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Effect of Thermal Variation and Steaming Time on the Rejection Capacity of Plantain (Musa Sapientum L.) at Gbadolite in the Democratic Republic of Congo

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Abstract: *The present study aimed to observe the effect of thermal variation and steaming time on the rejection capacity of plantain at Gbadolite in the Democratic Republic of Congo. The steamer was used to provide dry heat at the buckling scale according to the temperature and duration of steaming under in vitro conditions at the following temperatures and durations: 50°C, 80, 100 and 120°C for 1', 3 and 10'. Oven-dried subjects were set up in 4 randomized complete blocks, each containing 13 treatments: T0: control or non-oven-dried subject; T1: oven-dried reject at 50°C for 1'; T2: oven-dried reject at 50°C for 3'; T3: oven-dried reject at 50°C for 10'; T4: oven-dried reject at 80°C for 1'; T5: oven-dried reject at 80°C for 3'; T6: discharge steamed at 80 °C for 10'; T7: discharge steamed at 100 °C for 1'; T8: discharge steamed at 100 °C for 3'; T9: discharge steamed at 100 °C for 10'; T10: discharge steamed at 120 °C for 1'; T11: reject steamed at 120°C for 3'; T12: reject steamed at 120°C for 10'; 19; 22; 21; 22; 27; 28; 26; 25; 23; 26; 32; 48; 33 rejects per explant were obtained respectively. Thus, the best treatment remains explants steamed at 120° for 3'. In other words, explants should be heat-excited to stimulate rejection and shorten the weaning period.*

Keywords: *variation; temperature; steaming; plantain; Gbadolite; Democratic Republic of Congo*

I. Introduction

Plantains, consumed in a variety of forms, are central to the diets of people living in inter-tropical regions. Depending on the country, plantains rank first to fourth in terms of dietary importance in rural areas. Unlike dessert bananas, which are the subject of a well-organized global trade, plantains have little presence in international markets (Kwa & Temple, 2019).

Both the volume of banana production and the quantities marketed have grown rapidly in recent decades. World banana production is expected to increase by 10 million tonnes by 2029. The FAO has estimated world banana production at around 131.7 million tonnes in 2020, compared with 67.2 million tonnes in 2000, 37 million tonnes in 1980 and 21 million tonnes in 1961. On average, global banana production has risen from 69 million tonnes in 2000-2002 to 116 million tonnes in 2017-2019. Global production is expected to reach 126 million tonnes in 2029 (FAO, 2017; FAO, 2020).

However, this production needs to be improved due to demographic trends and poorly adapted or inadequate farming techniques. The unavailability of planting material for the extension or rejuvenation of existing plots and the creation of new plantations are undoubtedly the most important constraints (Kone et al., 2011). Indeed, finding suitable planting material is a major problem for farmers wishing to establish their farms by relying on natural rejection, as multiplication is low, with a rate of 5 to 10 in 10-18 months (Wilson, 1983).

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In Africa, plantain is mainly grown by smallholders. Its cultivation is an essential component of most agricultural systems (Koffi, 2004). It makes a significant contribution to food security, job creation and income diversification in rural and urban areas. In this way, it makes a significant contribution to the fight against poverty (Mialoundama et al., 2016).

In the Democratic Republic of Congo, plantain is the cash crop, which, in most cases, is the third most important source of household income after cassava, rice and maize. This crop plays a major role in food security. Bananas and plantains are rich in energy, mineral salts such as potassium, calcium and phosphorus, and vitamins A, B and C. Compared with other food crops, their production is second only to that of cassava (Dhed'a et al., 2019).

In North Ubangi in general, and Gbadolite in particular, plantain ranks eighth in terms of agricultural importance, after cassava, maize, groundnuts, rice, cowpeas, soybeans and beans. However, among staple foods, it ranks second after cassava (Molongo, 2022).

Despite its importance for development, very few studies have focused on the production of planting material for banana expansion. To set up a banana farm, planters harvest bayoneted shoots at least 6 months old and 1 to 1.30 m high. These are generally reduced to one unit per mother plant. This situation leads to problems in obtaining sufficient bayonet shoots for the farm (Ngo-Samnick, 2011).

