Combination of Rhizobacteria and Foliar Bio-Fertilizer Accelerating Maize and Soybean Crop Plants Growth Process in Arid Soil

Accepted 10th June, 2016

ABSTRACT

Soil nutrients availability is strongly correlated with cereal plants growing process. Arid soils because of their low fertility (rare nutrients) contrast with standard plants growth and development. However, group of micro-organisms that can be found in the rhizosphere have been suggested to overcome this concern without causing any environmental problem resulting from continued use of chemical fertilizers, herbicides and pesticides. In this sense, several studies showed that rhizobacteria *Pseudomonas fluorescens* associated to organic fertilizer speeds up cereal plants development procedure. Since, it has been widely demonstrated that rhizosphere bio-fertilizer improved cereal crop yield and growth, we quantified through the present analysis the speediness by which rhizobacteria *P. fluorescens* micro-organisms associated with natural fertilizer induced cereal plants development in arid soils northern of Cote d’Ivoire. The results of the present analysis showed that treatments based on (i) rhizobacteria *P. fluorescens* and (ii) rhizobacteria *P. fluorescens* + foliar bio-fertilizer influenced both maize and soybean cereal plants development improving their growth speed, resulting 1.2 fold more higher than those of soil standard condition (p-value <0.05). Hence, the present analysis suggested the substantial capacity of rhizobacteria *P. fluorescens* combined with foliar bio-fertilizer accelerating cereal plants growth process by increasing nutrient availability in low productive soil. In conclusion, this survey showed and quantified the propensity of rhizobacteria *P. fluorescens* as well as, foliar bio-fertilizer speeding cereals growth process in arid and low fertile soil promoting their use in agriculture practices in poor earths.

Key words: Rhizobacteria (*P. fluorescens*), foliar bio-fertilizer, maize (*Zea mays L*), soybean (*Glycine max*), growth process speed, arid soil.

INTRODUCTION

During the past century, industrialization of agriculture provoked a significant and essential productivity increase, which led to a greater amount of food being made available for the growing population. Along with this abundance, the appearance of serious environmental and social problems came with package problems that must be faced and solved. Nowadays, it is urgent to maintain the high productivity, but it is becoming urgent to alter as little as possible the environment. Clearly, we must then head for a more environmentally sustainable agriculture while maintaining ecosystems and biodiversity.

One potential way to decrease negative environmental impact resulting from continued use of chemical fertilizers, herbicides and pesticides is the use of plant growth-promoting rhizobacteria (PGPR) (Kloepper and Schroth, 1978). Plant growth promoting rhizobacteria (PGPR) are known to influence plant growth by various direct or indirect mechanisms (Perveen et al., 2002). Moreover,
benefits to plants from host plant growth promoting rhizobacteria interactions have been shown to include plant health and growth, suppress disease causing microbes and accelerate nutrient availability and assimilation (Mantelin and Touraine, 2004; Yang et al., 2009). These beneficial effects on plants can be achieved by the direct interaction between rhizobacteria and their host plant and are also indirectly due to their antagonistic activity against plant pathogens.

The important role that plant growth promoting rhizobacteria micro-organisms play in agriculture can be clearly deduced from the extensive research published until now (Farah et al., 2008; Shaharoona et al., 2006; Hernandez et al., 1995). The exact mechanism by which these plants growth promoting rhizobacteria accomplish the benefits on plants is not fully understood, though, it is becoming clear that all or some of the rhizobacteria traits allow them to greater or lesser extent to perform their effect(s). Clearly, we must then head for a more environmentally sustainable agriculture while maintaining ecosystems and biodiversity. Moreover, it would be very useful to match correctly the appropriate rhizobacteria with the right plant and environmental condition to achieve the best results on plant growth. Our previous study in agreement with several research works (Shaharoona et al., 2006; Adjanohoun et al., 2011) showed that the effects of rhizobacteria P. fluorescens bio-fertilizer on both growth and yield parameters of maize (Zea mays L.) plants improving their dry biomass production were obtained by the synergic action of both rhizobacteria Pseudomonas fluorescens and foliar bio-fertilizer (Diarrassouba et al., 2015; Noel et al., 2016).

