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Research Paper

Effects of water soaking pretreatment and season on the germination parameters of Terminalia ivorensis A. Chev. seeds in Kisangani, Democratic Republic of Congo

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ABSTRACT: *Since environmental concerns related to climate change and biodiversity erosion emerged, forest plantations have returned to the heart of international debates. Today's challenge is finding species and planting techniques that increase carbon sequestration and meet the many needs for goods and services from trees. This study aimed to determine the effects of soaking seeds in water, substrate and season on the germination parameters of Terminalia ivorensis A. Chev. seeds in the eco-climatic conditions of Kisangani. The effects of pretreatment, substrate and season were tested to do this. Two treatments (soaking seeds and no soaking) and three substrates (household waste, forest compost and pig droppings) were tested in the dry and rainy seasons. At the end of this experiment, it turns out that the rate of emergence or germination capacity, the germination energy and the germination speed do not vary according to pretreatment and substrate. Only the season significantly influences the emergence rate and the seeds' germination energy. The germination capacity and energy are better in the rainy than the dry season. These results are only a first contribution to understanding factors favouring the use of T. ivorensis in plantations in Kisangani. However, they highlight the need to test longer soaking times and the substrate's effects on seedlings' early growth.*

KEYWORDS: *Germination, Terminalia ivorensis, Soaking, Substrate, Season, Kisangani.*

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I. INTRODUCTION

In recent decades, forest plantations have experienced renewed interest around the world following the many economic and environmental challenges of the moment (Provendier & Balandier, 2004; Bisiaux et al., 2009; Collet et al., 2016; Piret, 2020; Lubala, 2022). On the one hand, the increase in the concentration of greenhouse gases in the atmosphere increases the need for wooded areas for carbon sequestration (Le Martin & Ferrone, 2014; Baul et al ., 2017; Lubala, 2022), hence the development of several mitigation mechanisms involving tree plantations such as REDD+ (Mayinga et al., 2015; Soe & Yeo-Chang, 2019; Sufo Kankeu et al., 2020; Reang et al., 2021). On the other hand, meeting the socioeconomic needs of populations living near forests increases pressure on tree resources, leading to increased deforestation (Jagger & Kittner, 2017; Jayathilake et al., 2021; Schroeder et al., 2022). This increasing deforestation leads to the loss of biodiversity and a decrease in the availability of wood energy. Hence, the interest in forest plantations is to ensure a sustainable supply of wood energy for millions of poor populations who depend on it (Bisiaux et al., 2009; Soe & Yeo-Chang, 2019; Kasekete et al., 2023).

However, this interest in forest plantations raises the question of choosing species to effectively respond to the many challenges associated with this new dynamic. Therefore, it becomes important to study the silvicultural characteristics of species with the potential for valorisation in forest plantations. Because of the recurring problems of seed dormancy and slow growth, the factors influencing seed germination and juvenile growth benefit from particular attention (Holou et al., 2011; Kaoutar et al., 2023; Bayala et al., 2024).

It is with this in mind that the present study was carried out in Kisangani, a region where the strong dependence of the population on traditional agriculture and wood energy leads to strong pressures on forest resources (Kambale et al., 2015; Kranz et al., 2018; Azenge & Meniko, 2020; Bahati et al., 2023). The study focuses on *Terminalia ivorensis* (A. Chev.), a species widely used in the region as a shade tree but whose performance in energy plantations remains unknown. Since its seeds may exhibit a certain dormancy (Ashton et al., 1983), the study seeks to determine the effect of pretreatment by soaking in water on the germination of its seeds with particular emphasis on the effect of the season.

II. MATERIALS AND METHODS

II.1. STUDY AREA

This study is conducted in Kisangani, Tshopo province, Democratic Republic of Congo (DRC) (Figure 1). The city enjoys a humid equatorial climate of type A f of the Köppen classification (Ebuy et al., 2016). Figure 1 gives the location of the study site.

