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Research Article
Effects of Planting Bed and Density on the Yield of Pineapple (*Ananas comosus* L. var., MD2) Grown in Short Rainy Season in Southern Côte d'Ivoire

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Abstract
Background and Objective: The insertion of MD2 pineapple in the international trade of fruits has helped reduce drastically the share of Côte d'Ivoire, a long-time leader in the European market with the variety Smooth Cayenne. In order to regain the lost market share, the Ivorian pineapple producers are considering a varietal diversification that goes through an adaptation of MD2 cultivation to the local ecological conditions. Thus, the study conducted in three pineapple-producing cities (Bonoua, Dabou, Tiassalé) aimed at improving the performance of MD2 variety in pedoclimatic conditions of Southern Côte d'Ivoire. **Methodology:** The effects of three planting beds: Flat land (TP), bare ridge (BSP) and ridge covered with polyethylene film (BAP) and two planting densities: 50000 and 70000 seedlings ha^{-1} (D50 and D70 respectively) were assessed on performance parameters through a split-plot design. **Results:** The results showed that in Bonoua and Dabou, the crop cycle of MD2 pineapple grown in short rainy season was relatively short (12 months) regardless of the planting bed and density. In Tiassalé, the average fruit weight and the highest gross yields were recorded on the ridges covered with polyethylene film. Furthermore, in all cities subjected to experiment, high planting densities (70000 plants ha^{-1}) were marked out by the highest yields. **Conclusion:** The adoption of these results by producers could improve the production of MD2 pineapple in Côte d'Ivoire.

Key words: MD2 pineapple, planting bed, planting density, yield, *Ananas comosus*

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Pineapple is the 3rd tropical fruit, in terms of yield, after banana and mango in the world[1] and holds an important place in the economy of many countries. Its worldwide yield increased[2] from 15.7 million tons in 2001 to 21.6 million tons in 2011. This corresponds to an average annual growth of 3.2% over this period. In the same year, the share of ECOWAS represented approximately 6.5% of worldwide yield. In Côte d'Ivoire pineapple ranks 2nd in terms of fruit yield after banana[3]. In 2007 with 59,000 t of fruit exported, the country ranked 1st among African exporters before Ghana (35,000 t) and Cameroon (9,300 t)[4]. In 2008, the pineapple from Côte d'Ivoire represented 1.2% of exports and generated nearly 34 billion as revenues[5]. It thus contributed by 1.6% to agricultural GDP and by 0.6% to national GDP[6]. A great number of smallholders (about a thousand) achieved about 70% of the Ivorian yield. On the other side, there were large industrial plantations that practiced mechanized cultivation and agronomic monitoring of plantations[3]. The main production areas were Eastern of Comoé river in the cities of Bassam, Bonoua, Adiaké and Aboisso where 80% of the pineapple was produced. The other producing cities were located in the Southeast of the country: Dabou, Tiassalé, Azaguie and Agboville[7].

However, the Ivorian exports consisting essentially of the Smooth Cayenne variety fell[8] from 57,546 t in 2009 to 37,089 t in 2011 despite the efforts of professional organizations in the industry to improve the quality and to face competition[9]. This drastic fall was due to the poor sales of pineapple variety Smooth Cayenne produced by Ivorian farmers following the launching on the international market of the fruits of MD2 or Extra Sweet variety[10], originating from South America, more appreciated by consumers due to its sweeter taste and its longer shelf life[11] at the expense of the Ivorian Smooth Cayenne. This led to the cessation of operations of most smallholders who turned to other crops that provide greater income.

To regain the lost market share, it is imperative for stakeholders in the Ivorian pineapple industry to adopt a varietal diversification policy that requires the mastery of MD2 cultivation in the local ecological conditions. Thus, for defining appropriate crop management techniques suitable for MD2 variety cultivation in Côte d'Ivoire, some trials have been set up in the old production areas of pineapple, especially in the cities of Bonoua, Dabou and Tiassalé.

