AKENTEN APPIAH-MENKA UNIVERSITY OF SKILLS TRAINING AND ENTREPRENEURIAL DEVELOPMENT

FACULTY OF AGRICULTURAL EDUCATION

MAMPONG-ASHANTI

EFFECTS OF STAKING METHODS ON GROWTH AND YIELD OF CUCUMBER

CHARLES OSEI

2024

AKENTEN APPIAH-MENKA UNIVERSITY OF SKILLS TRAINING AND ENTREPRENEURIAL DEVELOPMENT

FACULTY OF AGRICULTURE EDUCATION

MAMPONG-ASHANTI

EFFECTS OF STAKING METHODS ON GROWTH AND YIELD OF CUCUMBER

CHARLES OSEI

7191910036

A THESIS SUBMITTED TO THE DEPARTMENT OF CROP AND SOIL SCIENCES OF THE FACULTY OF AGRICULTURE EDUCATION OF THE AKENTEN APPIAH-MENKA UNIVERSITY OF SKILLS TRAINING AND ENTREPRENEURIAL DEVELOPMENT, IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF A DEGREE OF MASTER OF EDUCATION IN CROP AND SOIL SCIENCES

OCTOBER, 2024

DECLARATION

CANDIDATE'S DECLARATION

I hereby declare that except references to other people's works which have been duly acknowledged, this thesis is my own original work towards the award of a Master of Education in Crop and Soil Sciences and that this thesis or part has not been accepted for the award of a degree in this university, or elsewhere.

Charles Osei ……………………… ………………………..

(Student) Signature Date

SUPERVISOR'S DECLARATION

I hereby declare that the preparation and presentation of this thesis was supervised in accordance with the guidelines of the Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development on thesis work for the award of Master of Education in Crop and Soil Science.

Rev. Kwame Nkrumah Hope ……………………… ………………………..

(Supervisor) Signature Date

ACKNOWLEDGEMENT

My profound gratitude goes to Jehovah God for the guidance and protection throughout my work. I owe great debt to my supervisor Rev. Kwame Nkrumah Hope of the Department of Crops and Soil Science Education, and Faculty of Agriculture Education, Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development respectively for their encouragement, guidance and constructive criticism throughout this research work.

The next gratitude goes to all those who helped in diverse ways and contributed immensely to the success of this research work.

Finally, words cannot express my appreciation to my parents whose motivation and prayers saw me through my entire education.

DEDICATION

I dedicate this thesis to my supervisor, Rev. Kwame Nkrumah Hope and my lovely family for their care and prayers throughout the period of my masters education.

TABLE OF CONTENTS

DECLARATION iii
ACKNOWLEDGEMENT iv
DEDICATION v
TABLE OF CONTENTS vi
LIST OF TABLE ix
LIST OF FIGURES x
ABSTRACT xi

CHAPTER ONE: INTRODUCTION 1
1.1 Background of the study 1
1.2 Problem statement 2
1.2 Objective of the study 2
1.3 Significance of the study 3
1.5 Limitations of the study 4

CHAPTER TWO: LITERATURE REVIEW 5
2.1 Cucumber 5
2.1.1 Genetics for different characters 6
2.1.2 Floral biology and crossability 7
2.1.3 Sex Expression 9
2.2 Breeding methods of cucumber 11
2.2.1 Mass Selection 11
2.2.2 Bulk Population Method 11
2.2.3 Backcross Breeding Method 11
2.2.4 Pedigree Method 12
2.2.5 Heterosis Breeding 12
2.2.5.1 Protection of flowers and hand pollination 12
2.2.5.2 Removal of the buds of staminate flowers and open pollination 13
2.2.5.3 Chemical suppression of staminate flowers and open pollination 13
2.2.5.4 Use of gynoecious lines 13
2.2.5.4.1 Development of gynoecy 14
2.2.5.4.2 Gynoecious lines (Temperate and tropical) 14
2.2.6 Interspecific Hybridization 14
2.2.7 Biotechnological Innovations 15
2.2.7.1 Application of molecular markers 15
2.2.7.2 Genetic diversity and genetic map 15
2.2.7.3 Generation of molecular linkage maps and tagging of useful genes 16
2.2.7.4 Mapping of quantitative trait loci 17
2.3 Uses and Benefits of cucumber 18

2.4 Varieties of cucumber in the world and in Ghana 19
2.5 Production volumes in the world and in Ghana 20
2.5.1 Growth of cucumber crop 21
2.5.1.1 Climate and Soil 21
2.5.1.2 Land Preparation and Sowing 22
2.5.1.3 Plant Nutrition 22
2.5.1.4 Weed and Water Management 24
2.5.1.5 Fertilizer Application of cucumber 25
2.5.2 Nutritional and health importance 25
2.6.1.2 Protective staking 30
2.6.1.3 Supportive staking 31
2.6.2 Effect of staking on growth and yield of cucumber 32
2.8 Harvesting of cucumber 41

CHAPTER THREE: METHODOLOGY 47
3.1 Experimental sites and Location 47
3.2 Soil type and vegetation at the experimental site 47
3.3 Experimental Design, Treatment and Field layout 48
3.3.1 Experimental Design 48
3.3.2 Treatments 48
3.3.3 Field layout 48
3.4 Planting material 49
3.5.1 Land preparation and Planting 49
3.6 Cultural Practices 50
3.6.1 Weed control 50
3.6.2 Pest and Disease control 52
3.7 Data Collection and Statistical Analysis 52
3.7.1 Phenological Data 52
3.7.1.1 Days to 50% Emergence 52
3.7.1.2 Days to 50% flowering 52
3.7.1.3 Days to 50% fruiting 52
3.7.1.4 Days to Maturity 53
3.7.2 Vegetative Growth Data 53
3.7.2.1 Percentage plant establishment 53
3.7.2.2 Vine length 53
3.7.2.3 Number of leaves per plant 53
3.7.2.4 Number of branches 54
3.7.3 Yield and Yield components 54
3.7.3.1 Number of plants harvested 54
3.7.3.2 Number of fruits per plant 54

3.7.3.3 Fruit length 54
3.7.3.4 Fruit diameter 55
3.7.3.5 Fruit weight per plant 55
3.7.3.6 Total number of fruit per plot 55
3.7.3.7 Fruit weight per plot (Fruit yield) 55

CHAPTER FOUR: RESULTS 56
4.1 Number of leaves 56
4.2 Plant height 56
4.3 Leave Length 57
4.4 Leave Width 57
4.5 Stem girth 58
4.6 Fruit Length 58
4.7 Fruit Diameter 59
4.8 Fruit Weight (Tag) 59
4.9 Fruit Weight (Untag) 60

CHAPTER FIVE: DISCUSSION 61
5.1 The influence of staking on growth of cucumber 61
5.2 The influence of staking on yield of cucumber 62

CHAPTER SIX: CONCLUSION AND RECOMMENDATIONS 65
6.1 Conclusion 65
6.2 Recommendations 65

REFERENCES 66

LIST OF TABLES

Table 4.1: Number of leaves of cucumber as influenced by different staking methods.... 56
Table 4.2: Plant height of cucumber as influenced by different staking methods............. 56
Table 4.3: Leave Length of cucumber as influenced by different staking methods.......... 57
Table 4.4: Leave width of cucumber as influenced by different staking methods 57
Table 4.5: Stem Girth of cucumber as influenced by different staking methods............... 58
Table 4.6: Fruit Length of cucumber as influenced by different staking methods............ 59
Table 4.7: Fruit Diameter of cucumber as influenced by different staking methods......... 59
Table 4.8: Fruit Weight (Tag) of cucumber as influenced by different staking methods.. 60
Table 4.9: Fruit Weight (untag) of cucumber as influenced by different staking methods 60

LIST OF FIGURES

Figure 1: Anchor Staking 30
Figure 2: Protective Staking 31
Figure 3: Supportive Staking 31
Figure 4: Field layout 49

ABSTRACT

The study investigated the effects of staking methods on growth and yield of cucumber. The experiment was conducted at the Multipurpose crop nursery of the Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development, Mampong- Ashanti. The experimental design used was a randomized complete block design (RCBD) with three replications. The treatments used for the study were T1- No staking, T2- Supportive staking, T3- Anchor staking and T4- Protective staking. The data collected were subjected to analysis of variance (ANOVA) using Genstat statistical package (Genstat, 2011). The results revealed that there was significant difference ($P<0.05$) on the number of leaves at 2 WAP only. There was no significant difference ($P>0.05$) on the cucumber height for all the WAP. There was significant difference ($P<0.05$) on the leave length for only 3WAP. There was no significant difference ($P>0.05$) on the leave width for WAP. There was no significant difference ($P>0.05$) on the stem girth for WAP. The number of leaves, plant height, leaves length, leave width and stem girth of the cultivated cucumber increases to higher values with increasing weeks after planting. The string staking method recorded the highest number of leaves, plant height, leave length, leave width and stem girth. The string staking method recorded the highest fruit length, fruit diameter and fruit weight. There was significant difference ($P<0.05$) on the cucumber fruit length for only 3WAP. There was no significant difference ($P>0.05$) on the fruit diameter for WAP. There was no significant difference ($P>0.05$) on the fruit weight (tag) for WAP. There was no significant difference ($P>0.05$) on the fruit weight (untag) for WAP. String staking method should be used for cucumber production since it increases phonological and yield parameters.

CHAPTER ONE: INTRODUCTION

1.1 Background of the study

Cucumber (*Cucumis sativus*) belongs to the family Cucurbitaceae and has been consumed for over 3,000 years in Asia, where it is native (Pandey & Kujur, 2022). While cucumber is likely native to India (Yang & Sagar, 2022), some studies suggest that Egyptians also cultivated the crop in ancient times, with later adoption by the Greeks and Romans (Goel *et al.*, 2022). In contrast, the African horned cucumber (*Cucumis metuliferus*), a traditional food plant indigenous to Southern and Central Africa, is widely cultivated in countries such as Namibia, Botswana, South Africa, and Eswatini (Omokhua-Uyi & Van Staden, 2020).

The Kiwan variety, which is increasingly popular, is rich in vitamins (such as C and B6), as well as minerals like magnesium, calcium, potassium, and iron (Murray & Horswill, 2022). Additionally, Kiwan cucumbers contain antioxidants that help the body combat free radicals (dos Santos *et al.,* 2022), making them essential for maintaining a healthy lifestyle. Cucumbers also offer external health benefits, such as alleviating sunburn pain and reducing swelling (Uzal *et al.*, 2022).

Although cucumber is cultivated globally, the primary production regions include Asia, Euro-Asia, and the Middle East (Heigermoser *et al.*, 2022). However, cucumber production and productivity in Africa, especially in Ethiopia, remain low due to factors such as limited government support, low societal awareness, lack of improved varieties, pest and disease problems, and declining soil fertility (Prasad & Kothari, 2022).

Studies show that cucumbers grown with appropriate spacing and staking produce significantly better results than unstaked and unspaced plants, mainly due to reduced competition, better sunlight exposure for photosynthesis, and reduced overcrowding (Nweke *et al.,* 2013). Staking also optimizes yield, with higher fruit production in trellised plants compared to non-trellised ones (Tiwari *et al.,* 2020).

1.2 Problem statement

Cucumber, being a high-value crop, has seen increased commercial exploitation in greenhouses, providing an opportunity to improve growers' income. Protected cultivation offers the best option for increasing cucumber production, as it promotes a less restrictive environment for plant growth and development compared to open field conditions (Singh & Sharma, 2018). Due to the high costs associated with greenhouses, it is essential to develop specialized agronomic practices, such as pruning, optimizing stand density, staking, fertilization, and irrigation, to achieve high yield and fruit quality. In protected environments, cucumbers are predominantly grown with a single main stem, and axillary buds are eliminated regularly (Mendoza-Pérez *et al.*, 2018).

Plants are typically trained to arrange leaves optimally for maximizing light capture and improving ventilation, which reduces the incidence of pests and diseases, facilitates harvesting, and enables the use of higher plant population densities to obtain high-quality fruit yields (Gogoi *et al.,* 2020). Due to cucumber's rapid growth, manipulating plant architecture through pruning and staking is necessary for maximizing yields and fruit quality. Staking cucumber has been shown to increase fruit yield due to better light interception, as reported by Tiwari *et al.* (2020). Staking prolongs vegetative growth and delays fruit formation. In their study, Tiwari *et al.* (2020) found that staked cucumbers produced an average marketable yield significantly higher than non-staked cucumbers. The non-staked plants also produced more non-marketable fruits due to poor color quality, reduced fruit length, and the development of yellow bellies, which predispose fruits to spoilage.

Staking improves the color, fruit length, and sugar content of cucumbers (Mendoza-Pérez *et al.*, 2018). Despite the clear benefits of staking, there is limited literature on the optimal time for staking to achieve increased yield and fruit quality. Recent studies have focused on both pruning and staking practices in cucumber production (Singh & Sharma, 2018). Most of the previous research has concentrated on pruning methods and stand density (Tiwari *et al.*, 2020). This study aims to determine the effects of staking methods on the growth and yield of cucumber.

1.2 Objective of the study

The main objective of the study is to assess the effects of staking methods on growth and yield of cucumber. Specifically, the study will seek to

1. Assess the influence of staking on growth of cucumber
2. Determine the influence of staking on yield of cucumber

1.3 Significance of the study

The study will be of immense benefit to farmers since it will document information on effects of staking methods on growth and yield of cucumber. It will provide information on benefit of staking in cucumber production. This study reveals the different factors influencing the choice of staking in cucumber production. The study adds to existing theoretical literatures and further serves as a spring board for further studies in different geographical, economic and political settings. Thus, this study is targeted primarily at a Ghanaian and international audience within the vegetable production especially cucumber production as well as management and stakeholders in cucumber production

1.5 Limitations of the study

i. Financial constraint in carrying out the research work.

ii. Unfavorable climatic conditions at the time the project was on going such as continuous rainfall and short drought

CHAPTER TWO: LITERATURE REVIEW

2.1 Cucumber

Cucumber (*Cucumis sativus* L.) belongs to the Cucurbitaceae family and is a commercially cultivated crop worldwide. It originated in India, where it is found wild in the Himalayan region. As a member of the Cucurbitaceae family, it shares this grouping with other horticulturally significant crops such as melons and squashes. Of the 30 species in the genus *Cucumis*, *C. sativus* is of the highest economic importance and is commonly consumed fresh in salads, fermented as pickles, or cooked as a vegetable (Balkaya *et al.*, 2020). The cucumber fruit is borne on indeterminate, tendril-bearing vines that thrive in subtropical and tropical climates (Seymour *et al.*, 2020). Its interior ovary typically has three united carpels, and determinate cultivars have been developed for more compact growth and mechanical harvesting (Staub *et al.*, 2019).

