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A Short Review on African Horticultural Greenhouses

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ABSTRACT

African horticulture is increasingly portable, and horticultural greenhouses have played a significant role in boosting yields, resource productivity, and income by optimizing crop production environments, preventing pests and crop exposition to undesired climatic condi- tions during critical periods. To characterize production systems, progress made, challenges and perspectives for African horticultural greenhouses. A search combining the terms "Africa", "horticulture" and "greenhouse"was conducted on Scilit with a meta-analysis of the extracted data performed on ATLAS.ti using the terms "benefit", "areas", "commodities", "labour", "irriga- tion", "soil fertility", "pest management", and "market" as key terms. Horticultural greenhouses have helped expand production, mainly to unfavourable climatic areas from the semi-aridterritories in the Sahel to unimodal rainfall regions of Sub-Sharan Africa. As a result, the Africanhorticultural sector annual earns c.a., US$ 2.7 billion, primarily from flowers, fresh vegetables,seed, and spices exported to Europe. Kenya, with 63%of the earnings share, followed by South Africa, Tanzania, Ethiopia, and Uganda, are the primary producers. Large-scale farms build costly greenhouses while resource-constrained smallholders adhere to cheaper alternatives such as high tunnels. Low wages, the predominance of non-permanent jobs, gender inequali-ties, competing claims in water use for irrigation are among the most critical sectoral constraints. Growing investment in drip irrigation and rainwater storage are alternative solutions to counter water shortage. Horticultural greenhouses are likely to expand and improve substantially shortly, but there is a need to address labour, water use a access toinvestment funds by smallholders.

Keywords: African horticulture; Greenhouse; Fresh vegetables; Market.

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RESUMO

A horticultura em África representa uma das mais lucrativas actividades do sector agrícola enos últimos anos tem beneficiado largamente da expansão das áreas de produção em ambiente controlando através de estufas. Estas estufas ajudaram a aumentar de forma significativa a produtividade e renda por conta da optimização das condições de produção evitando o ataque pragas e doenças comuns e que depreciam a qualidade da colheita em camposabertos. Com o objectivo de estudar as características da produção de hortícolas em ambiente controlado, o progresso alcançado e faturas perspectivas para África, o presente estudo foiconduzido. Publicações sobre o assunto foram buscadas online no Scilit usando os termos "África", "horticultura" e "estufa". Identificadas as publicações, foi feita a meta-análise da literatura primária publicada com recurso ao ATLAS.ti, um software estatístico largamente usado pata análise qualitativa e quantitativa de dados. Os resultados mostraram que veio ajudar amelhorar o potencial productivo especialmente em climas desfavoráveis, como territórios semi-desérticos e semi-áridos. As explorações hortícolas em africanas ganham anualmente

cerca de US $ 2,7 bilhões, principalmente exportando para a Europa. O Kenya absorbe cerca de 63 % desta rendasegui-do pela África do Sul, Tanzânia, Etiópia e Uganda. Em grandes explorações comerciais, estufas com custos que rondam os US $ 2.000 são usadas. Aos pequenos produtores cabem alternativamente os túneis altos. As principais commodities exportadas são flores, vegetais, sementes e especiarias. Baixos salários e largas horas de trabalho são um dos principais constrangimentos trabalhistas identificados neste sector que está também abraços a conflitos de extração excessiva de água dos rios. A irrigação por gota-a-gota, armazenamento de água durante a época chuvosa são algumas das alternativas usadas para reduzir o consumo de água e conflitos associados. É provável que as estufas para horticultura se expandam substancialmente em breve, mas há uma necessidade de abordar as questõesde mão-de-obra e a escassez de água.

Palavras-chave: África; Horticultura; Estufa.

INTRODUCTION

Horticulture is among the most rapidly expanding agricultural sub-sectors in Africa, highly subsidizing the countries' economies (EKESI et al., 2011; JUSTUS and YU, 2014). It enables African countries to tap global markets (LANARI et al., 2016) with other commodities than the traditional crops such as coffee, tea, and tobacco (JUSTUS and YU, 2014; ULRICH, 2014).

For instance, a single 8 x 30 m greenhouse-producing tomato in Kenya has the potential to generate revenue of at least US$ 2,600, even under extreme conditions (NJAGI, 2011). Horticulture is helping small-scale farmers shift from subsistence to sustainable and profitable farming by boosting their productivity, reducing post-harvest losses, introducing them to new market networks, and job provision (LANARI et al., 2016). Part of the production is consumed within the house-holds, contributing to food security, but most are sold at competitive prices domestically or to export markets (EKESI etal., 2011).

Nevertheless, there are emerging issues. For instance, EKESI et al. (2011) mentioned climate change and invasive species, trade and quarantine concerns, high post-harvest losses associated with poor harvest and post-harvest handling – poor transport conditions and inadequate storage, incapacity to meet international quality and safety demands due to poor local and Global GAP compliance coupled with the prevalence of unstructured and inefficient supply chains. Failure to establish appropriate support services and the desirable policy environments are also limiting factors in Africa. However, African countries have successfully minimized environmental constraints through controlled environment production in greenhouses (PACK and MEHTA, 2012; FRIJA et al., 2009; JANICK and AIT-OUBAHOU, 1989).

