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Effect of Climatic Factors on the Phenological Stages of Two Solanaceae Species (*Solanum lycopersicum* L. and *Solanum aethiopicum* L.) in Market Gardening in San Pedro, Côte D'ivoire

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Abstract | **Original Research Article**

This study aimed to understand the influence of environmental factors on the phenological stages of two edible species of the Solanaceae family for their development and adaptation. The study was conducted on the experimental plot of the University of San Pedro. A randomized complete block design was implemented. Agronomic parameters were collected during the experiment, and climatic data were obtained from the online platform Tutiempo. The results showed that seed germination occurred as early as the 3rd day after sowing, with a high germination rate of 90% for eggplant and 77.5% for tomato. The vegetative growth of both studied species was influenced by abiotic conditions, particularly precipitation ($r = -0.30$; $p < 0.05$) and relative humidity ($r = 0.61$; $p < 0.05$), which showed variable correlations with growth parameters, thus reflecting contrasting effects of different environmental factors on plant development. This study highlights the importance of climatic factors and their effects on the developmental stages of these two crops belonging to the Solanaceae family.

Keywords: Phenological stages, Climatic factors, Market gardening, San Pedro, Côte d'Ivoire.

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INTRODUCTION

Agriculture constitutes the fundamental pillar of the Ivorian economy, employing more than 60% of the active population and contributing an average of 30% to 35% of the Gross Domestic Product (GDP) (Yapi, 2022). It is structured around two major sub-sectors: export crops, dominated by cocoa and coffee, and food and market garden crops, which are essential for population food security (Ducroquet *et al.,* 2017). Among the latter, fruit vegetables occupy a growing place in both daily diets and the local economy. In this context, tomato (*Solanum lycopersicum* L.) and African eggplant (*Solanum aethiopicum* L.), both belonging to the Solanaceae family, represent two market garden species of major interest. Tomato is one of the most popular crops worldwide, providing an important source of nutrients such as lycopene, carotenoids, flavonoids, and vitamin C (Kashyap *et al.,* 2020). Its global production was estimated at 192.32 million tonnes in 2023, harvested over an area of 5.4 million hectares (FAOSTAT, 2024). As for *Solanum aethiopicum*, it is considered a major staple food crop for local populations, rich in macronutrients and micronutrients, and endowed with several medicinal properties, notably in the treatment of arterial hypertension, diabetes, and skin infections (Adeniji *et al.,* 2012).

Despite their economic and nutritional importance, market garden production in Côte d'Ivoire remains insufficient to meet national needs, with a coverage rate estimated at 64.2% for a production evaluated at 360,000 tonnes in 2024, including 60,300 tonnes for tomato and 121,000 tonnes for eggplant (MEMINADERPV, 2024). This structural deficit is partly explained by the effects of climate variability, whose impact on agriculture is increasingly tangible in Côte d'Ivoire. Indeed, climate variability marked by seasonal and interannual variations in temperature and precipitation disrupts cropping calendars and leads to agricultural yield losses (Kouamé *et al.,* 2024).

In tropical zones, the factors exerting the greatest influence on these recurring events notably

include precipitation, relative humidity, and temperature (Encyclopædia B., 2024). In Solanaceae in particular, photoperiodic and thermal regulation represents the dominant mechanism controlling flowering and growth (Müller *et al.,* 2016). The phenological cycle of *Solanum lycopersicum* L. and *Solanum aethiopicum* comprises several successive phases: germination, vegetative growth, flowering, fruiting, and fruit ripening (Krause *et al.,* 2023). The duration and progression of these phases are closely linked to abiotic factors, notably temperature, humidity, and precipitation, variations of which can accelerate or slow down the vegetative cycle and affect final crop yields (Jones, 2008; Piao *et al.,* 2019). Consequently, it is imperative to update scientific data regarding the relationship between the phenological stages of these two species and climatic factors. Therefore, this study aims to understand the influence of environmental factors on the phenological stages of these two edible Solanaceae species for their development and adaptation. More specifically, it sought to evaluate the germination and growth parameters of the studied species and to determine the influence of abiotic factors, particularly climatic conditions, on their development.

