IMPROVING OF POD LENGTH AND YIELD OF SNAKE BEAN (*Vigna unguiculata* ssp. *sesquipedalis* L.) THROUGH MASS SELECTION IN SEVENTH GENERATION

Annur Syakirah binti Shamsul Azman
F16A0024

A Thesis Submitted in Fulfilment of the Requirements for the Degree of Bachelor of Applied Science (Agrotechnology) with Honours

Faculty of Agro Based Industry
Universiti Malaysia Kelantan

2020

DECLARATION

I hereby declare that the work embodied in here is the result of my own research except for the excerpt as cited in the references.

____

Signature

Student's Name :

Matric No :

Date :

Verified by :

____

Supervisor Signature

Supervisor's Name :

Stamp :

Date :

ACKNOWLEDGEMENT

Firstly, I would like to express my humblest gratitude to Allah s.w.t, the Most Merciful and Great, for letting me and make my way easier toward accomplishing this final year project. He also gave me chance and opportunity toward facing all the challenges and obstacles during the progress, and also make me brave and strong especially during the field work process.

I would like to thank my supervisor, Dr Dwi Susanto as he always guides me through all the field work and toward the finishing of this thesis writing. He never let me down, and always answers to all my curiosity about anything either regarding this final year project or other thing. I am grateful for this opportunity and learnt a lot from him.

I would like to appreciate to all the staffs at Agro Techno Park, as they assisted and guided me on using the selected land site after getting the approval, especially to Miss Lily, En Sa'arani and En Sharrif. They helped me a lot even during the clearance of the used land site.

I would also like to give a big thanks to my friends, especially Hanis Alia binti Zulkefli, Aqilah binti Kamaruzaman and Nawwar Syazwani binti Mohd Nasir as we were together under Dr Dwi's supervision for final year project. I am also thankful for all whose help me directly or indirectly to carry out and finish this research purpose. I wish that the thesis for my final year project would help toward improving any agricultural purpose for any crops and increasing the cultivation of plant that can give benefits to the future agriculture industry.

Peningkatan Panjang Pod dan Hasil Kacang Panjang (*Vigna unguiculata* ssp. *sesquipedalis* L.) melalui Seleksi Pukal dalam Generasi yang Ketujuh

ABSTRAK

Kacang panjang atau *Vigna unguiculata* merupakan sayur tropikal yang terkenal di Malaysia. Kacang Panjang mempunyai kandungan nutrisi yang tinggi seperti serat, protein, vitamin dan mineral dan mendapat permintaan yang tinggi di negara ini terutamanya untuk keperluan makanan harian. Bagi mendapatkan hasil kacang panjang yang berkualiti tinggi, satu kajian dalam mengenalpasti peningkatan panjang pod dan peningkatan hasil telah dijalankan melalui kaedah seleksi pukal. Seleksi pukal merupakan salah satu teknik pembiakbakaan tanaman dalam meningkatkan kuantiti dan kualiti tanaman tersebut. Seleksi kacang panjang ini telah dijalankan berterusan untuk beberapa generasi. Objektif kajian ini adalah untuk meneruskan seleksi kacang panjang bagi generasi yang ketujuh, di mana pod yang terpanjang dan mempunyai hasil yang terbaik telah dipilih. Pertumbuhan secara vegetatif dan generatif telah dikaji dan data telah direkodkan. Sebanyak 225 benih kacang panjang telah ditanam pada 9 batas dengan keluasan setiap batas 9-meter panjang dan 1-meter lebar. Lokasi penanaman kacang panjang adalah di Agro Techno Park UMK Kampus Jeli. Hasil kajian telah diuji secara analisis statistikal untuk menunjukkan nilai maksimum, purata dan sisihan piawai panjang pod kacang panjang. Hasil kajian membuktikan bahawa semakin meningkat generasi tanaman dilakukan, semakin panjang pod dan hasil tanaman yang dihasilkan oleh populasi kacang panjang itu.

Kata kunci: Kacang panjang, *Vigna unguiculata*, seleksi pukal, generatif, vegetatif, panjang pod, hasil

Improving of Pod Length and Yield of Snake Bean (*Vigna unguiculata* ssp. *sesquipedalis* L.) through Mass Selection in Seventh Generation

ABSTRACT

Snake bean or *Vigna unguiculata* is a popular tropical vegetable in Malaysia. Snake bean contains high nutritional contents such as fiber, protein, vitamins and minerals and has a high demand in this country especially to be consumed in daily meals. In getting a high quality of yield for this snake bean, a research of studying the improvement of pod length and yield through mass selection was done. Mass selection is one of plant breeding techniques in improving the quantity and quality of the plant. The selections of snake bean have been continuously done for several generations. The purpose of this study is to continue the selection of snake bean for the 7th generation where the longest pod and the highest yield was selected. The vegetative and generative growth of snake bean was observed, and the data was collected. There were 225 seeds planted in 9 beds where the size for each bed was 9-meter length X 1-meter width. The location of the planted snake bean was in Agro Techno Park in UMK Jeli Campus. The results of the study were tested by descriptive statistical analysis to show the maximum, mean and standard deviation of pod length. The results of this research explained that the further the generation, the longer the pod length and yield performance in snake bean population.

Keywords : Snake bean, *Vigna unguiculata*, mass selection, generative, vegetative, pod length, yield

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF SYMBOLS

Reference number

n	Sample size
R	Mean change in generation
S	Differences between mean of selected parents and mean of population
T_S	Mean of offspring
μ	Mean of population
h^2	Narrow-sense heritability
mg	Milligram
g	Gram
kg	Kilogram
mm	Millimetre
cm	Centimetre
m	Meter
m^2	Meter square (area)
°C	Degree Celsius
t	tonne

LIST OF ABBREVIATIONS

Reference number

FAO	Food and Agriculture Organization
USDA	United States Department of Agriculture
RM	Ringgit Malaysia

LIST OF EQUATIONS

CHAPTER 1

INTRODUCTION

1.1 Research background

Snake bean (*Vigna unguiculata* ssp. *sesquipedalis* L.) is a leguminous vegetable and commonly known as yard long bean, string bean, chinese long bean, pea-bean, sitao, bodi bean, bora, long-podded cowpea and asparagus bean as the pods length is about half a yard long, or 0.50 m (Lawrence and Moore, 2002; Owens, 2006). Snake bean mostly cultivated in China, Central and West Africa, Southeast Asia and the Caribbean (FOA, 1993). The snake bean probably originated in South China while it is native to East and South East Asia (Owens, 2006). It is a climbing annual vine crop. It is cultivated for its long and green pod color and cooked as vegetables, eaten raw for fresh or pulsed dry plant. The leaves are used as fodder and manure brown. The economic *Vigna* species exhibits a variety of attributes that make them especially valuable for use in many plant systems forms (Fery, 2002). Snake bean crop is crucial due to rising demands and high request from customers and others (Rosenfeld and Cunningham, 2011). Annual worldwide production of the different species of *Vigna* is estimated to be up to 20 million hectares, and nearly all this output is in developing countries (Fery, 2002). Because of high demand and insufficient snake bean production in Malaysia, imports from neighbouring country such as Thailand helped sustain the market (Madhavan, 2014). The local cultivation, adaptability and availability of snake bean are across most retail channels, usually purchased in the preparation for cuisines, with usage mainly not predicted to decrease rapidly in future. From nine selected vegetables, snake bean has been reported as one of that has contributed to sufficient domestic supply (Jabatan Pertanian Malaysia, 2006). Plant explorers and the plant germplasm preservation community had identified the potential importance of *Vigna* spp some long time ago (Fery, 2002). In addition, Fery (2002) also explained that most plant researchers have done a great work of preserving and collecting *Vigna* germplasm internationally. Hence, there is high potential for snake bean because of its nutritive food needs contribution especially in the tropical countries, where almost world population covering for malnourished population that lives there (Singh and Paroda, 1983). In Malaysia, Muar district in Johor, Bentong and Kuantan district in Pahang in 2009 were recorded as the largest snake bean growers (Anim, 2010). Furthermore, Anim (2010) also stated that one of the huge snake bean producers is Johor Bahru where the snake bean were produced about 14 metric tonnes per hectares in 2010.

1.2 Problem statement

There is an uptrend of importing snake bean, especially in cheaper imports from other countries such as China and Thailand (Madhavan, 2014). Insufficient production in Malaysia is forcing the importation of snake bean products from other countries. Thus, the issue of importing snake bean should be minimized, by increasing local production. In increasing local production by agronomy action, the mass selection of snake bean population with higher quality and using desirable trait should be implemented in Malaysia for encountering with these problems. Desirable traits or phenotypes such as longer pod length and better yield of parental plant can be used for the improvement of snake bean cultivar. So, this research is about to investigate whether the further generation of snake bean will influence the pod length of snake bean to be much longer and increase yield performance. The length of pod can vary from 45 to 75 cm (Lorz and Halsey, 1964). With the mass selection in breeding snake bean, the length can be expanded with higher quality. Thus, Malaysia has the possibility cover the demand for this vegetable crop. The snake bean also proven to be among most important vegetable crops produced from several countries such as Thailand, Philippines, Taiwan, Malaysia, Indonesia and China (Rachie, 1985).

1.3 Hypothesis

By mass selection, seed grown in this generation were selected from the longest pod in sixth generation, then the mean of pod length in this generation would be longer than in sixth generation. Statistically, this hypothesis can be written as:

H_0 : Using mass selection breeding method, pod length of snake bean in seventh generation is same as that of in sixth generation

H_1: Pod length of snake bean in seventh generation is longer than in sixth generation through mass selection breeding method

1.4 Objectives

The objectives of this research study were:

1) To generate population of snake bean grown from selected seeds of sixth generation

2) To continue selecting the longest pod length for the next generation through mass selection

1.5 Scope of study

This research focused on the selection of longest pod of seventh generation as a continuation selection that have been done from previous generation. The selected seeds from this generation, again, would be used to generate population for further selection as the basis for producing new higher yield cultivar.

1.6 Significant of study

The assumption involving the overall yield of snake bean crop with longer pod length and the plant produces the same number of pods. With that, the yield per plant will automatically increase. Thus, there is relationship between pod length and yield. Therefore, this study will contribute in producing new cultivar of highest yield production from seventh generation of snake bean.

1.7 Question of the research

The research question included in this research:

Does the seventh generation of snake bean have longer pod length than sixth generation?

1.8 Limitation of the research

Mass selection approach is one of the simplest methods in plant breeding, but there were also limitations to it. Firstly, in producing new cultivar with desirable trait, many generations would be needed. The limitation in this study is that the selection in this study was done in only one generation which is in seventh generation to select the pods that was more than 75 cm. It was done after the sixth generation done producing yield and seeds were collected from it. Mass selection method is also based on phenotypic performance, then the environmental factor may effect on it, directly and indirectly. Nevertheless, this method can be repeated for producing new generation with highly new cultivars despite the limitation but need to be tough in fieldwork by handling the generation by generation population.

CHAPTER 2

LITERATURE REVIEW

2.1 Botany background

2.1.1 Taxonomy of snake bean and its relatives

According to United State Department of Agriculture (USDA, 2012), snake bean has taxonomy as follow:

Kingdom: Plantae

Division: Magnoliophyta

Order: Fabales

Family: Fabaceae / Leguminosae

Genus: *Vigna* L.

Species: *Vigna unguiculata* L.

Sub-species: *Vigna unguiculate* ssp. *sessquipedalis* L.

