P-ISSN: 2305-6622; E-ISSN: 2306-3599

International Journal of Agriculture and Biosciences

www.ijagbio.com; editor@ijagbio.com

Research Article https://doi.org/10.47278/journal.ijab/2022.021

Resilience of tree fruit farming to climatic variability: study of some growth characteristics of Kent and Keitt varieties of mango (*Mangifera indica L.*) in the Koulikoro District, Mali

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Article History: 22-276 Received: 05-Sept-22 Revised: 28-Sept-22 Accepted: 03-Oct-22

ABSTRACT

Mali is one of the largest mango producing country in the world. Despite its production potential, the country's mango plantations are not resistant to the effects of climate change, the negative impacts of climate change affects the production, the adaptation of growth and the development of the main exportable varieties. The development of a tree crop resilient to the adverse effects of climate change is necessary to meet the ever-increasing demand. The objective of this study was to compare growth resilience techniques of Kent and Keitt varieties of mango in the face of environmental disruptions. The experimental study was conducted from 2016 to 2018 in an IPR/IFRA orchard in Katibougou to document growth traits. The behavior of the two mango varieties through four cultivation techniques was tested (mulched plowed plot, mulched unplowed, plot plowed plot, and unplowed un-mulched plot). Three different periods were selected after planting: from 6th to 11th month (February-June), from 12th to 18th month (July-November) and from 19th to 24th (December-April). The mulched plowed technique was the best technique to improve the resilience of mango varieties to climatic variability. Among all the growth traits studied: the survival rate, the length of Growth Unit (GU), the speed of GU, the number of leaves, the phyllochron duration, the plowing with mulching technique obtained the best values; particularly for the interval of time between the dates of emergence of two successive vegetative shoots (phyllochron), which was less than one month. Except for the growth rate of the GU, for all the growth studied traits, both varieties behaved similarly under the different cultivation techniques. The good resistance of the Kent variety with a survival rate of about 100%, and the phyllochron achievement time of the Keitt variety were noted. The technique of plowing with mulching could be proposed for adoption to mango producers in the Koulikoro district, and the choice of Kent or Keitt varieties could be made after confirmation tests.

Key words: Cultivation Techniques, Mango Variety, Resilience, Climate Change, Plowing, Mulching, Koulikoro.

INTRODUCTION

The mango tree (*Mangifera indica L.*) is native to the forests of India, where it still grows wild. Cultivated for more than 4,000 years, the mango tree has spread rapidly throughout the world: as early as the 16th century, the Arabs introduced it in Africa and the Portuguese established it in Central and South America (www.lesfruitsetlegumesfrais.com).

Today, the mango is cultivated in all tropical countries of the world. Several hundred different species are known, of which only a few are distributed commercially.

In Mali, the mango is the leading export fruit (Haidara, 2012). This is a promising sector that offers real development opportunities for the country, given the existing potential (200,000 tons of mangoes per year), of which more than 80,000 tons can be exported (non-fibrous), and the growing markets (EU, sub-region, Maghreb). Unfortunately, fresh mango exports remain dependent on climatic variations that have had a significant impact on yields (www.cirmali.org). Mali is one of the ten largest mango producing countries in the world (AMLEF, 2010), with an estimated fresh mango production potential of 575,000 tons. The main mango production basins are:

Cite This Article as: Diarra S, Sissoko S, Diawara MO, Traoré BM and Sidibé A, 2022. Resilience of tree fruit farming to climatic variability: study of some growth characteristics of Kent and Keitt varieties of mango (*Mangifera indica L.*) in the Koulikoro District, Mali. Int J Agri Biosci, 11(3): 157-164. https://doi.org/10.47278/journal.ijab/2022.021

Bamako and surrounding areas, Koulikoro, Bougouni, Sikasso, Yanfolila, Kolondieba, Kadiolo, Koulikoro, Baguineda, Kati, Kita, Siby and Ségou. Production is generally ensured by small owners of small orchards, between 2 and 3 hectares for the most part traditional. However, for less than 15 years, there have been large orchards in the Sikasso area of between 50 and 100 hectares in size (Diallo et al., 2016). Production is characterized by its diversity, with about 87 varieties grown (www.cirmali.org). However, only six of them (Kent, Keitt, Amélie, Tommy Atkins, Palmer and Valencia) are appreciated and exported in large quantities outside of Mali with some form of contractualization and requirements in terms of quality, quantity and timing (Diallo et al., 2016). Despite all the progress made in technical processing and the improved value of mango through exports, the mango sector is still subject to multiple constraints. Facing low productivity per hectare and numerous sanitary problems, many studies have been conducted on the main determinants of mango tree growth and development (Vayssieres & Vanniere, 2010; Dambreville, 2012; Reffye, 2017). Production in quantity and quality usually depends on a good plantation starting up in terms of growth and development of young seedlings. In order to meet the ever-increasing demand for mangoes in a context of climatic variability, it is important to test cultivation techniques with high-yielding varieties in order to determine which are more resilient. The work conducted in this study is based on cultivation practices that conserve soil moisture at the beginning of planting at the orchard scale. For this purpose, Kent and Keitt varieties of mango trees were preferred.