MATERIALS AND METHODS

Geographical Location

The study was carried out in the city of San Pedro, the regional capital of the San-Pedro region located in the Bas-Sassandra district between 4°85' North latitude and 6°92' West longitude (Figure 1), more specifically within the experimental farm of the Polytechnic University of San Pedro. Rainfall analysis in San Pedro shows a bimodal rainfall regime typical of the subequatorial climate of southern Côte d'Ivoire, characterized by two rainy seasons and two dry seasons. The long rainy season extends from March to July, peaking in May and June, followed by a short dry season in August. The short rainy season runs from September to November, followed by the long dry season from December to February.

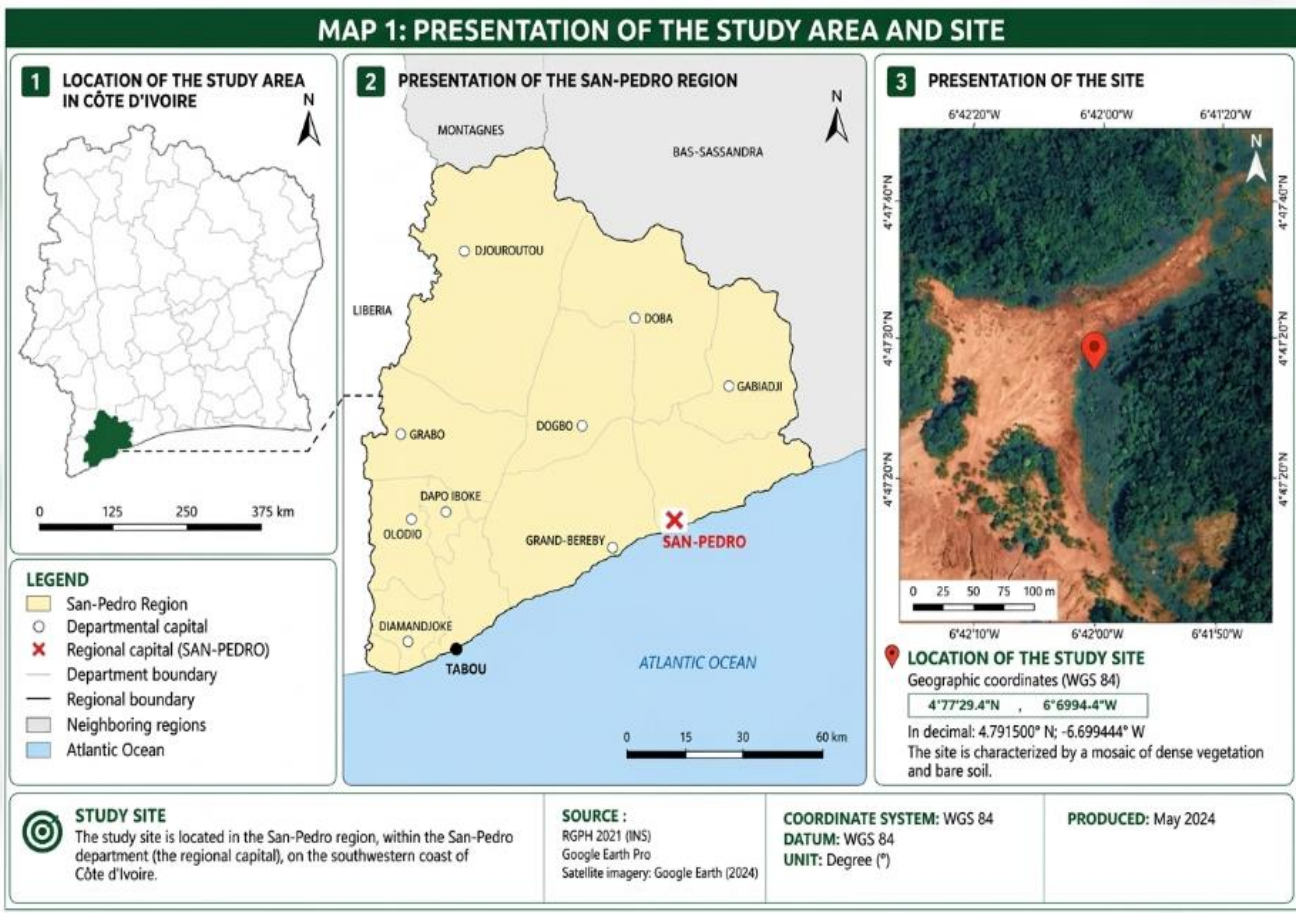


Figure 1: Experimental site (OSM, 2023)

Plant Material

The plant material used consisted of the *Kotobi* variety, a local eggplant cultivar highly prized in Côte d'Ivoire, and the *Padma F1* variety, a hybrid tomato cultivar used for its resistance to diseases and pests.

Methods

Experimental Design

The study was conducted on four raised beds for each of the two studied crops, with each bed measuring 2 m in length and 1.5 m in width, separated by an inter-bed spacing of 1 m. The plants to be studied were

selected randomly. Thus, three plants were selected per bed, with each bed constituting a block. Within the framework of this study, four blocks were retained per crop. Furthermore, a spacing of 50 cm was maintained between plants, and the design was identical for both studied species. Agronomic parameters were collected during the experiment, and climatic data were obtained from the online platform Tutiempo, a meteorological website providing historical data on climatic conditions.

Experimental Plot Preparation