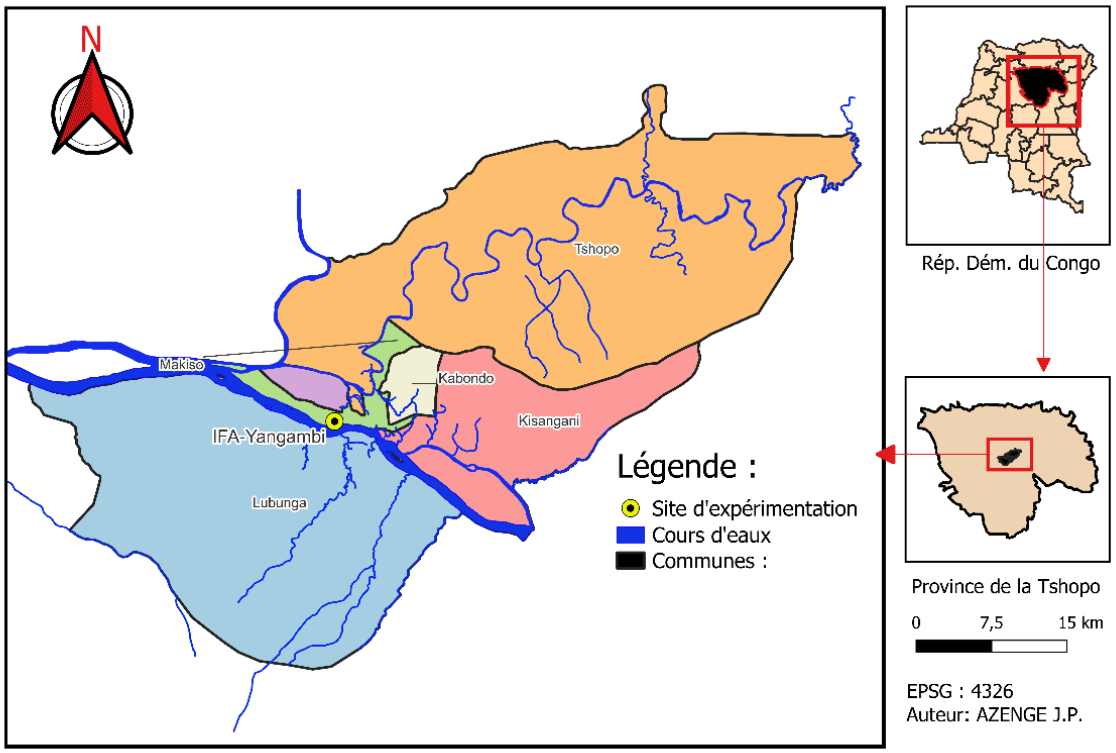

Figure 1: Location of the study area

Although more or less constant throughout the year, its temperature has two seasons. The hot season lasts 1.6 months, from January 21 to March 7, with an average maximum daily temperature above 30 °C. The hottest month in Kisangani is February, with a mean maximum temperature of 30 °C and a minimum of 22 °C. The cool season lasts 3.0 months, from September 9 to December 9, with an average maximum daily temperature below 28 °C. The coldest month in Kisangani is October, with a mean minimum temperature of 22 °C and a maximum of 27 °C (Figure 2).