There are several difficulties when assessing data on African horticultural greenhouses. However, scholarly records indicate the 1980's as the introduction of horticultural greenhouses in Africa (JANICK and Ait-Oubahou, 1989; JUSTUS and YU, 2014; ULRICH, 2014; ECKSTEIN et al., 1998). The practice might have started earlier but was undermined by social issues such as internal conflicts or civil wars. Such events destabilize industry development, research, and circulation of information, making it difficult to produce reliable statistics (CAMBAZA, 2018). Furthermore, industry secrecy, asymmetric distribution of information through value chains, and the predominance of informal markets result in poor specific records about the greenhouses. Also, most challenges, including labour and water supply issues, are common to greenhouse owners and the remainder, leading most statistics to be performed without distinction between both groups (EKESI et al., 2011; LANARI et al., 2016).

Finally, large-scale greenhouse practices are still emerging in Africa (ULRICH, 2014), perhaps with little representation within the overall horticultural industry. Thus, there are many gaps and grey areas in the knowledge about African horticultural greenhouses.

According to Pack and Mehta (2012), Sub-Saharan Africa alone has 200 million people in food insecurity, from which one-third are malnourished. The same authors added that, in East Africa, malnourishment affects 60% of the population, part of which is in a situation of famine. Governments and several organizations have been searching for sustainable ways to overcome poverty. Indeed, it was the first Millennium Development Goal (MDG), and it is now the first Sustainable Development Goal (SDG) (GRIGGs et al., 2013; SACHS and MCARTHUR, 2005), and, for instance, the Mozambican Govern- ment launched the Poverty Reduction Action Plan (PARP), strongly encouraging entrepreneurship and agricultural initia-tives (FMI, 2011). After two-year research, Pack and Mehta (2012) recommended the introduction of affordable green- houses as a sustainable direction for African farmers, as they can improve the competitiveness of their products. Few other examples demonstrate how beneficial greenhouses can be to Africa (FRIJA et al., 2009; JANICK and AIT-OUBAHOU 1989); Eckstein et al., 1998), but there is no systematic analysis of how horticultural greenhouses have been handled in the conti- nent, presenting its potential, challenges, success cases, and perspectives. The current review attempts to summarize what is known so far and provide an overview to researchers.

MATERIAL AND METHODS

This study comprises a bibliographical review and meta-analysis of published literature on African horticulture. The terms "Africa," "horticulture," and "greenhouse" were introduced together on the Scilit search engine. The codes were "benefit", "areas", "commodities", "labor", "irrigation", "soil treatment", "pest management", and "market". After certifying that all articles were related to the topic, the ATLAS.ti, a software largely used to perform qualitative and quantitative data analysis of published thematic literature, was used for further analysis.

RESULTS

Production Areas

Africa is predominantly within the tropical area, but its extreme latitudes are in subtropical areas. Furthermore, the vegetation varies substantially (Figure 1), from dense forests to deserts. There are also differences in altitude, temperature, and rainfall patterns that entail highly diverse farming environments. Such differences play a significant role in shaping the crop adaptability of Africa's highly diverse agro-environments. As a result, the most crucial fresh vegetable and fruit production hubs vary in Africa.

For instance, East African farmers have of years been cultivating cash crops, e.g., tea and coffee in the sub-humid tropical highlands characterized by bimodal rainfall seasons – long and short rains with an annual dry season characterized by high water shortages (PACK and MEHTA, 2012; LANARI et al., 2016). In these environments, new horticultural farms have been expanding to arid areas, more prone to conflicts over resources – land and water, such as Laikipia Count, Kenya (ULRICH, 2014). These are also characteristically low fertility areas with a harsh dry season. As a result, the expansion of horticultural greenhouses has been significant.

In Southern Africa, particularly South Africa, there has been a significant expansion of horticultural greenhouses. In South Africa, the explosion of the fresh vegetable market in banana and other subtropical fruits-based production areas, e.g., macadamia, avocado (ECKSTEIN et al., 1998), led more farmersto invest in horticultural greenhouses. The expansion of horticultural greenhouses in South Africa was also a direct result of the growing production of export flowers and vegetables, especially in Johannesburg (DE VISSER and DIJKXHOORN, 2012).

