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Cabbage (*Brassica oleracea*) Production in Kenya: A Review of its Economic Importance, Ecological Requirement and Production Constraints

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Review Article

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ABSTRACT

Cabbage is an important vegetable containing considerable amount of water, protein, lipids, carbohydrates, fibre, vitamins, assorted minerals, phenols and glucosinolates. In Kenya, cabbage production is done mainly by smallholder farmers for food and sale. The crop is mainly grown between 800m and 2900m above sea level. It plays an important role towards achieving improved human nutrition and health conditions, reducing poverty through food security, and enhancing ecosystem resilience as a source of income, human food, and livestock feed. Statistics show that though the average area under production has been growing since 2017, average production has been fluctuating and consumption increasing steadily. Profitable production of the crop within the

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country is mainly constrained by myriad of factors such as climate change effects, pest and disease prevalence, poor agronomic practices, land degradation, soil health deterioration, lack of structured marketing systems and poor research-extension- farmer linkages. Possession of limiting climate-smart agriculture knowledge and skills, challenging access to credit facilities and agro-processing technologies, as well as narrow post-harvest loss management knowledge and skills, was identified as other key cabbage production constraints within the country. It was however noted that the country has the potential to achieve profitable cabbage farming if the adoption of climate smart technologies, farmer-extension linkage, government policies, credit facilities as well a structured market system were streamlined. The current work reviews the cabbage crop, with emphasis on its biology, economic importance, ecological requirements, current production status in Kenya and production constraints.

Keywords: Cabbage; production constraints; climate change.

1. INTRODUCTION

Cabbage is an important vegetable widely consumed in the world. Its production varies around the world with China being the leading producer (32,800,000 tonnes) followed by India (8,500,000 tonnes), and Russia (3,309,315 tonnes) [1]. The origin of cabbage is not clear; however, it is suggested to have originated from the South and Western coast of Europe or the Eastern Mediterranean, Asia minor region, or ancient Greek [2,3]. According to Dixon [4] and Leike [5], the crop was first cultivated in the Netherlands in the 14th century, and later spread to other European and Mediterranean countries. It was introduced in Africa in the 16th century by European colonialists [4,6].

In Kenya, cabbage is cultivated by both small-scale and medium-scale farmers. It is grown in all parts that fall between 800m and 2900m above sea level [7,8]. The major producing areas include:Kiambu, Nakuru, Nyandarua, Nyeri, Muranga, Narok, Kerinyaga, Laikipia, Kisii, Nyamira, Meru, Bomet, Elgeyo Marakwet, Muranga, Trans-Nzoia, Makueni, Laikipia, Bungoma, and Kericho [7,9,10,11]. In the year 2020, the area under production was 30,258Ha amounting to 977,054 tons, while in the year 2019 it was 33, 473Ha amounting to 991,549 tons. In the years 2018, 2017, and 2016 the production area was 22,892Ha, 26,807Ha, and 25,926Ha respectively, amounting to 620, 523 tons, 713 360 tons, and 733,817 tons in that order [11,12,13].

Numerous varieties are grown in Kenya, however, the most popular include Gloria F1, Copenhagen, Sunny F1, Karen F1, Riana F1, Baraka F1, Queen F1, Polo F1, Pruktor F1, Serena F1, Sugar Loaf, Green Challenger F1, Golden Acre, and Rosy F1. Other varieties available in the market include Prize Drumhead, Fortuna, K-Y Cross, Early Market F1, Super Master F1, Oxylus, Star 3308 F1, Santa F1, Rotan F1, Field Winner F1, Globe Master Hybrid F1, Fanaka F1, Amigo, Amuko Si F1, Barak A F1, Blue Dynasty F1, Early Drum Head, Green Coronet F1, Fiona F1, Pretorai F1, Zawadi F1 and Tristar among others [14,15]. Most of this cabbage varieties are either consumed locally or transported to major towns within the country. The left over and over supply are utilized as dairy cattle and heifer’s feed.

