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Review

Yam (*Dioscorea* spp.) production trends in Cameroon: A review

Ignatius Nkendem Azeteh[1*], Rachid Hanna[2], Pierre Nekongo Sakwe[3], Achiangia Patrick Njukeng [1] and P. Lava Kumar [4]

[1]Department of Plant Biology, Faculty of Science, University of Dschang, P. M. B. 67, Dschang, Cameroon.
[2]International Institute of Tropical Agriculture (IITA), Ecoregional Center, P.M.B. 2008, Messa, Yaounde, Cameroon.
[3]Faculty of Agriculture and Veterinary Medicine, University of Buea, PMB 63, Buea, Cameroon.
[4]International Institute of Tropical Agriculture (IITA), Oyo Road, P.M.B. 5320, Ibadan, Oyo State, Nigeria.

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Yam (*Dioscorea* spp.) cultivation has the potentials to greatly contribute to poverty alleviation and food security, in Cameroon. The full production potentials of yams have not been exploited, leaving Cameroon with an annual production of 648,407 metric tons (MT) at the sixth position, among the six countries of the West African yam zone, with 67.3 million MT. This review highlights research gaps in the yam production chain, which can be exploited to enhance production in the country. Subsistent yam cultivation takes place in all five agro-ecological zones of the country. Although with many fluctuations, yield and production quantities have recorded a marginal net increase, since 1961. Cameroon has nine cultivated and 17 wild species, exploited by Baka pigmies for food, but there is no established genebank, thereby exposing the genotypes to genetic erosion. Cultivated species are both indigenous and exotic, and traditional seed systems (sorting, junking, and milking) are exploited for seed procurement. Minisett technology is also gaining grounds. Yam processing is very limited, and, coupled with poor conservation facilities, contributes to elevated post-harvest losses. The yam marketing system is poorly organized, and hinders farmers from reaping optimum benefit from the activity. Other major constraints to yam production include high labour demand, pests and diseases, absence of improved seeds and research neglect. There is the need for concerted efforts involving all stake holders in the yam production chain to enhance yam production in Cameroon.

Key words: Review, yam (*Dioscorea* spp.), production, Cameroon.

INTRODUCTION

Yam is an annual or perennial tuber-producing vine, belonging to the genus *Dioscorea* (family Dioscoreaceae) with about 600 species (Alexander and Coursey, 1969; Oben et al., 2016).The crop is an important staple for hundreds of millions of people in tropical and subtropical areas of Africa, Asia, South America, and the Caribbean

*Corresponding author. E-mail: aignanken6@yahoo.com, ignkeaze@gmail.com. Tel: +237 675 106 089.

and Pacific Islands (Degras, 1993; Ngo-Ngwe et al., 2014). Yam is most important in the “yam zone” of West Africa which covers the tropical and subtropical regions of Côte d’Ivoire, Ghana, Togo, Benin, Nigeria and Cameroon (Oben et al., 2016) where over 67.3 million metric tons (MT) (92.2%) of the world’s estimated 73 million metric tons (MT) of yams are produced yearly (FAO, 2017). Nigeria stands out as the highest producer with 47.9 million MT (65.7%) of the world’s production, while Cameroon with an annual production of 648,407 MT (0.9%), is ranked sixth in the West African yam zone and seventh in the world, behind Togo. On an annual base, yams are cultivated in Cameroon on a surface area of 57512 ha; with an average yield of 11.3 MT/ha (FAO, 2017).

Globally, there are 10 main cultivated yam species, originating from tropical areas of Africa, South East Asia and South America. These include *D. alata* L (Asiatic or water yam), *D. esculenta* (Lour) (Chinese yam), *D. opposite* Thunb, and *D. japonica* Thunb from Asia; *D. nummularia* Lam, *D. pentaphylla* L. from Asia and Oceania; *D. rotundata* Poir (White guinea yam), *D. dumetorum* (Kunth) Pax (Sweet yam) and *D. cayenensis* Lam (Yellow guinea yam) from West Africa; *D. trifida* L. (Cush-cush yam) from South America; and *D. bulbifera* L. from Africa and Asia (Coursey, 1976; Lyonga, 1976; Dansi et al*.,* 2013). Water yam is the most diversified and widely distributed species while White guinea yam has the world’s highest production level. Among the yam species, *D. alata, D. cayenensis and D. rotundata* are most economically important in the west African yam zone (Dansi et al*.,* 2013), while in Cameroon *D. alata, D. cayenensis, D. dumetorum, D. rotundata* are the most important species, cultivated in all agro - ecological zones of the country (Ngo-Ngwe et al*.,* 2014).

Yam is an important food plant because of its underground tubers and/or aerial bulbils, which are a good source of carbohydrates, proteins and vitamins, particularly vitamin C (Bell, 1983; Agbor-Egbe and Treche, 1995). In addition, yam and its products are reported to have a low glycemic index, which gives better protection against diabetes and obesity (Siadjeu et al*.,* 2015). Yam production is also a major income generating activity for the people of yam-growing areas (Acquah and Evange, 1994; Leng et al., 2016) and thus provides other opportunities for poverty alleviation and nourishment. Some species, particularly *D. zingiberensis,* which contain high concentrations of diosgenin, are used to produce contraceptive pills and sex hormones (Coursey, 1967). The crop also has socio-cultural importance and is an elitist food crop of choice in Cameroon.

Despite its importance, yam production and productivity have been limited by a range of constraints including unavailability and high cost of seed yams, high demands of labour, pre- and post-harvest pests, inadequate storage facilities, various diseases and institutional research neglect of the crop. Although yam has been cultivated in Cameroon for at least two centuries, research on the crop has generally been scanty compared with the rest of the countries of the African yam zone. The previous research on yam in Cameroon has been carried out in isolation and without any coordinated effort. The overall objective of this review paper is to compile available literature on yam and seed yam production in Cameroon, to highlight gaps on yam research in the country, with the aim of attracting the attention of researchers and donors to invest in enhancing yam production with potential spill over to neighboring countries in central Africa.

