

Correlation between Inflorescence Phenological Events of Mango (*Mangifera indica* cv Kent) and some Climatic Parameters in Cote D'ivoire

Original Research Article

ABSTRACT

Aims: It was aimed to investigate the relationship between two climatic parameters, temperature and relative humidity, and the flower-cutting interval of mangoes tree cv. Kent

Study Design: The experimental design used was the completely randomized design with triplicate.

Place and Duration of Study: The present research was developed in the Laboratoire de Biologie et Amélioration des Productions Végétales, UFR Sciences de la Nature, Université Nangui Abrogoua, Côte d'Ivoire and in the Centre National de recherche Agronomique, Station de recherche de Lataha (Lavononkaha), Korhogo, Côte d'Ivoire, between December 2015 to January 2018.

Methodology: One hundred (100) mango trees were chosen to constitute four blocks of mango trees cv Kent. Every three days, the phenological events were notified. Regular observations were performed to determine the time between the phenological events of the inflorescence. Thus, the inflorescence appearance and the first flower opening, the time between the first flower opening and the first fructification, in relation with temperature and relative humidity were determined.

Results: It was not observed a negative correlation between temperature, time of inflorescence appearance and the first flower opening. Moreover, the relative humidity revealed a positive correlation with this time. In addition, the time elapsing between the first flower opening and the first fruiting is negatively correlated with temperature but positively with relative humidity.

Conclusion: Negative correlation between the time elapsing from the inflorescence appearance and the first flower opening as well as the temperature. Furthermore, a positive correlation between was revealed between the inflorescence appearance and the first flower opening as well as the relative humidity. Similarly, for the elapses delay between the first flower opening and the temperature. In addition, correlation observed between fruiting time and relative humidity was positive.

Keywords: Temperature; relative humidity ; inflorescence; flower opening; fruiting; mango tree cv Kent.

1. INTRODUCTION

The geographical distribution of plant species, vegetation types and agricultural cropping patterns shows a strong influence of climate on plant growth. Temperature, precipitation (humidity) and seasonal patterns are key determinants of plant development, from flowering to fruiting, through a variety of mechanisms [1]. In mango tree, seasonal cyclical

changes in root, flower, fruit and their development depend on cultivars and climatic conditions. Varietal responses to the environment within and between mango cultivars explain their production performance [2]. A temperature regime of 25°C during the day and 15°C during the night as prevails during this period was found to be the optimum for flower induction [3]. The flowering intensity of mangoes was found to negatively correlate with relative water content [4]. The knowledge of the

phenology of other mango cultivars can be used for genetic breeding or even for cultivation in new planting areas and on the range of processes linked to agronomic management of the supply chain, it is important to know the periodic biological events involving the development of this species.

Mango production accounts for approximately 36% of the worldwide production of tropical fruit [5]. Mango occupies a choice place in the economy of the populations living in the North of Côte d'Ivoire. This fruit, whose consumption was once mostly local, has been a significant source of foreign exchange since it was massively exported [6]. Côte d'Ivoire is now the leading African exporter of mangoes, the country's third-largest export, after pineapple and banana, with which it contributes 4% of its GDP. With a production of 100,000 tons this year, of which more than 32,600 tons are exported to Europe, the country has risen to the rank of third supplier of mangoes on the European market, after Brazil (100,000 t) and Peru (80 000 t) [7]. During the 2016-2017 export season, mango yielded 6.5 billion CFA francs (nearly 10 million Euros) to Ivorian producers [8]. The Ivorian orchard is concentrated in the northern zone of the country [9]. Nearly 90% of the national production is provided by small planters, the balance from large operators. The first category is characterized by a set of factors such as areas of production ranging from plantations villages (less than 1-2 hectare) to controlled orchards (between 1 and 50 hectares), yields of less than 20 tons, more or less partial control of irrigation and phytosanitary treatments. Large farms in turn exceed 50 hectares, are fully irrigated and treated, and yields can easily be exceed 20 tons per hectare, or even reach 30 tons.