The inoculation of cereal seeds by the rhizobacteria P. fluorescens combined with bio-fertilizer increase the availability of soil in phosphorus and nitrogen ameliorating the efficiency of phosphate fertilizer and produces phytohormones which react as growth factor favoring crop plants growth (Contesto et al., 2008; Kang et al., 2010). Moreover, Shaharoona et al. (2006) showed the efficiency of Pseudomonas increasing significantly maize plant growth and production when adequate quantity of nitrate was provided. In the same tendency, Ahmad et al. (2008) and Estes et al. (2004) evidenced the positive influence of rhizobacteria on plant growth and development through a better seed germination and a greater development of the roots, which induce the increase in the absorption capacity of nutrients and water in plants. Considering as whole, the positive influence of rhizobacteria bio-fertilizer improving cereal plants growth and productivity has been widely demonstrated. In the present investigation, we purposed to quantify the influence of rhizoacteria P. fluorescens micro-organism on cereal crops assessing both maize (Zea mays L.) and soybean (Glycine max) plants growth process speed. In other words, the present study tried to quantify the effect of rhizoacteria P. fluorescens on both maize and soybean cereal plants development speed. For this purpose, several rhizobacteria bio-fertilizer treatments combination were processed and compared between themselves as well as, with arid soil standard conditions (soil in north of Cote d’Ivoire). Hence, treatment T₀ (maize and soybean seeds without any rhizobacteria P. fluorescens and/or bio-fertilizer treatment) has been assumed as reference condition evaluating both maize (Zea mays L.) and soybean (G. max) cereal plants growth speed by rhizoacteria P. fluorescens micro-organisms and foliar bio-fertilizer. For this purpose, several statistical parametric tests as well as, descriptive statistic graphics representation and analysis have been performed.

MATERIALS AND METHODS

Preparation of Inoculums of maize and soybean seed

RizofosLiq bio-fertilizer manufacture requires the strain of bacterium P. fluorescens specifically selected for its phosphorus solubilizing ability. If stored under the recommended conditions (cool below 25°C), the product contains 1 × 10⁹ CFU/ml in manufacturing. The inoculums were prepared from 500 ml RizofosLiq Premax-R + 200 ml of Premax-R for 100 kg of maize and/or soybean seed. The needed amount of Premax-R was put in a container and the required amount of RizofosLiq added. We mixed until a homogeneous mixture before inoculation of the required amount of seed. Indeed maize and soybean seed have been treated separately. What follows is planting seeds and making holes about 3 cm deep, in which two inoculated seeds of maize and/or soybean are deposited.

Experimental design and growth parameters measurement

For the present survey, both maize (Zea mays L.) and soybean (G. max) cereal seeds have been cured by (i) rhizobacteria P. fluorescens exclusively, (ii) foliar bio-fertilizer only, (iii) rhizobacteria P. fluorescens + foliar bio-fertilizer as well as, without any rhizobacteria and/or foliar bio-fertilizer treatments. The experimental sites were organized in different plot based on the type of rhizobacteria and/or foliar bio-fertilizer treatments. Then, (i) treatments T₀: plots planted without rhizobacteria (P. fluorescens) and without foliar bio-fertilizer; (ii) treatment T₁: subdivision sown with the seed inoculated with rhizobacteria (P. fluorescens) only; (iii) treatment T₂: land sown with the seed inoculated with rhizobacteria (P. fluorescens) bio-fertilizer and foliar fertilizer; and treatment (iv) T₃: subdivision with foliar bio-fertilizer only have been evaluated for growth parameters of both maize and soybean cereal crops.