In general, MD2 pineapple variety can be grown on soils with clay loam texture or loamy or sandy loam with pH between 4.5 and 6.5. An excellent preparation of these soils can help achieve a high level of productivity and quality of this pineapple variety[12]. The planting density to be adopted should reflect the size of fruits required for export of the crop and optimize the use of inputs with a view of having good economic profitability of the farm[13]. Also, high productivity of MD2 pineapple variety is only possible with densities[12] up to 70000 plants ha^{-1}.

In such a context, one wonders how MD2 pineapple variety can be produced in Côte d'Ivoire.

The objective of the study is to improve the yield of MD2 variety by cultivating the suckers in short rainy season, on various planting beds and densities in major pineapple producing areas located in Southern Côte d'Ivoire.

MATERIALS AND METHODS

Study areas: The trials were carried out in the cities of Bonoua (5°16'19" North latitude and 3°36'02" West longitude), Dabou (5°19'14" North latitude and 4°22'59" West longitude) and Tiassalé (5°53'53" North latitude and 4°49'41" West longitude) in Southern Côte d'Ivoire.

The climate in the city of Bonoua is hot and humid subequatorial[14]. The annual rainfall during the trials was 1674 mm. The soils are ferralitic, highly desaturated with sandy to sandy-clay textures[15].

The area of Dabou has quite similar characteristics to that of Bonoua. In contrast, the one of Tiassalé has a transitional equatorial climate[14] with an average annual temperature above 28°C[16]. During the experiment, the annual rainfall was 1166 mm. The ferralitic soils, more or less desaturated are sandy clay and silty[17].

The climate of the experiment sites is characterized by a long dry season (December-March), a long rainy season (April-June), a short dry season (July-August) and a short rainy season (September-November).

Materials

Plant material: The planting material consisted of first-generation suckers of MD2 pineapple, weighing between 400 and 500 g and taken from old plots located in the city of Bonoua.

Technical material: The technical equipment included tractors for plowing and ridging, tools such as machetes and hoes for weeding and SHOGUN-type backpack sprayers for fertilization, flower induction treatment, among others. Black polyethylene plastic films were used to cover ridges. A Globe Camry scales with pointer and a weighing range of 20 kg was used to weigh the fruits. The pesticides included herbicides (bromacil, 2 kg ha^{-1}), nematicide (cadusafos, 1 g seedling^{-1}), insecticide (chlorpyrifos-ethyl 480 g L^{-1}, 2 L ha^{-1}), fungicide (aluminum phosetyl, 7 kg ha^{-1}). The fertilizers applied to plants were urea (46% nitrogen), potash [standard potassium sulfate: Potassium oxide (K_2O) 50%, sulfur (S) 17%], the NPK/MgO [nitrogen (N) 11%, phosphate (P_2O_3) 5%, potassium oxide (K_2O) 27%, sulfur (S) 15%, magnesium oxide (MgO) 5%] and trace elements (boron 0.51 g L^{-1}, chelated copper EDTA 0.25 g L^{-1}, chelated iron EDTA 0.16 g L^{-1}, molybdenum 0.05 g L^{-1}, zinc 0.47 g L^{-1} of which chelated Zn EDTA 0.0065 g L^{-1}, chelated manganese EDTA 0.51 g L^{-1}). The recommended doses for major elements were met. Thus, 4-5 g of N plant^{-1} and 10-12.5 g of K plant^{-1} in the cycle were applied.

Methods: The experimental design was a split-split plot. Sucker planting was carried out on 06 October, 2011, in the short rainy season (psp). Over four factors studied, two were considered in the context of this study. Thus, planting bed and density were assessed for their effects on the gross yield.

The flat land (TP) and ridges covered (BAP) or non-covered (BSP) with polyethylene film, characterized the planting bed factor. The densities of 50000 and 70000 seedlings ha^{-1} (D50 and D70, respectively) are those that were subjected to experiment. On each elementary plot of 15$\times$10 m size, the suckers were planted in double rows. Total numbers of 26 and 30 seedlings with 0.3 and 0.2 m spacing between each have characterized D50 and D70, respectively. Thus in each city 1344 suckers were tested with three repetitions for a total of 4032 suckers.