Mango cv Kent originates from Florida and was introduced into Africa via the Foulaya experimental station in Guinea around 1950. The fruits reach maturity in the middle of the season [10]. The flesh is firm and has a pleasant taste. This mango matures very slowly and gradually. Fruits that are harvested close to maturity can be stored for a long time at cool temperatures. The fruit's excellent sensory qualities, the firmness of its flesh and its gradual ripening are all equally attractive features to retailers. Although it is difficult to grow, this mango is the standard in terms of quality on export markets. It depends heavily on the nature of the soil, the climate and especially the inflorescence phenological events [11]. The Kent variety constitutes 60 to 70% of Ivorian mango exports [12]. Every year, the key actors in mango industry, namely producers and

exporters, invest heavily in order to better organize harvest and export campaign, through which there is the control of the flower-cutting interval.

The knowledge of the phenological events of mango tree and climate parameters can be used on the range of processes linked to the agronomic management of the supply chain, it is important to know the periodic biological events involving the flowering development and fruiting. Considering that, the mango can get a place in the Ivorian agricultural development and be an effective tool in the fight against poverty, assessment of inflorescence phenological events in relation with climate are essential for mastering the flower-cut interval displaying option for good programming of crops to export. Thus, this study aimed to evaluate the correlation between the inflorescence phenological events of mango cv Kent and some climatic parameters in orchards in northern Côte d'Ivoire. This in order to help control the first section of the flower-cut interval which is the flower-set interval.

2. MATERIALS AND METHODS

2.1. Site of Study

The study was conducted from December 2015 to January 2018 in Lavononkaha (Korhogo), located in the North of Côte d'Ivoire located between 5 °15 W and 6°20 N longitudes, and 8°30 and 10°25 N latitudes. The dry season is accompanied by the harmattan between the months of December and February as well as peaks of heat between March and April. The vegetation consists of grassy savannahs and trees. The precipitations varies between 1200 and 1400 mm. The choice of orchard was guided by the rigorous maintenance he received which earned him the global-Gap certification.

2.2. Plant Material

The plant material consists of the inflorescence of the mango cv Kent. (Fig. 1). It is the main mango cultivar exported by Côte d'Ivoire [6].

Mango cv Kent was introduced at the Foulaya station in Guinea by Py in 1949. Over the past decade, it has been supplanting the other cultivars as West Africa's main export cultivar [7]. Some fruit characteristics are strongly influenced by soil types. The fruits are early, firm and colorful on the lateritic hillsides, whereas they can be dark green, late and physiologically disturbed on clay and wet bottom soils [13-14]. Kent produced between April 10 and May 20 in Ivory Coast. Mango cv Kent is characterized by a

relatively low water content of the pulp. The ripening of the fruit is very gradual. The soluble solids content of ready-to-eat Kent mangoes is high and can reach 22 °Brix in some fruits, while the acidity, lower at harvest than in other varieties, is higher after ripening [15]. The size of the Kent fruit, which is essentially the size of 7 to 10 (number of fruits per 4 kg carton), is very much in line with the demand of the European market. The ripe fruits are then red and yellow or red, green and yellow. They are much more attractive when they are ripe than at their harvest stage. Mango cv Kent therefore has many commercial qualities, which explains its success with European importers: good transport performance, high shelf life of ripe fruit kept cold, soluble solids content, good coloring of fruits produced in adequate [16].



Fig. 1. Inflorescences of mango tree cv Kent

2.3 Selection of Mango Trees

Approximately, 100 mango trees were chosen to constitute four blocks of mango trees (Fig. 2). The thirty-three (33) first mango trees in bloom within the orchard were selected for the different observations (Fig. 3). The experimental design was randomized blocks with 33 plants. The experience has been repeated every year for three years. An automatic recording thermohygrometer (Tinytag), placed in the orchard, under cover, was used to capture the different temperatures and relative humidity.

