

# Strawberry (*Fragaria* spp.): Cultivation, Production, Consumption, and Marketing in Cameroon

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## Abstract

Strawberry (*Fragaria* spp.) is one of the most important fruits classified as exotic fruits imported into Cameroon. To have an inventory of its cultivation in Cameroon, a survey study was carried out among eight farms of *Fragaria* spp. from January 2021 to February 2022. The plant was introduced in Cameroon in 2018. There are 13 varieties of *Fragaria* spp. currently cultivated. Among these 13 varieties, eleven are hybrids of *Fragaria x ananassa* ("Amiga", "Amine", "Camarosa", "Chandler", "Charlotte", "Elsanta", "Gariguette", "Madame Moutot", "Ostara", "Ruby gem" and "San Andreas"), and two of the hybrids of *Fragaria vesca* ("Maestro" and "Mara des bois"). The cropping system, irrigation system, and type of fertilizers applied differ from one strawberry farm to another. Biofertilizers (such as mycorrhizal), inorganic

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and organic fertilizers are actually used to improve production. The potential annual production of strawberries from January 2021 to February 2022, estimated based on the survey data, was 21.216 tons for all growers. Among these eight production farms, the Lolodorf BIO Farm presents 6000 kg (six tons) of strawberries and 100,000 stolons (seedlings) produced, from seven varieties of *Fragaria* spp. cultivated, with 6 varieties which are hybrids variety *Fragaria x ananassa* (“Amiga”, “Amine”, “Chandler”, “Gariguettes”, “Madame Moutot”, and “Ruby gem”), and one which is a hybrid of *Fragaria vesca* (“Mara des bois”). Certain diseases were also observed and recorded depending on the growing areas.

## Keywords

*Fragaria* spp., Cultivation Technique, Attack of Pathogens, Annual Production, Cameroon

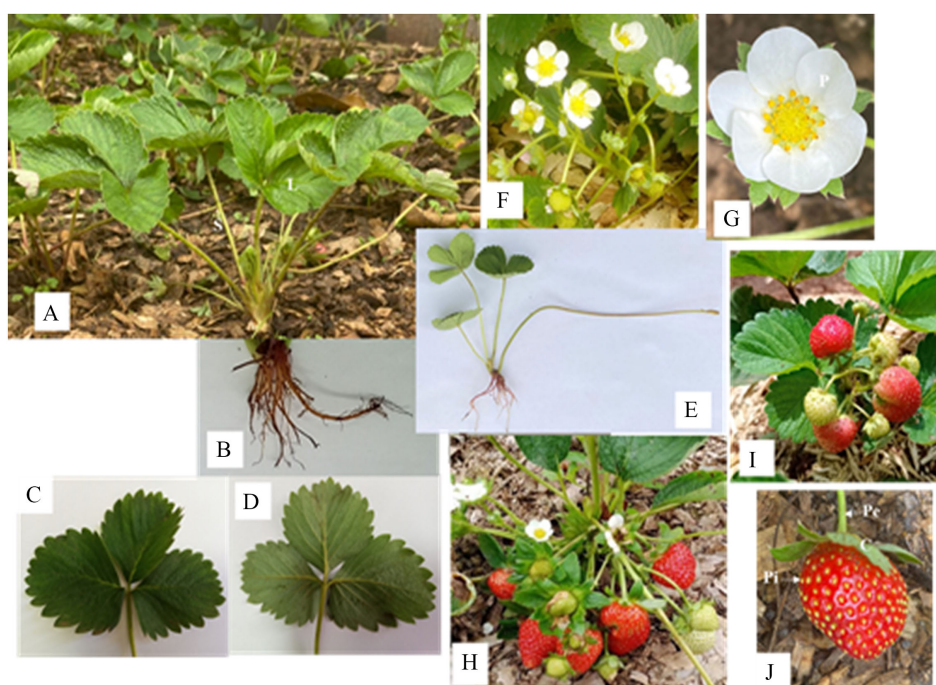
## 1. Introduction

The strawberry (*Fragaria x ananassa* var *duch*) is a red fruit plant of the Rosaceae family. The most common strawberry plant is the garden strawberry (*Fragaria x ananassa* Duch.), which is a hybrid of two wild octoploid species of American origin, *Fragaria virginiana* from the North American coast and *Fragaria chiloensis*, from the west coast of South America [1] [2] [3]. This perennial herbaceous plant, short in stature, fast-growing, and with a small genome, has a short reproductive cycle and easy vegetation [4] [5] [6] [7]. It is cultivated and appreciated for its fruit (or strawberry). During growth, strawberry plants form small tufts of leaves cut into three leaflets (Figure 1A) and attached to a thick stem, or rhizome (Figure 1B). The strawberry plant produces stolon (nets or runny) (Figure 1C and Figure D).

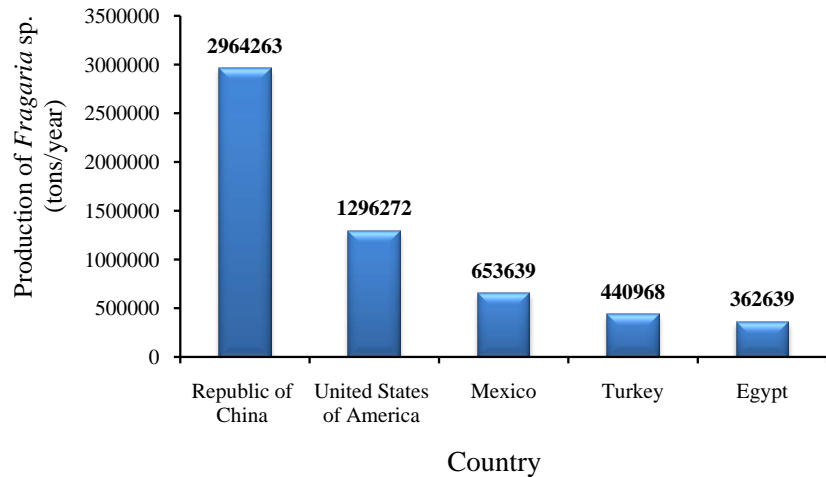
Its flowers are white (Figure 1E), and pollinated by the wind or bees. Its fruits (false fruit), red when ripe, come from the development of the flower receptacle (Figure 1F and Figure 1G). These fruits have many small hard seeds (achenes) on their outer surface (Figures 1H-J) [8]. These fruits are of various shapes (can be ovoid and oblong more or less rounded). Strawberry fruits are known to be nutritious, thanks to their many dietary and health benefits. They are appreciated for their characteristic aroma [9] and distinct taste [10]. They are widely consumed fresh or processed, combined with dairy and pastry products. They are the main sources of minerals and vitamins [11] [12]. They contain fat-soluble vitamins (A, E, K), but especially high in vitamin C (60 mg·100g<sup>-1</sup> of fresh fruit), vitamin B9 or folate (24 µg·100g<sup>-1</sup> of fresh fruit), and vitamin E. It is also a good source of iodine, magnesium, copper, iron, and phosphorus [13] [14]. They are also appreciated for being low in calories but rich in phenolic compounds (anthocyanins). According to Newerli-Guz [15] and Basu [16], they also have ellagitannins (ellagic acid), flaveola (quercetin), catechin, anthocyanins, and

kaempferol, which give them antioxidant, antidiabetic, antihypertensive, anti-hyperglycemic, carcinogenic and antihypertensive properties. Fruits are a source of bioactive compounds [17]. Ranking among the four fruits richest in antioxidant properties [12] [14] [17] [18], studies have shown that the consumption of strawberry fruits would contribute to the inhibition of liver cancer cells [18], the prevention of cardiovascular and neurological diseases, and even metabolic syndromes [10] [14] [19]. Clinically, Erlund *et al.* [20] have shown that the consumption of strawberries would contribute to the increase in lipoprotein, the drop in cholesterol, and postprandial glycemia (lipemia).