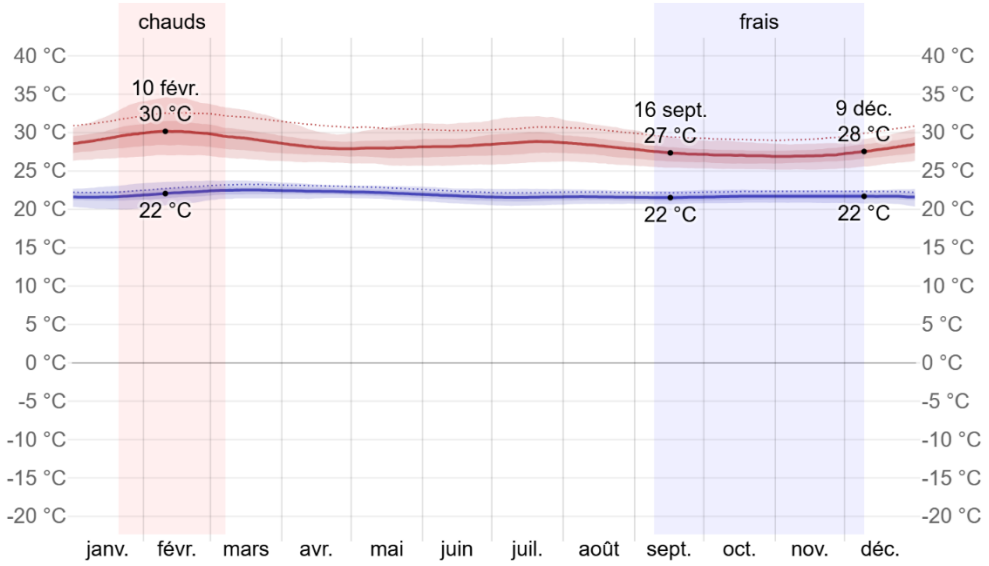

Figure 2: Intra-annual temperature variation in Kisangani (The daily average maximum (red line) and minimum (blue line) temperature, with bands from the 25th to the 75th percentile and from the 10th to the 90th percentile. The thin dotted lines are the corresponding perceived average temperatures. © WeatherSpark.com).

October is Kisangani's wettest month, with an average rainfall of 166 millimetres. January is the least rainy month, with an average rainfall of 54 millimetres (Figure 3).

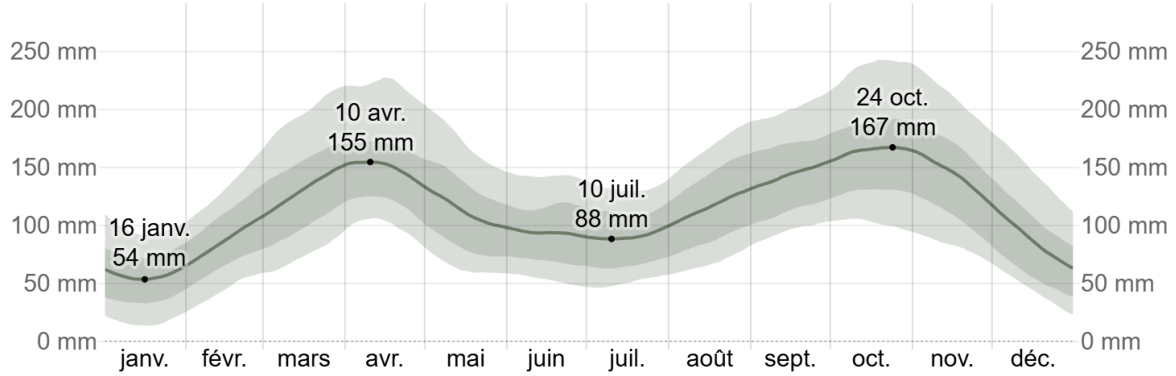

Figure 3: Intra-annual variation in rainfall in Kisangani (The average amount of rainfall (solid line) accumulated over a 31-day rolling period centered on the day in question, with bands from the 25th to the 75th percentile and from the 10th to the 90th percentile. The thin dotted line represents the corresponding average snowfall. © WeatherSpark.com).

II.2. EXPERIMENTATION

Healthy seeds with good conformation were collected from trees present at the Faculty Institute of Agronomic Sciences of Yangambi (IFA-Yangambi) in Kisangani. After sorting, they were separated into two batches of 180 seeds each for pretreatment. The first batch of 180 seeds was soaked in running water for two hours before sowing. The second batch was kept as is as a control. Before sowing, the polyethene bags were filled with three soil types, forming three substrates: household waste, forest compost and pig droppings. A total of 120 bags per substrate were made. Each substrate received 60 soaked seeds and 60 unsoaked seeds. 360 seeds were sown, including 180 soaked and 180 unsoaked. The first trial was conducted during the dry season; these seeds were sown in January 2023. The second trial was conducted in the rainy season (seeds sown in October). For both seasons, germination was monitored regularly every week for 5 weeks. The parameters studied are the emergence rate, germination energy and germination speed.