Furthermore, it has been observed that the decline in plantain production is generally explained by a complex of causes such as lack of resistance to nematodes, lack of resistance to periods of drought, preference for rich organic soils, high susceptibility to Cosmopolites sordidus and poor rejection (De Langhe et al., 1983).

Several techniques exist to increase the production of shoots on a banana plant. The simplest is practiced in the field, notably weaning, decapitation, false decapitation and planting rhizome quarters (Kwa, 2003). These methods allow efficient exploitation of the multiplication potential of each rhizome, which has the advantage of producing numerous vigorous shoots and being reproducible even by the inexperienced farmer (Bonté et al., 1995; Kone et al., 2011).

Among the complex causes, the one that caught the attention of this study was that of poor rejection of plantain. For this reason, it is necessary to contribute with simple and less expensive techniques capable of stimulating the rejection power of this crop.

In 2023, Molongo et al. experimented with the influence of temperature and steaming time on the viability of plantain bulbs, concluding that even at 100°C for 10', the bulb remained viable. So, this time, we observed the influence of this couple by integrating another temperature, that of 120°C, on the plantain's rejection capacity with a view to producing planting material.

It is assumed that the combination of thermal variation and steaming time influences the plantain's rejection capacity and leaf area. In addition, bulbs with high rejection capacity would produce shoots with small corms.

II. Research Methods

2.1 Environment

The present study was carried out in Gbadolite, in the province of Nord-Ubangi, in the Democratic Republic of Congo, at the Plateau des Professeurs of the University of Gbadolite in the Pangoma district in the commune of Gbadolite. According to GPS, the geographical coordinates of the site are as follows: 4°15'44" Latitude North and 20° 59 5"' Longitude East with an altitude of 394.7 m.

The relief of the town of Gbadolite is made up of plateaus, hills and plains, and the climate is of the Aw_2 type according to Köppen's classification (FACET, 2010). The soil is clayey-sandy, rainfall is relatively abundant with an annual average of over 1,600 mm, and insolation is low, representing 45% of total tropical energy radiation (Molongo et al., 2015). The direct solar radiation intensity is 25 g calorie/cm²/minutes (Molongo et al., 2019).

The vegetation in the town of Gbado-lite used to be evergreen equatorial rainforest, but as a result of the anthropogenic effects exerted on this forest, the vegetation has been reshaped by savannah dominated by *Imperata cylindrica, Pennisetum sp, Chromolaena odorata, Pannicum maximum and Mimosa pudica* (Molongo et al., 2022).

2.2 Materials

The materials used in this study were a dry heat oven to provide variable working temperatures, and plantain rejects from local cultivars harvested from farmers' fields in the Pangoma district: French and *Yongo* types. For this experiment, we used bayonet shoots with a diameter of around 7 cm and a length of 30 cm reduced to 15 cm, which are regularly used by musaculturists because of their high recovery rate, as shown in Figure 1.

Figure 1. *Diet, bayonet shoots of Yongo cultivar and selection according to corm size.*

The temperatures and durations of the treatments are illustrated in Figure 2.

Figure 2. *Steaming of banana plantain rejects in the laboratory of the Nord-Ubangi Provincial Health Division in Gbadolite (DR Congo)*

Potassium Permanganate (70%) was used to disinfect the knife during the hulling and weaning of plantain shoots.

2.3 Methods

The plantain shoots were dehydrated for 24 hours, stripped, trimmed, kept in the shade for 48 hours, then steamed, cooled for 12 hours and finally sown in the masonry propagator, 2 m long and 2 m wide, sheltered by a greenhouse.

In this study, plantain rejects were steamed. The apparatus is used to provide dry heat at the buckling scale according to the temperature and time pair at steaming under in vitro conditions at the following temperatures and times: 50°C; 80; 100 and 120°C for 1', 3 and 10'.

Parboiled subjects were installed on a device in 4 randomized complete blocks each containing 13 treatments including T0: the control or non parboiled subject; T1: parboiled rejection at 50 °C for 1'; T2: parboiled rejection at 50 °C for 3'; T3: parboiled rejection at 50 °C for 10'; T4: parboiled rejection at 80 °C for 1'; T5: discharge steamed at 80 °C for 3'; T6: discharge steamed at 80 °C for 10'; T7: discharge steamed at 100 °C for 1'; T8: discharge steamed at 100 °C for 3'; T9: discharge steamed at 100 °C for 10'; T10: discharge steamed at 120 °C for 1'; T11: discharge steamed at 120 °C for 3'; T12: discharge steamed at 120 °C for 10'.