The cucumber fruit's shape ranges from round to oblong or cylindrical, with small warts and spines derived from trichomes. High-quality slicing cucumbers are dark green and firm, with no wrinkled or pitted ends. The color and texture of the fruit are determined by its spine color, which is associated with the mature fruit color and netting patterns. While white-spined cucumbers are light green to yellow when mature, black-spined fruits are orange to brown and often netted. The flesh of most cultivars is crisp and white, although some varieties exhibit pale orange flesh. Cucumbers vary in size, with lengths ranging from 10 to 76 cm. When cucumbers mature, they change color from green to yellow and become inedible (Pascual *et al.*, 2017). Although cucumbers are botanically fruits, their sour-bitter flavor often leads to their treatment as vegetables in culinary contexts (Balkaya *et al.*, 2020).

Fruits are harvested at various stages of development. At the edible stage, cucumbers are typically green, but some cultivars can be white or yellow. They are generally harvested before the seeds fully enlarge and harden, with firmness and external glossiness serving as indicators of proper maturity. Parthenocarpic fruits grown in greenhouses are often harvested at lengths of 12–14 inches, weighing approximately 1 pound (Amiri *et al.*, 2016). Straight, uniformly cylindrical fruits, slightly tapered at both ends, are considered of the highest quality.

2.1.1 Genetics for different characters

In recent years, cucumber has been a focal point of genomic studies. The cucumber genome was sequenced in 2009, offering insights into traits such as disease resistance, sex expression, and cucurbitacin biosynthesis (Huang *et al.*, 2009). This genomic information has greatly aided the development of new cultivars and provided a deeper understanding of plant vascular function. Studies have also focused on identifying genes that control key morphological traits, resistance, and plant reproduction (Pan *et al.*, 2017). For example, multiple pistillate flowering in cucumbers is controlled by a single recessive gene, *mp*, and several genes have been associated with male sterility, including *ms-1* and *ms-2* (Jiang *et al.*, 2020).

Resistance to diseases like watermelon mosaic virus and downy mildew is genetically complex, with multiple genes contributing to resistance (He *et al.*, 2015). Genes such as *pm-1* and *dm* have been identified as significant contributors to disease resistance, with researchers continuing to explore the complex inheritance patterns of these traits (Wang *et al.*, 2019).

2.1.2 Floral biology and crossability

Cucumber flowers' opening and closing are highly influenced by light and temperature, with anthesis occurring between 5:30 a.m. and 7:00 a.m. Anthers typically dehisce between 4:30 a.m. and 5:00 a.m., and pollen fertility decreases sharply by afternoon (Jensen *et al.*, 2021). Cross-pollination between wild and cultivated cucumber species remains a challenge due to genetic incompatibilities. For instance, *C. sativus var. hardwickii*, found in the Himalayas, crosses readily with cultivated cucumber, but wild African species remain largely incompatible (Dane *et al.*, 2020).

Although cucumber is known as only a cultivated plant, a *Cucumis* form *Cucumis sativus* var. *hardwickii* R. (Alex.) with 2n = 2x = 14 crosses readily with cultivated cucumber. Duong *et al.* (2021) examined the Indian wild cucumber *Cucumis sativus* L. var. *hardwickii* Kitamura and 81 accessions of cultivated cucumber for six isozymes and concluded that Indian wild cucumber is a distant relative of cultivated cucumber. Wild African *Cucumis* species (mostly 2n = 2x = 24) are cross incompatible with cucumber, which are themselves cross-incompatible. Likewise, the wild, free living *C. hystrix* is only sparingly fertile with cucumber (Dey *et al.*, 2020). This species is found only in the Yunnan Province of Southern China, and has unique genetic attributes that make its taxonomic determination complex.

Cucumis hardwickii is a wild relative of *C. sativus* that grows in the foothills of Himalayan mountains and is used by native peoples of Northern India as a laxative (Paniagua-Zambrana *et al.,* 2024). This botanical variety is sympatric and cross compatible with *C. sativus* and possesses a multiple fruiting and branching habit that is not common in cucumber. *C. hardwickii*, therefore, represents the extreme in variation in *C. sativus* germplasm (Ahmed *et al.,* 2022), and, thus, has potential for increasing genetic diversity in commercial cucumber (Grumet *et al.*, 2022).

Depending upon the ratio of male, female, and bisexual flowers produced by the plant, cucumber plants are classified as monoecious, gynoecious, andromonoecious, or hermaphrodite (Li *et al.,* 2022). Monoecy, the most common flowering phenotype, produces numerous male flowers with infrequent female flowers (Li *et al.,* 2022). Gynoecious cucumber plants produce only female flowers (Li *et al.,* 2020). Andromonoecious plants produce perfect and staminate flowers on the same plant, while hermaphroditic plants produce perfect flowers with both staminate and pistillate organs (Shwe *et al.,* 2020). Most greenhouse-grown cultivars grown before 1980 were monoecious; however, modern cultivars are gynoecious hybrids (Sharma *et al.,* 2021). Although sex expression in cucumber plants is determined genetically, it can be modified by environmental factors; high nitrogen, short days, low light intensity, and low night temperatures are factors that favor femaleness.

2.1.3 Sex Expression

Sex expression in cucumber plays a critical role in commercial production, as it impacts the harvest date and yield. Cucumber plants are classified based on their flower types into monoecious (bearing both male and female flowers), gynoecious (bearing only female flowers), and andromonoecious (bearing both male and perfect flowers) (Saito *et al.*, 2017). Modern greenhouse cucumber cultivars are primarily gynoecious hybrids, which have been shown to increase fruit yield and uniformity (Malepszy & Niemirowicz-Szczytt, 2016).

The control of sex expression is a complex interplay between genetic and environmental factors. Ethylene plays a crucial role in inducing femaleness, while gibberellins promote maleness (Zhang *et al.*, 2020). The gene *CsACS1*, which regulates ethylene synthesis, is closely linked to female sex expression (He *et al.*, 2015). Advances in genetic research continue to provide new insights into the regulation of sex expression and the potential for manipulating flowering types to optimize commercial production.

2.1.3.1 Fruit set

The initiation of fruit set involves the stimulation of the ovary to develop into a rapidly growing fruit. In cucumber, fruit set can occur through pollination or parthenocarpy, which may be induced naturally (genetic) or chemically by applying growth regulators (Boonkorkaew *et al.*, 2020). Parthenocarpic cucumbers develop fruits without pollination, providing a significant advantage in greenhouse production and environments with poor pollinator activity.

2.1.3.2 Pollination

Fruit set in cucumber is typically initiated when pollination of the pistillate flower occurs, with pollen transferred to the stigma. For successful pollination, both male and female or perfect flowers must be open on the same day, and insect pollinators, such as bees, facilitate pollen transfer. Although hand pollination is possible, it is labor-intensive and not widely practiced commercially. Cucumber yield is strongly dependent on successful pollination unless the plant is parthenocarpic (Vallejo-Marin & Barrett, 2018).

2.1.3.3 Parthenocarpy

Pollination can be mimicked through the application of exogenous hormones, primarily auxin and gibberellin, to induce parthenocarpy. This process is referred to as induced parthenocarpy, while natural parthenocarpy occurs via endogenous growth signals (Chen *et al.,* 2018). However, there are conflicting reports regarding the genetic control of parthenocarpy in cucumber. While parthenocarpy is believed to be controlled by an incomplete dominant gene, recent findings suggest that multiple genes may be involved (Sun *et al.,* 2016). The expression of parthenocarpy is highly influenced by environmental factors and is more pronounced in cucumber lines with a higher proportion of female flowers. The mechanism of fruit-set initiation in parthenocarpic cucumbers is linked to auxin accumulation in the immature ovary, although some researchers argue that cytokinin synthesis plays a role (Chen *et al.,* 2018; Boonkorkaew *et al.,* 2020).

2.2 Breeding methods of cucumber

Cucumber breeding methods are determined by the specific market requirements, such as pickling or fresh market types. Breeding programs typically follow historically proven methodologies but are increasingly incorporating emerging technologies to enhance productivity and resistance traits. Cucumber is not prone to inbreeding depression, though considerable heterosis has been observed, which makes various breeding procedures applicable (Pandey & Choudhary, 2016).

2.2.1 Mass Selection

Mass selection is a straightforward breeding technique used to select desirable traits controlled by recessive genes, such as bush habit, spinelessness, and lack of bitterness (Mishra *et al.*, 2023). This method allows for the accumulation of favorable traits over successive generations.

2.2.2 Bulk Population Method

The bulk population method has been used to develop cucumber varieties resistant to diseases such as anthracnose and downy mildew. For example, pickling and slicing selections resistant to these diseases have been developed by crossing anthracnose-resistant introduction ‘PI 197087’ with downy mildew-resistant lines (Jones *et al.*, 2019).

2.2.3 Backcross Breeding Method

Backcross breeding is a method used to transfer a highly heritable trait (qualitative trait) into an otherwise superior inbred line. Examples include transferring traits such as determinate growth habit (de), downy mildew resistance (dm), and nematode resistance (mj) into cucumber lines. Typically, six generations of backcrossing to the recurrent parent are required to achieve the desired genotype (Pandey & Choudhary, 2016). Using this approach, lines resistant to scab and those combining high yield with quality fruit traits have been successfully developed (Zhou *et al.,* 2020).

2.2.4 Pedigree Method

The pedigree method involves selecting single plant segregates in the F2, F3, and later generations derived from crosses between desirable parents. This method allows breeders to track individual plants' traits across multiple generations to achieve the desired combination of characteristics in the final cultivar (Xie *et al.,* 2017).

2.2.5 Heterosis Breeding

Heterosis, or hybrid vigor, has been exploited in cucumber breeding for traits such as earliness, high yield, and quality fruits (Jat *et al.,* 2021). Various hybrid seed production methods are employed to maximize these traits.

2.2.5.1 Protection of flowers and hand pollination

This widely used hybrid seed production technique involves identifying pistillate and staminate flowers that will be used for manual pollination the following morning (Kumari *et al.,* 2021). The flowers are covered in the afternoon before anthesis, as indicated by a slight yellow tinge at the apex of the corolla tube. The following morning, pollen is transferred from staminate flowers to the stigma of pistillate flowers. Pollination in cucumbers must occur early in the morning, as stigma receptivity declines sharply after 7:00 a.m., requiring pollination before this time (Pandey & Choudhary, 2016).

2.2.5.2 Removal of the buds of staminate flowers and open pollination

In hybrid seed production fields, one row of the male parent is typically planted for every three rows of the female parent. Staminate flower buds are manually removed from the female parent to ensure cross-pollination. No staminate flowers are allowed to open until 4–5 fruits have set on the female parent. Afterward, later flowers may be stopped by cutting the growing point of the vine (Singh & Chaudhary, 2020).

2.2.5.3 Chemical suppression of staminate flowers and open pollination

Monoecious sex expression can be manipulated by applying ethrel, an ethylene-releasing chemical, at concentrations of 100–120 ppm. This treatment increases the number of pistillate flowers when applied at key developmental stages (first, third, and fifth true leaves). Once treated, the female parent produces only pistillate flowers for 25–30 days. After this period, cutting the vine's growing point halts further staminate flower development (Singh & Chaudhary, 2020).

2.2.5.4 Use of gynoecious lines

Gynoecious lines are essential for hybrid cucumber production. These lines are maintained through treatments with gibberellic acid (15 ppm) or silver thiosulphate (6 mM), which induce staminate flower production. The first F1 processing cucumber developed from a gynoecious line (MSU 71305) was named Spartan Dawn (Cramer & Wehner, 2016).

2.2.5.4.1 Development of gynoecy

There is a positive association between the number of female flowers per plant and fruit yield. Gynoecious lines may be selected from segregating progeny, and studies have demonstrated that the number of female flowers correlates with yield. Highly significant positive correlations between pistillate node percentages and yield were also identified in various populations (Cramer & Wehner, 2016).

2.2.5.4.2 Gynoecious lines (Temperate and tropical)

Stable gynoecious lines are now available for hybrid production, particularly in tropical conditions, which hold promise for increasing yields. True-breeding tropical gynoecious lines, such as 87-304-6, 87-316, and 87-338-15, have been successfully isolated (More & Budgujar, 2015). One such hybrid, 304 × R.K.S. 296, showed a 77.6% increase in heterosis over the better parent. Studies suggest that tropical gynoecious lines are more advantageous for hybrid seed production compared to temperate lines or monoecious parents.

In hybrid seed production, gynoecious lines are typically planted in a 4:1 female-to-male ratio under open-field conditions with isolated planting. The seeds harvested from the gynoecious line are hybrid seeds, while seeds harvested from the pollinator can be used as the pollen parent in future plantings (Cramer & Wehner, 2016).

Recent advancements in gynoecious lines have led to plants with predominantly pistillate flowers. Gynoecious hybrids, especially those with early fruit set, are instrumental in establishing systems for mechanical harvesting of processing cucumbers. Ethylene inhibitors such as silver nitrate and silver thiosulphate promote male blooms on gynoecious plants (Cramer & Wehner, 2016).

2.2.6 Interspecific Hybridization

Interspecific hybridization in cucumbers involves crossing *Cucumis sativus* (2n = 14) with related species, particularly those with disease resistance traits. The closest related species include *C. trigonus* (2n = 14), a source of resistance to fruit fly (*Dacus cucurbitae*), and *C. hardwickii* (2n = 14), believed to be the wild ancestor of cultivated cucumber. Hybridization with species such as *C. melo* (2n = 24), *C. anguria* (2n = 22), and *C. metuliferus* (2n = 24) has also been explored for transferring valuable traits (Zhang *et al.,* 2018).

2.2.7 Biotechnological Innovations

2.2.7.1 Application of molecular markers

In cucumber breeding programs, the targeted traits include early yield, tolerance to biotic stresses such as disease resistance, ideal plant type, quality (e.g., color and flavor), and overall yield. Molecular markers have been increasingly utilized in genetic mapping and breeding programs due to cucumber's relatively small genome size compared to other vegetable crops. The cucumber genome, consisting of approximately 4.25 × 10.8 base pairs, was first assembled at 243.5 Mb (Huang *et al.*, 2009).

2.2.7.2 Genetic diversity and genetic map

Assessing genetic diversity based on phenotypic traits alone has limitations, primarily because morphological characters are influenced by environmental conditions and plant development stages. Molecular markers, on the other hand, are based on DNA sequence polymorphism, independent of environmental factors, and show higher polymorphism, making them more reliable tools for diversity assessment (Jat *et al.,* 2021). This enables more efficient utilization of plant characteristics for developing varieties with improved yield, quality, and stress tolerance (Nishio *et al.*, 2016).

Markers such as SSR (simple sequence repeat) have been employed in studying cucumber genetic diversity. Pandey *et al.* (2013) explored the genetic diversity of Indian cucumber using SSR markers, which provided valuable insights into genetic variability. Previous efforts to create genetic maps based on phenotypic markers or isozyme markers, though significant, have been limited by the low occurrence and unstable expression of these markers in the cucumber genome. Yang *et al.* (2021) developed a comprehensive genetic map consisting of 347 markers spanning 816 cM, a size close to the estimated length of the cucumber genome.

