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ROSELLE (HIBISCUS SABDARIFFA L.): OVERVIEW OF ITS BIOLOGY, ECOLOGY, SOCIO-ECONOMIC IMPORTANCE AND CULTIVATION CONSTRAINTS IN WEST AFRICA

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ABSTRACT
Roselle (*Hibiscus sabdariffa* L) is a plant native to India and Malaysia, very widespread in West African countries. It is a shrub of the Plantae kingdom belonging to the Malvaceae family, of the Hibiscus genus and of the sabdariffa species. This study aims to provide additional information for a better valorization of sorrel cultivation in West Africa. It reports on the biology, ecology, socio-economic importance and constraints related to the cultivation of this species. The morphological and agronomic characterization makes it possible to distinguish two varieties of the sabdariffa species whose phenotypes are complementary: Hibiscus sabdariffa, variety sabdariffa and Hibiscus sabdariffa, variety altissima. Sorrel is a species of tropical and subtropical regions that adapts to very varied climates. It is generally cultivated for its leaves, seeds and calyxes, which constitute a source of income for West African formers. Sorrels are also exploited for their multiple food, nutritional and medicinal properties. Insect pests are the main constraints for sorrel cultivation in West Africa. These can lead in a yield decrease of up to 80%.

KEYWORDS: Roselle, Leaves, Calyxes, Seeds and Socio-economic importance.

INTRODUCTION

Roselle (*Hibiscus sabdariffa* L.) belongs to the Malvaceae family (Ghazali, 1999; Bakasso *et al.*, 2013). It is an annual or biennial plant of tropical and subtropical zones that adapts to all climatic conditions (Gomez-Leyva, 2008; Mera *et al.*, 2009; Mehdi, 2012; Kone *et al.*, 2018). It is native to Asia and is cultivated almost everywhere in Africa from arid and semi-arid regions (Senegal, Mali, Niger, Chad) to equatorial regions (Nigeria, Gabon, Congo Kinshasa) (Reameakers, 2002; Karma *et al.*, 2017; Ankrah *et al.*, 2018). In West Africa, sorrel is generally cultivated for its leaves, seeds, and calyxes which provide a source of income for farmers (Cissé *et al.*, 2009; Hussein *et al.*, 2010; Bakasso, 2010; McClintock *et al.*, 2011; Atta *et al.*, 2011; Louis *et al.*, 2013; Kaka-Kiari *et al.*, 2019a; Kaka-Kiari *et al.*, 2022a), and are used for a variety of food and medicinal purposes (Hassane, 2005; Bakasso, 2010; Atta *et al.*, 2011).

In some countries of the Sahel such as Niger, Burkina and Mali, the leaves are used to prepare sauces and can be eaten cooked as a salad (Ternoy *et al.*, 2006; Bakasso, 2010; Adamou, 2013; Kaka-Kiari *et al.*, 2021). In Niger, fresh sorrel leaves are also pounded, cooked and served with the rice dish as a spice (Bakasso *et al.*, 2013; Kaka-Kiari, 2020). The calyxes are used to make refreshing drinks called bissap (Bakasso, 2010; Bako *et al.*, 2010; Atta *et al.*, 2013; Aziato et *al.*, 2020). Bissap is now one of the most popular ceremonial drinks in West Africa (Kaka-Kiari *et al.*, 2019b). The seeds are used to make soumbala, which is widely consumed by the rural Sahelian population (Parkouda *et al.*, 2008; Bakasso, 2010). It is used in the preparation of dishes to enhance the taste of sauces accompanying cereal-based dishes such as rice, millet, sorghum, corn, etc. (Bengaly *et al.*, 2006; Aliou, 2009; Abdou *et al.*, 2020).

Roselle is often used in medication for its various secondary metabolites, which have therapeutic properties (Lépengué *et al.*, 2009; Atta *et al.*, 2011; Ansari *et al.*, 2013). Furthermore, sorrel has laxative, purgative, cardio-regulating, diuretic, sedative and toning properties (Olaniran *et al.*, 2013; Ognalaga *et al.*, 2015). This plant is also used to treat many diseases such as cough, toothache, and hypertension disorders (Bérhaut, 1979; Hassane, 2005).