The study was conducted on four beds of 2.4 m² each for both studied crops (eggplant and tomato). Plot preparation first consisted of weeding performed using a hoe and a machete. Subsequently, beds were formed using a hoe and a pickaxe. Additionally, a well was dug to water the plants. Thereafter, cow dung was spread over the beds, followed by watering. The beds were then mulched with palm fronds to conserve soil moisture and protect the soil. Daily watering was carried out to promote the decomposition of organic matter. Finally, fences were erected using palm fronds to prevent stray cattle and unauthorized persons from entering, thereby protecting the plot.

Nursery Establishment and Transplanting

Eggplant and tomato seeds were sown in a nursery using 200-cell plug trays. Germination parameters were measured over the first ten days of the nursery phase. Eggplant seedlings were transplanted on March 12, 2026, and tomato seedlings on April 10, 2026, after spending 21 days in the nursery. Each seedling was transplanted into soil with the same composition as the substrate in which it developed in the nursery. Transplanting was performed at sunset following thorough soil irrigation. Growth parameters were also monitored to study plant development after transplanting.

Evaluation of Seed Germination Parameters of the Studied Species

Determination of germination rate:

The germination rate (Tg) is the best indicator for identifying optimal germination conditions. It expresses, as a percentage, the ratio between the number of germinated seeds (Nbg) during the first 10 days after sowing and the total number of seeds sown (Nbt) (Al-Maskri *et al.,* 2003):

Tg = (Nbg / Nbt) × 100

Determination of germination speed:

Germination speed (ViGe), expressed in seedlings per day, was determined using the formula below. From the 1st to the 10th day after sowing, the number (ni) of seeds germinated each day (ji) since sowing was recorded. Germination speed (ViGe) is equal to the sum of the ratios between the number (ni) of seeds germinated and the day (ji) elapsed after sowing (Al-Maskri *et al.,* 2003):

ViGe = ∑ (ni / ji) [for i = 1 to 10]

Germination duration:

Germination duration (in days) represents the time elapsed between the first and last germination (Kouadio, 2022):