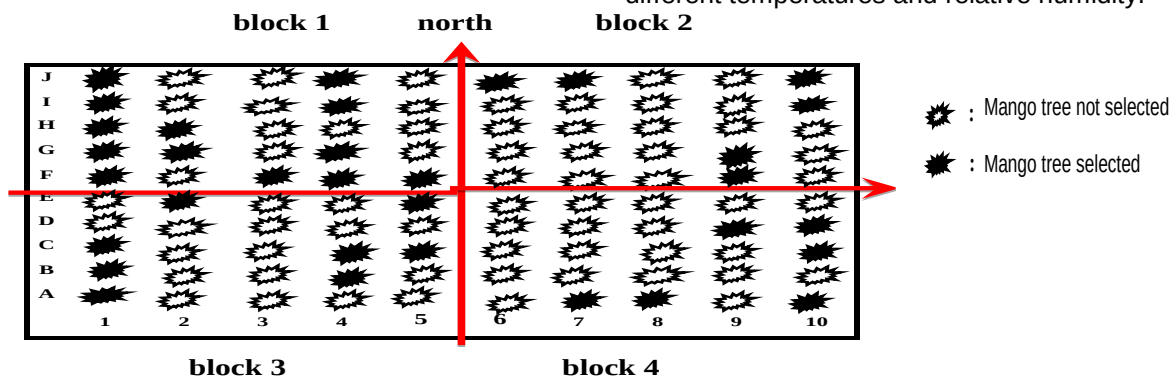


Fig. 2. Position of the selected mango trees in orchard

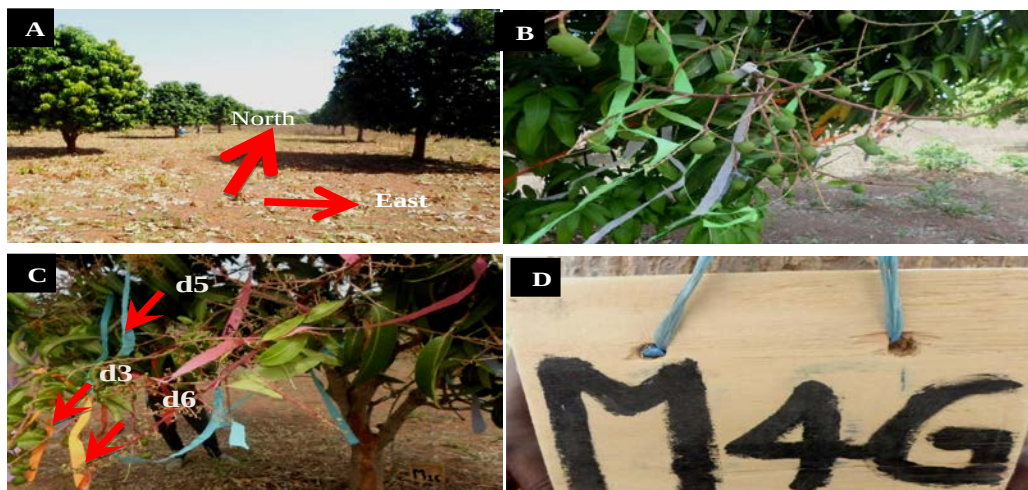


Fig. 3. View of the study plot

A : Alignment of mango trees from selected orchard, B: selected mangoes marked with string, C: selected inflorescences marked with string (orange string: selected inflorescences on 3rd day of selection blue string: selected inflorescences on day 5 of selection, yellow strings : selected inflorescences on the 6th day of selection); D: collar indicating the mango tree coordinates in the study orchard (M4G: mango tree on line 4 going east and on line G going north); d; day.

2.4 Inflorescences Selection

Every three days, the inflorescences appearing on the selected mango trees in each block were chosen and to constitute the inflorescences

groups according to their date of selection. The inflorescences selected on the same date were marked with string of the same color (Fig. 3C). This made it possible to follow them and note the different dates of the phenological events.