(1) Seed Emergence Rate

The emergence rate is given by the ratio between the number of plants emerged and the total number of seedlings, i.e. 15 seeds per treatment and substrate. The formula applied is given below.

$$\mathbf{Tg} = \frac{\boldsymbol{n}}{\mathbf{N}}\boldsymbol{x100}$$

Tg: germination rate in percentage (%); n: number of germinated seeds and N: total number of seeds sown.

(2) Germinative energy (Eg)

Germination energy, which reflects the speed of seed germination, is calculated from half the observation time of the germination power (Pg) or the germination rate (Tg). The following formula calculates germination energy:

$$\boldsymbol{Eg} = \frac{\boldsymbol{n_{1/2}}}{\boldsymbol{N}}\ \boldsymbol{x\ 100}$$

$n_{1/2}$: number of seeds germinated at half the time and N = number of seeds subjected to the test.

(3) Germination speed (Vg)

The germination rate is the number of seeds germinated in the third of days allowed for germination. In other words, it is the third of the germination power or germination rate. It is calculated by the formula below:

$$\boldsymbol{Vg} = \frac{\boldsymbol{n_{1/3}}}{\boldsymbol{N}}\ \boldsymbol{x\ 100}$$

Where: $n_{1/3}$ = number of seeds germinated a third of the time and N = number of seeds subjected to the test.

II.3. DATA PROCESSING AND ANALYSIS

The germination data were used to calculate the germination rate, energy, and speed. These three parameters were compared according to treatment, substrate and season. Student's parametric and ANOVA tests were performed for each of these comparisons with the ggbetweenstats () function of the ggstatsplot package (Patil, 2021) of the R 4.4.2 software (R Core Team 2024).

III. RESULTS

III.1. GERMINATION RATE OR GERMINATION CAPACITY

As can be seen in Figure 4, the seed emergence rate of T. ivorensis did not respond favourably to soaking the seeds in water for 2 hours before sowing. This can be seen in the p-value of 0.43 obtained after comparing the means with the Student t-test (Figure 4A). By analysing Figure 4B, we see that the substrate does not influence the seed germination rate of the species either. Despite the small differences in means observed, the variance analysis indicates that the emergence rate does not vary significantly depending on the substrate (p-value: 0.38). However, in Figure 4C, the season significantly influences the seed germination rate. The highest germination rates are observed in the rainy season, which reflects a link between the germination of T. ivorensis seeds and the season.

