Review on Okra (*Abelmoschus esculentus* (L.) Moench) Production, Nutrition and Health Benefits

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Abstract

Okra is a nutritious vegetable crop with numerous health benefits. The consumption of adequate quantity and quality vegetables is vital for the proper functioning of the human body. A general review of okra was done to increase awareness of the cultivation and utilization of okra and undertake more research. The knowledge of climate, soil fertility, field management, and its health benefits helps to promote okra production and utilization. Okra is mainly cultivated in tropical and subtropical regions, especially in warm climates with annual rainfall and mean temperatures of 900-1,000mm and 18^{o}C-35^{o}C, respectively. Sandy or clay loam soils with a pH from 6.0 to 6.8 are recommended for okra cultivation. Generally, okra requires 150kg/Nitrogen, 112kg/Phosphorus, and 75kg/Potassium per hectare. Moreover, optimum growth, yield, and quality are obtained with proper plant population and mostly it is achieved with a spacing of 50cmx40cm. Pest and diseases like okra yellow vein mosaic virus, okra enation leaf curl virus, and fruit borers are the major production constraints; they cause yield losses and lower quality of the produce. Okra is nowadays known as food with healthy and medicinal benefits due to its composition. Okra leaves, pods, and seeds are edible and they are very nutritious. Okra leaves possess anti-inflammatory, anti-hyperglycemic, anti-hyperlipidemic, and antioxidant properties. This paper reviews okra in general from cultivation, climate requirements, field management practices, its health and nutritional benefits. Knowledge of proper field practices for okra cultivation and its health benefits will motivate farmers and actors in the agriculture and health sectors to promote okra cultivation and its consumption.

Key words*: Okra, cultivation requirements, pest control, nutrients, health benefits*

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Introduction

Okra is one of the vegetable crops that has gained several local names depending on the region but it is attributed to the English name of lady's finger (Ndunguru & Rajabu, 2004; Sorapong, 2012). It belongs to the Malvaceae family (Naveed *et al*., 2009). Its immature fruit is greenish, succulent, and edible fresh with high nutritional contents. Okra is mainly cultivated for its fruit pods which are eaten-cooked in many African countries. It is also an essential vegetable in other tropical regions of the globe such as central Asia and South America. In Africa, it is grown in both the dry and wet cropping seasons but attracts a bigger profit during the dry season in Africa when the demand is often over the limited supplies.

For okra production, fertilizer is a very essential input. Supply of fertilizer is indispensable to improve the soil nutrient status and increasing crop yield. Olaniyi *et al*. (2010) reported that for better growth and development of okra, it requires nutrients such as nitrogen, phosphorus, potassium, calcium, sodium and Sulphur for fertility support and okra production. Lack of sufficient amounts of these nutrients lead to poor performance of okra with growth been affected yielding to low amount of produce (Olaniyi *et al*., 2010). The use of organic manure for okra production has helped to improved agricultural practice in some parts of African continent. Organic manure helps to ameliorate the physical condition of soil and give adequate amount of indispensable nutrients for the soil productivity. Okra responds well to the dressing of organic and inorganic manure. A combination of organic and inorganic fertilizers is a good choice to improve the fruit yield and to supply balance nutrient to okra crop (Olaniyi *et al*., 2010).

Okra, even-if is a robust and resilient vegetable crop, is sensitive to a myriad of disease, many insect pests and pathogens damages including powdery mildew, damping-off, root-knot nematodes, shoot and fruit borer, leaf hopper, white fly, red spider mites, mealy bug, fusarium wilt and bacterial blight (Kedar *et al*.,2014; Ibok,2019).

Generally, vegetables are colorful, vitamins, minerals and fiber rich foods. They are vital for the proper functioning of the human body. They are good sources of nutrients, but also have helpful phytochemicals and medicinal properties. Diversities in vegetable consumption increase the benefits to consumers, as source a vast and various number of nutrients and phytochemicals. According to FAO (2020), for good health, a person needs to consume many varieties of vegetables to gain different components in the diet. There is no single vegetable that can provide all of the nutrients a human body needs to be healthy. Insufficient intake of vegetables and fruits is estimated to cause around 14% of death from gastro-intestinal cancer worldwide, 11% of those due to heart disease and 9% of those caused by stroke (FAO, 2019).

Okra contains 1.9 g of protein out of 100 g of okra (Ndunguru & Rajabu, 2004). It has carbohydrates, potassium, enzymes, vitamins, calcium, and other minerals which many times are not available in the common food of people

living in developing nations. It plays then an important role in the human diet (Ndunguru & Rajabu, 2004). Consumption of young immature okra pods is important as fresh vegetables, and it can be consumed in different forms, principally as fresh included in the salad, cooked or soaked thin slices of okra in water overnight, or for up to 24 hours for a drink once the okra has squeezed any leftover fluid from the pods and combine it with the infused water (Ndunguru & Rajabu, 2004).

Okra is a major source of vitamins A, B, C, K, and minerals, including iron and iodine. It is an important vegetable source of viscous fiber. Okra seeds can be processed by drying and milling in flour, are very rich in protein and oil, and can improve meals (Okra leaves are also eaten. All the 3 parts, pods, seeds, and leaves are very rich in nutrients and phytochemicals. For all these contents, okra provides important elements for health which are often lacking in the diet in developing countries. Besides the nutrients, okra is known to pack antioxidants and fibers which are beneficial to consumer health. Okra is biologically classified as a fruit but is generally utilized as a vegetable in cooking. Okra comes in two colors, green and red. Both varieties taste the same and red turns green when cooked. Both varieties can be grown in tropical and subtropical regions.

Picture 1**. Okra pods, plant and seeds **(https://www.istockphoto.com/photos/okra-plant)

This review paper aims to increase awareness of okra cultivation and consumption, as well as raise biodiversity in vegetable fields and markets, especially in Rwanda and other tropical and sub-tropical countries. Currently, due to climate change and other factors, crops are severely destroyed by pests including the okra crop which experiences a loss of up to 94% from white fly infestation (Thomas, 2022). To ensure sustainable production of okra and reduce these losses, this review article gives detailed information specifically on the soils, climate, fertilization, pests and diseases, and nutritional value of okra. All these items are discussed here and will help okra growers for sustainable production and consumption of okra.