Parameters assessed

Duration of cycle phases: The duration of the different crop cycles of the seedlings were determined. The duration of the vegetative phase was assessed (in months) from sucker planting to floral induction treatment (TIF), when D leaves of the seedling son the plot reached a mass statistically equal to 70 g. The one of flowering was appreciated (in days) from floral induction treatment to the date when the last plant has flowered.

The interval between the TIF and harvesting was also assessed, as well as the duration of cycle (in months) which was established by summing the duration of the vegetative phase and the TIF-harvest interval.

Estimated gross yield and fruit size: At harvesting, the fruits were weighed individually depending on planting beds and densities.

The yield was calculated by summing the masses obtained and then estimated respectively for 50000 and 70000 seedlings ha^{-1}, depending on planting bed and density.

According to their masses, the fruits were sorted in different sizes which were: D14 (0.6-0.9 kg), C12 (0.9-1.1 kg), B10 (1.1-1.3 kg), B9 (1.3-1.5 kg), A8 (1.5-2.1 kg) and A5 (2.1-2.4 kg).

Statistical analysis of data: The data obtained were processed using statistics 7.1 software. An analysis of variance was used to study the simple effects of planting bed and density factors. In case of significant difference, the Newman-Keuls multiple comparison test at 5% threshold was used to classify the averages in homogeneous groups.

RESULTS

Duration of crop cycle phases: In the three cities that housed the experiments, the duration of flowering, the period between floral induction treatment (TIF) and harvesting (fruiting phase) were identical and respectively equal to 45 days and 5 months in all seedlings (Table 1). Thus, the duration of the crop cycle which ranged from 12-15 months, depended on that of the vegetative growth phase. The latter was equal to 7 months Bonoua and Dabou, regardless of planting bed and density. However, in Tiassalé, it lasted 8 months for planting on BAP and BSP beds whatever the density and on TP only at D70. It spread over 10 months for seedlings planted on TP at D50 density. Consequently, the duration of MD2 pineapple crop cycle in Tiassalé ranged from 13-15 months, against 12 months in Bonoua and Dabou regardless of planting bed and density.

Average fruit weight and estimated gross yields: The average weight of harvested fruits did not vary significantly in Bonoua and Dabou, depending on planting beds. It was on average respectively equal to 1.51 and 1.56 kg (Fig. 1). In Tiassalé, planting beds significantly influenced the average weight which highest value was observed on BAP with 1.44 kg and lowest one on TP with 1.23 kg.

Compared to the density, the average fruit weight did not vary significantly in Bonoua and Tiassalé where the values fluctuated from 1.48 kg (D70) 1.54 kg (D50) and 1.32 kg (D50) to 1.36 kg (D70), respectively (Fig. 2). However, in Dabou, the average fruit weight was important especially as planting density was low. The values recorded were equal to 1.61 kg for the density of 50000 seedlings ha^{-1} and 1.51 kg for that of 70000 seedlings ha^{-1}.

Table 1: Duration of crop cycle phases of MD2 pineapple grown in short rainy season in the cities of Bonoua, Dabou and Tiassalé

Cities	Planting density	Planting bed	Vegetative phase (month)	Flowering (days)	TIF-harvesting (month)	Full cycle (month)
Bonoua	D70	BAP	7	45	5	12
		BSP	7	45	5	12
		TP	7	45	5	12
	D50	BAP	7	45	5	12
		BSP	7	45	5	12
		TP	7	45	5	12
Dabou	D70	BAP	7	45	5	12
		BSP	7	45	5	12
		TP	7	45	5	12
	D50	BAP	7	45	5	12
		BSP	7	45	5	12
		TP	7	45	5	12
Tiassalé	D70	BAP	8	45	5	13
		BSP	8	45	5	13
		TP	8	45	5	13
	D50	BAP	8	45	5	13
		BSP	8	45	5	13
		TP	10	45	5	15