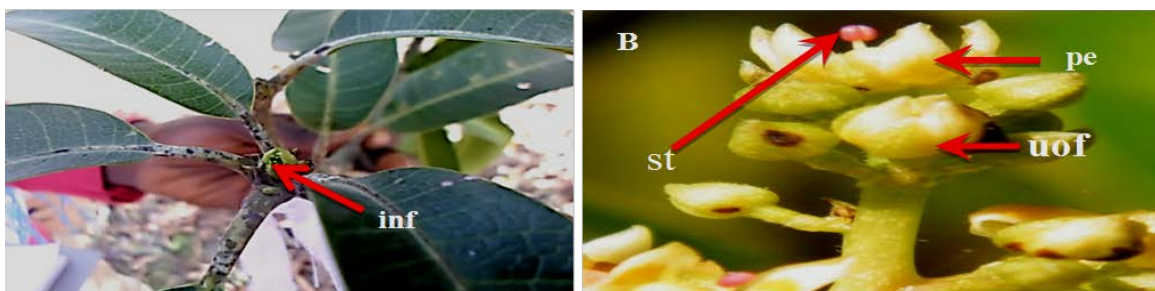


Fig. 5. Inflorescence of mango tree cv. Kent

A: Inflorescence newly appeared; B: first open flower within the inflorescence; inf: inflorescence; pe: petal; st: stamen; uof: unopened flower

2.5 Determination of the Phenological Events Time

Regular and daily observations of the inflorescences at the same hours, made it possible to note their dates of appearance, dates of first flower opening within them and dates of first fruit set. Visibility flower bud on the date of our passage is indexed as the date of inflorescence appearance. The flower bud should also be about 2 cm high to be retained (Fig. 5 A). A flower is considered open when at the date of our passage its stamens and pistil are visible and its petals open (Fig. 5 B). The delays between these events have been obtained and translated into the following formulas:

$$\text{Del AI / POF} = \text{DPOF} - \text{DAI}$$

$$\text{Del POF / PN} = \text{DPN} - \text{DPOF}$$

With Del = Delay; AI = appearance of inflorescence; POF = first flower opening within the inflorescence; PN = first set within the inflorescence; D = Date.

2.6. Temperature and Relative Humidity

2.6.1 Temperature and hygrometry recording equipment

Temperatures and relative humidity were regularly recorded in 15 minutes using a Tynitag 2 Plus thermohygrometer. It was placed in a protective cap and then installed on the mango tree (Fig. 6). The Tynitag explorer 4.9 software made it possible to recover the recorded data.

2.6.2 Obtaining temperature and relative humidity variables

Three days variation is applied during the inflorescences selection and makes it possible to appreciate the various temperatures or relative humidity acting on the inflorescences groups. The average of temperatures as well as of relative humidity received by each inflorescences group during the delays between the different phenological events were calculated according to the following formulas:

$$T_m (^{\circ} \text{C}) = \frac{\sum_i T (^{\circ} \text{C})}{N}$$

With T_m = mean of temperature; $\sum_i T$ = sum of temperatures recorded from the beginning of the delay until its end; N = number of records.

$$HR_m (\%) = \frac{\sum_i HR (\%)}{N}$$

HR : average relative humidity; $\sum_i$ HR : sum of the relative humidity recorded from the beginning of the delay until its end ; N : number of records

2.7. Statistical analysis

Data were analyzed using Statistica software (release 7.1). Spearman Rank correlation test followed by a comparison of means by Tukey HSD's test at the threshold 5% were used. Data are the means of three replicates.