Soils and climate requirements for the cultivation of okra

Soil requirement for okra cultivation

This plant can be cultivated on different soil types. However, the soil should be well-drained and fertile with enough organic matter to provide a high yield (Akinyele & Temikotan, 2007). It can be

produced on soils of sandy to clay types but because of its tap root system, relatively light, well-drained, rich soils are ideal. Besides, soils like friable, loose, well-manured loam are also desirable. A pH ranging from 6.0–6.8 is appropriate (Chittora *et al*., 2017). Nevertheless, some cultivars have some tolerance to salts and thus also to a larger pH range. All soils need to be pulverized, moistened, and enriched with organic matter before sowing (Chittora *et al*., 2017).

Climate requirement for okra cultivation

Okra is cultivated in tropical, subtropical, and warm temperate regions around the globe. In the tropics, this crop is cultivated throughout the year (NRC,2006). In the present world, okra is the most heat and drought-tolerant vegetable and can tolerate heavy clay soils and intermittent moisture but the crop is vulnerable to frost as it may harm pods (Rawat *et al*., 2020). The favorable condition is a long, warm, and humid growing period but it can be successfully cultivated and well produced in hot humid regions.

Okra is sensitive to extremely low temperatures and frost. The temperature requirement for normal growth and development is between 24°C and 28°C (Chittora *et al*., 2017). At 24°C the first flower bud may appear in the third leaf axil while at 28°C it may appear in the sixth leaf axil. This higher position is not necessarily accompanied by a delay in time because at higher temperatures the plants grow faster and the higher position is reached earlier. For faster plant growth still, higher temperature helps though it delays the fruiting. Okra crops become taller in the rainy season than in the warm season.

For good germination, soil temperature in the range of 25^{o}C to 35^{o}C is recommended but fast germination is observed at 35^{o}C (Chittora *et al*., 2017). Temperature below 17^{o}C causes a failure in seed germination while temperature above 42^{o}C causes flower buds to desiccate and yield losses in most of the cultivars (Chittora *et al*., 2017). Temperature above 26^{o}C promotes better growth of okra mostly in arid and semi-arid regions when combined with warm night temperatures (> 20^{o}C) (Incalcaterra and Vetrano, 2000; Tripathi *et al*., 2011; Ahmad *et al*., 2016; Hayamanesh *et al*., 2016, El-Shaieny and Bashandy, 2022).

The best reproductive phase occurs once okra growth matches with 25-35^{o}C as an average day temperature while temperature above 42^{o}C at flowering and pods filling stages cause injury to reproductive organs, cause flower to drop, inability of pollen, pod drop and decrease a total number of seeds in okra, growth and yield is loosen (Incalcaterra and Vetrano, 2000; Tripathi *et al*., 2011; Ahmad *et al*., 2016; Hayamanesh *et al*., 2016, El-Shaieny and Bashandy, 2022).

Crop coefficient values vary from the seedling to the maturity stage, it is lower at the seedlings and increases with crop development, reaching the maximum values at flowering and pod setting stages and declining towards maturity (Patil, 2010). Crop coefficient

differs from one season to another due to the difference in climate conditions and crop growth stage. Okra crop requires 547.4 mm as the total amount of water during the growth but this may fluctuate due to weather conditions (Patil, 2010).

Management practices for the cultivation of okra

Field management practices for Okra cultivation

Land preparation

Proper land preparation is recommended to make land suitable for okra growth and development. Land preparation is through plowing 2-3 times at a depth of 20-25 cm and making the soil fine by removing clods, stubbles, and weeds, and the soil becomes suitable for okra growth and development (Kumar *et al*., 2019). A well-rotted farm yard manure is added to the prepared land one week before planting/sowing. Well-rotted farm yard manure improves okra growth, yield, and quality parameters, and also it gives a higher benefit-cost ratio (Premsekhar & Rajashree, 2009). Field leveling and division into small plots is the final stage in land preparation. This helps in crop management and eases crop maintenance (Kumar *et*., 2019).

Okra needs nutrients to grow and to produce yield. Generally, okra requires soils with specific properties including: sandy or clay loam soils with medium drainage (Ali *et al*., 2017). When grown in heavy clay soils, proper drainage must be applied to avoid too high soil moisture content. Depending on the yield target. It is recommended to use neutral soil, not very acidic nor alkaline with a pH ranging from 6 to 6.5 (Ali *et al*., 2017).

Okra seed sowing and germination

Selection of improved varieties and knowledge of precise sowing time is very crucial in okra cultivation as the plant meets favorable environmental conditions at all the growth stages, growth duration is increased, and early vegetative growth (Bake *et al*., 2017a). The delay in sowing exposes okra crops to a period of high proliferation of pests and diseases (Reddy & Reddi, 2014).

Okra seed is characterized by a particular kind of seed dormancy due to seed coat structure and specifically due to the chalazal plug (Kumar *et*., 2019). This type of dormancy is called delayed permeability. The enhancement of germination is through overnight soaking with water for 6-12 hours before sowing. It is advised to start your okra cultivation with nursery preparation but also it is possible to use direct sowing but most of the time direct sowing gives poor germination. Bavistin at 0.2% (or other recommended pesticide in your region) is applied during seed soaking to protect seeds and seedlings from soil-borne diseases at the initial stages (Kumar *et*., 2019).

Spacing and okra production

The optimum growth, maximum pod, and seed yield is achieved by respecting the recommended plant spacing (Yadav *et al*., 2001). It is recommended to use closer spacing (45 cm x 30 cm) in the summer period while in the rainy season, wide spacing

(60 cm x 45 cm) gives the best results (Kumar *et.*, 2019). Different studies reported that the production of okra with high yield with large, tender, succulent, and vary marketable fruits are obtained with 50 cm x 40 cm of spacing at 2 days of harvesting interval (Gbaraneh, 2018). Besides, it is recommended to consider other factors like climate, variety, and sowing date because they influence crop spacing.