Nutritionally, the leaves and calyxes of sorrel are very rich in essential minerals, proteins and ashes (Atta *et al.*, 2010a; Atta *et al.*, 2013; Kaka-Kiari, 2020). The seeds are also rich in protein, fat, oil, ash, and carbohydrates (Halimatul *et al.*, 2007; Tchiégang and Kitikil, 2004; Mera *et al.*, 2009; Kaka-Kiari, 2020). Besides, sorrel is also grown for its fiber in some Africa producing areas (Mera *et al.*, 2009; Maunde, 2010; Mohammed *et al.*, 2013; Louis *et al.*, 2013).

This study attempts to provide additional information for a better valorization of sorrel production in West Africa. It addresses the biology, ecology, socio-economic importance and constraints associated with the cultivation of this species.

Biology of roselle

Origin, Expansion and Domestication

Roselle is an annual or biennial herb with an erect stem, more or less straight depending on the variety, which adapts to all climatic conditions around the world (Mehdi, 2012; Medagam *et al.*, 2015; Kone *et al.*, 2018). It probably originated in a region extending from India to Malaysia (Morton, 1987; Gomez-Leyva, 2008; Mera *et al.*, 2009; Mehdi, 2012).

The species was then widespread in Africa and then reached the New World in the 17th century via slave trade. It has been widely distributed in tropical and subtropical regions of both hemispheres, as well as in many areas of Western India and Central America (Morton, 1987; Mohamed *et al.*, 2012). For McClintock *et al.* (2011), the species is native to Africa where it has been domesticated in Sudan for 6000 years. It was produced first for its seeds and then for its leaves and calyxes (Ternoy *et al.*, 2006). Sorrel was first cultivated in Asia in the 20th century and breeding for fiber production took place in India, Sri Lanka, Thailand, Malaysia and Java (Mahadevan *et al.*, 2009; McClintock *et al.*, 2011).

In tropical Africa, it is common in the savannah areas of West and Central Africa (Wilson and Menzel, 1964; Fasoyiro, 2005; Gomez-Leyva, 2008). Indeed, wild-types specimens of *Hibiscus sabdariffa* have been collected from Ghana, Niger, Nigeria and Angola (McClintock *et al.*, 2011). Sorrel is also grown in most countries in the Sahelian zone such as: Burkina Faso, Mali, Niger, Senegal and Chad (Ternoy *et al.*, 2006; Bakasso, 2010; Tounkara *et al.*, 2011; Dadi, 2018).

Systematic and Classification of roselle

Hibiscus sabdariffa L. is a tetraploid species (2n = 4x = 72) whose chromosomes are related to the diploid (2n = 2x = 36) (*Hibiscus cannabinus* L.). It belongs to the phylum of flowering plants (spermaphyte) with more than 200 species native to tropical and subtropical regions around the world (Wilson and Menzel, 1964; Mclean, 1973; Cissé *et al.*, 2008).

Morphological and agronomic characterization makes it possible to distinguish two varieties of the *sabdariffa* species (variety *sabdariffa* and variety *altissima*) whose phenotypes are complementary (Sié *et al.*, 2009; Cissé *et al.*, 2009; Singh *et al.*, 2017; Ankrah *et al.*, 2018). *Hibiscus sabdariffa* var. *sabdariffa* has a strong juvenile vegetative vigor, high calyx and fruit productivity, low photoperiod sensitivity, and red organ color, meanwhile *Hibiscus sabdariffa* var. *altissima* has a strong adult vegetative vigor, higher fiber productivity, high photoperiod sensitivity, and green organ color. Sorrel is widespread in tropical regions and particularly in West Africa where it is widely consumed (Sié *et al.*, 2009). According to Morton (1987); Medagam *et al.* (2015), the variety *sabdariffa* is a vascular plant whose current scientific classification is as follows (Table 1):

Table 1: Classification of *hibiscus sabdariffa.*

Kingdom	Plantae
Branch	Spermaphytes
Sub-phylums	Angiosperms
Clade	Dicotyledons
Sub-clade	Dialypetals
Series	Thalamiflora
Order	Malvales
Family	Malvaceae
Genus	*Hibiscus*
Species	*Hibiscus sabdariffa* L. (1753)

Source: (Morton, 1987; Medagam *et al.*, 2015)

Vernacular names

H. sabdariffa L. is known by different names, depending on the regions and ethnic groups in the world (Table 2) (Amin *et al.*, 2008; Cissé *et al.*, 2009; Akanbi *et al.*, 2009; Mahadevan *et al.*, 2009; El Naim and Ahmed, 2010; Bakasso, 2010; McClintock *et al.*, 2011; Mehdi, 2012).