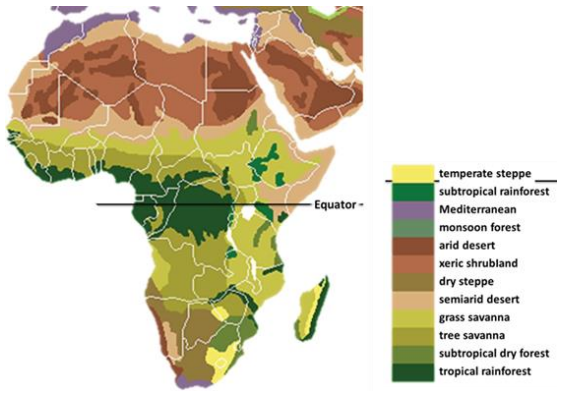

Figure 1 – The main biomes of Africa. Illustration by Koistinen [19], licensed under the Creative Commons Attribution-Share Alike 2.5 Generic.

There are very few scholarly publications describing horticultural greenhouses in African countries. The Canary Islands were technically a pioneer in greenhouse banana cultivation in the African territory (SAÚCO et al., 1992), but this is not considered in this study because the archipelago is politically part of Spain. The most frequently found data on horticultural greenhouses in Africa is related to Kenya, South Africa, Zambia, Morocco, Tunisia, Tanzania, Uganda, and Mozambique. As Table 1 shows, African horticultural products earn at least US$ 2.7 billion, and European companies are the primary buyers. Of these earnings, Kenya and South Africa represent approximately 63% and 21.1 respectively. Production in other countries such as Egypt, Rwanda, Ghana, and Nigeria might be under-reported.

Table 1 - Horticultural sales of African countries described in the scholarly literature.

Country	Main products	Major markets	Estimated annual revenue (US$)
Kenya	Flowers, fruits, and vegetables	Domestic, Europe, and the USA	1.7 billion
Tanzania	Flowers, vegetables, fruit, seeds	Europe and USA	120 million
Uganda	Fruit and vegetables	Europe and USA	100 million
Zambia	Flowers and fruit	Europe and USA	36 million
Mozambique	Citrus, banana, mango	South Africa	20 million
South Africa	Deciduous fruit, vegetables, flowers	Domestic, Europe, and the USA	570 million
Ethiopia	Flowers, fruits, and vegetables	Europe	113 million
Morocco	Banana, citrus, and vegetables	Europe	> 10 million*

Tunisia	Tomato, melon, peppers	Unspecified	20 million

Sources: Saúco et al. (1992), Frija et al. (2009), Tallontire, et al.(2005), Joosten (2007), and Janick and Ait-Oubahou (1989); *Only based on banana sales.

Elings, et al. (2015) mentioned them among the African countries where most greenhouses are concentrated. For instance, they describe greenhouse projects in Rwanda such as SMART, dedicated to tomato production, flower produc- tion at Gishali park, or the greenhouse production of tomatoes and other vegetables in Ghana. Mijinyawa and Osiade (2011) discussed 114 greenhouses in six locations of Nigeria, though they were all used for academic purposes rather than commer-cial.

East African countries seem to lead the horticultural business, and Europe is generally the primary buyer. Kenya pioneered the production for international supply chains, exporting flowers to Dutch auctions and British supermarkets (Lanari et al., 2016), Laikipia County is among the areas where the most prosperous greenhouses are (ULRICH, 2014). In 2000-2011, the number of horticultural greenhouse farms increased from 66 to (3.76 thousand km^2) to 97 (6.38 thousand km^2), i.e., 3.760 to 6.380 ha. This led to an annual increase in Gross Domestic Product (GDP) from approxi- mately 0.6% in 2002 to 6% in 2006 (Justus and Yu, 2014). According to Lanari et al. (2016), Kenya's high sales volumes stimulated flowers, fruit, and vegetables in Ethiopia, Tanza- nia, and Uganda. The increase in horticultural greenhouses in Kenya was highly motivated by better trade terms, a broader international market, high product diversification, and

increased product demand (JUSTUS and YU, 2014). In Ethiopia,approximately 2.000 ha of horticultural greenhouses produce roses, cuttings, and summer flowers produced mainly at altitudes of 1,600-2000 m (JOOSTEN, 2007).

Horticultural greenhouses are particularly important in Sahel, Northern Africa, arguably the continent's most water-limited area. Based on Frija et al. (2009) descriptions, by 2009, the total area dedicated to unheated small-scale greenhouse production in Tunisia was approximately 1467 ha, with 899 farmers managing a total of 5282 horticultural greenhouses. Approximately 572 ha (39 %) of these horticultural greenhouses are in the Teboulba region in Monastir. According to van Os et al. (2012), Algeria has two critical areas with protected cultivation: Algiers, the Mediterranean coast, and Biskra, the semi-desert south of the Rif mountains.

Commodities

African horticultural producers sell products in many forms, but they tend to abide by the end consumers' demands, mainly European (TALLONTIRE et al., 2005; EKESI et al., 2011). Fresh fruits and vegetables sold in natura of processed and flowers are essential commodities (TALLONTIRE et al., 2005; LANARI et al., 2016). A growing market for processed fruits and vegeta- bles, mainly through dried and powdered spices and juice or concentrates, is traded (EKESI et al., 2011). Morocco is an essential bridge between Northwest Africa and Europe, and it
is known to export winter vegetables and citrus to Europe. In Morocco, horticultural greenhouse production has boosted such exports (JANICK and AIT-OUBAHOU, 1989).

