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Grower's Guide: A Review for Sustainable Production of Okra (Abelmoschus Esculentus) in West Africa and Other Regions

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Abstract: This paper provides detailed information specifically the botany, history, and current statistical report on okra as well as how it is cultivated. Major biotic and abiotic stress factors impeding the production of okra and the sustainability aspect in the production of the crop are discussed. Many reasons for poor growth and development, low yield of okra as well as seed dormancy or okra plant death are mentioned. These include poor quality of seed and some biotic stresses particularly yellow vein mosaic virus (YVMV) and abiotic stresses such as salinity, drought, various water stresses and high moisture content. However, okra as a tropical and subtropical crop is drought-resistant, thus does well under drought conditions. Notwithstanding, high moisture content, salinity, and the yellow vein mosaic virus disease are the major factors affecting the crop. These conditions especially the yellow vein mosaic virus disease reduce okra yield to about 94% depending on the time of infestation after germination. To control the mosaic virus disease, very limited success has been achieved by chemical methods (including the application of neem oil, Acetamiprid, Imidacloprid and Trizophos), which also are not permanent since some resistant cultivar become susceptible with time. Therefore, advance breeding and development of host resistance to viruses and measures to combat salinity are the important strategies against these impeding conditions.
Keywords: Okra (Abelmoschus esculentus), okra production, yellow vein mosaic virus, stress factors, salinity

I. INTRODUCTION

According to a World Bank Report on West Africa Agricultural Productivity Program (WAAPP), agriculture provides 65 percent of employment and 35 percent of GDP in Africa, yet poverty remains severe in rural areas where most of the population relies on agriculture for a living. Sustainable agricultural growth may be a transformative strategy for poverty reduction by increasing farm revenues, creating jobs, and lowering food prices. This cannot however be achieved when procedures and knowledge about the sustainable production of major traditional crops in West Africa, such as okra are not clearly stated and widespread among the targeted audience.

Among many grown traditional crops is the West African Okra [*Abelmoschus caillei* (A. Chev) Stevels], a versatile annual, biennial, and occasionally perennial woody crop plant that grows widely in the humid West African sub-continent (Osawaru and Dania-Ogbe, 2010). Common okra (*Abelmoschus esculentus*) and West African okra are both used in West and Central Africa and accounts for around 10% of global okra production (Kumar *et al*., 2013). However, both varieties together provide food, feed and fibre for many poor inhabitants of the region who rely on agriculture for livelihood. Today, due to climate change and other factors, crops are ruined by pests including the okra crop which experiences a loss of up to 94 per cent from whitefly infestation (Chattopadhyay *et al*., 2011). To ensure a sustainable production of okra and reduce these losses particularly in West Africa, this paper provides detailed information specifically on the botany, history, current statistical data and a production blueprint that will aid growers. Major biotic and abiotic stress factors impeding the production of okra and sustainable remedies are discussed.

II. BOTANY

Okra (Abelmoschus esculentus), previously named Hibiscus esculentus (L.)
is the only vegetable crop of importance and significance in the Malvaceae family (Kumar *et al*., 2013; Gulsen *et al*., 2007). It is a tropical and subtropical vegetable mainly grown in warm weathers. Despite detailed classification and scientific name (Table 1), okra is called differently in different parts of the world. These include locally given names such as, Kacang Bendi, Qiu Kui, Okra, Okura, Okro, Quiabos, Ochro, Quiabo, , Gumbo, Quimgombo, Bamieh, Bamya, Quingumbo, Bamia,Ladies Fingers, Bendi, Bhindi, and Kopi Arab(Kumar *et al*., 2013).

Of all the species studied Abelmoschus esculentus has proven to be highly productive. It accounts for 90 percent of commercially grown okra. Probably, Abelmoschus esculentus (2n =130) is an amphidiploids (allotetraploid) which is derived from a wild species native to India, Abelmoschus tuberculatus Pal & H.B.Singh (2n = 58), and a species with 2n= 72 chromosomes (possibly Abelmoschus ficulneus (L.). According to Kumar et al., (2013), there are strong evidences suggesting that another species Abelmoschus caillei is also an amphidiploids with Abelmoschus esculentus being one of is parents. They mentioned that, of all common oka cultivars including the better known Clemson Spineless, Indiana, Emerald, and Pusa Sawani which have been used for about 30 years ago, none has shown any difference in use, thus making the common and West African okra not different. Morphologically Abelmoschus caillei is different from Abelmoschus esculentusin many ways. The epicalyx provides the most appropriate differentiating characteristic showing that the width of the epicalyx segments is 0.5–3 mm in Abelmoschus esculentus and 4–13 mm in Abelmoschus caillei (Kumar et al., 2013).