Table 2: Vernaculars names.

Oseille de Guinée, Roselle ou thé rose d'Abyssinie (in French; Jamaica, and Spanish); Roselle, Sorrel or Sour tea in English (UK and USA); Groseille de Noël in the West Indies; Flores de Jamaica Central America; Karkadé in Arabic (Soudan); Karkandji in Egypt; Nsa in Congo-Brazaville; Ngai-ngai in Central Africa; Bissap in Burkina, Mali, Senegal; bissap in Wolof (Senegal); Dâ in Bambara (Mali); Isapa in Yorouba and Zobo in Hausa in Nigeria; Sobolo in Ghana; Niger : Yakoua in Hausa; Guissima in Zarma; Pollé in Peulh; Karassou in Kanouri (Diffa)

Source : (Cissé *et al.*, 2009; Amin *et al.*, 2008; Akanbi *et al.*, 2009; Mahadevan *et al.*, 2009; El Naim and Ahmed, 2010; Bakasso, 2010; McClintock *et al*., 2011; Mehdi, 2012).

Morphological description of roselle

H. sabdariffa L. is a bushy annual or biennial species that can reach 1 to 2 m in height (Sameer and Ali, 2018), whose vegetative and reproductive systems have the following characteristics.

Root system

The root system of sorrel is pivoting, whitish and quite branched, which can reach a depth of 30 cm to 1 m, giving it resistance to prolonged spells drought (Somé, 2006). The set of white roots and a fibrous bark consists of a main root with several secondary roots (Dupriez and De Leener, 1987; Bakasso, 2010; Adamou, 2013).

Stem

The stem of the roselle is woody and robust at the base. Its height varies from 0.5 to 2 m depending on the varieties and cultivation methods (Morton, 1987). The main stem is a vertical axis at the top of which is a terminal stem bud. It has a bushy, prostrate or erect habit depending on the variety, with numerous primary, secondary and even tertiary ramifications.

The stem can exceed 2 m in height in fertile soils (Dupriez and De Leener, 1987; Morton, 1987). It is glabrous or hispid with hairs and even spiny tubercles formed by the agglomeration of lignified hairs. It can be green, light or bright red, purple red to green red depending on the variety (Dupriez and De Leener, 1987; Adamou, 2013). The stem's anthocyanin coloration might be a drought resistance trait (Bricage, 1983).

Leaves

The glabrous leaves with a toothed edge, alternate and stipulated, are simple, entire and/or lobed depending on the variety (Berhaut, 1979). The veined blade of the same color as the stem shows remarkable polymorphism during its development (Morton, 1987; Sanou *et al.*, 2005). It is initially simple and oval then lanceolate at the young leaf stage. As the plant ages, it goes through the stage of three lobes and then five lobes depending on the variety. Indeed, the lobes only affect the upper third of the limbus (Berhaut, 1979). Depending on whether the leaf is simple, trilobed or pentalobed, it has one, three or five main veins from which several secondary veins start. When fully grown, the blade is 7 to 10 cm long and wide (Bakasso, 2010). However, this size varies according to the varieties. For example, the blade can reach 9 to 15 cm long and 9 to 20 cm wide in Senegalese varieties (McClintock *et al.*, 2011), and 10 to 16 cm long and 10 to 20 cm wide in Thai varieties (Bakasso, 2010; Hien, 2012). The lamina is connected to the stem by a 4 to 12 cm long petiole of 4 to 12 cm at the base of which along with 6 to 10 mm long stipules (Bérhaut, 1979)

Sorrel inflorescence

The flowers of variable color are solitary in the axils of the leaves, bisexual and regular. They are carried by short peduncles of 2 to 5 mm with a convex floral receptacle. They are pentameric and have a floral formula: FF = 5S + 5P + nEt + 5C, with n = 20 (S: sepals; P: petals; Et: Stamen (Androcea); C: corolla) (Bricage, 1978).

