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RESEARCH ARTICLE

SOIL PROPERTIES AND AGRONOMIC EVALUATION OF TOMATO LINES (SOLANUM LYCOPERSICUM L.) IN THE NORTHWEST REGION OF GABON

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Abstract

The availability of tomato seeds adapted to local production conditions remains one of the major constraints for a sustainable tomato industry in Gabon. An agro-morphological characterization of ten tomato lines enabled us to assess their potential on the soil of the north-western region of Gabon. At this end, the properties of the soil were analyzed on the one hand, then, agronomic parameters of the tomato lineswere assessed on the other. Univariate and multivariate analyses of agronomic data were carried out using R software. Granulometric analysis revealed that the soil had a silty-sandy structure (29% coarse silt, 28.71% coarse sand). The mineralogical composition shows an assimilable phosphorus content of 15.51ppm and concentrations (in meq/100g) of potassium, calcium, sodium and magnesium of 0.41, 0.99, 0.32 and 0.60 respectively. For agronomic results, flowering time ranged from 26 to 36 DAS and first harvests from 70 to 84 DAS. Line L1 was the earliest and L9 the latest. For the yield, lines L4 (26.7 t/ha) and L8 (20.5 t/ha) were the most productive. The fruits with the best sizes were those of lines L2 (87.7 g) and L4 (86.6 g). Lines L1, L4, L5 and L8 were the firmest. The various diseases observed were downy mildew, spoon yellows and apical necrosis, with a moderate severity index (23,08 %) for all lines. These results show the agronomic performance of certain tomato lines on the sandy-loam soils of Gabon; and for varietal improvement programs to increase tomatoes productivity in Gabon.

Introduction:-

Market garden production is an important component of the African urban environment and represents the main activity in urban agriculture (Mushagalusa and Nkulu, 2020). Market gardening is a vital agricultural sector in sub-Saharan Africa due to the significant economic income it generates and the nutritional value of the food products it offers (Kere, 2016). It thus contributes to food and nutritional security, and supports people's family economies.

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Despite Gabon's significant potential in terms of its natural agro-ecological assets, the country remains highly dependent on food imports. The country imports over 80% of its food resources (Tsamoye, 2016). Less than 40% of the food needs of the population living in Gabon are satisfied by local agricultural production. This food deficit reflectsinto import costs of up to 450 billion FCFA, mainly from neighboring countries such as Cameroon and Congo (Belfegor, 2021). According to FAO estimates, Gabon has the lowest yield of fresh vegetables in the CEMAC zone, at 5.5t/ha. To meet local demand, this low production is offset by 1/3 of vegetable imports from Central Africa (Mariella et al., 2017). Among the vegetable’s crops, the tomato (Solanum lycopersicum L.) occupies a special place, as it is one of the most important vegetable crops in the world (Naika et al., 2005). According to FAO data, global production has risen rapidly over the last decade, from 141.4 million tonnes in 2009 to 177 million tonnes in 2016. Tomato, widely produced and consumed around the world, represents an economically valuable vegetable crop (Bergougnoux, 2014). It ranks second only to potatoes among the world's most widely consumed vegetables (Fondio et al., 2013). It plays an important role in the human diet and is eaten raw or processed. Medicinally, studies have shown that regular consumption of tomatoes or tomato-based products reduces the risk of cancer, cardiovascular disease, diabetes and osteoporosis (Chanforan, 2010).

Estimates for the last five years in Gabon show that tomato production occupies an average area of 45 ha for an estimated yield of 8511.5 kg/ha with annual production estimated at 385 tons (Biroungou, 2022). This production is far from meeting the growing demand of its population, which implies massive imports of tomatoes to fill the production gap. Apart from the persistence of rudimentary agricultural practices, several factors are contributing to Gabon's low tomato production: high pest pressure, the influence of climatic factors, soil degradation heavily impacted by human activities and, above all, the absence of high-performance varieties adapted to local climate and soil’sconditions. Indeed, the commercial hybrid varieties currently available are known to be generally sensitive to the country's biotic and abiotic factors (Gnacadja et al., 2022).

Very little research has been carried out to help improve tomato productivity, in order to provide one or more solutions for stakeholders (professional)in Gabon's tomato industry, which has so far struggled to develop. It is in this context that Gabon is developing a global research program aimed at "Strengthening tomato production in Africa for maximum sustainable yield". The aim of this study is to understand the soil properties and evaluate the agronomic potential of ten tomato (Lycopersicum esculentum) lines in northwestern Gabon, with a view to improving production.

Materials and Methods:-

Plant material

Ten tomatoes (Lycopersicum esculentum) lines developed from the Asian Vegetable Research and Development Center (AVDRC), two tomatoes varieties from the Institut National des RecherchesAgricoles du Benin (INRAB) and an one F1 hybrid variety used in the local trade were evaluated in the trial (Table 1).

Soilanalysis

Systematic random sampling of the soil in a square grid pattern was carried out on the cultivation site, followed by sieving through 2 mm mesh. The sample was analyzed at the soil laboratory of the Faculty of Agronomy, University of Abomey-Calavi, Benin. The following parameters were determined to provide indicative average data on the granulometric structure and physico-chemical characteristics of the soil at the site.

