Performance analysis of vegetable soybean (*Glycine max* L.) in humid tropics

By

SHILPASHREE N.
(2016-12-021)

THESIS

Submitted in partial fulfilment of the

Requirement for the degree of

Master of Science in Horticulture

(VEGETABLE SCIENCE)

Faculty of Agriculture

Kerala Agricultural University, Thrissur

DEPARTMENT OF VEGETABLE SCIENCE
COLLEGE OF HORTICULTURE VELLANIKKARA
KERALA AGRICULTURAL UNIVERSITY, THRISSUR - 680 656
KERALA, INDIA

2018

DECLARATION

I hereby declare that the thesis entitled **"Performance analysis of vegetable soybean (*Glycine max* L.) in humid tropics"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

Shilpashree N

Vellanikkara
14-06-2018

SHILPASHREE N.
(2016-12-021)

CERTIFICATE

Certified that the thesis entitled **"Performance analysis of vegetable soybean (*Glycine max* L.) in humid tropics"** is a record of research work done independently by **Ms. Shilpashree N.** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

Vellanikkara
14-06-2018

(S. Nirmala Devi)
(Major Advisor)
Professor & AICVIP
Department of Vegetable Science
College of Horticulture, Vellanikkara

CERTIFICATE

We, the undersigned members of the advisory committee of **Ms. Shilpashree N. (2016-12-021)**, a candidate for the degree of **Master of Science in Horticulture**, with major field in **Vegetable Science**, agree that the thesis entitled **"Performance analysis of vegetable soybean (*Glycine max* L.) in humid tropics"** may be submitted by **Ms. Shilpashree N.** in partial fulfilment of the requirement for the degree.

Dr. S. Nirmala Devi
(Major Advisor)
Professor & AICVIP
Dept. of Vegetable Science
CoH, Vellanikkara, KAU Thrissur

Dr. P. Indira
Professor and Head
Dept. of Vegetable Science
CoH, Vellanikkara, KAU Thrissur

Dr. P. Anitha
Associate Professor
Dept. of Vegetable Science
CoH, Vellanikkara, KAU, Thrissur

14.06.18
Dr. Jayasree Sankar S.
Professor and Head
Dept. of Soil Science and Agril. Chemistry
CoH, Vellanikkara, KAU Thrissur

EXTERNAL EXAMINER

Dr. T. S. Aghora, Ph.D, A.R.S
Principal Scientist
Division of Vegetable Crops
Indian Institute of Horticultural Research
ICAR, DARE Ministry of Agri. Govt. of India
Hessarghatta Lake Post, Bengaluru - 560 089

ACKNOWLEDGEMENT

And so comes the time to look back on the path traversed during the Endeavour and to remember the faces behind the action with a sense of gratitude. Nothing of significance can be accomplished without the acts of assistance, words of encouragement and gestures of helpfulness from others.

First and foremost, I bow my head before the ***Almighty God*** *who enabled me to successfully complete the thesis work in time.*

With immense pleasure, I avail this opportunity to express my deep sense of reverence, gratitude and indebtedness to my Major Advisor, ***Dr. S. Nirmala Devi*** *A. Professor & AICVIP Department of Vegetable Science, College of Horticulture, Vellanikkara, for her sustained and valuable guidance, constructive suggestions, unfailing patience, friendly approach, constant support and encouragement during the course of the research work and preparation of this thesis. She has been a support to me during each step of this venture. I really consider it is my greatest fortune in having her guidance for my research work and will be remembered forever.*

I express my heartfelt gratitude to ***Dr. P. Indira,*** *Professor and Head, Department of Vegetable Science, College of Horticulture and member of my Advisory Committee for her affectionate advice, valuable suggestions, constant support and cooperation throughout the course of study.*

I convey my deepest gratitude to ***Dr. P. Anitha,*** *Associate Professor, Department of Vegetable Science, College of Horticulture and my Advisory Committee for her expert advice, valuable suggestions, critical evaluation and support rendered during thesis work.*

I sincerely thank ***Dr. Jayasree Sankar S.*** *Professor and Head, Department of Soil Science and Agricultural Chemistry, College of Horticulture for her expert advice and constant inspiration during course of study.*