2.2.7.3 Generation of molecular linkage maps and tagging of useful genes

Genes governing economically important traits, such as disease resistance and horticultural characteristics, have been mapped in cucumbers (He *et al.,* 2022). Gene tagging, a crucial step preceding gene mapping, involves identifying markers closely linked to a gene of interest. Marker identification for monogenic traits is based on Mendelian segregation patterns and involves screening a limited number of samples with numerous markers (Jat *et al.*, 2021).

A powerful method for gene tagging is bulked segregant analysis (BSA), which pools segregating population samples based on their phenotype. This method is highly effective for identifying markers linked to both dominant and recessive monogenic traits (Zhang *et al.*, 2022). Several genes linked to disease resistance and quality traits have been mapped in cucurbits. For example, Yang *et al.* (2021) identified markers closely linked to the ZYMV resistance gene (Zym) and the scab resistance gene (Ccu) in cucumber populations. Similarly, Bradeen *et al.* (2001) mapped the downy mildew resistance gene (dm), further enhancing cucumber's resistance breeding potential.

2.2.7.4 Mapping of quantitative trait loci

Many agronomic traits in cucumbers are governed by quantitative trait loci (QTLs). A QTL represents a region of the genome associated with trait variation in a population (Wang *et al.*, 2020). The identification of QTLs helps in understanding the complex inheritance of polygenic traits, and flanking molecular markers can be used for molecular breeding programs (Nath *et al.*, 2017). Recombinant inbred lines (RILs) and near-isogenic lines (NILs) are often utilized for QTL mapping, as their near-homozygous nature reduces environmental effects and increases mapping accuracy.

QTL mapping has successfully identified regions of the genome associated with essential horticultural traits, including fruit size, shape, and resistance to diseases. Gao *et al.* (2020) analyzed QTLs for sex expression, fruit length, and fruit diameter in cucumber populations, revealing significant relationships between these traits. More recently, He *et al.* (2013) identified two major QTLs, pm 5.1 and pm 5.2, located on chromosome 5, which are responsible for powdery mildew resistance. These QTLs offer valuable markers for marker-assisted selection (MAS) in cucumber breeding programs, facilitating the development of superior, disease-resistant cucumber varieties (Pan *et al.,* 2020).

2.3 Uses and Benefits of cucumber

The medicinal properties of cucumbers have been recognized since ancient times. Various parts of the plant, such as the leaves, fruit, and seeds, have been explored for their therapeutic benefits. *Cucumis sativus* (cucumber) is widely valued in traditional medicine, particularly in Ayurveda, where it is used to manage aging (Mukherjee *et al.,* 2013). Cucumber is commonly used to address skin issues such as swelling, sunburn, and irritation due to its soothing, cooling, and emollient properties (Franco *et al.,* 2020). In Chinese folk medicine, different parts of the cucumber plant are also used for their anti-diarrheal, detoxicant, and anti-gonorrheal properties (Nema *et al.,* 2017).

Cucumber contains bioactive compounds with antioxidant, anti-wrinkle, antimicrobial, antidiabetic, and hypolipidemic properties, which support its use in various cosmetic applications (Mukherjee *et al.,* 2013). The plant has shown antihyaluronidase and anti-elastase activity, enhancing its role in skin creams, lotions, and facial masks (Sotiroudis *et al.,* 2020).

Cucumbers also offer significant nutritional benefits. Per 100 g of edible cucumber, there is 96.4 g of water, 0.7 g of protein, 0.1 g of fat, 1.5 g of carbohydrates, and 0.6 g of dietary fiber, along with vitamins and minerals such as calcium, magnesium, iron, and ascorbic acid (Watson, 2015). Cucumbers are a valuable source of lycopene, an antioxidant believed to reduce the risk of certain cancers and cardiovascular diseases (National Watermelon Promotion Board, 2016).

Studies on the chemical composition of cucumbers revealed that their fruits are rich in ascorbic acid and contain essential oils with antioxidant properties (Sotiroudis *et al.,* 2020). Additionally, seeds of cucumbers are a rich source of crude proteins and fats, including essential fatty acids such as linoleic and oleic acids (Fiume, 2012). Wani *et al.* (2015) concluded that cucumber seeds have high nutritional value due to their protein and lipid content, making them suitable for use in food formulations.

Despite these benefits, cucumber remains relatively underutilized in some regions. Its idiomatic expression, "as cool as a cucumber," reflects its numerous calming and refreshing properties, yet its potential is not fully realized in many parts of the world.

2.4 Varieties of cucumber in the world and in Ghana

Cucumbers are classified into two main categories based on their use: slicing and pickling varieties. Slicing cucumbers are typically consumed fresh, while pickling cucumbers are processed for canning. The slicing variety is characterized by thicker skins and longer fruits, while the pickling type has thinner skins and a more compact shape (Staub & Bacher, 2023).

Some common cucumber cultivars include open-pollinated varieties such as Marketmore 76 and hybrids like Dasher II and Cyclone. These varieties are widely grown in regions such as Africa, where cucumber cultivation is gradually expanding (Obeng-Ofori *et al.,* 2022). In

Ghana, popular varieties include Ashley, F1 Antilla, F1 Tropical, and Poinsett, which are resistant to common diseases like downy mildew and powdery mildew (Obeng-Ofori *et al.*, 2022). However, low yields remain a challenge due to the limited number of female flowers on monoecious plants. Pinching techniques, which promote lateral shoots and increase the production of female flowers, could potentially improve yields (Hikosaka & Sigiyama, 2020).

2.5 Production volumes in the world and in Ghana

Cucumber production is dominated by countries such as China, Turkey, and Russia. In 2020, global cucumber production reached 91.25 million tons, with China alone contributing over 67 million tons (FAOSTAT, 2022). Despite Africa's potential for cucumber cultivation, its production remains low, with South Africa and Kenya leading the way in commercial production (Karanisa *et al.*, 2022). In Kenya, for example, yields of up to 22.5 tons per hectare have been achieved with the Carmen F1 variety, nearing global averages (Gebresamuel *et al.*, 2021).

In Ethiopia, cucumber is still a relatively unknown crop among smallholder farmers, with limited production and no significant exports reported in recent years (Gebresamuel *et al.*, 2021). Similarly, Ghana's cucumber production is still developing but has shown steady growth. According to FAOSTAT (2022), cucumber and gherkin production in Ghana increased from 94 metric tons (MT) in 2001 to 117 MT in 2011, with further growth reported by the Ministry of Food and Agriculture (MoFA) in recent years.

2.5.1 Growth of cucumber crop

Cucumber is a creeping vine crop that grows by wrapping its tendrils around support frames. The plant has a taproot that extends deep into the soil, while the rest of the root system remains close to the surface (Sarkar *et al.*, 2022). Cucumbers are typically harvested 50 to 70 days after planting, with a single plant yielding 1 to 3 pounds of fruit per week during peak production (Wang *et al.*, 2022).

The African horned cucumber, a related species, is noted for its unique oval shape and prominent spines. It is cultivated primarily for its fruit, which is harvested before it reaches full maturity to avoid bitterness (Staeck, 2022). In general, proper pollination and cultivation techniques are essential for maximizing cucumber yields, and additional hives for insect pollination can significantly boost fruit production (Rahimi *et al.*, 2022).

2.5.1.1 Climate and Soil

Cucumber (*Cucumis sativus*) is a warm-season crop, best suited for subtropical and hot arid regions. The optimal soil temperature for cucumber germination is approximately 27°C, while pollination, fertilization, and fruit setting require temperatures between 24°C and 32°C (Hussain *et al.*, 2020). Cucumbers are highly sensitive to frost and low temperatures, which can significantly impact their growth and yield. Key environmental factors like temperature and photoperiod play a major role in sex expression in cucumbers. Higher temperatures and extended daylight hours often result in more male flowers, whereas cooler temperatures and shorter days favor the development of female flowers. Furthermore, high plant density and low moisture levels can increase the occurrence of pistillate flowers.

Additionally, light intensity and the time of day significantly influence anthesis, with temperature being a key factor affecting anther dehiscence and pollen fertility (Saeed *et al.*, 2023).

2.5.1.2 Land Preparation and Sowing

Cucumber grows best in deep sandy loam soils rich in organic matter, well-drained, and slightly acidic, with a preferred pH range of 6.0 to 7.0. Though somewhat tolerant of acidic soils, cucumber plants can only tolerate a pH as low as 5.0 (Jha *et al.,* 2019). Land preparation should begin 3–4 weeks before sowing, ensuring thorough soil preparation to minimize compaction and promote deep root penetration. Cucumbers can be grown during both the summer and rainy seasons, with sowing typically occurring in February-March for summer crops and June-July for rainy season crops. In Western India, cucumber sowing extends from September to February, and under protected cultivation, crops can be grown year-round. The recommended seed rate varies based on the planting distance between hills and rows, typically ranging from 2.5 to 3.0 kg/ha, with carbendazim treatment advised at 2.5 g per kg of seeds. Spacing of 2.0–2.5 m between rows and 80 cm between plants is recommended for optimal plant density and yield (Rai *et al.*, 2021).

2.5.1.3 Plant Nutrition

Cucumber is a fast-growing crop and responds well to manuring and fertilization. It is recommended to apply 200–250 q/ha of well-decomposed FYM or compost, mixed into the soil 20–25 days before sowing. Fertilizer requirements vary depending on the soil type, previous crops, and other cultivation factors, with band placement of fertilizers being the most effective. In areas with poor irrigation quality or high salt concentrations, a combination of band and broadcast placement can help lower salinity injury (Pandey & Choudhary, 2014).

The application of nitrogen (N) significantly influences cucumber flowering. For example, applying 80 kg/ha of nitrogen results in the maximum number of male flowers and delays female flower appearance. Urea is commonly used as a nitrogen source, promoting growth and fruit quality. Ammonium sulphate or calcium nitrate solutions applied at 300 ppm enhance fruit yield, while excess urea or ammonium reduces growth and yield (Pandey & Choudhary, 2014). Slow-release fertilizers such as KNO_3 and NH_4NO_3 can improve yield and fruit quality when applied in perforated plastic tubes.

Cucumber cv. 'Long Green' produced maximum and minimum number of male and female flowers, respectively, when N was applied at 80 kg/ha. Higher N rate (120 kg/ha) delayed the appearance of the first female flower (Sahu, 2022). As a source of nitrogen urea can be used in small quantity to root zone during earthing up or during drip watering. Liquid manuring of urea promotes growth and improved fruit quality than ammonium nitrate. Number and length of nodes, weight of fruits and total yield increases when solution culture of ammonium sulphate or calcium nitrate applied at 300 ppm but, when urea or NH_{4+} represented more than 50% of N source, plant growth and fruit yield reduced drastically.

More yield, earliness and improved fruit quality can be achieved if slow releasing fertilizers like KNO_3 +NH_4 NO_3 or NH_4 NO_3 + K_2SO_4 + $MgSO_4$ applied in the form of perforated plastic tubes. Increase in yield can be obtained by spraying 3% urea thrice at weekly interval starting after the first picking. Cucumber plants grown in cooler green house (14 to 29°C) and receiving N at 2 and 4 g/plant produced a yield of 120–250 q/100m^2 compared with 70–106 q/100 m^2 in a warmer (19.5 to 40°C) greenhouse. The quality of canned cucumber (freshness) before processing was found better under application of N at 80 to 120 kg/ha. Method and time of application can be concluded as organic manure is mixed with soil at the time of filling the soil mixture in the pits. When cucumbers are sown in flat bed method, well-decomposed organic manure is applied during field preparation through broadcast. Whole amount of phosphorus and potassium along with half to three fourth dose of nitrogen should be applied at the time of sowing or seedling transplanting. The remaining dose of nitrogen should be top dressed in two splits *i.e*., 30 and 45–60 days after sowing. Dose of nitrogen may be reduced or omitted (particularly by the second split) if growth is luxuriant (Pandey *et al.*, 2023).

2.5.1.4 Weed and Water Management

Weeds pose a significant challenge, causing yield reductions of 15 to 60%. Effective weed control requires 2–3 weeding operations, with the application of Pendimethalin at 3.3 liters per hectare as a pre-emergence treatment to control weed growth for up to 40 days after sowing. Water management is crucial, with cucumbers requiring consistent moisture, particularly during flowering and fruiting. Water stress or excess moisture can drastically reduce yields. The crop's moisture requirement ranges from 15 to 24 inches, with irrigation methods such as furrow irrigation in arid areas and overhead sprinklers in humid regions being preferred (Pandey & Choudhary, 2014).

2.5.1.5 Fertilizer Application of cucumber

Cucumber plants have moderately high mineral uptake requirements. A recommended fertilizer application includes 30 t/ha of cow dung manure, 50 kg of nitrogen, 45 kg of phosphorus, and 65 kg of potassium before planting. Nitrogen side dressing of 50 kg/ha should be applied three weeks after planting, followed by a top dressing three weeks later (Doltra & Muñoz, 2010). Excessive nitrogen can increase susceptibility to tip burn and diseases, as well as elevate nitrate content in the harvested product. Phosphorus is essential for energy processes in the plant, while potassium is vital for growth and flower protection (Diver, 2015).

2.5.2 Nutritional and health importance

Cucumbers provide a range of health benefits, containing essential vitamins, minerals, and water, with an estimated water content of 96% (Elavarasan *et al.,* 2022). This high water content aids in weight loss, making cucumbers a valuable food for obese individuals (Kim & Cho, 2022). Cucumbers also possess detoxifying properties due to their high water content (Kumar *et al.,* 2020). Additionally, cucumbers are low in calories, with only 16 calories per 104 g slice and 45 calories per 300 g cucumber, making them a suitable choice for calorie-conscious diets (Gupta *et al.*, 2022).

Cucumbers have anti-inflammatory properties and protect nerve cells from age-related decline (Kahraman & Toklu, 2022). Their fiber content can help relieve constipation (Wali *et al.*, 2022). Furthermore, cucumbers contain phytonutrients, carotenoids, and polyphenols, which may reduce the risk of chronic diseases such as cancer (Huerta-Reyes *et al.,* 2022).

Studies have shown that cucumbers are rich in antioxidants, potentially reducing oxidative stress linked to cancer and other diseases (Can *et al.*, 2022). Cucumber juice is also believed to support kidney health and help remove odor-causing bacteria in the mouth (Fang *et al.*, 2022).