Four features were evaluated during the growth phase (i) height of the plant, (ii) number of leaves, (iii) length of leaves and (iv) diameter of the collar which was measured
using an electronic sliding caliper. The growth parameters were evaluated using a centimeter as scale of measurement (cm). Both maize and soybean plants heights were measured from the ground level to the end of the longest petiole, and leaves number per plants was counted weekly. Experimental design consisted in a block of 4 treatments and 4 repetitions for the two analyzed maize (Zea mays L) and soybean (G. max) cereal crops. Blocks matching to each analyzed cereal varieties were divided into 16 basic plots corresponding to the under-investigated rhizobacteria treatments (treatments T₀, T₁, T₂ and T₃). The space between the ridges was 75 cm between rows and 40 cm between bunches with 2 plants per hill after thinning. Treatments T₀, T₁, T₂, and T₃ covered each elementary plot of 4 m × 4 m (16 m²). Each elementary plot contained 4 lines of 4 m long (Diarrassouba et al., 2015).

Statistical analysis

Multi-variant statistical analysis by box plot analysis was performed assessing the effects of rhizobacteria and/or foliar bio-fertilizer on both maize and soybean cereal plants growth speed. Furthermore, we performed a fitting curve analysis (Halimah et al., 2009; John, 2009; Dago et al., 2015) quantifying the impact of (i) rhizobacteria (P. fluorescens), (ii) rhizobacteria (P. fluorescens) + foliar bio-fertilizer and (iii) foliar bio-fertilizer improving and/or contrasting maize and soybean plants development speed. Statistical T- test was applied to discriminate the effect of rhizobacteria on cereals growth speed between treatments T₀, T₁, T₂ and T₃ treatments. Next we assessed the relationship between analyzed rhizobacteria (P. fluorescens) treatments and all considered growth parameters (leaves length and number and plants height and diameter) by a principal component analysis based on variable factor map function (Lê et al., 2008). Also, effect of rhizobacteria treatments on both maize and soybean growth parameters assessing the relationship between the latter’s as well as, their development speed by using ape library and/or function of R (R version 3.2.2) statistical software (R core team) was evaluated.

RESULTS

Global evaluation of maize and soybean plants growth by parallel box-plot analysis

We performed whole investigation regarding the dynamism of growth parameters for both maize and soybean seeds treated by rhizobacteria micro-organisms and/or foliar bio-fertilizer. The present parallel box-plot analysis showed that rhizobacteria treatment T₁ (cereal seeds treated by rhizobacteria P. fluorescens micro-organism exclusively) apparently exhibited potential blameless performance quantifying growth parameters development speed with respect to treatments T₀ (cereal seeds with any treatment), T₂ (cereal seeds treated by rhizobacteria + foliar bio-fertilizer) and T₃ (seeds treated by foliar bio-fertilizer exclusively) (p-value=0.01). The same analysis suggested a comparable effect (p-value >0.01) of both rhizobacteria treatments T₁ and T₂ assessing both cereals leaf length and leaf number growth parameters development (Figure 1).

However, the present parallel box-plot survey evaluating maize and soybean plants growth parameters speed reacting to rhizobacteria P. fluorescens, suggested a probable good performance of both treatments T₁ and T₂ as opposite to treatments T₀ and T₃ (p-value<0.1). Fisher test assessing the effect of rhizobacteria P. fluorescens on both analyzed maize and soybean plants development showed that treatment T₁ recording exclusively rhizobacteria P. fluorescens revealed a rapid development of height parameter (p-value<0.1) when treatment T₀ was assumed as reference (Figure 1B). Moreover, in the same tendency, it is also interesting to underline a relative good performance of treatment T₂ on the present analyzed growth parameters (Figure 1B). Furthermore, Figure 1D suggested a weak influence of rhizobacteria and/or foliar bio-fertilizer treatments on leaf length parameter oppositely to the other analyzed growth parameters. Taking together, these results supposed that (i) rhizobacteria P. fluorescens micro-organism and (ii) rhizobacteria P. fluorescens combined with foliar bio-fertilizer expand both maize and soybean plants growth parameters dynamism as opposed to foliar bio-fertilizer treatment alone as well as, to standard soil condition northern of Côte d’Ivoire.