YAM PRODUCTION IN CAMEROON

Major yam growing areas

Cameroon is located in the Gulf of Guinea, between latitude 1.7° N to 13.8° N, and longitude 8.4°E to 16.8°E and covers a surface area of 475,440 km^2. It shares common borders with Nigeria, Chad, Central African Republic, Gabon and Equatorial Guinea. The country is characterized by a wide variety of climatic zones and vegetations; tropical forest and swamp in the South, savannah landscapes in the North and altitude pastures on the Western Highlands (Yengoh and Ardö, 2014). Cameroon is made up of 10 administrative regions found in five main agro-ecological zones as detailed in Table 1 (Toukam et al*.,* 2009).

Subsistent yam cultivation is carried out in all the five agro-ecological zones, but major yam-growing areas are found in Zone II, III, IV and V, mostly in Adamawa, Southwest, Littoral, Northwest, West, East and Centre Regions. However, high levels of yam production have been reported in the North Region precisely in Mayo-Rey and Faro (Ngue-Bissa et al*.,* 2007). Adamawa Region (Mbe plain) is the highest producer followed by Southwest, Littoral, Centre, West, East and Northwest Regions (Ngassam et al*.,* 2007). Cameroon’s climate and soils, like other countries of the “yam zone” of West Africa are favourable for high level cultivation of yams and other root and tuber crops. However, yam diversity within regions is still very limited. Diversification and improved yam cultivation to meet growing demands of the galloping urban population need enhanced commitment of yam researchers and donors.

Yam production trend in Cameroon: 1961- 2017

In Cameroon, yam production has witnessed a lot of fluctuations but has more or less stagnated below an annual production of 650,000 MT, since1961 with a few peak periods in 1972/73 and 2017 (Figure 1). After the reunification of Cameroons in 1961, there was a cut in

Table 1. Main characteristics of agro-ecological zones of Cameroon.

Agro-ecological zones (constituent regions)	Annual rainfall (mm)	Elevation (masl)	Mean annual temp. (°C) (range)
Zone I: Sudano-sahelian (North and Far North)	500-900	250 - 500	28 (±7.7)
Zone II: High guinea savannah (Adamawa)	1500-1800	500 - 1500	23(±6.4)
Zone III: Western highland (West and Northwest)	1800-2400	1500 - 2500	21 (±2.2)
Zone IV: Humid forest with monomodal rainfall (Southwest and Littoral)	2000-11000	0 - 2500	26 (±2.8)
Zone V: Humid forest with bimodal rainfall (Centre, South and East)	1500-2000	400 - 1000	25 (±2.4)

masl= meters above sea level; *Source:* Toukam et al. (2009).

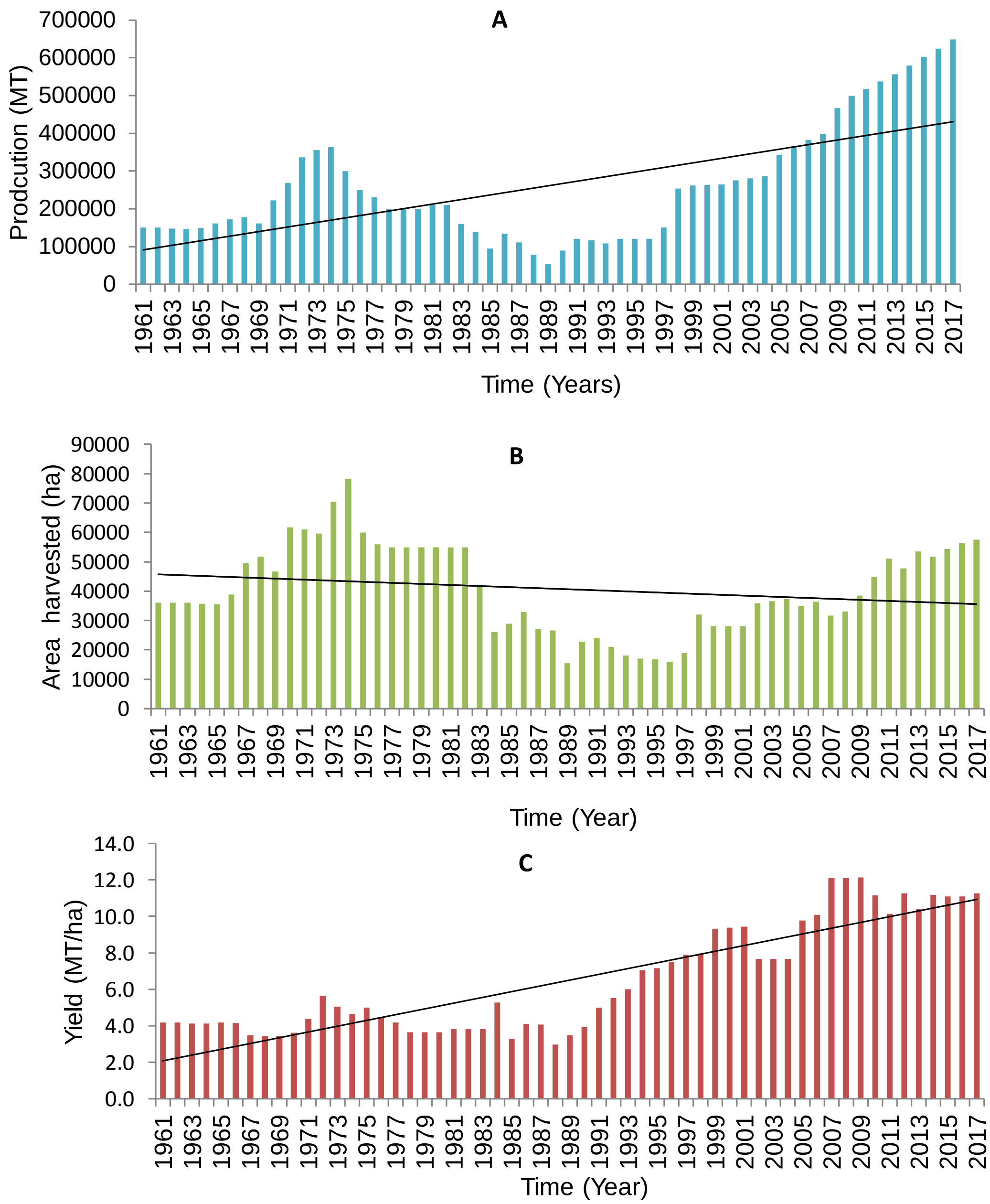

Figure 1. Variation of yam; (A) production quantities (MT); (B) area harvested (ha), and (C) yield (MT/ha) in Cameroon from 1961 to 2017.
Source: FAOSTAT (2017)