2.5.3 Ecological importance

Cucumber production is relatively sustainable, and there is no known impact on air, water, soil, and plants (Pańka *et al.*, 2022). The nature of cucumber is ideal for the regulation of the microclimate, and the root also helps to reduce soil erosion due to wind and runoff. The residue is also important for soil fertility improvement (Basirat & Mousavi, 2022). Researchers stated that the cucumber residues can be used for the preparation of natural fertilizers such as compost (Olowoake *et al.*, 2022). It also plays an important role in nutrient cycling and reduce organic loads (Pan & Pratolongo, 2022). Soluble nitrates and phosphates released from cucumber decomposition can be absorbed by the nearby microorganism (Zhao *et al.*, 2022). Developed nations have been producing different outputs from cucumber residues. As composts have high water content, cucumbers compost down incredibly quickly, they will not add a large amount of bulk to the compost heap, but that moisture will help other things compost down quicker so it is all good. Researchers have stated that carbon sink reduction by fruit removal triggers respiration but not nitrous oxide emissions from the root zone of cucumber (Nett *et al.*, 2019). Similarly, chopped or shredded cucumber leaves work well as summer mulch for many plants, allowing moisture to seep into the soil while protecting the soil from evaporative processes, and the leaves imperatively add nitrogen to the soil structure (Larkin, 2020).

2.6 Staking in cucumber

Staking or trellising is the use of bamboo, wood, metal poles, or other materials to support the plant and keep the fruit and foliage off the ground. Staking increases fruit yield and size, reduces the proportion of unmarketable fruit, and facilitates chemical spraying and harvesting. Staking allows better aeration, reduces attacks of fungus diseases and ensures better exposure of the foliage to light for better photosynthesis. Plastic tunnels are used for protection of off-season vegetables due to low temperature and chances of frost in an open field (Choudhary *et al.* 2021). Tomato plants are supported by 1.2 m high stakes to prevent the tomato fruits from being damaged by insects. At harvest, fruits damaged by insects are counted, the marketable fruits are size-graded (1-10 levels of sizes) and the number and weight of fruits in each grade are taken (Asante, 2022).

Countries like Philippines, Taiwan and Mexico, usually grow tomato with supports to obtain earlier, clean and larger fruits. Spraying and harvesting are made easier when tomatoes are supported. The author listed some methods of staking tomato plants in the above countries that include single staking method, triangle staking method, bench staking method, single and horizontal method, and fence and wire staking method (Asante, 2022). The author added that, the cost of staking varies in different geographic localities; 13%, 30%, 25%, and 12% in Columbia, Philippines, Taiwan and Mexico respectively. The methods of staking tomato also vary according to the plant type, the availability of staking materials and the individual requirement. He compared the yield and quality of tomato obtained from mulching and staking methods which was used with wood and fence wire (Asante, 2022). The result showed that, the bench and triangle methods gave significantly higher yields and higher returns, while the fence and wire method resulted to big economic loss because of its labor and material costs. Staking as the leaves of Telfaria species are palatable and nutritious and are very much cherished by goats. Therefore, staking can be used to protect vegetables from animals, diseases and also provides good quality vegetables (Asante, 2022).

The idea of staking because it facilitates harvesting of the leaves and pods and exposes the leaves for effective light reception; as light is one of the factors needed by leafy vegetables (Masrie & Girma, 2023). Staking also reduced the incidence of blossom end rot and fruit crack in tomato. In contrast, Masrie & Girma (2023) stated that, staked tomatoes are more susceptible to cracking, blossom end rot and sunscald problems and the total yield of staked plants is often lower than similar plants that are not staked. An experiment was conducted to examine the relative marketable leaf yield of fluted pumpkin (*Talfaria occidentalis*) on staked and un-staked bases using 4 x 4 randomized complete block design for three planting seasons 2003 to 2005. The result revealed no significant difference in marketable leaf yield between the staked (500.0 to 500.5 g) and un-staked (498.3 – 499.5 g) plants. The researcher concluded that, elimination of cost of stakes and staking operation would be of better economic return on revenue to farmers (Masrie & Girma, 2023).

Getahun & Habte (2017) described staking as an important production practices used by tomato growers mainly in the raining season. Staking experiment was done at Melkasa Research Centre on Money Maker and Heinz-1350 varieties and the result produced a yield of 6 and 6.5 tons/ha, respectively over un-staked plants. Staked tomato plants gave high yield of 58.3 tons/ha and 57.3tons/ha compared to the low response of 39.9 tons/ha and 33.4

tons/ha for un-staked plants of Marglobe and Money Maker in 1993. Getahun & Habte further confirmed that, staking of tomatoes plants for fresh fruit market increased yield and quality of fruits.

According to Dawson & Goldsmith (2018) upright plant dries off more quickly following rain or morning dew. It lessens disease problems since wet foliage is a breeding ground for all kinds of fruit and leaf diseases. Growing plants upright will eliminate disease such as anthracnose and buckeye rot these rots as well as lessen problems with slugs, mice and other pests, both large and small. Fruits can be seen and pick without breaking branches off the plant as you search. Masrie & Girma (2023) stated that, indeterminate varieties should be staked to facilitate pruning, pinching, harvesting, and other cultural practices. Staking provides better growth of tomato plant and branches, increased fruit bearing, and improved quality of fruits. It aids cultural operations like fruit picking, spraying, weeding, fertilizers application and ear thing up (Masrie & Girma 2023). They added that, staking can be done by two methods. First method is that the sticks of 1.5-2.0 meter length and 2.5 cm thickness are staked by the tomato plant as it grows. In the second method, a network of wire and bamboo is formed with the help of Sutali (small rope) branches. Staking and pruning can improve yield and fruit size, reduced fruit rot incidence and more convenient for crop care and makes harvest easier for the workers, commented in their guide on green beans ecology (Asante, 2022).

2.6.1 Methods of Staking

2.6.1.1 Anchor Staking

Anchor staking is type of staking where by two (2) sticks or poles are tied together over the bar pole that is laid across the center of the tied out cross poles, this is also called "Trellising'' this practice is also used as traditional staking method in most yam growing areas. The sticks or poles and as the cucumber vines begin to grow a 2 to 3 meter pole is needed to allow the vine to grow up towards the lapping bar.

Figure 1: Anchor Staking **Field survey (2021)**

2.6.1.2 Protective staking

This type of staking is done using single pole to each plant on the plot and detached plant, usually chopped from other plants or as part of the growing plants. Method of staking is generally applicable for yam growing areas.

Figure 2: Protective Staking **Field survey (2021)**

2.6.1.3 Supportive staking

This type of staking look-like cage; we used bamboo and splits of about two meter long. We pushed the split bamboo four of them into the soil around the cucumber plant and we tied with wire and will help support cucumber plants as they grow. This method of staking is generally applicable for tomato plant.

Figure 3: Supportive Staking **Field survey (2021)**

2.6.2 Effect of staking on growth and yield of cucumber

Staking involves using a thin wooden or metal post driven into the ground to support a plant (Falodun & Ogedegbe, 2019). This method, which involves using stakes to support growing seedlings, is commonly employed to improve plant structure and yield (Abma & Stake, 2014). Staking cucumber plants has several advantages, such as increasing plant population per acre, promoting early fruit ripening due to better ventilation and sunlight exposure, reducing pest and disease damage, and producing clean, attractive, and marketable fruits (Chanda *et al.*, 2021). Paucek *et al.* (2020) reported that in the United States and China, cucumber can be grown using various types of trellising systems, which enhance field operations and yield management.

Staking is influenced by factors such as the plant's growth habit (compact or spreading), size at maturity (small, medium, large), cultivar vigor, climate, soil moisture, nutrient availability, and the overall management system. Generally, stakes are driven about 3 cm into the ground, and an additional stake can be placed at the end of each section to reinforce the trellis. Plants are typically tied to the stake when they reach about 3 cm in height, with the first string placed approximately 10 inches above the ground and subsequent ties spaced 6 inches apart. Staking also impacts the number of branches per plant. Unstaked plants often produce more branches than staked ones due to less regulated growth. The number of branches per plant is also influenced by cultivar differences (Benlloch-González *et al.*, 2018).

The number of flowers and fruits per plant is affected by staking. Unstaked plants tend to produce a higher number of smaller flowers and fruits, while staked-pruned plants yield fewer, larger fruits. This could be due to the higher branch count in unstaked plants, which allows for more flowers but smaller fruits. The genetic differences between cultivars also play a role in the variation in flowering and fruiting (Benlloch-González *et al.*, 2018). Additionally, temperature variations during the growing season can cause flower and fruit abortion, impacting overall yield.

Staking also influences fruit weight. Staked plants generally produce larger, heavier fruits compared to unstaked plants (Alam *et al.,* 2016). This is primarily due to the effect of pruning, which limits the number of fruits, allowing for better nutrient allocation to remaining fruits. Consequently, staked plants tend to have higher marketable yields due to larger fruit size and fewer instances of fruit rotting (Musa *et al.,* 2021). Staked cucumber yields have been reported at 17,611 kg/ha and 21,667 kg/ha, compared to 17,139 kg/ha for unstaked plants. These findings align with Ogundare's (2015) study, which showed that staked cucumbers yielded 25 tons/acre, significantly higher than the 16.4 tons/acre from unstaked cucumbers. Forslund (2012) similarly concluded that staking doubles the quality of cucumber fruits compared to those grown on the ground. Furthermore, the number of non-marketable fruits is typically higher in unstaked plants due to increased rot and blemishes.

Musa *et al.* (2021) also highlighted that staking improves the color and reduces the incidence of yellow bellies in cucumbers, leading to better fruit quality. Nyamah (2011) added that staking enhances fruit color, length, and sugar content, further contributing to the marketability and nutritional value of the produce.

2.7 Pest and Diseases of cucumber

Cucumbers are vulnerable to various pests and diseases that can significantly impact their growth and yield. Common pests include aphids, whiteflies, leaf miners, beetles, mites, and caterpillars, which attack the plant by consuming its leaves, fruits, or stems, sometimes boring holes into the fruits (Ara *et al.*, 2017). Among these pests, whiteflies are particularly problematic as they feed on plant sap, excreting sticky honeydew that leads to sooty mold growth, which reduces the plant's photosynthetic capability and lowers yields. In addition to weakening plants, whiteflies can transmit harmful viruses that further threaten crop health (The Horticulture Development Unit, Directorate of Crop Services, 2014).

Diseases affecting cucumbers are caused by bacteria, fungi, and viruses and can spread through various vectors, including soil, water, air, contaminated tools, animals, and even human activity. Key diseases include leaf curl, a viral infection that causes leaves to curl and can spread rapidly if not controlled. Infected plants should be removed and destroyed immediately to prevent further spread. Viral diseases are particularly difficult to manage once they become established in the field (Musa *et al.,* 2021).

To manage pests like whiteflies, cultural control methods such as providing proper nutrition and irrigation, selecting resistant cultivars, and using reflective mulches have been effective in reducing infestations and disease transmission. Beneficial insects like lacewings, lady beetles, and minute pirate bugs can also help keep whitefly populations under control (Forslund, 2012). In regions with warmer climates, such as South Carolina, whitefly populations are more prevalent during the fall, but spring crops often avoid severe infestations due to cooler temperatures earlier in the growing season.

2.7.1 Management of disorders, diseases and pests

2.7.1.1 Diseases

***Downy mildew* (*Pseudoperonospora cubensis*)**

Generally, at initial stage small, irregular, yellowish lesions appear on leaves. Old lesions become necrotic and are clearly demarcated with light yellow areas. In high humid weather, faint, white downy fungus growth is observed on lower surface of the leaves.

Control measures

1. Soil should be well drained and seeds may be sown at wider spacing.
2. Field sanitation is followed to reduce the inoculum by burning crop debris.
3. The seed should be collected from disease free and healthy fruits to avoid the further infection.
4. The disease can be effectively controlled by spray of Mancozeb at 0.25% at seven days interval.
5. In severe conditions, two sprays of Metalaxyl + Mancozeb at 0.2% may be sprayed at 10 days interval.

***Powdery mildew* (*Sphaerotheca fuliginea*)**

White long patches or coating appears first on the under surface of the leaves, which later spread to both surfaces, stem, petiole and other succulent plant parts. Severe infection causes stunted growth and browning of leaves followed by premature defoliation. Usually, the fruits of affected plants do not develop to maturity. This disease is more severe under dry weather. The disease is favored by hot and humid weather, moderate temperature, reduced light intensity and succulent plant growth. Good conidial germination is observed within a temperature range of 22–31^{o}C with optimum at 28^{o}C and low relative humidity of 20% for less than 2 hours.

Control measures of Powdery mildew

1. The spray of Karathane at 1 % at different intervals as per need commencing from first appearance of disease gives good control.
2. All infected leaves should be collected and burned.

***Anthracnose* (*Colletotrichum orbiculare*)**

Disease symptoms are found on all above ground plant parts started from cotyledonary leaf to true leaves, stem and tendril. Light brown circular spots appear on the leaf, which later turns to deep brown. Elongated lesion observed on stem and circular to oval sunken lesions appear on the fruit and subsequently fruits shrivel, darken and finally dry up. Later on, infected fruit rot and infect all the seed, which is source of further primary infection. It is seed born disease and seed from infected fruits also carry the primary inoculum for further infection.

Control measures of Anthracnose

1. Seeds should be collected from disease-free plants.
2. Crop rotation should be followed.
3. The crop debris should be burned.
4. Seeds can be treated with carbendazim (2.5 g/kg of seed) before sowing.
5. Spray of chlorothalonil at 0.2 % as a prophylatic spray gives good control of this disease.
6. Foliar spray of systemic fungicide such as, carbendazim (0.1 %) has been found effective to control the disease.

***Angular leaf spot* (*Pseudomonas syringae pv, lachrymans*)**

It is an important bacterial disease where angular brown spots appear on the leaves as first symptom. On these spots bacterial ooze dries out to a white incrustation. The center of such spot-on leaves later dry and fall out giving ragged appearance. Spots on fruits are circular which crack open to exude amber- coloured liquid containing bacteria that subsequently infect the fruits and cause severe rotting.

Control measures of Angular leaf spot

1. Use disease free seeds.
2. Hot water treatment of seeds at 50°C for 30 minutes.
3. Seed treatment with 0.01% streptocycline solution for 30 minutes.
4. Spraying the crop with 0.01% streptocycline immediately after the appearance of the disease checks the secondary spread.

***Cucumber green mottle mosaic virus* (*CGMMV*)**

Major symptoms of CGMMV are slight clearing of veins and crumpling of the young leaves followed by a light or dark green mottle, together with blistering and distortion of the leaves. The CGMMV was first reported from India in bottle gourd. The cucurbit beetle is able to transmit the virus to the extent of 27 percent and it is not transmitted through seed. They had also reported that contaminated irrigation water also plays important role to spread the disease. The virus is very stable and mechanically transmissible at the time of cultural operation or pruning or simple by leaves rubbing of infected leaves.

Control of Cucumber green mottle mosaic virus

1. Early sowing of crops may reduce the disease due to low vector population.
2. Avoidance of contamination by working men and implement.
3. Spray of Dimethoate 30 EC at 2 ml/litre water at 10 days interval to manage the vectors.