Fitting curve analysis evaluating maize and soybean growth parameters speed in reaction to rhizobacteria P. fluorescens treatments

The present analysis confirmed the aptitude of (i) rhizobacteria (treatment T₁) and (ii) rhizobacteria + foliar bio-fertilizer (treatment T₂) treatments accelerating maize and soybean growth process speed (Figure 2). Fitting curves associated with treatments that recorded rhizobacteria P. fluorescens micro-organism are relatively higher than those related to treatments T₀ and T₃ (treatments without any rhizobacteria treatment) especially for height parameter (p-value<0.01). Assuming arid soil standard condition (treatment T₀) as reference, height parameter associated to conditions that include rhizobacteria treatments increased more than 1.2 fold for maize cereal plants (Table 1) suggesting a positive influence of rhizobacteria P. fluorescens improving maize growth speed process. However, Table 1 shows the speed average of each analyzed growth parameter for each considered rhizobacteria treatment showing a probable good influence of both rhizobacteria P. fluorescens.
Figure 1. Box-plot analysis assessing growth parameters speed by both Rhizobacteria *P. fluorescens* and foliar bio-fertilizer treatments.

Furthermore, evaluating the capacity of each treatment accelerating analyzed cereal plants growth process speed, we were able to show that all analyzed treatments exhibited an acceptable good stimulus (input) helping both maize and soybean development as shown in the first phases (1/3 phase) of each fitting graphic in Figure 2 (p-value< 0.01). Also, it is noteworthy to underline that all parameters associated with treatments T1 and T2 meanly recorded a potential best performance (brief 1/3 to 2/3 phases as reported in Figure 2) evaluating rhizobacteria *P. fluorescens* effect on both maize and soybean cereal plants growing speed, especially for height and leaves number parameters (p-value<0.1). These results suggested a good performance of rhizobacteria micro-organism increasing cereal plants growth process speed in low fertile region northern of Côte d’Ivoire.

**Comparison between maize and soybean cereal plants growth speed by rhizobacteria treatments**

Both maize and soybean plants growth process speed were compared by the different analyzed rhizobacteria treatments assuming arid soil standard conditions (treatment T0) as reference. The results of this analysis showed that generally; all analyzed growth parameters under rhizobacteria treatments increased 1.2 fold more with respect to those under standard condition. However, the present results suggested that maize plants under rhizobacteria and/or foliar bio-fertilizer treatments grow
faster than soybean cereal plants (Table 1). Moreover, both maize height and diameter parameters exhibited the highest growth speed with respect to the other analyzed parameters (Table 1). These findings are in agreement with previous results reported by Figures 1 and 2.

Furthermore, regardless of the analyzed cereal plants, rhizobacteria micro-organism treatments T₁ (rhizobacteria only) and T₂ (rhizobacteria + foliar bio-fertilizer) appear to display the same performance in arid soil (Table 1). However, maize leaf length growth parameter exhibited a constant growth speed for T₁, (rhizobacteria only) T₂ (rhizobacteria + foliar bio-fertilizer) and T₃ (foliar bio-fertilizer only) treatments as opposed to the other parameters (p-value>0.05). Finally, when compared to standard condition (treatment T₀; treatment without rhizobacteria microorganism and without foliar fertilizer), treatment T₂ displayed a good association with maize and soybean cereal plants growth process in low fertile soils.