TP: Flat land, BAP: Ridge covered with polyethylene film, BSP: Bare ridge, D50: Density 50,000 seedlings ha^{-1}, D70: density 70,000 seedlings ha^{-1}

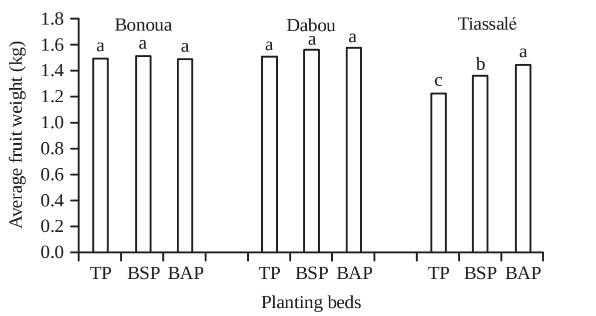

Fig. 1: Effects of planting bed on the average fruit weight of MD2 pineapple in the cities of Bonoua, Dabou and Tiassalé. Per city, the averages assigned with different letters on histograms are significantly different at 5% threshold (Newman-Keuls test), TP: Flat land, BAP: Ridge covered with polyethylene film, BSP: Bare ridge

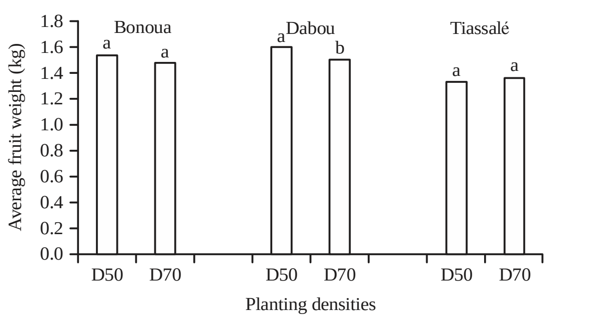

Fig. 2: Effects of planting density on the average fruit weight of MD2 pineapple in the cities of Bonoua, Dabou and Tiassalé. Per city, the averages assigned with different letters on histograms are significantly different at 5% threshold (Newman-Keuls test), D50: Density 50,000 seedlings ha^{-1}, D70: Density 70,000 seedlings ha^{-1}

Table 2: Effect of planting beds and densities combinations on the average fruit weight of MD2 pineapple in the cities of Bonoua, Dabou and Tiassalé

Planting beds and densities combinations	Average fruit weight (kg)		
	Bonoua	Dabou	Tiassalé
BAP/D50	1.51±0.04[a]	1.67±0.04[a]	1.46±0.02[a]
BAP/D70	1.48±0.04[a]	1.52±0.04[a]	1.45±0.02[a]
BSP/D50	1.56±0.04[a]	1.64±0.02[a]	1.40±0.05[ab]
BSP/D70	1.50±0.03[a]	1.51±0.03[a]	1.33±0.03[b]
TP/D50	1.55±0.04[a]	1.53±0.03[a]	1.15±0.03[b]
TP/D70	1.46±0.04[a]	1.50±0.04[a]	1.34±0.02[c]

Per city, the averages assigned with different letters in columns are significantly different at 5% threshold (Newman-Keuls test), TP: Flat land, BAP: Ridge covered with polyethylene film, BSP: Bare ridge, D50: Density 50,000 seedlings ha^{-1}, D70: Density 70,000 seedlings ha^{-1}

The differences between average fruit weight based on planting beds and densities combinations were not significant in the cities of Bonoua and Dabou. The values ranged from 1.46 kg (TP/70) and 1.56 kg (BSP/D50) in Bonoua and 1.50 kg (TP/D70) and 1.67 kg (BAP/D50) in Dabou (Table 2). However, in Tiassalé for the same parameter, they varied depending on planting beds and densities combinations. The highest values were recorded in seedlings stemming from treatments BAP/D50 (1.46 kg), while the lowest ones were recorded in those of treatments TP/D50 (1.15 kg). Overall, combinations integrating BAP beds induced the highest average fruit weights (Table 2).