Greenhouses produce mainly vegetables, fruit, flowers, and spices (EKESI et al., 2011; LANARI et al., 2016; ULRICH, 2014; PACK and MEHTA, 2012). Each country or region has its range of products, depending on its own environmental, socio-polit-ical, and economic context. Ekesi (2011) presented a fairly detailed list of fruits and vegetables produced in African Horticultural greenhouses. Most greenhouses produce carrot, ginger, garlic tomato, okra, chillies, onion, lentil, pea, mush- room, French beans, sweet pepper, turnip, celery, cucurbits, asparagus, cabbage, spinach, lettuce and other leafy commod- ities. The most common fruits are citrus, pineapple, banana, avocado, mango, guava, strawberry, peach, jack fruit, papaya, pear, apple, grape, grapefruit and passion fruit. Frija et al. (2009) added melon and olive oil production in Tunisian, and VAN OS et al. 2012) added sweet pepper in Algeria. In Morocco, the success of banana production led farmers to try kiwi fruit, tobacco, table grapes, and pineapple (JANICK and AIT-OUBAHOU, 1989).

In some circumstances, East African farmers grow beans and peas together with subsistence crops or intercropped to offer hired subsistence farmers extra income and access to more competitive markets (LANARI, 2014; LANARI et al., 2016). Janick and Ait-Oubahou (1989) mentioned spring melons along the edges of Moroccan banana greenhouses.

Horticultural Greenhouses in Africa

Most used horticultural greenhouses in Africa

Greenhouses vary in climatic conditions and technological complexity used to provide adequate temperature (FRIJA et al.,2009), depending on the growth environment created for improved production per unit area and required quality (ECKSTEIN et al., 1998). There is a considerable improvement as the businesses thrive, such as steel and aluminium to replace wooden structures. According to Pack and Mehta (2012), regular greenhouses cost over US$ 2,000 in East Africa. Multi-national corporations buy them to build commercial farms throughout several hectares and grow highly profitable fruit, vegetables, and flowers. Since the price is very high for smallholder subsistence farmers, as Pack and Mehta (2012) described, they use "affordable greenhouses" or high tunnels defined as glazing structures relying on a manual ventilation system. After an assessment of Algerian greenhouses, van Os et al. (2012) stated that it is possible to invest values as low as US$ 4.77 for a single tunnel (no plastic cover) for Canarian greenhouses and US$ 45.5 for a multi-span tunnel.

High tunnels differ from standard greenhouses because they used more affordable materials, such as random polypropylene copolymer type 3 (PPR) pipes to build the framework and bolted bamboo connectors (PACK and MEHTA, 2012). They only provide intermediate climate protection, but they can create a cool microclimate during the day's hottest hours and prevent winds during the night. In their study, Pack and Mehta (2012) found that the microclimate of high tunnels allowed farmers to extend the local growing season by planting earlier than usual and extend crop growth into dry seasons, the cover-age protected the plants from detrimental insects and small animals, and ultimately increase crop productivity cost-effec-tively. There is also an abundance of multi-span tunnels and the so-called Canarian greenhouses in Algeria, often groupedin large numbers (2012).

According to Frija et al. (2009), greenhouses in Teboulba, Tunisia, have plastic covering and a framework of metal ropes without unique heating systems inside. These greenhouses are usually 7–9.6 m tall, 2.8–4.7 m wide, and up to 60 m long. Farms in Morocco seem to produce tomato, other vegetables, and fruits in a similar type of unheated plastic greenhouses, occupying 1.25 ha and 6 m high designed specially to endure strong winds (JANICK and AIT-OUBAHOU, 1989). Though they are lower in height (down to 5 m) compared to Tunisian coun- terparts, Moroccan greenhouses are more expansive (100 m) and longer (125 m). Moreover, they have several design varia- tions made specially to prevent wind damage. Eckstein et al. (1998) said South African greenhouses for banana production were like those of the Canary Islands: 6 m tall, 1 ha in the area (100 x 100 m), with wooden poles due to availability and

price. South African floriculture is a legacy of Dutch colonial settlers, who also introduced Israeli greenhouse techniques (De VISSER and DIJKXHOORN, 2012).

Most commercial greenhouses operate steadily throughout the year (LANARI et al., 2016). However, there are different ways in which farmers build and employ greenhouses, depending on the farm size, environment, type of products, and access to resources. Large-scale producers have considerable investments for irrigation, acclimating technologies, agricultural input, and skilled management, while small-scale producers (usually with less than 0.5 ha) mostly use artisanal techniques (EKESI et al., 2011; PACK and MEHTA, 2012). In Kenya, as time goes by, small horticultural greenhouses are consolidating into more extensive and intensive (JUSTUS and YU, 2014).