**Relationship between analyzed rhizobacteria treatments assessing growth parameters development speed**

Principal component analysis associating rhizobacteria effect on growth parameters development speed (Figure 3) suggested a positive influence of treatments T₁, (rhizobacteria only); T₂ (rhizobacteria + foliar bio-fertilizer)
Table 1. Diameter, height, leaves number and leaves length growth parameters speed average values.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Maize Growth speed treatment (T₀)</th>
<th>Soybean Growth speed treatment (T₁)</th>
<th>Maize Growth speed treatment (T₂)</th>
<th>Soybean Growth speed treatment (T₃)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant diameter</td>
<td>Maize 0.86 mm/week</td>
<td>Soybean 0.97 mm/week</td>
<td>Maize 1.02 mm/week</td>
<td>Soybean 0.82 mm/week</td>
</tr>
<tr>
<td>Plant height</td>
<td>Maize 3.70 cm/week</td>
<td>Soybean 2.44 cm/week</td>
<td>Maize 4.46 cm/week</td>
<td>Soybean 2.1 cm/week</td>
</tr>
<tr>
<td>Leaf length</td>
<td>Maize 0.70 cm/week</td>
<td>Soybean 1.74 cm/week</td>
<td>Maize 0.81 cm/week</td>
<td>Soybean 2.1 cm/week</td>
</tr>
<tr>
<td>Leaf number</td>
<td>Maize 4.90 Leaves/week</td>
<td>Soybean 0.97 Leaves/week</td>
<td>Maize 5.50 Leaves/week</td>
<td>Soybean 4.53 Leaves/week</td>
</tr>
</tbody>
</table>

Figure 3. Principal Component Analysis (PCA) merging both individual (maize and soybean growth parameters) and variable (Rhizobacteria P. fluorescens and foliar bio-fertilizer treatment) factors assessing Rhizobacteria P. fluorescens. Micro-organism influence on both analyzed maize and soybean cereal plants development speed.

and T₃ (foliar fertilizer only) as opposite to treatment T₀ (p-value<0.1) on analyzing both maize and soybean cereal crops growing process. These results were in agreement with our previous observations (Figure 2). Moreover, these results evidenced the key role of rhizobacteria bio-fertilizer helping and accelerating cereal productivity in arid soil (Figure 3). Merging maize and soybean cereal crop plants growth parameters data and performed principal component analysis (PCA) was not able to distinguish analyzed rhizobacteria and foliar bio-fertilizer treatments impact on the latter’s growing speed.

However, Figure 3A showed that maize leaf number and height growth parameters were influenced by rhizobacteria and/or foliar bio-fertilizer treatments (p-value <0.01). In the same tendency, analyzing soybean cereal growth parameters speed shown in Figure 3A (individual factor map analysis) displayed plant height parameter as the best accelerated growth factors (p-value <0.1). Merging these two results (Figure 3A) we showed that rhizobacteria and/or foliar bio-fertilizer treatments exhibited differential speed acceleration effect on both maize and soybean height growth process (p-value<0.01).

However, the present analysis (Figure 3A and B) supposed a comparable impact of all analyzed rhizobacteria bio-fertilizer treatments accelerating maize and soybean diameters, leaf length as well as, leaf number
growth parameters development process. Considering as a whole, the present survey highlighted the potential capacity of rhizobacteria and/or rizhobacteria combined with foliar bio-fertilizer increasing the height speed of maize and soybean cereal plants development in low fertile soil.

**Rhizobacteria treatments T\(_0\), T\(_1\), T\(_2\) and T\(_3\) variance estimation assessing the effect of bio-fertilizer on cereals growth development speed**

Cereals development speed difference between rhizobacteria treatments T\(_1\), T\(_2\) and T\(_3\) was highlighted assuming treatment T\(_0\) (standard soil condition) as reference. The variance analysis suggested that both treatment T\(_0\) and T\(_1\) exhibiting a standard deviation around 2.85 and 1.07 respectively with a cumulative proportion of variance value estimated to 0.99 (p-value <0.05), were able to explain both maize and soybean growth parameters development speed variances. However, the high variability shown by treatment T\(_0\) could explain its relative high heterogeneity measuring both maize and soybean cereals growth parameters development (Figure 4). The same investigation showed that treatments T\(_1\) (rhizobacteria only), T\(_2\) (rhizobacteria + foliar fertilizer) and T\(_3\) (foliar fertilizer only) strongly normalized both maize and soybean growth parameters development speed with respect to rhizobacteria treatment T\(_0\).