Effect of weed on okra production

The removal of weeds is very important in okra cultivation as weeds may harbor insects that transmit virus diseases to the crop. The sustainability of the rural livelihood and the enhancement of okra yield is achieved with three weeding before harvest (Kugbe *et al.*, 2019) but it is advised to maintain a weed-free farm up to the harvesting time. Okra yield loss of about 54.1 to 90.6% was reported due to weed competition. The most critical period of crop weed competition in okra is up to 2-6 weeks after sowing. The use of herbicides for weed control is advocated for weed control due to their easy application and effectiveness in early control of weeds (Dash et al., 2020).

Recommended fertilizers

It is important to note that Phosphorus helps to promote flowering and more fruit production while among the several roles of Nitrogen, the promotion of more shoots needs to be emphasized. Okra has a relatively high nutrient demand (Katyal & Randhawa, 2020). The sources of those nutrients include both organic and inorganic amendments. Okra requires both macro-nutrients and micro-nutrients. The macro-nutrients include Nitrogen, Phosphorus, and Potassium while the micro-nutrients include: Boron, Iron, Manganese, and Zinc (Katyal & Randhawa, 2020). The amount of fertilizer applied shall be computed on the basis of Okra crop needs and the nutrients available in the soil as well as organic matter available in the soil. Considering the fertilizer added and that already in the soil, the Okra crop requires: 100kg of Nitrogen, 60 kg of P2O5, and 50 kg of K2O (Narendra *et al.*, 2017, Katyal & Randhawa, 2020).

Depending on the soil's physical conditions (water availability, soil texture, etc,…), it is recommended to split the application of fertilizers. Okra needs 50 kg of Nitrogen per Ha, 80 kg of P2O5, and 50 kg of K2O at planting time. After 30 days from planting time, Okra will need 50 kg per ha of Nitrogen. This amount is added during the earthling-up operation as a top dressing. The types of Nitrogen fertilizers may include Urea, Calcium Ammonium Nitrate, and Ammonium Sulfate. Hybrid varieties require higher doses compared to non-hybrids. Indeed, a dose of 150 kg of Nitrogen, 112 kg of Phosphorus (P2O5), and 75 kg of Potassium (P2O) are required (Narendra *et al.*, 2017, Katyal & Randhawa, 2020). In this case, the Okra crop needs 30% at planting, 40% after 4 weeks, and 30% after 7 weeks (Narendra *et al.*, 2017). P2O5 is scheduled as follows: 50% at planting and 50% after 4 weeks while K2O is applied as follows: 50% at planting, 25% after 4 weeks, and 25% after 7 weeks (Narendra *et al.*, 2017, Katyal & Randhawa, 2020). Splitting fertilizer application is very important for many reasons. Since Okra cropping shall avoid excessive soil moisture, and this

may be achieved by draining and using soil with good porosity, some nutrients may move away from the crop and get lost or feed weeds. Fertilizer solubilized in water used for drip irrigation may also be a wise method to avoid the loss of fertilizers (Narendra *et al*., 2017, Katyal & Randhawa, 2020).

The crucial role played by N is that it is the main component of amino acids. Amino acids form proteins and enzymes. Proteins contribute to crop body building and enzymes catalyze biochemical reactions within the crop. Nitrogen also plays the role of being part of chlorophyll, a molecule helping the plant to absorb energy from sunlight. Research has shown that the production of Okra can easily increase with soil Nitrogen increase. It has been also shown that Nitrogen combined with cropping spacing has improved crop growth as well as Okra pod production. Indeed, since Okra pods are rich in proteins, Nitrogen is definitely important. Additional field investigations have demonstrated a positive impact of Nitrogen fertilizer on fresh yields, plant height, number of fruits per plant, and number of leaves (Sumona *et al*., 2022).

The combination of Nitrogen and Phosphorus had no significant effect on plant growth and/or yield (Sumona *et al*., 2022). Each nutrient plays its specific role and it is not affected by the other. It was also found that sufficient N applied at the right time has influenced cell division, foliage, and flouring density as well as photosynthesis processes (Sumona *et al*., 2022). When some nutrients are not sufficient in the soil, the Okra crop shows some symptoms that can guide the farmers to replenish the soil. Table 1 below, summarizes the different elements needed by Okra crop, the deficiency symptoms, and the way to correct or control the problem

Table 1. ***Elements needed by Okra, their deficiency symptoms, and ways to control the deficiency*** *(Sumona et al., 2022)*

Element	Deficiency Symptoms	Correction
Nitrogen	Plants are stunned. The leaves are smaller than usual. The leaves are yellow. The shoots are thin. The pods are hard	Use the maximum amount of nitrogen fertilizer. A soil test can determine fertilizer dosage. In the absence of soil testing. 40 – 150 kg N / hectare can be applied. Spray three or four foliar sprays with 1% urea solution at 10-day intervals. Six foliar sprays with 2% urea solution at seven days starting from 20 days after sowing.
Phosphorus	The leaves are dark green. Plants are stunned.	Maximum use of phosphorus fertilizer. A soil test can determine dosage. In the absence of soil testing. 8-75 kg P2O5 /hectare can be applied.
Potassium	The number of leaves is low. The margins of the leaves are brownish yellow, brown or scorched. Burning of scorched leaves. Decreases plant growth. The old leaves turn yellow and marginal chlorosis is present.	Maximum use of potassium fertilizer. The soil test can determine dosage. 20 to 75 kg of potash per hectare can be used without soil testing. Foliar spray of KCl by 1%

Table 2. ***Micro-Elements needed by Okra, their deficiency symptoms and ways to control the deficiency*** *(Sumona et al., 2022)*