Most taxonomists have proven that snake bean belong to the botanical species *Vigna unguiculata* (L.). Verdcourt (1970) divided into three subspecies of snake bean (subspecies *unguiculata*, *catjang* (subspecies *catjang*), and yard long bean (subspecies *sesquipedalis*). However, Marechal et al. (1978) recategorized the subspecies *unguiculata*, *catjang*, and *sesquipedalis* as cultigroups of *unguiculata*, *biflora*, and *sesquipedalis*, respectively. Almost all snake bean breeders seem to have implement cultigroup scheme owned by Marechal et al. (1978) for cultivated *V. unguiculata* in classification and categorization. Other commonly used names include asparagus bean, sitao, bodi bean, and snake bean (Fery, 2002). From Lawrence and Moore (2002), it is also known as cowpea, yard long bean and long bean. Figure 2.1 shows the picture of snake bean pods with long, green pods as one of the vegetables and considered as legume plants worldwide.

Figure 2.1 Pods of snake bean

Snake bean was found among 150-190 species throughout all the tropical regions. From West Africa and India, the snake bean cultivation spread especially in South East Asia, Nigeria, Upper Volta, Uganda and the USA (Peter and Abraham, 2007). It is proven that snake bean found in South-East Asia and Steele and Mehra

(1980) stated that snake beans was introduced from India. In other study, snake beans were largely distributed Oceania, Europe and North America, and was originated from Southern East Asia (Lawrence ad Moore, 2012). Fery (2002) stated that the snake bean is a trellised and intensely cultured vegetable crop that is grown widely in southeast Asia.

2.1.2 Morphology

Snake bean is a herbaceous, climbing, or sub-erect to erect annual and can grow to 15-80 cm high. The leaves are broad at the blade, attached to the stem as it is stalk-like petiole. The leaf is either simple or compound where two simple leaves or one compound leaf may be attached to the node stem (Fery, 1985). Moreover, Fery (1985) stated that the inflorescences have 10 to 30 cm long peduncle, where it is has axillary where there is also a rachis with each node bearing a pair of flowers and an insect attractor which are cushion of extrafloral nectaries.

The pods are up to 50 cm long with range of 12 seeds per pod but depends on the length. The stems are usually smooth, square and twine about with the nodes that normally have violet colour (Owens, 2006). According to Owens (2006), the fruit is 30-120 cm long, thin and becomes constricted and bent at maturity. Snake bean also discovered for their long tender pods, from Steele and Mehra (1980).

2.1.3 Usage and Nutritional Values

In Malaysia, one of the famous recipe of dish from snake bean especially in countryside is by cooking them with coconut milk, mainly eaten with rice.

Figure 2.2 Snake beans cooked with coconut milk
(Source: Jeanette, 2012)

Snake bean is one of the most broadly consumed vegetable and serve as vital tropical multi-purpose legume. Snake bean cultivations have been increased for using their plant part, for example, unripe green pods, green leaves, young seeds and the roots (Peter and Abraham, 2007). Snake bean also have ethnobotany purpose which it can be consumed either cooked (Figure 2.2) or fresh. It also has commercial need that can be brought raw or packaged before distributed to the retailers. The retailers assigned this plant to decorate home gardens or houses and used as wildlife food resources (Lawrence and Moore, 2012). Its pods are edible and even leaves also used as vegetable (Owens, 2006). From Lawrence and Moore (2012), tips of snake bean stem can be steamed and eaten as green vegetable. Snake bean can be processed also as pickles and canned product (Jabatan Pertanian Malaysia, 2006). The fodder of snake bean can be processed, and its foliage could produce green manure (Reddy, 2009). The pods can be utilized in decoration by arranging nicely as snake bean had long pod that can be twined and turned into basket decorations (Jabatan Pertanian Malaysia, 2006).

Snake bean has a very high nutritional value. Immature snake bean leaves contain higher protein content compared to immature pods (Rosenfeld and Cunningham, 2011). The seeds are vitamin and mineral sources (Hall et al. 2003) and have the highest contents of folic acid among many plants. The snake bean nutrition quality is about 24.6% of crude protein (Peter and Abraham, 2007). Harvested dry seed of all of the Vigna crops can be directly consumed, and seeds can be used to make flour or produce sprouts (Fery, 2002). Table 2.1 shows nutritional content (element and mineral) contained in 100 g snake bean samples:

Table 2.1: Nutritional value in 100 g snake bean sample

Elements	Content (in 100 g sample)
Protein	2.10 g
Carbohydrate	4.00 g
Fat	0.90 g
Fiber	1.40 g
Calcium	61.00 mg
Phosphorus	33.00 mg
Cilium	53.00 mg
Natrium	5.00 mg
Beta carotene	513.00 µg
Vitamin B1	0.10 mg
Vitamin B2	0.60 mg
Vitamin C	48.50 mg
Vitamin K	10.05 mg

(Source: Jabatan Pertanian Negeri Pulau Pinang, 2011)

2.1.4 Production of snake bean

Globally, regions of Africa are the major producers and consumers of snake beans (Owens, 2006). The farmers grow snake beans for dry seed for human consumption and fodder for animal feed, and in the meantime also utilize the leaves and fruits or vegetables. Snake bean were widely grown in eastern Africa and southeast Asia primarily as a leafy vegetable. Steele and Mehra (1980) noted that the protein content of the leafy snake bean parts consumed annually in Africa and Asia is equivalent of 5 million tonnes of dry snake bean seeds and that this shown as much as 30% of the total food legume production in the low land tropics. Quin (1997) estimated the annual world snake bean crop at 12.5 million ha, and the total grain production at 3 million tonnes. Even West and Central Africa are the leading snake bean producing region in the world; where 64% of this region of the estimated 3 million tonnes of snake bean seed produced annually (Quin, 1997). Outside Africa, the major production areas are Asia and Central and South America. Brazil producing 600,000 tonnes annually as the world's second leading producer of snake bean seed (Guazzelli, 1988).

Some states in Malaysia also grow snake bean commercially. Jabatan Pertanian Malaysia (2006) reported that snake bean cultivation was widely planted in large areas about 3,020 hectares in 2009 with 41,680 metric tonnes production and total value of RM 102,200,000. Johor Bharu as one of the huge snake bean producers produced about 14 metric tonnes per hectare in 2010. Within three months, the production cost per hectare of RM 16,169 made profit for about RM 2,222 per hectare (Anim, 2012).

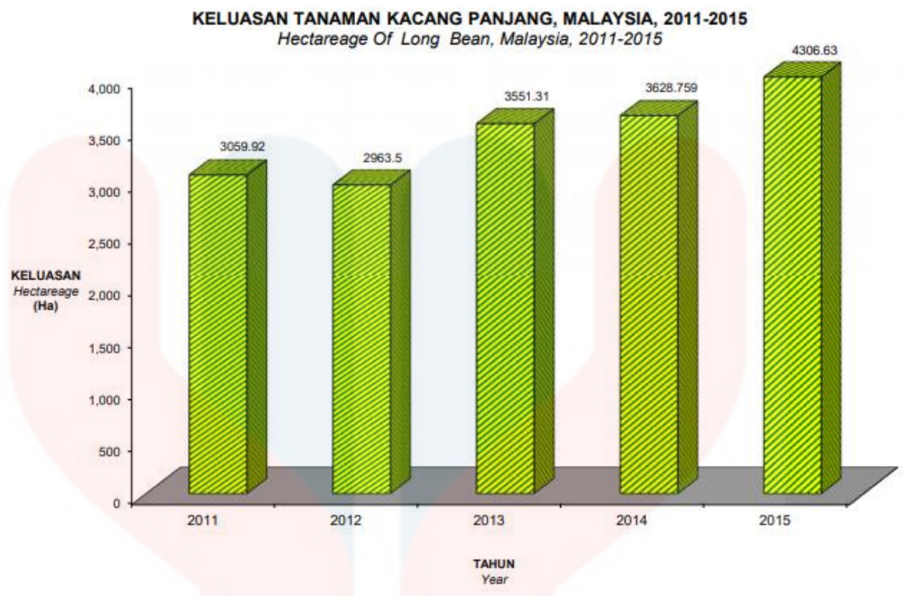

Figure 2.3: Graph of hectarage of snake bean in Malaysia from 2012 to 2016 (Jabatan Pertanian Malaysia, 2016)

Based from Figure 2.3, it shows that the hectarage of snake bean keep increasing year by year. This is because the demand was rising throughout all states in Malaysia (Jabatan Pertanian Malaysia, 2016). Thus, the local production needs to be maximized to fulfil the demand in the country and prevent the importation of snake bean from other countries.

2.2 Agronomic background

2.2.1 Soil and Temperature

Snake bean prefer to be planted on pH ranging from 5.5 to7.5 for better growth performance, as it is well adapted to be cultivated in acidic soil (Lawrence and Moore, 2012). This plant grows in any soil types from sandy to heavy clay soil for better performance of yield (Owens, 2006). Friable and loose soil condition is suitable to plant this vegetable crop. Snake bean can also survive in drought condition and still grow successfully in sandy and poor soils (Dugje et al., 2009). However, snake bean is intolerant and susceptible with heavy rain and water-logging that cause soil running off or leaching. Poor drainage or extended water logging need to be avoided as it is sensitive to that.

Dugje et al. (2009) said that snake bean can survive under rainfed conditions as well as by using irrigation or residual moisture along river or lake flood plains during the dry season, provided that the range of temperatures is between 28 and 30°C (night and day) during the growing season. Even in high temperature, poor soil quality and drought, snake bean is still able to grow and develop. Snake bean has better growth performance as warm season plant in temperature range from 21 – 35 °C (Krishnan, 2007). The snake bean plant is a warm-season annual plant that need at least 18 °C temperature throughout all stages of its development and the optimal growing temperature is in range of 28 °C (Craufurd et al., 1997).

2.2.2 Climate

Snake bean grow best in humid and warmer climates, and intolerant to frost (Lawrence and Moore, 2002). The rainfall requirement is necessary for its growth, meanwhile Owens (2006) stated that this vegetable crop adapt with proper irrigation management and climate suitability in monsoon season. Snake bean also is well oriented to a wide precipitation range (650-2,000 mm) at medium temperature. An annual rainfall regime such as 400 mm/year is a good condition for this plant. According to Dugje et al. (2009), snake bean performs well in agroecological zones where the rainfall range is between 500 and 1200 mm/year. Optimum climatic condition for cultivating snake bean is during raining season from September to November since the months received more rainfall to provide sufficient water supply to plant (Ofori and Klogo, 2005). Since it is well adapted under dry conditions, snake bean do not require too much water or nitrogen content in soil. This plant also has moderate adaptation to shade (Owens, 2006).

2.2.3 Harvesting

Snake bean can be harvested about eight weeks after planted, as the plant will continue producing pods if they are being harvested (Lawrence and Moore, 2012). Rosenfeld and Cunningham (2011) stated that to make sure a continuous pod production, snake pods must be harvested twice in a week after it started produce pods. The pods will always be produced by the plant for several weeks (Lerner, 2001). When the plant reached highest length, it is the exact period of harvesting, but before seeds become too swelled and dried.

Dugje et al. (2009) said, in early-maturing and erect varieties, one picking is enough compared to indeterminate and prostrate varieties, when the dried pods can be picked two or three times every harvesting period. Furthermore, the pods do not mature at the same time because of the staggered flowering period (Dugje et al., 2009).

2.2.4 Pests and Diseases

Insect pests are a large problem in snake bean cultivation (Singh and Van Emden, 1979). Thus, the developing cultivars with high resistance to insects is the goals for many breeding programs worldwide. Damage by insect pests on snake bean can be as high as 80–100% if not effectively controlled. The pests can be classified into three major groups: pre flowering, flowering or post flowering, and storage (Dugje et al., 2009). Snake bean are soft seeded annuals and have little potential for survival in the soil, thus it can be easily attacked. Anim (2010) stated that pests that attacks snake beans are snap bean fly (*Melanagrommyza phaseoli*), aphids (*Aphis craccivora*), bean fly pod borer (*Euchrysops cnejus*), pod borer (*Marucca testutalis*) and thrips (*Thrips* spp). Red spider mite attacks the crop during warm and dry season. Thrips is a pest early in the season, but the snake bean will grow them out, especially as the weather gets warmer and the plants grow faster (Lawrence and Moore, 2002).