Table1 Botanical classification of OKRA

Botanical classification	
Kingdom	Plantae
Division	Magnoliophyta
Class	Magnoliopsida
(Unranked)	Rosids
Order	Malvales
Genus	Abelmoschus
Species	A.Esculentus
Binomial name	Abelmoschus esculentus

III. HISTORY OF OKRA

Okra is one of the oldest cultivated vegetable crops. There is no unanimity over the geographical origin of okra. Some opined that okra originated in West Africa, East Africa, particularly Ethiopia, and South Asia (Aprilliz, 2017). According to Benchasri (2012) okra originated somewhere around the Ethiopia. It was cultivated by the ancient Egyptians since 12th century BC. In later years, the cultivation of okra spread throughout the Middle East and North Africa, and today, the crop is grown in many parts of the world, especially in tropical and sub-tropical regions.Okra is sensitive to frost, low temperature, water logging and extremes drought conditions. The cultivars in different countries have certain adapted distinguishing characteristics specific to the country to which they belong (Kumar et al., 2013). According to Lamont (1999) okra extended to the Caribbean and the United States in the 1700s, with claims that the crop was carried by slaves from West Africa, and was introduced to Western Europe soon after. In 1781, former U. S. President, Thomas Jefferson recorded the presence of okra in his garden (Lamont, 1999). The crop marched northward and was found in Philadelphia in 1781 and from 1800 onward it was mentioned by many garden writers (Lamont, 1999).

The Créoles in Louisiana learned from slaves the use of okra (gumbo) to thicken soups and it is now an essential phenomenon in Créole Gumbo. Okra can serve vast economic purposes as it can be grown on a large commercial farm or as a garden crop. Currently, okra plants are grown commercially in many countries such as India, Japan, Turkey, Iran, Western Africa, Yugoslavia, Bangladesh, Afghanistan, Pakistan, Myanmar, Malaysia, Thailand, India, Brazil, Ethiopia, Cyprus and in the Southern United States (Benchasri, 2012).

IV. USE OF OKRA

Okra is a versatile vegetable crop with almost all of its parts having one or other use (Lamont, 1999). Away from its known economic value, okra has medicinal uses and health benefits with abundant nutrients (Kumar *et al*., 2013; Lamont, 1999). As a dicotyledonous plant, the fruits, seeds, leaves, and stems of okra plants are useful. These parts can be used as food, for pulp production for making paper, and other materials (Lamont, 1999).

1) *OKRA As Food:* The fruits (pod) of okra plants can be boiled, cooked in soup or fried and consumed by humans and other animals. The fruit has a mucilaginous texture, and a very special taste. In West Africa, the pods can be sun-dried and eaten also. From the pods, seeds can be extracted and eaten separately or used for other purposes.

At the same time, the tender leaves of okra are often consumed as a vegetable in Western Africa, South-eastern Asia and other areas where a wide range of leafy vegetables are often consumed. However, the leaves of some varieties are to some extent hairy which is not desired by some people and leaves are cooked to reduce the feel of the hair. The tender shoots, flower buds, and calyxes are often eaten along with the leaves (Lamont, 1999). Okra is a source of oil and protein which are consumed. Okra seeds have a high content of unsaturated fatty acids, such as linoleic and oleic acids which are about 70%. The keeping quality of the oil is poor. It is readily hydrogenated into a solid and can be used as margarine. Okra has a high protein content that ranges from 18% to 27% that is very useful to the human body when consumed.

2) *OKRA Can Also Serve As A Substitute For Coffee:* Mature dried seeds of okra can be roasted and ground as a coffee substitute or added to coffee as an adulterant. Using ground okra seeds to make a coffee is widespread in El Salvador, and other parts of Central America, Africa, and Malaysia (Lamont, 1999). Coffee brewed from okra has a good aroma, but it lacks the stimulating effect of caffeine.
3) *OKRA Seeds Can Also Be Used To Make Curds:* Curds made from okra seeds have a creamy or light yellow color, a background flavor similar to that of tofu (vegetable curd made from soybeans). Okra vegetable curd has one drawback. Okra seeds contain the toxic pigment gossypol (or a gossypol-like compound), which can be disolved in oil and, thus, is included in the curd at concentrations that are much higher than in the original seed. To avoid possible long-term toxicity, it is best to remove the gossypol, as in cotton seed oil (Lamont, 1999).
4) *Medicinal Uses:* Okra roots are used for medicinal purposes.The roots are very rich in mucilage, having a strongly demulcent action.This mucilage can be used as a plasma replacement. An infusion of the roots is used in the treatment of syphilis (Kumar *et al*., 2013). The juice of the roots is used externally in Nepal to treat cuts, wounds and boils. The leaves furnish an emollient poultice. A decoction of the immature capsules is demulcent, diuretic and emollient. It is used in the treatment of catarrhal infections, dysuria and gonorrhoea (Kumar *et al*., 2013).
5) *Paper Making:* Okra can be used for making paper pulp. The fiber of the okra plant, like that found in other plants of the Malvaceae family which okra belongs to, is a suitable material for making paper. Okra stems contain longer fibers in their woody cores than most other dicotyledonous plants and these can be used for paper making. Additionally, when okra pod is boiled, it becomes highly mucilaginous. This mucilage has been used as a spreading agent in the manufacture of paper in Malaysia (Lamont, 1999).
6) *OKRA Plant As Fuel Wood:* When okra stems are thoroughly dried, they form good and inexpensive fuel wood.