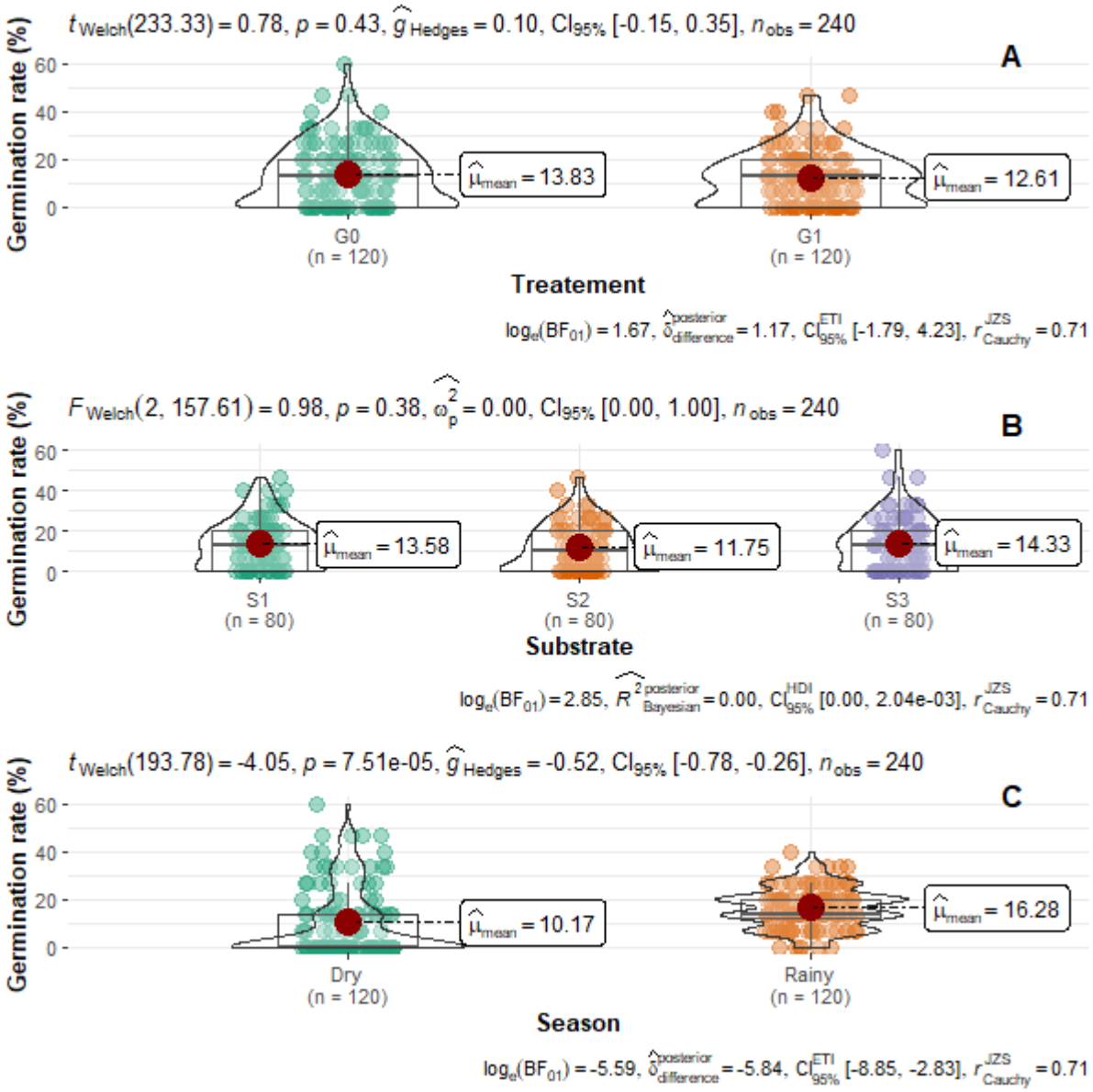

Figure 4 Effect of treatment, substrate and season on the germination rate of *Terminalia ivorensis* seeds in Kisangani (A: treatment, B: substrate and C: season. G0: unsoaked seeds and G1: soaked in water for 2 hours before sowing. S1: household waste; S2: forest soil; and S3: pig droppings. Dry: dry season; and Rainy: rainy season).

III.2. GERMINATIVE ENERGY

Figure 5 shows the influence of treatment, substrate and season on the germination energy of T. ivorensis seeds. Analysis of Figure 5A shows that seeds not soaked in water before sowing gave higher germination energy than those soaked before sowing, i.e. 59.05% and 51.35%, respectively. However, as shown by the results of the Student t-test, this difference is insignificant. This, therefore, implies that we cannot conclude that soaking seeds in water has any effect on the germination energy of this species. The same situation is observed concerning the substrate. Numerically, pig droppings gave a germination energy of 60.89%, followed by household waste at 56.26% and forest soil at 47.51%. However, variance analysis shows no real significant difference in germination energy between these three substrates (Figure 5B).