the import of white yam from the former Eastern Nigeria, due to the West Cameroon government's concern with the loss of currency to Nigeria through importation of this commodity. This led to a drastic decrease in the supply of yams in Cameroon, to meet high demand in the country. Efforts to increase yam production led to the formation of the West Cameroon yam scheme in 1963 (Lyonga and Ayuk-Takem, 1982), with the duty to develop new yam varieties and to set a practical framework to reduce yam importation from Nigeria (Ngeve, 1998). Through this scheme, the government promoted yam production by demonstrating the importance of yam cultivation to farmers, training them on yam husbandry and supplying them with subsidized seed yams (over 167,000 seeds of 'Ogoja' yams) from Nigeria, which later became too expensive to import. Attention was turned to the then Central South Province of the country where the 'Mban' cultivar of *D. rotundata*, (characterized by smaller tuber size and low yield), was a substitute, especially in the hot lowlands. This government effort led to a large increase in yam production (215,000 to 380,000 MT) between 1969 and 1973 (Figure 1). Institut de Recherches Agronomiques Tropicales et des Cultures Vivrieres (IRAT) in charge of food crop research at the time later included yam research in its program. However, yam cultivation was and is still left in the hands of peasant farmers, who lack inputs and adequate knowledge in yam cultivation, to meet growing demands. Yam production as a result, dropped steadily from 1973 to 1989, followed by another rising phase to present time, 2018 (Figure 1).

Yam cultivation in the Mbe plain entered into crisis within the 1973 to 1989 period, as a result of lack of material and an unfavourable production calendar. Following the creation of the cotton producing company (SODECOTON) in 1974 and extension of its activities along the Garoua – Ngaoundere road axis, many youths within the plain developed lack of interest in yam cultivation, in favour of cotton farming, attracted by better offers such as; access to loans, farm inputs and mechanized farming from the company (Seignobos, 1998). Furthermore, due to the almost total dependence on a single yam cultivar (*Bakokae*) at the time, and lack of means to conserve tubers in the first harvest (weaning), the economic activity, based on yams sales, was restricted to the period between mid-July and February/march, leaving a gap in October and November. This helped to discouraged yam cultivation in the zone.

The net, although slow increase in yam production after 1989, might probably be due to the introduction and adoption of minisett technology in the country's seed system through the National Agricultural Extension and Research Program (PNVRA) in the early 1980s. This was jointly carried out by Cameroon's ministry of agriculture, Institute of Research for Agricultural Development (IRAD), Universities-particularly the "Faculté d'Agronomie et des Sciences Agricoles (FASA)"of the University of Dschang, in collaboration with IITA. The program was funded by African Development Bank (ADB), Cameroon government, World Bank, and International Fund for Agricultural Development (IFAD) (Nchinda et al*.,* 2010). For proper coordination of research to meet the needs of the entire country, the national program for roots and tubers development (NPRTD) was created in 1997, with the goal to develop improved varieties of cassava, cocoyam, taro, yams, sweet potatoes and Irish potatoes. Through the program more yam farmers were trained on seed yam production through minsett technology (Ngue-Bissa et al*.,* 2007). However, in comparative terms, this increase in yam production is consistently far lower than in the other countries of the West African yam zone, with a last rank of sixth amongst the six countries of the zone. Lyonga (1976) and Ngue-Bissa et al*.* (2007), projected 1,324,000 and 722,509 MT of yam production in 1980/81 and 2002/2003, respectively, but these projections are far higher than FAO yam production estimates for this same periods.

Area harvested has remained stagnant below 80,000 ha, with a slight overall decline since 1961, nevertheless production has continued to increase, although slowly, between 1990 and 2017 (Figure 1), with a concomitant and progressive yield increase as well (Figure 1; FAO, 2017). This indicates that yam production is not expanding in terms of surface area cultivated, but farmers involved in the yam sector might have gained more experience in yam production procedures and need more encouragement through research to enhance yam production. In 2006, the national yield estimate for yam in Cameroon stood at 6.08 MT/ha (Nchinda et al*.,* 2010), accounting for about 50% of the African average yield of 11 MT/ha. However, according to the food and agricultural organization statistics for the same year, Cameroon recorded a yield of 10.1MT/ha. Among the main yam-growing regions, the best yields (11.13 MT/ha) have been recorded in Adamawa. However, in Zone III (Western highlands), annual yields as low as 3.08 MT/ha have been recorded (Ngue-Bissa et al*.,* 2007). Enhanced holistic research on yams will therefore better promote yam production in the country, in a manner similar to attention given to other root and tuber crops such as cassava and taro which have seen greater investment in research, especially improved varieties, which is credited with the production increase of those crops (Ngassam et al*.,* 2007; Njukwe et al., 2014).

YAM CULTIVATION

Growing season

The yam growing season in Cameroon varies with agro-ecological zones, but throughout the country the planting season extends from November to May with harvesting 6 to 10 months later, depending on the species and variety. Acquah and Evange (1991) reported that the growing season also varies within the agro-ecological zone. In

Table 2. Effects of planting date on the yield of *Oshie* white yam (*D. rotundata*) in the high altitude savannah of Cameroon.

Planting date	Part of tuber used for seed and yield (MT/ha)	
	Terminal	Basal
December	31.0	25.8
February	26.1	21.7
March	18.5	15.4
April	7.6	6.4
May	5.6	4.7

Source: Adapted from Ngeve (1998).