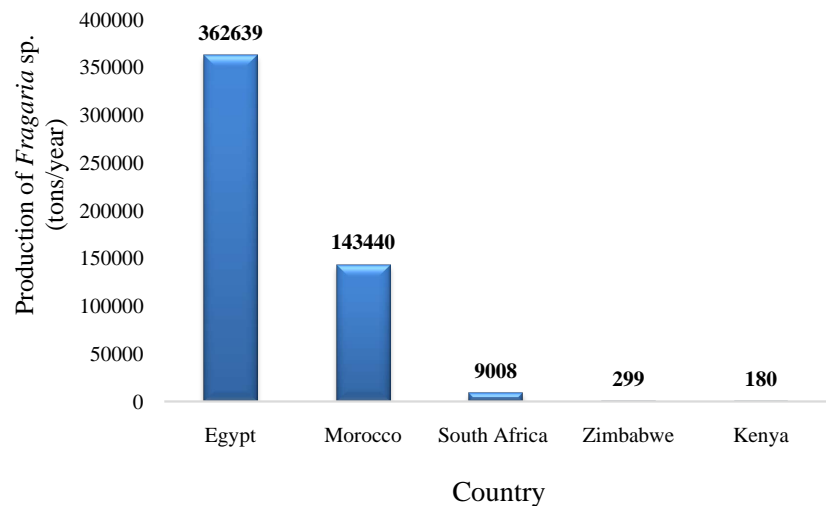
Nowadays strawberry cultivation is practiced on three of the five continents. The African, American, and Asian continents. The annual production of these strawberry fruits is increasing worldwide and varies significantly depending on the production area. According to FAOSTAT [21], the top five producing countries in the world are the People's Republic of China (2,964,263 tons), the United States of America (1,296,272 tons), Mexico (653,639 tons), Turkey (440,968 tons) and Egypt (362,639 tons) (Figure 2) (Atlas Big 2018-2021). However, on the African continent, Egypt, which occupies the 5th place in the world, is the first strawberry-producing country followed by Morocco (143,440 tons), South Africa (9008 tons), Zimbabwe (299 tons), and Kenya (180 tons) (Figure 3) (Atlas Big 2018-2021).



**Figure 1.** Morphology of *Fragaria* spp. plant. The aerial part of the plant (A), root system (B), trifoliate leaf (internal and external face) (C and D), daughter plant with runner stolon (E), the aggregate of flower (F), flower (G), the aggregate of fruit with unripe and ripe fruits (H and I) and fruit (J). Stem (s), Leaf (L), Petal (P), Calix (C), pits (seeds), and Pedicel (pe). Photos taken during the survey carried out from January 2021 to February 2022.



**Figure 2.** Top five strawberry producing countries in the world (Authors' compilation from Altas Big 2018-2021).



**Figure 3.** Top five strawberry producing countries in Africa (Authors' compilation from Altas Big 2018-2021).

It is recognized that the strawberry plant is classified among the exotic plants recently introduced and whose culture is still spreading more and more in Africa. Writings illustrate its introduction in Africa around the year 1956 in South Africa by Jan van Riebeeck, the first Governor of the Dutch settlement established in Cape Town [22]. Then its culture spread gradually in countries such as Morocco, Egypt, Kenya, Zimbabwe, and Algeria. Despite its richness in five agroecological zones [23] and its description of Africa in miniature [24], Cameroon is one of the countries where strawberry cultivation is still taking off [25]. Since its introduction by Mr. Rahaman BIDIMA, in 2018 in West Cameroon, precisely in Fombot (Noun Subdivision) [26], the interest given to this speculation by certain farmers has given rise to a certain number of questions in relation with the different varieties in country, fertilizers currently used by farmers

involved in the cultivation of this plant to improve their production, the different parasitic attacks that can influence the growth and even production of strawberry plants in different growing zones, ... It is with these in mind that the objective of this work was to carry out an inventory of strawberry cultivation among identified farmers carrying out large-scale production or not of fruits and seeds on the extent of the territory.

## 2. Material and Methods

### 2.1. Area of Study

The fields of the eight farmers, who cooperated in the investigation, were located in 4 regions in Cameroon. These eight farms were located in the Central region; African red gold (Obala) and agricultural Cérés (Elat Minkom and Yaoundé); Mbidjoro Sustainable Living Environment, based in Adamawa in the Northern region; the KAFFO farm (Baham), King Farms (Bafoussam), the Bafoussam farm (Bafoussam), Agro Ankh (Dschang), in the West region and the Lolodorf organic farm, in Lolodorf in the South of Cameroon. These four regions belong to three agroecological zones of Cameroon namely the Guinean high savannah zone in the North (Zone II) (with hydromorphic soil of pH 5.3 to 6.5, average annual temperature between 28°C - 30°C, a rainfall of 1500 mm/year for 150 rainy days, and an altitude between 1200 to 1800 m), the Western high plateaux zone (Zone III) (with very fertile soils, pH 5.3 to 6.5, the average annual temperature of 22.5°C, rainfall of 1500 - 2000 mm/year for 180 rainy days, and an average altitude of 1500 m), and the humid forest zone with bimodal rainfall (Zone V) (with ferralitic, acidic, clayey soils, with low nutrient retention capacity, pH 4.5 to 5.5, the average annual temperature of 23°C, rainfall of 1500 - 2000 mm/year for two distinct wet seasons, and an average altitude of between 500 - 1000 m). These agroecological zones are characterized by different factors such as climate, soil types, altitude, rainfall, etc.

### 2.2. Survey Carried Out on the Cultivation of *Fragaria* spp.

A survey study was carried out among eight farmers of *Fragaria* spp. in Cameroon from January 2021 to February 2022. The study was realized using a questionnaire, making it possible to highlight important information on strawberry cultivation such as existing varieties, cultivated, and their origin. For each variety of *Fragaria* spp., parameters like fruit color, fruit shape, productivity of plants at early or mature age, and everbearing or non-everbearing appearance of strawberry plants after fruiting were evaluated in the eight farms visited. 10 to 20 fruits were picked and then brought to the laboratory for evaluation of the range of fruit weight and the taste of these fruits. In each farm visited, the investigation was also focused on cultural practices applied, the type of fertilizers used, different diseases observed in leaves and fruits in the field, pest attacks, and pollinators, different anomalies encountered in farms in flowers and fruits, the total cultivated areas, and the annual production. In addition, the investigation also

visualized marketing that is currently done around the cultivation of the strawberry.

### 2.3. Data Analysis

The results obtained from this survey were presented, in the form of images, tables, and graphs. The software Microsoft Excel 2016 has been used to trace graphics.