Benefits of Greenhouse Production in Africa

Essential benefits of greenhouses were in the introduction, but it is important to note that such benefits apply to any form of horticulture. Instead, this section will mention specific benefits of greenhouse horticulture as Justus and Yu (2014) and Frija et al. (2009) explained, and social accolades of horticultural production in general as Lanari (2016) and Ulrich (2014) presented. The latter applies equally to any form of horticulture, but it is worth mentioning why greenhouses are an asset for community development.

Justus and Yu (2014) and Frija et al. (2009) stated that greenhouses with sterilized soils: (1) allow a controlled environment with constant weather, preventing undesirable phenomena such as frost, strong wind, hail, or heavy rain, and using the soil as a free energy source; (2) allow better planning and monitoring for planting, crop management, control of humidity and carbon dioxide, increasing the accuracy of harvesting projections; (3) protect the plants against weed, pest, and disease, particularly in tropical areas.

There are benefits of greenhouses or horticulture in general beyond any direct outcome of the production of income for farmers. Instead, Lanari et al. (2016) and Ulrich (2014) mentioned the so-called multiplier effects. For instance, horticulture opens opportunities for the community to build shops around the farms and their products, and other shops sell food and other items to the employees. Horticulturists also stimulate transport services to bring the workers every day. Moreover, large-scale producers help fund healthcare centres and schools, maintenance of roads, assistance to families, and infrastructures.

It is perhaps mentioning a success story in Morocco, published by Janick and Ait-Oubahou (1989) when greenhouse production of bananas started in 1988. At that time, banana imports were no longer sustainable, and the local open-field production was minimal, with low quality yet expensive produce. The shift to greenhouse production was highly profitable, recovering the investment in one year and increasing the area from 5 ha to 720 ha from 1982 to 1988. In the end, the price per hectare was US$ 56,000-62,000. This case and others in the Canary Islands (SAÚCO et al., 1992) encouraged South African farmers to adopt the same method for banana production some years later (ECKSTEIN et al., 1998). By extension, the example from Morocco might have impact- ed agricultural practices in countries surrounding South Africa with solid commercial bonds such as Mozambique (MATSOLO et al., 2016).

Labor

Horticulture presents various employment opportunities in Africa due to its high labour-intensive nature. In Africa, labour is frequently flexible, informal, and gendered, with a significant workforce dedicated to production and post-harvest activities (TALLONTIRE et al., 2005; LANARI et al., 2016). For instance, it has generated thousands of jobs in Kenya, especially for unskilled workers, primarily women (LANARI et al., 2016), though gender differences still occur considerably (TALLONTIRE et al., 2005). Nevertheless, it is worth praising the increase from 5,900 workers in 2003 to more than 11,600 in 2014 (LANARI, 2014).

Employees have been vehemently claiming higher wages (ULRICH, 2014). According to Lanari et al. (2016), salaries areconsiderably higher in Kenya, where workers receive US$ 2-3/day. However, in Kenya, excessive working time, physically demanding work, and health hazards lead to a growing complaint about inadequate work hours (TALLONTIRE et al., 2005; ULRICH, 2014; LANARI, 2014). Out-growers need to follow to meet the increasingly strict standards demanded by the international buyers, forcing most to overload workers (ULRICH, 2014). Overtime work is another major issue, particu- larly during the peak periods of the season, i.e., at harvesting. It mainly affects non-permanent workers, especially in situations of compulsory or short-notice over time, because the employees have to compromise time already dedicated to personal duties (TALLONTIRE et al., 2005). For instance, the hired workforce is usually composed of peasants with their farms, and they end up neglecting their subsistence crops (LANARI et al., 2016).

There are three significant types of employment: casual, seasonal, and permanent (TALLONTIRE et al., 2005; LANARI et al., 2016). Informal employees usually do not participate in the trade union and lack benefits such as social security, maternity leave, housing assistance, or severance pay, and this might be especially detrimental for women, considering their responsibilities within their households (TALLONTIRE et al., 2005; LANARI, 2014). Furthermore, non-permanent workers are sometimes victims of sexual harassment and abuse, under threats of being fired or not re-hired if they refuse. The lack of representation in workers' organizations to denounce such episodes of misconduct aggravates the situation.

