the NPK_{122222}, NPK_{151515} treatments and of the value of the NPK-free control treatment are significant. The contribution of NPK_{151515} treatment to this level of deficit has a significant impact on the increase in plant height than NPK_{122222}. With a water deficit of 520ml, the value of the average height of the plants varies with the treatments. The statistical evaluation of the values of NPK treatments and that of the control treatment Without NPK are significant. The contribution of NPK_{122222} and NPK_{151515} treatments to this level of deficit has a significant impact on the increase in plant height. With a water deficit of 345ml, the value of the average height of the plants varies with the treatments. The statistical evaluation of the values of the two NPK treatments and that of the control treatment Without NPK are significant. The contribution of NPK_{122222} and NPK_{151515} treatments to this level of deficit has a significant impact on the height of the plants. NPK_{151515} treatment has the highest effect in increasing the height of the plants.

Evaluation of the effect of NPK complex fertilizers on the collar circumference of C1001F plants in the different levels of water deficit during the 45 day trial

Table 9: General marginal average of the circumference at the collar of the plants and the variations in the margins of deviations in % as a function of the controls in each water level

Average collar circumference (cm) by water level according to treatments and the margins of deviations in % according to controls during the 45 days of test			
Water level / Treatments	690ml (Water control)	520ml	345 ml
Without NPK (absolute control)	0,76±1	0,56±0,86	0,52±0,69
Absolute control in %	100%	100%	100%
NPK 12 22 22	1±1	1,09±1,25	0,83±0,90
Margins of deviations	+31%	+94%	+59,60%
NPK 15 15 15	1±1	1,08±1,20	0,84±0,80
Margins of deviations	+31%	+93%	+62%

The descriptive evaluation of the effect of NPK treatments on the average collar circumference of the plants within each water level shows that in the state of normal water satisfaction of the plants (690 ml), the effect of NPK fertilizer on the circumference at the collar of the plants is significant. NPK_{151515} increases the girth of the plants by 31% more than the absolute control. Plants under NPK_{122222} have a 31% increase in collar circumference than the absolute control (Table 9, Figure 8). At the first level of water deficit (520ml), the circumference at the neck of the plants remains maintained and high in the plants with the contribution of the two NPK complexes. NPK_{151515} increases the collar circumference of plants by 93% more than the absolute control, while NPK_{122222} increases the collar circumference by 94% more than the absolute control, (Table 9, Figure 8). At the second level of water deficit, or the water stress is severe, the circumference at the collar of the plants remains very large in the plants under supply of NPK fertilizer. The circumference at the collar of the plants under NPK_{151515} exceeds by 62% the value of that of the absolute control, and those under the NPK_{122222} by 59.60% that of the absolute control, (table 10, figure 8). Plants under NPK keep a very high collar circumference during periods of water deficit than plants without the addition of NPK complex.

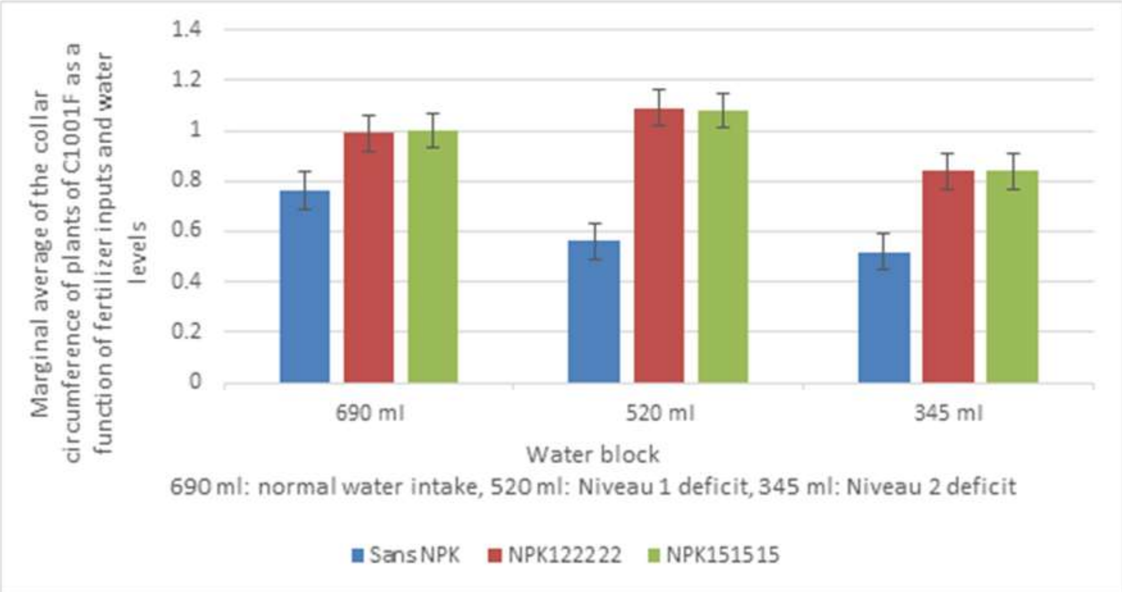

Figure 8 : Evolution of the collar circumference of plants of C1001F as a function of the water blocks and fertilizer inputs