Buea (Bonakanda), a major yam-growing area in agro-ecological zone IV (Southwest Region), planting extends from November to February and first (ware yam) harvest takes place from May to July, while the second (seed and ware yam) harvest takes place from August to October. In Malende within the same agro-ecological zone, planting goes from February to May and harvesting extends from November to April. Seignobos (1998) reported that in the northern parts of the country particularly at Mbe plain in Adamawa, planting starts from mid-March to the start of June and ware yam harvest from September to January. The same study indicates that the variety of *D. rotundata* called *Bakokae,* commonly cultivated in the zone is planted in April and May, and harvest starts in September while the early-maturing variety called *Ngang* is planted in April and harvested by mid-July. In the high altitude savannah, the yield of *Oshie* white yam (a variety of *D. rotundata*) reduced by 16, 40, 75 and 82%, if instead of December, planting is carried out in February, March, April and May (Table 2). Furthermore, the terminal parts of the tubers used as seeds produce better than the basal parts (Ngeve, 1998). This indicates that planting in December, before the arrival of rains, is favourable for yam production within this zone, and generally emphasizes the importance of proper timing of the planting date in yam cultivation. Information related to the yam-growing season is lacking, for other yam species and yam-growing agro-ecological zones.

Seed yam sources

Local yam varieties are inherited and cultivated as part of the culture in many areas of the country. This is the case with varieties of *D. rotundata* called *Bakokae* and *Ngang* which are intensively cultivated in the Mbe plain of Adamawa (Seignobos, 1998). Also, local varieties of *D. dumetorum* (in most parts of the country), *D. alata* and *D. rotundata* (Mban cultivar) in the Centre and South Regions, and *D. cayenensis* in the West and Northwest Regions have probably been domesticated and cultivated as part of the people's culture. Many exotic species and varieties have also been imported from Guadeloupe – West Indies (cultivars of *D. alata, D. trifida*), Nigeria (many cultivars of *D. rotundata, D. alata* "Ogoja" and *D. cayenensis*) (Lyonga, 1976) and Côte d'Ivoire (*D. alata* cv. "Florido"). Seed yams of both exotic and local varieties are maintained through many traditional seed propagation techniques such as milking/weaning. In yam varieties with double harvest, the first harvest called milking produces ware yams which are generally larger in size, physiological immature and more fragile to conserve (Dumont, 1998). The second harvest generally produces smaller and physiologically mature tubers which mostly serve as planting material. Although scarce, seed yams are also bought from local markets. Seedling and foodstuff development authority (MIDEVIV) in the 1980s and NPRTD, have produced and distributed seed yams to farmers in the country (Nchinda et al*.,* 2010).

Despite these efforts, lack of improved clean seed yams remain a major constraint to yam production (Acquah and Evange, 1994). In addition to its high cost, accounting for about 323,680CFA (US $560) (40%) of production cost per hectare, seed yams are very scarce and improved varieties are lacking in Cameroon. Furthermore, the fact that yam is mostly propagated vegetatively, using tubers which are equally used as food, greatly contributes to seed yam scarcity. Smallholder farmers, who produce most of the yams in Cameroon, also consume their own seed yams during periods of food shortages, leading to severe shortages of planting material for the next season. There is therefore an urgent need to develop and adopt alternative seed yam propagation techniques, to improve clean seed yam availability and subsequent yam production capacity in Cameroon.

Weight of seed yams

Since yam production in Cameroon is carried out mostly by smallholder farmers, the exact seed yam weight is not an important consideration to them, as they only estimate the size of their setts. All other aspects being at their optimum, the size of tubers produced is directly related to the size of setts used. Lyonga (1976) reported that 125 g yam setts are best for seed yam production while 375 to 500 g are best for ware yam production. Seignobos (1998) reported that for the yam cultivar called *Bakokae* the Dourou people of Adamawa use seed yam size of about 12 cm, mostly weighing between 250 and 400 g but could attain 625 g. The earlier the planting date, the larger the sett size required, to resist irregular rains at the start of the planting season.

Seed yam propagation

Both innovative and traditional methods are employed in Cameroon for seed yam production. These include seeds obtained from milking/weaning/tapping, small ware tuber sett cuttings, seed yam from minisett technology (Ngeve and Nolte, 2001; Ngue-Bissa et al*.,* 2007; Nchinda et al*.,* 2010). Milking/weaning, is the most popular traditional method for seed yam production. Seignobos (1998), reported that to sustain cultivation of *Bakokae* and *Ngang* (Cultivars of *D. rotundata*) at the Mbe plain, this technique is commonly used by farmers as a means of producing planting material for the next planting season. The technique consists of carefully digging, cutting around the collar and removing the main yam tuber without damaging roots at about five to six months after planting. The remaining part of the stem is properly covered with soil and allowed to produce smaller adventitious tubers, which are harvested after about three months to serve as seeds. Sorting is another traditional method, in which small seed sized tubers from species that produce both ware and seed sized tubers, are sorted and used as seed yams (Figure 2), while larger ones are eaten or sold. This technique has the risk of selecting and using infected small tubers. Large ware tubers are sometimes cut into seed sized setts and used as seed yams (Ngue-Bissa et al*.,* 2007), a technique called “junking” (Figure 2; Aighewi et al*.,* 2014).

Innovative yam seed propagation techniques include minisett technology which is gradually being adopted by yam farmers in parts of the country. Through the National Root and Tuber Development Program (NPRTD), the International Institute of Tropical Agriculture (IITA), and Institute of Agricultural Research for Development (IRAD), many yam farmers have been trained on the technique (Ngue-Bissa and Mbiaranodji, 2007). Unfortunately, no assessment has probably been done to improve on this outreach strategy (Nchinda et al*.,* 2010). Some farmers, particularly in the Southwest Region, now consider the technique profitable and have embraced it. Other methods of seed yam propagation such as vine rooting, tissue culture, aeroponics, temporary immersion bioreactor technology, somatic embryogenesis (Mignouna et al*.,* 2016), have not been adopted in Cameroon.