The effect of planting beds on the estimated gross yield varied differently within each city and depending on it (Fig. 3). In Bonoua, the estimated gross yields were statistically identical regardless of the planting bed used, with values that fluctuated between 89.70 and 91.47 t ha^{-1}. However, in Dabou and Tiassalé, respectively, planting beds BSP and BAP led to the highest yields. In these cities, cultivation on TP led to the lowest yields with 90.77 t ha^{-1} in Dabou and 75.52 t ha^{-1} in Tiassalé.

With respect to density, all the plantations established at 70000 plants ha^{-1} led to higher yields compared to 50000 plants ha^{-1} (Fig. 4). The values recorded in Tiassalé were on average, 10-15% lower than in Bonoua and Dabou.

Regarding planting beds and densities combinations, the yields did not significantly vary in Bonoua where they fluctuated between 75.69 and 105.00 t ha^{-1} (Table 3), unlike Dabou and Tiassalé. In the latter cities and for all the combinations studied, the highest yields were recorded in treatments involving the density of 70000 seedlings ha^{-1} (Table 3).

Fruit size: The analysis of the results showed that at least 80% of the yield had a size greater than C12 in Bonoua and Dabou

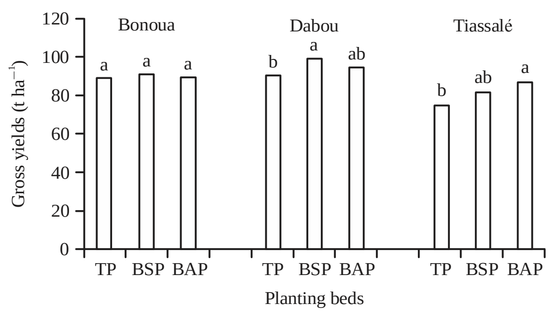

Fig. 3: Effects of planting beds on the gross yield of MD2 pineapple in the cities of Bonoua, Dabou and Tiassalé. Per city, the averages assigned with different letters on histograms are significantly different at 5% threshold (Newman-Keuls test), TP: Flat land, BAP: Ridge covered with polyethylene film, BSP: Bare ridge

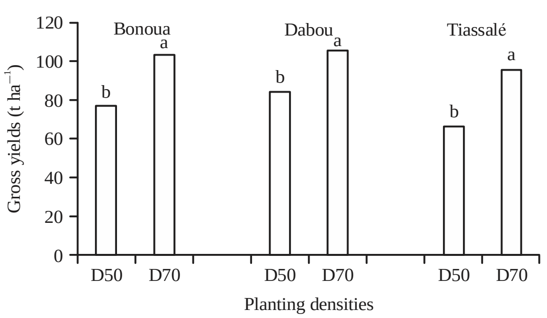

Fig. 4: Effects of plant density on the gross yield of MD2 pineapple in the cities of Bonoua, Dabou and Tiassalé. Per city, the averages assigned with different letters on histograms are significantly different at 5% threshold (Newman-Keuls test), D50: Density 50,000 seedlings ha^{-1}, D70: Density 70,000 seedlings ha^{-1}

regardless of planting bed (Table 4) and density (Table 5) and their combinations (Table 6). However, in Tiassalé, at least 25% of fruits had a size ranging between D14 and C12 considering the same factors studied, except the planting bed BAP (Table 4, 5) and the combinations involving it and the densities studied (Table 6).