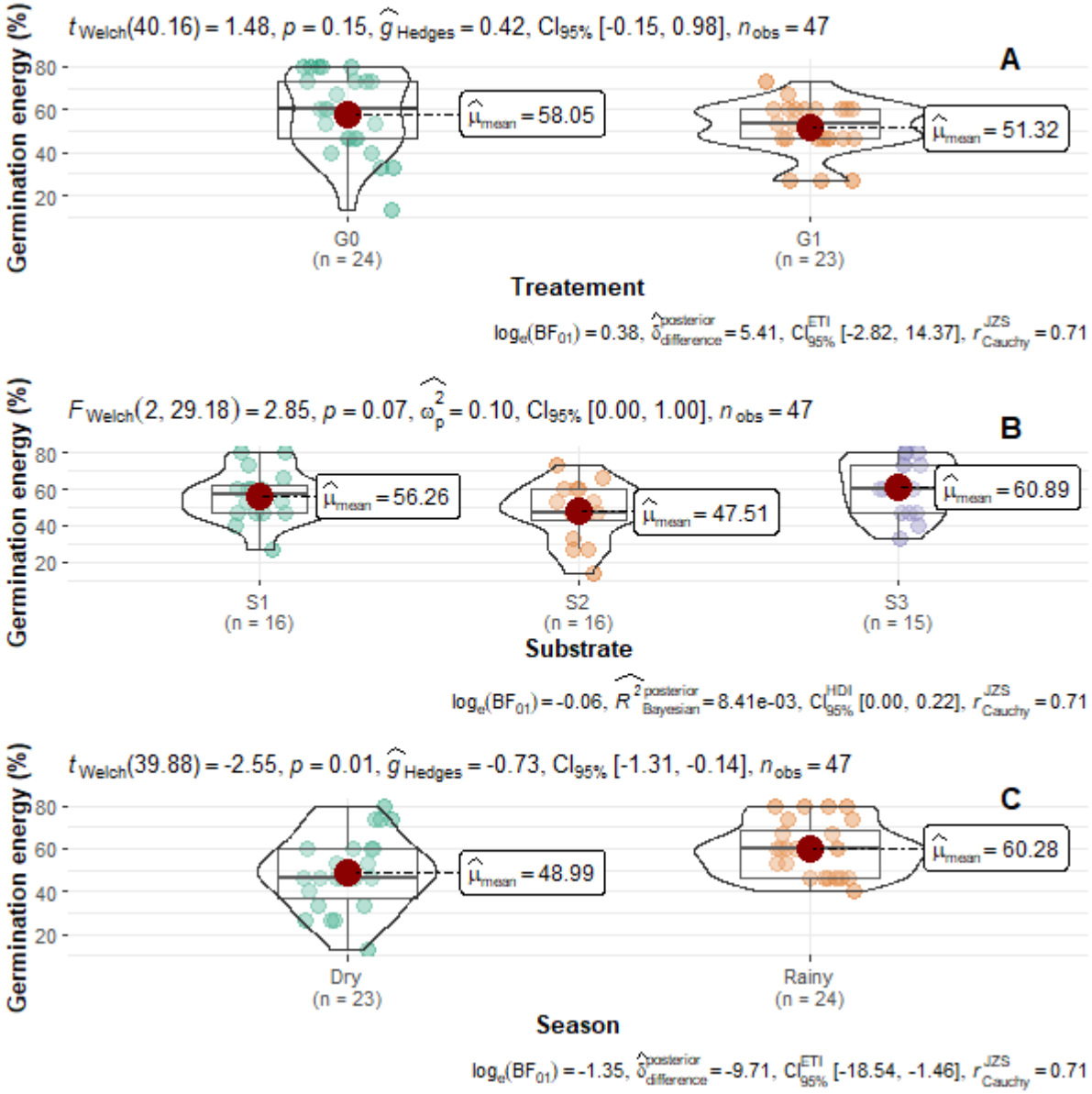

Figure 5 Effect of treatment, substrate and season on the germination energy of *Terminalia ivorensis* seeds in Kisangani (A: treatment, B: substrate and C: season. G0: unsoaked seeds and G1: soaked in water for 2 hours before sowing. S1: household waste; S2: forest soil; and S3: pig droppings. Dry: dry season; and Rainy: rainy season).

However, as for the germination rate, the season significantly influences the germination energy of T. ivorensis seeds. We see in Figure 5C that the rainy season gives better results, with an average germination energy of 60.28%.