MATERIALS AND METHODS

Experimental site

The study was conducted in one of the orchards of the Rural Polytechnic Institute of training and Applied Research (IPR/IFRA) of Katibougou located at around 70km from Bamako and 3.5km from Koulikoro city. The coordinates are as follows: 12°56' North latitude, 7°37' West longitude, 326 m altitude. The relief is particularly characterized by hills and plateaus to the northwest and east. A sandstone massif overhangs a rather narrow valley whose lowlands are periodically flooded by the waters of the Niger River. The Soudano-Sahelian climate, characterized by two seasons. The average annual rainfall is 850mm. The average temperature is 39°C in the hot dry season versus 21°C in the cool dry season (Katibougou Weather Station, 1998). The main soil types encountered on the experimental site are tropical ferruginous soils with a silty to sandy texture at the top and a silty texture at depth.

Plant material

The plant material used in this study was mango varieties, Kent and Keitt, both from the Genetic Resources Unit of the Rural Economy Institute (URG/IER) in Mali, in order to comply with the requirements of the study. All the young plants collected (12 months old) were grafted at the beginning of the rainy season. The mango planting in orchards is based essentially on the Kent and Keitt varieties in the district of Koulikoro. And these two varieties are well appreciated by consumers outside the country (Diallo et al., 2016; Diarra et al., 2021).

Methodology

Trial set-up

The plot used in this study was fallow for 3 years. The development work started in June 2017 with the felling of trees, which was followed by root clearing. Then a deep plowing of about 70cm was done in July 2017. A cross pulverization made it possible to make uniform the plot from the point of view levelling. The trial was conducted in a Split-Plot design with two factors. The principal factor was plowing practices, composed of four treatments: plowed plot; plowed and mulched plot; unplowed but mulched plot; and unplowed or control plot. The secondary factor was mango varieties, composed of two sub-treatments: Kent and Keitt varieties. The trial was composed of three blocks or replications; one replication consisted of four main plots and each made up of two lines of the secondary plot. Each of the secondary plot received mango plants, for a total of 24 mango plants per main plot. The trial included 36 plants of the Kent variety and 36 plants of the Keitt variety, for a total of 72 mango plants in the entire trial. To determine the planting holes, we proceeded by using the 3-4-5 method to first find the right angles. Then we drew the planting lines. On each line, the identification of the hole locations was done. Each hole had a depth of 1 meter, a width of 0.80 meters and a unique spacing of 7 meters by 7 meters between holes. A random draw was used to identify the position of the secondary plots.

Trial management

The most important management of the mango trees in this study was apply fertilization, irrigation, and mulching.

Fertilization

The main fertilizer used was well-decomposed organic manure at a rate of 30 tons per hectare, or 20 kg per hole (52% of the hole). This initial dose was increased by 5 kg for each tree in subsequent years. To the organic fertilizer, 10kg of wood ash, 2kg of cotton cake and 1kg of ammonia sulfate were added annually to the hole of each tree.

Irrigation

The plot was irrigated for three years with different frequencies and quantities of water.

- During the first year of the trial, water was supplied to each plant only once a week. The amount of water applied was 30 liters per plant.
- During the 2nd year, water was supplied to each plant only once for 2 weeks. The amount of water given was 120 liters per plant.
- During the 3rd year, water was supplied to each plant only once for 3 weeks. The quantity supplied was 270 liters of water per plant.

Mulching with dry grass

This operation aimed at ensuring a better conservation of the soil moisture during the period between two watering.

The activity was carried out in October of each year during the three years of the experiment; by making a basin of 1m diameter around each mango tree; establishing a layer of straw 0.30m thick in the basin; leaving a free space around the trunk at the base of each tree; and placing a moderate residual insecticide (carbofuran) under the straw in order to avoid the proliferation of termites and direct contact with the straw layer.

Observations and measurements

Observations on growth parameters started one week after the emergence of the first vegetative shoot from the plant. The technique of direct observations described by FAO (1983) was used. This technique recommends to carry out observations and organ sampling on the different previously identified zones of the tree.

The period of observations was divided into 3 periods:

- Period from the 6th to the 11th month (February - June),
- 12th to 18th month (July - November),
- Period from 19th to 24th month (December - April) after planting.

The main parameters that were measured were taken at the organ level and on two (02) central plants in each main plot (1 plant per variety).

Measure of growth

Measurements included: rates of recovery (3 months after planting) and survival (24 months after planting) and the Growth Unit (GU) complex. At this level, the height, the speed of growth of the axis, the number of leaves, the phyllochron (time interval between the dates of emergence of two (02) successive vegetative shoots, in days) were determined.