Table 3: Effect of planting beds and densities combinations on the gross yield of MD2 pineapple in the cities of Bonoua, Dabou and Tiassalé

Planting beds and yields combinations	Gross yields (t ha^{-1}) Bonoua	Dabou	Tiassalé
BAP/D50	75.69±2.00^{a}	83.40±1.89^{c}	73.03±1.14^{c}
BAP/D70	103.80±2.46^{a}	106.07±2.66^{a}	101.56±1.74^{a}
BSP/D50	77.94±1.87^{a}	92.93±3.58^{b}	70.07±2.51^{c}
BSP/D70	105.00±2.22^{a}	105.63±2.30^{a}	93.04±2.00^{b}
TP/D50	77.34±1.87^{a}	76.39±1.53^{c}	57.46±1.27^{d}
TP/D70	102.06±3.06^{a}	105.15±2.88^{a}	93.59±1.67^{b}

Per city, the averages assigned with different letters in columns are significantly different at 5% threshold (Newman-Keuls test), TP: Flat land, BAP: Ridge covered with polyethylene film, BSP: Bare ridge, D50: Density 50,000 seedlings ha^{-1}, D70: Density 70,000 seedlings ha^{-1}

Table 4: Distribution (%) per size of MD2 pineapple fruits grown during the short rainy season depending on planting bed in the cities of Bonoua, Dabou and Tiassalé

Cities	Planting beds	Fruit size (%) D14	C12	B10	B9	A8	A6	A5
Bonoua	BAP	3.6	19.43	17.60	18.43	21.57	14.30	5.07
	BSP	3.6	14.39	18.08	18.29	23.23	15.17	7.24
	TP	4.74	18.01	18.33	20.38	19.71	13.78	5.05
Dabou	BAP	2.93	13.76	17.76	17.41	23.78	15.79	8.67
	BSP	0.97	10.54	21.98	21.20	21.40	18.38	5.53
	TP	2.3	16.95	16.68	19.71	22.06	15.89	6.41
Tiassalé	BAP	1.88	13.93	23.04	23.35	22.41	12.46	2.93
	BSP	6.21	24.15	18.52	21.69	16.38	10.08	2.46
	TP	6.70	30.57	23.73	19.07	13.68	5.39	0.87

TP: Flat land, BAP: Ridge covered with polyethylene film, BSP: Bare ridge, D14: 0.6-0.9 kg, C12: 0.9-1.1 kg, B10: 1.1-1.3 kg, B9: 1.3-1.5 kg, A8: 1.5-2.1 kg and A5: 2.1-2.4 kg

Table 5: Distribution (%) per size of MD2 pineapple fruits grown during the short rainy season depending on planting density in the cities of Bonoua, Dabou and Tiassalé

Cities	Planting density	Fruit size (%) D14	C12	B10	B9	A8	A6	A5
Bonoua	D50	3.13	14.68	17.70	18.26	21.99	16.36	7.90
	D70	4.02	18.84	17.94	18.44	22.68	13.41	4.67
Dabou	D50	0.86	11.70	16.09	18.91	25.15	18.31	8.97
	D70	3.44	15.96	19.64	19.89	21.05	14.50	5.33
Tiassalé	D50	3.72	21.58	21.86	20.56	18.79	10.98	2.51
	D70	5.42	22.32	21.55	22.39	17.61	8.73	1.97

D50: Density 50000 seedlings ha^{-1}, D70: density 70000 seedlings ha^{-1}, D14: 0.6-0.9 kg, C12: 0.9-1.1 kg, B10: 1.1-1.3 kg, B9: 1.3-1.5 kg, A8: 1.5-2.1 kg and A5: 2.1-2.4 kg

Table 6: Distribution (%) per size of MD2 pineapple fruits grown during the short rainy season depending on planting beds and densities combination in the cities of Bonoua, Dabou and Tiassalé