However, considering standard deviation parameter as tool to estimate the normalization effect of analyzed treatments on the present analyzed cereal growth development speed, we showed that treatment T\(_2\) recording rhizobacteria and foliar bio-fertilizer (standard deviation=0.06) resulted strongly influenced by treatment T\(_3\) (standard deviation=0.04) as opposed to rhizobacteria treatment T\(_1\) (standard deviation=1.07). This observation supposed a good synergy between both rhizobacteria *P. fluorescens* micro-organism and natural fertilizer increasing cereal plants development in low fertile soil. Altogether, these results evidenced a normalization effect of rhizobacteria and foliar fertilizer accelerating both maize and soybean cereal plants development as opposed...
Interaction between maize and soybean growth parameters assessing rhizobacteria influence on their growing speed

Here, we evaluated the relationship by phylogeny analysis based on Euclidian distance of Pearson correlation between both maize and soybean cereal plants growth parameters, assessing rhizobacteria *P. fluorescens* as well as, foliar bio-fertilizer treatments impact on the former development speed process. The present survey evidenced a strong difference between maize and soybean replying to rhizobacteria and/or foliar bio-fertilizer treatments T₁, T₂ and T₃ accelerating these plants growing procedure (Figure 5).

Furthermore, our analysis showed high correlation value (*R* ≥0.92; *p*-value ≤0.05) between (i) maize height, (ii) maize leaves number and (iii) maize diameter growth parameters evaluating rhizobacteria *P. fluorescens* treatments influence on maize plants development in arid soil north of Cote d'Ivoire. In other words, Figure 5 suggested that maize seeds treated with rhizobacteria *P. fluorescens* as well as, by foliar bio-fertilizer improved maize growing process favoring a strong synergy between maize growth parameters. However, the same analysis suggested a low agreement between maize leave length parameter and (i) maize height, (ii) maize leaves number and (iii) maize diameter growth parameters. This
Table 2. Descriptive statistic of both analyzed maize and soybean growth parameters (leaf length, leaf number, plant height, and plant diameter).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Maize diameter</th>
<th>Soybean diameter</th>
<th>Maize height</th>
<th>Soybean height</th>
<th>Maize leaf length</th>
<th>Soybean leaf length</th>
<th>Maize leaf number</th>
<th>Soybean leaf number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>0.94</td>
<td>0.96</td>
<td>4.18</td>
<td>2.36</td>
<td>0.78</td>
<td>0.97</td>
<td>5.11</td>
<td>1.82</td>
</tr>
<tr>
<td>Median</td>
<td>0.94</td>
<td>0.98</td>
<td>4.21</td>
<td>2.42</td>
<td>0.80</td>
<td>0.98</td>
<td>5.2</td>
<td>1.78</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>0.12</td>
<td>0.08</td>
<td>0.42</td>
<td>0.18</td>
<td>0.05</td>
<td>0.07</td>
<td>0.48</td>
<td>0.20</td>
</tr>
<tr>
<td>Variance</td>
<td>0.015&lt;sup&gt;NS&lt;/sup&gt;</td>
<td>0.006*</td>
<td>0.03&lt;sup&gt;NS&lt;/sup&gt;</td>
<td>0.002&lt;sup&gt;NS&lt;/sup&gt;</td>
<td>0.03&lt;sup&gt;NS&lt;/sup&gt;</td>
<td>0.005*</td>
<td>0.23&lt;sup&gt;NS&lt;/sup&gt;</td>
<td>0.003*</td>
</tr>
</tbody>
</table>

NS: No statistical significance; * P-Value ≤0.05 (Statistical significance at 0.05).

observation suggested that improvement of maize plant growth by rhizobacteria stimulus relatively influenced leaves length factor (Figure 5). In contrast, soybean leaves length growth parameter exhibited a good agreement with the latter (soybean growth parameters) growth process. Then, we suspected that the difference between maize and soybean monitoring cereal plants growth process speed in the arid soil northern of Cote d'Ivoire could be due to leaves length parameter. Furthermore, as previously shown (Figure 3), the present analysis highlighted and confirmed differential effect of rhizobacteria *P. fluorescens* treatments (p-value ≤0.05) on both maize and soybean height growth parameter (Figure 5). In addition, descriptive statistic survey (Table 2) suggested a heterogeneous effect of rhizobacteria and/or foliar bio-fertilizer stimulus on maize growth parameters as opposed to those of soybean plant improving plants growth process (variance parameters on Table 2).