Women frequently receive temporary, seasonal, and casual work (TALLONTIRE et al., 2005; LANARI et al., 2016). In Kenya, South Africa, and Zambia, they make up to 50-75% of the workforce, usually performing the most labour demanding tasks such as harvesting and packing (LANARI, 2014; TALLONTIREet al., 2005). According to Tallontire et al. (2005), firms consider women more productive in such activities, stating their ability to perform tiresome and delicate work without complaining. As of 2007, all supervisors of horticultural greenhouses in Zambia were men. Tallontire et al. (2005) added that Kenyan horticultural labour has a considerably higher proportion of permanent jobs when compared to South Africa and Zambia, primarily due to the predominant export product. Flowers – Kenya's main export products – are peren- nial, constantly requiring harvesting and post-harvesting activities, and in such cases, it seems advantageous to prepare a workforce more stable, skilled, and knowledgeable about the standard to ensure high quality (TALLONTIRE et al., 2005). Special holidays such as Valentine's Day or Christmas are likely the primary reasons the industry requires extra labour from temporary, seasonal, or casual workers. Vegetables and fruit, main exports from Zambia and South Africa, respective- ly, are seasonal, making it advantageous to hire non-perma- nent employees (TALLONTIRE et al., 2005). Ethiopia's green- house flower industry presented remarkable progress in social justice, as the country had over 21,000 employees in 2005 (64.4% female) and approved a policy to raise the number to 70,000 in 2009/2010 (JOOSTEN, 2007).

Crop husbandry practices

Irrigation and Water Use

Lanari et al. (2016) said horticulture is a major water consumer, resulting in conflicts between large and small-scale farms, municipalities, and downstream users, especially in the dry season. In Tunisia, Morocco, and Algeria, the agricultural sector consumes 80% of the water (FRIJA et al., 2009). In Kenya, farmers frequently use river water for irrigation, and the population frequently accuses large-scale horticulturists of worsening water shortages during the dry season. Commercial farms require year-round irrigation in response to their demand, regardless of the period of season (JUSTUS and YU, 2014; LANARI, 2014; ULRICH, 2014, LANARI et al., 2016). How- ever, in Kenya, the law demands large scale farmers to store three months' worth of water during the rainy season (LANARI et al., 2016). However, river levels have also been declining due to variations in rainfall and possibly high withdrawals (LANARI, 2014).

Due to their semi-arid climate and variable rainfall, water use conflicts are as severe and perhaps worse in North African countries, including the Southern Mediterranean region. The latter is prone to high water losses through evaporation (HANDY, 2001).

In Kenya, horticulturists have been adhering to groundwa- ter and rainwater storage (e. g. from rainfall or floodwater) or efficient irrigation techniques to save water (LANARI, 2014) asan alternative to river water pumping. According to Frija et al.(2009), it is a standard policy in North Africa to develop irrigation infrastructure and control renewable water resourc- es, and supply policies resulted in considerable use of irriga- tion water at highly subsidized expenditure. Three ways of addressing the increasing demand for irrigation water: (1) by upgrading the administration of collective irrigation systems, encouraging users' involvement through organizations; (2) initiating a cost recovery objective to reformulate the water pricing system; and (3) encouraging the farmers to adopt water-saving technologies. From their research in Tunisia, Frija et al. (2009) found that the overall technical efficiency of the greenhouse highly correlates to the efficiency of irrigation and, ultimately, the productivity and competitiveness at a farm level.

African greenhouse horticulturists are increasingly using drip irrigation due to its water-saving advantages over other conventional irrigation methods. Drip irrigation systems can reduce water requirements by 50% in the high tunnel, compared to open field conditions (PACK and MEHTA, 2012; LANARI et al., 2016). Over 75% of the farms around Mount Kenya use drip irrigation and other efficient techniques to maximize the precision of water delivery to each plant (LANARIET al., 2016). In Teboulba, Tunisia, a well or public source
supplies tanks, usually one per farm (FRIJA et al., 2009). Water pipes or drip irrigation systems connect tanks to the green- houses. Similar irrigation systems seem to be used in Moroc- co, with dispersion by micro-sprinklers (30–50 L/plant daily).

These greenhouses also use overhead sprinklers to reduce summer temperatures and warm them during winter (JANICK and AIT-OUBAHOU, 1989). In South Africa, greenhouses for banana production use a double line drip system (0.45 m x 2 L/h drippers) for irrigation and fertigation, also with an overhead micro-system (6 x 3 m spacing, 1 mm/h precipita- tion) for cooling (ECKSTEIN et al., 1998). In Biskra, cooling also requires evaporative cooling, using a pad and fan, because of the low relative humidity (VAN OS et al., 2012).

Soils types and fertilizer use

According to Justus and Yu (2014), soil types do not seem to be the primary motivation for farmers to build greenhouses, as there is no association between the type of soil and the distribution of greenhouses throughout Kenyan highlands semi-arid zones. Instead, allocation of greenhouses seems more significantly associated with population density, average rainfall, average slope, and distribution of dams. Contrarily, the mountainous topography of northern Tunisia has little cultivable land in high rainfall areas, highly impact- ing the location of farms (FRIJA et al., 2009).

African greenhouse crops are usually planted in native sterilized soil, free of pathogens and nematodes (Justus and Yu, 2014). Roses are grown on raised beds, 60 cm above the soil, but other flowers do not require such treatment

(JUSTUS and YU, 2014). Janick and Ait-Oubahou (1989) described the

best sites for banana as low areas with deep, well-drained low-salt soil (< 1.2 g NaCl/L) with active carbamates, though they can be sandy, along the littoral coast, and they need to be protected from strong winds, using windbreaks such as cypress, acacia or bamboo around the perimeter of the greenhouse.