Dg (days) = Ddg − Dpg

Evaluation of Growth Parameters of the Studied Species

Determination of mean plant stem height:

The height of the main plant stems was measured using a ruler graduated in centimeters, from the base of the plant (collar) to the last node bearing the apical bud. The mean stem height (Hmt) for a given block was determined using the formula below, equal to the quotient of the sum of all plant stem heights (Hp) in a given block divided by the number of plants (Np) in that block. This parameter was measured every five days after transplanting (Aka, 2024):

Hmt = ∑ Hp / Np

Mean plant stem diameter (circumference):

Plant diameter was measured using a vernier caliper at a height of 5 cm. However, for plants measuring less than 5 cm, diameter was measured just below the two cotyledonary leaves. Mean plant diameter (Dmp) per block was calculated as the sum of the diameters of all plants (∑ Dp) in a block divided by the number of plants (Np) in that block (Aka, 2024):

Dmp = ∑ Dp / Np

Determination of mean number of leaves per plant:

The mean number of leaves per plant per block was determined after transplanting every 5th day during vegetative growth. Leaf counts excluded cotyledonary leaves. The mean number of leaves per plant (Nmf) for a given block is the quotient of the sum of the number of leaves of all plants (∑ Nf) in a given block divided by the total number of plants (Np) in that block (Aka, 2024):

Nmf = ∑ Nf / Np

Linear Regression

Linear regression analysis makes it possible to determine the strength of a linear relationship between two quantitative variables. This method was used to evaluate the correlation between the phenological stages and the studied climatic factors (Konaté *et al.,* 2020). For $r < 0$, the linear relationship is negative; for $r > 0$, the linear relationship is positive; and when $r = 1$ or -1, the relationship is strong.

RESULTS AND DISCUSSION

Evaluation of Germination and Growth Parameters of the Studied Species

Germination Parameters

Table I below presents the results of the parameters evaluated during germination. Out of 200 seeds sown, 180 seeds germinated for eggplant and 155 seeds germinated for tomato, yielding a germination rate

of 90% for eggplant and 77.5% for tomato. Germination duration was 7 days for both studied species. Accordingly, germination speeds were 28.96 seeds/day for eggplant and 27 seeds/day for tomato.

Table I: Evaluation of germination parameters

Studied Parameters	Eggplant	Tomato
Germination rate (%)	90	77.5
Germination speed (seeds/day)	28.96	27
Germination duration (days)	7	7

Growth Parameters

Growth parameters measured in the experimental plot showed differences between the two studied species. Tomato exhibited a mean height of 28.38 cm compared to 12.88 cm for eggplant. Mean stem diameter was 2.51 cm for eggplant, whereas that of tomato was 2.12 cm. Regarding foliage, eggplant had a mean number of leaves of 23.84 compared to 11.58 for tomato. Table II below illustrates the growth parameters measured in the experimental plot.

Table II: Evaluation of growth parameters

Parameters	Eggplant	Tomato
Mean height (cm)	12.88	28.38
Mean diameter (cm)	2.51	2.12
Number of leaves	23.84	11.58

Relationship Between Abiotic Factors and Vegetative Growth of the Studied Species

Relationship Between Temperature and Number of Leaves of the Studied Plants

Analysis of the relationship between temperature and the number of leaves yielded a weak correlation ($r = 0.06$; $p < 0.05$) (Figure 2A), indicating that temperature exerts a slight statistically significant influence on eggplant. For tomato, the correlation was negative ($r = -0.43$; $p < 0.05$) (Figure 2B), indicating that temperature has a significant negative influence on leaf emergence in tomato.