The height in cm of the axis was determined at each measurement by a ruler (metal ruler in miniature). The speed was calculated each time by making the ratio of distance to time.

The phyllochron was determined from each sampling date which allowed us to know the number of shoots emitted by each GU. From these data we were able to determine the number of days between two (02) successive vegetative shoots, days corresponding to 50% of the population (FAO, 1983).

RESULTS

Experimental conditions

The year 2016 was the wettest year during the study period with 1000mm and 2018 a relatively dry year with only 800mm of rainfall (Fig. 1). The temperature evolution showed that the temperature gradually increases from January to reach its maximum in April and early May with 33.5°C. With the arrival of the monsoon, humid wind, the temperature begins to fall from mid-May 28.7°C (progressive installation of the rainy season). It starts to rise again from September, and then decreases at the end of November. The temperature variation curve thus presents two maxima: the first one occurs at the beginning of April and the second one at the end of October (Fig. 2).

Experimental results

The main information obtained on the growth of the two (02) varieties of mango through the evaluation of the influence of cultural practices were subject to statistical analysis.

Recovery rate three months after planting

The recovery rate three (03) months after planting was estimated at 100% for the two (02) varieties and this for all the cultural practices. The emission of the first true leaves after plantation by the graft was realized in two (02) months.

Survival rate 24 months after planting

Statistical analysis of the 24-month survival rate of the two varieties revealed a significant difference between the effects of cultural techniques and the effects of varieties. However, it did not reveal a significant difference between the effects of the cultivation techniques and varieties interaction. The application of the Newman-Keuls test at the probability threshold (5%) showed three distinct

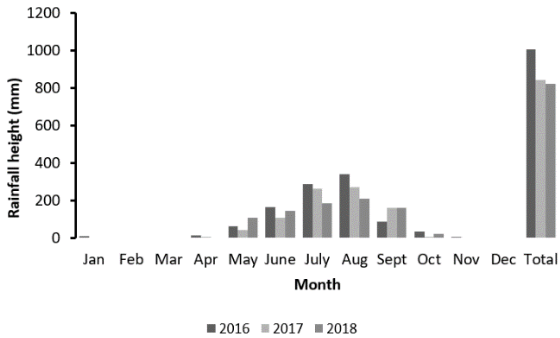

Fig. 1: Annual rainfall data during the experiment years (Katibougou weather station, 2016-2018).

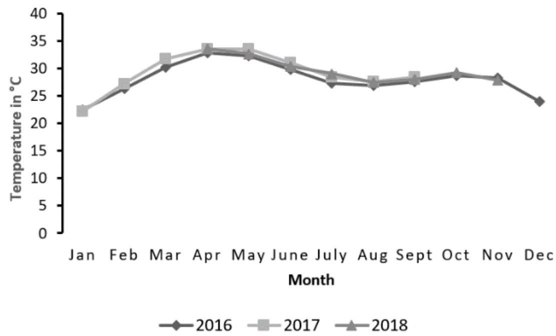

Fig. 2: Variation curve of monthly temperature data during the 2016-2018 experimental years (Katibougou weather station, 2018).

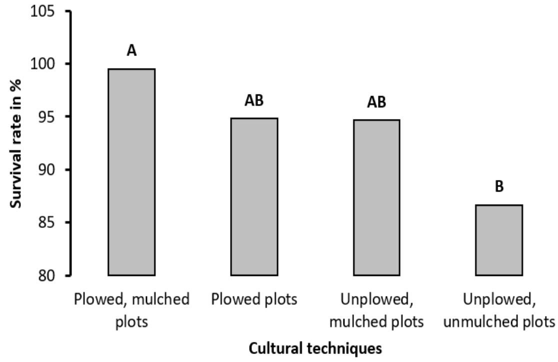

Fig. 3: Effect of cultural technique on the survival rate of the plants during 24 months.

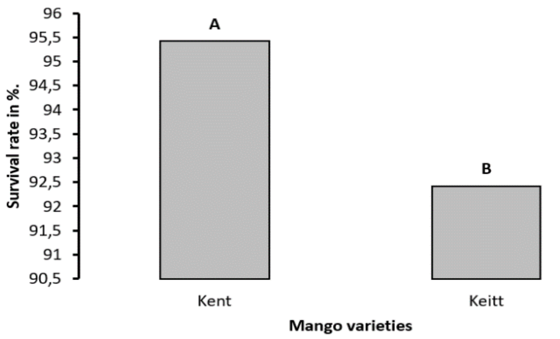

Fig. 4: Effect of variety on plant survival rate for 24 months.