Table 10 : Statistical evaluation of the effect of NPK_{122222} and NPK_{151515} treatments on the collar circumference of the plants according to the control treatment Without NPK, at the various water levels

Circumference average at the collar / Treatments	Circumference average at the collar at 690ml		Circumference average at the collar at 520ml		Circumference average at the collar at 345ml	
Without NPK	Without NPK	0,76a±1	Without NPK	0,56a ±0,86	Without NPK	0,52b±0,69
NPK_{122222}	NPK_{122222}	1a±1	NPK_{151515}	0,89b±1,25	NPK_{151515}	0,83a±0,90
NPK_{151515}	NPK_{151515}	1a±1	NPK_{122222}	1,1c±1,20	NPK_{122222}	0,84a±0,80

The numbers followed by different letters are significantly different at 5% risk

At the normal water intake of 690ml, the average value of the circumference at the collar varies with the treatments. The statistical evaluation of the values of the NPK treatments and that of the control treatment Without NPK, shows that the variations in the values are statistically insignificant. The contribution of NPK treatments to this level of deficit has no major effect on the increase in the circumference at the collar of the plants. With a water deficit of 520ml, the average value of the circumference at the collar varies with the treatments. The statistical evaluation shows that the values of treatments NPK_{122222}, NPK_{151515} and that of the control treatment Without NPK are significant. The contribution of NPK treatments to this level of deficit has a significant impact on the development of the circumference at the collar of the plants. With a water deficit of 345ml, the value of the average number of primary roots varies with the treatments. The statistical evaluation shows that the values of the NPK treatments and that of the control treatment Without NPK are not significant. The contribution of NPK treatments to this level of deficit has no significant impact on the increase in the number of primary roots emitted.

Discusion

Impact of NPK fertilizers on plants assessed using the number of primary roots parameter

The comparison of the values of the treatments inside the water levels shows that during a normal water level (690ml), the contribution of the NPK complexes stimulates the emission of the primary roots more than the treatment without the contribution of NPK. Statistical evaluation shows that this stimulation of the number of roots by contribution of NPK complexes is significant. The contribution of NPK treatments to the hydric control of 690ml of water improves the number of primary roots emitted. This allows the plant normal rooting and greater absorption of organic matter and minerals. At a low water deficit of 520ml, the NPK_{151515} treatment improves the number of primary roots emitted by 21% than the absolute control and the NPK_{122222} treatment by 11% than the absolute control. Statistical evaluation shows that this variation in the number of roots by contribution of NPK complexes is significant. The contribution of NPK treatments to this level of deficit increases the number of primary roots emitted, which improves the tolerance of the plant. NPK complexes inhibit the effect of water deficit and stimulate the growth of plants, in particular the NPK_{151515} complex. With a high water deficit of 365ml, the plants under the NPK_{151515} complex have a primary root number greater than 10% over those of the absolute control, those under NPK_{122222} have a primary root number greater than 6% over those of the control. The statistical evaluation shows that this variation in the values of the number of roots emitted relative to the control in the treatments is not significant. The contribution of NPK treatments to this level of deficit has no significant effect on the number of primary roots emitted.

Impact of NPK fertilizers on plants evaluated using the length of plants roots parameter

The descriptive comparison of the treatment values within the water levels shows that in normal water conditions, the plants under absolute control (without NPK) have a high elongation of the roots than those of plants under NPK_{122222} of 8% and that those plants under the NPK_{151515} of 12%. The statistical evaluation of the values of the treatments under the 690 ml water control shows that the elongation of the roots under the absolute control is not significant and the contribution of NPK treatments has no effect on the elongation of the roots. Plant roots tend to elongate under all three treatments. With a water deficit of 520ml, the plants under the NPK complexes have a high elongation than those under the absolute control. The margins of variation show that the plants under NPK_{151515} have a root elongation of 14% more, while those under NPK_{122222} (reference control) have a elongation of 6% more than those under the absolute control. Statistical evaluation of the treatment values under this deficit shows that these variations are not significant. The contribution of NPK treatments has no significant impact on root elongation. With a 345ml water deficit, the plants under the NPK complexes have a slightly higher elongation than those of the control. The margins of variation show that the plants under NPK_{151515} have a root elongation of 5% more than those under the absolute control while those under NPK_{122222} have an elongation of 2% more. The statistical evaluation of the treatment values shows that these variations are not significant. The contribution of NPK treatments does not affect the elongation of the roots

Impact of NPK fertilizers on plants in category C1001F evaluated using the height of plants parameter