## 3. Results

### 3.1. Variety of *Fragaria* spp. Currently Cultivated in Cameroon

The results of the survey carried out among eight farmers show that in Cameroon, 13 varieties of *Fragaria* spp. are currently cultivated (Table 1). Among these 13 varieties, eleven are hybrids of *Fragaria x ananassa* (“Amiga”, “Amine”, “Camarosa”, “Chandler”, “Charlotte”, “Elsanta”, “Gariguette”, “Madame Moutot”, “Ostara”, “Ruby gem” and “San Andreas”), and two of the hybrids of *Fragaria vesca* (“Maestro” and “Mara des bois”) (Table 1).

**Table 1.** Different varieties of *Fragaria* spp. introduced and cultivated in Cameroon.

Species	Varieties	Chromosome complement	Common Name
<i>Fragaria x ananassa</i>	<i>Fragaria x ananassa</i> “Amiga”	Octoploid hybrid	“Amiga”
<i>Fragaria x ananassa</i>	<i>Fragaria x ananassa</i> “Amine”	Octoploid hybrid	“Amine”
<i>Fragaria x ananassa</i>	<i>Fragaria x ananassa</i> “Camarosa”	Octoploid hybrid	“Camarosa”
<i>Fragaria x ananassa</i>	<i>Fragaria ananassa</i> “Chandler”	Octoploid hybrid	“Chandler”
<i>Fragaria x ananassa</i>	<i>Fragaria x ananassa</i> “Charlotte”	Octoploid hybrid	“Charlotte”
<i>Fragaria x ananassa</i>	<i>Fragaria x ananassa</i> “Elsanta”	Octoploid hybrid	“Elsanta”
<i>Fragaria x ananassa</i>	<i>Fragaria x ananassa</i> “Gariguette”	Octoploid hybrid	“Gariguette”
<i>Fragaria x ananassa</i>	<i>Fragaria x ananassa</i> “Mme Moutot”	Octoploid hybrid	“Madame Moutot”
<i>Fragaria x ananassa</i>	<i>Fragaria x ananassa</i> “Ostara”	Octoploid hybrid	“Ostara”
<i>Fragaria x ananassa</i>	<i>Fragaria x ananassa</i> “Ruby gem”	Octoploid hybrid	“Ruby gem”
<i>Fragaria x ananassa</i>	<i>Fragaria x ananassa</i> “San Andreas”	Octoploid hybrid	“San Andreas”
<i>Fragaria vesca</i>	<i>Fragaria vesca</i> “Maestro”	Diploid	“Maestro”
<i>Fragaria vesca</i>	<i>Fragaria vesca</i> “Mara des Bois”	Diploid	“Mara des Bois”

Data obtained during the survey carried out from January 2021 to February 2022.



The eight farmers we met do not grow the same varieties. The cultivated varieties come from different origins (Table 2). It should be noted that in West Cameroon, King and KAFFO Farms, are currently the major suppliers of Maestro variety seed plants. At the BIO Farm of Lolodorf in the South, the production is concentrated on two varieties, *Fragaria x ananassa* “Ruby Gem”, and *Fragaria x ananassa* “Mara des Bois”. In the Center region, Cérés Agricole is recognized in the sale of grain seeds and seedlings of *Fragaria x ananassa* “Madame Moutot” and *Fragaria x ananassa* “Ruby Gem”. All farmers cultivate the varieties of the two strawberry hybrids (*Fragaria x ananassa* and *Fragaria vesca*) introduced in Cameroon, with the exception of the Red Gold of Africa which only cultivates the varieties of *Fragaria vesca* (Table 2).

**Table 2.** Different varieties cultivated in Cameroon and their origins

Farms	Varieties	Origin	
KAFFO Farm	<i>Fragaria x ananassa</i> “Ruby gem”	Dschang (Cameroon) Bafoussam (Cameroon) Pologne France Sénégal	
	<i>Fragaria vesca</i> “Maestro”		
	<i>Fragaria vesca</i> “Mara des Bois”		
	<i>Fragaria x ananassa</i> “Camarosa”		
	<i>Fragaria x ananassa</i> “Charlotte”		
	<i>Fragaria x ananassa</i> “Ostara”		
	<i>Fragaria x ananassa</i> “San Andreas”		
Agro Ankh	<i>Fragaria x ananassa</i> “Elsanta”	Baham (Cameroon)	
Cérés Agricole	<i>Fragaria x ananassa</i> “Charlotte”		
	<i>Fragaria x ananassa</i> “Madame Moutot”	BIO farm of Lolodorf (Cameroon)	
	<i>Fragaria x ananassa</i> “Ruby Gem”		
	<i>Fragaria x ananassa</i> “Ruby Gem”		
<i>Fragaria vesca</i> “Mara des Bois”			
BIO farm of Lolodorf	<i>Fragaria x ananassa</i> “Gariguette”	Senegal	
	<i>Fragaria x ananassa</i> “Madame Moutot”	Burkina Faso	
	<i>Fragaria x ananassa</i> “Chandler”	Kenya	
	<i>Fragaria x ananassa</i> “Amine”	Morocco	
	<i>Fragaria x ananassa</i> “Amiga”		
Mbidjoro Sustainable Living Environment	<i>Fragaria vesca</i> “Maestro”	Europe	
Bafoussam Farm	<i>Fragaria x ananassa</i> “Madame Moutot”	Ouest (Cameroon)	
	<i>Fragaria x ananassa</i> “Ruby Gem”		
King Farms	<i>Fragaria x ananassa</i> “Madame Moutot”	BIO farm of Lolodorf (Cameroon)	
	<i>Fragaria x ananassa</i> “Charlotte”		
	<i>Fragaria vesca</i> “Maestro”		France
	<i>Fragaria x ananassa</i> “Ruby Gem”		
Red Gold of Africa	<i>Fragaria vesca</i> “Mara des Bois”	Ouest (Cameroon)	
	<i>Fragaria vesca</i> “Maestro”		
	<i>Fragaria vesca</i> “Mara des Bois”		

Data obtained during the survey carried out from January 2021 to February 2022.

These different varieties grown in Cameroon have different morphological characteristics. Among them, we can distinguish early, everbearing, and non everbearing varieties (Table 3). All fruits produced are red in color which varies between blood red, vermilion red, light red, and dark red, depending on the variety. The majority of fruits produced have an ovoid shape. *Fragaria x ananassa* “Camarosa” plants grown at KAFFO Farm are very early and productive. This variety appears non-everbearing like *Fragaria x ananassa* “Madame Moutot” (grown at Cérés Agricole, BIO farm of Lolodorf, Mbidjoro Sustainable Living Environment, and King Farms) and *Fragaria x ananassa* “Gariguette” (grown only at BIO farm of Lolodorf now in Cameroon) (Table 3).