Reddy (2009) stated that diseases on snake bean plants are bacterial blight that is caused by bacteria, leaf blight which appear on leaves as water soaked, often angular shaped spots and gradually grow to form large-brown spots of dead tissue, and snake bean mosaic virus caused by the virus. Leaf spot is one of disease suffered by snake bean plant where the leaves first start to develop small wet lesions that grow in size and dry out, usually becoming over an inch wide, brown and papery, with a yellow border (Jabatan Pertanian Malaysia, 2006).

2.3 Plant Improvement

2.3.1 Breeding method background

In plant improvement, breeders and researchers across the world have collected all the techniques and methods from thousands of years back. During these early, growers will select the best plants from the crop each year to provide the seed for the next generation and sometimes procure seed from other farmers and settlers, engaged in basic product collection and fresh germplasm adoption (Kloppenburg, 2004). According to Kloppenburg (2004), he describes how the original settlers obtained and grew Native American varieties for subsistence while slowly adapting their own varieties to the new environment, with subsequent groups of immigrants contributing their own species and varieties to the stock.

There are three different reproduction mode in plant which are self-pollinated, cross pollinated and clonal propagation plant. Plant breeders use a variety of methods and techniques to develop different cultivars (Acquaah, 2012). Acquaah (2012) also stated that the genetic structure and the phenotypic uniformity of the product vary in the products of plant. In addition, the nature of the product has implications for how producers maintain it with regard to the planting of the next season. There are many methods include in breeding self-pollinated species, and one of them is mass selection method (Acquaah, 2012).

2.3.2 Mass Selection background

Mass selection method had been implemented by early plant breeders in early 18th century after plant breeding technique was introduced, as they selected superior phenotype to be grown for next growing season (Arterburn et al., 2008). Acquaah (2012) stated that mass selection is often described as the oldest method of breeding self-pollinated plant species. Self-pollinated species have a genetic structure that involves the selection of methods to improve them. Furthermore, snake bean are naturally inbred and therefore one of the goals of a self-pollinated species breeding program in which variability is generated by crossing is inbreeding to fix genes (Acquaah, 2012).

Nevertheless, certain breeding strategies of self-pollinated plants are not followed by crossing. Mendel's laws of genetics have proven the plant breeding scientific basis since 1900. The goal of mass selection is to obtain a population with better and more stable phenotypes (Bos and Caligari, 2008). Chaisan (2013) stated that mass selection is also defined as the phenotypic selection from individuals based on the phenotypic appearance according to the information based on their ancestors, clones, offspring, or other relative performance. The improvement is limited to the genetic variability that existed in the original populations (i.e., new variability is not generated during the breeding process). Acquaah (2012) also said that the goal in cultivar development by mass selection is to improve the average performance of the base population. Selection is the most easy and basic procedure in plant breeding. Mass selection techniques consist two different selection, positive mass selection to decide and retain the wanted superior traits of desirable plants, and negative mass selection, which is to identify and eliminate the plants with undesirable traits (Chaisan, 2013).

The advantages also include the genetic variability preservation and increase the local varieties of crops despite simple to conduct, cost reasonable and fast. Mass selection generates genetic variability and rather useful for improving the quality of plant production.

Acquaah (2009) stated that the trait of interest also needs to be exclusively heritable for the selection to be efficient and the expected outcome for the chosen heterozygotes to segregates for next generation if no progeny tested being done. A selection index will be used to improve seed yield per unit area, where target trait is evaluated via classifying the relationship between the target trait and the other traits; this approach can simultaneously improve traits related to yield (Hill and Mackay, 1996). Mass selection techniques has also conducted on usual buckwheat of Shinano No. 1 and Togakushi varieties on the application rate of fertilization, which then proven a huge change in rate for both varieties at 1.3 times higher compared to previous generate (Inoue et al., 2002).

2.3.3 Heritability

Heritability is a variance ratio of a population which is obtained at specific time location, species which expresses the total genetic value (Visscher et al., 2008). Visscher et al. (2008) also stated that heritability calculates the variation in the species where parents passing by the genes copy to the following genotypes. The higher heritability describes the higher efficiency in using mass selection in breeding programme. The narrow sense heritability explained the predicting outcome of the selective breeding in specific population, said Snustad and Simmons (2012).

CHAPTER 3

MATERIALS AND METHOD

3.1 Place and time

This project was carried at Agro Techno Park UMK Jeli Campus in Kelantan. The project started from early of May until the second week of August 2019. The timeline of snake bean was about ten weeks, where vegetative data was collected during the first 8 weeks. The harvesting from the planting area of snake bean was also including the collection of generative data.

3.2 Plant materials

The planting materials used in this research were the selected snake bean seeds gained from the previous 6^{th} generation. About 225 seeds were used for this study. Raffia ropes, measuring tape and hoe were used for the land preparation and water was needed for irrigation. To cover the plots, silver shine plastic was used for weeds growth inhibition and soil moisture conservation. The amount of silver shine used was by following the bed size. Scissor, marker pen and tin can for hole making process. Organic compost, urea and chemical fertilizer which are NPK 15:15:15 was applied to the plot and mixed together as shown on table below.

Table 3.1 The dosage of fertilization applied to the snake bean crop

No	Rotation	Time	Type of fertilizer	Amount of fertilizer per bed	Total amount of fertilizer used
1.	1	0 day	Organic compost	9.00 kg	81.00 kg
2.	1	0 day	NPK (15: 15: 15)	0.30 kg	2.70 kg
3.	1	0 day	Urea	0.27 kg	2.43 kg

3.3 Land preparation and seed sowing

Land preparation was started with clearing land site, by eliminating all rocks and unwanted materials there. Snake bean population was planted on nine beds. The size of one bed was 1 metre × 9 metres. The spacing within the plants was 60 cm and between the rows was 40 cm. Each plot consists of 25 plant from 2 rows, the first row had 12 holes, and the other had 13 holes. Total numbers of plants that were planted were 225 plants to fulfil the basic population requirement for mass selection and as to follow the previous research generation of snake bean.

Seeds was sowed on tray first before transplanted on plots. Fertilizers were mixed together on each plot and being ploughed to enhance soil fertility (Table 3.1). After that, the beds were covered with silver shine plastic. After the germination of seed on the tray, transplanting of seedlings were done by making holes on all the silver shine. Trellis was set up for the crops to climb to. Thus, the trellis built for the snake bean support system with 2 m height of wood and bamboo connected with ropes and nets and strengthen each post at the end.

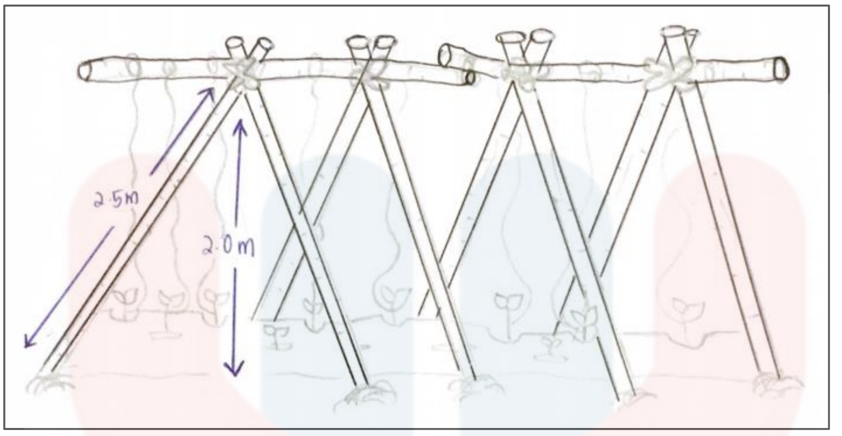

Figure 3.1 Trellis measurement for the set up

3.4 Experimental layout

The planting space was 60 cm X 40 cm. Total numbers of plants that were planted are 225 plants. The layout of this experiment is shown below:

Land area (m^2)	: 20 m X 10 m = 200 m^2
Space between rows	: 40 cm
Space between plants	: 60 cm
Diameter of a hole	: 10 cm
Total plant per plot	: 25 plants
Total overall plot	: 25 X 9 beds = 225 plants

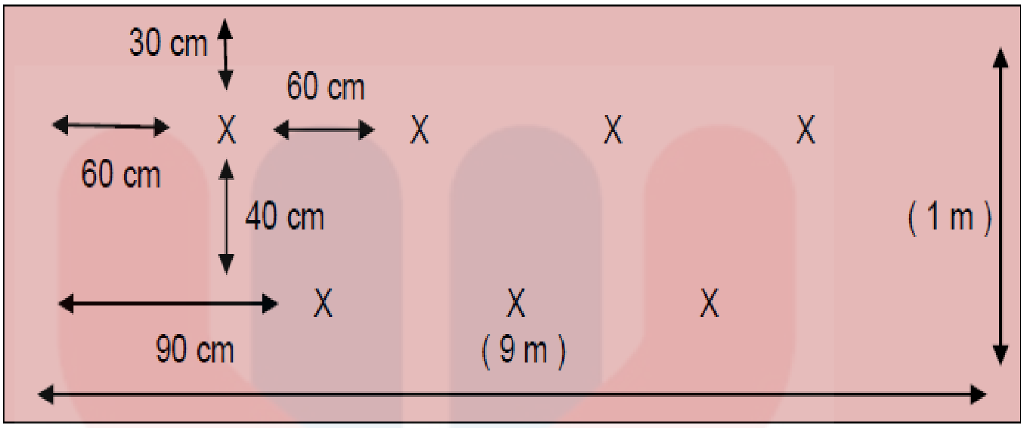

Figure 3.2: Layout per Experimental Unit

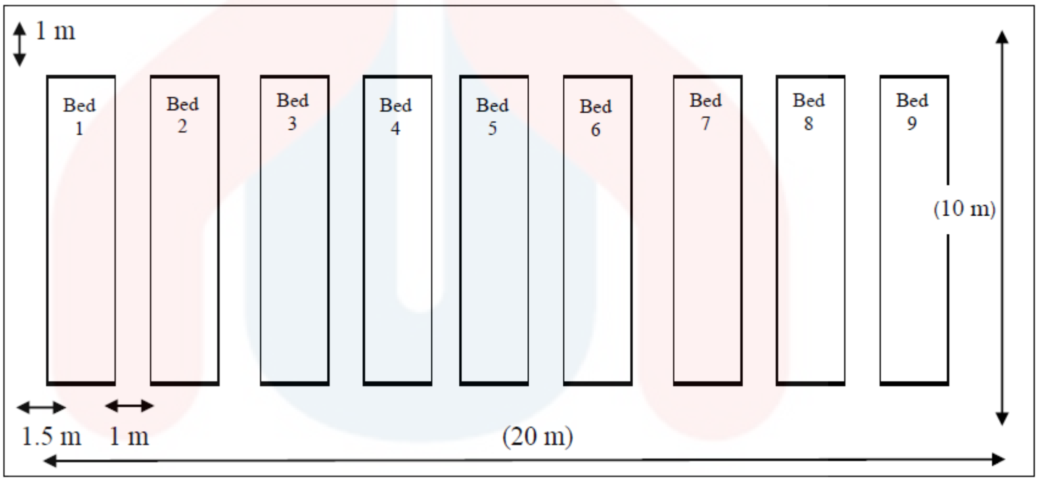

Figure 3.3: Experimental Layout

3.5 Mass selection technique

The population of snake bean was started from zero generation and the previous generation was sixth generation. This research was the seventh generation of snake bean population. The interest phenotype for mass selection technique is the pod length. Thus, all snake bean pod from sixth generation that measured more than 75 cm length were left on branch of plant and not harvested. Then, the pods were left to dry, all of the dried seeds inside the pods were collected and used for planting the next generation.