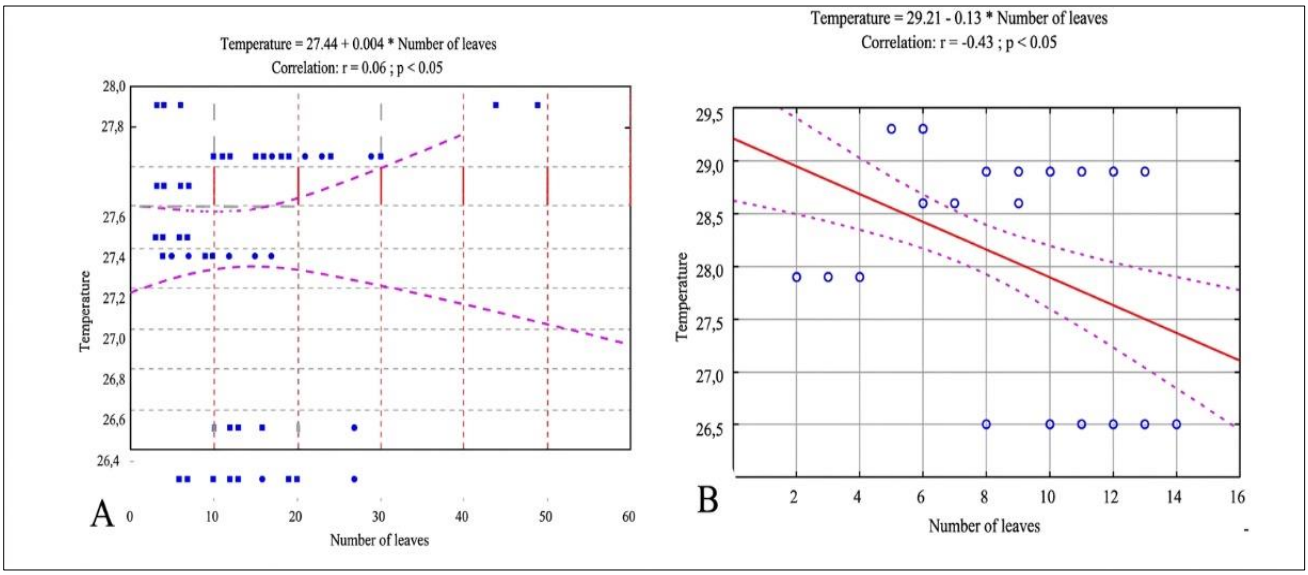


Figure 2: Correlation between temperature and the number of leaves of the studied plants (A: Eggplant plant, B: Tomato plant)

Relationship Between Precipitation and Size of the Studied Plants

Analysis of the relationship between precipitation and plant size in eggplant yielded a negative correlation ($r = -0.37$; $p < 0.05$) (Figure 3A). This result indicates that low precipitation has a significant negative influence on height growth in eggplant. For tomato, a strong positive correlation was observed ($r = 0.84$; $p < 0.05$) (Figure 3B). This analysis reveals that increased rainfall was accompanied by enhanced plant growth, indicating that water availability strongly contributed to the vegetative development of the crop.