III.3. GERMINATION SPEED

As for the previous parameters, the pretreatment by soaking in water for 2 hours and the substrate do not significantly influence the germination rate of T. ivorensis seeds under the conditions of this experiment (Figure 6 A and B). Numerically, the unsoaked seeds (G0) seem to give a higher germination rate than the soaked seeds, but this difference remains non-significant, as shown by the results of the Student t-test (p-value: 0.12). As for the substrates, the highest germination rate is observed with pig droppings (46.7%), followed by household waste (40%) and forest soil (36.65%). However, these differences are non-significant in terms of the germination rate and the germination energy.

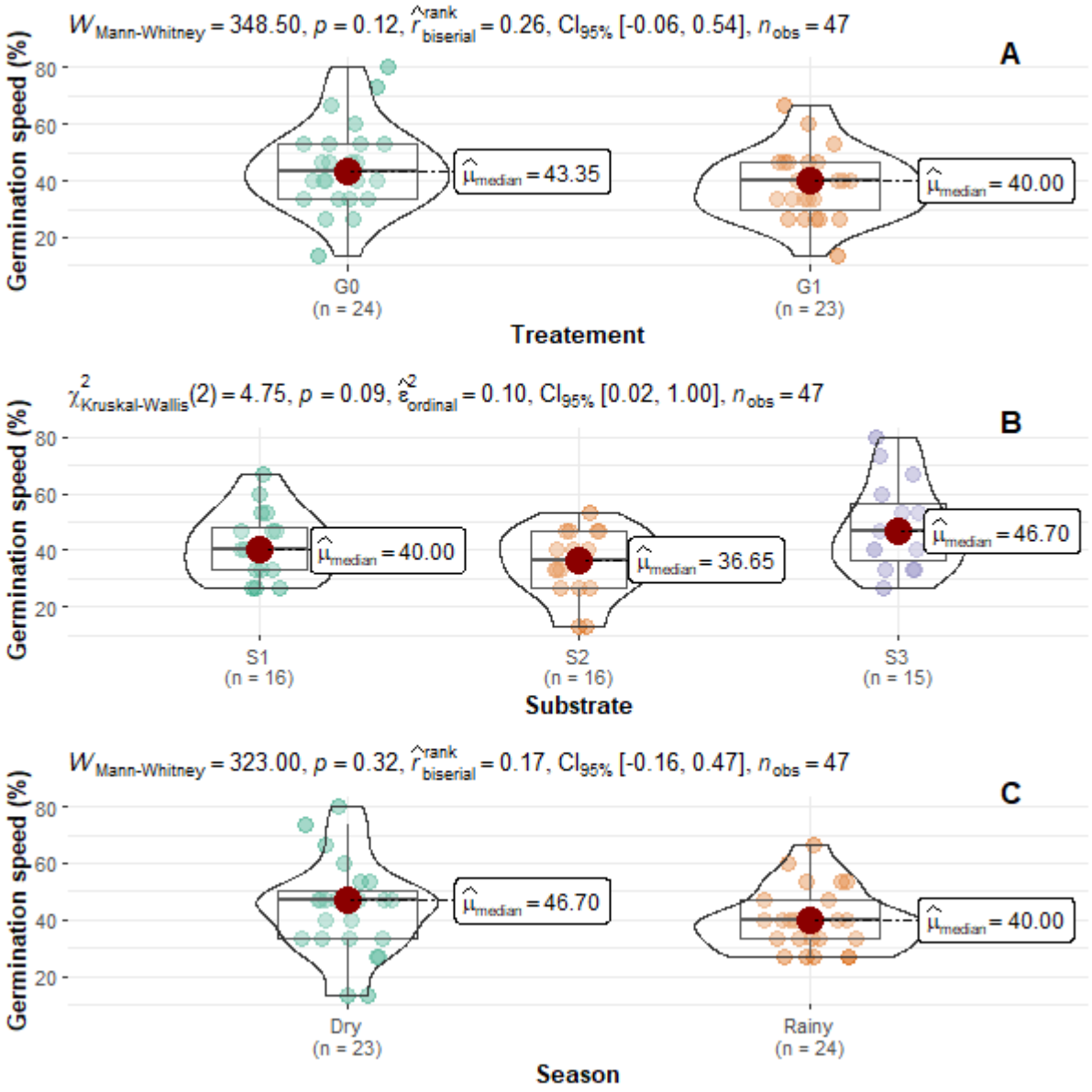

Figure 6 Effect of treatment, substrate and season on the germination rate of *Terminalia ivorensis* seeds in Kisangani (A: treatment, B: substrate and C: season. G0: unsoaked seeds and G1: soaked in water for 2 hours before sowing. S1: household waste; S2: forest soil; and S3: pig droppings. Dry: dry season and Rainy: rainy season).