V. AREA, SPREAD AND PRODUCTION

Okra is produced in many parts of the world. Almost all continents of the world produce okra. However, Europe, including the Scandinavia, North America and other cold regions are among the least okra-producing continents and lack authentic records regarding the crop. According to the Knoema (2019), the okra production in Europe fluctuated substantially in recent years, and tended to decrease through the period of 2000 - 2019, and ended at zero production in 2019. Thus, these regions are not important okra-producing regions due to their climate and cultures. The most important okra-producing countries are India, Nigeria, Sudan, Pakistan, Ghana and Egypt (Benchasri, 2012; Doymaz, 2005). However, recent statistics published by Atlas Big on the production of okra indicates that the top ten world okra-producing countries are: India, Nigeria, Sudan, Mali, Pakistan, Cote d'Ivoire, Cameroon, Ghana, Egypt, and Malaysia (Table 3).

Table 3.Top ten okra producing countries in the world (Source:Atlas Big, 2020)

Country	Production (Tonnes/year)	Availability (kg/capita)	Area (ha)	Yield (kg /ha)
India	5,507,000	4.12	485,000	11,354.6
Nigeria	1,978,286	10.02	1,463,46	1,351.8
Sudan	287,300	7.04	26,754	10,738.6
Mali	241,033	12.61	21,488	11,217.1
Pakistan	117,961	0.58	15,584	7,569.5
Cote d'Ivoire	112,966	4.54	41,035	2,752.9
Cameroon	90,780	3.82	33,377	2,719.8
Ghana	66,360	2.24	3,160	21,000
Egypt	57,721	0.59	5,033	11,467.4
Malaysia	55,856	1.71	3,692	15,128.9

The global production of okra (both common okra and West African okra) as fresh fruit-vegetable is estimated at 8.9 million tonnes per year according to Atlas Big 2020 statistics and other reports. Common okra makes up about 90% of this quantity. It is only in West and Central Africa (accounting for about 10% of world production) that common okra and West African okra are both used. They share the market equally in this region of the world (Kumar *et al*., 2013). The total area of okra-production has increased over the years (Benchasri, 2012). In 1991-92, the total cultivated area under okra was 0.22 million hectares and the production was 1.88 million tonnes. Between 2006-07, the area increased to 0.396 million hectares and the global production also increased to 4.07 million tonnes. In 2009-10, the area increased to 0.43 million hectares and the production to 4.54 million tonnes (Benchasri, 2012). In 2012, production reached 6 million tonnes (Kumar *et al*., 2013; Benchasri, 2012), before reaching the current 8.9 million tonnes. It is expected to increase further between 2021 and 2028 according to the Fortune Business Insight recent (2021) report on okra seed market size, share, and industry.

VI. CROP PHYSIOLOGY

1) *Seeds:* Okra is a vegetable crop propagated by seeds. They must be of quality, placed in the suited climatic condition and given care and attention for proper growth and yield. There are many reasons for poor growth, development and low yield of okra. Poor quality of seed and climate change cause some biotic stresses particularly yellow vein mosaic virus (YVMV). Abiotic stresses such as salinity and water stresses are some of the most important reasons for low yield and even plant death.
Furthermore, it is good to note the species and varieties before propagation as some cultivars belonging to specific species or varieties of okra have longer production cycle and others may react slight differently to conditions such as salt and moisture content during germination and vegetative stages (Shahid *et al*., 2011; Babalola *et al*., 2020). The genus *Abelmoschu*s, of okra has four domesticated species known today (Babalola et al., 2020). These include *A.esculentus* (common okra) which is the most widely cultivated species in many parts of the world including South and EastAsia, Africa, and the southern USA. The next species is the *A. caillei* (West African okra). This species has a longer production cycle, and it is mainly cultivated in the humid zone of West and Central Africa (Babalola *et al*., 2020). In some countries such as Solomon Islands and Papua New Guinea, *A. caillei* is cultivated for its leaves as it does not flower and develop pods. *A.moschatus* is another domesticated species mainly cultivated for its seed. What is interesting is that, not all of these species can do well under the same cropping systems and growth conditions especially at the germination stage. Commercial okra growers usually practice sole cropping, and prefer the early, homogeneous and introduced cultivars. In traditional agriculture which is mostly done for subsistence, farmers grow okra landraces in home gardens or in fields with other food crops (Benchasri, 2012). In West and Central Africa, the land races often consist of a mixture of *Abelmoschus esculentus* and *Abelmoschus caillei;* with *Abelmoschus esculentus* being predominant in dry climates, while *Abelmoschus caillei* in humid climates (Benchasri, 2012). Under humid tropical conditions a full grown okra crop consumes about 8 mm of water per day to support all physiological aspects of the crop (Benchasri, 2012). In West African Countries, including Nigeria which is the world's second highest okra-producer, okra is produced mainly during the rainy season, even though, depending on varieties used, it can be grown all year round with the aid of irrigation (Babalola *et al*., 2020). Okra seeds must be disease freed, of good quality and moist (not fully wet) for optimal germination. High moisture content usually leads to seed dormancy. Marsh (1993) reported that high moisture greatly decreased the emergence of okra (var. Clemson Spineless) causing 83% dormancy and just 17% of emergence after 22 days of planting. It is therefore important to keep the seed and the soil relatively less moist.
2) *Biotic stress:* Many pests and diseases infest okra plant at different stages during cultivation. However, these can be controlled or avoided by proper management and good cultural practices - except for the yellow vein mosaic virus which offers different condition. The yellow vein mosaic virus often infest the okra plant at the vegetative stage (after germination). The symptoms are mostly found three weeks after planting in the young leaves. It begins by leaf yellowing, and later move to leaf distortions, vein clearing, mosaic, leaf curling, leaf puckering or blistering, chlorotic spots, upward leaf curling along the edges of leaves and stunted growth.The disease yellow vein mosaic virus which is transmitted by the whitefly (*Bemisia tabaci*) (Chattopadhyay *et al*., 2011; Kumar *et al*., 2017) is reported to be one of the most destructive plant diseases in India and other parts of the world. The mosaic virus causes great loss by affecting quality and fruit yield as high as 93.8% depending on age of plant at the time of infection (Chattopadhyay *et al*., 2011). Control of the mosaic virus is nearly impossible, but whitefly which is the source of the virus can only be prevented by conventional means of insect pest control. The virus produces typical vein yellowing and thickening of leaves forming a network of veins and veinlets in the infected leaves. In the beginning, the leaves exhibit only yellow colored veins but under severe infection, the leaves become completely chlorotic and turn yellow.