2.7.1.2 Insect Pests

***Red pumpkin beetle* (*Aulacophora foveicollis Syn. Raphidopalpa foveicollis*)**

The red pumpkin beetle is very destructive, particularly in summer season when the plants have two to four leaves. Adults feed on the cotyledonary leaves damaging the seedling and foliage by biting and making the holes. At flowering stage of the crop, beetle sometimes damage the floral parts and reduce the fruit set (Fountain, 2022). Infection is more severe in the plains than in the hills. The adult beetle lays 250-300 orange/yellow eggs in clusters in the soil near the collar of the plant (Rai *et al.*, 2021). Grubs are attacked in the root zone of the plant results sudden wilting of the plant due to disruption of the transportation of food materials.

Control measures of Red pumpkin beetle

1. Summer ploughing helps to expose and kill the grubs.
2. To reduce the infection, cucurbitaceous crops should not be sown repeatedly in the same field for more than one season.
3. Adults should be collected and killed.
4. If seeds are sown in November, then damage may be avoided.
5. Two-three spray of Dimethoate 30 EC at 2 ml/litre water at 10 days interval is recommended at early growing stage.
6. Tolerant lines should be identified to avoid the infection (Pandey *et al.,* 2003).

***Fruit fly* (*Bactrocera cucurbitae*)**

Adult fly of this polyphagous pest having a wide host range is 4–5 mm long, ferruginous-brown in colour with hyaline wings. On hatching, the maggots feed inside the fruits and infested fruits can be identified by the presence of resinous liquid which oozes out of the punctures made by the flies for oviposition. The infested fruits start rotting due to secondary infection of different micro-organisms.

Control measures of Fruit fly

1. Collection and destruction of the infested fruits along with the maggots to prevent the carryover of the pest.

2. Racking the soil under the vines frequently and plough the infested field after harvest the crop to kill pupae.
3. Spray the crop with 3.0% neem oil or Malathion 50 EC at 1.5-2 ml/litre water.
4. Application of poison bait. Bait is prepared by mixing 20 g Malathion 50% WP with 500 g molasses + 20 g yeast hydrolysate. This mixture is mixed with 2 litres of water for poison baiting and 20 liters of water for bait spray.

***Leaf miner* (*Liriomyza trifolii*)**

Leaf miner attack is observed more in early crop. Leaf miner makes mines in the leaves, especially in mature leaves. The larvae scrap the chlorophyll and leaf tissues. The eggs hatch within 2–3 days and larvae feed between the lower and upper epidermis by making zigzag tunnels.

Control measures of Leaf miner

1. Collection and destruction of the infected old leaves containing pupae of leaf miner.
2. Judicious use of nitrogenous fertilizers.
3. Spray the crop with Imidacloprid 17.8 SL (0.5-0.6 ml/litre of water) for better management.

***Leaf thrips* (*Taeniothrips claratris; Thrips tabaci*)**

These thrips are very destructive at early stage of crop. Hundreds of thrips are found to colonise on both the surface of young apical leaves that cause curling, twisting and retarded growth of apical plant parts. Their activity attained peak stage during March-April.

Control measures of Leaf thrips

1. Spraying the apical plant parts with Imidacloprid 17.8 SL at 0.5-0.6 ml/litre waters.

2.8 Harvesting of cucumber

Cucumbers commonly harvested when they are green before full maturity. Harvesting delay can lead to lower quality of fruit and faster deterioration after harvest (Lamikanra 2015). Texture is an important quality attribute of cucumber. Consumer prefers a firm and crispy cucumber. Mold and other microorganisms grow rapidly on fresh cucumber at ambient temperature and high humidity due to higher water content and available nutrients for microorganisms. Cucumber contaminated with mold stored at ambient temperature can become soft in 12-18 hours (Costilow *et al.*, 2016). Food industry replaces fresh cucumbers with pickled cucumber because of less shelf life, quality and stability of fresh cucumbers (Hamma *et al.*, 2012). The whole fresh cucumber can be stored for 7-10 days in refrigerator and shelf life for sliced cucumber is 1-2 days. Handle carefully to minimize damage to the thin skin. A healthy plant should produce 24-30 marketable fruits. Because of their thin skin European cucumber fruits lose moisture rapidly and soften unless precautions are taken. Short-term storage is possible by covering fruits and storing them in a cool moist area.

Fruits that must be kept for more than a few hours should be wrapped in clear plastic film and stored at high humidity (90-95%) and low temperature (50-55 ^{o}C) but do not store at temperatures below 45 ^{o}C (Marr, 2015). Cucumbers are harvested at a range of developmental stages, depending on the intended use. The time from planting until the beginning of harvest generally ranges between 45 to 60 days, depending on the cultivar and growing conditions. Cucumber fruit should be harvested at an immature stage; near full size but before the seeds are fully enlarged and become hard (Smith, 2017). The two main external indices of harvest maturity are fruit size and skin colour. The main internal indices of harvest maturity are seed development, locular jelly formation, and flesh texture. The principal index of harvest maturity is fruit size (Brown & Green, 2020). The proper size depends on the use and the cultivar. Fresh market slicing cucumbers should be at least 15 cm long and firm to the touch. Skin colour is another widely used index for assessing fruit maturity. The peel should be uniform dark green colour when harvested. It should also have a noticeable wax deposit on the surface. However, some cultivars may naturally produce a lighter green fruit and environmental conditions may also affect skin colour. Fruits are generally at their highest eating quality when the skin is uniformly green. The fruit should not be allowed to turn yellow. Yellow fruits are overmaturing. Fruit that are too mature have a tough leathery skin and are bitter in flavour (Brown & Green, 2020).

In the case where over-mature fruit have been inadvertently left on the vine, they should be removed as soon as possible. Old fruit left on the vine will slow flowering and the development of new fruit. A cross-sectional slice obtained from the center of the fruit can be taken to assess internal fruit maturity. At proper harvest maturity, a jelly-like material will be formed in the seed cavity. Seed development is also used to determine harvest maturity. The seeds should be uniform white in colour and immature. Large, slightly yellow, or hard seeds are an indication of over-maturity and low fruit quality. The fruit texture should be firm and crisp. Harvesting should be conducted during the coolest time of the day, preferably in the morning, after the leaves and fruit have completely dried (Marr, 2015).

Harvesting when the plants are wet will encourage the spread of foliar diseases. On the other hand, waiting until the heat of the afternoon to begin harvest will result in slightly softer and more flaccid fruit. The fruit generally have their highest water content at this time. The harvested cucumbers should be kept as cool as possible (Marr, 2015). Cucumbers should be harvested every other day for best yield and quality. The cucumber fruit grows rapidly to harvest size and picking the fruit as soon as they reach marketable size will maintain the vitality and productive capacity of the plant (Smith, 2017). The fruit should be handled carefully to prevent bruising and injury to the surface. Cucumber fruit should be carefully removed from the vine using one of two harvest techniques. The first technique involves squeezing the stem attached to the vine between the thumbnail and forefinger, followed by pulling off the fruit from the vine (Brown & Green, 2020). This will leave a jagged stem section which will require trimming with a pruning shear or knife. The second technique, which is preferable, is to use a small knife to severe the fruit stem from the vine at a point just above the shoulder of the fruit.

Done properly, the stem will not have to be re-cut during packing. The fruit should never be torn off the vine, as this will result in damage to the vine and/or fruit. Fruit which has been pulled off the vine are often “plugged”. Plugging causes the very end of the fruit tissue to pull loose from the fruit (Smith, 2017). This is a quality defect, leaving an exposed crater of internal pulp tissue at the end of the fruit. The plugged area is an open wound which is highly susceptible to decay. Cucumbers should be carefully put in a light-weight container, either made of wood, or plastic. If necessary, line the inside of the container with protective padding to prevent fruit scarring and abrasion (Brown & Green, 2020). The container should be well ventilated and hold up to about 25 kg of fruit (Marr, 2015). Never put cucumbers in plastic bags or containers where air will be excluded for any period of time. Fruit kept in non-ventilated containers will lose skin colour and firmness due to a buildup of heat inside the container. Once the field container is full, it should be taken to a shaded, well-ventilated temporary holding area. Avoid leaving the fruit exposed to direct sun for more than 15 minutes. The cucumbers should be moved to the cleaning and packing area as soon as possible (Brown & Green, 2020).

2.8.1 Post Harvest Handling

Cleaning

Any remaining soil in the ground spot area or other surface stains should be removed at the time of harvest. This can be done manually by rubbing the fruit surface with a soft damp cloth or cotton gloves. Washing the fruit is more efficient if the cucumbers are particularly dirty, or if the quantity of fruit is large. In this case, the fruits are submerged in a large wash tank and the surface is rubbed by hand or with a soft brush. The wash water should be clean and properly sanitized to reduce the potential for the spread of disease. Sodium hypochlorite (household bleach) is commonly used since it is an inexpensive and readily available wash water sanitizing agent. It is effective against decay organisms when added to the wash water at a concentration of 150 ppm and the water is maintained at a pH of 6.5 (Jones & Parker, 2016). As the wash water becomes contaminated with soil and organic matter, the sanitizing ability of hypochlorous acid is diminished. Therefore, the wash water tank should be changed when necessary and filled with clean water with 150 ppm hypochlorous acid. After cleaning, the fruit is generally placed on a soft mesh or wire table to dry before sorting and grading (Marr, 2015).

Grading

Table or slicing cucumber quality is primarily based on size, uniformity of shape, firmness, and skin colour. Additional quality indices are the amount of surface blemishes and peel injury, and incidence of decay. High quality cucumber fruit should be straight, uniformly green, and have an appropriate length-diameter ratio. They should also have small seeds and a desirable flavour (Brown & Green, 2020).

Waxing

Cucumbers are often treated with a food-grade liquid wax after grading. The purpose is to replace some of the natural wax removed during washing and cleaning, to retard water loss, and to improve appearance. The wax is similar to mineral oil and may be applied by hand rubbing or by roller brushes (Jones & Parker, 2016).

Packing

Cucumbers should be packed in strong, well-ventilated containers. Wooden containers which allow for stacking without collapsing are appropriate for the domestic market. Durable plastic crates are also acceptable. Mesh sacks should not be used as they provide little protection to the fruit (Smith, 2017). Cucumbers for export should be packed in strong well ventilated fiberboard cartons with minimum test strength of 275 psi. Carton size varies depending on market destination, but typically contains 25 kg of fruit. If cucumbers are packed in smaller cartons they are sold by count, with 24-count being a popular size.

Temperature management

The optimum temperature for storage and transport of cucumbers is 10°C. At this temperature, cucumbers can be expected to have a 2-week market life. Shriveling, yellowing, and/or decay are likely to be apparent beyond two weeks. Peel colour will start to change to yellow after about 10 days at 10°C. Storage of cucumbers below 10°C should be avoided, as this will result in chilling injury. Holding cucumbers without refrigeration at ambient temperature will result in noticeable shriveling and decay after one week (Smith, 2017).

Management of relative humidity

Although cucumbers have a waxy skin, they are susceptible to water loss during storage and marketing. Small sunken lesions may appear on the fruit surface within several days at a low relative humidity (RH). In addition, the fruit loses its firm crisp texture. A small depression at the point of stem attachment may develop. The ideal RH for holding cucumbers is 95 percent (Marr, 2015).

CHAPTER THREE: METHODOLOGY

3.1 Experimental sites and Location

The experiment was conducted at the Multipurpose crop nursery of the Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development, Mampong- Ashanti. Mampong-Ashanti lies at the transitional zone between the forest in the South and northern savannah of Ghana. Mampong - Ashanti lies at an altitude of 402 m above sea level and occurs within latitude 01.45 north of equator and longitude 7^{o} 4'0” N and 1^{o} 24'0” west of the Greenwich Meridian. Mampong-Ashanti has a bimodal rainfall pattern with annual rainfall between 1094.4 mm and 1200 mm and monthly mean rainfall of about 91.2 mm. (Ghana Meteorological Department, 2005). The major rainy season occurs from March to July while minor rainy season occurs from September to November (Ghana Meteorological Department, 2005). Between the two seasons is a short dry spell in August (Ghana Meteorological Department, 2005). Mampong Ashanti has a daily temperature of about 30.5 ^{o}C. The area consists of patches of tall elephant grass to the north and mixed patches of dry forest and grassland to the south.

3.2 Soil type and vegetation at the experimental site

The soil at the experimental site is derived from the Voltain sandstone of Afram plains. It belongs to the savannah Ochrosol class and is characterized by deep sandy loam; free from pebbles. It is well drained and contains moderate organic matter. The soil has a good water holding capacity. It has been classified by FAO/UNESCO (2008) legend as chromic Luvisol and locally as Bediesi series. It is good for tuber, cereal, and legume crops production. The pH ranges from 6.0 to 6.5. The experimental site had been used for the cultivation of various crops such as carrot, tomatoes, maize, cowpea, okra and sweet potato. Grasses such as nut grass (*Cyperus rotundus*), giant star grass (*Cynodon plectostachus*) and guinea grass (*Panicum maximum*) being the most dominate grass.

3.3 Experimental Design, Treatment and Field layout

3.3.1 Experimental Design

The experimental design used was a randomized complete block design (RCBD) with three replications.

3.3.2 Treatments

The treatments used for the study were:

T1- No staking

T2- Supportive staking

T3- Anchor staking.

T4- Protective staking

3.3.3 Field layout

The total field size of 11.1 m ×11 m was demarcated, cleared, lined and pegged. Each experimental plot measured 2.4 m x 3 m. A 1.0 m was left between blocks and 0.5 m between plots.

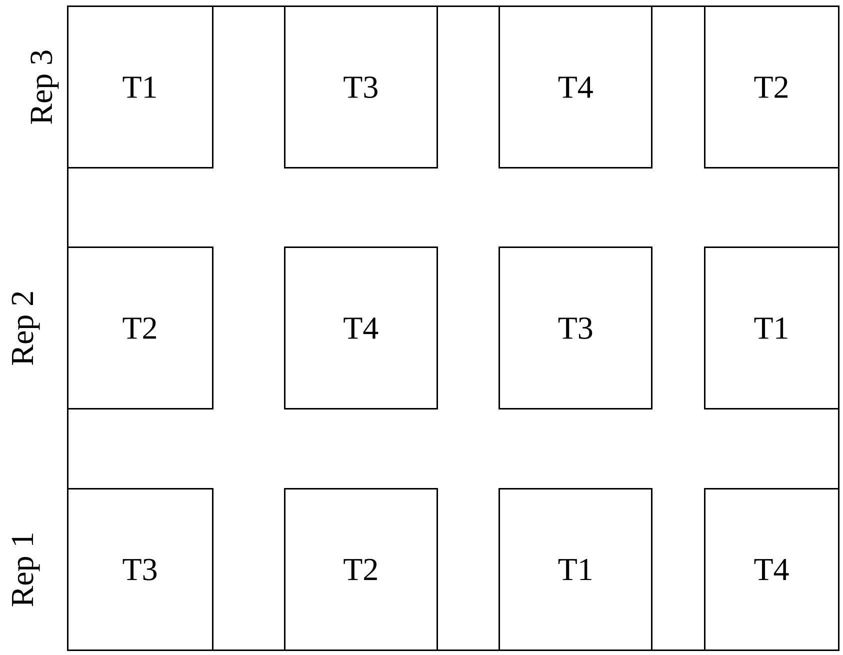

Figure 4: Field layout

3.4 Planting material

Cucumber seeds were bought from a licensed Kyeiwaa Agro-chemical store in Mampong-Ashanti. This cucumber variety was used because it has resistant to diseases, have high yield capacity, drought resistance in favourable for all weather patterns. The English cucumber was used for the study.