My heartfelt thanks to my beloved teachers, ***Dr. Sarah T. George, Dr. T. Pradeep Kumar, Dr. S. Krishnan, Dr. Diji Bastain and Dr. Beena V. I.*** *and for their encouragement, valuable help and advice rendered during the course of study.*

I place my sincere thanks to ***Joi sir, Masood, Remmya chichi, Geethu chichi, Greeshma chechi, Shobhana chechi, Shanta Chechi, Aneesa cheta, Lohithakshan cheta*** *who helped me in several ways for the completion of this venture.*

With pleasure I express my heartfelt gratitude to my classmates, ***Dharini, Remzeena, Aruna, Kavya, Pooja, Navya, Ashwini, Nagendra, Madhusudhan, Niranjana and Shreelaja*** *whose constant support and encouragement could never be forgotten. I also express my thankfulness to my dear friends for their great understanding and constant support throughout my research period.*

I wish to express my thanks to my loving seniors and juniors ***Lokesh, Arun kumar, Jeevan, Ramya, Raghu, Umesh ,Raju, Deepa, Sadanand, Shankar, Megha, Keerthi, Sarthak, Poojashree, Veera , Minnu, Anit, Malavika, Akhila, Manjunath, Supritha*** *of PG from College of Horticulture, KAU.*

I wish to express my sincere thanks to our librarian, ***Dr. A.T. Francis*** *for the whole hearted cooperation and support.*

I wish to express my thanks to **National Talent Scholarship scheme** *by* **Indian council of Agriculture Research** *for the financial assistance offered during the study period.*

On my personal ground, I cannot forget the fondness, constant support and encouragement showered by my loving family. I deeply express my special whole hearted thanks to my loving parents, **Nagarathna** *and* **Nagaraju**, *dearest brother,* **Rakshith** *and my relatives for their everlasting support, sacrifice, prayer and blessings. I convey my affection and heartfelt gratitude to my dearest persons,* ***Manasa, Mahesh, Nagendra, Radha, Veda, Rohith, Dhananjay Sir, Mulla Sir, Lakshmi Mam, Viju Mam*** *without whose moral support, blessings and affection this would not have been a success.*

It would be impossible to list out all those who have helped me in one way or another in the completion of this work. I once again express my heartfelt thanks to all those who helped me in completing this venture in time.

Shilpashree N.

Affectionately Dedicated to My Family

CONTENTS

LIST OF TABLES

LIST OF FIGURE

LIST OF PLATES

INTRODUCTION

I. INTRODUCTION

Vegetable soybean (*Glycine max* L.) is an immature soybean that is consumed as a vegetable or snack belonging to family Fabaceae. It is also called as Green soybean or Edible soybean in North America, Edamane in Japan and Maodou in China. Vegetable soybean is harvested at the immature R6 (fully expanded seed) stage (Fehr and Caviness, 1977). Although, a minor crop in the world, it is quite popular in East Asia, especially in Japan, China, Korea and Taiwan. In recent years, it is gaining importance in India due to its nutritional quality.

Vegetable soybean is recognized as a "tidbit" rather than a basic food. Although there are few available data on consumer preferences, vegetable soybean is widely accepted because of its characteristic volatile flavor, sweetness and presence of amino acids. Major quality requirements of vegetable soybean in terms of palatability are appearance, taste, flavor and texture (properties of structure). The pods should be bright-green with spotless surface and good shape to fetch a good price in the wholesale and retail market. The primary requirement is good pod appearance.

The use of Vegetable soybean (Edamame) was first recorded around 200 B.C. as a medicinal plant in China (Shurtleff and Aoyagi, 1971) and is still very popular (Jian, 1984). Historically, edamame was grown between rice bunds, but due to surplus production of rice and official pressure to convert paddy fields to other crops, field production has become more common in Japan (Gotoh, 1984). Japan is the largest commercial producer of edamame. Taiwan supplies over 99 per cent of those imports as frozen edamame (Kono, 2000).

Globally soybean occupies an area of 111.52 million hectares, with a production of 276.03 million tons and productivity of 2475 kg per hectare. The USA, Brazil, Argentina, India and China are the leading producers and represent more than 90% of world soybean production. United States is leading in terms of area, production and productivity contributing to more than the 43% of the world soybean production. India stands fourth in area with 12.2 m ha with annual production of 11.98 million tons and average productivity of 1079 kg per hectare. It is extensively cultivated in Madhya Pradesh, known as the soybean bowl of India, contributing 65-70 % of the country's soybean production, followed by Maharashtra, Rajasthan, Andhra Pradesh and Karnataka. Vegetable soybean is cultivated in around 108.83 lakh ha area in India with production of 104.36 lakh MT.