There will be reduction of leaf chlorophyll and the infected plants give a stunted look and produce small-sized pale yellow fruits (Kumar *et al*., 2017). The virus reacts differently based on the age of the infected plant. According to Kumar *et al*. (2017), the growth of plants infected within 20 days after germination, is retarded; few leaves and fruits are formed and loss may be about 94%. They reported that the extent of damage declines with delay in infection of the plants. Plants infected with the virus 50 and 65 days after germination suffer a loss of 84 and 49%, respectively (Kumar *et al*., 2017).

3) *Management Of The Mosaic Virus:* The yellow vein mosaic virus is nearly impossible to control. White fly is the main agent responsible to transmit the viruses that leads to yellow vein mosaic virus disease. Therefore, management of this disease turns around the control of this vector (whitefly). In addition to removing different host plants from all corners of the field and other practices, application of agrochemicals like Acetamiprid, Imidacloprid and Trizophos record positive effect towards reducing the incidence of the virus (Kumar *et al*., 2017). The use of different eco-friendly management agents like mixture of oil (0.5%) and washing soap (0.5%), marigold as trap crop planted in between rows of okra and spray of imidacloprid (0.05%) are effective. Neem oil and imidacloprid, each applied independently also significantly reduced the pest population with imidacloprid having a reduction of 90.2% (Kumar *et al*., 2017). But with time, the whitefly tend to resist most of these chemicals and cause even more damage. Therefore, breeding a resistant cultivar to the the mosaic virus is important since the virus is taking the center stage in West Africa other parts of the world. Unfortunately, the availability of source of resistance for the virus is limited in the cultivated species of Okra. However, wilds pecies *A. manihot* ssp. *manihot*, *A. callei* and *A. tuberculatus* are reported to be resistant against yellow vein mosaic virus. But these varieties become susceptible in 2-3 years. This breakdown in resistance probably happens due to development of new strains of the virus (Kurmar *et al*, 2017). Therefore, advance breeding technique is recommended for the improvement of okra.
4) *Salinity:* The decline in optimum yield of okra is also due to salts, which are deposited in soil by the use of brackish underground water and addition of industrial effluents in our canals which also adds salts in irrigation water. This application of saline water reduces the transpiration and causes an imbalance in evapo-transpiration rate and induces the reduction in yield (Shahid *et al*., 2011). Among the abiotic stresses such as heat, cold, drought and salinity the salt stress exerts more drastic effect in terms of low productivity (Shahid *et al*., 2011). Even though okra is a C_4 plant (Mncube *et al*., 2017), high salt contents in okra plant reduce the growth and production by affecting physiological processes, including modification of ion balance, water status, mineral nutrition, stomatal conductance, and most importantly the photosynthetic efficiency (Shahid *et al*., 2011). Salt stress affects okra plant physiology at both whole plant and cellular levels through osmotic and ionic stress. Some of the ways are through the accumulation of salt in the roots and leaves. High concentration of salts in the root zone decreases soil water potential and the availability of water. This deficiency in available water under saline condition causes dehydration at cellular level leading to osmotic stress. The excessive amounts of toxic ions like Na^+ and Cl^- create an ionic imbalance by reducing the uptake of beneficial ions such as K^+ , Ca^{2+}, and Mn^{2+} (Shahid *et al*., 2011). The higher ratios of toxic salts in leaf apoplasm lead to dehydration and turgor loss and death of leaf cells and tissues. Salt stress has various effects on okra plant physiological processes such as increased respiration rate and ion toxicity, changes in the plant growth, mineral distribution, membrane instability resulting from calcium and potassium displacement by sodium, membrane permeability, and decreased efficiency of photosynthesis. The most important process that is affected by salinity is photosynthesis. Reduced photosynthesis under salinity is not only attributed to stomatal closure leading to reduction of inter cellular CO_2 assimilation, but also to non-stomatal factors like reduction in green pigments and leaf area. There is increasing evidence that salts affect photosynthetic enzymes, chlorophylls and ionic contents (Shahid *et al*., 2011). Additionally, high ratios of salts in root zone affect different processes like root density, root turgor pressure and its growth, and ultimately create hindrance in water absorption. Okra plant at earlier growth stages is more sensitive to salinity, as it affects water relations and nutrient uptake of plants, while the ionic stress in turn reduces leaf expansion. During long term exposure to salinity, plants experience ionic stress, which can lead to premature senescence of adult leaves and thus reduction in photosynthetic rate is a common observation. Salinity changes photosynthetic parameters, including osmotic and water potential, transpiration rate, leaf temperature and relative leaf water content.