Cities	Planting beds and densities combination	Fruit size (%)						
		D14	C12	B10	B9	A8	A6	A5
Bonoua	BAP/D50	3.24	16.67	18.29	17.82	20.60	16.20	7.18
	BAP/D70	3.97	21.43	17.06	19.05	22.42	12.70	3.37
	BSP/D50	3.01	12.50	17.36	18.75	23.38	16.44	8.56
	BSP/D70	4.05	15.99	18.83	17.81	23.08	14.17	6.07
	TP/D50	3.68	14.48	16.32	21.84	20.00	17.93	5.75
	TP/D70	5.68	21.10	20.08	19.07	19.47	10.14	4.46
Dabou	BAP/D50	1.09	13.13	14.22	16.19	24.73	18.82	11.82
	BAP/D70	4.55	14.43	20.75	18.58	22.92	13.04	5.73
	BSP/D50	0.86	6.65	16.95	20.17	27.25	19.96	8.15
	BSP/D70	1.78	15.05	21.78	21.98	19.41	15.05	4.95
	TP/D50	0.63	15.03	17.12	20.25	23.38	16.49	7.10
	TP/D70	3.99	18.49	16.18	19.12	20.80	15.55	5.88
Tiassalé	BAP/D50	1.50	13.09	21.24	22.96	24.46	14.38	2.36
	BAP/D70	2.25	14.72	24.74	23.72	20.45	10.63	3.48
	BSP/D50	4.10	21.45	19.52	20.24	18.55	12.29	3.86
	BSP/D70	8.22	26.71	17.58	23.06	15.30	7.99	1.14
	TP/D50	8.25	42.27	28.35	15.46	5.67	0.00	0.00
	TP/D70	6.09	25.96	21.91	20.49	16.84	7.51	1.22

TP: Flat land, BAP: Ridge covered with polyethylene film, BSP: Bare ridge, D50: Density 50000 seedlings ha^{-1}, D70: Density 70000 seedlings ha^{-1}, D14: 0.6-0.9 kg, C12: 0.9-1.1 kg, B10: 1.1-1.3 kg, B9: 1.3-1.5 kg, A8: 1.5-2.1 kg and A5: 2.1-2.4 kg

DISCUSSION

The vegetative phase that lasted 7 months in Bonoua and Dabou was relatively short regardless of the planting bed and density. Thus, in these cities, the mass of fresh matter in the D leaf of seedlings (70 g) was reached 7 months after sucker cultivation commencement. This is required to achieve the floral induction treatment (TIF) which marks the end of the vegetative phase. The short duration of this phase could be explained by favorable pedoclimatic conditions of these cities. Indeed, the sandy to sandy clay nature of quite drained and airy soils favors the rapid growth of pineapple seedlings[17]. The regular and abundant rainfall in these areas also contributes[18].

In Tiassalé, the duration of the vegetative phase of seedlings was relatively long. The critical mass of D leaves was reached late compared to Bonoua and Dabou and especially in seedlings grown in TP/D50. These findings may be due to low and erratic rainfall (1166 mm) and a sandy clay and silty soil conducive to induration on the site of Tiassalé[19,20]. Thus, the favorable impact of ridges on soil loosening and drainage, as well as that of the polyethylene film on reducing its in duration and maintaining moisture[21], contributed to the rapid root and leaf growth of pineapple seedlings[17,22]. Moreover, for the high planting density (D70), the humidity maintained for a long time around pineapple plants would be beneficial to their growth[12].

Furthermore, contrary to the duration of the vegetative phase, the fruiting one was the same on all experimental sites. This finding corroborates that of Lebeau *et al.*[22]. For these researchers, except for situations where seasons are well differentiated, fruiting has a duration which varies slightly compared with the vegetative phase. The latter is long and strongly influenced by environmental conditions as well as the technical level of cropping practices.

In Bonoua, the lack of impact of planting beds on average fruit weight and yield is most likely due to the good sandy clay texture of the soil. This would not require significant preparation before sucker planting. In this such a pedological context, it seems unwise to increase the costs of production of pineapple plantations by establishing bare ridges or covered with polyethylene film. The latter case where plastic mulching would not be necessary, would greatly limit the risks of environmental pollution due to its use[23,24].

In Dabou as well as in Bonoua, the average fruit weight was not influenced by planting beds unlike the gross yield for which the best result was recorded in BSP and the lowest in TP. The beneficial effect of bare ridges was probably the increase of water infiltration area for the benefit of the plants whose growth was favored[17]. This has induced thus a good yield. On the covered ridges (BAP), an amount estimated at 35-50% of rainwater would flowover the polyethylene film and be lost to the detriment of plants[17].