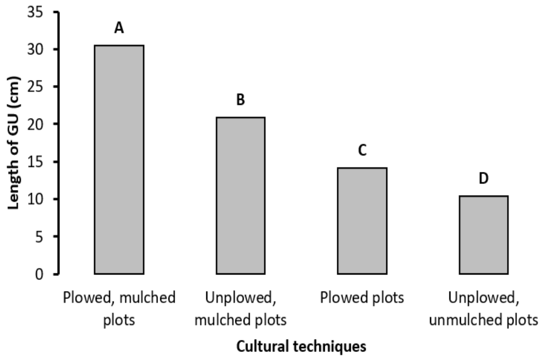

Fig. 5: Effect of cultural technique on GU length from 6th to 11th month after planting.

homogeneous groups (A, AB and B) for cultural techniques and two groups (A and B) for varieties. The results in Fig. 3 show that seedling survival was higher in the plowed and mulched plots, followed by the ploughed and unplowed but mulched plots. Plant survival was lowest in the unplowed, unmulched plots. Plant survival is higher for the Kent variety than for the Keitt variety (Fig. 4).

Growth measurement

At the level of the growth unit (GU) axis

GU length from 6th to 11th month after planting (AP)

The analysis of variance showed a highly significant difference (P<1%) between the effects of cultivation techniques and variety effects. However, it did not reveal any significant difference between the effects of the cultivation techniques and varieties interaction. Four (4) distinct homogeneous groups (A, B, C, and D) for cultural techniques and two groups (A and B) for varieties were obtained with the application of the Newman-Keuls test at the probability threshold (5%). The plowed and mulched plots had a higher GU size than the unplowed and mulched plots, which in turn had a higher GU size than the unploughed and mulched plots; the unplowed and unmulched plots had a lower GU size (Fig. 5). The Keitt variety was more favorable to increasing GU length compared to the Kent variety (Fig. 6).

GU length from 12th to 18th month after planting (AP)

A highly significant difference (P<1%) between the effects of cultivation techniques and the effects of varieties following the analysis of variance. But a significant difference between the effects of the cultivation techniques and varieties interaction was not detected. The application of the Newman-Keuls test at the probability threshold (5%)

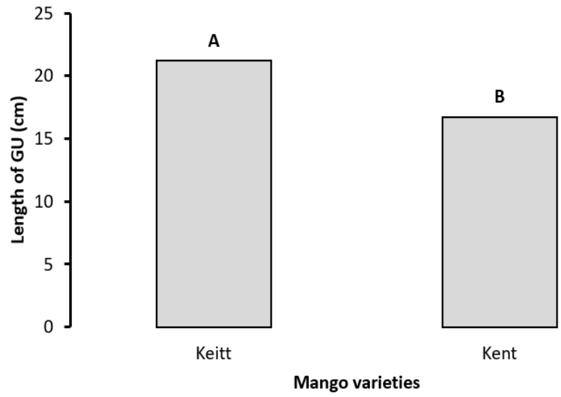

Fig. 6: Effect of variety on GU length from 6th to 11th month after planting.

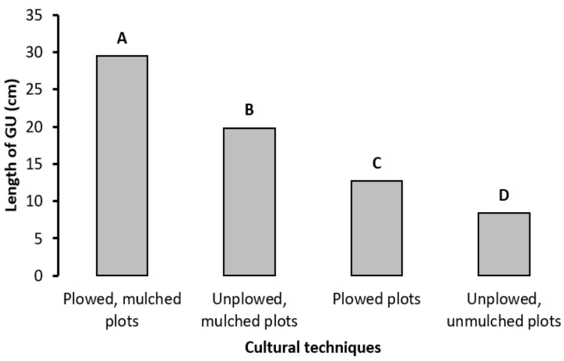

Fig. 7: Effect of cultural technique on the length of the GU 12th to 18th month after planting.

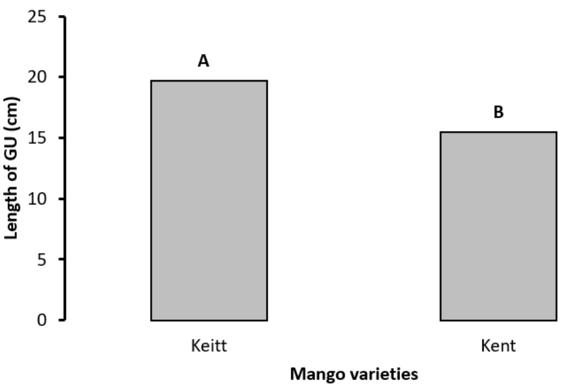

Fig. 8: Effect of variety on GU length from month 12 to 18 after planting.

showed four (04) distinct homogeneous groups (A, B, C and D) for cultural techniques and two groups (A and B) for varieties. Plants on mulched tilled plots had a higher GU size (29.47cm) than those on non-mulched tilled plots (19.83cm). The plowed plots had the 3rd largest GU and the unplowed, unmulched plots had the 4th largest GU (8.42cm) (Fig. 7).

The variety Keitt was more favorable to increase the GU height compared to the variety Kent with 19.71 and 15.49cm respectively (Fig. 8).