3.5.1 Land preparation and Planting

The experimental site was ploughed, harrowed and leveled few days after slashing and spraying with herbicide (Glyphosate 432 EC) since weeds on the field were too grown. Ploughing was also done to obtain the desired germination and growth of crop. The cucumber seeds were sown on 22nd April, 2021 after the plots have been prepared. The seeds were sowed in rows at the depth of 4-5 cm. Three seeds were planted per hill at a spacing of 60 cm x 30 cm. Each experimental plot contained four (4) rows with (10) plants per row.

The total number of plants per plot for cucumber seedling were 40 plants. Germination started four (4) days after sowing and in ten (10) days later vacant holes were refilled.

3.6 Cultural Practices

3.6.1 Weed control

The first weeding was done manually using a hoe on the 1th May, 2021, thus two weeks after seedling emergence. The second weeding was done on the 14th of May, 2021 using a hoe and also just before tasselling. This was to ensure that weeds did not compete with the crops for nutrients and water. Hand pulling of weeds was done two weeks after planting and continued at two weeks interval.

3.6.2 Fertilizer application

NPK inorganic fertilizer was applied two weeks after planting at the rate of 300 kg ha^{-1}. NPK (30 grams per plant). The fertilizer was directly applied to the crop using side placement method and worked into the soil by using a dibber.

3.6.3 Irrigation

Due to erratic rainfall, supplementary irrigation was carried out since cucumber is a field crop. Subsequent watering was also done every other day in the morning using water holes and watering cans. Each plant was given equal amount of water.

3.8.2 Staking

As plants grow and from fruit setting, it requires proper staking with the help of bamboo sticks and wires. Depending on the type of variety (indeterminate) keep the height of bamboo and wire support. Three staking methods namely; anchor, single and string were used for the study. The staking was done after flowering of the cucumber.

Anchor Staking

Anchor staking is type of staking where by two (2) sticks or poles are tied together over the bar pole that is laid across the center of the tied out cross poles, this is also called “Trellising’’ this practice is also used as traditional staking method in most yam growing areas. The sticks or poles and as the cucumber vines begin to grow a 2 to 3 meter pole is needed to allow the vine to grow up towards the lapping bar.

Protective staking

This type of staking is done using single pole to each plant on the plot and detached plant, usually chopped from other plants or as part of the growing plants. Method of staking is generally applicable for yam growing areas.

Supportive staking

This type of staking look-like cage; we used bamboo and splits of about two meter long. We pushed the split bamboo four of them into the soil around the cucumber plant and we tied with wire and will help support cucumber plants as they grow. This method of staking is generally applicable for tomato plant.

3.6.2 Pest and Disease control

Incidence of pests and diseases were monitored periodically by frequent visit to the experimental site to check for cucumber pest and diseases. Insecticide (*Cypermenthrin* at the rate of 150- 80g/ 16L per knapsack was applied four weeks after planting using CP 15 knapsack sprayer on the cucumber plants. However, no disease was encountered in the field throughout the experimental period on both crops.

3.7 Data Collection and Statistical Analysis

Data were collected on phenological, vegetative growth and yield and yield components. The following records were taken;

3.7.1 Phenological Data

3.7.1.1 Days to 50% Emergence

The number of days to 50% emergence from planting per plot was counted on plants from the two central rows and the mean recorded/computed.

3.7.1.2 Days to 50% flowering

This was determined as the number of days when 50% of the plants within the two harvestable central rows had flowered from the day of planting of seeds.

3.7.1.3 Days to 50% fruiting

The number of days to 50% fruiting per plot was counted from the harvestable area (middle row) and the mean recorded.

3.7.1.4 Days to Maturity

The total number of plants within the two middle rows after sowing to maturity was counted and the mean computed.

3.7.2 Vegetative Growth Data

3.7.2.1 Percentage plant establishment

The percentage plant establishment at twenty one (21) days after planting was measured by counting the number of plants that had established and the percentage plant established subsequently estimated.

3.7.2.2 Vine length

The Vine length was measured from the base to the apical part of the vine of the four (4) plant tagged from the two central rows four weeks after planting (4WAP) and at 14 days intervals using a meter rule and the mean recorded.

3.7.2.3 Number of leaves per plant

The total number of leave per plant was counted separately for four (4) plants within the two middle rows four weeks after planting (4WAP) and at every 14 days intervals using a meter rule and the mean recorded.

3.7.2.4 Vine girth/ diameter

The Vine girth/ diameter was measured from the widest part of the stem just above the soil level using vernier caliper four weeks after planting (4WAP) and at every 14 days interval and the mean recorded.

3.7.2.4 Number of branches

The total number of branches per plant was counted separately for four (4) plants within the two middle rows four weeks after planting (4WAP) and at every 14 days interval and the mean recorded.

3.7.3 Yield and Yield components

3.7.3.1 Number of plants harvested

The total number of plants harvested per experimental plot was counted from the two central rows and the mean recorded.

3.7.3.2 Number of fruits per plant

The total number of fruits per plant from the six (6) plant within the two central rows was counted at each harvest and the mean estimated.

3.7.3.3 Fruit length

The fruit length was measured on five (5) randomly selected matured fruit from the two central rows from the base to the tip of the fruit using meter rule and the mean was recorded.

3.7.3.4 Fruit diameter

The fruit diameter was measured using the vernier caliper from the widest part of the fruit after harvest. This was determined on five (5) randomly selected fruits from the two central rows after harvest and the mean was estimated.

3.7.3.5 Fruit weight per plant

The fruit weight per plant six (6) tagged plants from the two central rows was weighed with an electronic weighing scale and the mean was computed.

3.7.3.6 Total number of fruit per plot

The total number of fruits per plot from the two central rows per plot was counted separately after each harvest and the mean computed.

3.7.3.7 Fruit weight per plot (Fruit yield)

At each harvest, the total number of matured fruit was weighed for each of the harvested fruits from the two central rows using electronic weighing scale and the mean was recorded.

3.8 Statistical Analysis of Data

The data collected were subjected to statistical analysis of variance (ANOVA) using Genstat statistical package (Genstat, 2011), and where significant differences were obtained, least significant difference (LSD) was used to separate means at 5% probability.

CHAPTER FOUR: RESULTS

4.1 Number of leaves

Table 4.1 indicated that there was significant difference ($P<0.05$) on the number of leaves for only at 2WAP. The number of leaves increase with increasing weeks after planting. The string staking method recorded the highest number of leaves at 3WAP (6.03), 4WAP (8.37) and 5WAP (9.7) respectively.

Table 4.1: Number of leaves of cucumber as influenced by different staking methods

Staking Method	2WAP	3WAP	4WAP	5WAP
Anchor	3.50	5.70	7.57	8.9
Single	3.50	5.77	7.8	9.07
String	3.50	6.03	8.37	9.7
No treatment	3.50	5.40	7.53	9.03
Mean	3.5	5.73	7.82	9.18
STD	0.00	0.37	0.54	1.01
P-VALUE	S	NS	NS	NS

4.2 Plant height

Table 4.2 indicated that there was no significant difference ($P>0.05$) for plant height throughout the WAP. The plant height increases with increasing weeks after planting.

Table 4.2: Plant height of cucumber as influenced by different staking methods

Staking Method	2WAP	3WAP	4WAP	5WAP
Anchor	2.66	4.38	11.3	39.5
Single	2.97	5.37	14.48	40.91
String	2.72	5.55	14.15	47.07
No treatment	2.77	4.39	11.38	42.77
Mean	2.78	4.92	12.84	42.56
STD	0.278	0.80	2.98	7.56
P-VALUE	NS	NS	NS	NS

4.3 Leave Length

Table 4.3 indicated that there was significant difference ($P<0.05$) for the leave length only at 3WAP. The leave length increases with increasing weeks after planting. The string staking method recorded the highest leave length at 2WAP (4.01), 3WAP (8.57). Single staking method recorded the highest leave length for 4WAP (13.34) and 5WAP (11.59) respectively.

Table 4.3: Leave Length of cucumber as influenced by different staking methods

Staking Method	2WAP	3WAP	4WAP	5WAP
Anchor	3.67	8.10	10.34	11.51
Single	3.34	8.09	13.34	11.59
String	4.01	8.57	10.50	10.98
No treatment	3.38	6.26	9.14	10.49
Mean	3.60	7.75	10.83	11.14
STD	0.44	1.15	2.71	1.02
P-VALUE	NS	S	NS	NS

4.4 Leave Width

Table 4.4 indicated that there was no significant difference ($P>0.05$) throughout the growing period of the crop. The leave width increases with increasing weeks after planting.

Table 4.4: Leave width of cucumber as influenced by different staking methods

Staking Method	2WAP	3WAP	4WAP	5WAP
Anchor	4.17	9.11	12.97	14.20
Single	4.45	9.83	13.27	13.77
String	4.52	10.25	13.71	15.02
No treatment	4.26	8.72	12.27	14.02
Mean	4.35	9.48	13.05	14.45
STD	0.53	1.08	0.73	0.93
P-VALUE	NS	NS	NS	NS

4.5 Stem girth

Table 4.5 indicated that there was no significant difference ($P>0.05$) on the stem girth. The stem girth increases with increasing weeks after planting. The string staking method recorded the highest stem girth in all the weeks after planting for 2WAP (1.41), 3WAP (2.63) and 4WAP (3.45) respectively.

Table 4.5: Stem Girth of cucumber as influenced by different staking methods

Staking Method	2WAP	3WAP	4WAP	5WAP
Anchor	1.34	2.43	3.21	3.89
Single	1.37	2.45	3.25	3.86
String	1.41	2.63	3.45	3.87
No treatment	1.37	2.35	3.21	4.05
Mean	1.37	2.46	3.28	3.92
STD	0.08	0.23	0.16	0.24
P-VALUE	NS	NS	NS	NS

4.6 Fruit Length

Table 4.6 indicated that there was significant difference ($P<0.05$) on the fruit length at 3WAP. The fruit length decreases with increasing weeks after planting. The string staking method recorded the highest fruit length for 3WAP (21.13), 4WAP (22.57) and 4WAP (18.93).

Table 4.6: Fruit Length of cucumber as influenced by different staking methods

Staking Method	2WAP	3WAP	4WAP	5WAP
Anchor	20.13	20.10	18.98	17.4
Single	21.17	21.10	19.75	17.07
String	20.60	21.13	22.57	18.93
No treatment	17.33	18.60	18.66	16.83
Mean	19.81	20.23	19.99	17.55
STD	1.73	1.77	2.49	1.16
P-VALUE	S	NS	NS	NS

4.7 Fruit Diameter

Table 4.7 indicated that there was no significant difference (P>0.05) on the fruit diameter. The fruit diameter decreases with increasing weeks after planting for anchor, singly and no treatment.

Table 4.7: Fruit Diameter of cucumber as influenced by different staking methods

Staking Method	2WAP	3WAP	4WAP	5WAP
Anchor	18.10	18.40	17.45	15.23
Single	17.50	18.17	16.90	14.63
String	18.77	19.40	16.20	16.07
No treatment	17.43	18.20	17.60	14.50
Mean	17.95	18.54	17.01	15.14
STD	0.97	1.05	0.90	1.01
P-VALUE	NS	NS	NS	NS

4.8 Fruit Weight (Tag)

Table 4.8 indicated that there was no significant difference (P>0.05) for WAP on the fruit weight (tag). The fruit weight did not show a pattern of whether increasing or decreasing with increasing weeks after planting for the treatments.

Table 4.8: Fruit Weight (Tag) of cucumber as influenced by different staking methods

Staking Method	2WAP	3WAP	4WAP	5WAP
Anchor	2.00	2.50	2.75	1.93
Single	1.85	3.35	2.56	1.68
String	2.01	2.51	2.77	1.80
No treatment	1.45	2.01	2.14	1.67
Mean	1.83	2.34	2.56	1.77
STD	0.41	0.42	0.43	0.22
P-VALUE	NS	NS	NS	NS

4.9 Fruit Weight (Untag)

Table 4.9 indicated that there was no significant difference (P>0.05) for WAP on the fruit weight (untag). The fruit weight (untag) did not show a pattern of whether increasing or decreasing with increasing weeks after planting for the treatments. The anchor staking method recorded the highest fruit weight (untag) of 2.25 for 4WAP and the lowest for no treatment of 0.87 respectively.

Table 4.9: Fruit Weight (untag) of cucumber as influenced by different staking methods

Staking Method	2WAP	3WAP	4WAP	5WAP
Anchor	1.04	2.00	2.25	1.22
Single	1.25	1.85	2.06	1.22
String	1.19	2.01	2.07	1.33
No treatment	0.87	1.45	1.65	1.22
Mean	1.09	1.83	2.00	1.25
STD	0.31	0.41	0.56	0.18
P-VALUE	NS	NS	NS	NS

CHAPTER FIVE: DISCUSSION

5.1 The influence of staking on growth of cucumber

There was significant difference ($P<0.05$) for only 2WAP on the number of leaves. The number of leaves increase with increasing weeks after planting. The string staking method recorded the highest number of leaves. There was no significant difference ($P>0.05$) for all the WAP on the plant height. The plant height increases with increasing weeks after planting. The string staking method recorded the highest plant height. There was significant difference ($P<0.05$) for only 3WAP on the leave length. The leave length increases with increasing weeks after planting. The string staking method recorded the highest leave length for 2WAP (4.01), 3WAP (8.57). Single staking method recorded the highest leave length for 4WAP (13.34) and 5WAP (11.59). There was no significant difference ($P>0.05$) for WAP on the leave width. The leave width increases with increasing weeks after planting. The string staking method recorded the highest leave width in all the weeks after planting. There was no significant difference ($P>0.05$) for WAP on the stem girth. The stem girth increases with increasing weeks after planting. The string staking method recorded the highest stem girth in all the weeks after planting. Nweke *et al.*, (2013) on their study revealed that staking had effect on the vegetative growth of cucumber, although all the parameters measured for vegetative growth were non-significant at $P=0.05$. The number of branches, number of leaves, vine length and leaf area were higher in the staked than the non-staked treatment. This may suggest that the leaves on the staked plants were all exposed to greater light interception leading to a higher accumulation of photosynthesis for vegetative growth. Hanna and Adams (1991) reported that staking cucumber increased the fruit yield because of better light interception. The number of days to 50% anthesis was higher in the staked than the non-staked treatment. This agrees with the findings of Jansen *et al.* (2021) who observed that staking prolongs vegetative growth and delays fruit formation. The non-staked treatment consistently produced lower values in all the vegetative parameters evaluated except in the number of flowers. Devi *et al.* (2020) found that the number of fruits per plant, fruit weight, number of branches per plant, number of leaves per plant, leaf size and plant height were significantly affected by staking in both varieties of Tomatillo. Kengar (2011) reported that number of leaves per plant was varied from variety to variety (Kengar, 2011). The size of leaves per branch was deferred from variety to variety. Unlike this study, Devi *et al.* (2020) found out that the staking significantly affects plant height of Tomatillo. The no. of branches of local cultivar was the number of branches per plant was higher in unstaked – unpruned (10) similarly to stake – unpruned the similar results were found in the present experiment (Mulato-Brito and Peña-Lomelí, 2007; Nodi, 2016). The maximum (35.33) number of fruits per plant from staking while the minimum (27.05) number of fruits per plant was found from non-staking and pruning.