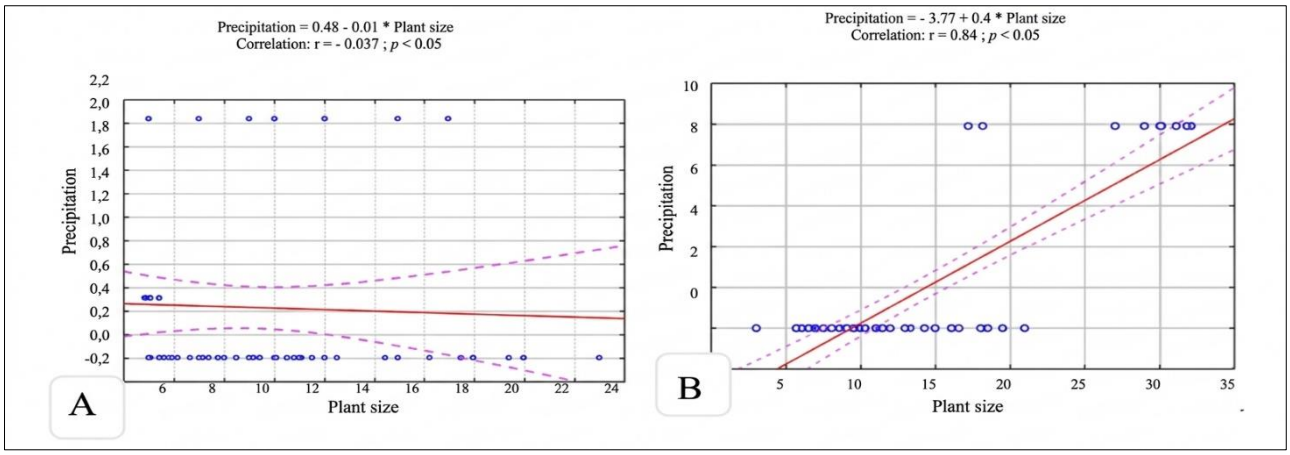


Figure 3: Correlation between precipitation and the size of tomato and eggplant plants (A: Eggplant plant, B: Tomato plant)

Relationship Between Relative Humidity and Circumference of the Studied Plants

Analysis of the relationship between relative humidity and plant circumference yielded a positive correlation ($r = 0.52$; $p < 0.05$) (Figure 4A). These results suggest that humidity contributed favorably to the vegetative development of eggplant. Regarding tomato, the analysis showed a positive correlation ($r = 0.35$; $p < 0.05$) (Figure 4B), indicating a moderate influence of this climatic factor on plant circumference.

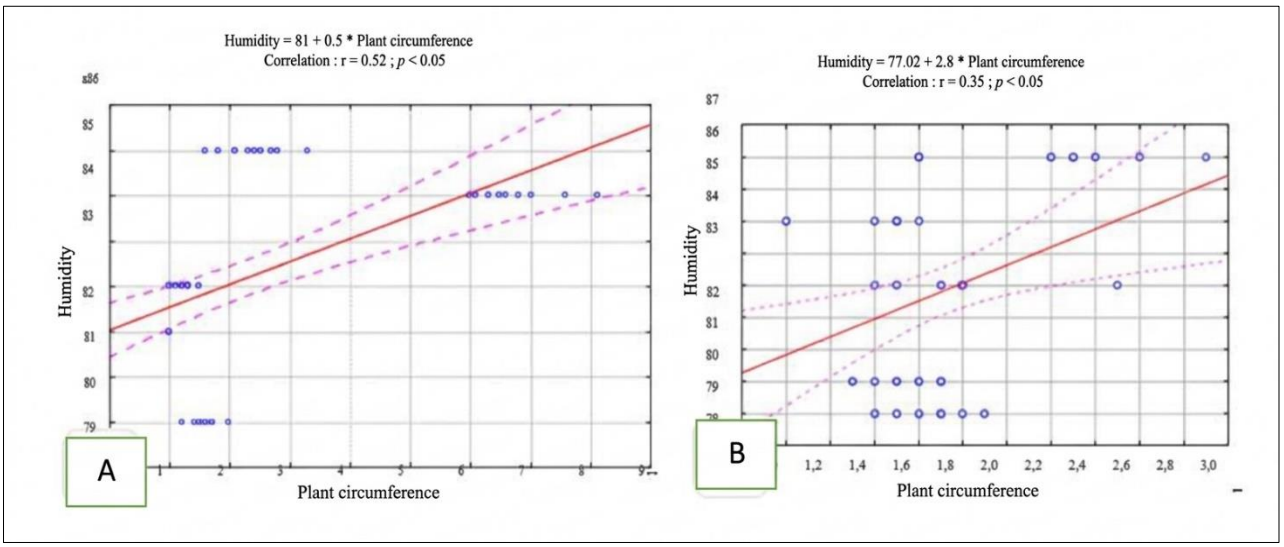


Figure 4: Correlation between humidity and plant circumference (A: Eggplant plant, B: Tomato plant)