GU length from 19th to 24th month after planting (AP)

Analysis of variance of length showed statistically similar results with those obtained during the 12th to 18th month after planting.

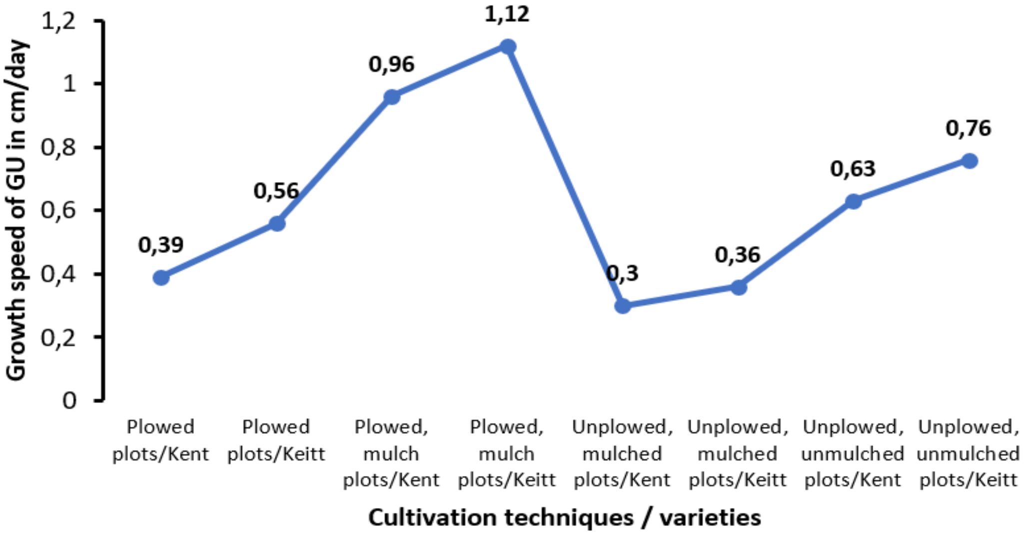

Fig. 9: Growth speed from months 6 to 11 AP.

Growth speed of the GU in centimeters per day from the 6th to the 11th month after planting (AP)

The speed curve (Fig. 9) showed a higher growth rhythm of the GU of the seedlings on the plowed and mulched plots (1.12cm/day) than that of the GU of the seedlings on the unplowed and mulched plots. It was also noted that the GU of seedlings on ploughed plots grew faster than that of seedlings on unplowed, unmulched plots. The growth rhythm of the Keitt variety was found to be faster than that of the Kent variety for all cultivation techniques.

Growth speed of the GU in centimeters per day from the 12th to 18th month after planting (AP)

The higher growth rhythm of plant GU on the plowed and mulched plots compared to plant GU on the unplowed, mulched plots (Fig. 10). The GU of seedlings on plowed plots grew faster than that of seedlings on unplowed and unmulched plots. As for the GU speed from the 6th to the 11th month after planting, the growth speed of the Keitt variety was shown to be faster than that of the Kent variety for all cultivation techniques from the 12th to the 18th month too.

Growth speed of the GU in centimeters per day from the 19th to 24th month after planting (AP)

Analysis of variance of speed revealed statistically equal results with those obtained during the 12th to 18th month after planting.

Number of leaves from the 6th to the 11th month after planting (AP)

The analysis of variance of the results revealed a highly significant difference (P<1%) only between the effects of cultivation techniques. It did not reveal any significant difference between the effects of varieties and those of the interaction of varieties and cultivation techniques. The application of the Newman-Keuls test at the probability threshold (5%) showed two (2) distinct homogeneous groups (A and B). In the plots plowed with mulch, unplowed with mulch and plowed plots, the plants statistically emerged the same number of leaves and this number was statically higher than the number of leaves obtained in the plots unplowed without mulch (Fig. 11).

Number of leaves from the 12th to the 18th month after planting (AP)

The analysis of variance of the results revealed a highly significant difference at P<1% between the effects of cultivation techniques, but no significant difference between the effects of varieties. Application of the Newman-Keuls test at the probability level (5%) showed two distinct homogeneous groups (02) (A and B). The statistical difference in number of leaves was found mainly between the plants on the unplowed, unmulched plots and all other plots (Fig. 12).

Number of leaves from the 19th to the 24th month after planting (AP)

A highly significant difference between the effects of cultivation techniques was revealed in the analysis of variance, but no significant difference between variety effects. The application of the Newman-Keuls test at the probability threshold (5%) showed two (02) distinct homogeneous groups (A and B). The plants that were introduced in the mulched plots, the plowed plots and the unplowed mulched plots obtained the highest number of leaves and were statistically superior to the plants that were introduced in the unplowed unmulched plots (Fig. 13).

