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Introductory Chapter: Studies on Cucumber

Huixia Jia and Haiping Wang

1. Introduction

Cucumber (*Cucumis sativus* L.) belongs to *Cucumis* genus in *Cucurbitaceae* family and is an economically important fruit vegetable. There are three wild or semi-wild varieties of cucumber: *C. sativus* L. var. *hardwickii*, *C. sativus* L. var. *sikkimensis*, *C. sativus* L. var. *xishuangbannanensis*. Cucumber is indigenous to India and likely originated from the foothills of the Himalayan Mountain [1, 2]. Cucumber was cultivated ~3000 years ago in India, and it seems to spread rapidly to Western Asia, and then to Southern Europe [2]. Cucumber was introduced respectively to North China through the Silk Route and to South China from Burma and India-China border, and subsequently spread to East Asia [2]. Genome variation analysis showed cucumber core germplasms were divided into four geographic groups including India, Eurasia, East Asia, and Xishuangbanna [3]. Nowadays, cucumber is widely cultivated in temperate and tropical regions throughout the world [4]. The total production of cucumber was 87,805,086 tons worldwide, and Asia was the largest producer accounting for 84.9% of the world's total production in 2019 (www.fao.org/faostat/en/). With abundant water, nutrients and phytochemical composition, cucumber has versatile uses in culinary, therapeutic and cosmetic purposes [5, 6]. Cucumber has multiple advantages such as diploid, small genome, short life cycle and self-compatible mating system, so it is suitable for genetic studies. Moreover, cucumber has been identified as a model plant for studying sex determination and plant vascular biology [7]. Consequently, numerous studies have been conducted to discover the miracle of cucumber. The book will cover the extensive benefits, production and market, cultivation and management, pests and diseases, breeding progress of cucumber.

2. Biological characteristics

Cucumber is an annual climbing herbaceous plant. The root system is shallow and mainly distributes in the cultivated land layer of 30 cm. The stem is vine with different degree of apical dominance. The cross section of the stem is rhombus, and the epidermis of the stem has burrs. The axillae on the stem have the ability of branching, and the number of branching varies greatly among varieties. The cotyledons of cucumber are opposite and long elliptic; euphylla are alternate, simple, pentagonal palmate or cordate in outline, and the blades are 3–7 lobed. The flower is axillary, unisexual and occasionally hermaphrodite. The calyx is green with bristles, and the corolla is yellow. The colour of young fruit changes from white to pale green, while mature fruit is yellow or brown when ripened. The shape of the fruit is diverse, such as clublike, cylindrical and spherical. Each fruit has 100–400 seeds. The weight of 1000 seeds is about 20–40 g.

3. Culinary, therapeutic and cosmetic uses of cucumber

At present, cucumber is the fourth most widely cultivated vegetable after tomato, cabbage and onion [8]. Cucumber has versatile uses in culinary, therapeutic and cosmetic purposes [5, 6]. Nutritional and epidemiological researches have shown various benefits of cucumber. For example, cucumber contains abundant nutrients and has crunchy texture and unique flavor, so it is a quintessential vegetable used for a variety of dishes, and it is also indispensable for salad, soup and smoothie. Cucumber is rich in superior hydration and phytochemicals, which have diverse health benefits including weight loss, anti-inflammation, remedy for multiple diseases of eczema, constipation, hypertension, atherosclerosis, cancer, etc. [9]. Recent studies found that the presence of kaempferol in cucumber is an important antidiabetic agent [10]. Furthermore, cucumber is popularly used for natural beautification and for skin treatments [11].

4. Influence factors and solutions of cucumber fermentation

Cucumber pickles are most commonly fermented vegetable and widely consumed throughout the world [12]. Good fermentation depends on the proper combinations and interactions of multiple physical, chemical and microbiological factors [13]. Brine storage and process operations are susceptible to oxidation reactions during the fermentation process, and this has adverse influence on the quality property of cucumber pickles. To control the influence factors of cucumber fermentation, researchers have done many efforts on modern and advanced technologies, such as reducing the concentration of brining sodium chloride, developing the brining properties using lactic acid bacteria cultures, developing an anaerobic tank system, preventing cucumber gaseous deterioration by pouring of CO₂ from fermentation brines [13]. After storing the brine, excess salt and organic wastes need to be leached to complete the product processing, and these wastes are sources of serious environmental concern. Thus, the waste disposal needs to be solved in the cucumber pickle industry.

5. Performance, structure and constraints of cucumber market

Marketing is vital for linking production and consumption and facilitating agricultural productivity and employment [14]. Market performance is the ultimate result of various market activities, and market structure is the organization characteristics of the market that influence the nature of competition and pricing [15]. Both male and female participate in cucumber marketing, and the male–female rate has great differences in different regions. The wholesalers are older than the retailers. In Ibadan, most of the retailers were within 31–40 years age, whereas most of the wholesalers were within 41–50 years age. It's gratifying that cucumber marketing is usually profitable for the retailers and wholesalers at both peak and lean seasons of cucumber production. However, the cucumber market is competitive, and inequality exists in the market. Commodity perishability is an important constraint in cucumber market. Thus, it is indispensable to reduce perishable degree and prolong storage time after post-harvest.