In Tiassalé, planting beds have had an impact on the average fruit weight and yield. Thus, the BAP gave the most significant results, while the lowest were observed in TP. In this city where the pedoclimatic conditions are quite harsh, covered ridges, while reducing evaporation and increasing the soil temperature, contributed to root growth[25] and good plant development during the vegetative phase in dry season (December-March). The poor results recorded on flat ground could be explained not only by the low rainfall, but also by the induration of soil due to its texture.

Furthermore, on all the sites subjected to experiment, the flowering-fruiting phase which occurred in most cases during the rainy season (April-June), contributed to increase the mass and volume of fruits[22].

The effect of density on the average fruit weight was not significant in Bonoua and Tiassalé unlike Dabou. In this latter city, the values were relatively lower at the high density (D70), probably because of a bulking effect of leaves in plant growth.

This observation is not due to seedlings competition for water or mineral nutrition, since all the seedlings have individually received the same dose of fertilizer.

The yield values were higher at D70 than D50 on all the sites subjected to experiment, as also noted by Leon and Kellon[13]. This result is dependent on the relatively large number of fruit harvested at high density, but also the reflection of the size obtained. For the latter parameter, at least 75 and 80% of the yield had a size beyond C12, respectively in Tiassalé and Bonoua or Dabou, regardless of planting bed and density.

In Bonoua and Dabou, the effect of planting beds and densities combinations was not significant on the average fruit weight unlike in Tiassalé where the most significant values were induced by treatments integrating the ridges covered with polyethylene film. In the latter case, the effect of covered ridges was predominant. Indeed, Mangara *et al.*[26] and Tossou[27] reported that the presence of polyethylene film on the soil prevents the development of adventitious plants. Thus, pineapple seedlings are not subject to competition from adventitious plants for water and nutrients from the soil. This favors plant growth and a good yield over time.

No effect of planting beds and densities combinations was recorded on the gross yield in Bonoua, unlike the cities of Dabou and Tiassalé where the highest yield values were recorded in treatments involving high densities (D70). In the latter cities, it appears that the effect of high densities was decisive and favorable to the conservation of soil moisture[12]. This has led to an increase in the availability of water in the soil for seedlings, especially in the case of the city of Tiassalé where rainfall is low and temperatures are high.

CONCLUSION

The promising results obtained under these experimental trials are attributable to a good performance of plants during the vegetative growth phase in the dry period following the short rainy season planting, due to soil texture in Bonoua and Dabou or covered ridges in Tiassalé. A regular and abundant rainfall in Bonoua and Dabou during the flowering-fruiting phase of plants, has also contributed to that.

The development of MD2 pineapple plantations in short rainy season in Southern Côte d'Ivoire is very productive at the density of 70000 plants ha^{-1}. Concerning planting beds, the flat land can be recommended in Bonoua, bare ridge or possibly flat land in Dabou depending on the financial possibilities of the producer and ridge covered with polyethylene film in Tiassalé.

The adoption of these results by producers in the different pineapple producing cities could contribute to improving the MD2 pineapple cultivation in Côte d'Ivoire.

SIGNIFICANCE STATEMENTS

Following the introduction of MD2 pineapple variety in the international fruit trade, the share of Côte d'Ivoire, a long-time leader in the European market with the Smooth Cayenne variety has dropped drastically. In order to become once again leader in the international market, the stakeholders in the Ivorian pineapple industry have decided to practice varietal diversification that requires adaptation of MD2 cultivation to local ecological conditions. However, even if there is a crop management technique for the cultivation of Smooth Cayenne variety in Côte d'Ivoire, the Ivorian producers do not have the one of MD2 pineapple adapted to local ecological conditions. This study is a contribution to the development of crop management techniques for the production of MD2 pineapple variety in Côte d'Ivoire.

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