Phyllochron data in days from months 6 to 11 after planting (AP)

The analysis of variance for this period revealed a highly significant difference ($P < 1\%$) between the cultural technique effects, no significant difference between the variety effects. It also did not detect a significant difference between the effects of the cultural techniques and varieties interaction. The Newman-Keuls test at the significance level (5%) showed four (04) distinct homogeneous groups (A, B, C and D). Fig. 14 revealed that the seedlings on plowed mulched plots achieved phyllochron in less than one month (26.5 days) followed by those on unplowed mulched plots (27.5 days) and plowed plots (29.5 days). Plants on unplowed, unmulched plots achieved phyllochron beyond one month (35.5 days). The average phyllochron recorded during this period was 29.8 days.

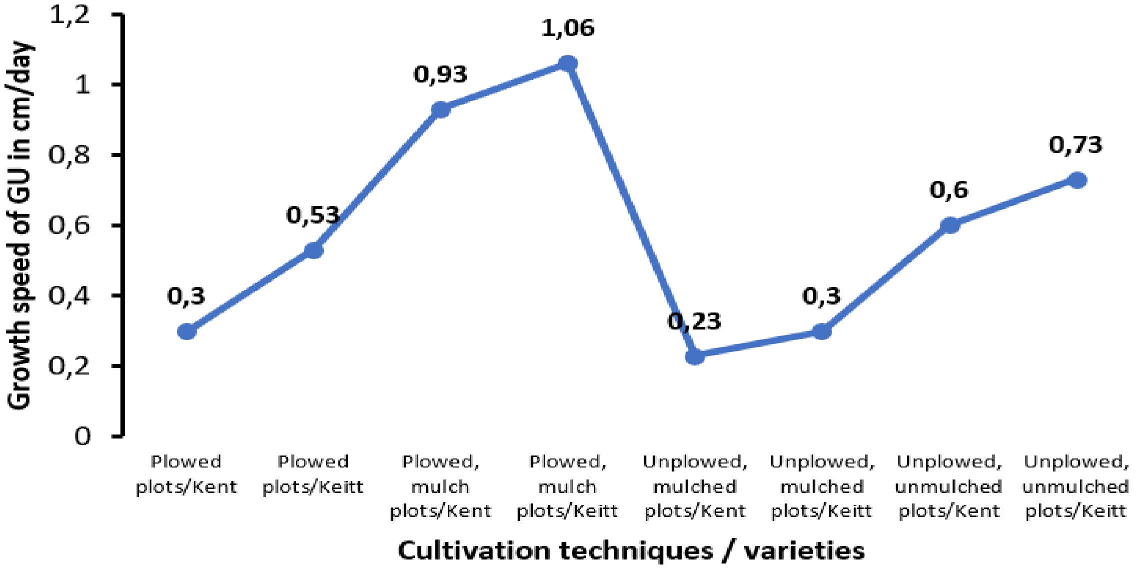

Fig. 10: Growth speed of the GU from months 12 to 18 AP.

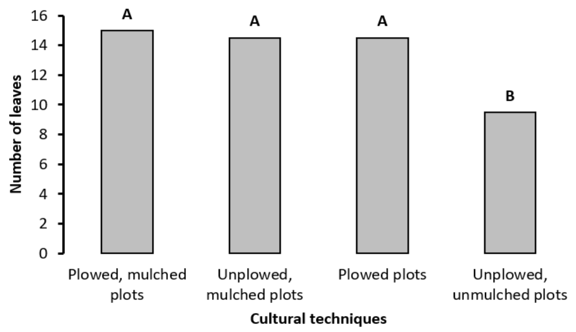

Fig. 11: Effect of technique on the number of leaves from months 6 to 11 AP.

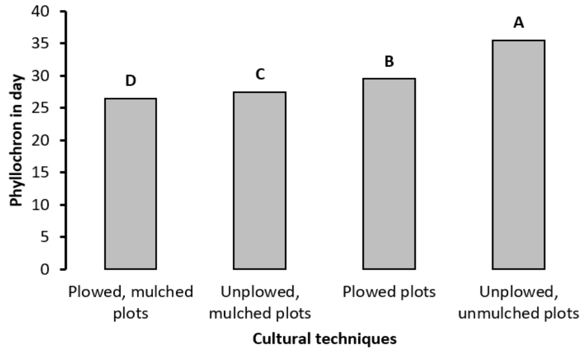

Fig. 14: Effect of the cultural technique on the phyllochron from months 6 to 11 AP.

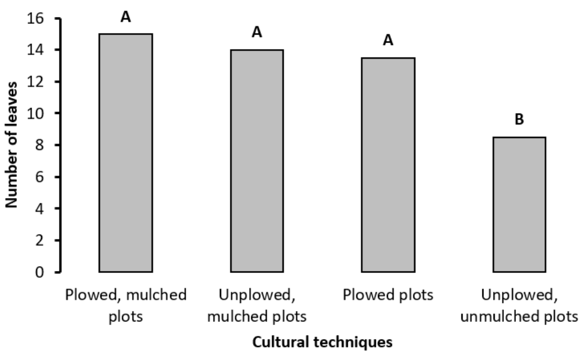

Fig. 12: Effect of technique on the number of leaves from months 12 to 18 AP.