**Table 3.** Morphological description of *Fragaria x ananassa* and *Fragaria vesca* varieties identified in Cameroon.

Varieties of <i>Fragaria</i>	Taste of fruit	Weight of the fruit (g)	Color of the fruit	Form of fruit	Plant maturity	Remarks
<i>Fragaria ananassa</i> <b>Amiga</b>	Half sweet, half sour and juicy	15 - 30	Red	High fruit firmness with long fruit shape	Vigorous plant high production	Everbearing variety
<i>Fragaria ananassa</i> <b>Amine</b>	Half sweet, half sour and juicy	15 - 30	Red	Oblong ovoid	Medium and productive	Everbearing variety
<i>Fragaria ananassa</i> <b>Camarosa</b>	Sweet and juicy	15 - 30	Dark red	Oblong ovoid	Very early and productive	Non everbearing variety
<i>Fragaria x ananassa</i> <b>Chandler</b>	Sweet, juicy, and spicy	15 - 50	Dark red	Conical	Everbearing variety	Everbearing variety
<i>Fragaria x ananassa</i> <b>Charlotte</b>	Half sweet, half sour, and juicy	15 - 50	Blood red	cordiform	Vigorous, hardy and productive	Everbearing variety
<i>Fragaria x ananassa</i> <b>Elsanta</b>	Sweetened with raspberry flavor	20 - 30	Red	Oblong ovoid more or less rounded	Early and productive	Everbearing variety
<i>Fragaria x ananassa</i> <b>Gariguette</b>	Sweet, and juicy	10 - 25	Vermilion red/Light red	Ovoid	Medium and productive	Non everbearing variety
<i>Fragaria x ananassa</i> <b>Madame Moutot</b>	Half sweet, half sour, and juicy	20 - 70	Dark red	Rounded	Medium and productive	Non everbearing variety
<i>Fragaria x ananassa</i> <b>Ostara</b>	Sweet and juicy	30 - 50	Dark red	Oblong ovoid more or less rounded	Medium and productive	Everbearing variety
<i>Fragaria x ananassa</i> <b>Ruby gem</b>	Half sweet, half sour, and juicy	30 - 50	Dark red	Ovoid	Early and productive	Everbearing variety
<i>Fragaria x ananassa</i> <b>San Andreas</b>	Sweet and juicy	30 - 50	Light red	Oblong ovoid more or less rounded	Early and very productive Disease resistant	Everbearing variety
<i>Fragaria vesca</i> <b>Maestro</b>	Sweet, and juicy	15 - 30	Dark red	Oblong ovoid more or less rounded	Early and productive	Everbearing variety
<i>Fragaria vesca</i> <b>Mara des Bois</b>	Sweet, and juicy	15 - 30	Light red	Oblong ovoid	Normal and productive	Everbearing variety

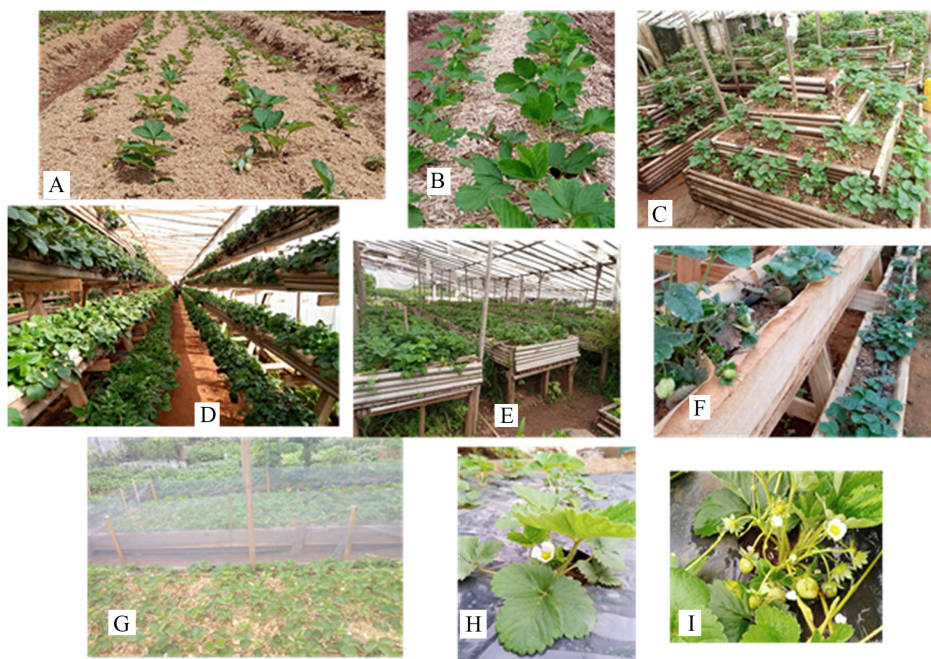
Data obtained during the survey carried out from January 2021 to February 2022.



### 3.2. Cultivation System and Types of Fertilizers Used

In all the strawberry farms visited the results of the survey show that the cultivation of this plant was done in monoculture in varying areas between 200 and 20,000 m<sup>2</sup>. Farmers either cultivate directly in the field (in the majority of strawberry plants) (**Figure 4A**) and/or in propagators built using planks or bamboo (**Figure 4B**) (case of Cérés Agricole, King Farms, Bafoussam Farm, KAFFO Farm, and Agro Ankh), with the exception of KAFFO Farm, where cultivation is done above ground in a shade house (**Figures 4C-E**). The runners produced are considered seedlings, and before transferring them to the fields, these runner plants were grown for 2 to 4 weeks in the nursery. However, the strawberry growers of the KAFFO Farm and the Bafoussam Farm practice direct sowing of runners in the field directly after weaning. Crop irrigation by strawberry growers varies from one strawberry plantation to another, with frequencies ranging from once a day (KAFFO Farm, Cérés Agricole, King Farms, Bafoussam Farm, and Red Gold of Africa), to twice a day (BIO farm of Lolodorf then every three days (Agro Ankh) and 3 times a week (Mbidjoro Sustainable Living Environment).

In most strawberry farms, plants are irrigated with watering cans, except at the KAFFO farm, where the farmer has set up a drip irrigation system (**Figure 4F**). For open-field cultivation, strawberry growers mulch the plants with wood



**Figure 4.** Strawberry cultivation device used by strawberry growers. Cultivation of strawberry plants directly in the field and mulch of the strawberry plants with wood shavings (Cérés Agricole, Mbidjoro Sustainable Living Environment, and Bafoussam Farm) (A, B, and G), cultivation in different forms of propagator (Cérés Agricole, King Farms, Bafoussam Farm, KAFFO Farm, and Agro Ankh) (C, D, E, F, and G), and plasticulture farming system (BIO farm of Lolodorf and Red Gold of Africa (H and I). *Data obtained during the survey carried out from January 2021 to February 2022.*

shavings (preferably white shavings) (Cérès Agricole, Mbidjoro Sustainable Living Environment, and Bafoussam Farm) (Figure 4A and Figure 4B), or realize plasticulture farming (BIO farm of Lolodorf and Red Gold of Africa) (Figure 4H and Figure 4I). The cultivation of the plants is done from January 2021 to February 2022 in all the strawberry fields. However, the periods of the maximum harvest of fruits in the eight farms visited vary between July and December. The cropping systems and fertilization of strawberry plants applied vary according to the grower's (Table 4). From the survey carried out, it appears that the strawberry farmers fertilize with biofertilizer, inorganic, and organic fertilizers Table 4. The applications of inorganic fertilizers were recorded in KAFFO Farm, King Farms, Bafoussam Farm, and Red Gold of Africa (Table 4). As for the organic and mineral fertilizers used, they are of various nature. Mycorrhizae applications are made only in KAFFO Farm. It should be noted that these fertilizers are applied, either before or after sowing.