Systems integrating drip irrigation and a fertigation unit are standard in Teboulba, Tunisia, allowing irrigation to introduce liquid fertilizers in water (FRIJA et al., 2009). Sometimes they use a system of tubes with no particular technology for efficient water delivery. As already mentioned, a combination of drip irrigation and fertigation also seems familiar in South African greenhouses (ECKSTEIN et al., 1998). In Morocco, Janick and Ait-Oubahou (1989) reported the starting fertilizer per plant for banana as containing 100 g of triple superphosphate, 50 g of 200–300 g of N, 250–300 g of P, and 500–700 g of K. NH_4NO_5, and 50 g of K_2SO_4, and the following monthly application results in a yearly quantity of 200–300 g of N, 250–300 g of P, and 500–700 g of K.

Integrated Pest Management

Through studies in Kenya, Lanari et al. (2016) observed that across most horticultural greenhouses, the use of agrochemicals - pesticides, herbicides, insecticides, and inorganic fertilizers is highly correlated with the type of product and also the level of resource endowment. Arthropod pests are the primary reason African horticultural production is insufficient to meet the demand (EKESI et al., 2011). Thus, their control is a key to increasing production and improving livelihoods. There have been successful efforts to introduce biological control agents in several countries (Table 2), mainly to counter attacks in fruit orchards. Flowers do not suffer as much from the burden of pests, possibly because restrictions for the use of chemical pesticides are not as severe as for food (LANARI et al., 2016). Most research in this field occurred in Kenya and East African countries, but studies from virtually all Sub-Saharan Africa (EKESI et al., 2011).

Janick and Ait-Oubahou (1989) mentioned the most important pesticides used in Moroccan greenhouse production of bananas. First, they treat the seedlings with nematicides such as organophosphates or carbamates. In severe infestations, they apply these compounds at intervals of 1 to 3 months. They also expose the soil to sunlight before planting and soil nematicides. Furthermore, they were planning to introduce methyl bromide for new seedlings. In their study based on Algerian multi-span tunnels, van Os et al. (2012) recommended using insect nets to prevent Tuta absoluta, whitefly, and trips when they are open for some ventilation.

Janick and Ait-Oubahou (1989) used fungicides to control Verticillium theobromae, the mould responsible for cigar stub. Regarding viruses, the authors recommended prevention by purchasing disease-free stocks produced through tissueculture, and they said this is the best option to control any pathogen. It also helps to ensure uniformity of the product, especially if the seedlings come from the same plant. After five harvests, the farmers uncover the greenhouses for solarization during summer, remove all plant material, and treat the soil with a nematicide.

There are health and environmental risks associated with chemical pesticides and fertilizers. For instance, Lanari et al. (2016) warned about such risks to floriculture workers, even though they wear masks because legislation regarding exposition to chemicals for flowers is strict. They also mentioned that such chemicals might wash into rivers or water tables, resulting in environmental issues.

Table 2 – Example of African success cases in insect biological control.

Country/area	Culture	Pest	Biocontrol agent	Level of success
East Africa	Cabbage and kale	*Plutella xylostella*	*Diadegma semiclausum*	≤ 66%
Kenya	Vegetables, fruits, and flowers	Thrips	*Metarhizum anisopliae*	> 70%
Kenya, Mozambique, Benin	Fruits and vegetables	Tephritid fruit flies	*Fopius arisanus*	> 40%
Uganda, Kenya, Tanzania, Malawi	Citrus, coffee, and guava	*Aleurothrixus floccosus*)	*Cales noacki*	Very effective
Nigeria	Mango and citrus	*Rastrococcus invadens*)	*Gyranusoidea tebygi* + *Anagyrus mangicola*	81–100%

Source: Based on Ekesi et al. (2011).

Market

Most Africa-based large commercial horticultural companies have guaranteed market access, with minimal government intervention in trade. However, governmental assistance through the development of support infrastructures led to considerable growth of the horticultural sector (Ekesi et al., 2011). Janick and Ait-Oubahou (1989) stated that greenhouse horticultural success in Morocco was due to grower competency and entrepreneurial skills vigorously exploring high-tech agricultural service industry with the availability of government credit and support of education, extension, and research organizations.

Most African horticultural greenhouses grow products for domestic and export markets (Ekesi et al., 2011; Lanari et al., 2016). A relatively smaller quantity is produced for subsis-

tence or sold at farm gate prices in the surrounding rural areas (Ekesi et al., 2011). In Algeria, most of the local greenhouse produced vegetables is consumed locally, with the country

exporting very little (van Os et al., 2012). Several reasons can explain this situation. Among them is that the sector produces a slight surplus, and the population has enough purchasing power to sustain the market. Alternatively, it might be because

the local products do not meet the quality standards introduced in significant export markets.