5.2 The influence of staking on yield of cucumber

There was significant difference ($P<0.05$) for only 3WAP on the fruit length. The fruit length decreases with increasing weeks after planting. The string staking method recorded the highest fruit length for 3WAP (21.13), 4WAP (22.57) and 4WAP (18.93). There was no significant difference ($P>0.05$) on the fruit diameter at WAP. The fruit diameter decreases with increasing weeks after planting for anchor, singly and no treatment cucumber plants. The string staking method supported produce the highest fruit diameter in all the weeks after planting. There was no significant difference ($P>0.05$) for WAP on the fruit weight (tag).

The fruit weight did not show a pattern of whether increasing or decreasing with increasing weeks after planting for the treatments. The single staking method recorded the highest fruit weight and the lowest for no treatment. There was no significant difference (P>0.05) for WAP on the fruit weight (untag). The fruit weight (untag) did not show a pattern of whether increasing or decreasing with increasing weeks after planting for the treatments. The anchor staking method recorded the highest fruit weight (untag) and the lowest for no treatment. Nweke *et al.* (2013) reported that the yield parameters assessed were found to be higher on the staked plants than that vine on the ground. The result agreed with the findings of Singh & Sharma (2018) who observed that the yield of super select cucumbers were higher for the trellised treatment than for the non-trellised treatment.

Ogundare (2015) reported that staked cucumber gave an average marketable yield of 25 ton/acre as against 16.4 tons/acre of the non-staked cucumber. While Jansen *et al.* (2021) concluded that staked cucumber produced fruits that double the quantity of the ones on the ground. The number of non-marketable fruit was higher in the non-staked than the staked treatment. This could be attributed to the poor quality in the color of the fruit, reduced length of fruit and development of yellow bellies on the fruits, which predisposes them to spoilage. Ogundare (2015) reported that staking brings about an increase in color quality, fruit length and sugar content of the fruits. Also, Singh & Sharma (2018) affirmed that staking improves the color and lower the incidence of yellow bellies in cucumber. The non-staked treatment consistently gave least values in all the yield parameters evaluated except in the number of non-marketable fruits. Maximum fruit weight (89.19 g) in the case of single staking plant while fruit weight was lowest (63.07) in unpruned plants and non-staking plants (Sowley and Damba, 2013) Fruit weight was significantly the largest with string staking (50.2g) and the lowest with high platform (44.7g). Stem pruning had much influence on individual fruit weight. Significantly, the highest weight of fruit was obtained from the plant with two stems (50.1 g) and the lowest from no pruning treatment (45.0 g) (Masrie & Girma, 2023). Different tomato cultivars other than cucumber behaved significantly different from each other concerning various parameters. Other studies (Masrie & Girma, 2023) have shown that tomato plants unlike cucumber grown without staking are more prone to fruit cracking due to exposure of fruits to direct sunlight and higher fruit temperature, according to Asante (2022), direct sunlight and higher fruit temperature reduce cuticle resistance and firmness of the fruit.

CHAPTER SIX: CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The result showed that staking had effect on the vegetative growth and yield of cucumber. The non-staked cucumber plants consistently gave least values in all the vegetative and yield parameters. The cucumber plants supported with string staking method produced the highest number of leaves, plant height, leave length, leave width and stem girth. The string staking method recorded the highest fruit length, fruit diameter and fruit weight. The anchor staking method recorded the highest fruit weight

6.2 Recommendations

1. String staking method should be used for cucumber production
2. Government and other stakeholders should take steps to provide training, conferences, and workshops on means of cultivation of cucumber on a large scale and pay attention to food and nutrition security.
3. Additional research of this kind may be conducted using different varieties for improved authentication, depending on the circumstances.

REFERENCES

Abma, R., & Stake, B. (2014). *Cucumber cultivation methods*. Agricultural Journal, 12(4), 45-52.

Ahmed, I., Rohman, M. M., Hossain, M. A., Molla, M. R., Azam, M. G., Hasan, M. M., & Hossain, A. (2022). A study on the phenotypic variation of 103 cucumber (*Cucumis sativus* L.) landraces for the development of desirable cultivars suitable for the changing climate. *Life*, *12*(8), 1235.

Alam, S., Johnson, C., & Mendez, R. (2016). "The effects of staking on cucumber fruit size and yield." *Journal of Agricultural Science*, 8(2), 101-108.

Amiri, R., Safaei, M., & Khandan, A. (2016). Effects of environmental conditions on greenhouse cucumber yield. *Horticultural Studies*, 24(2), 102-109.

Ara, T., Roberts, J., & Singh, N. (2017). "Pests and diseases in cucurbit crops." *Plant Pathology Journal*, 15(3), 67-78.

Asante, P. Y. (2022). *Effect of different plant spacing and staking on growth and yield of tomato (Solanum Lycopersicum L.)* (Doctoral dissertation, University of Education, Winneba).

Bag, A., Biswas, S., Dey, P., & Das, S. (2022). "Antioxidant and anti-inflammatory properties of cucumbers." *Journal of Food Science and Nutrition*, 8(1), 45-58.

Balkaya, A., Ozbakir, M., & Ozkan, O. (2020). Cucurbitaceae genetic diversity and production trends. *Journal of Agricultural Science and Technology*, 22(1), 55-66.

Basirat, Z., & Mousavi, H. (2022). *Cucumber crop management and cultivation techniques*. Journal of Horticulture, 12(2), 145-156.

Behera, T. K., Verma, A. K., & Sahoo, S. (2022). "Advances in cucumber breeding: A comprehensive review." *Plant Breeding*, 141(3), 101-112.

Benlloch-González, M., Alejandre, J. C., & Guillén, M. (2018). "The effect of temperature on cucumber flowering and fruiting." *Journal of Horticultural Science*, 23(1), 120-128.

Bhatt, M., Kapoor, A., Sharma, R., & Goyal, P. (2022). "Cucumbers as a potential aid in diabetes management." *Journal of Plant Biochemistry and Physiology*, 10(2), 150-162.

Boonkorkaew, P., Suraninpong, P., & Tanaka, K. (2020). Parthenocarpic fruit set and hormone interactions in cucumbers. *Journal of Plant Growth Regulation*, 39(2), 314-326.

Bradeen, J. M., Staub, J. E., Wye, C., Antonise, R., & Peleman, J. (2001). Towards an expanded and integrated linkage map of cucumber (*Cucumis sativus* L.). *Genome*, 44(1), 111-119.

Brown, J., & Green, P. (2020). *Cucumber cultivation and post-harvest handling*. Agricultural Sciences Journal, 34(2), 123-135.

Can, M., Altan, Z., Ozkan, S., & Karaca, M. (2022). "The antioxidant potential of cucumbers in reducing cancer risks." *Oncology and Nutritional Research*, 7(3), 120-135.

Chanda, M., Han, R., & Li, W. (2021). "Impact of staking on the productivity of cucumber in controlled environments." *Journal of Horticultural Research*, 11(2), 85-93.

Chandra, P., Kumar, A., Singh, V., & Patel, R. (2022). "The increasing prevalence of non-communicable diseases in Africa." *African Journal of Medical Science*, 14(2), 98-112.

Chaudhary, R. (2022). *Greenhouse cucumber production and management*. Horticultural Science Journal, 18(4), 225-234.

Chen, J., Liu, G., & Shen, W. (2018). Hormonal regulation of fruit development in cucumbers: The role of auxins and gibberellins. *Frontiers in Plant Science*, 9, 662-670.

Cheryld, M., Hamilton, R. K., & Lavoy, S. (2018). Staking and fruit cracking in tomatoes: A comparative study. *Plant Physiology Journal*, 12(3), 134-145.

Choudhary, B. R., Verma, A. K., & Singh, D. (2021). Tunnel Technology of Cucurbit Cultivation in Hot Arid Region. In *Dryland Horticulture* (pp. 313-325). CRC Press.

Cramer, C. S., & Wehner, T. C. (2016). Gynoecious cucumbers for hybrid seed production. *Horticultural Reviews*, 44, 129-158.

Dane, F., Gong, P., & Liu, J. (2020). Wild Cucumis species and their contribution to cucumber breeding. *Plant Breeding Reviews*, 43(3), 301-319.

Dawson, T. E., & Goldsmith, G. R. (2018). The value of wet leaves. *New Phytologist*, *219*(4), 1156-1169.

Devi, C., Patel, R., & Singh, M. (2020). "Impact of staking and varieties on growth and yield of Tomatillo." *Journal of Horticultural Sciences*, 45(2), 123-135.

Dey, S. S., Behera, T. K., Bhatia, R., & Munshi, A. D. (2020). Accelerated breeding in cucumber using genomic approaches. *Accelerated Plant Breeding, Volume 2: Vegetable Crops*, 271-299.

Diver, S. (2015). "Nutrient management in cucurbits: The role of phosphorus and potassium." *Agricultural Practices Review*, 12(4), 150-165.

Doltra, J., & Muñoz, P. (2010). "Fertilizer management in cucurbit crops." *Soil Fertility Research*, 9(2), 102-110.

dos Santos, A. C., Ferreira, S. L., de Lima, G. P., & Nogueira, A. S. (2022). Antioxidant properties of cucumber varieties. *Journal of Food Science*, 45(3), 467-475.

Duong, T. T., Dung, T. P., Tanaka, K., Nhi, P. T. P., Shigita, G., Imoh, O. N., & Kato, K. (2021). Distribution of two groups of melon landraces and inter-group hybridization enhanced genetic diversity in Vietnam. *Breeding science*, *71*(5), 564-574.

Elavarasan, K., Anand, B., & Subramaniam, R. (2022). "Water content and nutritional benefits of cucumbers." *Journal of Horticultural Research*, 11(1), 24-36.

Falodun, A., & Ogedegbe, J. (2019). "Staking practices in vegetable farming." *Journal of Agricultural Practices*, 14(1), 42-55.

Fang, Y., Liu, Z., Zhang, H., & Wang, X. (2022). "Cucumber's role in oral hygiene." *Journal of Oral Health and Nutrition*, 6(4), 52-66.

FAOSTAT. (2022). *World production and yield statistics*. Food and Agriculture Organization. https://www.fao.org/faostat

Fiume, Z. (2012). *Safety assessment of Cucumis sativus (cucumber)-derived ingredients as used in cosmetics*. Cosmetic Ingredient Review, 10(4), 291-308.

Forslund, M. (2012). "The role of staking in improving cucumber fruit quality." *International Journal of Vegetable Science*, 19(4), 135-143.

Fountain, M. T. (2022). Impacts of wildflower interventions on beneficial insects in fruit crops: A review. *Insects*, *13*(3), 304.

Franco, J. A., Ríos, J. J., & Ruiz, J. M. (2020). "Therapeutic uses of *Cucumis sativus*: A critical review." *Phytomedicine Journal*, 27(1), 90-95.

Gao, Z., Zhang, H., Cao, C., Han, J., Li, H., & Ren, Z. (2020). QTL mapping for cucumber fruit size and shape with populations from long and round fruited inbred lines. *Horticultural Plant Journal*, *6*(3), 132-144.

Gebresamuel, B., Girma, T., & Belay, A. (2021). "Status and potential of cucumber production in Ethiopia." *Journal of Agricultural Science*, 16(3), 189-198.

Getahun, D., & Habte, B. (2017). Experiences of rain-fed tomato production in an open field. *Int. J. Sci. and Res*, *6*(2), 1335-1343.

Goel, A., Tiwari, P., & Chauhan, V. (2022). Ancient history of cucumbers: From Egypt to Rome. *Historical Agriculture Studies*, 15(1), 85-90.

Gogoi, B., Neog, P., Saikia, P., & Deka, R. (2020). Impact of staking and pruning on cucumber yield under greenhouse conditions. *International Journal of Horticultural Sciences*, 15(2), 234-242.

Gong, X., Li, H., Wang, Q., & Zhao, T. (2022). "Anti-inflammatory properties of cucumbers." *Nutrition and Inflammation Research Journal*, 9(3), 89-101.

Grumet, R., Lin, Y. C., Rett-Cadman, S., & Malik, A. (2022). Morphological and genetic diversity of Cucumber (*Cucumis sativus* L.) fruit development. *Plants*, *12*(1), 23.

Gupta, A., Sharma, P., Verma, S., & Arora, K. (2022). "Nutritional benefits of cucumber in weight management." *Journal of Diet and Nutrition*, 13(1), 78-85.

Hanna, H. Y., Adams, A. J., & Story, B. A. (1987). Double cropping cucumber and tomato with staking: Yield and quality evaluation. *Agronomy Journal*, 79(3), 580-585.

Hardy, J. K., & Rowell, B. (2002). Effects of trellising on cucumber yield and quality. *Journal of Agricultural Science*, 58(2), 120-130.

He, X., Liu, H., Liu, R., Song, W., & Yao, X. (2013). Fine mapping of powdery mildew resistance gene pm 5.1 in cucumber (*Cucumis sativus* L.). *Theoretical and Applied Genetics*, 126(7), 1925-1933.

He, Y., Wei, M., Yan, Y., Yu, C., Cheng, S., Sun, Y., & Miao, L. (2022). Research advances in genetic mechanisms of major cucumber diseases resistance. *Frontiers in Plant Science*, *13*, 862486.

He, Z., Dong, Z., & Yan, P. (2015). Inheritance of disease resistance in cucumber: A molecular perspective. *Plant Genetics and Pathology Journal*, 61(4), 318-329.

Heigermoser, M., Winterhalter, P., & Muller, C. (2022). Global cucumber production: An overview. *Agricultural Systems*, 198, 103-112.

Hikosaka, M., & Sigiyama, Y. (2020). *Yield improvement in monoecious cucumbers using pinching techniques*. International Journal of Greenhouse Production, 8(3), 211-219.

Huang, S., Li, R., & Zhang, Z. (2009a). The cucumber genome provides insight into plant vascular function and sex expression. *Nature Genetics*, 41(12), 1275-1281.

Huang, S., Li, R., Zhang, Z., Li, L., Gu, X., Fan, W., & Wang, J. (2009b). The genome of the cucumber, *Cucumis sativus L. Nature Genetics*, 41(12), 1275-1281.