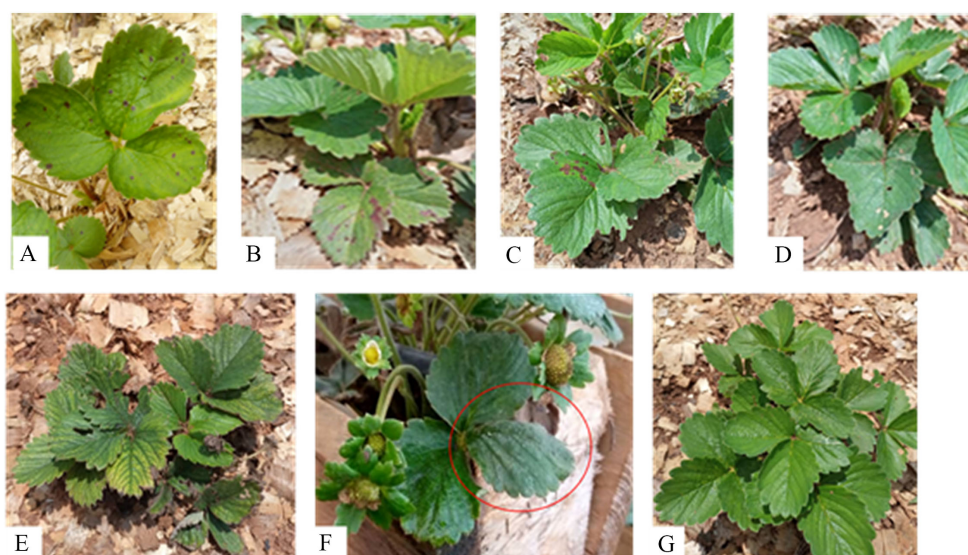
**Table 4.** Type of fertilization and examples of some fertilizers actually used in strawberry farm in Cameroon.

Farms	Types of fertilizers	Fertilizers	Application
Cérès Agricole	Organic	EM Compost	During sowing and every month after sowing
Red Gold of Africa	Organic	-	Before sowing
	Chemical	-	
Mbidjoro Sustainable Living Environment	Organic	EM Compost Chicken manure	After sowing
BIO Farm of Lolodorf	Organic microorganism	Bio-fertilizers	
Agro Ankh	Organic	Compost	Before sowing
		Chicken manure	
		<i>Tithonia diversifolia</i> leaf extract	
		Rabbit Urine	
Bafoussam Farm	Organic	Cow dung	Before sowing
		Chicken manure	
	Beef bone powder		
KAFFO Farm	Chemical	Chemical fertilizer (Urea)	After sowing
	Chemical	Chemical fertilizer "Super charge"	
	Organic	Chemical fertilizer "Super GRO"	
	Chemical	Chemical fertilizer "Super GRO"	
King Farms	Organic	Chemical fertilizer "le di Gro"	After sowing, for organic fertilizers, each two weeks
		Chicken manure	
	Purin, Animal Urine		
	Microorganism	Mycorrhiza	

Data obtained during the survey carried out from January 2021 to February 2022.

### 3.3. Diseases Identified in Strawberries in the Field

The strawberry plant, like all plants cultivated in Cameroon, also suffers from attacks by pathogens and pests. Despite the fact that this introduced plant has adapted easily, we note that the disease symptoms observed during the surveys, at the level of the leaves and fruits of the plant are not identical to all the production farms. These attacks mark the presence of bacterial, viral, and fungal pathogens (Figures 5-7) (Table 5). On the leaves, black spots (Figure 5A and Figure 5G), purple spots (Figure 5B), and common leaf spots (Figure 5C) were observed in almost all the farms (Table 5). White leaf spots (Figure 5D) (Cérès Agricole, Red Gold of Africa, Mbidjoro Sustainable Living Environment, and KAFFO Farm); leaf yellowing (Figure 5E) (Cérès Agricole, Red Gold of Africa, BIO Farm of Lolodorf, and Bafoussam Farm), and whitish down on the upper and lower leaf surfaces (Figure 6F) (KAFFO Farm) were also recorded. Melinda [27], Baroncelli [28], Abd-El-Kareem [29], and Mykhailenko [30] attribute these black spot symptoms to anthracnose caused by *Colletotricum acutatum* or *Colletotricum gloeosporioides*, or *Cercospora fragariae*, and purple blight caused by *Diplocarpon earlianum*, while the common leaf spots are caused by *Mycosphaerella fragariae*. On the other hand, white leaf spots are thought to be the result of *Ramularia grevilleana* attacks [29] [30]. However, the plant yellowing observed (Figure 5D), could be characteristic of iron chlorosis or the result of prolonged drought. The whitish down observed here characterizes attacks by *Podosphaera aphanis*, causing powdery mildew.



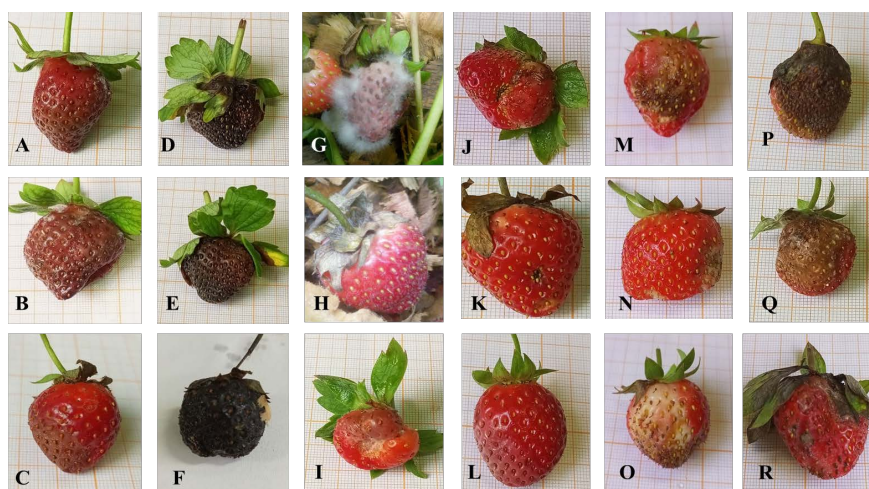
**Figure 5.** Expression of the disease on the leaves of *Fragaria* sp. in the different farms visited. Black spots (A), purple spots (B), and common leaf spots (C), were observed on leaves in all the field, White leaf spots (D) in Cérès Agricole, Red Gold of Africa, Mbidjoro Sustainable Living Environment, and KAFFO Farm; leaf yellowing (E) in Cérès Agricole, Red Gold of Africa, BIO Farm of Lolodorf, and Bafoussam Farm. Data obtained during the survey carried out from January 2021 to February 2022.