3.6 Maintenance

The irrigation system was ensured in sufficient amount to supply water to all snake bean plants by watering the plants regularly in the morning and evening. Proper irrigation was done with manual irrigation using hose twice a day. Weeding was done on the surface area of the beds and drainage where manual weeding was done by hand and using hoe for every week. This was necessary for improving high quality of yield production and minimizing the competition for sunlight and food between weeds and snake bean plant. Pest and disease prevention were also a critical factor that need to be focused in planting snake bean.

The snake bean pods were ready to be harvested around eight weeks after planting and can be seen when the bean pod showed an increase of size in the pod diameter. The matured snake bean pods were harvested once in two or three days, continuously for eight weeks until the plants would stop producing pods and complete its cycle. The length and weight for each pod harvested were measured and data was collected, for every harvesting cycle. The total yield production was also recorded. Then, the longest pods were picked and dried before the seeds were collected and kept for the next generation research purposes.

3.7 Data sample collection and analysis

All the data were collected and recorded from germination until the harvesting period has ended. There were four samples randomly chosen from each plot. The pods that were more than 75 cm were left remain on plants, processed to be matured and dried for the seed collection. This step was conducted for mass selection purposes.

3.7.1 Variable observed

The growth and progress of snake bean was observed by following the parameters which were plant height, number of leaves per plant, number of branches per plant, length of pod, yield per plot and yield per plant. The following the parameters shows:

i. Plant height

The measurement of plant from the ground until the shoot tip of the plant. The plant height measurement was taken once a week for eight weeks.

ii. Number of leaves per plant

Number of leaves per plant was taken once per week for eight weeks.

iii. Number of branches per plant

Number of branches per plant was taken once per week for eight weeks.

iv. Length of pod

Length of pod was measured for every pod length to get the minimum, maximum and mean of the pods. Harvesting was conducted on every two or three days after seventh week of planting.

v. Yield per plant

Yield per plant means the data collected based on the yield of plant samples. The data was collected during harvesting which happened on every two or three days after seventh week of planting and was divided by the number of samples of each beds.

vi. Yield per plot

Total yield per plot was collected during harvesting from all plants in the beds including the samples. Harvesting was on every two or three days after seventh week of planting.

3.8 Statistical analysis

For data analysis, some parameters were analysed in this research, which are heritability and descriptive statistics. All the data was recorded and analysed by using Descriptive

Statistics with the help of Excel Computer Programme. This analysis includes the length of pod, weight of pod, the minimum, maximum, mean, mode, median, standard deviation and variance of pod length.

Besides that, heritability was calculated by using the formula:

$\sigma^2 = V\alpha \, / \, Vp$ ……………. (Equation 1)

$Vp = Vg + Ve$ …………….. (Equation 2)

Where, σ^2 = Variance

Vp = phenotypic variance

Ve = environmental variance

Vg = genetic variance

Narrow sense heritability was calculated by using the formula:

μ = mean of population

T_0 = mean of offspring

T_S = mean of selected parents

R = A measurement of how much the mean has changed in one generation (R = T_0-μ) ……………. (Equation 3)

S = Differences between the mean of selected parents and the mean of population (S = T_S-μ) ……………. (Equation 4)

Therefore,

$$h^2 = \frac{R}{S}$$ ……………. (Equation 5)

(Source: Snustad and Simmons, 2012)

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Vegetative data

4.1.1 Plant height

From Figure 4.1, the plant height was increasing from day to day, as the plant will continue to develop, growth and climb towards any support system that exist. Bed 1 and 4 recorded the highest plant height among all other beds. This is because the seeds selected from bed 1 to 4 was from the longest pods in previous generation. In assisting the plant to climb higher, trellis was used. This is also to aid the plant in achieving more amount of sunlight for photosynthesis process. To prove that plants had gained basic need for optimal growth such as water, space, fertilizer and sunlight, the height will not stop increasing. Growing higher upward also reduce competition with another plants. Figure 4.1 shows the plant height of snake bean for 56 days in nine beds.

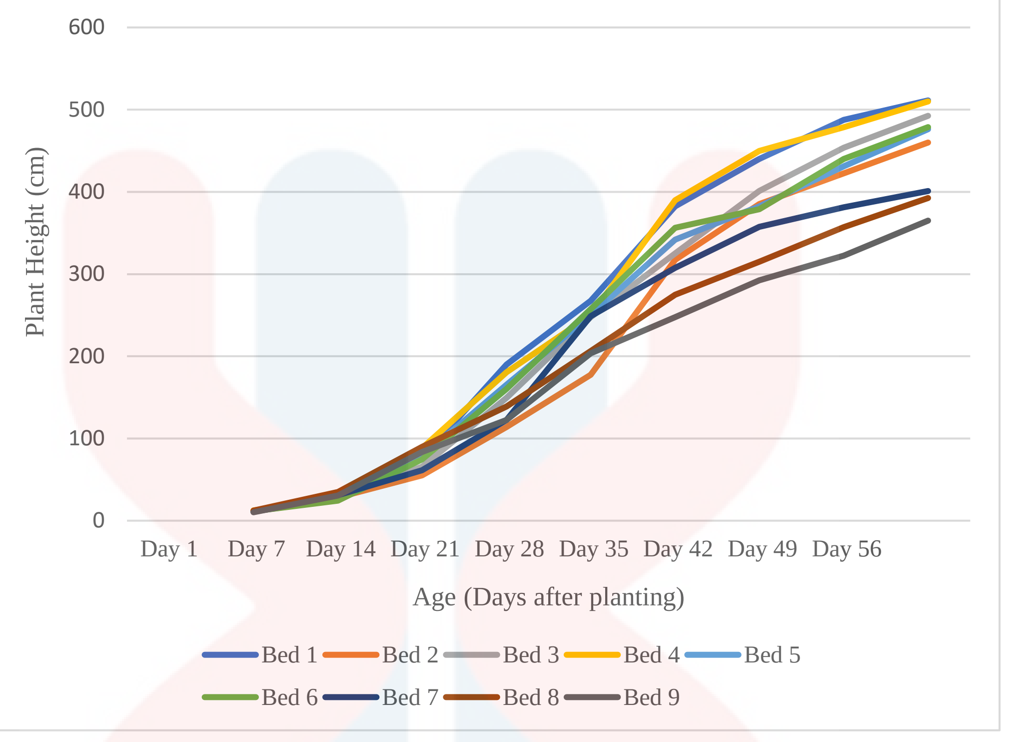

Figure 4.1 The plant height of snake bean plants in all beds

4.1.2 Leaf number

Figure 4.2 was illustrated according to eight weeks or 56 days of data collected for leaf number in each plant sample. The graph above figured out that the average number of leaves increased gradually for eight weeks in seventh generations. There was a significant different between the productions of leaves for plant, as each plot in different generation produced different number of leaves in each week. The highest leaf number recorded was in bed 6. This is because bed 6 acquire sufficient basic requirement for the plants. The lowest value of snake bean leaves is in bed 9, as many factors may affect the number of leaves developed such as weather or insufficient amount of water intake into the plants. Figure 4.2 described the number of snake bean leaves in eight weeks from 9 plots.

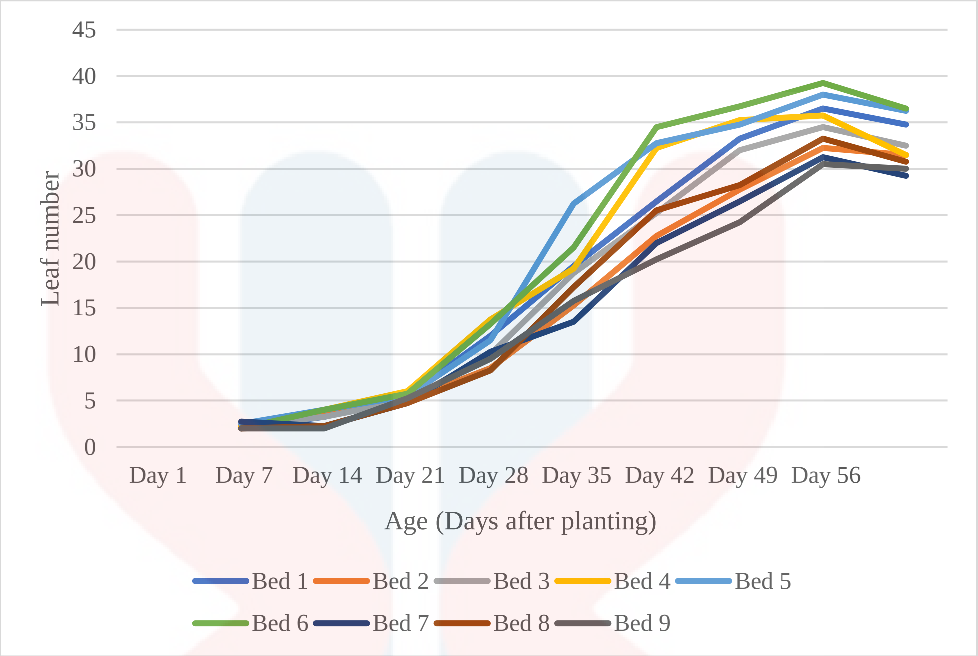

Figure 4.2 The leaf number of snake bean plants in all beds

4.1.3 Branch number

The graph in Figure 4.3 depicted that mean number of branches of snake bean increases for every week until day 56. Most of the number of branches formed from seven to nine branches for this generation in higher maturity period. Thus, the highest number of branches was in the seventh and eighth week. It can be shown that different branches number produced by different plant. Number of branches then determined the leaf number formed by each plant in the generation. The higher the branch number, the higher the number of leaves produced. The development of branches will increase as the trellis help them to grow higher and longer upward, to reach direct sunlight from the sun for photosynthesis sunlight. Figure 4.3 below depicted the number of snake bean branches in eight weeks.

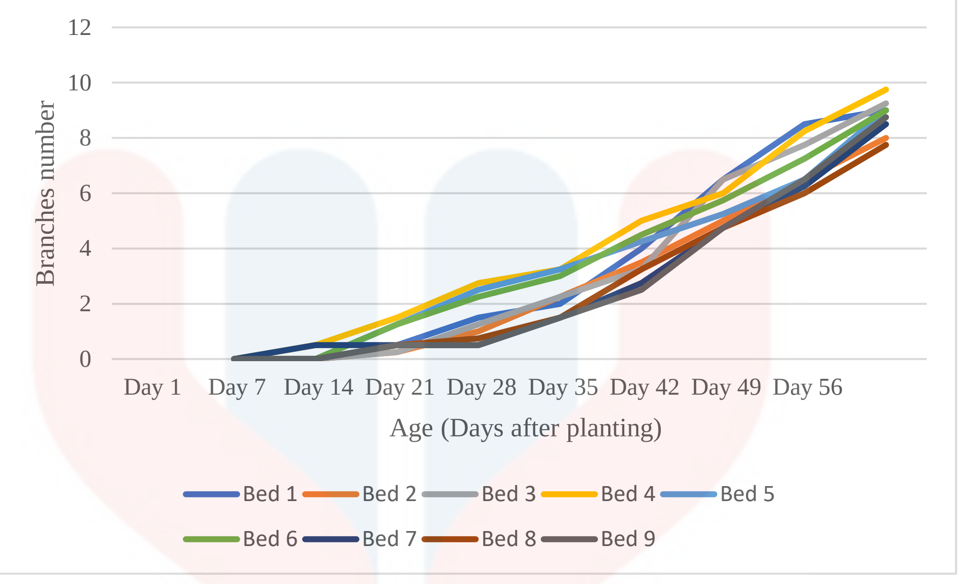

Figure 4.3 Number of snake bean branches in nine beds

4.2 Generative data

The generative parameter was crucially important for the study toward accepting the hypothesis and achieving the objectives of the research, thus the quality of snake bean increased.

4.2.1 Pod length

Table 4.1 shows the frequency of different range of pod length in all seven generation in units and percentages. According to Figure 4.4 and 4.5, the mean of pod length was proportional to the frequency number of pods for overall yield production of snake bean population.