Calyx

The calyx is commonly called sorrel flower. It is made up of 5 accrescent triangular sepals fused at the base and has an epicalyx made up of about ten squat, short, triangular-shaped bracteoles (McClintock *et al.*, 2011). It becomes fleshy and can reach 3 to 4 cm long, then 2 to 3 cm wide or more after the fall of the corolla (Berhaut, 1979). It is variable in color, depending on the variety, and the pigmentation of the calyx is concomitant with the formation of flower buds (Sow, 1997).

Corolla

It is made up of 5 free petals 5 to 7 cm wide and of variable color depending on the variety. It has a twisted preflowering where each petal is covered and covering. The corolla opens a few hours before fertilization (Morton, 1987).

Androcea

It is the male organ of the flower. It is formed by a staminal column bearing reniform, unilocular and modified anthers which dehisce longitudinally (Bakasso, 2010).

Pistil

The superior ovary, gamocarpic, globose, with a unique gynobasic style, is formed of 5 carpels and 5 chambers. Each cell has 2 rows of ovules with axial placentation. The staminal column encompasses the longer, held style terminating in a five-lobed stigma lined with sticky papillae (Morton, 1987).

Fruit

The fruit is an ovoid capsule up to 2.5 cm long, almost glabrous to appressed pubescent, enclosed in the calyx, (Morton, 1987; McClintock *et al.*, 2011). At maturity, it is composed of the calyx and the capsule, containing numerous seeds of blackish color variable according to the variety, irregularly round about 0.5 cm in diameter (Dupriez and De Leener, 1987). The capsule dehisces at full maturity through the five mid-carpellar longitudinal clefts. The fruit can contain 25 to 35 seeds of variable size depending on the variety (Hien, 2012).

Seed

The seeds are kidney-shaped dark brown or coffee in color and are arranged in rows on both sides of each valve. At a low percentage of humidity (8%) and stored at optimal temperatures, the seeds can retain their viability for up to five (5) and a half years (Milligo, 2005).

Growth and Development of roselle

The vegetative growth period lasts about 4 to 6 months. Seedling emergence occurs 3 to 5 days after sowing (Diallo, 2007; Bakasso, 2010; Kaka-Kiari, 2020). The first branch appears in the axils of the leaves, about 17 to 20 days after sowing (Adamou, 2013). Harvesting of leaves can start 6 to 8 weeks after sowing (Morton, 1987). It stimulates branching and consequently increases leaf production (Kaka-Kiari, 2020). Flowering starts when the day length is less than 12 hours (Sié *et al.*, 2009; Nouri, 2011), at the earliest 2 months after sowing, and at the latest 7 months (McClintock, 2011).

The flower buds appear in the axils of the leaves on variable dates, on average 50 to 60 or even 70 days after sowing (Bakasso, 2010; Adamou, 2013). At maturity, that is to say 20 to 30 days after the appearance of the flower buds, the flower blooms (Bérhaut, 1979). Fertilization occurs only 24 hours after the flower opens (Adamou, 2013). In the Malvaceae family, the flowers are usually protandrous. Cross-pollination is entomophilous, i.e. ensured by nectariferous insects, but self-fertilization is often observed (Bricage, 1978). The fruits begin to ripen two or three weeks after fertilization (Morton, 1987).

Roselle ecology

Hibiscus sabdariffa L. is a species from tropical and subtropical regions that adapts to a wide variety of climates (Duke, 1983; Morton, 1987; Mohamed *et al.*, 2012; Mehdi, 2012; Louis *et al.*, 2013; Medagam *et al.*, 2015). This ecological amplitude has allowed its cultivation on almost all soil types and climates of Africa, Asia, Europe and America (Oyewole and Mera, 2010; Mehdi, 2012). Moreover, it is a plant that requires humus-rich, well-drained soil that is fairly rich in mineral elements, with an optimal pH of 6 to 7 for optimal growth (Mehdi, 2012). With a deep root system, the plant needs an appropriate soil depth (Bakasso, 2010). Sorrel is relatively drought resistant (Hien, 2012).