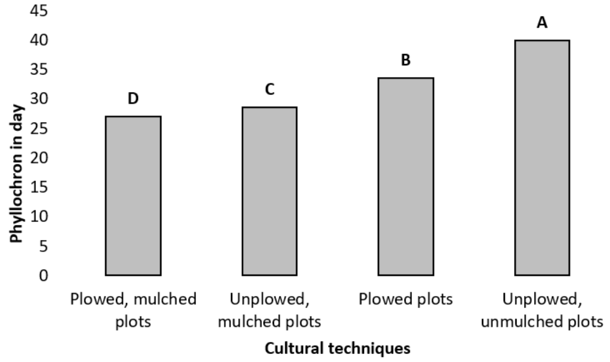

Fig. 15: Effect of the cultural technique on the phyllochron from months 12 to 18 AP.

Phyllochron data in days from months 12 to 18 after planting (AP)

A highly significant difference (P<1%) between the effects of the cultivation techniques and no significant difference between the cultivation techniques and varieties in the analysis of variance. The Newman-Keuls test at the significance level (5%) showed four (04) distinct homogeneous groups (A, B, C and D). The seedlings in the plots plowed with mulch and unplowed with mulch achieved the phyllochron in less than a month with respectively 27 and 28.5 days. On the other hand, the phyllochron achieved in more than one month was achieved in the plots plowed simply and not plowed without mulch with 33.5 and 39.8 days respectively (Fig. 15). The average phyllochron for the period was 32.2 days, i.e. more than one month.

Phyllochron data in days from months 19 to 24 after planting (AP)

The analysis of variance revealed a highly significant difference (P<1%) between the effects of cultural techniques and between variety effects. The Newman-Keuls test at the significance level (5%) showed three (03) distinct homogeneous groups (A, B and C) for the cultural techniques. Fig. 16 below shows that the plants in the mulched plots achieved phyllochron in less than one month

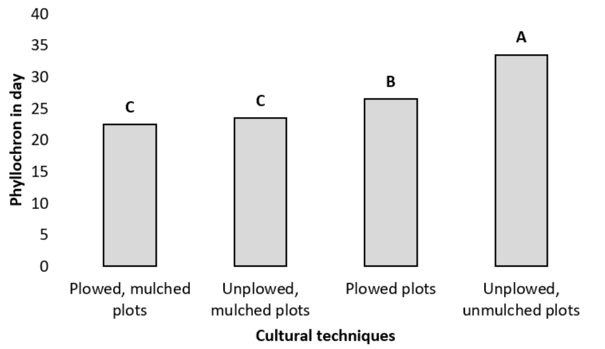

Fig. 16: Effect of the cultural technique on the phyllochron from months 19 to 24 AP.

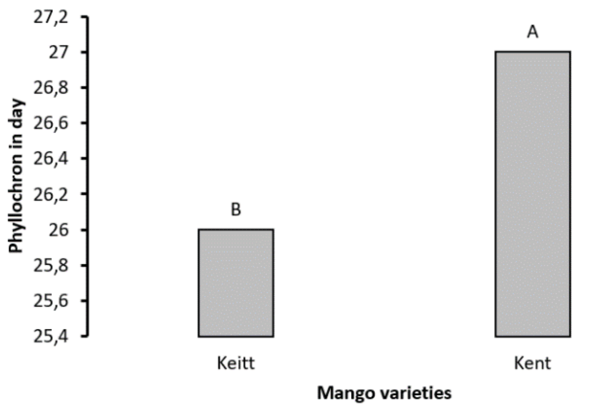

Fig. 17: Effect of variety on phyllochron from months 19 to 24 AP.

as well as those in the unplowed mulched and plowed plots. The phyllochron of more than one month is observed on the unplowed, unmulched plots. An average phyllochron of 26.5 days was recorded during this period.

The two varieties used all completed their phyllochron in less than one month; however, it should be noted that the variety Keitt was able to reduce the time to complete the phyllochron by one day compared to the variety Kent with 26 and 27 days respectively (Fig. 17).