Table 4.1 Frequency of Different Range of Pod Length in Seven Generation (percentages)

Class Interval of Pod Length (cm)	Frequency of Different Range of Pod Length in Seven Generation (percentages) — Generation							
	0^{th}	1^{st}	2^{nd}	3^{rd}	4^{th}	5^{th}	6^{th}	7^{th}
15 to 19.5	0 (0)	0 (0)	0 (0)	1 (0.03)	1 (0.02)	3 (0.08)	1 (0.03)	0 (0)
20 to 24.9	0 (0)	19 (0.43)	3 (0.05)	14 (0.29)	21 (0.30)	25 (0.68)	6 (0.18)	2 (0.06)
25 to 29.9	3 (0.38)	30 (0.68)	11 (0.19)	37 (0.76)	76 (1.09)	30 (0.81)	11 (0.32)	1 (0.03)
30 to 34.9	4 (0.51)	49 (1.11)	43 (0.76)	63 (1.31)	265 (3.79)	113 (3.05)	54 (1.58)	7 (0.21)
35 to 39.9	6 (0.76)	122 (2.77)	88 (1.55)	187 (3.88)	397 (5.67)	126 (3.41)	105 (3.07)	32 (0.95)
40 to 44.9	26 (3.30)	661 (14.49)	234 (4.13)	421 (8.73)	598 (8.55)	265 (7.16)	264 (7.72)	75 (2.23)
45 to 49.9	172 (21.86)	727 (16.49)	456 (8.05)	654 (13.56)	911(13.02)	301 (8.14)	378 (11.05)	168 (5.00)
50 to 54.9	185 (23.51)	1173 (26.60)	762 (13.45)	777 (16.11)	1144 (16.35	579 (15.65)	574 (16.78)	738 (21.93)
55 to 59.9	178 (22.62)	1369 (31.04)	1197 (21.13)	817 (16.94)	1293 (18.48)	853 (23.06)	656 (19.18)	949 (28.20)
60 to 64.9	110 (13.98)	116 (2.63)	1157 (20.42)	730 (15.13)	1077 (15.39)	549 (14.84)	590 (17.25)	774 (23.00)
65 to 69.9	73 (9.28)	56 (1.27)	858 (15.14)	569 (11.79)	794 (11.35)	514 (13.90)	383 (11.20)	337 (10.01)
70 to 74.9	28 (3.56)	55 (1.25)	533 (9.41)	333 (6.90)	349 (4.99)	293 (7.92)	238 (6.96)	160 (4.75)
75 to 79.9	2 (0.25)	20 (0.45)	232 (4.09)	142 (2.94)	58 (0.83)	36 (0.97)	93 (2.72)	44 (1.31)
80 to 84.9	0 (0)	12 (0.27)	64 (1.13)	52 (1.08)	8 (0.11)	9 (0.24)	36 (1.05)	35 (1.04)
85 to 89.9	0 (0)	1 (0.02)	25 (0.41)	20 (0.41)	4 (0.06)	2 (0.05)	15 (0.44)	28 (0.83)
90 to 94.9	0 (0)	0 (0)	3 (0.05)	7 (0.15)	1 (0.03)	1 (0.03)	9 (0.26)	9 (0.27)
95 to 99.9	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	7 (0.20)	4 (0.12)
100 to 104.9	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (0.03)
105 to 109.9	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (0.03)	1 (0.03)
Total	787	4410	5666	4824	6997	3699	3421	3365
Source		(Yusniza, 2016)	Farahanim, 2018)	(Nuradlina, 2018)	(Zahrotul Jannah, 2019)	(Noor Atika, 2019)	(Unpublished data)	

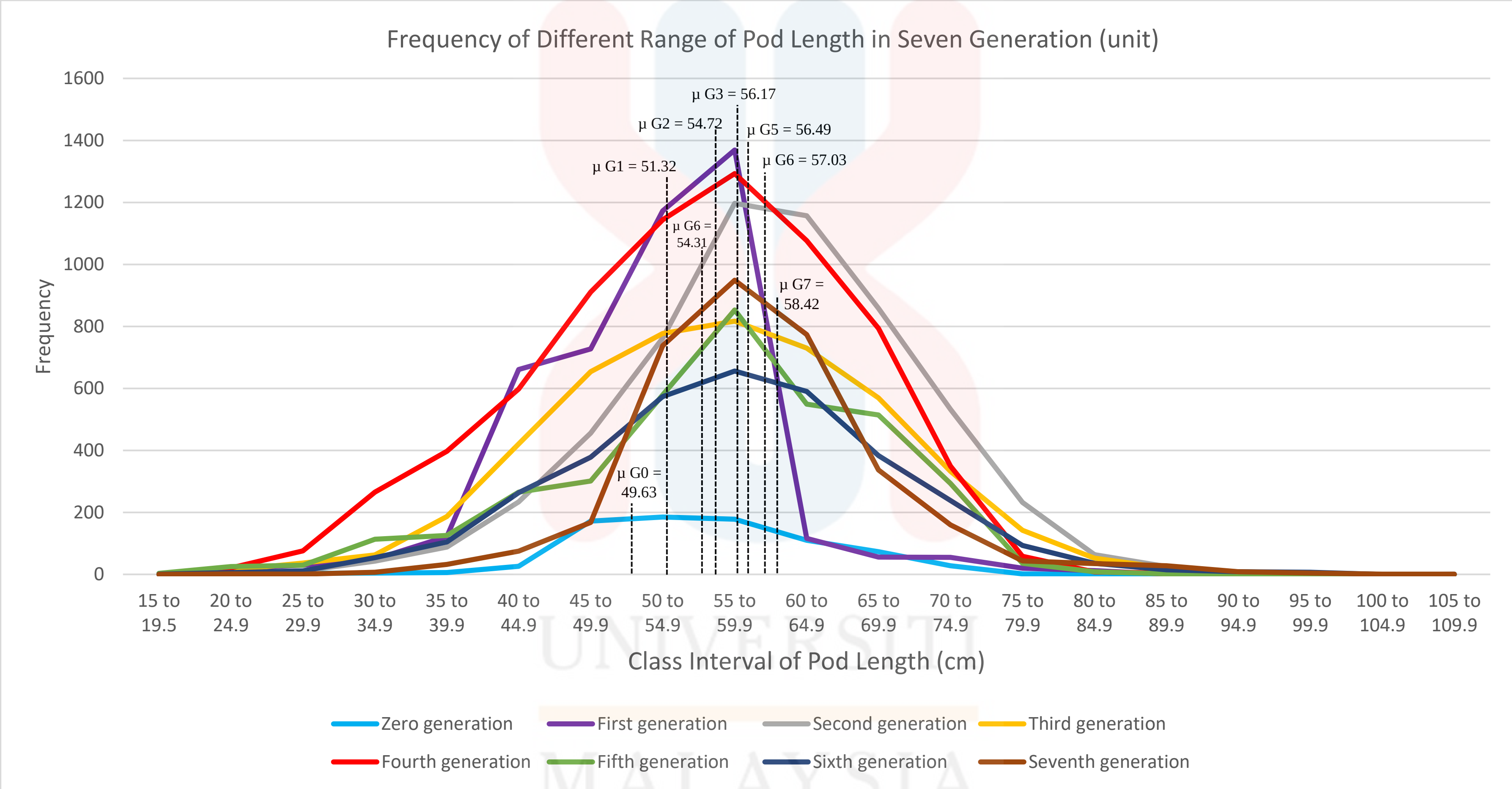

Figure 4.4 The frequencies of snake bean pod for all class interval of length

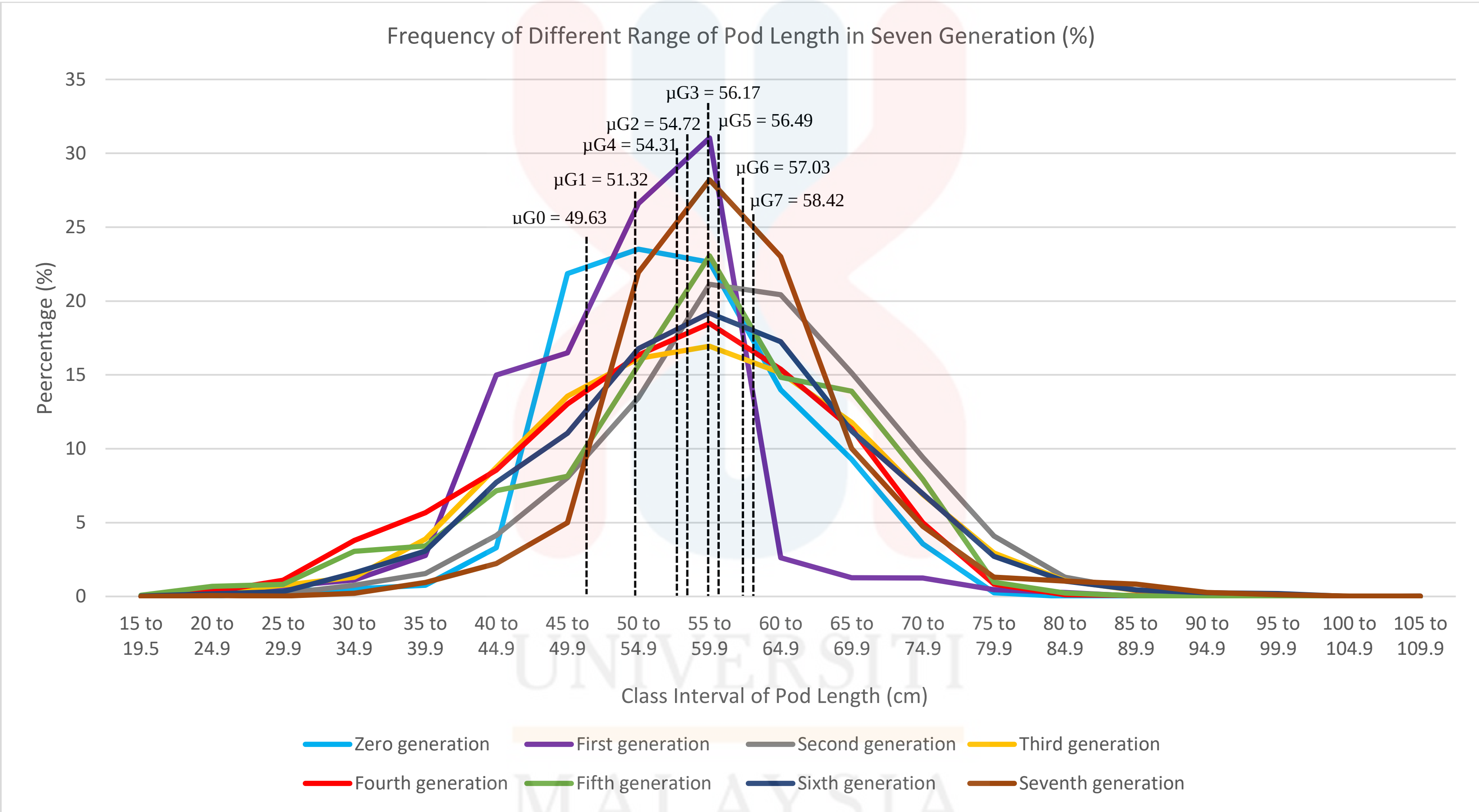

Figure 4.5 The frequencies of snake bean pod for all class interval of length in percentage (%)

Figure 4.4 and 4.5 shown a clear explanation where the frequency of snake bean pod was increased accordingly from generation to generation. The further the generation, the higher the mean of od length in that generation, thus the class interval of the pod length also had move forward, as the interval class also expanded in sixth and seventh generation.