Yam cultivation methods

Land preparation

Yam cultivation practices in Cameroon vary from region to region. In general, yam farmers in the country prefer long fallowed land or newly opened land for yam cultivation since yam requires high soil fertility. All starts with land preparation, which generally involves manual clearing and tilling of the soil into mounds, ridges, or flat beds. Pfeiffer and Lyonga (1987) reported that the preparation of ridges takes about 35 to 40% of the working time used in yam cultivation. A few commercial farmers use tractors but most employ manual labour for this purpose. Lyonga (1976) reported that growing yams on ridges or mounds does not have any significant effect on the yield of *Oshie* white yams (Table 3). However, flat beds affect the shape of tubers and increase tissue damage due to exposure to the heat of the sun. On the contrary, Seignobos (1998) reported that at Mbe plain in Adamawa, planting on flat beds reduces the yield of *Bakokae* and *Ngang* by 30 to 35% compared to ridges. This stresses the need to determine and implement adapted planting methods that can promote yield in all the yam-growing zones.

Planting

Land preparation is followed by planting and mulching with grass during dry periods, to limit desiccation. There is no precise plant density per hectare, as farmers mostly estimate the quantity of plants in their farms, in terms of the number of ridges or estimated farm sizes. Lyonga (1976), reported that there is no significant difference in yield of *Oshie* white yam when planted at a density of 20,000 and 15,000 stands/ha (Table 3). The yield in both cases is significantly higher, compared with a plant density of 15,000 and 5,000 stands/ha (Table 3). However, average tuber yield decreases with increased plant density. Except at Mbe plain, where “Dourou” people practice mono-cropping of yams (Figure 2), farmers in the rest of the main yam-growing areas, particularly in the Western highland and forest zones, intercrop yams with maize, cocoyam, cassava, coffee, groundnuts and many other food crops (Figure 2) (Lyonga, 1976; Ngeve, 1998). This is mostly for food security, since yam is not a staple food crop, but more or less a cash crop in the country. However, reports indicate that, intercropping of *D. rotundata* with maize significantly reduces yield by as much as 57.3% (Ngeve, 1998).

Improvement of soils fertility

Although yams, especially white guinea yam (*D. rotundata*), are very demanding in soil fertility, Lyonga (1976) reported that the application of inorganic fertilizer

Figure 2. Some traditional seed yam systems, cropping patterns and ware yams marketing locations in Cameroon: (A) Small tubers selected for setts (Sorting); (B) 200-250g setts sliced from large tubers (junking), (C) section of a monocropped farm (D) yams intercropped with cocoyam, (E) section of a road side market at Mbe (Ngaoundere – Garoua highway), Adamawa Region (F) section of the terminal market at Bamenda, Northwest Region.

does not significantly improve the yield of the variety called *Oshie* white yam (Table 3). However, other studies indicate that in the Western highland the same cultivar (*Oshie* white yam), produced better yields in the presence of inorganic (especially nitrogenous) fertilizer (Ngeve, 1998). Vernier (1998) reported that the application of inorganic fertilizer negatively affects the organoleptic properties of yam tubers, and also renders them more susceptible to post-harvest pests and diseases. Besides, many farmers cannot afford these fertilizers due to high prizes. This indicates the necessity to evaluate and adopt cheaper alternatives, particularly organic fertilizers, to enhance yam production.

Field management

For weeds and pest management, a few farmers treat their seed yams with insecticides of varying names, to destroy insect pests and apply herbicides such as "Roundup" to reduce weeds. Most farmers do manual weeding and many do not treat their seed yams before

Table 3. Effects of seed-bed preparation, fertilizer application and plant density on the yield of *Oshie* yam in Cameroon.

Effect of plant pattern	Flat beds	Ridges
Total yield (MT/ha)	17.62[a]	15.70[a]
Good tuber yield (MT/ha)	15.93[a]	15.67[a]
Net loss (%)	6.4	0.19
Fertilizer application		
Fertilized	16.97a	16.16[a]
Non-fertilized	17.03a	15.30[a]
Effects of plant density (stands/ha)		
20,000	21.92[a]	
15,000	19.92[a]	
15,000	14.51[b]	
5,000	9.16[c]	

Values with different letters attached are significantly different at p=0.05 (DMRT).
Source: Lyonga (1976).

planting. Many farmers use wooden stakes to support the vines for adequate exposure to sunlight while others do not consider the practice important. Shorter stakes are preferable in the North while taller ones are preferable in the Southern part of the country (Lyonga and Ayuk-Takem, 1982). Ngeve (1998), reported that staking is not absolutely necessary for *D. dumetorum*, but for *D. rotundata* and *D. cayenensis,* providing a yield increase of 52 and 39%, respectively. The same information does not exist for other yam species and cultivars. In their quest for stakes, farmers cut down small trees which gradually become scarce and protected. Alternative staking material needs to be adopted, to save the forest.

Exploitation of wild yams by Baka pigmies

Baka pigmies of East and South-East Cameroon, carry out a form of yam cultivation called "paracultivation" on wild edible yams (Dounias, 2001). "Paracultivation" is a combination of technical patterns and social rules which structure the exploitation of wild yams. In paracultivation, a specific technical process is involved in harvesting vertical elongated tubers of paracultivated wild yams such as *D. praehensilis* and *D. semperflorens*. In the technique, the soil bordering the tuber is carefully excavated using a special auger or sharpened stick and the tubers are removed for food, making sure to preserve a portion of the tuber with the head, and to leave the terminal part of the tuber. The pit is then back-filled with a mixture of earth and humus. The refilled soil is enriched with organic matter and is less compacted than the original soil, so that new tubers encounter less mechanical resistance, during their growth and development. As such, paracultivation promotes increase tubers within each yam pit (Dounias, 2001). Paracultivation aims at encouraging production, so that the plant can be repeatedly exploited, and voluntarily maintained within its natural environment, in order to better respond to the seasonal mobility of these forest dwellers. This maintenance of plants in the forest is the key difference between paracultivation and proto-farming and is a step to yam domestication.

Several social rules which code wild yam exploitation by Baka pigmies include: Exclusive rights of ownership with possible inheritance of managed plants, ritual protection, and specific treatment which the resource receives, such as food (prestige dishes, components of bride wealth) (Dounias, 2001).