The substrate used was sawdust previously disinfected with boiled water, and the trimmed shoots were scarified to inhibit apical growth of the mother stem in an agricultural greenhouse 10 m long and 10 m wide. The sprouts were weaned as shown in figure 3.

Figure 3. *Planting and weaning in an agricultural greenhouse in Gbadolite (DR Congo)*

The present study observed the following parameters: recovery rate (in %) $= \frac{\text{Nombre des rejets repris}}{\text{Nombre total des rejets plantés}}\ x\ 100$ (Molongo et al. 2022); weaned shoot height using a tape measure; weaned shoot corm diameter using a caliper; leaf area (in cm^2) using the following ratio: $Sf\ (en\ cm2) = \frac{D\,x\,d}{2}$ either length (in cm) : leaf width (in cm) x 2; the number of weaned shoot leaves and the number of shoots emitted per bulb by counting.

The results were analyzed using Excel and IBM SPSS 20 Statistics software; a single-criterion analysis of variance was used for classification with sampling; the F Snedecor test was adopted to identify the significant difference between treatment means; the Tukey test was used to detect smaller significant differences and to group treatments.

III. Results and Discussion

3.1 Trade-in Rate

The recovery rate was assessed, and the results are shown in Figure 4.

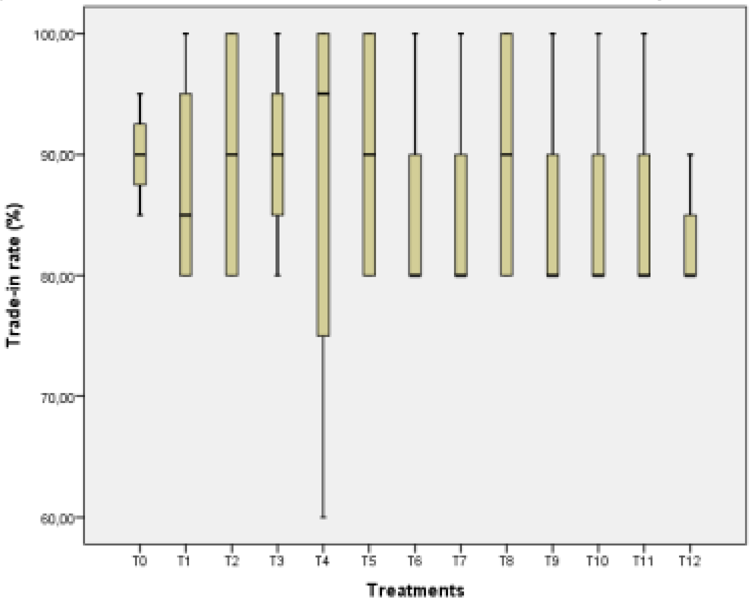

Figure 4. *Trade-in rate (%)*

The recovery rate varied between 82.5% and 90% for both steamed and control subjects. Such viability is due to the enrichment of water in the tissues, which enables the plant to adapt to higher temperatures. Coefficients of variation were below 30%, so rates were homogeneous. Statistical analysis revealed that there was no significant difference between treatments with regard to this parameter. Such a rate sufficiently demonstrates that rejects were viable in both controls and steamed subjects, even at 120°C for 10'.

3.2 Discharge Height

The height of weaned rejects is shown in Figure 5.

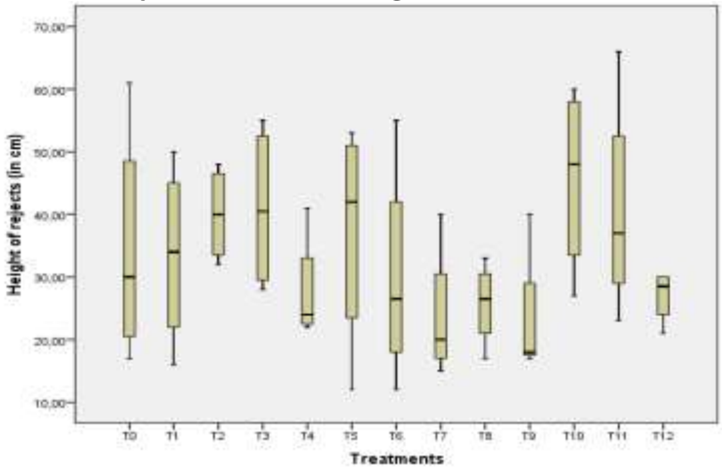

Figure 5. *Height of weaned rejects*

It was observed that shoot height varied between 23.2 cm and 41 cm, respectively, for shoots steamed at 100°C for 10' and 50°C for 10'. The coefficient of variation showed that subjects were heterogeneous, with no significant difference between treatments.