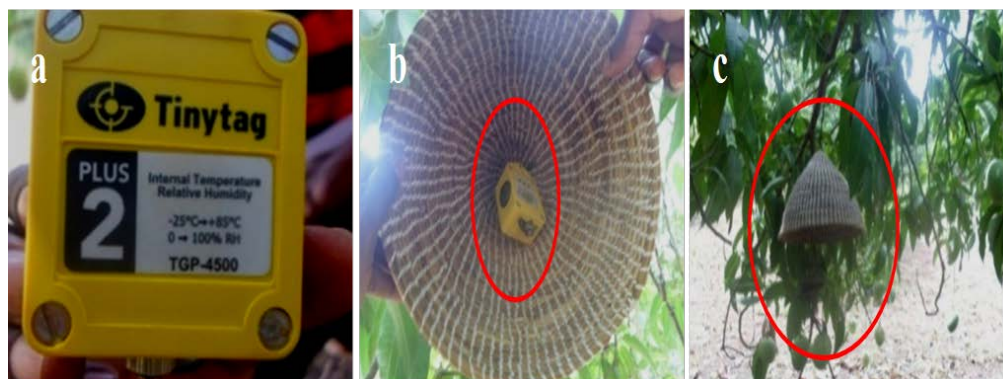


Fig. 6. Use of thermohygrometer

a: thermohygrometer; b: thermohygrometer placed in a protective cap; c: thermohygrometer installed on a mango tree

3. RESULTS

3.1 Correlation between Temperature, Delay, Inflorescence Appearance and the First Flower Opening within the Inflorescence

Table 1 shows that the delay between the inflorescence appearance and the first flower opening within inflorescence, under the northern of Côte d'Ivoire conditions, lies between 8.92 and 11.91 days. It also reveals that the times obtained according to the average temperatures which have occurred by the groups of inflorescences are significantly different. In each group, 58 inflorescences were observed. Except the group 1 of inflorescence (Inf 1) which obtained a short time, longer times were

obtained with groups of inflorescences which received the smallest average temperatures (Inf 4, Inf 2, Inf 3 and Inf 5). As for the shorter times, they were obtained with groups of inflorescences which received the highest average temperatures (Inf 9, Inf 8 and Inf 7). Analysis of these results by the significant Spearman Rank Correlation test marked at $p < .05$ gives a correlation coefficient of -0.867 (data not shown). This coefficient, which is close to -1, reveals the existence of a negative correlation between the ambient temperature and the delay between the inflorescence appearance and the first flower opening within this one. In addition, the various phenological events that appeared, such as inflorescences, flowers and fruiting bodies are shown in Fig. 7.

Table 1. Time between inflorescence appearance and first flower opening in relation temperatures

Group of inflorescences	Temperature (°C)	Delay (days)	Effective
Inf 1	25.89 ± 0.14 ^a	09.16 ± 3.57 ^A	58
Inf 2	25.57 ± 0.20 ^b	11.10 ± 2.30 ^B	58
Inf 3	25.78 ± 0.31 ^c	11.38 ± 2.70 ^C	58
Inf 4	25.44 ± 0.37 ^d	11.91 ± 2.94 ^D	58
Inf 5	25.80 ± 0.33 ^e	11.27 ± 2.26 ^E	58
Inf 6	25.98 ± 0.53 ^f	09.92 ± 2.06 ^F	58
Inf 7	27.63 ± 0.14 ^g	09.14 ± 2.01 ^G	58
Inf 8	28.46 ± 0.08 ^h	09.53 ± 2.46 ^H	58
Inf 9	28.54 ± 0.05 ⁱ	08.92 ± 2.44 ^G	58

Inf : group of inflorescences followed by the rank of selection day. Values represent the mean of triplicates. In a column, values followed by the same letter are not significantly different (test of Tukey HSD at 5%).