Element	Deficiency Symptoms	Correction
Boron	Okra leaves become distorted and brittle. They are small in size and have irregular pod growth. Pods are like small stumps. They do not last long but stay connected for a long time. The leaves begin to fall off. Plant growth stops. Distortion of new leaves (in severe cases, the growing point dies) and the appearance of a wide yellow border on the margins of old leaves. Stagnant growth and thick yellow long lines formed in the skin markings.	Foliar spray of 0.2% borax at clear intervals. Applying 10 kg borax per hectare on previously deficient land will prevent boron deficiency.
Iron	Decreased plant growth; Chlorosis occurs in young leaves.	Foliar spray of FeSO4 by 0.5%
Manganese	Symptoms-Manganese deficient plants have medium to upper leaf veins that appear green against a faint light green to the yellow blade.	Spray the foliage with MnSO4 by 0.1% (100 g / 100 L water) on plants.
Zinc	Marked depression in leaf production and leaf size occurs within three weeks, and leaf mottling develops after two weeks. The diameter of the stem was reduced.	Foliar spray of ZnSO4 0.5% or soil application of 10kg ZnSO4 / hectare.

Major insect pest and diseases of okra

Okra is subjected to damage by different viruses, nematodes, insects, and fungi although there is large variance in their degree of infestation. Some of the reported insects are jassids white flies, aphids, ants, shoot and fruit borer, etc. Okra is also subjected to the damage of many diseases causing pathogens affecting leaves, flowers and fruits.

Insect-pests

Jassids/Leaf hopper (*Amrasca biguttula biguttula*)

Okra leaf hopper is a dangerous insect pest damaging the okra crop (Uthamsamy & Balasubramanian, 1978, Meena *et al*., 2010, Prithiva *et al*., 2019). Cloudy weather is a favorable condition that increases the population and builds up of leaf hoppers. Both nymph and adult affect the ventral leaf surface by sucking the sap and injecting toxic saliva into the tissues of the plant. The symptom characterization of leafhopper injury is phytotoxemia (hopper burn) due to the desapping of leaves by nymphs and adults (Hooda *et al*., 1997). There is observation of plant stunting and inability to set flowers and fruits.

Shoot and fruit borer

Shoot and fruit borer (*Earias vittella, E. Insulana* is highly distributed during

high temperatures and remains active throughout the year. In the rainy season, there is less damage. It infects okra during the fruiting stage where larvae bore into the fruits and contaminate the fruit with excreta. Okra shoot and fruit borer (OSFB) infestations typically accounted for a 48.97% loss in the okra pod yield. The OSFB larvae cause damage in the vegetative and reproductive phases of the okra. Larvae also bore into the flower buds and fruits in the reproductive stage, and feed on internal tissues. Therefore, the infested flower buds drop off, and infested fruits become deformed in shape, which lowers their market value. OSFB alone causes a damage of between 52.33% and 70.75%. Alternative approaches are paramount to avoid dependence on chemical insecticides. Botanical insecticides are an alternative promising approach that only damages target insects without harming beneficial natural enemies and establish food and healthy environments (Choudhury *et al*., 2021). Shoot and fruit borer (*Earias vittella*) is reported to be among the major pests in okra cultivation by causing direct injury to tender shoots and fruits (Sultane *et al*., 2017). That pest causes about 69% losses in marketable yield as reported by Jayanth *et al*., 2021. The borer larvae cause injury in two ways. Firstly, larvae bore into growing shoots and move down by creating tunnels inside. Therefore, the shoots droop downward or dry up. Secondly, the larvae make the pod to be unfit for human consumption by entering the inside of the pod and making holes (ayanth *et al*., 2021).

Diseases

Yellow Vein Mosaic

This is a viral disease that is most important and destructive in okra cultivation. It infects okra at all growth stages, cause a high decline in growth and yield. The white fly is the major transmitter of yellow vein mosaic. Okra shows these damaging signs whenever attacked by this disease: chlorosis, the entire network of veins in the leaf bland become yellow (Uppal *et al*., 1940). Small leaves, stunted growth, veinlets become yellow, and fruits distorted (Venkataravanappa *et al*., 2012a). There is a restriction of flowering and fruit setting on the infected plant; once formed are smaller and harder. Okra yield losses are from 50 to 94% if the incidence of the Yellow Vein Mosaic is 100% (Fajinmi & Fajinmi, 2010).

Okra Yellow Vein Mosaic is the most serious disease of okra and is transmitted by white flies (*Bemisia tabaci* Gen.). Infection rate may reach up to 100% but in the field, yield loss ranges between 50% and 94% depending on the stage of crop growth. If infection occurs in the first 20 days after germination, the growth of plants stops, few leaves and fruits are formed and yield loss reaches up to 94%. As a plant's age increases the rate of yield loss decreases due to pathogens. Plants of 50 and 65 days old suffer a loss of 84 and 49%, respectively (Muhammad et al., 2012).

Okra Enation Leaf Curl Disease

It is a virus disease characterized by the leaf curling, thickening of the vein, and area of the leaf surface is reduced (Singh, 1996). Yield losses of 80-90% are

known in severe infestation (Singh, 1996).

In case there is an attack of this disease, the following can be helpful: Spray alpha-cypermethrin at 7.5ml/15L of water. A pyrethroid. IRAC code: 3A. WHO Class II (Moderately hazardous). REI: 24 hrs. PHI:14. Apply three times at 7-14 days intervals depending on vector situation. Alternate with other chemical group insecticides after three applications. Spray lambda-cyhalothrin at 50ml/15L of water. A pyrethroid. IRAC code: 3A. WHO Class II (Moderately hazardous). REI: 24 hrs. PHI:14 days. Apply three times at intervals of 7-14 days. Spray the field with imidacloprid at 5-7ml/15L of water. Systemic neonicotinoid insecticide. IRAC code: 4A.WHO Class II (Moderately hazardous). REI: 24 hrs. PHI:7-14 days. Apply three times at intervals of 7-14 days depending on the vector population (Moses *et al*., 2016).