4.2.2 Mean and maximum pod length in every generation

Table 4.2 Mean, standard deviation and maximum length of pod for all generation

Generation	Mean (cm)	Standard Deviation	Maximum length of pod (cm)	Source
0th	49.63	8.50	78.00	
1st	51.32	8.43	88.00	(Yusniza, 2016)
2nd	54.72	9.72	90.00	(Farhanim, 201)
3rd	56.17	11.13	92.00	(Nuradina, 2018)
4th	54.31	10.80	93.00	(Zahrotul Jannah, 2019)
5th	56.49	10.84	94.50	(Noor Atika 2019)
6th	57.03	10.83	106.00	(Unpublished data)
7th	58.42	8.35	107.00	

Table 4.2 shows the mean, standard deviation and maximum length of pod for all generation. From zero generation to seventh, the mean was increasing. Mean of pod length in first generation was 51.32 cm and increased by 3.40 cm for the second generation. Then, there are also some differences between fourth and fifth generation, which is by 2.18 cm. From sixth to seventh generation, the mean also increased by 1.29 cm. This showed that the highest mean of pod length is in seventh generation. As the average pod length increased by each generation, the traits were proven to be improved.

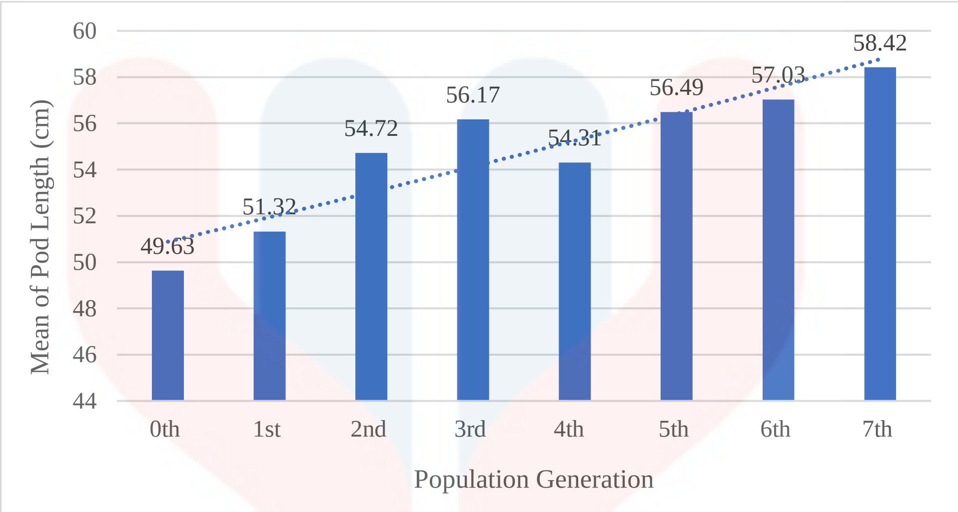

Figure 4.6: Graph of mean of pod length in all generation

Then, based on figure the maximum length for each generation is also different, and increased. Starting from 78 cm in zero generation, followed by 88 cm, 90 cm, 92 cm, 93 cm, 94.5 cm, 106 cm and the highest is 107 cm in seventh generation.

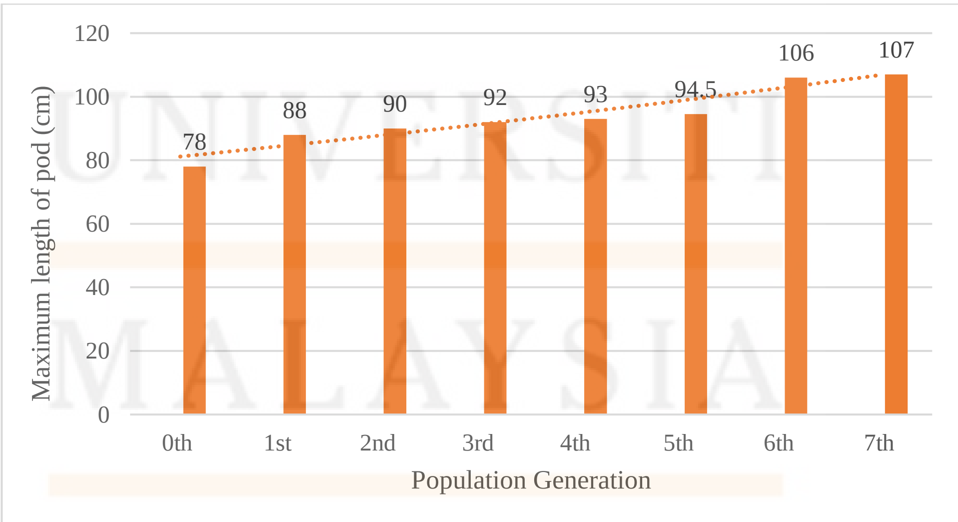

Figure 4.7: Graph of maximum length of pod from zero to seventh generation

There was improvement on the maximum pod length from generation to generation. The graph showed positive result as shown and gave a good impact on gene improvement by the implementation of mass selection method on snake bean plant population.

4.2.3 Yield of plant

Table 4.3 The yield production of snake bean for all generation

Plot	Generation						
	1	2	3	4	5	6	7
1	5.39	1.41	3.50	5.38	2.72	6.37	7.86
2	3.57	1.60	3.50	5.78	4.01	6.96	7.63
3	4.46	1.86	2.80	4.09	5.83	7.34	8.16
4	-	3.50	3.10	2.24	4.89	7.19	8.60
5	-	2.37	3.70	1.40	3.10	5.89	8.59
6	-	0.91	3.00	0.90	2.66	8.17	9.82
7	-	-	-	-	2.40	9.33	9.23
8	-	-	-	-	-	7.63	8.84
9	-	-	-	-	-	9.73	7.58
Total (kg)	13.42	11.65	19.60	19.79	25.61	68.61	76.31
Source	(Yusniza, 2016)	(Farhanim, 2018)	(Nuradlina, 2018)	(Zahrotul Jannah, 2019)	(Noor Atika, 2019)	(Unpublished data)	

Table above described a significant difference of the yield production of snake bean population. From the first to seventh generation, the yield of pods produced were rising. The highest yield was collected in seventh generation which was 76.31 kg, followed by sixth (68.61 kg), fifth (25.61 kg), fourth (19.79 kg), third (19.60 kg), first (13.42 kg) and second (11.65 kg) respectively. The yield performance of snake bean production showed that the population of this crops had contributed to a great yield production.

Table 4.4 The average production of yield per m^2 (kg) of snake bean for all generation

Generation	Total plantation area (m^2)	Yield per m^2 (kg)	Source
1	56	0.240	(Yusniza, 2016)
2	54	0.216	(Farhanim, 2018)
3	68	0.288	(Nuradlina, 2018)
4	57.6	0.344	(Zahrotul Jannah, 2019)
5	50.4	0.508	(Noor Atika, 2019)
6	81.0	0.847	(Unpublished data)
7	81.0	0.942	

Table 4.4 depicted the total yield produced by snake bean plant per unit area (m^2). From the first generation, the yield produced was 0.24 kg. Then, in third generation, there was an increment as the yield per unit area was 0.288 kg. The following generation also generated higher yield production. It can be seen, as the higher the pod mean of the generation, the higher the yield performance of the snake bean population. The highest yield obtained was from seventh generation which is 0.942 kg.

Table 4.5 Average yield of snake bean per plant (g) for seventh generation

Bed	Yield per plant (g)
1	490.75
2	543.25
3	480.00
4	491.50
5	495.00
6	528.00
7	647.75
8	688.50
9	660.25
Average	558.33

The average of yield production of snake bean per plant for every bed was shown in table 4.5. The average yield per plant was the highest in bed 8 which is 688 kg, meanwhile the lowest is in bed 3 (480 g). The total of average yield per plant is 5025 g and the average per plant is 558.33 g. With large population of snake bean, the yield performance per plant and per plot also increased.

Table 4.6 described the average of yield production of snake bean per plant for every generation. The average yield per plant was the highest in generation 7 which is 339 g which were produced from 225 plant, meanwhile the lowest is in generation 1 (51 g). This shows that the further the generation, the higher the yield produced per plant. When yield performance per plant and per plot increase, this research achieved its objective and accepted the hypothesis, where further generation with longer pod length would produce higher yield performance.

Table 4.6 The average production of yield per plant (g) of snake bean for all generation

Generation	Total number of plants	Average yield per plant (g)	Source
1	265	51	(Yusniza, 2016)
2	168	69	(Farhanim, 2018)
3	240	82	(Nuradina, 2018)
4	240	82	(Zahrotul Jannah, 2019).
5	168	152	(Noor Atika, 2019)
6	225	305	(Unpublished data)
7	225	339	

4.2.3 Heritability

In narrow sense heritability, the additive genes calculated in percentage gave the value based on pod length, in order to identify and knowing the trait response in a selection. Mass selection technique was implemented in the study to improve the quality of snake bean plant, in terms of pod length and yield performance of this crop for every generation. By choosing better phenotypic expression from the parent seed, the selection was made and keep replanting in the next generation to have a better result performance.

The formula used for narrow-sense heritability was (Snustad and Simmons, 2012):

$$\sigma^2 = V\alpha \,/\, Vp$$ …….. (Equation 1)

$$Vp = Vg + Ve$$ ...…... (Equation 2)

Where, σ^2 = Variance

Vp = phenotypic variance

Ve = environmental variance

Vg = genetic variance

Narrow-sense heritability was calculated by using the formula:

μ = mean of population

T_0 = mean of offspring

T_S = mean of selected parents

R = A measurement of how much the mean has changed in one generation (R = T_0-μ) ……………. (Equation 3)

S = Differences between the mean of selected parents and the mean of population (S = T_S-μ) …………….. (Equation 4)

Therefore,

$$h^2 = \frac{R}{S}$$ …………….. (Equation 5)

(Source: Snustad and Simmons, 2012)

From the stimulus, snake bean heritability of snake bean was compared for each generation. Table below depicted the comparison of narrow-sense heritability for each generation of snake bean population.

Table 4.7 Narrow-sense heritability of snake bean for sixth and seventh generations

Element of heritability	Narrow-sense heritability in Sixth Generation	Narrow-sense heritability in Seventh Generation
μ	56.49	57.03
T_0	57.03	58.42
T_S	81.39	83.39
R = T_0 - μ	0.54	1.39
S = T_S- μ	24.9	26.36
h^2 = R/S	0.0217	0.0527

The value of heritability gave small percentage of snake bean phenotypic trait. Those value could explain as the estimation to the genetic in origin because the constant heritability were across the species and population (Visscher et al., 2008). Thus, the breeding value that show the additive value of individual genetic is also the total of mean effects of alleles carried by the individual. From Table 4.10, the heritability of narrow sense is increasing from 0.0217 or 2.17% in sixth generation to 0.0527 or 5.27%

in seventh generation. This result prove that higher heritability value shows higher efficiency of mass selection method for snake bean population in further generation. The value did show the variance of additive genes passed from the chosen parents. The heritability is actually affected by the specific factors of the plant population such as genetic variance effect, variation and allele frequencies, caused by the environment factor or others.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

From this research, vegetative data was collected from leaf number, branch number and plant height. The graph for all vegetative data were constantly increasing for each bed in all weeks. These data showed that the soil, condition, fertility and effect are same between each plot. Then, the mean of pod length increased from 57.03 cm in sixth generation to 58.42 cm in seventh generation. The differences showed a positive pod length improvement in snake bean population. Even the yield production of snake bean increased from 68.61 kg in sixth generation, compared to 76.31 kg in seventh generation. This result indicated that the pod length of snake bean in further generation is longer than in previous generation. This research also proved that, with longer pod length, the yield production rose up. Then, narrow-sense heritability proved that the snake bean could continue using mass selection as the snake bean genetic diversity value is increasing from 2.17% in sixth generation to 5.27% in seventh generation. This result prove that higher heritability value shows higher efficiency of mass selection method for snake bean population in further generation.