Hussain, S., Akhtar, N., & Baig, M. (2020). "The effect of temperature on cucumber pollination and fruit setting." *International Journal of Agricultural Science*, 15(2), 112-118.

Jat, G. S., Behera, T. K., Lata, S., & Kumar, S. (2021). Classical genetics and traditional breeding in cucumber (*Cucumis sativus* L.). *Cucumber economic values and its cultivation and breeding*, 201-215.

Jensen, K., Karlsson, M., & Roberts, D. (2021). Floral biology and pollination mechanisms in greenhouse cucumber. *Journal of Horticultural Science*, 56(1), 44-53.

Jha, V., Gupta, M., & Sahu, K. (2019). "Soil pH and its effect on cucumber growth." *Soil Science and Horticultural Studies*, 8(1), 45-59.

Jiang, F., Wang, Q., & Li, X. (2020). Genetic control of male sterility and female flowering in cucumber. *Horticultural Breeding Journal*, 47(3), 298-304.

Jones, H. A., Smith, D. L., & Xu, H. (2019). Disease-resistant cucumbers for commercial production. *Journal of Horticultural Science and Biotechnology*, 94(1), 145-151.

Jones, R., & Parker, D. (2016). *Post-harvest handling of cucumbers: Techniques and recommendations*. Postharvest Technology Journal, 29(3), 210-225.

Kahraman, H., & Toklu, N. (2022). "The neuroprotective potential of cucumber." *Journal of Neurodegenerative Studies*, 12(2), 66-80.

Karanisa, E., *et al.* (2022). *Cucumber production and export potential in South Africa*. Agronomy Today, 13(1), 75-85.

Kengar, A. (2011). "Varietal influence on leaf number and branch size in cucumbers." *Plant Breeding and Crop Science*, 6(4), 250-257.

Kim, H., & Cho, S. (2022). "The role of cucumber in weight loss." *Journal of Nutritional Research*, 10(3), 130-141.

Kumar, S., Rana, S., & Yadav, P. (2020). "Cucumber's detoxifying properties." *Journal of Health and Nutrition*, 7(1), 40-51.

Kumari, R., Kumar, R., & Mehta, D. K. (2021). Expression of heterosis and residual heterosis for traits of earliness and yield in cross combinations of cucumber (*Cucumis sativus* L.) developed by introgression of indigenous and exotic sources. *Scientia Horticulturae*, *277*, 109781.

Li, Z., Han, Y., Niu, H., Wang, Y., Jiang, B., & Weng, Y. (2020). Gynoecy instability in cucumber (*Cucumis sativus* L.) is due to unequal crossover at the copy number variation-dependent Femaleness (F) locus. *Horticulture research*, *7*.

Li, Z., Niu, H., & Guo, Y. (2022). Cucumber sex determination: Aspects of gene interactions. *The Cucumber Genome,* 145-157.

Lobine, D., Naik, R., & Pillay, M. (2022). "Cucumber: A powerful source of antioxidants." *Journal of Nutraceutical Science*, 6(4), 170-182.

Malepszy, S., & Niemirowicz-Szczytt, K. (2016). Advances in sex expression and hybrid breeding of cucumbers. *Cucurbit Genetics Cooperative Report*, 39(1), 22-27.

Marr, G. (2015). *Best practices in fresh produce storage*. Journal of Postharvest Biology, 12(1), 45-53.

Masrie, B., & Girma, T. (2023). Effect of stem pruning and staking time on growth and yield of tomato (*Lycopersicon esculentum* Mill. Var. Mersa) at Mersa, North Wollo, Ethiopia. *Vegetos*, *36*(3), 1080-1088.

McAvoy, T. A. (2015). The effects of sunlight on tomato fruit quality: Implications for fruit cracking. *Journal of Crop Management*, 29(4), 199-208.

Mendoza-Pérez, R. G., Chávez-Castillo, F., & López-Hernández, R. (2018). Management of cucumber growth in greenhouses: A review. *Journal of Greenhouse Crop Research*, 24(4), 315-328.

Mishra, M. G., Singh, P. K., Pandey, P., & Sohi, M. A. (2023). Breeding Approaches for Vegetable Crops. *Plant diversity*, *42*(3), 122-136

More, T. A., & Budgujar, N. V. (2015). Breeding tropical gynoecious cucumbers for hybrid seed production. *Journal of Plant Breeding and Genetics*, 11(4), 230-245.

Mukherjee, P. K., Rai, S., & Mukherjee, K. (2013). "Phytochemical and pharmacological overview of *Cucumis sativus* L." *Journal of Pharmaceutical Sciences*, 12(2), 265-278.

Mulato-Brito, R., & Peña-Lomelí, A. (2007). "Effect of pruning and staking on cucumber yield." *Agricultural Science Journal*, 9(2), 112-118.

Murray, P., & Horswill, L. (2022). Nutritional composition of the Kiwan variety of cucumber. *Food Chemistry*, 350, 128-135.

Musa, A., Mahmud, A., & Salim, R. (2021). "Effects of staking on cucumber yield and quality in tropical climates." *Journal of Tropical Agriculture*, 29(3), 188-198.

Nath, P., Devi, N., & Lal, S. (2017). QTL mapping in vegetable crops: Opportunities and prospects. *Horticultural Plant Journal*, 3(5), 183-195.

National Watermelon Promotion Board. (2016). *Lycopene content in cucumbers*. Journal of Nutritional Studies, 14(2), 113-118.

Nishio, S., Kubota, M., & Goto, S. (2016). Genetic diversity and population structure in cucumber (*Cucumis sativus* L.). *Horticultural Research*, 3, 160-169.

Nodi, M. (2016). "The effect of staking on fruit yield in local cucumber varieties." *Journal of Agricultural Research*, 21(1), 45-59.

Nweke, O. J., Ekwu, L. G., & Onuoha, N. (2013). Influence of staking and spacing on cucumber fruit yield. *Journal of Agronomy*, 8(4), 234-240.

Obeng-Ofori, D., Addae, P., & Ababio, E. (2022). "Common cucumber varieties grown in Ghana and their disease resistance." *West African Journal of Horticulture*, 9(2), 231-246.

Ogundare, F. (2015). "Comparative analysis of staked and non-staked cucumber crops." *Journal of Agricultural Studies*, 18(2), 234-240.

Omokhua-Uyi, A., & Van Staden, J. (2020). African horned cucumber cultivation in Southern and Central Africa. *Journal of Ethnobotany*, 16(2), 256-262.

Onanuga, A., Adeleke, S., & Adepoju, T. (2022). "Global cucumber production statistics and trends." *Agricultural Data Review*, 5(1), 15-24.

Pan, Q., Hu, Y., & Chen, H. (2017). Advances in cucumber genetics and breeding. *Plant Breeding Reviews*, 41(2), 153-176.

Pan, Y., Wen, C., Han, Y., Wang, Y., Li, Y., Li, S., & Weng, Y. (2020). QTL for horticulturally important traits associated with pleiotropic andromonoecy and carpel number loci, and a paracentric inversion in cucumber. *Theoretical and Applied Genetics*, *133*, 2271-2290.

Pandey, A., & Choudhary, B. (2016a). Advances in cucumber breeding and genetics. *Plant Breeding and Genetics Review*, 3(4), 47-62.

Pandey, A., & Choudhary, B. (2016b). Hybrid seed production in cucumbers: Methods and techniques. *Agricultural Sciences Journal*, 12(6), 114-122.

Pandey, A., & Kujur, A. (2022). The historical and medicinal uses of cucumber. *Journal of Botanical Sciences*, 78(2), 145-153.

Pandey, R. K., & Choudhary, A. (2014). *Comprehensive guide to cucumber cultivation*. New Delhi: Horticultural Research Publications.

Pandey, S., & Kujur, A. (2022). *Cucumber plant biology: An overview*. Botany Research, 11(3), 150-165.

Pandey, S., Dubey, R. K., Singh, S., Kumar, S., Singh, S., & Behera, T. K. (2023). diara land cultivation of cucurbitaceous crops. *Indian Horticulture*, *68*(2), 77-81.

Pandey, S., Singh, B., & Kumar, R. (2013). SSR-based genetic diversity assessment of cucumber (*Cucumis sativus L.*) accessions. *Indian Journal of Genetics and Plant Breeding*, 73(1), 10-14.

Paniagua-Zambrana, N. Y., Bussmann, R. W., & Kikvidze, Z. (2024). Cucumis melo L. *Cucumis sativus* L. Cucurbitaceae. In *Ethnobotany of the Mountain Regions of Eastern Europe: Carpathians* (pp. 1-12). Cham: Springer International Publishing.

Pascual, L., Avila, C. M., & Garcia, F. (2017). Advances in fruit shape and texture in cucumber. *Journal of Plant Physiology*, 221(3), 59-65.

Paucek, P., Ryu, K. N., & Sun, H. (2020). "Cucumber trellising systems in modern agriculture." *Horticultural Techniques Review*, 16(1), 89-99.

Prasad, M., & Kothari, P. (2022). Challenges in cucumber production in Ethiopia. *African Agriculture Review*, 16(4), 277-285.

Rai, A., Khatri, P., & Joshi, M. (2021). "Land preparation techniques for cucumber cultivation." *Journal of Agricultural Innovations*, 14(3), 220-235.

Saeed, F., Anwar, S., Hussain, A., & Raza, M. (2023). "The role of environmental factors in cucumber flowering and fruiting." *Journal of Plant Physiology*, 18(1), 29-44.

Sahu, P. (2022). *Integrated Nutrient Management in Cucumber (Cucumis sativus L.)* (Doctoral dissertation, Department of Vegetable Science, OUAT, Bhubaneswar).

Saito, K., Matsumura, H., & Nakamura, T. (2017). Genetic diversity and molecular markers in cucumber sex expression. *Horticultural Genetics*, 60(2), 141-150.

Sarkar, P., Sharma, S., & Bhatnagar, A. (2022). "Root system architecture of cucumbers: Implications for crop management." *Journal of Plant Physiology*, 34(1), 78-87.

Seymour, G. B., Ostergaard, L., & Grant-Downton, R. (2020). Developmental genetics of fruit formation in cucurbits. *Annual Review of Plant Biology*, 71(1), 57-80.

Sharma, P., Kaur, M., Sharma, A., & Bhardwaj, N. (2021). Breeding vegetables for protected cultivation: A review. *Himachal Journal of Agricultural Research*, *47*(1), 1-17.

Shwe, E., Wu, B., & Huang, S. Q. (2020). Both small and large plants are likely to produce staminate (male) flowers in a hermaphrodite lily. *Plant diversity*, *42*(3), 142-147.

Singh, G., & Sharma, N. (2018). Advances in greenhouse cultivation of cucumbers for high yield and quality. *Journal of Horticultural Technologies*, 29(3), 98-105.

Singh, P., & Chaudhary, R. (2020). Chemical control of sex expression in cucumbers for hybrid production. *Journal of Plant Growth Regulation*, 28(3), 455-462.

Smith, L. (2017). *Cucumbers: Growing, harvesting, and quality control*. Horticulture Today, 45(4), 88-102.

Sotiroudis, T. G., Sotiroudis, G., & Xenakis, A. (2020). "Antioxidant properties of cucumber essential oils and bioactive compounds." *Journal of Phytochemistry*, 34(1), 45-52.

Sowley, E. N., & Damba, E. (2013). Effect of staking on cucumber (*Cucumis sativus*) yield and fruit quality. *Journal of Plant Science*, 5(1), 15-23.

Staeck, L. (2022). *The African horned cucumber: Unique species with promising potential*. Journal of African Horticulture, 7(2), 91-105.

Staub, J. E., & Bacher, J. (2023). Cucumber as a processed vegetable. In *Processing vegetables* (pp. 129-193). Routledge.

Staub, J. E., Wehner, T. C., & López-Sesé, A. I. (2019). Cucumber. In *Vegetable Breeding Handbook* (pp. 175-191). Springer.

Sun, Y., Wang, X., & Yuan, Y. (2016). Genetic basis of parthenocarpic fruit development in cucumber (*Cucumis sativus*). *Theoretical and Applied Genetics*, 129(7), 1447-1457.

The Horticulture Development Unit, Directorate of Crop Services. (2014). *Pest management guidelines for cucurbit crops*.

Tiwari, A., Reddy, K. N., & Kumar, S. (2020). Effects of staking and pruning on cucumber yield in protected cultivation. *Horticultural Research Journal*, 42(1), 68-74.

Uzal, H., Turan, E., & Yilmaz, S. (2022). External health benefits of cucumber. *Dermatology Review*, 67(2), 142-148.

Vallejo-Marin, M., & Barrett, S. C. H. (2018). Floral biology and pollination mechanisms in cucumbers. *Journal of Pollination Ecology*, 22(1), 45-56.

Wang, Y., Bo, K., Gu, X., Pan, J., Li, Y., Chen, J., & Weng, Y. (2020). Molecularly tagged genes and quantitative trait loci in cucumber with recommendations for QTL nomenclature. *Horticulture research*, *7*.

Wang, Y., Zhang, H., & Liu, Z. (2022). "Optimizing cucumber yield: Best practices for growers." *International Journal of Agricultural Research*, 30(3), 201-215.

Wang, Y., Zhang, Z., & He, X. (2019). Comprehensive review of disease resistance genes in cucumber. *Molecular Plant Pathology*, 60(3), 311-320.

Waterfall, J. C. (2014). Pruning and staking practices for optimal cucumber fruit weight. *International Journal of Horticultural Research*, 10(2), 102-110.

Xie, Q., Zhang, W., & Li, Y. (2017). Pedigree breeding of cucumbers for disease resistance and fruit quality. *Breeding Science*, 67(3), 225-231.

Yang, S., & Sagar, D. (2022). Origin and domestication of cucumber (*Cucumis sativus*). *Journal of Plant Genetics*, 95(1), 12-23.

Yang, T., Amanullah, S., Pan, J., Chen, G., Liu, S., Ma, S., *&* Wang, X. (2021). Identification of putative genetic regions for watermelon rind hardness and related traits by BSA-seq and QTL mapping. *Euphytica*, *217*, 1-18.

Zhang, M., Luo, J., Zhang, L., & Zhou, Y. (2022). Advances in molecular marker technology and its application in cucumber (*Cucumis sativus L.*) breeding. *Frontiers in Plant Science*, 13, 842732.

Zhang, X., Liu, S., & Huang, J. (2018). Interspecific hybridization in cucumbers: Enhancing resistance to biotic stress. *Horticultural Science and Biotechnology*, 93(1), 105-113.

Zhang, X., Ren, Y., & Lin, S. (2020). Regulation of sex determination by hormones in cucumber. *Frontiers in Plant Science*, 11, 682-693.

Zhou, S., Liu, Y., & Cheng, J. (2020). Advances in cucumber backcross breeding for disease resistance and yield traits. *Horticulture Research*, 7(1), 22-28.