Okra leaf curl disease:

It is caused by the Okra leaf curl virus that infects all stages of the plant from the vegetative stage up to the harvesting stage and is transmitted by whitefly. Okra leaf curl disease is a serious disease in okra crops affecting okra production (Fauquet & Thouvenel, 1987, N'Guessan *et al*., 1992, Swanson & Harrison, 1993, Bigarré *et al*., 2001). It was recently reported to be associated in Africa with a complex of begomoviruses: *Cotton leaf curl Gezira virus* (CLCuGV) (Idris &Brown, 2002, Shih *et al*., 2009), *Okra yellow crinkle virus* (OYCrV) (Shih *et al*., 2007) and *Hollyhock leaf crumple virus* (HoLCrV) (Bigarré *et al*., 2001, Idris *et al*., 2002) and DNA beta satellites (Idris *et al*., 2002, Kon *et al*., 2009). In Africa and generally on the globe, begomo viruses are the major constraint to vegetable production.

Okra shows these damaging signs whenever attacked by this disease: severe stunting, failure to produce normal pods, senescence of premature leaves, leaf curl, and small vein thickening followed by veinal necrosis. At severe infestation, the margins of the affected leaf turn inwards, and leaves turn downwards, vein yellowish is developed on the lower surface (Gamal, 2003).

In case of attack, the following direct control can be done: Rogue-infected plants at very low disease incidence and destroy by burning or burying; Place yellow sticky traps at different locations in the field to attract white flies; Spray with 5 tablespoons of dishwashing soap in 20 liters of water at 7-14 days intervals; Spray neem seed water extract (5% concentration, w/v) to control vectors just after their appearance (second and third sprays must be applied at 14 days interval (Moses et al., 2016).

Harvesting time

The first harvest starts after 40-45 days after transplanting in most varieties but this period can be prolonged depending on cultivated variety. Fruit picking is on alternate days or at intervals of 2-3 days (Talukder *et al*., 2003, Vikash *et al*., 2019). The fruits of most okra varieties become fibrous after 10-12 days of flowering, therefore early picking is recommended. The summer crop is with a lower yield than the rainy crop (Vikash *et al*., 2019).

Post-harvest handling: like other vegetable crops, the harvested okra

fruits are taken to the cooling room to maintain fruit quality. Pod sorting is done based on size and then packed. The preservation of colour, texture, or weight is with storage conditions of 7-10^{o}C temperature and 90-95% Relative Humidity for 7-10 days (Vikash *et al*., 2019).

Nutrition and health benefits of Okra (*Abelmoschus esculentus*) vegetable
Nutritional value of Okra

Okra is a diet food. According to Gemede *et al*. (2015), okra crops, leaves, pods, and seeds are edible and are all very nutritious. Different nutrients in different okra parts and their concentrations have been shown in different literature. From the same author, okra leaves, per 100g edible parts, 4.40g are proteins, 0.60g are fat, 2.10g are fibers, 532mg are Ca, 70mg are P, 0.70mg are Fe, 59 mg are ascorbic acid, 385 ug are B-carotene, 0.25mg are thiamin, 2.80mg are riboflavin and 0.20mg are niacin (Gemede *et al*., 2015).

According to Agbo *et al*., (2008), from 100g of okra young immature pods, 0.2g is fat, 1.70g are fibers, 84g is Ca, 0.04mg is thiamin, 0.60mg is niacin and 47mg are ascorbic acid while okra seeds contain 20% to 40% of oil depending on the extraction method. About 47.4% of the oil consists of linoleic acid, a polyunsaturated and essential fatty acid for humans. Seven-day-old fresh okra pods are the most concentrated in nutrients (Agbo *et al*., 2008).

Okra pods nutrients content per 100 g edible portion is water (88.6 gr), energy (144.00 kJ / 36 kcal), protein (2.10 gr), carbohydrate (8.20 gr), fat (0.20 gr), fiber (1.70 gr), Ca (84.00 mg), P (90.00 mg), Fe (1.20 mg), β carotene (185.00 µg), riboflavin (0.08mg), thiamin (0.04 mg), niacin (0.60 mg), ascorbic acid (47.00 mg) (Kahlon *et al*., 2007, Saifullah & Rabbani, 2009;). The presence of Fe, Zn, Mn and Ni also has been reported by Kendall and Jenkins (2004). Differences may be to different soils and varieties, and this increase our curiosity to know which are nutritional values of okra parts on our soils and varieties.

The seed contains proteins, balanced in lysine and tryptophan amino acids, which are missing in cereals and pulses. Mature okra seeds are good sources of protein that could be as high as poultry eggs and soybean (Akintoye *et al*., 2011). It is seen that okra seeds-based food can complete cereal-based food for an adequate equilibrated diet in proteins. The increase of protein, ash, carbohydrates, mucilage, N, P, K, Ca and Mg contents of okra fruits are due to different organic manure sources and NPK fertilizer (Adekiya *et al*., 2020) while protein content is significantly increased in late planting. Also, ash and mucilage content increased under mild drought conditions (Keyvan Rad *et al*., 2022).

Health Benefits of Okra

Okra is known to have health benefits including anti-diabetic, anti-cancer and anti-inflammatory properties. Phenolic compounds are known to have antioxidants, anti-inflammatory, anti-cancer activities (Woumbo *et al*, 2022). Okra pods and seeds are rich in phenolic compounds like quercetin derivative, catechin oligomers and hydroxycinnamic derivative. Okra, especially fresh pods, in addition to phenolic, are rich in vitamin C (ascorbic

acid) and vitamin A (Beta carotene) which are antioxidants, also protective of cancer (Woumbo *et al*, 2022).

The fiber diet is advisable for diabetic, high pressure and heart attack problems by its ability to reduce absorption of sugars and preventing hyperglycemia and decreasing cholesterol level. Okra products are rich in insoluble fibers and viscous fibers able to reduce sugar and cholesterol level in blood (Dubey & Mishra, 2017). For Okra minerals, vitamins, fiber and phenolic content, it is food to incorporate in human diet to control non communicable diseases such as high pressure, heart and cancer disorders.