Particle size and physico-chemical parameters analyzed:

1. Granulometric texture: Robinson(1949) method based on Stokes' law.
2. Apparent density, porosity and water saturation rate: CEAEQ (2009)method
3. Soil pH(water) and pH(KCl)**:** potentiometric method (ISO 10390**)**
4. Organic matter (OM) content: Bell (1964) method
5. The ash content of the mass of inorganic residue obtained after incineration
6. Total nitrogen: Kjeldahl (1883) method
7. Assimilable phosphorus content (Pass): Bray and Kurtz (1945) method.
8. Exchangeable cations (potassium content), total sodium, total calcium and total magnesium: atomic absorption spectrophotometry (AAS) using the method of Helmke and Sparks (1996)

Experimental set-up

The experiments were carried out on the site of the Agence de Développement Agricole du Gabon (ADAG) in the Avorbam district, located in the Commune of Akanda (0°31'40.69 "N and 9°23'39.10 "E) Komo-Mondah Department in the Estuaire Province north of Libreville. The study area is characterized by constant heat, high humidity and frequent, abundant precipitation. Temperatures range from 24 to 33°C during the day and 24 to 29°C at night, with average humidity varying between 85 and 93%. Annual rainfall ranges from 2,926 to 3,935 mm.

The trial was laid out in a Fischer block design with 3 replicates. The "plant material" factor studied was made up of 13 variants, including 10 lines and 3 varieties. The experiments consisted of 39 treatments for 3 replicates. The cultivation plot consisted of a 10 m^2 soil bed (LxW: 1.5 m x 6.6 m). Plants were transplanted at 60 cm x 40 cm spacing (60 cm between rows and 40 cm between plants on the row), giving a density of 21,000 plants/hectare. The variants were arranged randomly in each block. The distance between two elementary plots was 0.5 m. Each block was separated by a 1.5 m aisle. The total trial area, including the 1.5 m aisle around the plot, was 735.3 m^2.

Based on the site's previous cultivation history, a basic fertilizer amendment (hen droppings at a dose of 3kg/m^2 and a standard proportion of 10g/m2 N15P15K15) was applied before transplanting the seedlings. The plants were watered daily as required and weeded manually.

Data collection

Observations were made at different stages of tomato development on a predefined sample. The sample consisted of seven (07) plants per elementary plot, randomly selected and fixed, excluding border plants. Observations of fruit quality were carried out on a sample of ten (10) ripe fruits randomly selected within each elementary plot.

The following parameters weremeasured: Emergence time (Dl), Flowering time (Df), Maturity time (Dm), Cycle time (Dc), Recovery rate (Tr), Flowering height (Hf), Fruit width (Larf), Fruit length (Lonf), Average fruit weight (Mmf), Number of healthy fruits (Nfs), Number of damaged fruits (Nfa), Healthy fruit weight (Pmfs), Damaged fruit weight (Pmfa), Net yield (RdtN), Potential yield (RdtP), Fruit shape (Frf), Fruit firmness (Fmf).

Disease diagnosis was based on conventional symptomatic parameters for the manifestation of fungal, bacterial and viral diseases of tomato at 30 DAR. The degree of severity according to the pathogen-host reaction rating scale(Vakalounakis et Fragkiadakis 1999) was also assessed

Data analysis and statistical processing

The raw data collected were reported and processed using Excel spreadsheet, version 2016. The mean values of quantitative data were also calculated in Excel. An analysis of variance (ANOVA) with one classification criterion was performed for all parameters studied, to check for significant differences between means. When a significant difference was observed between the different characteristics ($P_{value} < 0.05$), the means were compared using Duncan's and Fisher's LSD tests at the 5% threshold to classify the means into homogeneous groups. The structuring of line variability was carried out through grouping using Principal Component Analysis (PCA) to assess the similarity between the accessions analysed and to understand the existing relationships between them. Hierarchical Ascending Classification (HAC) was performed to classify accessions into homogeneous groups according to the Ward method, using a Euclidean distance similarity index. These multivariate analyses were performed using R software [version 4.1.2].

Results:-

Soil analysis

Granulometric analysis.

Results of soil'sparticle size (Table 2) shows that it consists on average of 29% coarse silt, 11.2% fine silt, 23.44% fine sand, 28.71% coarse sand and 6.5% clay. Among other things, the test site had an organic carbon content of 0.99%, a total nitrogen content of 0.046%, an assimilable phosphorus content of 15.51ppm and a concentration (in meq/100g) of potassium, calcium, sodium and magnesium of 0.41, 0.99, 0.32 and 0.60 respectively. Results in kg/ha are as follows:

(K): kg K/ha ÷ 876 = meq K /100 g soil (0.41x876 = 359.16 kg/ha)

(Mg): kg Mg/ha ÷ 272 = meq Mg /100 g soil (0.60x272 = 163.2 kg/ha)

(Ca): kg Ca/ha ÷ 448 = meq Ca /100 g soil (0.99x448 = 443.52 kg/ha)

Soil acidity. The values for pH-$_{H2O}$ and pH-$_{KCl}$were 4.98 and 4.56 respectively, indicating soil acidity trends.

Agro-morphological variability and yield potential

Analysis of tomatoes lines' agronomics performance revealed that they differed each over significantly ($P < 0.05$) in their mean values for the various traits studied. Some lines performed better than the control (T3), while others performed less well. For the 13 lines studied, emergence or germination time (Dg) was 6 days after sowing (DAS) for all accessions, except for lines V1 and V2 for which germination was early, i.e. 4 days after sowing. Flowering was late for the line (L9), i.e. 36 days after transplanting (DAR), and early for L1, V2 and T3, i.e. an interval of 26 DAR. Descriptive analysis (Table 3) shows that the minimum and maximum values for the maturity delay trait (Dm) were from70 to 84 DAR respectively. The cycle time (Dc)length interval ranged from 81 to 92 JAR.Flowering height (Hf) ranged from 55.10 to 71 cm, with an average of 63.46 cm.