In China, USA, Taiwan and Japan vegetable soybean are extensively cultivated and consumed as vegetable. It is also used for preparation of snacks, soups, salads, processed into sweets and canned food, innovative products such as green milk, green tofu, and green noodles. Frozen edamame is used as a top source of nutrients and as very high calorific value. (Shanmugasundaram and Yan, 1999; Mebrahtu and Devine, 2010). Vegetable soybean has become an important export cash crop in Japan, China, U.S. and Europe (Keatinge *et al.*, 2011) but in India it is not much popular.

Vegetable soybean is rich in protein, vitamins A, C and E, unsaturated fats, phosphorous, thiamine and riboflavin. Because of its characteristic-pleasing aroma and sweet taste it is widely appreciated in Japan and China (Masuda, 1991). Dry vegetable soybean seed is larger (usually over 30 g/100 seeds), has higher soluble sugar content and a lower number of chemical components associated with negative flavors than grain soybean (Konovsky *et al.,* 1994). Soybean seed has anti-nutritional substances, such as protease inhibitors. But, one-third of activity of trypsin inhibitor (TI) is less in its vegetable form and is more nutritious than grain soybean.

Unlike most of the vegetable proteins that are deficient in supplying all the essential amino acids (EAAs), the soybean protein stands unique by supplying all 10 EAAs including lysine. Soybean having cardio friendly oil fulfills 30 per cent of world vegetable oil requirement. Apart from quality protein and oil, soybean also has many therapeutic components *viz.,* lactose free fatty acids, antioxidants like vitamins C, K and D and folic acid, vitamins of B complex group *viz.*, nicotinic acid (23 μg/g), pantothenic acid (15 μg/g), thiamine (12 μg/g), pyridoxine (8 μg/g), riboflavin (3.5 μg/g) and biotin (0.7 μg/g) and isoflavones like genistein and daidzein (Mathur, 2004).

In the world, many vegetable soybean varieties have been bred and cultivated. These soybean genotypes are short in duration (65-75 days) permitting it to fit into narrow windows in a crop rotation and yield high around 40 tons/hectare, of which 10 t/ha is consumable and the rest is usable as fodder or green manure (Shanmugasundaram and Yan, 2004). There is a great potential and promise for its widespread cultivation in India. At present, vegetable soybean is not much popular in India, but its introduction with better acceptable genotypes will help in enhancing nutritional security. Hence efforts are being made to breed high yielding soybean varieties in India.

An improvement in yield and quality of self-pollinated crops like vegetable soybean is effected mainly through identification of genotypes with desirable characters from the germplasm or by creating variation through recombination and/or induced mutagenesis followed by selection. The basic requirement for adopting a suitable breeding method is sound knowledge of the genetic make-up of the characters and their expression in different genetic backgrounds. The presence and magnitude of genetic variability in a gene pool is the pre-requisite for a breeding programme. The knowledge of certain genetic parameters is essential for proper understanding and implementation of any crop improvement programme. Genetic parameters like GCV, PCV, heritability and GA are useful biometrical tools for determination of genetic variability. The pod yield is a complex character, quantitative in nature and an integrated function of a number of component traits. Therefore, selection for yield per se may not be much rewarding unless other yield attributing traits are taken into consideration. Correlation study provides a measure of association between characters and helps to identify important characters to be considered while making selection. Knowledge of correlation between pod yield and other characters is helpful in selection of suitable plant type. The present investigation was aimed at understanding the performance of vegetable soybean in humid tropics and the study of variability, heritability, correlation, path analysis and genetic advance in the germplasm of vegetable soybean.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

2.1 Genetic variability

Basavaraja *et al.* (2005) conducted a study to understand variability, heritability and association among various traits in a set of vegetable soybean genotypes. They observed significant variation for yield and its component traits, among those seed yield varied from 4983 kg ha^{-1} to 2033 kg ha^{-1}. They also reported that released vegetable soybean variety, Himso 1563 produced highest seed yield with higher pod length, pod width, bolder seeds, dwarf stature and early attainment of physiological maturity.