Conclusion

Okra as a tropical and subtropical crop is drought-resistant, thus does well under drought conditions. However, its soil needs to be pulverized, moistened and enriched with organic matter before sowing. It is prone to extremely low temperature and frost. The crop should be sown during the start of the rain, otherwise delay in sowing expose okra crop to the period of high proliferation of pests and diseases.

It is recommended to use a closer spacing in summer and wider spacing in rainy season for best results. This crop requires a combination of organic and inorganic fertilizer nutrient sources to achieve proper growth and higher yields. Okra starts being harvested at a month and half with a continuous harvesting. Okra is sensitive to pest and diseases, not withstanding, high moisture content, salinity, and the yellow vein mosaic virus disease are the major factors damaging it. These conditions especially the latter one reduce okra productivity up to around 94 percent depending on the time of infestation after emergence. Very limited success has been achieved by application of neem oil, use of chemicals such as Imidacloprid and rocket), which also are not permanent to avoid pesticide resistance build-up of some insects where some resistant cultivars become susceptible with time.

However, this vegetable crop contains vitamin C, fibre, vitamin B_9 and antioxidants. The edible fruit is valuable for very good supplement of vitamins, proteins and minerals in food of people from the developing nations, where they depend on cereal crops, which are lacking them. Okra has a big number of potentials for improving livelihoods in urban and rural regions and it is also considered as the powerhouse of precious nutrients that is low in calories and is free from fats. Okra fruit also gives important antioxidant properties, mostly due to their high content in Vit. C, flavonoids, and carotenoids as well as therapeutic properties against hyperlipidemia, diabetes, ulcers, microbes and neurodegenerative diseases.

REFERENCES

Adekiya, O., A., Ejue, W., S., Olayanju, A., Dunsin, O., Aboyeji, C., M., Aremu, C., Adegbite, K. & Akinpelu, O. (2020). Different organic manure sources and NPK fertilizer on soil chemical properties, growth, yield and quality of okra. Scientific Reports, 10:16083| https://doi.org/10.1038/s41598-020-73291-x

Agbo A.E., Gnakri D., Beugie GM, Fondio L. & Kowame c. (2008). Maturity degree of four okra fruit varieties and their nutrients composition. Elect.J. Food Plant Chem. 5:1-4.

Ahmad, J., Balal, R.M., Shahid, M.A., Akhtar, G., Akram, A., Khan, M.W., & Zubair, M. (2016). Characterization of okra genotypes at reproductive stage under hightemperature stress. Int J Chem Biochem Sci, 9, 44-48.

Akintoye H.A., Adebayo A.G. & Aina, O.O. (2011). Growth and yield response of okra intercropped with live mulches. Asian Journal of Agriculture Research. 5:146- 153.

Akinyele B.O.& Temikotan T. (2007). International Journal of Agricultural Research, 2: 165-169.

Ali, A., Ahmad, B., Hussain, I., Ali, A. & Ali Shah, F. (2017). Effect of phosphorus and zinc on yield of lentil. Pure Applied Biology. 6, 1397–1402.

Bake, I.D., Singh, B.K., Singh, A.K., Moharana, D.P. & Maurya, A.K. (2017). Impact of planting distances and sowing dates on yield attributing traits of okra [Abelmoschus esculentus (L.) Moench] cv. Kashi Pragati. International Journal of Current Microbiology and Applied Sciences 6(7), 4112-4125.

Bigarre, L., Chazly, M., Salah, M., Ibrahim, M., Padidam, M., Nicole, M., Peterschmitt, M., Fauquet, C. & Thouvenel, J. C. (2001). Characterization of a new begomovirus from Egypt infecting hollyhock (Althea rosea). European Journal of Plant Pathology 107, 701–711.

Chittora, A., Singh, N., & Dhirendra Kumar, S., D., (2017). PRODUCTION TECHNOLOGY OF OKRA. Marumegh: Volume 2(1), ISSN: 2456-2904. Available online at www.marumegh.com, Accessed on 4th May, 2023.

Choudhury, M.A.R.; Mondal, M.F.; Khan, A.U.; Hossain, M.S.; Azad, M.O.K.; Prodhan, M.D.H.; Uddain, J.; Rahman, M.S.; Ahmed, N.; Choi, K.Y.; (2021) Evaluation of Biological Approaches for Controlling Shoot and Fruit Borer (Earias vitella F.) of Okra Grown in Peri-Urban Area in Bangladesh. *Horticulturae 7*, 7. https://doi.org/10.3390/horticulturae7010007

Dash,S.K.,Tripathy, P.,Sahu, G., Pathak,M., Padhan,B., & Nayak H.,(2020).Effect of integrated weed management practices on growth, yield attributes and yield of okra (Abelmoschus esculentus (L.) Moench) cv. Utkal Gaurav. Journal of Crop and Weed, 16(3): 253-255.

Dubey P. & Mishra S. (2017). A review on: Diabetes and okra (Abelmoschus esculentus). Journal of Medicinal Plants studies. 5 (3), 23-26.

El-Shaieny, A. A. H. & Bashandy, T. (2022). Effect of Planting Dates on Growth, Yield and Physiological Traits of Okra (Abelmoschus esculentus L. Moench.), and Field Evaluation for Heat Tolerance. J. of Plant Production, Mansoura Univ., Vol. 13 (5):141 – 150, available online at: www.jpp.journals.ekb.eg.

Fajinmi, A.A. & Fajinmi, O.B. (2010). Incidence of okra mosaic virus at different growth stages of okra plants (Abelmoschus esculentus (L.) Moench) under tropical condition. Journal of General and Molecular Virology 2: 28-31.

FAO (2020): Fruits and vegetables-your deity essentials. The International Year of Fruits and Vegetables 2021. Background paper. FAO, Rome.

FAO, (2019): The state of food security and nutrition in the world 2019: safeguarding against economic slowdowns and downturns. FAO, IFAD, WHO WFP, and UNICEF.