Variability was observed in yield components and fruit quality parameters. Fruit length ranged from 4.8 cm to 7.9 cm and fruit width from 3.3 cm to 7.7 cm, with averages of 7.05 and 5.46 respectively. Numbers of healthy (Nfs) and damaged (Nfa) fruits ranged from 12 to 570 fruits (with an overall mean of 181.2) and from 3 to 231 fruits (with an overall mean of 99.92) respectively. The average mass of fruit harvested per line (Mmf) varied from 40.10 to 87.80 g fruit/line. Potential yield in tonnes per hectare (RdtP) ranged from 0.90 to 38.60t/ha, and net yield in tonnes per hectare (RdtN) from 0.60 to 26.70t/ha. Lines L2, L4, L5, L8, V1 and T3 have both theoretical and potential yields in excess of 15t/ha.

The frequencies of the fruit quality characteristics presented in Table 4 show significant variability between characteristics.The results of descriptive analyses of fruit quality parameters are shown in Table 4.

Observations of fruit shape and firmness revealed five (05) morphological aspects and two levels of firmness: The rounded elongated shape (ovoid) was the most representative (L4, L5, L6 and T3). Heart-shaped (L7, L8 and L9) and slightly flattened (L1, L10 and V1) shapes accounted for 23.08%, while rounded shapes (L2 and L3) accounted for 15.38%. Only V2 has a cylindrical shape. For most lines, notably L2, L3, L6, L7, L9, V1 and T3, firmness average was at 61.53%. V1 was the only variety to show soft firmness.

Variability of the characteristics studied (Table 5)

The first level of analysis (one-way ANOVA) revealed significant differences ($P < 0.05$) between lines for the agronomic performance parameters studied. However, it does not allow us to assess the level of interaction that exists between the variables themselves on the one hand, and between the variables and the lines on the other. The table revealed, for significant correlation values ($P < 0.05$), highly positive correlations between germination time (Dg) and fruit width (lFr) ($r = 0.69$), then between germination time (Dg) and average fruit mass (Mmf) ($r = 0.77$). Positive correlations are observed between recovery rate (Tpr) and flowering time (Df) with $r = 0.65$; flowering time and ripening time (Dm) ($r = 0.68$). This correlation also exists between height at flowering (Hf) and fruit length (LFr), height at flowering and fruit width with "r" equivalent to 0.55 and 0.56 respectively. There was also a positive correlation between number of healthy fruits (Nfs) and average healthy fruit weight (Pmfs) [r = 0.76], number of healthy fruits (Nfs) and net yield (RdtN), [r = 0.76], number of sound fruit (Nfs) and potential yield (Rdtp), [r=0.66], number of damaged fruit (Nfa) and average weight of damaged fruit (Pmfa, [r = 0.84], number of damaged fruit (Nfa) and potential yield (Rdtp, [r = 0,66], average fruit mass (Mmf) and potential yield (Rdtp, [r = 0.65], average healthy fruit weight (Pmfs) and net yield (RdtN, [r = 1], average healthy fruit weight (Pmfs) and potential yield Rdtp, [r = 0,90], average weight of damaged fruit (Pmfa) and potential yield (Rdtp, [r = 0.63] and finally between net yield (RdtN) and potential yield (Rdtp) [r = 0.90].

On the other hand, negative correlations are observed between ripening time (Dm) and fruit length (LFr) [r = -0.57] and fruit length (LFr) and number of spoiled fruits (Nfa) as well as between fruit length (LFr) and number of healthy fruits (Nfs) with "r" values from-0.56 to -0.55 respectively.

Structuring line variability

The grouping of lines by PCA (Table 6) showed the eigenvalues and percentage variance of quantitative traits contributing to total variation. According to the kaiser criterion criterion (Akanvou et al., 2012) which follows the principle of minimum inertia, any axis with an eigenvalue greater than 1 should be retained for analysis.

The first three axes were selected to describe the total variability of tomato accessions. These axes alone explain 72.80% of the total information between lines. The total variability of axes 1, 2, and 3 were 32.71%, 25.22%, and 14.87%, respectively.

The correlation circle (Figure 1) obtained after PCA with the first two axes cumulating at 57.93% explains the degree of representation and correlation between variables.

The first principal component (axis 1), with 32.71% of total variation, was strong, and traits relating to potential yield (RdtP), net yield (RdtN), average healthy fruit weight (Pmfs) and average fruit mass (Mmf) were positively correlated with average damaged fruit weight (Pmfa), number of healthy fruits (Nfs) and number of damaged fruits (Nfa). Therefore, it can be described as an axis of line productivity and quality. The second principal component (axis 2) describes 25.22% of variability. It groups together, according to the importance of their contributions, on the one hand, the characters "number of healthy fruits (Nfs) and cycle delay (Dc)", which are strongly and positively correlated, and on the other hand, the character's germination delay (Dg), fruit length (LFr) and fruit width (lFr), which are strongly and negatively correlated. This axis reflects the phenological stage of the plants and fruit dimensions.

The third component (axis 3), which explains 14.87% of the variation, highlights the links between flowering time (Df) and recovery rate (Trp), which were strongly and positively correlated. Axis 3 provides complementary information to Axis 2, wich is related to the phenological stage of the plant.