Roselle requires 450-500 mm of well-distributed rainfall over a period of 90-120 days (Morton, 1987) or at least 100-150 mm rainfall per month during its vegetative growth (McClintock, 2004). Dry spells in the final months of growth favor good calyx production, while too much rain or moisture is likely to lower calyx quality and yields (McClintock *et al.*, 2011; Mohamed *et al.*, 2012; Abdourahamane, 2016). Excess humidity can also delay flower formation and fruit maturation (Leko, 2004; Gueye *et al.*, 2012). Its optimum cultivation temperature is between 25 and 35°C during its vegetative phase (Mehdi, 2012). The growth of the plant stops at 14°C and then dies after 15 days. Calyx production decreases below 17°C (Duke, 1983; Hien, 2012).

The flowering time of sorrel is much more influenced by temperature (Jan and Stuart, 2000). However, excessive heat exposure might cause the leaves to have a bitter taste or a high level of acidity (Adamou, 2013). Sorrel is a photosensitive plant that flowers optimally when the day is less than 12 hours long (Reameakers, 2002; Sié *et al.*, 2009; Mehdi, 2012). To prevent early flowering, sorrel requires 13 hours of daylight throughout its vegetative growth (Dupriez and De Leener, 1987).

Importance of roselle

Food importance

H. sabdariffa L. is one of the few crops in which all aerial parts are eaten almost everywhere in Africa. The various organs (leaves, calyxes and seeds) of the plant are very rich in carbohydrates, proteins, amino acids, lipids and vitamins (A and C) (Tchiégang and Kitikil, 2004; Endrias, 2006; Maffo *et al.*, 2016). They are also rich in ash, calcium, magnesium, sodium, potassium, zinc, iron, manganese and phosphorus (Halimatul *et al.*, 2007; Mera *et al.*, 2009; Atta *et al.*, 2010a; Atta *et al.*, 2010b; Tounkara *et al.*, 2011; Atta *et al.*, 2013, Kaka-Kiari, 2020). The seeds of sorrel are as rich in oil (16%) as those of cotton and soybeans, which are subject to industrial exploitation (Morton, 1987; Endrias, 2006; Maffo *et al.*, 2016; Kaka-Kiari, 2020). The calyxes are richer in mineral elements than the seeds (Atta *et al.*, 2013). The acid taste is due to the presence of potassium oxalate which has the property of removing rust stains (CIRAD and GRET, 2002).

Sorrel calyxes, leaves, and stems are mixed in oil and served with vegetable rice in rural areas of Senegal and Mali (Ternoy *et al.*, 2006). The red calyxes are also consumed and their decoction used as a cold drink (bissap) (Aziato *et al.*, 2020) especially during the period of Ramadan (Bakasso, 2010). They are also used in the production of red wine in Africa (Aziato *et al.*, 2020). In addition, the greenish, pink or white calyxes with red bands are also cooked and then mixed with paste or groundnut cake to prepare a popular salad (Adamou, 2013). These calyxes are also used in the preparation of millet, rice or corn couscous (Kaka-Kiari, 2020). The anthocyanin pigments of the calyxes confer a red color to

the drinks highly appreciated by the populations (Aziato *et al.*, 2020).

In Niger, young leaves are mostly used as a cooked vegetable in traditional rice dishes (Adamou, 2013). They are also prepared in salads after cooking (Leko, 2004). In some regions of Niger, old sorrel leaves are picked, pounded, wrung and dried, then packaged in the form of small disks that can be used during the dry season (Kaka-Kiari *et al.*, 2019b). In other regions, these leaves are first boiled, then wrung out before being dried for long-term storage or simply pressed and then dried (Bakasso *et al.*, 2013). The seeds are saved to serve as seeds and the excess is used to prepare "soumbala" (Parkouda *et al.*, 2008; Bakasso, 2010; Atta *et al.*, 2011). The preparation of soumbala can be done with the seeds of a single variety or with a mixture of seeds from different varieties (Abdou *et al.*, 2020). The seeds are often used as poultry feed and as an aphrodisiac coffee substitute (Mahadevan *et al.*, 2009). In some countries, such as Uganda, the seeds are eaten roasted (FAO, 1990).