Fauquet, C. & Thouvenel, J.C. (1987). Maladies virales des plantes en Côte d'Ivoire. Documentations Techniques no46 (Paris: ORSTOM).

Gamal A. M. G. (2003). Okra leaf curl virus: A monopartite begomovirus infecting okra crop in Saudi Arabia. Arab journal of Biotechology, Vol. 6, No. (1): 139-152.

Gbaraneh, D., L. (2018). Effect of plant spacing and harvest interval on the growth, fruit quality and yield of okra (Abelmoschus esculentus (L.) Moench) in Port Harcourt, Nigeria. International Journal of Agriculture and Earth Science,4(4) ISSN 2489-0081, www.iiardpub.org

Gemede H.F., Ratta N., Haki G.D., Woldegiorgis A.Z.,& Beyene F. (2015). Nutritional quality and health benefit of Okra (Abelmoschus Esculentus): A review. International Journal of Nutrition and Food Science, 4(2), 208-215.

Hayamanesh, S., Keitel, C., Ahmad, N., & Trethowan, R. (2016). Physiological and biochemical response to high temperature stress in Okra (Abelmoschus esculentus L .Moench). GeophyRes Abs, 18, 18481-1.

Hooda V S, Dhankar B S & Singh R. (1997). Evaluation of okra cultivars for field resistance to the leafhopper, Amrasca biguttula biguttula Ishida. Insect science and its application 17: 323–27

Ibok, O. (2019). Diseases of Okra (Abelmoschus esculentus). Available from: https://www.agriculturenigeria.com/manuals/production/pest-diseases/diseases-of-okraabelmoschus-esculentus/ [Accessed: 20th April, 2023].

Idris, A. M. & Brown, J. K. (2002). Molecular analysis of Cotton leaf curl virus-Sudan reveals an evolutionary history of recombination. Virus Genes 24, 249–256.

Idris, A. M., Mona. H. Hussein, A. M. Abdel-Salam & Judith. K. Brown (2002). Phylogenetic relationships for okra leaf curl- and hollyhock leaf crumple-associated begomoviruses and first report of associated satellite DNAs.

Incalcaterra, G., & Vetrano, F. (2000). Effects of two sowing dates and plastic mulch on okra production. Acta Hortic, 533, 329-336.

Jayanth S., Bhanderi, D.R., Chawla, SL, Patel, A.I., Saravaiya, S.N. & Sakriya, S.G. (2021). Screening of okra genotypes across environments for resistance against shoot and fruit borer,

yellow Vien mosaic virus and enation leaf curl virus. The Pharma Innovation Journal; 10(11): 407-413. l http://www.thepharmajournal.com

Kahlon T.S., Chapman M.H., & Smith G.E (2007). In vitro binding of bile acids by okra beets asparagus eggplant turnips green beans carrots and cauliflower. Food Chemistry. 103, 676-680,

Katyal, J. C. & Randhawa, N. S. (2020). Micronutrients. FAO Fertilizer and Plant Nutrition Bulletin. Journal of Energy Natural Resources. 9, 1–9.

Kedar, S. C., Kumaranag, K. M., Bhujbal, D. S., & Thodsare, N. H. (2014). Insect pests of okra and their management. Popular Kheti, 2(3), 112-119.

Kendall C.W.C.& Jenkins D.J.A., (2004). A dietary portfolio: maximal reduction of low-density lipoprotein cholesterol with diet. Current Atherosclerosis Reports 6:492-498,

Keyvan Rad, S., Madani, H., Heidari Sharifabadi., H., Mahmoudi, M., & Nourmohamadi G., (2022). Effects of different irrigation intervals and sowing time on yield attributing traits of okra (Abelmoschus esculentus L.). Arabian Journal of Geosciences 15, 740 (2022). https://doi.org/10.1007/s12517-022-09663-6

Kon, T, Rojas, M. R., Abdourhamane, I. K., & Gilbertson, R. L. (2009). Roles and interactions of begomoviruses and satellite DNAs associated with okra leaf curl disease in Mali, West Africa. Journal of General Virology, 90, 1001–1013, DOI 10.1099/vir.0.008102-0

Kugbe X. J.; Salifu A.& Ebenezer S.K. (2019). Growth and Yield of Okra (Abelmoschus esculentus L. Moench) as Affected by Planting Date and Weeding Regime in Northern Ghana. Journal of Agriculture and Crops.5(4), 43-47. https://doi.org/10.32861/jac.54.43.47

Kumar, V., Ramjan, Md. & Das, T. (2019). Cultivation Practices of Okra. Biomolecule Reports, Popular Article; ISSN:2456-8759, https://www.researchgate.net/publication/331556777

Meena N K, Kanwat P M, Meena A & Sharma J K. (2010). Seasonal incidence of jassids and whiteflies on okra, Abelmoschus esculentus (L.) Moench in Semi-Arid Region of Rajasthan. Annals of Agricultural and Biological Research 15(1): 25–9.

Moses,E., Brentu,F., C. & Nyarko,F. A., (2016). Leaf curl disease of okra-Ghana. PlantwisePlus Knowledge Bank, doi:10.1079/pwkb.20167800966, CABI International, ,

Muhammad, A., Khan, M., Rashid, A., Ehetisham-ul-haq, M., Javed, M., & Sajid,M., (2012). Epidemiology of Okra Yellow Vein Mosaic Virus (OYVMV) and Its Management through Tracer, Mycotal and Imidacloprid, American Journal of Plant Sciences, 3 No. 12, 2012, pp. 1741-1745. doi: 10.4236/ajps.2012.312212.

N'Guessan, K.P., Fargette, D., Fauquet, C. & Thouvenel, J.C. (1992). Aspects of the epidemiology of Okra leaf curl disease in Côte d'Ivoire. Tropical Pest management, 38, 122-126.