5.2 Recommendation

Future research about breeding technique, especially regarding mass selection method need to be re-investigated. In order to accomplish that purpose, more plant is required to ensure that the selected genes from the best phenotypic trait of longer pod length and higher yield traits can be implemented for future research or kept in germplasm storage.

REFERENCES

Acquaah, G. (2012). Breeding Self-Pollinated Species. Principles of Plant Genetics and Breeding, Second Edition, John Wiley and Sons, Ltd, Chichester, UK. p. p. 282-312.

Anim, M. (2010). Kos Kacang Panjang. Anim Agriculture Technology, Anchor Company Respective and Role in Enhancing the Malaysian Seed Industry. https://animhosnan.blogspot.com/2010/10/kos-kacang-panjang.html. Accessed on 12 November 2019.

Anim, M. (2012). Kacang Panjang. Anim Agriculture Technology, Anchor Company Respective and Role in Enhancing the Malaysian Seed Industry. https://animhosnan.blogspot.com/2012/10/kacang-panjang.html. Accessed on 12 November 2019.

Arterburn, M. A., Jones, S. S., and Kidwell, K. K. (2008). Soils, Plant Growth and Crop Reproduction. Encyclopaedia of Life Support Systems (EOLSS). Vol. 1 Plant Breeding and Genetics.

Bos, I., and Caligari, P. (2008). Selection Methods in Plant Breeding, 2nd Edn. Dordrecht: Springer.

Chaisan, T. (2013). Breeding of Self-Pollinated Crops and Biotechnological Tools for Crops Improvement. Center for Agricultural Biotechnology, Kasetsart University.

Craufurd, P.Q., Summerfield, R.J., Ell, R.H., and Roberts, E.H. (1997). Photoperiod, Temperature and the Growth and Development of Cowpea (*Vigna unguiculata*). In: Singh, B.B., Mohan Raj, D.R., and Dashiell, K.E. Jackai LEN (eds) Advances in Cowpea Research. Copublication Intl InstTropical Agric (IITA) and Japan Intl Res Center Agric Sci (JIRCAS). Sayce, Devon, UK, p.p. 75–86.

Dugje, I.Y., Omoigui, L.O., Ekeleme, F., Kamara, A.Y., and Ajeigbe, H. (2009). Farmer's Guide to Cowpea Production in West Africa. International Institute of Tropical Agriculture, Ibadan, Nigeria.

Hill, W. G. and Mackay, T. F. (1996). Introduction to Quantitative Genetics, 4th Edn. Harlow: Longman.

Fery, R.L. (2002) The Genetics of Cowpea: A Review of the World Literature. In: Singh, S.R., and Rachie, K.O. (eds) Cowpea Research, Production and Utilization. John Wiley and Sons, Ltd., Chichester, NY, p. p. 25–62.

Food and Agriculture Organization. (1993). Underexploited and Potential feed Legumes in Asia. FAO PARA Publication. FAO, Bangkok, Thailand.

Krishnan, G. T.R. (2007). Chapter 8 – Legume Vegetables. In: Horticulture Science Series Vol. 4 Vegetable Crops. New India Publishing Agency. p.p 181-187.

Guazzelli, R.J. (1988). In: E.E. Watt and J.P.P. de Araujo (eds.), Cowpea Research in Brazil. Copublication of International Institute of Tropical Agriculture, Ibandan, Nigeria, and Empresa Brasileira de Pesquissa Agropecuaria, Brasilia, Brazil, p.p. 65–77.

Hall, A.E., Cisse, N., Thiaw, S., Elawad, H.O.A. and Ehlers, J.D. (2003). Development of Cowpea Cultivarsand Germplasm by the Bean/Cowpea CRSP. Field Crops Res 82:103–134.

Hazel, L. N. (1943). The genetic basis for constructing selection indexes. Genetics 28, 476–490.

Inoue, N., Kumagai, H., and Hagiwara, M. (2002). Improvement of Fertilization Rate by Mass Selection in Common Buckwheat. Faculty of Agriculture, Shins University, Fagopyrum 19: 49-53.

Jabatan Pertanian Malaysia. (2006). Tanaman Sayuran Kacang Panjang. Jabatan Pertanian Malaysia. Retrieved on February 26, 2016). http://www.doa.gov.my/ Accessed on 12 November 2019

Jabatan Pertanian Pulau Pinang. (2011). Kacang Panjang. Jabatan Pertanian Pulau Pinang. http://jpn.penang.gov.my/index.php/perkhidmatan/teknologi-tanaman/sayur-sayuran/76-kacang-panjang-sp-14169. Accessed on 12 November 2019.

Jabatan Pertanian Malaysia. (2011). Kacang Panjang. Jabatan Pertanian Pulau Pinang. http://www.doa.gov.my/. Accessed on 12 November 2019.

Jeanette, M. (2012). Philippines Cooking Long Bean. Jeanette Blogspot. http://www.kitchen.amoores.com/2012/09/18/yard-long-beans-with-coconut-milk/. Accessed on 12 November 2019.

Kloppenburg, J.R. (2004) First the Seed: The Political Economy of Plant Biotechnology, 2nd edition, University of Wisconsin Press. p.p 1492-2000.

Lawrence, J. H. and Moore, L. M. (2002). Plant Fact Sheet/Guide Yard Long Bean *Vigna unguiculate* (L.) Walp. Ssp. *sesquipedalis* (L.) Verdc. United States Department of Agriculture (USDA) Natural Resources Conservation Services (NRCS): http://plant-materials.nrcs.usda.gov. Accessed on 12 November 2019.

Lerner, B.R. (2001). Growing Beans in the Home Vegetable Garden. Purdue University Cooperative Extension Service.

Lorz, A.P., and Halsey, L.H. (1964). Snap Pea, A New Cream Type Southern Pea Variety for Snap Pod Use. Univ. Florida Agr. Expt. Sta. Cir. S-160.

Madhavan, U. (2014). Market Analysis and Strategy: Baby Leaves and Long Beans. Euromonitor International Ltd.

Marechal, R., Mascherpa, J.M., and Stainer, F. (1978). Taxonomic Study of a Group Species Complex of the Genera *Phaseolus* and *Vigna* (*Papilionaceae*) on the Basis of Morphological and Pollen Data by Computer Analysis 28:1–273.

Noor Atika, A. (2019). Mass Selection for Improvement of Pod Length and Yield of Snake Bean (*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdc.) in the Fifth Generation (thesis). Faculty of Agro Based Industry, University Malaysia Kelantan Jeli Campus.

Nuradlina Nabilah, A. (2018). Mass Selection for Improvement of Length and Yield of Snake Bean (*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdc.) CV MKP5 in the Third Generation (thesis). Faculty of Agro Based Industry, University Malaysia Kelantan Jeli Campus.

Nur Farhanim, A. L. (2018). Mass Selection of Snake Bean (*Vigna unguiculata* ssp. *sesquipedalis* (L.) Verdc.) cv MKP5 for Pod Length and Yield in Second Generation (thesis). Faculty of Agro Based Industry, University Malaysia Kelantan Jeli Campus.

Ofori, K., and Klogo, P.Y. (2005). Optimum Time for Harvesting Yard Long Bean (*Vigna sesquipedalis*) for High Yield and Quality of Pods and Seeds. Retrieved on 2005. Journal of Agriculture and Social Sciences: http://www.ijabjass.org. Accessed on 12 November 2019.

Owens, G. (2006). Snake Bean. Northern Territory Government.VF7: Pg. 1 – 3.

Peter, K.V. and Abraham, Z. (2007). Chapter 6 – Tropical Vegetables Crops. In: Biodiversity in Horticultural Crops Vol. I. Daya Publishing House. p.p. 156 – 158.

Quin, F.M. (1997). Introduction. In: B.B. Singh, D.R. Mohan Raj, I.E. Dashiell, and L.E.N. Jackai (eds.), Advances in Cowpea Research. Copublication of International Institute of Tropical Agriculture (IITA) and Japan International Research Center for Agricultural Sciences (JIRCAS), IITA, Ibadan, Nigeria. p.p 9-15.

Rachie, K.O. (1985). Introduction. In: S.R. Singh and K.O. Rachie (eds.), Cowpea Research, Production and Utilization. Wiley, Chichester, England. p.p. 21 – 28.

Reddy, P.P. (2009). Chapter 6 – Leguminous Vegetable Crops. In: Advance in Integrated Pest and Disease Management in Horticultural Crops Vol. 2 Vegetable Crops. Stadium Press (India) Pvt. Ltd. p.p 194 – 200.

Rosenfeld, A. and Cunningham, S. (2011). Growing Yard Long Beans. Garden Organic.

Singh, S.R., and Van Emden, H.F. (1979) Insect Pests of Grain Legumes. Annu Rev Entomol 24:255–278.

Singh, V.P. and Paroda, R.S. (1983). The Winged Bean: A Review. Haryana J. Hort. Sci., 12 (3-4):200-211.

Snustad, D. P. and Simmons, M. J. (2012). Calculation of Narrow-Sense Heritability. Principle of Genetics 6th Ed.

Steele, W.M., and Mehra, K.L. (1980) Structure, Evolution and Adaptation to Farming Systems and Environments in Vigna. In: Summerfield RJ, Bunting AH (eds) Advances in Legume Science. Royal Botanic Gardens, Kew, UK. p.p. 393–404.

United States Department of Agriculture (USDA). (2012). Plant guide: Yard long bean *Vigna unguiculata* (L.) Walp. ssp. *sesquipedalis* (L.) Verdc. http://Plant-Material.ncrs.usda.gov. Accessed on 12 November 2019.

Verdcourt, B. (1970). Studies in the Leguminosae-Papilionoideae for 'Flora of Tropical East Africa': IV. Kew Bul. p.p. 507–569.

Visscher, P. M., Hill, W. G. and Wray, N. R. (2008). Heritability in Genomics Era-Concepts and Misconceptions. Natural Reviews. p.p. 225-266.

Yusniza, M. C. Y. (2016). Mass Selection for Improvement of Pod Length and Yield of Snake Bean (*Vigna unguiculata* ssp. *sesquipedalis* (L.) cv MKP5 in the First Generation (thesis). Faculty of Agro Based Industry, University Malaysia Kelantan Jeli Campus.

Zahrotul Jannah, A. (2019). Mass Selection of Snake Bean (*Vigna unguiculata* ssp. *sesquipedalis*. (L.) Verdc.) for Pod Length and Yield in Fourth Generation (thesis). Faculty of Agro Based Industry, University Malaysia Kelantan Jeli Campus.