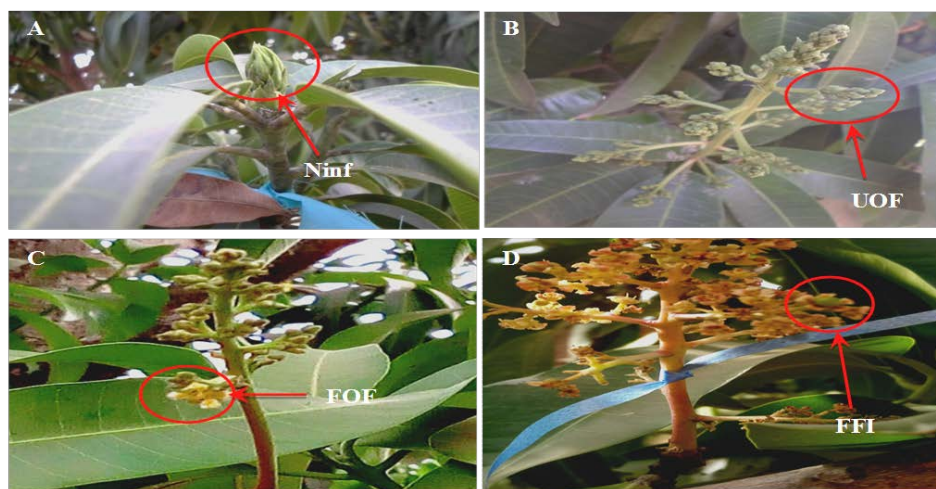


Fig. 7. Different phenological events of mango tree cv Kent

A: newly emerged inflorescence; B: 6-day inflorescence; C: 10-day inflorescence; D: 17-day inflorescence; Ninf: new inflorescence; UOF: unopened flower; FOF: first opening of flower within the inflorescence; FFI: first fruit set within the inflorescence

3.2 Correlation between Relative Humidity, Time of Inflorescence Appearance and First Flower Opening

The relative humidity received by the groups of inflorescences as well as the times are significantly different (Table 2). It is also observed that the shortest times were obtained with the groups of inflorescences which received the smallest relative humidity (Inf 1, Inf 7, Inf 8 and Inf 9). The long times were obtained with the groups of inflorescences which received the highest relative humidity (Inf 2, Inf 3, Inf 4 and Inf 5). The significant Spearman Rank Correlation test marked at $p < 0.05$ indicates a coefficient of 0.767 (data not shown). This coefficient, which is close to 1, reveals the positive relationship between these two parameters.

3.3 Correlation between Temperature, Time, Inflorescence Appearance and First Flower Opening within the Inflorescence

Table 3 show that the temperatures received by the groups of inflorescences as well as the delays are significantly different from each other. In addition, the longest times were obtained with the groups of inflorescences which received the smallest temperatures (Inf 1, Inf 2 and Inf 4). Relative to short times, they were obtained with

groups of inflorescences which received the highest temperatures (Inf 9, Inf 8 and Inf 10). The significant Spearman Rank Correlation test marked at $p < 0.05$ indicates a correlation coefficient of -0.830 (data not shown). Otherwise, this coefficient which is close to -1, reveals the existence of a negative relationship between these two parameters.

3.4. Correlation between Relative Humidity, Delay, First Flower Opening within the Inflorescence and First Fruit Set within the Inflorescence

The results show that relative humidity received by the groups of inflorescences as well as the delays are significantly different from each other (Table 4). Similarly, the longest delays were obtained with groups of inflorescences that received the highest average relative humidity (Inf 1, Inf 4, Inf 5 and Inf 6). As for the shortest delays, they were obtained with groups of inflorescences which received the lowest relative humidity (Inf 9, Inf 8 and Inf 10). In addition, the significant Spearman Rank Correlation test marked at $p < 0.05$ indicates a coefficient of 0.721 (data not shown). This coefficient, which is close to 1, reveals the existence of a positive relationship between these two studied parameters.

4. DISCUSSION

The mango trees grown in more than 100 countries distributed in tropical or subtropical latitudes that provides weather conditions for the occurrence of vegetative flows between season, as rising temperatures allow higher rates of cell

division and a good enzyme functioning that increase dry matter and new organs [17]. The results of the study reveal the existence of a negative correlation between the temperature and the time elapsing from the inflorescence appearance to the first flower opening. The smaller temperatures that reduce the time

Table 2. Time between inflorescence appearance and first flower opening in relation with relative humidity

Group of inflorescences	Relative humidity (%)	Time (days)	Effective
Inf 1	23.06 ± 0.88 ^a	09.16 ± 3.57 ^A	58
Inf 2	25.09 ± 0.69 ^b	11.10 ± 2.30 ^B	58
Inf 3	24.88 ± 1.80 ^c	11.38 ± 2.70 ^C	58
Inf 4	28.14 ± 1.53 ^d	11.91 ± 2.94 ^D	58
Inf 5	32.86 ± 2.34 ^e	11.27 ± 2.26 ^E	58
Inf 6	30.58 ± 2.57 ^f	09.92 ± 2.06 ^F	58
Inf 7	21.87 ± 2.04 ^g	09.14 ± 2.01 ^G	58
Inf 8	22.08 ± 0.51 ^h	09.53 ± 2.46 ^H	58
Inf 9	20.49 ± 1.05 ⁱ	08.92 ± 2.46 ^G	58

Inf : group of inflorescences followed by the rank of selection day. Values represent the mean of triplicates. In a column, values followed by the same letter are not significantly different (test of Tukey HSD at 5%).