YAM CONSUMPTION AND OTHER USES

As in all countries of inter-tropical areas of the world, yam contributes immensely to food security, and has socio-cultural as well as medicinal values. Yam is consumed in various forms; mostly boiled and eaten with soup, and pounded yam (fufu), roasted, baked, or fritters in wheat flower, and as chips (Agbor-Egbe and Treche, 1995; Leng et al., 2016). It is sometime made into flour and mixed with sugar and milk particularly for consumption by children. Yam processing and transformation remain very limited, which contributes to elevated post-harvest losses. Generally, yam is not considered a staple food crop in Cameroon even among yam farmers, who consider it more, as a cash crop. This is the case with the "Dourou" people of Adamawa who carry out intensive yam cultivation for sale, but only consume it during famine (Muller, 2005). Yam is a highly solicited prestigious component of the diet, consumed by all but mostly producers and persons with a high purchasing power, considering the relatively higher cost of tubers compared with other food crops such as cereals and cassava.

The Baka pigmies of East Cameroon also exploit many wild varieties of yam for food and medicines. This is the case with *D. praehensilis,* which is used as an important starchy food, while toxic varieties are used to poison their arrows which are used for hunting (Dounias, 2001).

YAM STORAGE AND MARKETING IN CAMEROON

Storage practices

Many farmers lack adequate yam storage facilities, and have resorted to on-farm conservation of ware and seed yams. In this case tubers are left inside the soil when vines dry-off. The farmer regularly passes around to assess and cut-off sprouting shoots. Other traditional methods include silos, heap on the soil, straw shelter, shelves, and clay barns (Ngue-Bissa et al*.,* 2007). Traditional yam storage practices do not provide enough protection against rot and pests, and do not facilitate regular inspection, in order to detect damage and prevent excessive weight loss by tubers. It is necessary to improve yam storage to reduce post-harvest losses, optimize yields of the crop and consequently, encourage farmers who are key actors in the yam production chain in the country.

Yam marketing

Tubers of five main yam varieties (*D. rotundata, D. alata, D. cayenensis, D. bulbifera, and D. dumetorum)* are those commonly sold in Cameroonian markets. However, there is no standard yam market in the country. According to Ngassam et al*.* (2007), any location where yam producers and buyer's carryout their interactions maybe considered as a market or transaction point. These include farm gates, road sides (between production areas and urban cities or markets), and organized markets (local/retail markets found in villages, secondary whole sale markets based in rural areas, and terminal markets found in main towns of the country). Ngassam et al*.* (2007) also reported the existence of 53 yam markets in Cameroon, 38 of which are retail markets, 13 secondary and two terminal whole sale markets. In the country, 21% of yams are sold at farm gates, 11% at road sides and 68% in markets. Road side yam sales points in the Southwest Region are found along the Ekondi-Titi – Kumba – Buea – Douala highway; in northern part of the country along the Ngaoundere – Mbe – Garoua highway; and in the Centre region along the Mbangassina – Bafia – Ombessa – Obala – Yaounde highway.

Local markets are found in most villages where they are organized at least once a week, and help to supply whole sale markets. Secondary markets in Penda Mboko, Muea, Muyuka, and Mbonge supply whole sale markets in Douala, Yaounde, Bafoussam, Bamenda, Gabon and Equitorial Guinea. Those in Mbangassina, Ntui, Ombessa, Okola, Pouma and Mbankomo supply Yaounde; and the ones in Ngaounyanga, SasaMbersi, Karna Manga, and Wack supply Ngaoundere, Garoua, Maroua, Kousseri, Tchad, and Central African Republic.

Terminal wholesale markets are found at main towns of the country: Bafoussam, Bamenda, Bertoua, Buea, Douala, Garoua, Maroua, Ngoundere and Yaounde. However, adapted terminal wholesale markets are lacking. One of the wholesale market located at "Ancienne Gare de New Bell" in Douala, like others, lacks buildings with hygienic conditions needed to handle yam tubers.

Lack of markets (as in Mann, Sir, Deyna and Toubaga in Mbe plain), coupled with poor road networks, long distances to nearest markets, inadequate and poorly adapted transportation facilities, and heavy weight of tubers (Ngassam et al*.,* 2007), limit farmers' ability to move their goods to the markets. They are forced to sell their crops at farm gates, sometimes at very low prizes which discourage further investment in yam cultivation. Also, production basins are highly disconnected, making it impossible for farmers from different basins to interact and exchange ideas and planting material to enhance production and render yam cultivation more profitable.

Seignobos (1998) reported that 3 to 5 tubers of *Bakokae* were sold at 1500 CFA (US $2.6) in 1988. In 1997, following devaluation of the CFA, the same number of tubers of *Bakokae* and those from Nigeria were sold at 1500 CFA (US $2.6) to 2000 CFA (US $3.5) and *Ngang* at 500 CFA (US $0.9). Presently, ware yam tuber prices vary greatly with zones and seasons. During harvest, heaps of 3 to 5 medium size tubers are sold at 2000 CFA (US $3.5) at road side markets in Adamawa Region (Figure 2). The prices are much higher at terminal markets, ranging from 1000 CFA (US $1.7) for medium size tubers to 4500 CFA (US $7.8) or more for larger ones (Figure 2). At the local markets, seed yams are generally not sold as individual seeds but mostly in basins, baskets or heaps, which vary in prize from one zone to the other. Acquah and Evange (1991) reported a breakeven prize of 236.6 CFA (US $0.41) per seed yam in Fako Division, South West Region of Cameroon. The yam marketing system is not well coordinated, not adequate, and adapted markets are lacking. This makes it difficult for small holder yam farmers to reap optimum benefits from the activity.

GENETIC DIVERSITY AND CONSERVATION (GENEBANK) OF YAMS IN CAMEROON

Genetic diversity of yams in Cameroon

Cameroon has a very wide diversity of cultivated and wild edible yam species and varieties. Lyonga (1976) reported the existence of nine cultivated yam species in

Cameroon, which are: *Dioscorea rotundata* (white yam), *D. alata* (water yam), *D. cayenensis* (yellow yam), *D. dumetorum* (sweet yam or cluster yam), *D. bulbifera* (aerial yam), *D. esculenta* (Chinese yam), *D. trifida, D. librechtsiana,* and *D. schimperiana.* Of these nine species; *D. rotundata*, *D. dumetorum*, *D. alata*, *D. cayenensis* are the most popular species (Ngeve, 1998; Ngo-Ngwe et al., 2014). *Dioscorea trifida,* which was introduced in the 1970s, remained with the research program and might have been lost from the germplasm (Lyonga, 1976) due to lack of maintenance. Aerial yam is mostly cultivated as well as exists in the wild in the southern parts of the country, and *D. dumetorum* is most adapted to high altitude savannah zone (Northwest and West Regions). *D. alata*, *D. rotundata*, and *D. cayenensis* are cultivated in almost all agro-ecological zones of the country (Ngeve, 1998).