**DISCUSSION**

Chemical fertilizers are generally used to supply essential nutrients to the soil plant system throughout the world. However, the prices, availability and the environmental concerns of chemical fertilizers especially the azote fertilizers (N fertilizers) are real issues of today's agriculture.

Use of microbial inoculants or plant growth-promoting rhizobacteria (PGPR) for the enhancement of sustainable agricultural production is becoming a more widely accepted practice in intensive agriculture. In many parts of the plant growth-promoting rhizobacteria are free-living soil bacteria that aggressively colonize the rhizosphere/plant roots, and enhance the growth, and yield of plants when applied to seed or crops (Kumar et al., 2014). We previously showed that rhizobacteria *P. fluorescens* associated with foliar bio-fertilizer improve maize crops adjusting the synergy between growth and yield parameters (Diarrassouba et al., 2015; Noel et al., 2016).

Furthermore, several studies confirmed plant growth ability of rhizobacteria *P. fluorescens* (Contesto et al., 2008; Kang et al., 2010). Mirjana et al. (2012) showed that plant promoting growth rhizobacteria increase maize dry weight and yield. the present study aims at quantifying the capacity of rhizobacteria *P. fluorescens* micro-organism as well as, foliar bio-fertilizer accelerating cereal crop plants growth process speed in arid and low fertile soil northern of Cote d’Ivoire since low soil fertility is often the major constraint for production of food grains. For this purpose, we processed both maize and soybean plants growth parameters by several statistical tests and graphics representation. We then showed through a multi-variant box-plot analysis and/or parallel box-plot analysis (Figure 1) that both rhizobacteria and rhizobacteria + foliar bio-fertilizer treatments (rhizobacteria treatments $T_1$ and $T_2$) enhanced both maize (*Zea mays L.*) and soybean (*G. max*) cereal plants growth process (p-value <0.1). These observations suggested the high capacity of rhizobacteria *P. fluorescens* as well as, foliar bio-fertilizer accelerating both maize and soybean cereal plants growth process by increasing nutrient availability in the present considered low productive soil (Umesha et al., 2014; Diarrassouba et al., 2015).

The present study also showed that rhizobacteria *P. fluorescens* + foliar bio-fertilizer treatments increased and accelerated both maize and soybean cereal plant development process to 1.2 fold in the arid soil in the north of Cote d'Ivoire. Considering as a whole, we demonstrated that treatments based on both (i) rhizobacteria *P. fluorescens* and (ii) rhizobacteria *P. fluorescens* associated with foliar bio-fertilizer represented a good alternative to chemical fertilizer on increasing cereals development process in arid soil (p-value <0.05). Moreover, fitting curve associated to treatment $T_1$ and $T_2$ (treatments that include rhizobacteria *P. fluorescens* micro-organism) result to be higher than those associated to treatments $T_0$ and $T_3$ (treatment without any rhizobacteria *P. fluorescens*) suggesting the high performance of rhizobacteria + foliar bio-fertilizer accelerating both maize and soybean growth development process (Figure 2). Indeed, combination between rhizobacteria micro-organism and foliar bio-fertilizer (treatment $T_2$) exhibited a high aptitude improving cereal growing process as opposed to treatments $T_1$ and $T_3$ (Table 1) when arid soil northern of Cote d'Ivoire (treatment $T_0$) was considered as reference condition (p-value<0.05).

However, the present findings showed that (i) rhizobacteria, (ii) rhizobacteria + foliar bio-fertilizer and
(ii) foliar bio-fertilizer treatments (treatments T_1, T_2 and T_3 respectively) improved both maize and soybean cereal plants development as opposed to treatment T_0 (Figure 3). These results exhibited the latter (treatment T_0; arid soil standard condition northern of Côte d'Ivoire) as a good reference condition assessing rhizobacteria _P. fluorescens_ micro-organism + foliar bio-fertilizer aptitude accelerating cereal growing process.