3.3 Corm Diameter

Figure 6 shows the results for the corm diameter of weanlings.

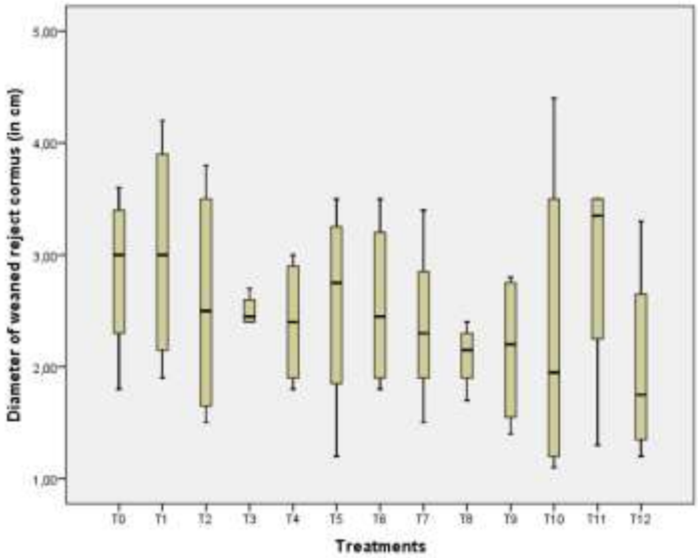

Figure 6. *Corm diameter of weaned shoots (in cm)*

It should be noted that the smallest corm diameter (2 cm) of weaned shoots was obtained in subjects steamed at 120°C for 10', while the largest (3 cm) was obtained in subjects steamed at 50°C for 1'. The effect of overcrowding in corms justifies this situation steamed at 120°C, as they are obliged to be supported by a single corm with a limited amount of reserve under *ex-situ* conditions. The coefficient of variation indicates a certain degree of heterogeneity between treatments, meaning that plantain bulbs do not produce shoots of the same corm size in the same way. Statistical analysis showed that there was no significant difference between treatments with regard to this parameter.

3.4 Number of Leaves

The number of leaves on weaned shoots is shown in Figure 7.

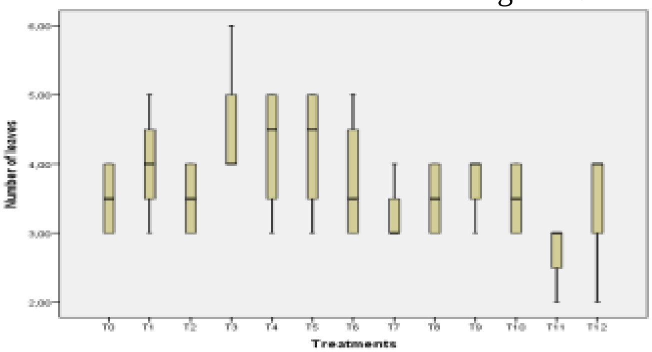

Figure 7. *Number of leaves on weaned shoots*

The results shown in Figure 6 suggest that the smallest number of leaves (3) in weaned shoots was observed in subjects treated at 120°C for 3' and the largest (5 leaves) in subjects steamed at 50°C for 10'. This parameter followed the same trend as crown diameter, but the number of leaves was homogeneous across treatments, with a coefficient of variation of less than 30%. Statistical analysis also showed that there was no significant difference between treatments.

3.5 Leaf Area

The leaf area was assessed, and the results are shown in Figure 8.