Cultivated yam species are composed of many cultivars, whose names vary with national languages (French and English), nearly 250 local languages and source of the cultivar. Some cultivars of *D. rotundata* are thus called *Bakokae* and *Ngang* in the Adamawa (Seignobos, 1998; Dansi et al., 2001), *Calabar, Malende, Oshie, Mbot, Bonakanda* (*Agar*) in the southern parts of the country (Lyonga, 1976; Mignouna et al., 2002). Similarly, some cultivars of *D. cayenensis* are called "*igname jaune*" and *Batibo*; those of *D. alata* called *Ogoja* (Lyonga, 1976) and *D. dumetorum* called "*igname sucrée*" or *sweet yam*. Sometimes different names may as well refer to the same cultivar, thereby creating confusion in assigning local landraces to given species. The most popular cultivar of *D. rotundata* are; *Bakokae, malende, Bonakanda* and *Calabar* yam; *D. cayenensis* are *Batibo* or *Nkambe* (commonly called yellow yam or Igname jaune); *D. alata* is *Ogoja.* Amongst these cultivated yam species, *Oshie* and *Mbot* are recommended for plateau regions and *Bonakanda* and *Ogoja* for lowlands, while *Batibo* is suitable for the plateau regions (Lyonga, 1976). More trials with other varieties need to be conducted, so as to determine the most adapted for each agro-ecological zone, and consequently, improve on yam production.

Dumont et al. (1994) reported the existence of high yam diversity in Cameroon, with 16 yam species. Dounias (2001) also reported the existence 17 probable rainforest wild yam species, among which 10 are edible and are exploited by Baka pigmies for food (Hladik and Dounias, 1996; Sato, 2001; Yasuoka, 2013). These edible varieties include *D. hirtiflora* Benth, *D. semperflorens* Uline, *D. praehensilis* Benth, *D. mangenotiana* Miège, *D. burkilliana* Miège (KeKe), *D. minutiflora* Engl, De Wild and Dur, and three uncharacterized species.

Further, DNA analysis using flow cytometry has indicated four ploidy levels among accessions of four yam species from Cameroon. The ploidy levels include diploid (*D. dumetorum*), tetraploid (*D. cayenensis, D. rotundata*and *D. alata*), hexaploids (*D. alata and D. rotundata*) and octoploids (*D. cayenensis*) (Ngo-Ngwe et al., 2014). Contrary to previous reports of triploids, pentaploids or octoploids among *D. alata* collections from Chad, Puerto (Muthamia et al., 2014) and IITA Ibadan (Obidiegwu et al., 2009b); Cameroon accessions lack these ploidy levels. Furthermore, only diploids have been reported among *D. dumetorum* collection in Cameroon (Ngo-Ngwe et al., 2014), yet Obidiegwu et al. (2009a), reported the existence of triploids in IITA collection. Dansi et al. (2001), using flow cytometry, also reported three ploidy levels (tetraploid, hexaploid and octaploid) in the *D. rotundata-cayenensis* complex from Cameroon. Siadjeu et al. (2015), using morphological descriptors, reported a high genetic diversity in a collection of *D. dumetorum*in Cameroon. Mignouna et al. (1998), from nuclear DNA analysis, using amplified fragment length polymorphism (AFLP), reported that *Bakokae* cultivar of Cameroon is a close genetic relative of *cv Noworfon* from Nigeria, *Gnidou* and *Terkokonou* from Benin and *cv Zrezou* from Côte d'Ivoire. Based on chloroplast DNA analysis of eight yam species from Cameroon, *D. esculenta* has the lowest phylogenetic diversity while *D. cayenensis* and *D. praehensilis* (a wild species) have the highest phylogenetic diversity (Ngo-Ngwe et al., 2015).

These high ploidy levels amongst and across yam species, in addition to the taxonomically complex nature of the genus, with a wide number of species and high morphological diversity (Mignouna et al., 2002), coupled with varying cultivar names render assessment of genetic diversity of yams in the country more challenging. Considering the importance of genetic diversity in yam breeding programs and yam biodiversity conservation, it is important for more elaborate and robust genetic studies with morphological and molecular markers associated to gain more insight into the genetic diversity of yams in Cameroon.

Conservation of Cameroon's yam cultivars (Yam genebank)

Although there have been indications of a wide diversity of yam species and varieties in Cameroon, cultivated yams in the country seem to have suffered from serious genetic erosion. Elite species such as *D. rotundata, D. cayenensis D. dumetorum D. alata D. bulbifera* are available all over, but others such as *D. esculenta, D. trifida, D. liebrechtsiana,* and *D. schimperiana* are rare, and might have been completely lost due to lack of maintenance. This has been due to lack of interest in yam research and conservation. Yam production is left in the hands of peasant farmers who may have access only to a single variety (where alternatives are not available), or use their own local criteria to select varieties they can cultivate, at the detriment of others which are left to be eroded away. There have been many attempts in

Cameroon, to collect and preserve yam germplasm. Lyonga (1976) established a germplasm collection made of 89 accessions, 11 varieties (eight local and three exotic), and nine yam species: *D. alata, D. bulbifera, D. cayenensis, D. dumetorum, D. esculenta, D. liebrechtsiana, D. rotundata, D. shimperiana and D. trifida* (Lyonga et al*.,* 1973). Other attempts to collect and preserve yam germplasm have been carried out at IRAD Bambui and Ekona as well as IITA. These collections seem to have been maintained only in the field (where they are exposed to a lot of environmental stress), without any back-up in the form of *in-vitro* culture or in cryopreservation.