**Table 5.** Diseases observed during strawberry cultivation in Cameroon from January 2021 to February 2022.

FARMS	Type of diseases	Disease observed in leaf	Disease observed in fruit	Treatments
<b>KAFFO Farm</b>	Fungal disease	- Black spots on leaves;	- Strawberry fruit rot with a cooking appearance	HM 10 45 10; HM 5 5 45 Potassium Sulfate
		- Purple spots on the leaves;	- Grey rot of strawberry fruit	
		- White spots on the leaves	- Collar rot of plants - Necrosis on the fruit	
<b>Cérés Agricole</b>	Fungal disease	- Black spots on leaves;	- Strawberry fruit rot with a cooking appearance	EM 5 Herbagreen, EMA
		- Purple spots on the leaves;	- Grey rot of strawberry fruit	
		- Common leaf spots	- Collar rot of plants	
		- White spots on the leaves	- White streaks on strawberry fruit	
<b>Agro Ankh</b>	Fungal and viral diseases	- Yellowing of the leaves	- Necrosis on the fruit	<i>Tithonia</i> leaf extract, cooking ash and rabbit urine
		- Black spots on leaves;	- Strawberry fruit rot with a cooking appearance	
		- Purple spots on the leaves;	- Grey rot of strawberry fruit	
		- Common leaf spots	- Collar rot of plants	
<b>Mbidjoro Sustainable Living Environment</b>	Fungal disease	- Leaf wilting	- White streaks on strawberry fruit	Biopesticides
		- White spots on the leaves	- Necrosis on the fruit	
		- Black spots on leaves;	- Strawberry fruit rot with a cooking appearance	
		- Purple spots on the leaves;	- Grey rot of strawberry fruit	
<b>BIO Farm of Lolodorf</b>	Fungal disease	- Common leaf spots	- Collar rot of plants	Bokachi, fern manure, Herbagreen
		- White spots on the leaves	- White streaks on strawberry fruit	
		- Black spots on leaves;	- Strawberry fruit rot with a cooking appearance	
		- Purple spots on the leaves;	- Grey rot of strawberry fruit	
<b>Bafoussam Farm</b>	Fungal and Viral diseases	- Common leaf spots;	- Collar rot of plants	Garlic extract (macerated garlic + water) and Neem
		- Yellowing of the leaves;	- White streaks on strawberry fruit	
		- Black spots on leaves;	- Strawberry fruit rot with a cooking appearance	
		- Purple spots on the leaves;	- Grey rot of strawberry fruit	
<b>King Farms</b>	Fungal disease	- Leaf wilting;	- Collar rot of plants	EM 5 EMA LES Purin
		- White spots on the leaves;	- White streaks on strawberry fruit	
		- Yellowing of the leaves;	- Necrosis on the fruit	
		- Black spots on leaves;	- Strawberry fruit rot with a cooking appearance	
<b>Red Gold of Africa</b>	Fungal disease	- Purple spots on the leaves;	- Grey rot of strawberry fruit	Pesticide
		- Leaf wilting;	- Collar rot of plants	
		- White spots on the leaves;	- White streaks on strawberry fruit	
		- Yellowing of the leaves;	- Necrosis on the fruit	

Data obtained during the survey carried out from January 2021 to February 2022.





**Figure 6.** Disease expression on *Fragaria* sp. fruits in the different farms visited. Strawberry fruit rot (A, B, C, d, E, and F), strawberry powdery mildew (G, H, and I), Necrosis (J, and K), Pink soft rot (L), White patches (M, N, and O), brown-coloured soft (P, and Q), and grey mould (R). Data obtained during the survey carried out from January 2021 to February 2022.



**Figure 7.** Expression of rot symptoms in *Fragaria x ananassa* and *Fragaria vesca*. Stem rot (A), pedicel rot (B) and fruit rot (C). Data obtained during the survey carried out from January 2021 to February 2022.

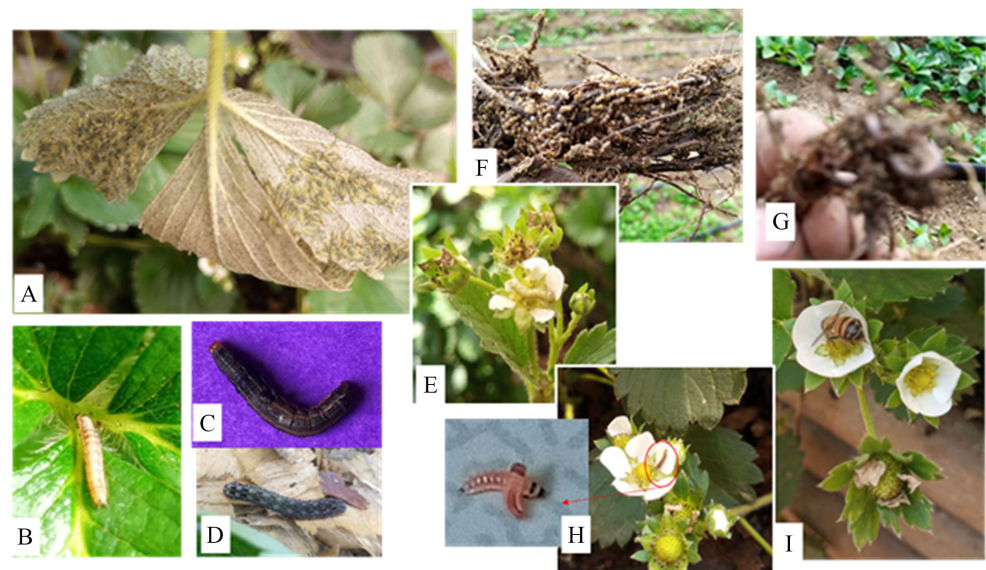
Several pathogen-related attacks result in the progressive destruction of the fruit. This is the case for strawberry fruit rot, presenting a soft, watery appearance with a baked appearance (Figures 6A-C). Michelle and Natalia [31] attribute this symptom to attacks by *Phytophthora cactorum* responsible for brown heart disease. This baked appearance of the fruit turns black until the fruit dies (Figures 6D-F). This symptom was visible in almost all the strawberry farms visited. The appearance of whitish fuzz on the kernels and on the fruit observed in Cérés Agricole, BIO Farm of Lolodorf, Mbidjoro Sustainable Living Environment, and KAFFO Farm (Figures 6G-I) is characteristic of the presence of strawberry powdery mildew, caused by *Podosphaera aphanis* [30]. Necrosis, which allows highlighting, the presence of *Colletotrichum fragariae* responsible for the anthracnose of strawberries (Figure 6J and Figure 6K) (KAFFO Farm, Cérés Agricole, Agro Ankh, Bafoussam Farm, and King Farms). Pink soft rot recorded on strawberry fruit (Figure 6L), was also present in all farms. White patches which later become gray-coloured soft rots (Figures 6M-O), brown-coloured

soft rots that tend to harden (Figure 6P, and Figure 6Q), and grey mould (Figure 6R) were also observed on strawberry fruit. These fruit attacks were recorded in all strawberry crop farms. The varieties of *Fragaria x ananassa* (“Madame Moutot”, “Charlotte”, “Elsanta”, “Ruby gem”, “Ostara”, and “San Andreas”) and *Fragaria vesca* (“Maestro” and “Mara des bois”), have presented the crown rot in some plants (Figure 7). Abd-El-Kareem [29], and Mykhailenko [30], attributed this symptom of crown rot to *Phytophthora fragariae* attacks.

In Cameroon, among the thirteen varieties of cultivated strawberry, the most disease resistant strawberry variety is the *Fragaria x ananassa* “Charlotte”. The phytosanitary approach in response to the different symptoms related to pathogens identified in the eight strawberry farms is either by chemical or biological application (Table 5). The KAFFO farm, the Cérés Agricole, the Mbidjoro sustainable living environment, and Red Gold of Africa fight against these pathogen attacks by applying more chemical phytosanitary products as present in Table 5.