According to van Os et al. (2012), whole-sale markets sell vegetables, rarely sorting, grading, cooing, packing, or any form of marketing. Sometimes exchanges occur between neighbouring countries, but the important destinations of the products are Europe, the USA, Saudi Arabia, and South Africa (EKESI et al., 2011). South Africa is the official African intermediary between the surrounding countries' and non-African companies (Cambaza et al., 2018a).

Most fresh products go to European countries, especially Belgium, France, Germany, Italy, The Netherlands, the UK, and Switzerland (EKESI et al., 2011). Based on studies performed in Kenya, South Africa, and Zambia, Tallontire (2005) described two primary ways the products enter the European market: UK retailers and Dutch Auctions. According to these authors, European countries buy 66% of South African deciduous fruit exports, 94% of Kenyan flower exports, and all Zambian vegetable and flower exports. UK retailers import 75% of the fruit and vegetables and 50% cut-flower among these products. Dutch Auctions are the world leader in sales of cut flowers, obtaining most of the Sub-Saharan African cut flowers. For instance, it imports more than 90% of Zambian export-quality roses and over two-thirds of Kenyan cut flowers. The auctions are likely the easiest way to export African flowers because they are relatively less regulated than UK retailers.

According to Ekesi et al. (2011), the value chain components receive information disproportionately, and such a lack of coordination renders the entire system highly inefficient. Tallontireb et al. (2005) recommend integration through multi-stakeholder participation to promote fairness and give the entire industry more stability. For instance, gender issues result from the pressure imposed by the buyers and the frequent perception among producers that male and female employees excel at different skills.

Future Perspectives

Horticultural greenhouses and high tunnels are likely to become more common in Africa due to their evident advantages and success stories. For example, Elings et al. (2015) recently presented strategies to enhance the Ghanian greenhouse horticulture sector. Unfortunately, the minimal volume of scholarly reports on the subject suggests that they are under-reported, especially considering the high level of finan-

cial success and sustainability in different areas of Africa. In part, the limited information might be due to research still undergoing, waiting for conclusive results, or even industrial secrecy to prevent competition. In truth, once the product makes into the market, it is hard to distinguish if it comes froma greenhouse or open field and, from a consumer's perspec- tive, it might not even matter. In any case, as small-scale farmers and companies start using high tunnels or greenhous- es, incentives rise, and research and academic institutions expand through Africa (Cambaza et al., 2018b), there will be anincrease in the volume of publications on the subject soon.

Changes in the policy environment will likely affect the landscape of the trade practices and, ultimately, production and labour. Since supply chains are demand-oriented (TALLON- TIRE et al., 2005), European consumers and companies have the "upper hand" regarding decision-making on how the products should be. The consumer end is pressuring towards gender equality and social security throughout the African value chains (TALLONTIRE et al., 2005) but, on the other end, the industry itself is not offering decent wages considering the work overload (TALLONTIRE et al., 2005; LANARI et al., 2016). Thus, gender issues will probably improve, but the salaries will not increase considerably, and they might even remain steady or decline, especially for temporary or casual workers, unless competent authorities draw some efforts to change the scenar-io.

It seems that the technical part (labour and resources) of horticultural greenhouses will improve due to development itself. Successful cases are already encouraging new initia- tives, resulting in a feedback loop between investment and returns. These predictions seem optimistic in Kenya due to the high proportion of permanent jobs (TALLONTIRE et al., 2005), a thriving cut-flower industry, employees' opportunity to improve their skills, improving and source-diversified irriga- tion (LANARI et al., 2016), and new low-cost alternatives such as high-tunnel (PACK and MEHTA,2012).

CONCLUSIONS

Horticultural greenhouse systems in Africa are still emerging, and there are several challenges to gain a "mainstream" status, but the evidence so far showed their potential to improve the production of several commodities all over the continent. Africa is not a monolith, and challenges vary with countries or areas. However, there is an everyday necessity to ensure and possibly standardize certain environmental condi-

tions to grow some crops because most value chains are consumer-driven, and the buyers are the same. Furthermore, policies are increasingly demanding, not just by requiring certain levels of quality and safety but also by demanding a particular set of practices such as gender equity and social justice throughout the value chain.

Farmers shall find sustainable ways to address four signifi- cant issues: greenhouse affordability, low wages, gender inequity, and water shortage. Regarding affordability, high tunnels are a promising direction as a kick-start for small-scale farmers into more competitive markets. Labour and water issues can be resolved through policymaking and enforcing, and initiatives integrate entire value chains to promote social justice, fair trade, and a more homogeneous distribution of information. Regarding water, efficient irriga- tion and water sources alternative to rivers also seems the positive steps to follow.

Pest management also requires some attention, but it has already been improving considerably due to the wonders of biotechnology and the transfer of pests' natural enemies from some areas to others. Still, despite the current and emerging challenges, it seems safe to assume that horticultural greenhouses systems have been an asset to African economies, and they shall be encouraged to subsistence farmers to alleviate poverty.

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