Our findings also showed the capacity of rhizobacteria _P. fluorescens_ micro-organism to impact and enhance both maize and soybean height parameter. In other words, rhizobacteria treatments accelerate both analyzed cereals morphologic development (Figure 3). However, the same analysis suggested the best performance of rhizobacteria treatments enhancing maize growth development as opposed to soybean suggesting difference between these two cereal cultures reacting to rhizobacteria bio-fertilizer (Figures 3 and 5) (Noel et al., 2016).

Furthermore, the present study highlighted the strong influence of rhizobacteria treatments on (i) maize leaves number, (ii) maize height and (iii) soybean height parameter as opposed to the other considered growth parameters (Figure 3A). A statistical variance analysis was performed to assess the effect of each analyzed rhizobacteria treatments on maize and soybean growing process. Our results supposed that the high variability provoked by treatment T_0 assessing cereal plants development speed could explain its relative high heterogeneity processing both maize and soybean cereals growth factors (Figure 4). The same survey suggested a normalizing effect of treatments T_1 (rhizobacteria _P. fluorescens_ micro-organism), T_2 (rhizobacteria _P. fluorescens_ + foliar fertilizer) and T_3 (foliar fertilizer only) on both maize and soybean growth speed (Diarrassouba et al., 2015). This normalization process allowed harmonizing analyzed cereal growing process speed. In addition, considering standard deviation as parameters to approximate the normalization effect of analyzed rhizobacteria _P. fluorescens_ treatments on both maize and soybean plants growth speed, we suspected that treatment T_2 recording rhizobacteria _P. fluorescens_ micro-organism and foliar fertilizer (standard deviation=0.06) was strongly influenced by treatment T_3 (standard deviation=0.04) as opposed to rhizobacteria treatment T_1 (standard deviation=1.07) supposing a good synergy between both rhizobacteria micro-organism from rhizosphere and natural foliar fertilizer (Figure 4) increasing cereal plants development in low fertile soil (Mirjana et al., 2012).

Furthermore, the present study (Table 2) evidenced a heterogeneous behavior of maize growth parameters relying to rhizobacteria _P. fluorescens_ stimulus in arid soil as opposed to those of soybean cereal plant (p-value ≤0.05). Then, our findings confirmed that maize and soybean cereal plants exhibited different replies to rhizobacteria stimulus in arid soil (Noel et al., 2016) especially for height growth parameters that resulted significantly differentially influenced (p-value ≤0.05) between the two processed cereals plants (Figure 5). At this point, there is a need to improve our understanding regarding relationship between cereal plants yield rate and growth speed process helping to optimize grain production in arid soil by rhizosphere composition as well as, natural bio-fertilizer. Furthermore, as our knowledge is concerned, this study is the first one, quantifying rhizobacteria _P. fluorescens_ activities improving cereals growing speed process northern of Côte d’Ivoire as well as, Western Africa arid soil.

**Conclusion**

In conclusion, this study allowed to quantify the integrating effect of rhizobacteria _P. fluorescens_ associated with foliar bio-fertilizer enhancing both maize and soybean cereal plants growth process speed in arid region (northern Côte d’Ivoire). Indeed, we showed that rhizobacteria _P. fluorescens_ + foliar bio-fertilizer treatment increased 1.2 fold growth proportion speeds of both analyzed cereal plants in low fertile earth region northern of Côte d’Ivoire. Finally, the present study proposed the integration of both rhizobacteria _P. fluorescens_ micro-organism and foliar bio-fertilizer as a potential solution increasing nutrient availability in poor and arid soil improving cereal growth development process and productivity.

**ACKNOWLEDGEMENTS**

The authors wish to thank Rizobacter S.A for the financial support for the field trial as well as, facilitating this study.

**REFERENCES**


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