Narendra Kumar Meena, Rajesh Kumar Meena, R. S. Dhaka, & Om Prakash Meena, (2017). Response of Nitrogen, Phosphorus and Potassium Levels on Growth and Yield of Okra (Abelmoschus esculentus (L.) Moench) cv. Arka Anamika. International Journal of Pure Applied Biosciences. 5 (4), 1171-1177

National Research Council, "Okra". (2006). Lost Crops of Africa: Volume II: Vegetables. Lost Crops of Africa. 2. National Academies Press. ISBN 978-0-309-10333-6. Retrieved 2008-07-15,

Naveed, A., Khan, A.A., & Khan, I.A. (2009). Generation mean analysis of water stress tolerance in okra (Abelmoschus esculentus L.). Pak. J. Bot., 41: 195-205.

Ndunguru, J., & Rajabu, AC. (2004). Effect of okra mosaic virus disease on the above-ground morphological yield components of okra in Tanzania. Scienta Horticulturae, 99: 225-235.

Olaniyi, J.O, W.B. Akanbi., O.A. Olaniran & O.T. Ilupeju (2010). The effect of organo-mineral and inorganic fertilizers on the growth, fruit yield, quality and chemical compositions of okra. Journal of Animal & Plant Sciences, Vol. 9, Issue 1: 1135- 1140. http://www.biosciences.elewa.org/JAPS; ISSN 2071 – 7024.

Patil,. C. S. . (2010). Crop coefficient and water requirement of Okra (Abelmoschus Esculentus L. Moench). MAUSAM, 61(1), 121–124. https://doi.org/10.54302/mausam.v61i1.783

Premsekhar, M. & Rajashree, V. (2009). Performance of Hybrid Tomato as Influenced by Foliar Feeding 2 of Water-Soluble Fertilizers: Am.-Eurasian J. Sustain. Agric., 3(1): 33-36.

Prithiva J N, Ganapathy N, Muthukrishnan N, Mohankumar S & Chandrasekhar C N. (2019). Preliminary screening of okra genotypes for leafhopper resistance Amrasca biguttula biguttula (Ishida) (Homoptera: Cicadellidae). Journal of Pharmacology and Phytochemistry 8(3): 2537–41.

Rawat, N., Karnatak, A.K. & Srivastava, R.M. (2020). Population dynamics of major sucking insect pests of Okra in agro-climatic condition of Pantnagar. Journal of Entomology and Zoology Studies; 8(1): 540-545.

Reddy, T.Y. & Reddi, G.H.S. (2014). Principles of Agronomy. Kalyani Publishers, Ludhiana., 185p.

Saifullah M. & Rabbani M.G. (2009) Evaluation and characterization of okra (Abelmoschus esculentus L. Moench.) genotypes. SAARC Journal of Agriculture. 7, 92-99.

Shih, S. L., Kumar, S., Tsai, W. S., Lee, L. M. & Green, S. K. (2009). Complete nucleotide sequences of okra isolates of Cotton leaf curl Gezira virus and their associated DNA-β from Niger. Arch Virol 154, 369–372 (2009). https://doi.org/10.1007/s00705-008-0304-6.

Singh, S.J. (1996). Assessment of losses in okra due to enation leaf curl virus. Indian Journal Virology, 12:51-53.

Sorapong Benchasr, (2012). Okra (Abelmoschus esculentus(L.) Moench)

as a Valuable Vegetable of the World. Ratar. Povrt. 49:105-112.

Sumona Akhter, A.K.M. Ruhul, A. & Abdul, A. C.M. (2022). Organic and Mineral Fertilization-Induced Yield and Seed Quality of Okra (Abelmoschus esculentus L.). Journal of Plant Sciences, 17: 102-111.

Swanson, M. M. & Harrison, B.D. (1993). Serological relationships and epitope profiles of isolates of okra leaf curl geminivirus from Africa and the Middle East. Biochimie 75:707–711.

Talukder, M.A.H, Mannaf, M.d., Alam, M.K, Mohammed, S. & Amin, M.M.U (2003). Influence of Sowing Time, Plant Spacing and Picking Interval on the Growth and Yield of Okra. Volume 6, DO: 10.3923/pjbs.2003.1626.1630, Pakistan Journal of Biological Sciences.

Thomas, W.D, (2022). Grower's Guide: A Review for Sustainable Production of Okra (Abelmoschus esculentus) in West Africa and Other Regions. International Journal of Research Applied Sciences& Engeneering Technology. 10(10), 128-138.

Tripathi, K.K., Warrier, R., Govila, O.P., & Ahuja, V. (2011). Biology of Abelmoschus esculentus L. (okra). Ministry of environment and forests Government of India.

Uppal, B.N.; Varma, P.M. & Capoor, S.P. (1940). Yellow vein mosaic of bhendi. Curr. Sci. 9: 227-228.

Uthamsamy S & Balasubramanian M. (1978). Efficacy of some insecticides in controlling the pests of bhendi (Abelmoschus esculentus (L.). Pesticides 12: 39-41.

Venkataravanappa V, Reddy CNL, Jalali S, & Krishna Reddy M. (2002). Molecular characterization of distinct bipartite begomovirus infecting bhendi (Abelmoschus esculentus L.) in India. Virus Genes.;44(3):522–535. doi: 10.1007/s11262-012-0732-y.

Vikash, K., Ramjan, Md. & Twarita, D. (2019). Cultivation Practices of Okra, Biomolecule Reports- An International eNewsletter, Popular Article, ISSN:2456-8759. Available on https://www.researchgate.net/publication/331556777_Cultivation_Practices_of_Okra, accessed on 4th February 2023.

Woumbo C.Y, Kuate D., Tamo D.G.M. & Womeni H.M. (2022). Antioxidant and antidiabetic activities of a polyphenol rich extract obtained from Abelmoschus esculentus (okra) seeds using optimized conditions in microwave-assisted extraction (MAE). Nutrition and Food Science Technology. Volume 9 - 2022

Yadav, S.K., B.S. Dhankhar, D.P. Deswal & R.P.S. Tomer. (2001). Effect of sowing date and plant geometry on seed production and quality of o kra (Abelmoschus esculenthus L.) cv. Varsha Uphar. Seed Research. 29(2), 149-152.