Grouping of lines by CAH

Hierarchical Ascending Classification (HAC) was performed based on the quantitative variables studied. The dendrogram produced (Figure 2) using Ward's method (1963) identified three clusters.

The CAH results identified three clusters. Cluster 1 is made up of lines L7, L9, L10 and T2. Cluster 2 consists solely of T1, while cluster 3 includes lines L1, L2, L3, L4, L5, L6, L8 and the Lindo control (T3). The v-tests (test values) obtained (Table 7) were used to sort the variables in order to identify those characterizing the clusters.

Table 7 shows that seven variables were used to group lines in Cluster 1: "ripening time, average fruit mass, weight of healthy fruit, weight of damaged fruit, number of damaged fruit, net yield and potential yield"; for Cluster 2: "germination time, fruit length and number of healthy fruit"; for Cluster 3: "germination time, average fruit mass, weight of damaged fruit and potential yield".

Variability in the identification of disease types and levels

Cases of fungal diseases such as mildew were observed on certain lines. Similarly, leaf curling with symptoms of spoon yellows was observed. Blossom end necrosis diseases were also identified.

However, the level of disease severity varies through lines from "Grave" to "No disease" (table 8).

Symptom characteristics of mildew have been observed in some plants. Black, pale, irregular, and oily patches were observed on leaves, stems, and fruits, which were blackened and hardened with a bumpy appearance. These symptoms were observed on lines L4, L5, and L6 with a moderate level of disease (23.08%), and on line L1 with a low level of disease (slight). Symptoms were not observed in the control group.

Typical symptoms of spoon yellows disease (leaf curling, yellowing, stunting) were observedin lines L8 and L9 (mild level of disease), and in L7 and T2 (moderate level of disease).

The physiological damage assessed was the presence of apical necrosis, recognizable by a black spot at the tip of the fruit, making it unmarketable. Apical necrosis is the most damaging disease observed on all lines, with 93% of fruit attacked of moderate to severe severity, including half (53%) of the lines studied The most severe level of damage was observed for lines L3 and L10 (15.38%), and moderate damage for L1, L2 and L4. Only control T2recorded no apical necrosis.

Discussion:-

Soil analysis

According to the texture triangle (FAO) used to determine soil texture, granulometric structure results of the soil sampled clearly shows a silty-sandy structure [Silt: 40.6%; Sand 52.15%; Porosity: 32.76] in the experimental site. This typical soil structure of the Coastal North region of Gabonese capital, Libreville have been also described by Ondo (2011). Indeed, this is a fairly common soil type that is also more frequent in areas where soils are formed from alluvial deposits, such as river floodplains and deltas. They are permeable to water and air due to their textural porosity, resulting in good aeration, soil drainage and root development. However, in the dry season, these soils tend to dry out very quickly, resulting in high water requirements. This composition (low clay content) also explains the average values obtained for bulk density, porosity and water saturation rate, which are related parameters.Measures of pH[pH-$_{H2O}$ =4.98;pH-$_{KCl=}$4.56] indicate soil acidity up to the required range for tomato cultivation [5.5 - 7.5]. Concerning total organic matter, the soil has an average rate of 1.706, indicating that the site is not organically rich. The C/N ratio is used to assess the quality and degree of evolution (mineralization) of organic matter. The results of this study show low mineralization, reflected by a C/N ratio of over 12 (21.61). In cultivated soils, mineralization is generally considered high when the C/N ratio is below 8, good when it is between 8 and 12, and low (nitrogen availability is a limiting factor for biological activity) when the ratio is above 12 (Genot et al., 2007). Soil pH is influenced by the soil's organic matter content. Soil acidity influences the solubility of nutrients and hence their availability to plants. The studied soil presents a high acidity for tomato cultivation thus, correction of acidity is necessary, increasing soil pH by adding organic matter has been reported by Konfe et al (2019) and Toundou et al, (2014). Indeed, for plant production, soil acidity is a complex of several factors involving nutrient or non-nutrient deficiencies, low micro-organism activity and poor plant root growth that limits nutrient and water uptake (Ondo, 2011; Fageria and Baligar, 2008).

The results of these parameters indicate that the soil's acid pH, organic matter content, low clay content and water saturation rate suggest low metal retention by the soil's solid phase.

Minerals found in the soil are important elements for plant growth and development, especially K and P, which are essential for flowering and fruiting. The mineralogical data in this study show that, in terms of the requirements necessary for market gardening, the soil studied has relatively low levels of assimilable phosphorus (34.75 kg/ha) and calcium (443.52 kg/ha). On the other hand, potassium (359.16 kg/ha) and magnesium (163.2 kg/ha) levels were average for a soil intended for market gardening. These results justify the addition of minerals (for correction) as part of the basic fertilization carried out during the trial. Magnesium is a major constituent of chlorophyll and is therefore important in photosynthesis; it also plays an important role in the transport of phosphorus in plants and carbohydrates in leaves and stems (McAlister et al., 1998). These elements influence the mineralization of the organic fraction. The positive effect of phosphorus and nitrogen on the mineralization of organic matter has been reported by several authors (Gnankambary et al., 2008; Lompo et al., 2009). Phosphorus is a critical plant nutrient, but it is often limited in soils used for market gardening. Potassium, on the other hand, plays an important role in plant water uptake and transport. The research results also highlight the importance of soil fertility for market gardening, as well as the strategies used by farmers to build soil fertility in peri-urban market gardening systems. In summary, to improve the fertility of the silty-sandy soil of coastal North region in Gabon, in the way to sustain an optimal quality of market gardening productivity of tomato cultivation, it would be necessary to apply (i) acidity correction and (ii) amendments rich in phosphorus and calcium, while maintaining adequate levels of potassium and magnesium.