DISCUSSION

Germination and Growth Parameters

The higher germination rate of eggplant (90%) compared to tomato (77.5%) could be explained by better seed quality or better adaptation of the species to the pedoclimatic conditions of the experimental site. The germination speed of eggplant reached 28.96 seeds/day, slightly higher than that of tomato (27 seeds/day). These results indicate that both species achieved high germination rates consistent with the germination performance stated by the seed supplier, Semivoire. The closeness of the results obtained could be attributed to their belonging to the same botanical family, Solanaceae (Feller *et al.,* 1995). Regarding plant growth, the results show that tomato plants exhibited a markedly higher mean height than eggplant, at 28.38 cm versus 12.88 cm, respectively. This difference could be explained by the naturally more upright growth habit of tomato. Indeed, tomato is an herbaceous plant whose numerous cultivars exhibit indeterminate growth, characterized by the continuous production of sympodial units generally composed of three leaves followed by an inflorescence. This growth pattern promotes continuous stem elongation and contributes to plant height growth (Périlleux *et al.,* 2014).

Correlation Between Vegetative Growth and Abiotic Factors

The results obtained show that climatic parameters influenced the growth of eggplant (*Solanum aethiopicum*) and tomato (*Solanum lycopersicum*) differently. These differences can be attributed to the specific ecophysiological requirements of each species as well as their adaptive capacity to the environmental conditions of San Pedro. Regarding temperature, the correlations observed in eggplant were generally weak or

negligible for all studied parameters. The number of leaves (r = 0.08) appeared practically independent of the recorded thermal variations. This weak influence could be explained by the narrow thermal amplitude observed during the experiment (26.2 to 28 °C). According to Schippers (2000), *Solanum aethiopicum* is well adapted to the warm climates of tropical African regions, which confers growth stability under moderate temperature fluctuations. Conversely, tomato exhibited negative correlations between temperature and the number of leaves (r = -0.43). These results suggest that an increase in temperature exerts an unfavorable effect on vegetative growth. These findings corroborate the work of Jones (2008) and Sato et al. (2000), who reported that optimal tomato growth generally occurs between 18 and 27 °C and that temperatures above this range can negatively affect vegetative and reproductive development.

Relative humidity showed an overall favorable effect on both crops, with positive correlations observed with circumference in eggplant (r = 0.52) and in tomato (r = 0.35). These results suggest that adequate relative humidity helped mitigate the effects of water stress and maintained favorable physiological conditions for vegetative growth. However, the moderate correlation coefficients indicate that other environmental factors also contributed to the observed variability. Precipitation emerged as the climatic factor exerting the greatest influence on crop growth. The results showed correlations of r = -0.37 in eggplant and r = 0.84 in tomato, respectively. This weak negative relationship observed during this study could suggest a certain adaptive capacity of eggplant to variations in water regime and water availability. In tomato, these results underscore the decisive role of water availability in the growth of this species. Water is essential for physiological processes involved in cell division and elongation, nutrient transport, and the maintenance of photosynthetic activity, according to Müller et al. (2016). Moreover, Doorenbos and Kassam (1979) emphasized that water deficits significantly affect the growth and yield of market garden crops, particularly tomato, which is well known for its sensitivity to water stress.

CONCLUSION

This study aimed to understand the influence of environmental factors on the phenological stages of two edible species of the Solanaceae family for their development and adaptation. It emerged that the cultural practices implemented during the study enabled good germination rates and growth for both species. The results obtained show that climatic conditions—notably temperature, humidity, and precipitation—play a decisive role in the vegetative growth of the plants. The strong correlations observed between these factors and growth parameters reflect their importance in the development of market garden crops. Ultimately, this study demonstrates that managing environmental factors and adopting sound cultural practices are essential elements for optimizing tomato and eggplant production in Côte d'Ivoire.

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