APPENDICES

Appendix 1 Fertilizing calculation for snake bean calculation

(Size of planting bed is 9, land area per hectare is 10 000 m^2)

1. Compost fertilizer

   10 000 m^2 = 10 000 kg

   81 m^2 = 81 X 10 000 / 10 000 = 81 kg

   For each bed required: 81 / 9 = 9 kg

2. NPK fertilizer (15: 15: 15)

   10 000 m^2 = 333 kg

   81 m^2 = 81 x 333 / 10 000 = 2.7 kg

   For each bed required: 2.7 / 9 = 0.3 kg / 300 g

3. Urea fertilizer

   10 000 m^2 = 300 g

   81 m^2 = 81 x 300 / 10 000 = 2.43 kg

   For each bed required: 2.43 / 9 = 0.27 kg / 270 g

Appendix 2 Plant Height in Seventh Generation of Snake Bean Population (cm)

Bed	Week0	Week1	Week2	Week3	Week4	Week5	Week6	Week7	Week8
Bed 1	11.3	26.0	76.0	190.0	267.5	382.5	440.0	487.5	511.3
Bed 2	11.5	28.3	55.3	114.0	177.5	317.5	385.0	422.5	460.0
Bed 3	10.8	29.3	65.8	149.3	247.5	325.0	401.3	453.8	492.5
Bed 4	12.5	26.5	88.3	180.5	250.0	390.0	450.0	478.8	510.0
Bed 5	11.3	27.3	78.3	165.3	250.0	342.0	382.5	431.3	476.3
Bed 6	11.5	24.3	74.8	160.5	257.5	356.3	378.8	440.0	478.8
Bed 7	11.3	31.0	61.3	122.5	248.8	307.5	357.5	381.3	401.0
Bed 8	12.3	35.0	90.0	138.8	206.3	275.0	315.0	357.0	392.5
Bed 9	10.3	30.5	83.8	122.5	203.8	247.5	292.5	322.5	365.0
Average	11.4	28.7	74.8	149.3	234.3	327.0	378.1	419.4	454.1

Appendix 3 Leaf Number in Seventh Generation of Snake Bean Population

Bed	Week0	Week1	Week2	Week3	Week4	Week5	Week6	Week7	Week8
Bed 1	2.0	3.3	5.5	12.0	19.5	26.5	33.3	36.5	34.8
Bed 2	2.5	3.5	5.0	8.5	15.3	22.8	27.8	32.3	31.5
Bed 3	2.3	3.3	5.0	10.0	18.8	25.3	32.0	34.5	32.5
Bed 4	2.3	4.0	6.0	13.8	19.3	32.3	35.3	35.8	31.5
Bed 5	2.5	4.0	5.5	11.5	26.3	32.8	34.8	38.0	36.3
Bed 6	2.0	4.0	5.8	13.3	21.5	34.5	36.8	39.3	36.5
Bed 7	2.8	2.3	4.8	10.3	13.5	22.0	26.5	31.3	29.3
Bed 8	2.0	2.3	4.8	8.3	17.3	25.5	28.3	33.3	30.8
Bed 9	2.0	2.0	5.3	9.5	15.8	20.3	24.3	30.5	30.0
Average	2.3	3.2	5.3	10.8	18.6	26.9	31.0	34.6	32.6

Appendix 4 Branch Number in Seventh Generation of Snake Bean Population

	Week0	Week1	Week2	Week3	Week4	Week5	Week6	Week7	Week8
Bed 1	0.0	0.0	0.5	1.5	2.0	4.0	6.5	8.5	9.0
Bed 2	0.0	0.0	0.3	1.0	2.3	3.5	5.0	6.5	8.0
Bed 3	0.0	0.0	0.3	1.3	2.3	3.3	6.5	7.8	9.3
Bed 4	0.0	0.5	1.5	2.8	3.3	5.0	6.0	8.3	9.8
Bed 5	0.0	0.0	1.3	2.5	3.3	4.3	5.3	6.5	9.0
Bed 6	0.0	0.0	1.3	2.3	3.0	4.5	5.8	7.3	9.0
Bed 7	0.0	0.5	0.5	0.5	1.5	2.8	4.8	6.3	8.5
Bed 8	0.0	0.0	0.5	0.8	1.5	3.3	4.8	6.0	7.8
Bed 9	0.0	0.0	0.5	0.5	1.5	2.5	4.8	6.5	8.8
Average	0.0	0.1	0.7	1.4	2.3	3.7	5.5	7.1	8.8

Appendix 5 Average Pod Length on each Bed of Seventh Generation of Snake Bean Population (for non-sample plant)

Bed	1	2	3	4	5	6	7	8	9
Mean of Pod Length	57.08	58.46	59.25	57.88	58.44	59.33	58.20	58.03	58.53
Average of Pod Length for Seventh Generation = 58. 42 cm									

Appendix 6 The Frequency and Percentage of Pod Length of Seventh Generation of Snake Bean Population

Length according to Class Interval (cm)	Frequency	Percentage (%)
15 to19.9	0	0.0
20 to 24.9	2	0.1
25 to 29.9	1	0.0
30 to 34.9	7	0.2
35 to 39.9	32	1.0
40 to 44.9	75	2.2
45 to 49.9	168	5.0
50 to 54.9	738	21.9
55 to 59.9	949	28.2
60 to 64.9	774	23.0
65 to 69.9	337	10.0
70 to 74.9	160	4.8
75 to 79.9	44	1.3
80 to 84.9	35	1.0
85 to 89.9	28	0.8
90 to 94.9	9	0.3
95 to 99.9	4	0.1
100 to 104.9	1	0.0
105 to 109.9	1	0.0
Total pod	3365	100.0
Mean (cm)	58.42	
Standard Deviation	8.35	
Maximum length (cm)	107.00	
Minimum length (cm)	20.00	

Appendix 7 Calculation for Mean and Standard Deviation for Seventh Generation

Range (cm)	Frequency	Cumulative frequency	Midpoint, x	fx
5 to 9.9	0	0	7.45	0
10 to14.9	0	0	12.45	0
15 to 19.5	0	0	17.45	0
20 to 24.9	2	2	22.45	44.9
25 to 29.9	1	3	27.45	27.45
30 to 34.9	7	10	32.45	227.15
35 to 39.9	32	42	37.45	1198.4
40 to 44.9	75	117	42.45	3183.75
45 to 49.9	168	285	47.45	7971.6
50 to 54.9	738	1023	52.45	38708.1
55 to 59.9	949	1972	57.45	54520.05
60 to 64.9	774	2746	62.45	48336.33
65 to 69.9	337	3083	67.45	22730.65
70 to 74.9	160	3243	72.45	11592
75 to 79.9	44	3287	77.45	3407.8
80 to 84.9	35	3322	82.45	2885.75
85 to 89.9	28	3350	87.45	2448.6
90 to 94.9	9	3359	92.45	832.05
95 to 99.9	4	3363	97.45	389.8
100 to 104.9	1	3364	102.45	102.45
105 to 109.9	1	3365	107.45	107.45
Total	3365			198714.3
Mean, μ	58.42			
Standard deviation, ∂	8.35			

Mean, $\mu = \frac{\sum fx}{f} = \frac{198714.3}{3365} = 58.42$ cm

Standard deviation, $\partial = \frac{\sqrt{((\frac{\sum fx}{\sum N} - \mu^2)}}{N} = \frac{\sqrt{(\left(\frac{198714.3}{21}\right) - (58.42^2))}}{21} = 8.35$

Appendix 8 Total Yield of Nine Beds of Seventh Generation of Snake Bean Population (g)

Harvest Date (2019)	Bed 1	Bed 2	Bed 3	Bed 4	Bed 5	Bed 6	Bed 7	Bed 8	Bed 9	Total
1) 18/5	-	-	24.0	210.0	39.0	47.0	-	-	-	320.0
2) 20/5	21.0	-	86.0	33.0	34.0	-	-	-	-	174.0
3) 22/5	49.0	23.0	254.0	424.0	23.0	87.0	-	-	-	860.0
4) 24/5	83.0	155.0	284.0	235.0	125.0	122.0	-	-	-	1,004.0
5) 26/5	358.0	75.0	295.0	509.0	281.0	494.0	-	-	-	2,012.0
6) 28/5	480.0	303.0	540.0	608.0	670.0	795.0	73.0	-	41.0	3,510.0
7) 30/5	795.0	253.0	707.0	760.0	775.0	690.0	231.0	14.0	44.0	4,269.0
8) 01/6	540.0	380.0	944.0	980.0	1,148.0	970.0	358.0	20.0	180.0	5,520.0
9) 03/6	969.0	760.0	1,345.0	1,190.0	1,660.0	1,430.0	690.0	370.0	470.0	8,884.0
10) 10/6	1,896.0	1,150.0	880.0	695.0	660.0	887.0	788.0	780.0	488.0	8,224.0
11) 13/6	565.0	1,760.0	407.0	430.0	540.0	548.0	608.0	906.0	595.0	6,359.0
12) 16/6	121.0	307.0	250.0	314.0	179.0	477.0	1,276.0	1,150.0	1,104.0	5,178.0
13) 19/6	17.0	264.0	151.0	124.0	256.0	325.0	786.0	705.0	487.0	3,115.0
14) 22/6	-	31.0	77.0	68.0	133.0	248.0	570.0	358.0	350.0	1,835.0
15) 25/6	-	-	-	52.0	89.0	243.0	477.0	702.0	260.0	1,823.0
16) 28/6	-	-	-	-	-	106.0	365.0	650.0	154.0	1,275.0
17) 30/6	-	-	-	-	-	139.0	278.0	205.0	337.0	959.0
18) 02/7	-	-	-	-	-	98.0	79.0	145.0	296.0	618.0
19) 04/7	-	-	-	-	-	-	63.0	79.0	133.0	275.0
Total Weight (g)	5,894.0	5,461.0	6,244.0	6,632.0	6,612.0	7,706.0	6,642.0	6,084.0	4,939.0	56,214.0
Total Sample Weight (g)	1,963.0	2,173.0	1,920.0	1,966.0	1,980.0	2,112.0	2,591.0	2,754.0	2,641.0	20,100.0
Grand Weight Total (g)	7,857.0	7,634.0	8,164.0	8,598.0	8,592.0	9,818.0	9,233.0	8,838.0	7,580.0	76,314.0

Appendix 9 Total Yield Per Plant Sample on Nine Beds of Seventh Generation of Snake Bean Population (g)

	Weight per Plant Sample (g)								
	Bed 1	Bed 2	Bed 3	Bed 4	Bed 5	Bed 6	Bed 7	Bed 8	Bed 9
Sample 1	694.0	379.0	388.0	267.0	480.0	543.0	765.0	779.0	836.0
Sample 2	327.0	680.0	363.0	572.0	670.0	663.0	641.0	742.0	701.0
Sample 3	409.0	697.0	442.0	470.0	245.0	229.0	428.0	564.0	489.0
Sample 4	533.0	417.0	727.0	657.0	585.0	677.0	757.0	669.0	615.0
Total Weight (g)	1,963.0	2,173.0	1,920.0	1,966.0	1,980.0	2,112.0	2,591.0	2,754.0	2,641.0
Average Weight (g)	490.8	543.3	480.0	491.5	495.0	528.0	647.8	688.5	660.3
Average of Yield Per Plant in Seventh Generation = 558.33 g									

Appendix 10 Calculation for Narrow Sense Heritability

Narrow-sense heritability was calculated by using the formula:

μ = mean of population

T_0 = mean of offspring

T_S = mean of selected parents

R = A measurement of how much the mean has changed in one generation ($R = T_0 - \mu$)

S = Differences between the mean of selected parents and the mean of population ($S = T_S - \mu$)

Therefore,

$$h^2 = \frac{R}{S}$$

From the result obtained,

Calculation for seventh generation:

Mean of population, μ = 57.03

Mean of offspring, T_0 = 58.42

Mean of selected parents, T_S =

$$= \frac{(77.45X44) + (82.45X35) + (87.45X28) + (92.45X9) + (97.45X4) + (102.45X1) + (107.45X1)}{(44 + 35 + 28 + 9 + 4 + 1 + 1)}$$

= 83.39

R = (T_0-μ) = 58.42 - 57.03 = 1.39

S = (T_S-μ) = 7.16 – 57.03 = 26.36

$h^2 = \frac{R}{S} = \frac{1.39}{26.36}$ = 0.0527

Calculation for seventh generation:

Mean of population, μ = 56.49

Mean of offspring, T_0 = 57.03

Mean of selected parents, T_S =

$$= \frac{(77.45X93) + (82.45X36) + (87.45X15) + (92.45X9) + (97.45X7) + (102.45X0) + (107.45X1)}{(93 + 36 + 15 + 9 + 7 + 0 + 1)}$$

= 81.39

R = (T_0-μ) = 58.42 - 57.03 = 0.54

S = (T_S-μ) = 7.16 – 57.03 = 24.9

$h^2 = \frac{R}{S} = \frac{0.54}{24.9}$ = 0.0217

Appendix 11: The selection of seeds from longest pods in sixth generation

Appendix 12: The sowed seed has grown in tray and ready to be transplanted

Appendix 13: The weeding done between each plot

Appendix 14: The harvested snake bed from each plot before data collection