Agro-morphological trait performance and yield potential

Analysis of variance highlighted the existence of variability for all the traits studied through tomato lines. Varieties from INRAB had a short germination time (4 days). Whereas the AVDRC lines and the Lindo control had a longer germination time (6 days). Senan et al, (2015) also noted that AVRDC-derived varieties had low germination power compared with local varieties under hot humid tropical climate conditions. This difference in germination could be linked to the difference in the dormant state in which seeds cannot germinate even under favorable conditions. Similarresultswereobserved by Aya et al (2011)who show that seed dormancy and germination are controlled by the combined action of several genes and two hormones. Abscisic acid (ABA) induces and maintains dormancy, while gibberellic acid (GA) promotes dormancy breaking and germination. The same authors point out that this process is influenced by environmental factors.

The recovery rate for the entire collection was over 50%. Line L8 had the best recovery rate at 100%, compared with the lowest (53%) for L1. This may be explained by the adaptation of plants to the environment. According to (SIB, 2017) seed germination, growth, and development of tomatoes are influenced by the environment, particularly climate.

Regarding phenological stages, the results distinguished early and late lines in relation to flowering time, maturity time, and cycle length. In fact, regarding flowering time (Df) and maturity time (Dm), variabilities are linked to the difference between their crop cycles and environmental effects. Short-cycle varieties flower early, whereas long-cycle varieties flower late. These results corroborate those of Fondio et al. (2013) and Coulibaly et al. (2019), who indicated that from flowering to fruit ripening, several endogenous physiological and biochemical phenomena are involved, notably the mobilisation of mineral elements for floral initiation and fruit filling. The capacity of each line to draw mineral elements and water for the plant's metabolic needs under the effect of environmental factors (light, temperature, etc.) varies greatly and influences flowering time, fruit set, and fruit ripening. In addition, Fondio et al. (2013) pointed out that the difference in production duration between varieties may be due to external factors, including fungal, bacterial, or viral disease attacks, which can affect plant development, thus reducing production capacity.

The results obtained for the potential and net yields showed variability between the lines. Line L4 showed the highest yield (26.7 t/ha), ahead of the Lindo control (20.7 t/ha). Line L9 had the lowest yield (0.6 t/ha). This difference can be explained on the one hand by alternating rain and sun, creating a humidity and heat cocktail favourable to the development of diseases in certain lines, and on the other hand by the sensitivity to pests (insects and pathogens) which causes rotting of certain fruits.

These results are similar to those of Yéri (2017), who showed that the observed low production could be explained by several climatic and environmental factors.

The fruit quality parameters revealed variability within the lines. In fact, for the shape trait, there was very high variability among the five modalities observed. According to Gilles (2018), high variability indicates a high potential for varietal improvement. Similarly, Kansie (2017) pointed out that fruit shape is an important criterion in tomato breeding. This diversity in shapes is linked to the genetic traits of the varieties. Variations in fruit firmness were observed with an overall average of 61.53%. The firmest fruits were those of lines L1, L5, and L8, and the Lindo control. This parameter is a key criterion for assessing fruit quality and physicochemical conditions. It determines the ability of a fruit to withstand handling and transport. According to Garane (2019), the difference in firmness is the result of the permanent availability of mineral elements to the plant throughout the cycle, which determines fruit firmness, which is why correcting the mineral content would improve fruit quality in the future. The same authors also pointed out that temperature and storage time influence fruit firmness.

Characteristic correlation and lineage grouping

The correlations between the studied quantitative variables are particularly important for varietal selection and improvement. The variable "number of damaged fruits" has a negative effect on yield, while the "number of healthy fruits" had a positive effect on average fruit weight and yield. Fruit rejection (damaged fruit) can be explained by the sensitivity of certain lines to biotic and abiotic factors. This explains the low net yield recorded for certain lines. Yield increase is linked to the number of fruits harvested (NFR) and average weight, which are traits associated with the genotypic and phenotypic expression of the variety (de Souza et al., 2012).

The grouping of lines identified four lines for cluster 1, one for cluster 2, and eight for cluster 3, including the Lindo control. The test values (v-test) obtained (depending on whether they are greater than three in absolute value) made it possible to distinguish the variables that strongly characterise the lines in each cluster.

Cluster 3, which groups together more than half the lines in the trial is characterized by the variables:"average fruit weight", "weight of damaged fruit" and "yield". It should be noted that, with the exception of "ripening time", all the other variables that characterize cluster 1 group together lines with poor agronomic performance, as for these variables, the means (in this group) compared with those of the collection are low. Cluster 2 showed negative v-tests for the variables "germination time" and "fruit length»; only the variable "number of healthy fruits" showed a positive v-test. In this cluster, these values were relatively lower than those of the collection.