Table 3. Time between first flower opening and first fruit set in relation to temperatures

Group of inflorescences	Temperature (°C)	Time (days)	Effective
Inf 1	25.83 ± 0.13 ^{ac}	11.85 ± 1.87 ^A	55
Inf 2	25.98 ± 0.15 ^b	09.71 ± 1.34 ^B	55
Inf 3	26.03 ± 0.50 ^b	07.34 ± 2.91 ^C	55
Inf 4	25.79 ± 0.46 ^a	09.11 ± 3.15 ^D	55
Inf 5	25.85 ± 0.65 ^c	08.40 ± 1.90 ^E	55
Inf 6	27.61 ± 0.18 ^d	08.21 ± 2.08 ^F	55
Inf 7	28.35 ± 0.03 ^e	06.10 ± 1.30 ^G	55
Inf 8	28.50 ± 0.10 ^f	06.65 ± 2.58 ^H	55
Inf 9	28.68 ± 0.13 ^g	06.24 ± 2.07 ^I	55
Inf 10	28.36 ± 0.14 ^e	05.46 ± 1.42 ^J	55

Inf : group of inflorescences followed by the rank of selection day. Values represent the mean of triplicates. In a column, values followed by the same letter are not significantly different (test of Tukey HSD at 5%).

Table 4. Time between first flower opening and first fruit set in relation with relative humidity

Group of inflorescences	Relative humidity (%)	Time (days)	Effective
Inf 1	27.61 ± 0.23a	12.85 ± 1.87 ^A	55
Inf 2	23.88 ± 0.60b	10.71 ± 1.34 ^B	55
Inf 3	26.43 ± 3.13c	08.34 ± 2.91 ^C	55
Inf 4	31.52 ± 3.54d	10.11 ± 3.15 ^D	55
Inf 5	36.04 ± 2.23e	09.40 ± 1.90 ^E	55
Inf 6	31.35 ± 2.57f	09.21 ± 2.08 ^F	55
Inf 7	22.38 ± 0.29g	07.10 ± 1.30 ^G	55
Inf 8	21.03 ± 0.90h	07.65 ± 2.58 ^H	55
Inf 9	19.18 ± 1.28i	07.24 ± 2.07 ^I	55
Inf 10	16.06 ± 0.07j	06.46 ± 1.42 ^J	55

Inf : group of inflorescences followed by the rank of selection day. Values represent the mean of triplicates. In a column, values followed by the same letter are not significantly different (test of Tukey HSD at 5%).

between these two phenological events of the inflorescence suggest an influence of temperature on the events that mark the

beginning and the end of this delay. In fact, flowering or inflorescence appearance, which is the event of the beginning of the time, is under

the influence of temperature as reported by several studies [12;18;19]. Moreover, the works of Joubert *et al.* [20] and Muhammad *et al.* [21] that mango bloom is due to stress caused by low temperatures. Thus, there is a negative allometric relationship between the temperature and the time elapsing from the inflorescence appearance to the first flower opening [22; 23]. In addition, the flower opening is also influenced by the temperature. Indeed, under the temperature effect, the differential growth of flower between the inner face and the outer face causes the opening of the latter [24-27]. Similarly, Patrick [28] reported that flower development is influenced by sufficient temperatures. On the other hand, the results revealed the existence of a positive relationship between the relative humidity and the time elapsing from the inflorescence appearance to the first flower opening. These results indicate that relative humidity is another important factor influencing the development of mango inflorescences, including the inflorescence appearance and the flowers opening [23; 29; 30]. Indeed, inflorescences development requires a high relative humidity in order to reduce the energy losses caused by perspiration [31; 32]. Conversely, a low relative humidity will slow down the development of those. Moreover, relative humidity influences the inflorescences appearance by vernalization. This phenomenon which is a period of low temperatures and high relative humidity, seems to start the inflorescences appearance. Moreover, Letswaart *et al.* [33] showed that, in normally, the Flowering Locus C (FLC) gene prevents flowering [34; 35]. However, prolonged exposure to low temperatures, and high relative humidity, induces the accumulation of a protein called Vin3 (Vernalization Insensitive 3) within the cells of the plant whereas Vin3 causes the inactivation the FLC gene, and would start flowering [36-38].