### 3.4. Pest Attacks and Pollinator

In the eight strawberry farms visited, strawberries are cultivated and produced throughout the year. Apart from the damage caused by fungal, bacterial, and viral pathogens, it is worth noting that other losses are the result of pest attacks (Figure 8). In strawberry farms visited the presence of strawberry whitefly larvae in clusters on the underside of the leaves was noted in Agro Ankh (Figure 8A). They live in colonies under the leaves of the plants. To feed, they suck the sap and cause the plant to weaken. During their growth cycle, they attack strawberry flowers (Figure 8B) and feed voraciously on the leaves in their larval growth



**Figure 8.** Damage observed in *Fragaria* sp. plant in the field. Aspects of pest attacks (A, B, C, D, E, F, G, and H) in leaves and roots of *Fragaria* sp., and pollinators (I) identified in the strawberry fields during the surveys. Data obtained during the survey carried out from January 2021 to February 2022.



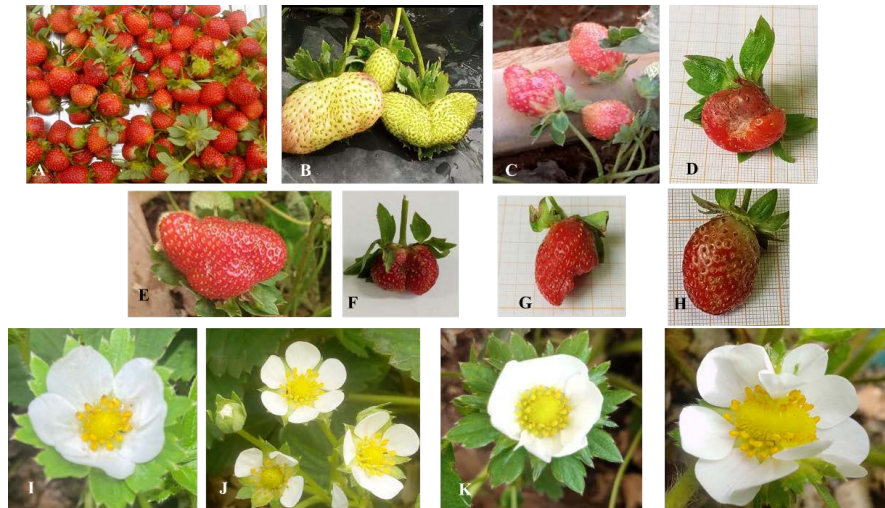
stage (**Figures 8C-E**). In addition, termite attacks are recorded in the root system in BIO Farm of Lolodorf. All plants with termites in the root system had a poor root system with fresh roots and absorbent hairs. Almost all the roots present were dry (**Figure 8F**). This totally dried-out root system would be the cause of the poor hydromineral nutrition of the plant. In some propagators in BIO Farm of Lolodorf and Cérés Agricole, myriapods escaped into the root system (**Figure 8G**). It has also been noted the attacks of trips on the flowers in Cérés Agricole, Mbidjoro Sustainable Living Environment, Red Gold of Africa, and Bafoussam Farm (**Figure 8H**).

Thrips are classified among the most important pests of Strawberries [32] [33]. At the level of the different crops, the damage caused by their attack is so far evaluated on the quality of the harvested fruits. The evaluation of damage caused by these thrips on the total production was not evaluated during the survey. Slugs were also found in some propagators. The bee was the most common pollinator found in strawberry flowers in all the farms in the morning and evening (**Figure 8I**).

### 3.5. Malformations Observed in Strawberry Fruits and Flowers during Cultivation

Apart from the attacks of pathogens and pests recorded, damage responsible for the loss of production has also been observed. This damage of non-pathogenic origin was identified in almost all strawberry farms (**Figure 9**). Unlike normal fruits (**Figure 9A**), fruit malformations were recorded. Some fruits, of irregular color (**Figure 9B**), presented a flattened heart shape, presenting a median groove. According to Sharma [34], this symptom is that of strawberry fruit albinism, caused by high levels of nitrogen in the soil.

Similarly, poorly developed or deformed fruits have been observed, presenting a clover-shaped (**Figure 9C**), cherry-shaped (**Figure 9D**), or having four lobes (**Figure 9E**) appearance. These different malformations can be the result of the insufficient pollination, the reduction of the development of stamens affected by temperatures that are not cold enough [35] [36] the presence of a low density of pollinators such as bees in the field [37], the exposure of plants to variations between high and low temperatures [38], and also the presence of heavy rain [39]. Moreover, in the various sites visited and belonging to the three agroecological zones of Cameroon where strawberry cultivation is currently done, the variations in temperature and rainfall are totally different. Furthermore, Saeid [40] and Osvalde [41], also attribute the appearance of these malformations to the quality of hydromineral nutrition. However, good mineral nutrition in plants depends on several factors such as the pH of the soil, the physicochemical characteristics of the soil, the practices of fertilization, the type of fertilizer applied, the climate, etc. [42] [43] [44]. In addition, other causes of production loss such as rodent attacks (**Figure 9F** and **Figure 9G**) and trips (**Figure 9H**), were observed in all strawberry-growing farms. The results of the survey revealed that the strawberry variety “Charlotte” grown in the KAFFO farm site also presented



**Figure 9.** Different types of deformation observed in *Fragaria* sp. fruits, in the different strawberry farms. Normal fruits at harvest present in all the farms (A), flattened heart-shaped fruits with furrows (B), clover-shaped fruits (C) cherry-shaped fruits (D), or four lobes (E) present in KAFFO farm, the Cérés Agricole, the Mbidjoro sustainable living environment, and Red Gold of Africa. Rodent and trip attacks (F, G, and H) present in all the farms. Flower of the *Fragaria x ananassa* “Charlotte” variety with 5, 6, 8 or 12 petals observed in the fields of Agro Ankh. Data obtained during the survey carried out from January 2021 to February 2022.

differences in the morphological appearance of the flowers. It appeared in the same field, in strawberry plants, flowers having a number of 5, 6, or 8 petals (Figures 9I-L). In the field, plants with a higher number of petals recorded on strawberry flowers mainly presented malformed fruits at harvest.

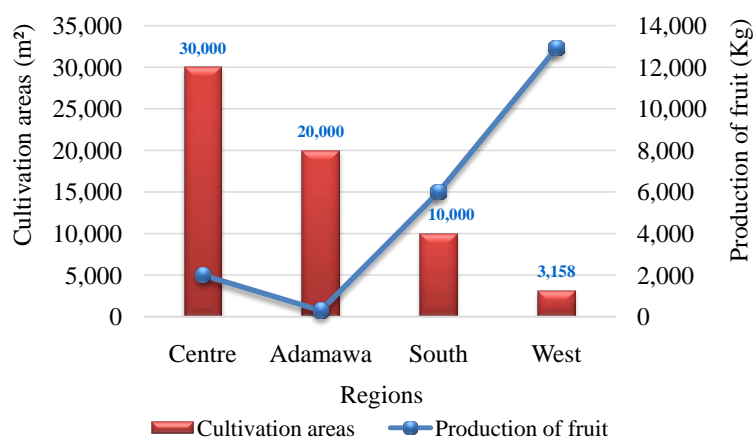
### 3.6. Potential Annual Production of Strawberry Fruits during the Survey in Cameroon

From the survey carried out in the eight strawberry farms, from January 2021 to February 2022, it appears that the production per unit area varies from one strawberry plantation to another. The estimated values of this current production, were obtained from the growers. This would therefore partly explain why Cameroon is absent on the list of world strawberry production. The cultivation areas vary a lot among different farms (Table 6). These cultivation areas are 1ha in BIO farm of Lolodorf and Red Gold of Africa, and 2 ha, at Cérés Agricole and Mbidjoro Sustainable Living Environment. The rest of the strawberry growers still have cultivation areas less than or equal to 2000 m<sup>2</sup>. The highest annual production was recorded at the BIO farm of Lolodorf (6000 kg). However, it should also be noted that despite the small cultivation areas, some strawberry farms sometimes presented annual productions greater than or equal to 4000 kg. This is the case of the KAFFO Farm (4500 Kg) and Agro Ankh (4000 Kg) (Table 6). It can be seen that the low productions were recorded in Mbidjoro Sustainable Living Environment (300 kg) and by Cérés Agricole (500 kg), with the largest production areas (20,000 m<sup>2</sup>) (Figure 10).