The results of the Ascending hierarchical classification (AHC), indicate that the variables affecting yield (number of healthy fruits, average fruit mass, weight of damaged fruits and potential fruit yield)the "ripening time" and the "number of healthy fruits" are those that discriminate the cluster. Thus, while there is considerable variability within the lines, the variability between the groups remains the greatest. According to Kansie (2017), a lower level of intra-accession genetic variability than of inter-accession variability is characteristic of self-pollinating species. This observation supports the results obtained, given that tomatoes are a self-pollinating species. Most of the lines in Cluster 3 produced good-sized fruits. This means that lines with a high average weight would be predisposed to produce large fruits, which would have a significant effect on their marketability. In addition, the variable "number of healthy fruits, which could reflect tolerance to biotic and abiotic factors, and the "time to early maturity" discriminate cluster 1 and cluster 2 respectively. These lines have traits that can be exploited for varietal selection. Indeed, improved soil quality and crossbreeding trials should be carried out to improve agronomic performance and fruit quality. The results of ascending hierarchical classification revealed high-performance accessions L2, L5, L4, L6, L7, and L8. Only lines L2 and L5 clearly stood out from the Lindo control. These high-performance lines can be used as progenitors or as parental lines in breeding programs.

Disease tolerance of lines

The moderate severity index for all the diseases and damage recorded on the lines could be explained by the acceptable level of tolerance of these lines to these diseases. The fungal disease observed (downy mildew) is caused by Phytophthora infestans. Downy mildew can attack all the aerial organs of the plant (Hadjer, 2013). Although parasitic pressure is low, this, combined with the influence of the environment, could nonetheless justify the low yields obtained for certain lines. The proliferation of pathogens is thought to be induced by environmental factors unfavorable to tomato cultivation (Torres, 2020).

Most of the lines tested proved tolerant to spoon yellows. Tomato Yellow Leaf Curl (TYLC) is the disease that causes curling and yellowing of tomato leaves(Rebolledo, 2007).This disease is caused by Tomato yellow leaf curl virus (TYLCV) which belongs to Geminiviridae family and genera of Begomovirus. TYLC is transmitted by the whitefly, Bemisiatabaci Gennadius, which belongs to the "Geminivirus" group group (Zi et al., 2010). It is considered one of the most devastating viral diseases of tomato crops. Damage can be 50-70% if the attack is late, and 100% if it occurs in the nursery (Basak, 2016). The low level of virosis proliferation is thought to be due to the fact that the study area and conditions (humid) were not conducive to the proliferation of the vector (Bemisiatabacci). These results are similar to those ofZi et al. (2010) which show that B. tabaccivector outbreaks were more prevalent in the dry season, and that symptoms were more pronounced on varieties in this season.

The apical necrosis observed on the lines (with a more severe level for lines L3 and L10) reflects their susceptibility to this disease, reducing yields. These results could be due to the alternation of rain and sun during the fruiting phase, which would have resulted in a much higher rate of fruit damage. Identical results were obtained in southern Côte d'Ivoire during the evaluation of nine tomato varieties. Not only was bacterial wilt observed, but also damage leading to rejection due to excessive calcium uptake in the cells following excess irrigation water, resulting in low yields (Fondio et al., 2013).

All these results show that a better adaptation of the lines to the conditions of the study area can be observed for future trials with adequate inputs of organic matter, adjustment of soil pH, controlled irrigation and appropriate phytosanitary treatment for environmentally-friendly organic farming.

Illustrations

Tables

Table 1:- List of tomato line used for the trial.

Designation	Type	Origin
CLN3961D	Line 1 (L1)	AVDRC
CLN4018C	Line 2 (L2)	AVDRC
CLN3961C	Line 3 (L3)	AVDRC
CLN4066G	Line 4 (L4)	AVDRC
CLN4079L	Line 5 (L5)	AVDRC
CLN4066E	Lineage 6 (L6)	AVDRC
CLN4079M	Line 7 (L7)	AVDRC
CLN4079D	Line 8 (L8)	AVDRC
CLN4032C-8	Line 9 (L9)	AVDRC
CLN3940C	Line 10 (L10)	AVDRC
Bento 02 (TLCV15)	Variety 1 (T1)	INRAB
Bento 02 (Akikon)	Variety 2 (T2)	INRAB
LINDO:	Control (T3)	LOCAL TRADE

Table 2:- Results of particle size and physico-chemicalanalyzes of substrates.

Substrates	pH		Org.C	Ash.C	W.S.C	Nt	C/Nt	Av.P	K	Ca	Na	Mg	Ap.D	C.silt	F.silt	Clay	F.sand	C.sand	Porosity
	H2O	KCl	%					ppm	méq/100g				g/cm3	%					
Soil	4,98	4,56	1,706	97,61	23,85	0,046	21,61	15,51	0,41	0,99	0,32	0,60	1,34	29,4	11,2	6,5	23,44	28,71	32,76

O.C=Organiccarbon;Ash.C=ash content; W.S.C= Water saturation rate; Nt=total nitrogen; C/Nt=Carbon to total nitrogen ratio; Av.P=Availablephosphorus; K=potassium; Ca=Calcium; Na=Sodium; Mg=magnesium; Ap.D=Apparent density; C.silt=Coarse silt; F.silt=Fine silt; F.sand=Fine sand; C.sand=coarsesand

Table 3:- Results of descriptive analysis of quantitative variables.

Variable	Minimum	Maximum	Moyenne	Ecart-type	C.V (%)	Pr>F	Signifiance
Dg	4	6	5,69	0,75	12,67	0,002	S
Trp (%)	53	100	87,35	11,8	12,98	0,772	NS
Df (j)	26	36	30,77	3,63	11,34	0,197	NS
Dm (j)	70	84	77,31	4,93	6,13	0,795	NS
Dc (j)	81	92	87,85	4,33	4,74	0,522	NS
Hf (cm)	55,1	71	63,46	4,54	6,88	0,278	NS
LFr (cm)	4,8	7,9	7,05	0,85	11,63	0,278	NS
lFr (cm)	3,3	7,7	5,46	1,26	22,3	0,009	S
Nfs	12	570	181,2	144,36	76,56	0,106	NS
Nfa	3	231	99,92	58,51	56,25	0,565	NS
Mmf (g)	40,1	87,8	73,22	16,052	21,06	0,087	NS
Pmfs (Kg)	0,6	26,7	12,83	8,2	61,41	0,672	NS
Pmfa (Kg)	0,3	18,4	7	4,54	62,38	0,520	NS
RdtN T/ha	0,6	26,7	12,83	8,2	61,41	0,672	NS
RdtP T/ha	0,9	38,6	19,85	10,24	49,6	0,959	NS

Table 4:- Descriptive statistics for quality parameters.