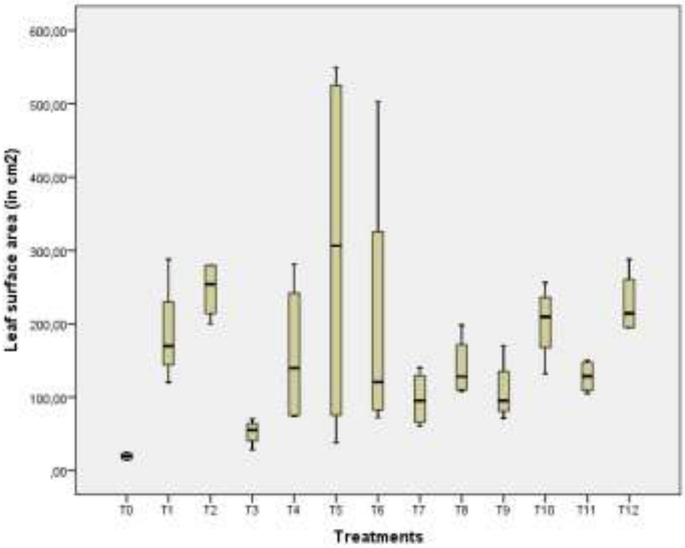

Figure 8. *Leaf area (in cm²)*

Looking at the results in Figure 7, the leaf area in this study was smallest in the controls (19.3 cm^2) and largest (300 cm^2) in the rejects steamed at 80°C for 3'. The coefficient of variation showed that leaf area was heterogeneous between treatments. Statistical analysis showed that treatments differed significantly; Tukey's Test grouped them in the same way as steamed subjects differed from controls.

3.6 Number of Rejects Weaned, Frequency of Weaning, Day At 50% Reject

The number of releases per corm is recorded in Figure 9.

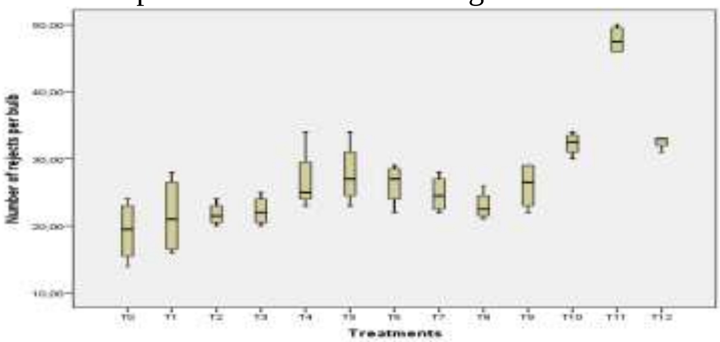

Figure 9. *Number of releases per cormus.*

In terms of rejects per bulb, 19 weaned rejects were counted in the control group and 48 weaned rejects in the group tested at 120°C for 3'. The observed coefficient of variation was less than 30%, which means that weaning power was homogeneous throughout the investigation. Statistical analysis revealed that the difference between treatments was significant; the best treatment was the subject treated at 120°C for 3', which was no different from other treatments, notably those steamed at 120°C for 10' and 1'; 80°C for 3'; 80°C for 1' and 10'; 100°C for 10' and 1', but these were different from rejects treated at 100°C for 3'; 50°C for 10'; 50°C for 3'; 50°C for 1' and controls. In other words, heat stimulated the bulbs' rejection capacity, dehydrating them to make the eyes perceptible, capable of budding and thus giving rise to shoots as planting material.

The Day to 50% weaning was shorter in steamed plants (14 days) than in control plants, especially in shoots steamed at 120°C for 3', where weaning was observed at around 10 days, but longer in control plants (over 14 days); weaning took place after 30 days in steamed plants at 100 and 120°C, but at 37 days at 50 and 80°C under greenhouse conditions. The frequency of weaning was proportional to the temperature and duration of steaming, with bulbs steamed at 50 and 80°C undergoing two weanings; bulbs steamed at 100°C underwent 3 weanings, while bulbs steamed at 120°C underwent 4 weanings.

3.7 Discussion

The present study evaluated the influence of thermal variation and steaming time on the rejection capacity of plantain under *ex-situ* conditions *with a* view to stimulating the release of shoots as propagation material.