DISCUSSION

The objective of this study was to test techniques for improving growth resilience of Kent and Keitt mango varieties under climate variability. During the years of the experiment, cumulative annual rainfall gradually decreased from 1002 mm of rain in 2016 to 822 mm of rain in 2018. This trend of decreasing annual rainfall amounts is in agreement with that mentioned in the case of a previous analysis of 1981-2014 data by Traoré (2015). During the three years, annual temperatures had two maxima, the first occurring in early April with 33.5°C and the second in late October with 29.2°C. The same months are reported by the Koulikoro weather station as the warmest periods over the past 20 years, with average monthly values of 40°C and 35°C in April and October, respectively (www.donneesmondiales.com Station météo Koulikoro). Faced with decreasing rainfall amounts and increasing temperatures, mango plantations become vulnerable to the effects generated (PROMISAM, 2008), especially in the first years of planting (Vayssieres et al., 2007; Dambreville, 2012). The increase in temperature and high interannual variability in rainfall amounts negatively impact the productivity of mango orchards in general and those with Kent and Keitt varieties (DRA, 2016). A 100% recovery rate observed three months after planting with all the cultural practices tested and with both varieties. This good recovery rate is explained by the planting of mango seedlings during the rainy season (July). The seedlings especially received enough water at the start. Young plants require regular and sufficient watering, especially during planting, to ensure good recovery (Nadie et al., 2009). The survival rate obtained 24 months (2 years) after planting is acceptable with all the cultivation techniques applied. The best survival rate (99.5%) was obtained on the plowed and mulched plot, followed by the unplowed but mulched and plowed but not mulched plots. The low survival rate (86.67%) was observed on the control plot which was neither plowed nor mulched. The good survival rate of young plants is explained by the morphogenetic structure of the mango tree, which is a good example of survival. Indeed, its strong and deep roots allow it to get the water it needs in the deep layers, and thus to survive in case of drought (Pardessus, 2002; https://jardinage.lemonde.fr). The Kent variety had a higher survival rate than Keitt with 95.42 and 92.42% respectively. The Kent variety is a reproductive variety but above all resistant which makes it a reference variety produced in most Latin American and African mango exporting countries (UNCTAD, 2016).

All organs of a plant result from growth and development processes (Bell, 1991). Under unfavorable feeding conditions (water and mineral), mango growth slows down, leaves lose vigor and wilt (Nadie et al., 2009). The mulched plots gave the best results of growth measurements on the Growth Unit (GU) complex in terms of height, axis growth rate and number of leaves during the three observation periods: from 6^{th} to 11^{th}, 12^{th} to 18^{th} and 19^{th} to 24^{th} months after planting. This good result is mainly due to the combination of plowing and mulching. Several studies have shown the importance of plowing and mulching in agriculture. Plowing reduces soil compactness to facilitate root growth, increase water infiltration, stimulate the activity of soil organisms (FAO, 2015). Mulching retains water by limiting its evaporation under the feet of the plants. Indeed, through mulching, water remains in the soil over a longer period of time. The water is available to the plants for a long time and provides them with an environment that is more conducive to their growth due to the available water. The phenomenon of leaching and leaching is reduced by the presence of a mulch, which limits the impoverishment of the soil (https://blog.defi-ecologique.com). The unplowed but mulched plots were still slightly better than the plowing without mulch and the unplowed and unmulched (control) plots.

The phyllochron is the time interval between the sequential emergence of successive leaves on the main stem of a plant (Bunting et al., 1965). In this study we estimated the duration of the phyllochron in days during the three periods, for each cultural technique and with the two varieties. The analyses revealed that the shortest duration (less than one month) of phyllochron was observed with the plowing and mulching technique in all three periods of the experiment. This shows that this technique improves the speed of plant growth. The speed of plant development before flowering is usually characterized by the rate of primordia production, the rate of visible leaf emission and the rate of completion of successive leaf blades (Rickman and Klepper, 1995). The longest average duration (32.2 days) was found during the period from the 12th month to the 18th month (July - November) after planting. The shortest duration was less than one month (26.5 days) during the 19th to 24th month (December - April) after planting. These results indicate the influence of period on phyllochron duration. Cao and Moss (1989a) and Masle et al. (1989) suggested that photoperiod is also a factor that can influence phyllochron. Several authors have shown that among the environmental factors, temperature is the predominant factor affecting phyllochron (Gallagher, 1979; Baker et al., 1980; Kirby et al., 1982a; Hay and Delécolle, 1989; Cao and Moss, 1991). The study also revealed a significant difference of one day in phyllochron duration between the Keitt and Kent variety with 26 and 27 days, respectively, during the 19th to 24th month (December - April) after planting. This result may be due to different photoperiod and temperature responses of the varieties.

Conclusion

The objective of this study was to follow the physiological evolution of two mango varieties using different cultivation techniques in order to identify the one that best adapts to water deficit. The choice of techniques was motivated by their accessibility to the planters.

On the whole of the growth characters studied like the survival rate, the height and the speed of the GU, the number of leaves, the duration of the phyllochron through the various cultural techniques. The technique that proved to be the best in improving growth traits such as survival rate, speed of the GU, height, number of leaves, and phyllochron duration is the one that combines plowing with mulching.

The results will enable decision-makers and technicians in charge of the development of the mango sector to increase awareness among planters of the adoption of the technique that combines plowing and mulching with a 30 cm thick layer with the Kent and Keitt varieties.

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