Variables	Terms and conditions	Workforce/Methods	Frequency by modality (%)
	Elongatedovoid	4	30.76
	Rounding	2	15.38
Form (Frf)	Cordiform	3	23.08
	Cylindrical	1	7.69
	Slightlyflattened	3	23.08
	Farm	4	30.76
Firmness (Fmf)	Soft	1	7.69
	Moderatelyfirm	8	61.53

Table 5:- Correlation matrix between the studied variables (at the 5% threshold).

	Dg	Trp	Df	Dm	Dc	Hf	LFr	lFr	Nfs	Nfa	Mmf	Pmfs	Pmfa	Rdt N	Rdt P
Dg	1,00														
Trp	0,16	1,00													
Df	0,16	0,65**	1,00												
Dm	-0,20	0,46	0,68**	1,00											
Dc	-0,43	0,40	0,45	0,33	1,00										
Hf	0,29	-0,30	-0,07	-0,49	0,06	1,00									
LFr	0,39	-0,19	-0,30	-0,57	-0,31	0,55	1,00								
lFr	0,68**	-0,14	0,23	-0,24	-0,45	0,56	0,54	1,00							
Nfs	-0,46	-0,03	-0,01	0,00	0,33	0,10	-0,54*	-0,33	1,00						
Nfa	-0,25	-0,15	-0,10	-0,20	0,01	-0,14	-0,55*	-0,26	0,54	1,00					
Mmf	0,77**	0,06	-0,15	-0,54	-0,28	0,37	0,18	0,38	0,00	0,19	1,00				
Pmfs	0,06	0,04	-0,15	-0,41	0,19	0,44	-0,07	-0,02	0,76**	0,36	0,53	1,00			
Pmfa	0,21	-0,11	-0,10	-0,37	-0,21	-0,02	-0,24	0,02	0,13	0,84**	0,52	0,23	1,00		
Rdt N	0,06	0,04	-0,15	-0,41	0,19	0,44	-0,07	-0,02	0,76**	0,36	0,53	1**	0,23	1,00	
Rdt P	0,14	-0,01	-0,17	-0,50	0,06	0,34	-0,16	-0,01	0,66**	0,66**	0,65**	0,90**	0,63**	0,90**	1,00

Table 6:- Eigenvalue matrix from Principal Component Analysis of the line of tomato.

Components	AXIS 1	AXIS 2	AXIS 3
Eigenvariance	4,91	3,78	2,23
Total variance (%)	32,71	25,22	14,87
Total accumulated variance (%)	32,71	57,93	72,81
Dg	-0,20	-0,70**	0,49
Trp	-0,18	0,30	0,74**
Df	-0,31	0,26	0,80**
Dm	-0,65**	0,50	0,38
Dc	-0,06	0,61**	0,38
Hf	0,40	-0,48	0,21
LFr	-0,01	-0,84**	-0,01

lFr	0,11	**-0,**75**	0,34
Nfs	0,59	**0,**67**	0,01
Nfa	0,58	0,48	-0,28
Mmf	**0,**71**	-0,41	0,29
Pmfs	**0,**88**	0,19	0,21
Pmfa	0,59	0,05	-0,16
RdtN	**0,**88**	0,19	0,21
RdtP	**0,**96**	0,18	0,10
**: Variables contributing most to the formation of the axes indicated			

Table 7:- Cluster characteristic variables.

Variables	**V. test**		
	Cluster1	**Cluster2**	**Cluster3**
Dg		-2,34	
Trp			
Df			
Dm	2,16		-2,82
Dc			
Hf			
LFr		-2,74	
lFr			
Nfs		2,80	
Nfa	-2,25		
Mmf	-2,20		2,90
Pmfs	-2,51		
Pmfa	-2,20		2,08
RdtN	-2,51		
RdtP	-2,99		2,44

Table 8:- Plant health diseases range of severity.

Diseases	Terms and conditions	Percentage [%]
	Light	7,69
Downymildew	Moderate	23,08
	No disease	69,23
	Light	7,69
Jaundice in a spoon	Moderate	23,08
	No disease	69,23
	Grave	15,38
Apical necrosis	Light	53,84
	Moderate	23,08
	No disease	7,69