2. BOTANY OF CABBAGES

Taxonomically, cabbage is classified under kingdom Plantae, division Spermatophyta, class Dicotyledonae, family Cruciferae/Brassicaceae or (mustard), and genus Brassica [3,16]. Within this genus, there are many species, which include *Brassica oleracea var. capitata* (white cabbage) and *Brassica rapa* subsp. *Pekinensis* (Napa cabbage) [3,16,17,18]. Within a species, there are different categories of cabbage depending on their colour. These categories are green, while others are red/purple. Green cabbages range from very dark to very light and these light green-coloured cabbages are referred to as "white" cabbages because the inner leaves are white. Red/purple cabbages range widely in colour, with some appearing deep purple [5]. Within each cabbage category, various varieties have been bred to suit different ecological zones. Phenotypically they are leafy biennial crops, but they are grown as annual vegetables that are 40 – 60 cm tall [3,16]. Some of these varieties form an oval shape when mature, while others are round-shaped [19].

When cabbage matures, the basal leaves form a rosette of 7 to 15 sessile outer leaves each 250 to 350 × 200 to 300mm in size. The upper leaves form a compact flattened globosely ellipsoidal head that is 100 to 300mm in diameter that is formed because of fleshy leaves overlapping on one another around a single growing point. The stems are unbranched, 200 to 300mm long and are gradually thickened upwards. The single growing point has a ramified system of thin roots, where several fibrous roots are emerging from the taproot. About 90% of these roots are found in the upper 200 to 300 mm of the soil to the ground surface and some laterals penetrate down to 1.5 to 2m deep [16]. Closely related members of cabbages (*Brassica oleracea* Capitata and *Brassica rapa* subsp. *Pekinensis*) include; kale and collards (*Brassica oleracea* Acephala), Chinese broccoli (*Brassica oleracea* Alboglabra), cauliflower (*Brassica oleracea* Botrytis), Brussels sprouts (*Brassica oleracea* Gemmifera), kohlrabi (*Brassica oleracea* Gongylodes), broccoli (*Brassica oleracea* Italica), Field mustard (*Brassica rapa* subsp. Oleifera), Choy sum *(Brassica rapa* subsp. parachinensis) Bomdong (*Brassica rapa var.* glabra), Bok choy (*Brassica rapa* subsp. Chinensis) [16,17,18].

3. CABBAGE ECOLOGICAL REQUIREMENTS

Cabbage requires a relatively cool and humid climate [20]. The optimum temperatures for growth and development range from 15°C to 25°C. It is resistant to frost and can survive temperatures as low as -3°C without damage [14,16,21]. Water requirement is variety depended and varies from 380mm to 500mm per crop throughout the growing period. Crop water use, however, increases with growth period with a peak towards the end of the season during head maturity. Soil moisture less than 380mm causes limping and wilting while moisture higher than 500mm causes root rot leading to crop death [22]. Irrigation and water management or conservation practices are therefore important to ensure adequate soil moisture in areas prone to high evaporation [23]. This crop is equally sensitive to flooding, therefore, during the rainy season, appropriate drainage canals must be in place to drain off the excess water after heavy rain [14].

Light plays a key role in cabbage growth. It is crucial in determining photo-morphogenesis and photosynthetic biosynthesis [24]. Adequate light intensity is therefore required for maximum photosynthesis. Where light intensity is insufficient, photosynthetically active radiation (PAR), leaf chlorophyll content, and photosynthetic rate will decrease resulting in reduced formation of carbohydrates, leading to stem elongation and etiolation [25]. Sufficient light at photosynthetic photon flux density (PPFD) of 10 µmol m^{-2} s^{-1} is therefore needed to suppress the succulent elongation to increase dry matter deposition [26].

According to Adeniji [20], the cabbage crop is termed to be a heavy feeder that needs plenty of nutrients. It, therefore, thrives well under deep, well-drained fertile loamy soils with approximately 600mm rooting depth and adequate amounts of nutrients such as nitrogen, phosphorus, and potassium. Although Nitrogen plays a critical role in vigorous growth and all metabolic activities, excess levels cause loose head formation and internal decay. Phosphorus on the other hand plays a critical role in metabolism, germination, and root development [27,28]. Low Potassium (K) on the other hand results in marginal necrosis and lower head quality, but when it is in excess it can cause the heads to open. The plant has high Sulfur requirement, and it is sensitive to Calcium, Magnesium, and Boron deficiency. The general fertilizer recommendation is therefore 100 - 150kg/ha N: 50 – 65kg/ha P: 100 - 130kg/ha K. The fertilizer is applied in splits that are site specific. For example, three splits can be applied as follows: a basal, 3 weeks after transplanting, and during heading. In a situation where soils are sandy addition of manure and a mulching layer of 15 to 20cm deep is recommended [14,16].