Shahid *et al*. (2011) reported that plants grown under the highest (75 mM) salt stress showed the lowest values (8.44 cm) of root length indicating that salt stress affect root length. A significant reduction in plant height was also noted in all the plants grown at different salinity levels. The maximum plant height of 45.67 cm was observed in plants grown under control while the salinity levels of 25, 50 and 75 mM NaCl showed the values for plant height as 41.98, 34.02 and 26.33 cm. It is therefore clear that salinity level 75 mM exerted the maximum drastic effects on plant height as compared to the control and other salinity levels. The salinity also influenced the yield of okra by affecting both the pod weight as well as pod length. Similarly, maximum decrease in pod weight was recorded at 75 mM followed by 50 and 25 mm.

The plants grown under 75 mM showed the minimum (5.39 g) as compared to the non-saline control with highest pod weight (7.06 g). The salinity levels 25 and 50 mM showed the moderate pod weight values of 6.76 and 5.98 g, respectively. Similarly decline in pod length was observed at all salinity levels with maximum reduction at 75 mM and minimum reduction at 25 mM salt stress while control exhibited the maximum pod length followed by 50 mM. also It also confirmed that the photosynthesis rate and stomatal conductance are also influenced by salinity in all the plants grown under saline environment. The highest salinity (75 mM) caused the maximum reduction in both photosynthesis rate and stomatal conductance as compared to the low salinity. In addition to this, many studies also confirmed this negative physiological impact of salinity stress on okra. A1Taey (2017), reported that soil salinity reduced water availability to plant roots via negative (low) osmosis potential, as well as decrease in germination dynamics of plant seeds by ionic toxicity of Na and Cl. Significant differences were found in fruit-set, yield, photosynthetic rates, stomata conductance and total chlorophyll content as compared to non-saline condition. In general, salinity affects almost every aspect of the physiology and biochemistry of plants (AlTaey, 2017) and it is one of the major challenges facing the okra crop in Asia and Africa. Therefore, it is important and recommended to keep the soil pH between 5.8 and 7.0. Additionally, some cultural practices can also be performed to influence different growth regulators so as to create positive impact on pod weight, plant height, root length, shoot length etc. These plant growth regulators affect various aspects of plant physiology, mainly vegetative and reproductive traits including yield and seed production. Different concentrations (0, 50, 100 and 200 ppm) of gibberellic acid and naphthalene acetic acid, alone or in different combinations had positive impact on plant growth, pod production, seed yield and seed quality. Growth regulators are less effective when applied individually as compared to their combined use. However, performance of plants treated with individual plant growth regulators can be better than the untreated plants. The number of leaves per plant and plant height can be higher in okra plants when sprayed with gibberellic acid and naphthalene acetic acid at the concentration of 200+100 ppm as well as with gibberellic acid and naphthalene acetic acidat 200+200 ppm. The number of pods per plant, pod length, pod fresh and dry weight, seed yield and seed quality (in terms of germination percentage and 1000-seed weight) can also be at the maximum level in okra plants receiving foliar spray of both gibberellic acid and naphthalene acetic acidat 200+200 ppm (Shahid *et al*, 2013). These signify the role of gibberellic acid and naphthalene acetic acid in okra pod production for fresh consumption as well as for seed yield.

VII. OKRA PRODUCTION: BLUEPRINT

A. Start

The crop rotation practices (*Figure 1*) are very important as they promote sustainability, minimize disease infestation and have large ecological benefits. Okra must be planted after spreading compost and planting cover crop:

1) The protective canopy formed by a cover crop reduces the impact of rain drops on the soil surface thereby decreasing the breakdown of soil aggregates. This greatly reduces soil erosion and runoff, and increases infiltration. Decreased soil loss and runoff translates to reduced transport of valuable nutrients, pesticides, herbicides, and harmful pathogens associated with manure from farmland that degrade the quality of streams, rivers and water bodies and pose a threat to human health.
2) A cover crop slows the velocity of runoff from rainfall and snowmelt, reducing soil loss due to sheet and rill erosion.
3) Over time, a cover crop regimen will increase soil organic matter, leading to improvements in soil structure, stability, and increased moisture and nutrient holding capacity for plant growth. These properties will reduce runoff through improved infiltration (movement of water through the soil surface) and percolation (movement of water through the soil profile).
4) A cover crop will increase soil quality by improving the biological, chemical, and physical soil properties.
5) As a “trap crop”, a cover crop will store nutrients from manure, mineralized organic nitrogen or underutilized fertilizer until the following years’ crop can utilize them, reducing nutrient runoff and leaching.
6) When a cover crop is managed for its contribution to soil nitrogen, the application of a nitrogen fertilizer for the subsequent crop (okra) may be less, thereby lowering costs of production, reduced nitrogen losses to the environment and reducing the use of purchased nitrogen fertilizer that is produced using fossil fuels.
7) Cover crops will reduce or mitigate soil compaction and facilitate okra roots penetration. Deep tap roots of some cover crops grown in the fall and spring when compacted layers are relatively soft and can penetrate these layers.
8) Cover crops will reduce soil moisture deeper into soil profile by evapo-transpiration resulting in better tillage and traffic conditions.
9) A cover crop provides a natural means of suppressing soil diseases, and pests. It can also serve as a mulch or cover to assist in suppressing weed growth.

10) A cover crop can provide high-quality material for grazing livestock or hay making and can provide food and habitat for wildlife, beneficial insects, and pollinators.

Major start processes

The start of every production process begins with the preparation of the soil. This process is very important for okra. Usually, okra is planted onto raised beds covered with black plastic mulch. Soil needs to be cultivated and granular fertilizer worked into the soil prior to forming beds. Okra is susceptible to soil borne pathogens such as Verticillium and Fusarium wilt. An effective strategy to combat these diseases is through fumigation of the land in the fall of the year prior to planting, even though diseases may surface during the later stages of the plant. Okra plant is propagated mainly by using seeds production and through other vegetative parts (transplanting) which are not used often in Africa (Fufa, 2019). The seeds are obtained from the mother plants and stored to be used as propagules for the next growing season or bought. When obtained from mother plants, the easiest way to keep the seed is to leave it in the pods. Seed weight varies from 30 to 80 g 1000^{-1} seeds, and it may be hard also after a period of storage (Benchasri, 2012).

In cold regions, if the plant is to be transplanted in the field, okra seeds should be started indoors in peat pots under full light 3 to 4 weeks before the last spring frost date to catch the peak summer. On an average, the last spring frost occurs on 15th May. Plant okra outdoor in the spring 2 to 3 weeks after all danger of frost has passed. The preparation practices like clearing, top dressing, mulching etc. as indicated in must be done and site be made ready. It is also possible to start okra outdoor in the cold regions as long as the plants are covered with a cold frame or grow tunnel until the weather warms up fully. The covering must be 2 to 3 feet tall, so that the plants have room to grow. If one do not start the okra plants early, the grower should wait until there is a stable warm weather. It is better to plant okra in the garden when the soil has warmed to about 65° or 70°F. In warmer areas such as West Africa, okra can be started directly in the garden at any time of the year. However, it is ideal when the rainy season meets okra at its vegetative stage.

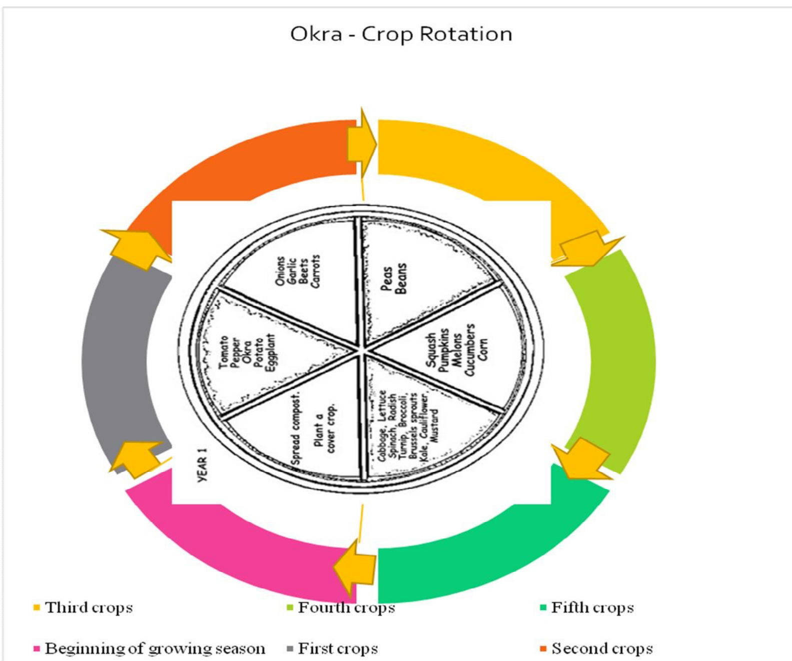

Figure 1.Okra crop rotation

B. Establishment

The establishment of okra either in the field or indoor is easy. The process primarily begins with the seed which is obtained from the mature okra pod or bought. Ensure that the seed is of quality.The seed is usually dibbled directly in the field (2-3 seeds per hole) (Benchasri, 2012). Optimum plant densities are in the range of 50,000 – 60,000 plants per hectare and emergence takes place within one week (Benchasri, 2012). When the plants are about 10 cm tall, they are thinned to one plant per hole. This time is also ideal for transplanting. It is worth noting that germination and initial growth are improved greatly by cultural practices such as mulching, watering before the hottest part of the day, and sowing on ridge sides least exposed to direct sunlight, that lower soil temperature (Benchasri, 2012). The optimal soil types of okra are the loamy and sandy which must be moist (not highly/wet). The following must be kept in mind for optimal growth, development and yield:

1) As a warm-weather crop, okra appreciates full sun.
2) Okra is adaptable and will grow in most soils, though it performs best in well-drained soil that is rich in organic matter.
3) Soil should ideally be on the acidic side, with a pH between 5.8 and 7.0. This is because most of the plant nutrients (mostly macro nutrients) needed for the okra plant are mainly available and favored by soils slightly on the acidic side and closed to neutral or exist in soil with the pH level in this range.
4) If planting okra seedlings, they should be spaced 1 to 2 feet apart to give them ample room to grow.
5) Okra seeds should be sown about 1 to 2 inch deep and 12 to 18 inches apart in a row. Hard or coated seeds can be soaked around 8 to 10 hours (preferably overnight) in tepid water to help speed up germination.
6) Usually watering once in 2 to 3 days is sufficient (under very hot and humid conditions water every day).
7) During rainy seasons the moisture content must be checked before watering. Many times plants are killed by overwatering. Therefore, insert a finger into the soil to check moisture inside before watering.
8) Okra takes around a week to 10 days for germination.
9) Okra plants are tall, so, they must be spaced out in the rows 3 to 4 feet apart.

C. *Pre-Production*

Adequate soil fertility is critical to healthy and vigorous plants, especially for maintaining high levels of production. It is therefore recommended that plants be side-dressed after establishment with 10-10-10, aged manure, or rich compost (½ pound per 25 feet of row). A balanced liquid fertilizer should also be applied monthly depending on the nutrient status of the soil. Research conducted in 2015 and 2016 at Vineland indicated that, okra plants respond best to 75 kg/ha of nitrogen.Again, it is recommended to apply 50 kg/ha of nitrogen pre-planting and an additional 25 kg/ha through fertigation during the growing season. Fertigation should be applied weekly from the time the first flower blooms up to the end of August. Approximately 5 kg of nitrogen in the form of potassium nitrate is recommended per hectare per week. Additionally, the following activities should begin at the pre-production stage and must continue at the production stage and/or throughout the okra plant's life:

1) Eliminate weeds when the plants are young, then mulch heavily to prevent more weeds from growing. Apply a layer of mulch 2 to 3 inches high.
2) When the seedlings are about 3 inches tall, the plants should be thinned so that they are 12 to 18 inches apart, if they are not already.
3) Keep the plants well-watered using an active irrigation system throughout the summer months. One inch of water per week is ideal, but more can be used if the field or production is done in a hot or arid region.

D. *Production*

Normally, there are not too many practices and operations at this stage and after planting okra since it will reach harvesting shortly within two or three months. Okra plants will produce large flowers about 2 months after planting. Most of what is done from the vegetative to the flowering stage are considered continuation of what is stated at the pre-production stage. However, the okra plants should be monitored at this stage to ensure that the best cultural practices are employed for growth and optimal yield. These include the appropriate irrigation level, weeding, pruning and getting rid of pests, diseases and insects to guarantee high quality okra pods. These also guarantee and support other physiological processes such as pollination, photosynthesis etc. Therefore, it is important to provide maximum care for the plant at this stage. By this, the grower may harvest multiple times without ruining the okra plant.

Care during the production season

Cultivate around the okra plants to remove weeds and grass. To avoid damaging the okra roots, weeds should be pulled close to the plants by hand. Pruning is useful during harvest by cutting the leaf attachment just below the pod. After the first harvest, apply fertilizer that must be scattered evenly between the rows. Mix it lightly with the soil. Water the plants after fertilizing.

1) *Control of Pests and insects:* There are many insects that are attracted by the okra plant, especially at flowing. Many insecticides and other practices are therefore available as remedies. Sevin is a synthetic insecticide which may be used. But the organic options which include sulfur and Bt-based insecticides are recommended. Sulfur has also fungicidal properties and helps in controlling many diseases.
2) *Control Of Diseases:* Diseases are most severe in cloudy, damp weather, and other unfavorable climatic conditions in okra. Excessive heat and very limited water (rainfall) also promote diseases such as the mosaic virus diseases (Kumar et al., 2017). Active diseases on record include damping off (Pythium sp., Rhizoctonia sp.), Fusarium wilt (Fusarium oxysporum f. sp, vasinfectum), powdery mildew, yellow vein mosaic virus, etc.

It is necessary to treat diseases with an approved fungicide if diseases appear or treat them using other appropriate methods. Growers apply neem oil, sulfur, and other fungicides available for use. It also depends on the type of diseases or disease that has infested the okra plant. However, maintaining best practices will prevent many diseases.