Once the opened buds, the young flowers bloom and can be fecundated to give a young fruit [39; 40]. However, this study reveals that the times elapsing between the first flower opening at the level of the inflorescence and the a young fruit appearance is negatively correlated with temperature [23; 41]. Indeed, high temperatures reduce the time while the low ones lengthen it. Thus, this result shows that temperature affects fecundation and fruiting. In addition, several studies reported a strong influence of temperature on pollen production and pollen tube growth [42-44]. However, except for this physical parameter, it is worth noting that fructification, which is a phenological phenomenon, is also linked to the action of

pollinating insects [45; 46] because in mango flowers pollination is primarily entomophilous and crossed [47]. The time of fruit-bud-differentiation in mango is known to be governed by climatic parameters, which varies from place to place. Mango flowering is an important physiological event that sets the start of fruit production. Mango trees flower in response to the age of the last vegetative flush in tropical conditions. Warm temperatures are required for an organism's physiological development [48], notably to induce flowering. Temperature optimums, including lower and upper thresholds, differ across species and varieties, even individual plants, their specific organs and the age or developmental state of those organs [49]. Cesaraccio *et al.* [50] stated that the accumulation of heat over time is called physiological time, and growing degrees are a more accurate measure of development than physical time. According to Davenport and Núñez-Elisea [51] the growth of mango trees is ephemeral in tropical conditions, with periodic initiation of vegetative or reproductive shoots occurs from resting buds of terminal stems in several flushes per year. Generally vegetatively induced flushes of growth occur during warm spring, summer, and early fall months [52; 53]. In subtropics, the ambient temperature is the primary regulator of vegetative or reproductive induction at the time of shoot initiation. The cold and dry periods are essential to the mango trees flowering and wet periods favour vegetative flows emissions [37; 54, 55].

Relative humidity is positively correlated with this time. Indeed, the longest times were obtained with the inflorescences groups which received the highest relative humidity while the short times were obtained with that received the lowest relative humidity. In addition, sugars are the major constituents of nectars and therefore represent the main energy supply for pollinators [56]. An abundant nectariferous secretion rich in sugars assures an important frequentation of the trees by the insects and, at the same time, makes it possible to obtain better seed yields [57; 58]. As a result, the flowers frequentation by pollinating insects also relates to the sweet taste of nectar. However, a high relative moisture could reduce the "sweet" taste of nectar (to dilute), and therefore limit pollinating insects visitation [59]. This has the consequence of delaying fertilization, thus to lengthen this period of fruiting. On the other hand, a lower humidity will allow having a less diluted nectar so sweeter this would cause a much greater attraction of insects [47] and thus to support fecundation quickly, thus shorten the fruiting time.

5. CONCLUSION

The study highlighted a negative relationship between the time elapsing from the inflorescence appearance and the first flower opening as well as the temperature. Inflorescence which received the lowest temperatures had the shortest time between these two phenological events of the inflorescence. In contrast, the inflorescences that received the highest temperatures had much longer times between the inflorescence appearance and the first flower opening. In addition, the study revealed the existence of a positive correlation between the relative humidity, the elapsing delay between the inflorescence appearance and the first flower opening. It is the same for the elapses delay between the first flower opening and the temperature. On the contrary, a positive correlation between this fructification time and the relative humidity was observed.

CONSENT

The author declares that written informed consent was obtained from the participants for publication of this paper.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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