The ideal soil pH for the crop ranges from 5.5 to 7.5 [14,15,16]. Where the soil pH is above 6.5, the leaves become dark, and the leaf margins die back while pH below 5.5, causes chlorosis and retarded growth. In saline soils, the crop is highly susceptible to blackleg disease [15,16]. Drainage is recommended in waterlogged soils and leaching of salts in saline conditions [23].

4. ECONOMIC IMPORTANCE OF CABBAGES

According to Wambani et al. [29], and Kibata [30], cabbage is among the popular leafy vegetable that is widely consumed by both rural and urban dwellers in Kenya. It is highly nutritious comprising of 92% water, 1% proteins, 0.1% lipids, and 5% carbohydrates [31]. It also contains 2% fiber, Vitamin A, C, and K, and mineral ions, like calcium, iron, sodium, zinc, magnesium, phosphorus, and potassium, which are crucial in human nutrition and health [32,33]. Cabbage also contains phenolics and glucosinolates [methylsulfinylbutyl isothiocyanate (sulforaphane, SFN) and phenethyl isothiocyanate (PEITC); and indole-3-carbinol (I3C) and 3,3′-diindolylmethane (DIM)] that are anti-carcinogenic for effective reduction of cancer-related diseases and prevent type 2 diabetes, cardiovascular diseases, inflammation of digestive systems, cataracts, and Alzheimer's disease [34,35]. The cabbage anticancer antioxidants are active against: lung cancer, gastric cancer, breast cancer, prostate cancer, colon cancer, rectum cancer, liver cancer, and pancreatic cancer [1]. A high intake of cabbages also ensures sufficient levels of iodine in the body of humans which can aid the proper functioning of the brain, thyroid gland, and nervous system [36].

The cabbage industry serves as a source of employment for many Kenyans ranging from small-scale farmers to middlemen and agribusiness players [8]. This empowers the rural population especially women and youths who are largely unemployed, have little capital and limited access to land, working under labour constraints. In return money obtained from this enterprise contribute to food and nutritional security at the household level as well as enabling women and youths attain some degree of financial independence within family budget [37,38,39].

5. PRODUCTION CONSTRAINTS OF CABBAGE FARMING IN KENYA

Despite the growing population and increased demand for food and nutrition security within the country, cabbage industry growth has been constrained over the years. Cabbage farming has been challenged by a myriad of factors such as pest and disease prevalence, the impact of climate change, land degradation, soil health decline, competing farm enterprises, erratic rains leading to water scarcity, weed infestation, land tenure systems, and land fragmentation, poor Structured Supply Chain and Market Systems, post-harvest losses, limited primary processing technologies and services, lack of harvesting technologies as well as poor agronomic technical knowledge [14,15,40,41].

5.1 Pest and Disease Prevalence

Cabbage is very susceptible to pest infestations in the field, which causes huge losses [40,42]. The major insect pests infesting cabbages in Kenya and other African states include the diamondback moth (*Plutella xylostella*), the cabbage webworm (*Helula undalis*), white butterfly (*Pieris brassicae*), cabbage aphid (*Brevycoryne brassicae*), cabbage looper (*Trichoplusia ni*) and green peach aphids (*Myzus persicae*) [15;40,42]. However, the diamondback moth, (*Plutella xylostella*), and cabbage webworm (*Helula undalis*) are the most destructive insect pests of cabbage crops (15,43,44]. These insect pests infest the *Brassica oleracea* crop at different stages of growth, causing huge destruction during the growth stages and eventually resulting in huge yield losses [42,44]. Other cabbage pests that attack at seedling stage include cutworm (*Agrotis spp*) flea beetles (*Phyllotreta striolata*), cabbage root maggot (*Delia radicum*), ants (*Formicidaes ssp*.), cabbage head caterpillar (*Crocidolomia pavonana*), and spider mites (*Tetranychus spp*).