Figures:-

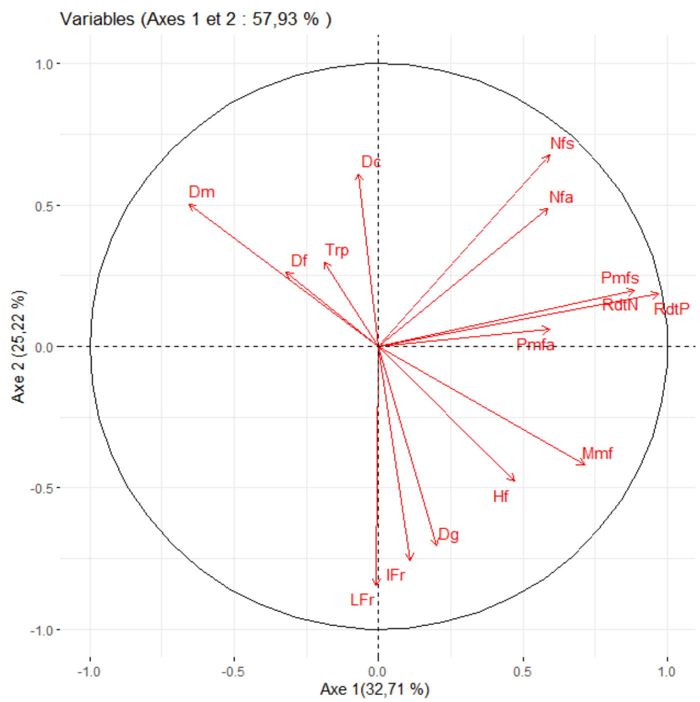

Figure 1:- Projection of quantitative variables in the factorial plane by axis 1 and 2 of the Principal Component Analysis (PCA).

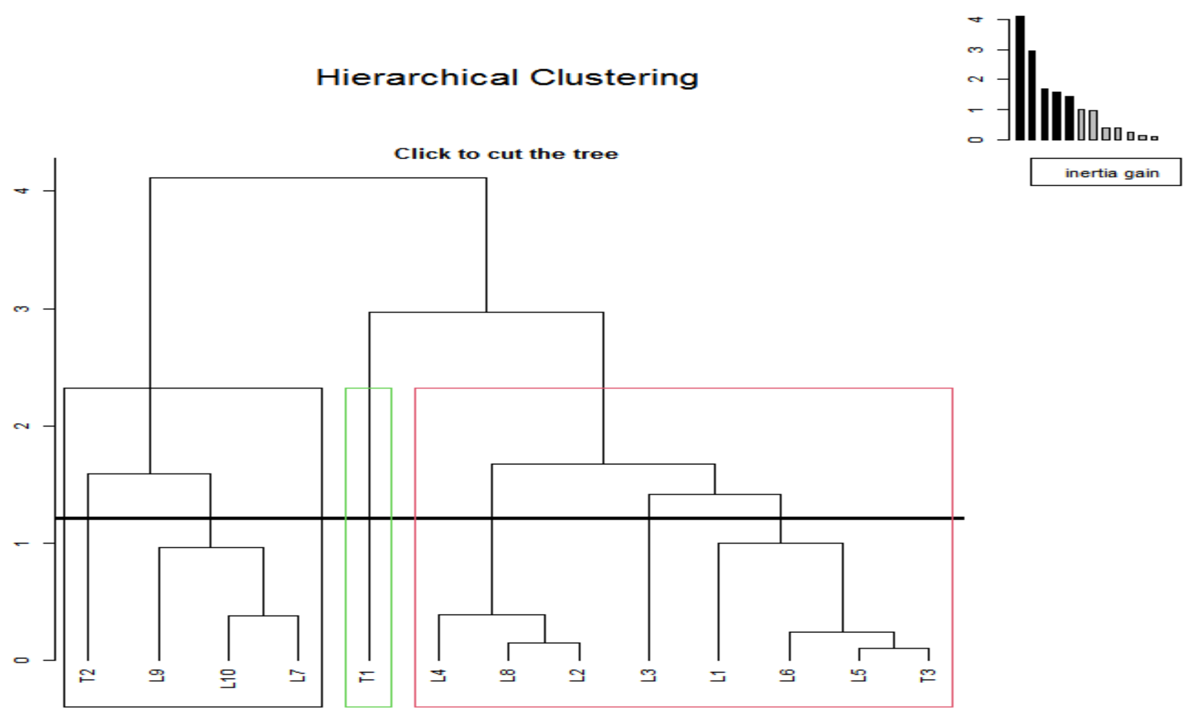

Figure 1:- CAH dendrogram of tomato lines.

Conclusion:-

Knowledge of the agro-performing traits of a crop population is fundamental to varietal improvement. The aim of this study was to evaluate the adaptation potential of ten tomato lines to the agroecological conditions of the coastal northern region of Gabon(Libreville). Soil analysis revealed a silty-sandy nature, High acidity, and an organic matter composition below the requirements for tomato cultivation. Amendments could correct the soil's deficiencies to ensure optimal plants productivity. Agronomic characterization reveals that there is variability in agro-morphological criteria between the lines selected for this study. Morphological evaluation according to descriptors showed variability in fruits shape, firmness and sensitivity to biotic and abiotic stresses. The variations observed for these traits are thought to be linked to exogenous factors, notably environmental, but also endogenous to the lines themselves (genetic factors). Variability in quantitative traits is based on parameters such as "recovery rate", "flowering time" and "yield components". The various analyses carried out enabled us to group the lines into three (03) groups according to their common traits. "Time to maturity" and "number of healthy fruits" are the variables that best discriminate the groups. The study resulted in the selection of 6 genotypes: L2, L5, L4, L6, L7 and L8, all of which showed interesting agronomic performances, reflecting their adaptation to the study area environmental conditions. This study provides a research perspective on the improvement of soil amendment systems and linesof interest (tomato varieties) bothforpromove the tomatoemarket gardening in coastal North region in Gabon and possible varietal improvement. This will make it possible to develop new high-performance varieties adapted to improving tomatoeproductivity in the Gabon ‘s environemental conditions.

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