**Table 6.** Potential annual yield of strawberry fruits produced estimated in Cameroon between January 2021 and February 2022.

Regions	Strawberry farms	Fruit production (Kg)	Cultivation areas (m <sup>2</sup> )	Seedling production
Centre	Cérès Agricole	500	20,000	4000
	Red Gold of Africa	1500	10,000	-
Adamawa	Mbidjoro Sustainable Living Environment	300	20,000	5000
South	BIO farm of Lolodorf	6000	10,000	100,000
West	Agro Ankh	4000	500	2000
	KAFFO Farm	4500	450	3000
	Bafoussam Farm	416	208	-
	King Farms	4000	2000	10,000

Data obtained during the survey carried out from January 2021 to February 2022.

**Figure 10.** Potential annual strawberry production values in the four regions of growth in Cameroon from January 2021 to February 2022 based on data collected near growers.

These already considerable productions per year can be justified by the agricultural techniques and the cropping system set up for the monitoring of the plants in the strawberry fields; the number of varieties used; the types of fertilizers applied; the soil drainage system; the age of the plants; the quality of the soil; the pH of their soil; the variation of the temperature in the region; the variation of the climate of the growing area; and the control of parasit attacks (fungal, viral and bacterial) by appropriate plant protection methods. However, it was also noted that in these strawberry farms, there is a lack of skilled labor for the constant monitoring and adequate control of the plants during their growth cycle until production. The data collected during this survey, therefore, show that the total annual production of strawberry fruits in Cameroon in 2021 (from January 2021 to February 2022) was estimated at 21,216 kg for strawberry fruits and 124,000 runner plants to be used as seedlings, for an annual production area of

63,158 m<sup>2</sup>. In addition, it should be noted that the BIO farm of Lolodorf has a higher stolon production (seedlings from strawberry plants) (100,000 plants/year) (**Table 6**) than all the other farms.

The observed fruit production may also be justified by the fact that almost all strawberry growers focus on seedlings production for the popularization of the species. However, it should be noted that the annual production of strawberry fruits in Cameroon by region is very high in the South and the West regions of Cameroon with 6000 kg and 12,916 kg respectively, for cultivable areas of 10,000 m<sup>2</sup> and 3558 m<sup>2</sup> (**Figure 10**). In the western region, the high production of fruits can be justified by the number of four strawberry growers present and the strawberry cultivation system used, which occupies less space compared to those used in the other farms. Nevertheless, at the Bio farm of Lolodorf, the 6000 kg produced is attributed to the diversity of cultivated strawberry species. The result of the survey also shows that the most productive variety of *Fragaria* spp. following strawberry plants are *Fragaria vesca* “Maestro” (Mbidjoro Sustainable Living Environment and King Farms), *Fragaria x ananassa* “Madame Moutot” (Cérès Agricole and King Farms), *Fragaria x ananassa* “Charlotte” (Agro Ankh and Bafoussam Farm), *Fragaria x ananassa* “Ruby Gem” (BIO Farm Lolodorf and KAFFO Farm), and *Fragaria vesca* “Mara des Bois” (Red Gold of Africa). From the survey study, it was not obvious to have the different dates of introduction of each variety. However, it should be noted that seniority in cultivation varies from one field to another. It is recorded that cultivation has been carried out for 1 year at the Red Gold of Africa (Obala) and at the Bafoussam Farm (Bafoussam); 2 years at Mbidjoro Sustainable Living Environment (MSLE) (Ngaoundéré); 3 years respectively at the KAFFO Farm (Baham) and Cérès Agricole (Elat Minkom and Yaoundé) and the BIO Farm of Lolodorf (South); 3 years for the Agro Ankh (Dschang) and 5 years in King farms (Baham).

### 3.7. Marketing of Strawberry Seeds and Fruits

The results of the investigations carried out with the managers of the eight strawberry farms visited show that they focus on both seedlings (runners) and fruit production. The fruits produced are already sold in supermarkets and also to individuals. The price of the seedlings varies according to the farm, from 0.87 - 3.32\$ depending on the variety desired. Charlotte, Ciflorette, Mara des Bois, Ostara, San Andreas, cost 0.87\$, Gariguette, Madame Moutot, Maestro, 1.16\$, Camarosa (1.33\$), Amiga, Amine, Chandler, (1.66\$), Ruby gem (1.99\$) and El-santa, more expensive (3.32\$). Moreover, the price of 1kg of strawberry fruit varies between 16.58\$ and 19.9\$ in all the strawberry farms visited.

The sale of strawberry seedlings (stolon's) and fruits are popularised by them through Facebook pages: We note for the BIO Farm of Lolodorf; <https://www.facebook.com/fermedelolodorf/>, the structure of Agro Ankh; <https://www.facebook.com/agroankh/>, Cérès Agricole in Yaoundé; <https://www.facebook.com/ceresagricole/>, King farms with the common name

“Fraise Bio 2037”;  
<https://www.facebook.com/people/Fraise-bio-237/100076204417219/>, and Red Gold of Africa <https://www.facebook.com/watch/?v=362733385138490>. Or, in another part using the YouTube channels, <https://www.youtube.com/watch?v=hUQQtfmQi6kk>, for KAFFO Farm and Cérès Agricole (<https://www.youtube.com/watch?v=XJKcb6E-tXQ>), or/and WhatsApp group. Apart from communication via social networks, these strawberry farmers also communicate by word of mouth. The managers of strawberry farms are well trained in field of strawberry cultivation, and some are Master from the University of Dschang with strong knowledge in Biochemistry. All these strawberry farms receive students for academic training. These students come from universities and agricultural institutes. They also train individuals in the framework of personal training courses. In addition, trials of transformation and production of products based on strawberry fruits are more and more set up, which is the case of strawberry jam, produced by Agro Ankh, Cérès Agricole, KAFFO Farm, Mbidjoro Sustainable Living Environment, Bafoussam Farm and Red Gold of Africa, and of ice creams mixed with natural strawberry fruits (produced by Cérès Agricole).

#### 4. Conclusion

This survey study provides important data on the state of the culture of *Fragaria* spp. in Cameroon. Strawberry cultivation is gradually spreading throughout the national territory. It is already done in four of the country's ten regions, belonging to three agroecological zones. The potential annual production from January 2021 to February 2022 was estimated at 21,216 kg for strawberry fruits and 124,000 runner plants to be used as seedlings, on a total area of 63,158 m<sup>2</sup>. Producers maximize the production of runners which are sold as seedlings. Cérès Agricole is so far the only farm that also offers seed grains to customers. Processing trials are also set up, such as the production of strawberry jam (Agro Ankh and Cérès Agricole) and ice cream from strawberry fruit (Cérès Agricole).

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## Data Availability

Data will be made available on request.

## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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