Generally, these yam germplasm collections have often not included wild and sometimes edible species, which have high phylogenetic diversity and provide important resource material for breeding programs. Due to difficulties to maintain yam germplasm collection in the field, a yam genebank does not exist in Cameroon today. This absence of a yam genebank, which is a prerequisite to any yam breeding program, has probably contributed to the low yam production level in the country. This calls for an urgent need for surveys, collection, characterization and maintenance of a complete yam germplasm collection for Cameroon.

SEED SYSTEMS, GENOMICS AND YAM IMPROVEMENT

Literature indicates that yam farmers in Cameroon procure their planting material, mainly through traditional informal seed systems (sorting, weaning, junking, kin heritage, donation from friends, buying from markets, and domestication), without any quality control. Farmers reserve about a half or more of their year's harvest to use as seeds for the next planting. This traditional seed systems favour the accumulation of pre- and post-harvest diseases (fungal, bacterial, nematodes, viral) and pests, rendering planting material to lose its viability, and leads to sub-optimal yields and post-harvest tuber loss. The seed system is also characterized by low propagation rates (Balogun et al*.,* 2014). But a major pre-requisite for improved yam productivity, production and storability is the availability of high quality improved planting material (genotypes). The use of minisett technology and in-vitro culture (rarely used in the country) contribute in increasing the seed yam propagation rate, but do not have provision of cleaning infected seed yams and are genotype-dependent as well. New genetic and genomics technologies such as marker assisted selection, genetic engineering and genome editing are important tools in developing improved plant varieties (Ronald, 2014). These improved varieties are equipped with desirable traits that render the yams high yielding with enhanced nutritional content to reduce the land area exploited for agriculture; resistant to pre- and post-harvest pest and diseases to reduce yield loss while improving storability; and tolerant to environmental stress.

Among pathogens of yam diseases, viruses which reduce yield and hamper exchange of germplasm belong to six different genera and are genetically and serologically very heterogeneous with reports of the host (*Dioscorea* spp.) genome containing endogenous pararetroviruses (Bousalem et al*.,* 2009). This complicates diagnosis using the conventional nucleic acid-based and serological tools: Enzyme-linked immunosorbent assay (ELISA), polymerase chain reaction (PCR), rolling cycle amplification, recombinase polymerase amplification (RPA), which target known viruses. These still allow the spread of viruses through planting material, even those generated by *in-vitro* culture. Next generation sequencing technology which help to detect novel and pararetroviruses in planting material including *in-vitro* culture generated ones (Bömer et al*.,* 2018), will help to produce clean seed yams to boost yam production.

CONSTRAINTS TO YAM PRODUCTION IN CAMEROON

Constraints to yam production in Cameroon include; high labour cost and requirement, lack of mechanization, high cost and scarcity of seeds, poor soil fertility, pre- and post-harvest pests (insects, nematodes, rodents) and diseases (viral and fungal), lack of adequate conservation facilities, absence of improved (high yielding and disease-resistant) varieties, absence of coordinated research, and unavailable or poorly coordinated and adapted markets (Lyonga, 1976; Ngeve,1998; Ngassam et al*.,* 2007). Diseases are a very important constraint to yam production, which affects yield and quality of tubers. These diseases include anthracnose caused by (*Colletotrichum gloeosporioides*), tuber rot caused by different soil-borne fungi (e.g. *Aspergillus niger*) (Dania et al., 2016) and yam mosaic virus disease complex.

Yam virus disease has been reported to be a very important constraint to yam production, with yield loss of over 50% reported on *D. rotundata*, due to infection by *Yam mosaic virus* (YMV)*,* genus *Potyvirus* and *Cucumber mosaic virus* (CMV) - *genus* Cucumovirus (Adeniji et al*.,* 2012) in other countries of the West African yam zone, where there is regular uncertified exchange of yam germplasm (accompanied with viruses) through unchecked land borders. Viruses infect yam singly or mixed and include members of the genera *Cucumovirus, Badnavirus, Potyvirus, Macluravirus, Comovirus and Potexvirus* which have been reported in most surveys (Njukeng et al*.,* 2014). These viruses produce varying symptoms (including mosaic, shoe-stringing, chlorotic spotting, leaf crinkling, mottling, stunting) on the plants, reduce plant vigour and consequently, cause a reduction in yield and quality (Adeniji et al*.,* 2012; Njukeng et al*.,* 2014). Mvila (1991) reported the occurrence of yam mosaic disease in two regions of Cameroon and Offei

(2003) reported the occurrence of Yam virus 1(YV1) in Cameroon. Recently, Njukeng et al. (2014) reported a high incidence (81.7%) and distribution of YMV and yam badnaviruses (YBV) infecting yams in two agro-ecological zones of the country. These researchers indicate a high incidence of single infection by YMV (52%), YBV (66.2%) and mixed infection of both viruses (36.2%). However, this review indicates that research on yam virus diseases in Cameroon is still very scanty. Considering the fact that many viruses have been identified in other countries of the African yam zone where there is uncontrolled exchange of germplasm (accompanied by viruses) through unchecked land borders, it will be important to enhance research on yam virus diseases in Cameroon, to promote control measures to limit the spread and effects of these viruses within the sub region.

RESEARCH ON YAM IN CAMEROON

According to Ufuan (2010 unpublished) in a baseline survey on the capacity for yam research in Cameroon's Universities, research institutes and Non-governmental organizations (NGOs), on-going research work related to yam is scanty and current research activities on the crop are focused on nutrition, agronomy, entomology, production, agricultural economics, and postharvest technology, and marketing. It is clear from the survey that less than 30 researchers are involved in yam research and that most of these researchers are either aging and/or are part-timers. Similarly, very few students are carrying out graduate and post-graduate research related to yam (Ufuan and Njualem, 2010).

CONCLUSION

Based on the forgoing presentation of the state of yam in Cameroon, it is evident that yam production has very high potentials in alleviating poverty and improving food security in Cameroon. Cameroon has a huge diversity of yam genotypes which can be exploited in yam breeding programs. However, yam production has not been maximized due to several challenges imposed by the nature of the crop and low R & D investments on yam crop improvement. All stakeholders in the yam production chain need concerted efforts to enhance yam production in the country. Adequate funding is of capital importance.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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