Plant biomass is also consumed by animals, but can also be spread on fields to increase the soil fertility (Pasternak, 2002). The empty capsules of their seeds and the dry leaves are used as fodder (Kaka-Kiari, 2020). The fibers from the bark of the stalks are used to make beds made from millet or sorghum stalks (Bakasso, 2010; McClintock *et al.*, 2011). The stem is also used as a source of pulp in the paper industry in many parts of the world (Ghasemi *et al.*, 2015; Simon *et al.*, 2021). In Niger, the ashes from the burnt stems are sometimes mixed with the seeds to ensure their preservation (Kaka-Kiari, 2020; Kaka-Kiari *et al.*, 2022b).

Medicinal importance

Since Antiquity, sorrel has been used as an infusion or decoction to treat anemia, colds, constipation, itching, sore throats and infertility (Dupriez and De Leener, 1987; Bakasso, 2010; Atta *et al.*, 2011). The maceration products of the sweet and spicy calyx parts is often used in cold treatment (Bérhaut, 1979; Morton, 1987).

In addition, the leaves, calyxes and seeds of sorrel are used in traditional pharmacopoeia (Sinsin and Kampmann, 2010; Ansari *et al.*, 2013). The preparation of the fleshy part with the crushed roots is used as a moist dressing to ripen abscesses and is also used to rub the chest of patients suffering from bronchitis with intercostal pain (Bérhaut, 1979; Hassane, 2005). The extract of *Hibiscus* leaves would have a strong antioxidant power which would allow the degradation of cholesterol. Therefore these leaves could be useful in the prevention of cardiovascular diseases in which, cholesterol plays an important role (Endrias, 2006; Atta *et al.*, 2011). The decocted calyxes are diuretic, urinary antiseptic and antiscorbutic (Morton, 1987; Atta *et al.*, 2011; Louis *et al.*, 2013). For its high quantity of vitamin C, anthocyanins, amino acids, and mineral salts, calyx extract is a natural dye that can replace manufactured red dyes in a variety of nutritional, medical, and industrial applications (Abou-Ellail *et al.*, 2014).

From a medico-magical viewpoint, sowing roselle at the edge of fields would protect them from evil spirits (Bérhaut, 1979). The juice of the leaves and even the calyxes could facilitate delivery for pregnant women (Bakasso, 2010).

Economic importance

Over the last few decades, the international trade of sorrel calyxes has increased steadily (McClintock, 2004). Exports of chalices from Africa are mostly to the United States and Europe, particularly France and Germany, which account for around 80% of the European market of around 3,000 tons of calyxes. In 1998, the United States and Germany spent between $1200 and 1700 US dollars per ton for Egyptian and Sudanese roselle. Prices for Chinese roselle were relatively lower, with nevertheless prices fluctuating due to the supply unpredictability. In 2003, a drop in product quality in Thailand and China as a result of excessive rain, caused prices to rise to 4,000 US dollars per ton (Ternoy *et al*., 2006; Bakasso, 2010; McClintock *et al.*, 2011).

Sudan is the main producer of sorrel in Africa (Ternoy *et al.*, 2006). The annual cultivated area varies between 11,000 ha and 57,000 ha, depending on rainfall and prices. In 1995, Sudan exported roughly 32,000 tons (McClintock *et al.*, 2011). According to the Central Bank of Sudan (2012), the quantity of dry calyxes exported was 18,531 tons in 2011 and 15,656 tons in 2012 for a net gain of 17.59 million US dollars and 14.09 million US dollars, respectively (Ibrahim *et al.*, 2013). In Cameroon, the sale prices of calyxes on the markets are highly fluctuating depending on supply and demand. In Cameroon, the sale prices of calyxes on the markets are highly fluctuating depending on supply and demand. Thus, it was observed on the markets purchase prices varying from 200 to 500 FCFA per plate of 250 g and from 8,000 to 15,000 FCFA per bag of 30 kg (Folefack *et al.*, 2008).