The dry season gives the highest germination speed (46.7%). However, as shown by the results of the Student t-test (p-value: 0.32), the season does not significantly influence the germination speed of T. ivorensis seeds under the experiment's conditions.

IV. DISCUSSION

It was observed in this study that the germination rate and speed of T. ivorensis seeds are not influenced by soaking the seeds in cold water for 2 hours. Several explanations could be proposed, but the soaking duration is the most plausible. Indeed, a soaking duration of 2 hours does not seem sufficient to obtain better results compared to different durations used in other studies and for other species (Kaoutar et al., 2023). For example, Garba et al. (2020) obtained better results with a soaking duration of 72 hours for Tamarindus indica, which is far superior to the duration of 2 hours tested in this study. As for them, Sinadouwirou et al. (2022) obtained better germination rates for Detarium microcarpum for a soaking duration of 24 hours. In another study, Dardour et al. (2014) reported a better effect with boiling water for 24 hours. This shows that if soaking in tap water does not give good results with durations greater than 24 hours, soaking in boiling water could be considered. However, there are also studies where soaking seeds had no significant effect. This is the

case of the study by Dossa et al. (2020), who found that soaking *Detarium senegalese* seeds did not improve the latency time and significantly negatively affected the seed germination rate. However, ultimately, the argument about soaking duration is not to be generalised. Soaking does not affect the germination of T. ivorensis seeds, as better results have been obtained with durations of only a few minutes (Bayala et al., 2024). In other cases, soaking has negatively affected germination (Sogo et al., 2021).

Three substrates were tested: household waste, forest soils and pig droppings. As with the pretreatment, none of these three substrates significantly affected the germination of T. ivorensis seeds. Nevertheless, as the abundant literature on this subject shows, the substrate is not for nothing in the germination and juvenile growth of plants (González et al., 2010; Dardour et al., 2014; Djeugap et al., 2017; Dossa et al., 2020; Yélemou et al., 2021; Camara et al., 2023). Expanding the experimental design could make it possible to highlight this effect. If that fails, other substrates will have to be tested. Among the three substrates tested in this study, forest soils were the ones that gave the worst results in terms of germination. This formation raises many questions, given the good results obtained in other studies and for other species (Djeugap et al., 2017; Camara et al., 2023).

T. ivorensis seeds in the context of Kisangani, and this is for the germination rate and the germination energy. However, the germination speed is not significantly influenced by the season. Indeed, as shown by Dossa et al. (2020), the rainy season is very favourable for the growth of tree seedlings. However, its effect on seed germination has not yet been clearly defined.

V. CONCLUSION

This research aimed to determine the factors promoting the germination of *Terminalia ivorensis* (A. Chev.) seeds in the eco-climatic conditions of Kisangani. The effects of pretreatment, substrate and season were tested to do this. Pretreatment consisted of soaking the seeds in tap water for 2 hours before sowing. Three substrates were used: household waste, forest compost and pig droppings. The tests were conducted in the dry and rainy seasons to see seasonality's effect on seed germination. This experiment shows that the germination rate, energy, and speed do not vary depending on the treatment and substrate. This implies that *Terminalia ivorensis* seeds can be sown without soaking and in any substrate. Only the season significantly influences the seeds' germination rate and germination energy. Germination rate and germination energy are better in the rainy than in the dry season. The results obtained on the effect of soaking *Terminalia ivorensis* seeds in water indicate that it is important to test longer durations, of 24 hours or more, as is the case in other studies for other species.

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