The values of the treatments subjected to the normal water intake 690ml, show that the height of the plants is higher under the NPK complexes. NPK_{151515} raises plant height by 13% more than the absolute control. NPK_{122222} raises it by 4% more than the absolute witness. The statistical evaluation of the values of the three treatments shows a significant effect of the treatments on the height of the plants. The contribution of the NPK_{151515} treatment in particular, at this water level increases the height of the plants more. Data from treatments under 520ml water deficit show that NPK complexes stimulate more height growth of plants. NPK_{151515} and NPK_{122222} each increase the height of the plants by 19% more than that of the absolute control. The statistical evaluation of the treatment values shows that the variation in values is significant. The contribution of the treatments NPK_{122222} and NPK_{151515} at this level of the deficit inhibits the effect of the deficit and supports the growth in height of the plants. The values of the treatments subjected to the 365ml water deficit show that the NPK complexes stimulate the height growth of the plants more. NPK_{151515} increase the height of the plants by 15% more than that of the absolute control, NPK_{122222}, him by 7%. The statistical evaluation of the treatment values shows that this variation in values is significant. The contribution of treatments NPK_{122222} and NPK_{151515} attenuated the effect of the deficit by supporting the height growth of the plants. NPK_{151515} is the most effective complex at this level of deficit.

Impact of NPK fertilizers on plants in category C1001F evaluated using the circumference parameter at the collar of the plants

The values of the treatments under the normal fluid intake 690ml, show that the circumference at the collar of the plants is higher under the NPK complexes. NPK151515 and NPK_{122222} each increase the girth of the plants by 31% more than that of the absolute control. The statistical evaluation of the values of the treatments under the 690ml water control shows that the increase in the circumference at the collar under the contribution of NPK treatments is not significant. The contribution of NPK treatments has no significant impact. The values of the treatments under the 520ml water deficit show that the NPK complexes improve the circumference at the collar of the plants. NPK_{151515} increases the collar circumference of plants by 93%, NPK_{122222} raises it by 94% more than the absolute control. The statistical evaluation of the treatment values shows that the variation in values is significant. The contribution of NPK treatments to this level of deficit has a significant impact on the circumference of the collar. NPK_{122222} is the most active complex at this level of deficit. The values of the treatments subjected to the 365ml water deficit show that the NPK complexes stimulate the circumference at the collar of the plants more. NPK_{151515} increases the collar circumference by 62% more than the absolute control, NPK_{122222} increases the collar circumference by 59.60% more than the control. The statistical evaluation of the treatment values shows that this variation in values is significant. The contribution of treatments NPK_{122222} and NPK_{151515} attenuated the effect of the deficit by improving the circumference at the collar of the plants.

Conclusion

The root and vegetative study of the C1001F category of oil palm during a water deficit period with the supply of NPK complex fertilizers is important to assess the level of impact of NPK complexes in improving the tolerance of C1001F plants under water deficit. Parameters such as the number of primary roots emitted, the length of the roots, the height of the plants, and the circumference at the collar were essential to evaluate the effect of the NPK complexes on the root and vegetative growth of the C1001F category in normal period and water deficit. The expression of the margins of deviations of the values of the parameters compared to the absolute control (without contribution of NPK) made it possible to evaluate the contribution of the NPK complexes in the growth of plants in normal water period and in water deficit. Also, the NPK treatment has been highlighted which further improves the root and vegetative development of C1001F in the various water levels. The statistical evaluation with Anova followed by the Newman-Keuls means comparison test, of the values of the parameters under NPK treatments and under the control treatment Without NPK made it possible to determine the significant impact of the treatments on the parameters studied. Thus at the normal water intake of 690ml, the values of the various parameters studied vary with the treatments. However, the statistical analysis shows that the variations in the values are not significant for the parameter length of the roots and circumference at the collar. NPK treatments do not act on the growth of these parameters in the 690ml water supply. On the other hand, it acts on the growth of the parameters number of primary roots and height of the plants, hence the variations in values are significant for these parameters under 690ml. The NPK151515 complex stimulates the most. At 520ml water intake (first level of deficit), the values of the various parameters studied vary with the treatments. Statistical analysis shows that the variations in values are not significant for the root length parameter. On the other hand, the variations in values are significant for the parameters number of primary roots emitted, height of the plants, and circumference at the collar. NPK treatments, in particular NPK_{151515}, support the growth of these parameters with 520ml water deficit. With the 345ml water intake (second level of deficit), the values of the various parameters studied vary with the treatments Statistical analysis shows that the variations in values are not significant for the parameter length of the roots, number of primary roots emitted, but are significant for the parameters height of the plants and circumference at the collar. NPK_{151515}, supports more the growth of these parameters with the 345ml water deficit. This treatment has thus shown its capacity to inhibit the effects of stress with low water deficit and to attenuate the inhibitory effect of stress with high water deficit, which makes it possible to improve the tolerance of C1001F during periods of water deficit. The effective NPK complex on root development should be determined over time.

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