Mebrahtu and Mohamed (2006) assessed the genetic variation that existed in thirty-one vegetable soybean genotypes for green pod yield, hundred pod weight, pod length, plant height, total sugar and individual sugars (glucose, fructose, sucrose, raffinose, and stachyose) and to determine the association of green pod yield with the individual and total sugars. They reported that there was substantial genetic variation for green pod yield, plant height and pod length as indicated by relatively large genotypic variance components.

The analysis of variance was carried out by Ramteke *et al.* (2010) for plant height, nodes $plant^{-1}$, branches $plant^{-1}$, 100 seed weight, days to 50 per cent flowering, days to maturity, grain yield, oil and protein content in soybean. The results revealed that high heritability for days to maturity, days to 50 per cent flowering, plant height, nodes, oil and protein content, indicating the additive mode of gene action.

Aditya *et al.* (2011) studied the genetic parameter and correlation of eight quantitative traits including grain yield in thirty one soybean genotypes. Among the traits, seed yield per plant exhibited highest estimate of PCV (47.74) and GCV (41.83) followed by dry matter weight per plant (PCV=33.99, GCV=31.15) and number of pods per plant (PCV=33.48, GCV=30.16). Heritability was highest for days to50 per cent flowering, number of primary branches per plant and 100 seed weight (91%). High heritability coupled with high genetic advance was recorded for number of pods per plant and dry matter weight per plant.

Salimath *et al.* (2011) reported significant genetic variation in the 62 progeny lines of soybean for yield and other yield attributing characters except pod length and number of seeds per pod. They also reported that 6 lines showed resistance or moderate resistance to rust and these lines will be the primer for developing improved soybean genotypes with resistance to rust disease.

Ghodrati (2013) evaluated twelve soybean genotypes for genotypic variation, phenotypic correlations and broad sense heritability for seed yield and some quality characters in three growing seasons. Results showed significant differences for seed yield and quality characters which suggested sufficient genetic variation for efficient selection.

The genetic variability in forty five genotypes of soybean of diverse origin and highly significant differences among the genotypes for all the characters studied were reported by Reni and Raob (2013). High PCV coupled with high GCV, observed for branches per plant, pods per plant, biological yield, harvest index and yield per plant indicate the presence of wider adaptability for these traits and suggested the less influence of environment in the expression of characters.

Baraskar *et al.* (2014) evaluated sixty one soybean genotypes to study genetic variability, heritability and genetic advance for 15 characters. The analysis of variance revealed significant variations for all characters. The high values of GCV and PCV were observed for number of clusters per plant, seed yield per plant, biological yield per plant, number of pods per plant and plant height indicating presence of sufficient genetic variability for selection in these traits. High heritability accompanied by high genetic advance for plant height, number of clusters per plant, number of primary branches per plant, seed yield per plant, biological yield per plant and number of pods per plant suggested selection could be effective for these traits.

Among twelve soybean genotypes, yield per plant was reported highest in NRC-86. Highest PCV was observed in 13 yield component traits for seed yield per hectare, seed yield per plant and number of pod per plant and GCV was observed in 13 yield component traits for number of pod per plant, seed yield per hectare and seed yield per plant indicating that these characters could be used as selection for crop improvement (Suresh Rao *et al.* (2014)

Kumar *et al.* (2015) evaluated forty two soybean genotypes for their agro-morphological traits and the extent of genetic variability. Analysis of variance revealed that the mean performance for yield and its components were having significant differences among all the genotypes for all the characters.

The genetic variability of eleven morphological characters in twenty eight soybean accessions during rabi season was studied by Mahbub *et al.* (2015). Analysis of variance revealed significant differences among the genotypes and all the characters recorded moderate to low phenotypic and genotypic coefficient of variation. Genotypic coefficient of variation recorded was highest for seed yield per plant (31.45%) followed by number of branches per plant (29.90%) and plant height (27.42%).

Mishra *et al.* (2015) conducted genetic variability analysis of 12 morphological traits including seed yield per plant in fifty recently evolved genotypes of soybean. There was significant difference between genotypes for all the traits under study except number of branches per plant and number of pods per plant. The highest PCV and GCV was revealed for number of pods per plant, followed by biological yield per plant, number of seeds per plant. The number of pod clusters per plant indicated that larger share for variation for economic traits is genetically significant and selection resulting from phenotypic state would be supportive for the improvement of these traits.