Diseases negatively affect cabbage yields if not properly managed. The most disastrous diseases are classified as fungal, and bacterial. Fungal diseases include; Leaf Spot (*Alternaria brassicae*), Blight (*Alternaria brassiciola*), Downy Mildew (*Perenospora parasitica*), Damping off *(Pythium debaryanum*), Sclerotinia rot/ White Mould (*Sclerotinia sclerotiorum*) Yellows or Fusarium Wilt (*Fusarium oxysporum* f. sp *conglutinans*), and Black Leg (*Phoma lingum*). Conversely, common bacterial diseases include; Bacterial Soft Rot (*Pectobacterium carotovorum)*, Black Rot (*Xanthomonas campestris* pv. *campestris*), Wire Stem (*Rhizoctonia solani*), and Clubroot of Cabbage (*Plasmodiophora brassicae*), [14,15,45]. Most fungal diseases are commonly field based while bacterial diseases are both field and post-harvest.

5.2 Climate Variability and Limited Climate Smart Agriculture Knowledge and Skills

Considering that optimal crop growth and yield necessitate provision of all nutrients in correct forms and amounts, water plays a major role as a solvent for all soil chemical reactions that eventually determine germination, nutrient uptake, metabolisms, assimilation, photosynthesis, and all other plant biochemical processes [46,47]. Most of the cabbage production regions within the country have been experiencing either unpredictable, increased, or reduced rainfall over the past years. The constant off-season increased or erratic rainfall coupled with limited climate-smart agricultural knowledge and adoption among other factors constrain cabbage production within production areas leading to increased wastage due to high levels of moisture during maturity, or increased disease infections or reduced yields. [14,41]. Cabbage being a cool and humid climate crop, the optimum temperatures for growth and development range from 15°C to 20°C, therefore temperatures above 24°C delay maturity and vegetative growth and the number of leaves increase leading to the formation of loose heads or failure of head formation [19,48,49]. This makes Kenyan farmers in cabbage-producing areas depend heavily on cooler seasons for cabbage production.

5.3 Competing Farm Enterprises

The demand for highly valued food has become the driving factor for resource allocation which consequently influences resources allocated to cabbage production [50]. Competing farm enterprises because of pressure from food demand by the growing human population have created challenges in cabbage production with farmers, shifting to the production of vegetables with faster maturity rates and higher revenue [51,52].

5.4 Land Degradation and Declining Soil Health

Land degradation interacting with climate change represents one of the biggest and most urgent challenges for humanity today. According to FAO reports, land degradation within Kenya which is commonly in the form of poor soil health is attributed to poor agricultural activities. The activities include: i) Poor fertility management and nutrient cycling (ii) intensification iii) land subdivision leading to limited fallow period iv) leaching of soil nutrients into deeper soil horizons in areas that receive relatively high amounts of v) soil erosion vii) nutrient mining; viii) physical, chemical, and biological degradation of the soil through acidification and soil pollution [53,54,55,56,57,58]. According to Weil and Brady [46], adequate availability of nutrients in rightful proportions is paramount in crop growth and productivity. Availability of these nutrients for crop uptake is, however, determined by prevailing soil physical, chemical, and biological properties which are often compromised in unhealthy soils. Owing to the fact that the mineralogy of most cabbage growing regions is acidic in nature, poor soil health management predisposes the soils to acidity problems leading to poor availability of certain essential macronutrients and biota as well as the toxicity of some micronutrients [46,57,59]. This situation calls for continuous soil health management through the application of amendments such as organic fertilizers, inorganic fertilizers, and lime as well as the adoption of integrated soil fertility management climate-smart technologies. This is challenging in most of the cabbage growing areas because farmers grow cabbage as a monocrop, season after season and the inputs are also shared with other high-value crops. This leads to nutrient mining leading to poor yields and low returns to capital. Farmers who use commercial fertilizers also often use straight fertilizers that don't provide all limiting nutrients within their soils.