The recovery rate during this study varied between 82.5% and 90%; such a recovery rate shows that the offshoots were carefully selected, and this situation corroborates that of Bangata et al. (2018) according to which good quality cultivars are capable of giving a recovery rate of over 85%. As the case of mortality is very minimal, such a recovery confirms the thesis that the banana is classified as a mega-thermal plant due to its waterlogged tissues, which enable it to withstand high temperatures (Molongo, 2022; Molongo et al., 2023).

The average height of weaned shoots in this study was over 17.7 cm, and 23 cm of Saba cultivars with a coefficient of variation of 11%; the corm diameter of subjects in our research ranged between 2 and 3.3 cm (Bangata et al., op. cit). The average corm diameter was 1.4 - 2.4 cm greater than that observed by Bangata et al. (2019); this is justified by the fact that small explants with a high number of seedlings lead to competition for reserves under semi-controlled conditions.

The number of leaves at weaning was between 3 and 5 per shoot, which were transplanted into polyethylene bags filled with potting soil and sawdust, watered and installed in a hardener before moving on to the nursery to alleviate stress and trigger rhizogenesis. Thanks to the root-leaf synergy, these leaves are able to lead independent lives. This situation corroborates that of Kwa (2003), according to whom weaning took place around 3 to 6 weeks later, when the plants formed had between three and five leaves. The young banana plants were then taken out of the germinator and transplanted under the shade in black or opaque 0.5 L polyethylene bags filled with a mixture of soil and coffee parchment and sterilized over a wood fire for at least 12 hours.

In addition to the controls, which produced 19 shoots per bulb, explants from steamed subjects produced between 22 and 48 shoots, respectively, for the bulb steamed at 50°C for 1' and the bulb steamed at 120°C for 3' after 30 to 37 days; a similar timeframe to that of Bangata et al. (2019). The number of releases in this study was greater than the 10 and 20 plants per explant obtained by Kwa (op. cit) and Molongo et al. (2015).

The same authors reported that good-quality cultivars were able to produce the highest number of weaned seedlings per fragment, 6 and 7 seedlings, after one month's incubation. On the other hand, the lowest number of weaned seedlings was found in explants from banana Dessert Gros Michel, which yielded 2 seedlings. The same authors obtained the highest number of weaned seedlings per explant from Saba and Cardaba cooking bananas, giving 35 and 34 seedlings, respectively, followed by Bubi plantain with 31 seedlings. Whereas the lowest total number of seedlings was observed in Dessert Gros Michel, emitting 23 seedlings. We note that our results were lower than the 96 and 106 seedlings obtained from a 90 and 60 cm circumference stump, respectively (Lyadunga et al., 2020).

Comparing these results, we observed that heat stimulated rejection and shortened the weaning period by 7 days. Control explants were weaned after 37 days, and control explants after 30 days. The program extended the study period to 4 months. This time frame corroborates that of Paka et al. (2019), according to whom the weaning duration shows that cultivars produce seedlings within a time interval of between 90 and 121 days, or 3 to 4 months, compared with that reported by other studies, whose values ranged from 64 to 150 days, or 2 to 5 months.

The results show that the cultivars evaluated can produce seedlings in the greenhouse in a short time by stimulating the shoots with heat, which is interesting for avoiding possible rotting of the stumps by dehydrating the shoots and making their dormant eyes more suitable for budburst with a view to producing the shoots as planting material in favor of musaculturists in a short time. This thesis is supported by Kone et al. (2011), who argue that the technique used was characterized by the destruction of the meristem and the presence of a hormonal balance in plantain, including gibberellic acid, which promotes the lifting of dormancy in young buds, and auxins, which inhibit bud development.

IV. Conclusion

This study was initiated to observe the influence of temperature and steaming time on the rejection power of plantain (Musa et al.) at Gbadolite in the Democratic Republic of Congo.

The results show that 19 weaned shoots were counted on the control bulbs and 48 weaned shoots on the subjects steamed at 120°C for 3';

The leaf area in this study was smallest in the controls (19.3 cm2) and largest (300 cm2) in the rejects steamed at 80 °C for 3';

Shoots with a small corm diameter (2 cm) were those weaned from subjects steamed at 120°C for 10', while the largest (3 cm) were weaned from subjects steamed at 50°C for 1'.

As plantain is a crop of great scientific and socio-economic importance, it is important to compare the rejection power of cultivars of the same type and to carry these trials through to production in order to study agro-morphological characteristics.

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