Senegal and Mali are the leading producers of sorrel in West Africa. However, the majority of their production is for family consumption or sold in local markets (McClintock *et al.*, 2011). In Senegal, the average annual income from the sale of sorrel leaves varies from 41 to 500 US dollars (Diouf *et al.*, 2007). In addition, in Burkina Faso, Benin, Ivory Coast, Mali, Mauritania, and Senegal, an iced bag of 30 to 50 cl is sold between 25 and 50 FCFA, while a 1 liter bottle between 1000 and 1500 FCFA (McClintock, 2004).

In Niger, the sale of sorrel seeds provides farmers with an income of 5,000 to 45,000 or even 60,000 FCFA per year depending on the sales period and the region (Bakasso, 2010). Prices are significantly higher during the sowing period, rising from 150 FCFA at harvest to

more than 350 FCFA per local seed measurement unit in the rainy season before the next harvest (Diallo, 2007). According to Bakasso (2010), the measurement of calyxes, especially those used for the preparation of drinks, can cost from 1000 to 1500 FCFA during the lean season, exceeding the price of the kg of millet, the country's main food crop.

Constraints related to the growing of roselle

The main constraints associated with sorrel cultivation include the soil's low organic matter content and the reduction in cultivable areas, both of which caused by rapid growing populations (Bakasso, 2010); the poor performance of the means of production used (little or no use of improved seeds, fertilizers, rudimentary agricultural tools, obsolete rural infrastructure) (Diallo, 2007); the farmers' poverty hampers mechanization and intensification of sorrel cultivation (Hassane, 2005); poor cultivation practices (Kaka-Kiari *et al.,* 2020). In the event of significant production, farmers lack secure outlets to sell their products (Bakasso, 2010). This constitutes an obstacle to the good emergence of sorrel cultivation.

So far, pest infestation has been identified as one of the major constraints for roselle cultivation (Bakasso, 2010; Olaniran *et al.,* 2013). The yield reduction caused by insect pests could reach 82.44% (Nouri, 2011; Olaniran *et al.,* 2013). According to Simon *et al.* (2018), the impact and infestation of insect pests throughout the vegetative and reproductive growth stages of roselle could result in an 87.5% in fresh calyx yield. Fajinmi and Fajinmi (2006) reported that the insect is the basis of mosaic virus transmission leading to a reduction in sorrel yield of about 50%. In Nigeria, Daramola (1984) observed 30 species of insects regrouped in 15 families and 4 orders infesting roselle in farmers' fields. Olaniran *et al.* (2013) listed 5 species of insect pests in 5 families and 4 orders. In a study in Makurdi (Nigeria), Simon *et al.* (2021), recorded 105 species belonged to 45 families and 8 orders of insect pests of Guinea sorrel.

Roselle is also susceptible to fungal infestations. The main effects include lesions on the stem leading to wilting and rotting of the collar caused by *Rhizoctonia solani*, brown and blackish circular spots on the leaves caused by *Ascochyta cannabis hibiscus* (De Cambiaire, 1997); rust caused by *Puccinia garkiana*, the agent responsible for small necroses and characteristic red-brown spots (rusts); leaf scorch caused by *Phomas sp* (Sanou *et al.,* 2005); Sigatoka caused by *Cercospora abelmoschi* (Ndiaye, 1996); browning or whitening, rots on roots and stems by *Macrophomina phaseolina* (Aliou, 2009; Bakasso, 2010; Nouri, 2011); growth retardation caused by *Fusarium oxysporium* sp. *vasinfectum* (Sié *et al.,* 2011); attacks on the leaves of *Hibiscus sabdariffa* L. from sowing to harvest by *Nisotra uniformis* and *Nisotra dilecta* (Gueye *et al.,* 2012).

CONCLUSION

Roselle belongs to the Malvaceae family. It is an important crop as its leaves, calyxes, and seeds play a substantial socioeconomic role in African populations. Roselle is cultivated in all the tropics, particularly in Africa, Central America and Asia. The different organs of the plant are very rich in carbohydrates, proteins and lipids. They are also rich in ash, calcium, magnesium, sodium, potassium, zinc, phosphorus, etc. Insect pests are the major constraints for sorrel cultivation, which can lead in a yield loss of up to 80%.

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