5.5 Poor Structured Supply Chain and Market Systems

According to Dyeyi and Zenda [60], access to profitable marketing of agricultural produce rely on infrastructure, supply chain and institutions. Availability of better transport network enables access to markets hence minimizing information dissymmetry about input and output quality and prices. There, however, exists poor coordination between supply chain actors of most perishable farm products, along with inefficient retail cold chain management practices within the country; identified as the vital causes of cabbage and other perishable crop produce wastage. Both commercial and small-scale farmers utilize considerable time in coordinating the supply chain of their cabbages to reach markets, but large percentage of their produce is often spoilt before it reaches the target market. This cabbage spoilage, deterioration and wastage, results in revenue losses for players within the cabbage value chain whose burden is often carried by producers. According to Chamberlin and Jayne [61], market access within most agricultural production areas has improved slightly over the years with large numbers of independent traders buying directly from rural farms. This mechanism has however been a drawback to farmers with some traders either under-weighing commodities or offering low prices. At times farmers incur losses due to impassable roads during rainy seasons leading to the destruction of cabbages and other fresh produce before reaching the market.

5.6 Access to Agro-Processing Technologies

According to Kirsten et al. [62] and KALRO [14], farmers' access to agro-processing technologies is crucial to guarantee the profitability of a product after harvesting; something that limits crop production in most African countries. Most cabbage farmers within the country either don't have access to agro-processing facilities or have access to old and outdated processing methods. This exposes them to high post-harvest losses leading to low enterprise profitability.

5.7 In Adequate Access to Agricultural Information and Extension Services

Access to agricultural information is critical and very crucial to increased agricultural productivity [63]. According to Yaseen [64], limited information sources in rural areas constrain farmer's agricultural production and growth. Public agricultural extension officers offer a significant role in linking farmers with current technologies and market information. Currently agricultural extension services are dismally offered to farmers, yet the government spends on agricultural research as a proportion of GDP. By 2016 it was 0.48%, approximately one-third of its value in 2006 [65]. The research- extension – farmer link in Kenya has however been deteriorating over the years with the current extension: farmer ratio standing at 1800:1 compared to the FAO recommendation of 400:1 [66,67,68,69]. As a result, many farmers have limited sources of useful and reliable soil and water management, agronomic and marketing information leading to low uptake of technologies, crop production and yields in the region.

According to Ndambiri et al. [70] and Dhakshana and Rajandran [71], there exists a positive relationship between new technologies adoption level and the availability of credit. Availability of credit eases the cash constraints and enables farmers to easily purchase inputs such as improved cultivars, fertilizer, and pesticides. Lack of security among horticultural farmers in Kenya, however, limits their access to credit facilities [72]. Additionally, though government policies play a major role in cushioning farmers, unlike other crops, there exists a limited specific legal or regulatory framework for most horticultural crop production [73].

5.8 Land Fragmentation and Land Tenure Challenges

High population densities within Kenya's highlands imply that farm sizes per farmer have continuously declined, with the average total farm size near the slopes of Mt. Kenya being between 1.0 and 2.0 hectares. Several enterprises are allocated within these small sized pieces limiting mechanization and economic viability. This also encourages intensification while limiting integrated soil fertility and integrated pest and disease management.

6. CONCLUSION AND RECOMMENDATIONS

The review indicates that cabbage plays a significant role in achieving improved human nutrition and health conditions and lowering poverty through food security and income generation. They act as a source of human food and nutrition by playing a role in the management of diseases such as cancer-related diseases, type 2 diabetes, cardiovascular diseases, and inflammation of the digestive system. Statistics show that although the area under production has been increasing over the years. Production on the other hand has not increased significantly and it is constrained by myriad factors. Some of the factors that constrain cabbage production within Kenya include Pests and disease prevalence, climate change effects, soil health decline due to nutrient mining without adequate replenishment. Other factors such as poor access to agricultural information, credit facilities, poorly structured marketing systems as well as access to agro-processing technologies play a key role in constraining cabbage production within the country. Land fragmentation, poor post-harvest losses management and delivery systems were also identified to be key limiting factors. The review revealed that the country has the potential to support maximum cabbage production. This however requires adoption of climate smart technologies, improved post-harvest handling technologies, farmer-extension linkage, government policies, credit facilities as well as structured market system.

ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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