6. Soil moisture and fertilizer management of cucumber

Inappropriate farming systems and poor agronomic management are responsible for low yield of cucumber. The quality/fertility status of soils is essential for growth and development for cucumber [16]. With good moisture and fertilizer management, optimum yield of cucumber might be attained. The conventional irrigation methods including flooding irrigation, furrow irrigation and drip irrigation have been widely applied for a long time in cucumber cultivation because of their low cost or simple operation [17, 18]. However, these irrigation methods are surface irrigation and are driven by positive pressure, which may cause low water use efficiency, water wastage and nutrient loss [16, 19]. To solve these problems, new irrigation technique such as negative pressure irrigation that controls automatically water release based on the soil water potential difference should be encouraged [16]. Inadequate fertilizer use causes low soil fertility that cannot provide sufficient nutrients for the normal growth of cucumber. The integration application of inorganic and organic fertilizer is more beneficial than the sole use of inorganic fertilizer or organic manures in cucumber production [20]. Moreover, fertilizer sources need to dissolve or decompose to make nutrients available for cucumber plants, so soil fertility also depends on soil water, temperature and density. Consequently, the soil management strategies such as negative pressure irrigation, seasonable fertilization, application of organic mulches and conservation tillage should be appropriately applied for sustainable production of cucumber.

7. Biostimulators promote growth of cucumber under soilless cultivated condition

Soilless cultivation in substrate culture is an important cultivation pattern for cucumber in greenhouses. The substrates should have specific physical properties including pore volume, air and water capacity, and density of substrates. Studies indicate that biostimulators can stabilize the production process to enhance plant growth under stress conditions. For instance, humate can increase vitality and growth of plants, improve seed germination, promote nutrient uptake, enhance transport and availability of micronutrients, and increase ion-exchange capacity. Lactates can produce bioregulatory effects to improve nutrient balance and plant vitality [21]. *Bacillus subtilis*, as a microorganism from the rhizosphere, can accelerate plant growth, stimulate the process of formation of plant organs, and enhance the resistance of biotic and abiotic stresses [21]. Application of biostimulators mixture (humate, lactate, and *Bacillus subtilis*) prevent growth reduction of cucumber under pH and temperature stresses through enhancing the root growth, whereas the growth is markedly reduced under stresses if no biostimulator is applied.

8. Pests and diseases during cucumber cultivation and production

During growth process, cucumber might be affected by multiple insect pests and diseases, resulting in decrease of yield and quality. The major insect pests in cucumber including *Diabrotica undecimpunctata*, *Acalymma vitatum*, *Bactrocera cucurbitae*, *Raphidopalpa foveicollis*, *Epilachna implicate*, *Myzus persicae*, *Aphis gossypii*, *Anasa tristis*, *Trialeurodes vaporariorus*, *Bemisia tabaci* and *B. argentifolii* [22, 23]. Currently, the pest management mainly relies on chemical pesticides

that cause environmental pollution, pest resistance, and disturbance of balance between the pests and natural enemies. Moreover, this control strategy is harmful to human health. Therefore, an integrated pest management including pest monitoring, cultural method, host resistance, botanicals, biological control, and judicious use of chemicals is recommended for controlling these pests [24, 25]. Many diseases caused by viral, bacterial, fungal and nematode pathogens severely affect the cultivation and production of cucumber. Viruses infecting cucumber belong to three genera: *Potyvirus*, *Cucumovirus* and *Crinivirus* [26]. Especially, the CMV, ZYMV, WMV, MWMV, PRSV and BPYV are major viruses that cause severe symptoms to cucumber. Downy mildew, powdery mildew and anthracnose also cause substantial losses of cucumber production [27]. Some pathogenic fungi including *Alternaria tenuis*, *Fusarium equiseti*, *Phytophthora capsici*, *Botrytis cinerea* and *Cladosporium tenuissimum* cause rotting and high post-harvest losses of cucumber [28]. Furthermore, root-knot nematodes are prevalent destructive pathogens of cucumber [29]. Though a series of chemicals have been evaluated and screened to control these diseases, the biological control strategy and high-resistant varieties of cucumber need be developed and created to resist diseases in efficient and environmental ways.

9. Polyphenols act as antioxidants in cucumber to defense stresses

Plant secondary metabolites play important roles in adapting to various environments and defending against biotic and abiotic stresses. Cucumber is a rich source of phenolic compounds that are important secondary metabolites [30, 31]. The antioxidant capacity of cucumber seems to be attributing to polyphenols that scavenge singlet oxygen, hydroxyl and lipid peroxy radicals to prevent lipid oxidation. Better understanding of the molecular regulation of polyphenols biosynthesis is crucial to increase the production of polyphenols. Polyphenols are derivatives of phenylpropanoid pathway which involves an array of enzymes. Among these, phenylalanine ammonia lyase, chalcone synthase, cinnamate 4-hydroxylase and dihydroflavonol reductase play important roles [32]. In-depth study of these key enzymes in cucumber will facilitate to reveal the molecular mechanism of polyphenol synthesis, which is helpful for advancement in biotechnological and industrial applications.

10. Progress of traditional breeding and molecular breeding in cucumber

In the past decades, traditional breeding has played essential roles in cultivar innovation of cucumber. Some superior varieties with early maturity, high yield and high resistance have been developed through hybridization and mutagenesis [33]. However, this progress is slow because of the long cycle and difficulty in selection of stable genetic characters or genotypes. To overcome the obstacle of traditional breeding, molecular breeding technologies including molecular marker assisted breeding, genome-wide design breeding and genetic engineering have been applied in cucumber to accelerate the breeding cycle and select desirable traits. Molecular breeding of cucumber has made some progress and achievements on completion of genomics, genetic architecture and molecular mechanism underlying important traits, and creation of high quality and multi-resistant varieties [7, 34–36]. With increasing consumption demand of cucumber, more new varieties with excellent comprehensive properties are in need, and we might make some efforts from the following aspects: (i) expanding collection and utilization of cucumber germplasm

resources; (ii) establishing highly efficient gene editing and genetic transformation technologies in cucumber; (iii) identifying new loci or genes associated with key agronomic traits of cucumber and combining multiple molecular markers of excellent traits into one variety; (iv) realizing rapid accumulation of omics genotypes and phenomics [37].

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