3) *Pollination:* Okra plant is a self-pollinated (autogenous) crop, but considered as often cross - pollinated due to its showy corolla; and the extent of cross pollination is 4 - 19% depending on cultivar, competitive flora, insect population and season. Since okra is an often cross pollinated crop, an isolation distance of 200 m between cultivar is recommended for production of pure seed (Fufa, 2019). Hybrid seed production of the heterosis is exploited in okra for production of other (particularly F1) hybrids (Fufa, 2019). Generally, hand emasculation and pollination are to produce hybrid seed in okra. Emasculation of flowers of female parent is done before anthesis. Emasculated flower are covered with butter paper bags and pollination is done the next day in the morning and again covered with the bag. But hand emasculation and pollination are uneconomical due to less seeds/fruit. Use of male sterility can be induced by use of chemicals and irradiation (Fufa, 2019).

E. Crop Evaluation

Evaluation of okra crop can be done through visual observation, but requires some important considerations. Certainly, the first harvest will be ready in about 2 months after planting.The okra should be harvested when it is about 2 to 3 inches long. To be marketable, okra must meet some essential retail specifications viz.,

1) The okra must be 6.3 to 11.5 cm in length and 12.7 to 25.5 mm in diameter.
2) Marketable pods should also exhibit the following characteristics: a tender consistency, good colouring, an even shape and be free of pest and disease damage. Finally, as part of the evaluation process, the weight of okra pods can be measured and recorded.

F. Harvest

Okra needs to be harvested regularly, as pods quickly become overgrown and therefore unmarketable. Ideally, okra should be harvested every two days. To harvest okra, cut the stem just above the cap with a knife; if the stem is too hard to cut, the pod is probably too old and should be discarded. It is advisable that the harvester wears gloves and long sleeves when cutting the okra because most varieties are covered with tiny spines that will irritate your skin. This will not be the case when it is a spineless variety. After the first harvest, remove (pruning) the lower leaves to help speed up production. Okra seed is easily saved for next season by leaving some of the last pods on the plant until they get very large. They should be removed and dried. The seeds may be separated easily from the pods.

G. Post-Harvest

Okra is a highly perishable vegetable crop. For consumption, okra can be stored for 3 to 5 days in the refrigerator. Okra that is too mature can be dried, cured, and used in flower arrangements. To store okra, put the uncut and uncooked pods into freezer bags and keep them in the freezer. You can then prepare the okra any way you like throughout the winter months when it becomes impossible to produce okra (in cold regions). Okra can also be canned to have it throughout the winter. In hot areas, okra can be produced nearly throughout the year. In these places, okra can usually be dried and processed into different meals. After harvesting, other okra plant material such as leaves and stems can be put in a compost pit.

VIII. DISCUSSION

Okra has been cultivated and eaten since many years ago. It is a highly nutritious vegetable that is quick and easy to grow, rich in vitamin C and aids digestion as well as boost immune system. Cultivation of okra continues to increase worldwide as knowledge about the crop increases. Between 1991-92, okra was cultivated on 0.22 million hectares with just 1.88 million tonness of production. Today, okra is cultivated on more than 0.5 million hectares with 8.9 million tonnes of fruits per year. It is expected to further increase in future. Even though the crop has been given less attention and has a poor history of breeding against pest and diseases as compared to other crops, its production has sharply increased over the years. Such increase in warm climates can be attributed to many factors, including the influence of the production practice on the plant physiology particularly in India and Nigeria, improvement in technology coupled with the crop's warm weather loving nature. However, as the change in climate seems to present this positivity, it also presents a negative effect on the sustainability of the crop by the introduction of other conditions like the rising level of pests and diseases that affect the crop. Okra is resistant to many pests, diseases and other impeding growth conditions including heat and drought, even though they may be detrimental in extreme cases.

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However, there are other conditions such as salinity and yellow vein mosaic virus infestation that are directly or indirectly connected to change in climate that are highly detrimental to the crop. For a sustainable production of okra, these conditions must be remedied; because they cause huge loss and ruin the crop. In India and in some parts of West Africa where okra is largely produced, the mosaic virus is active that depending on the time of infestation, it reduces okra yield to as high as about 94%. Therefore, if the crop has to continue to exist and do well in many parts of the world, control of these conditions is important. To control the mosaic virus disease, very limited success has been achieved by chemical methods including neem oil, Acetamiprid, Imidacloprid and Trizophos, which are also not permanent solutions. Development of host resistance to viruses and/or salinity is one of the important strategy against these impeding conditions. Effort should be made towards breeding for resistance through gene pyramiding by incorporating different gene to the susceptible line. Moreover, different resistant source are available for yellow vein mosaic virus. But due to sterility problem, it is not easy to transfer the resistant genes directly. Restoration of fertility through colchicine treatment in the crosses between resistant wild and susceptible species could be a suitable technique. Furthermore, very limited work has been done regarding molecular breeding of okra due to availability very few molecular marker or absent of all genomic information of okra. It causes problem to find the exact resistant gene in the plant. So identification and validation of molecular marker for screening of resistance is required.

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