Pagde *et al.* (2015) estimated the genetic variability of 30 soybean types grown during *kharif*. Results revealed that pods per plant exhibited highest genetic variability, followed by plant height, seed yield per plant, secondary branches per plant, test weight, seeds per pod. Pods per plant expressed highest heritability and genetic advance.

Ramya and Mummigatti (2015) evaluated twelve soybean accessions for variability in plant growth, duration to attain reproductive R1 and R6 stages, physiological parameters and pod yield(at R6 stage). The studies revealed that, the genotypes Swarna and AGS-610 had maximum plant height, highest number of branches and maximum yield compared to other genotypes. There was positive relation between plant height, number of branches, leaf area, photosynthetic activity, chlorophyll content, and dry matter accumulation with seed yield. Similarly, genotypes with highest photosynthetic rate, maximum leaf area, and highest chlorophyll content recorded maximum pod yield and seed yield. Therefore, the genotypes with maximum plant height, number of branches, highest number of days between R1 and R6 stage, with highest photosynthetic activity and yield attributing traits resulted in maximum pod and seed yield.

Alil *et al.*(2016) conducted genetic variability study of soybean varieties during *kharif* 2013. The results revealed that PCV was greater than GCV for all traits except oil content where, PCV and GCV were equal. The PCV and GCV values ranged between 24 and 28per cent for number of pods plant^{-1}, and 4 and 3 per cent for days to maturity, respectively. Highest heritability was observed for oil content (99%) and lowest heritability was noticed for days to pod formation (31%). Economically important characters including pod number plant^{-1}, 100 seed weight and seed yield exhibited high variability and heritability with moderate genetic advance.

Belagali and Kulkarni (2016) screened seven vegetable soybean varieties/ genotypes *viz.*, EC175329, KDS-726, 2000-05, Seminol, Karune and DSb 21 along with JS 335 for physical, chemical and sensory parameters. Among these varieties, Karune exhibited highest pod length (42.42 mm), pod width (11.63mm), pod thickness (9.50 mm) and weight of 100 pods (135.50 g). The highest seed length was evidenced in control JS 335 (12.89) whereas lowest was noticed in variety Seminol (9.72 mm).Sensory evaluation of boiled soybean revealed that varieties Karune and DSb 21 showed higher acceptable indices (86.85) while minimum was observed in genotype EC175329(74.07). Among the quality characteristics studied JS 335 exhibited highest yellow (b^* = 22.39) colour and hard texture (0.926 gf) compared to other vegetable soybean varieties/genotypes. Variety Karune and DSb 21 were found to be nutritionally superior and organoleptically acceptable.

Ekka and Lal (2016b) carried out the analysis of variance for all characters in twenty soybean genotypes *i.e.* days to 50per cent flowering, plant height (cm), branches per plant, clusters per plant, pods per plant, days to maturity, pod length (cm), seeds per pod, seed index (100 seed weight), seed yield per plant (g). Based on the mean performance among 20 genotypes, SL-778 (17.86) followed by PS-1447 (11.54) were found to the best genotypes for seed yield per plant indicating the presence of amount of variation for these characters. High heritability was observed for grain yield per plant (95%) and number of pods per plant (94%). Moderate values of genetic advance was observed for pods per plant (13.25) followed by days to maturity (12.69). Genotypic correlation analysis indicates that pods per plant (0.748^{**}), seed index (0.665^{**}), clusters per plant (0.489^{**}), plant height (0.485^{**}) and pod length (0.481^{**}) showed positive significant association with grain yield per plant. Phenotypic correlation analysis indicates that pods per plant (0.723^{**}), seed index (0.586^{**}), plant height (0.456^{**}), clusters per plant (0.430^{*}) and pod length (0.348^{*}) showed positive significant association with seed yield per plant.

Kuswantoro (2017) conducted a study to estimate the genetic variability of promising soybean lines. The studies revealed that characters of days to flowering, number of branches plant^{-1}, number of reproductive nodes plant^{-1}, 100 grains weight and grain yield had broad genetic variability, while days to maturity, plant height and the number of filled pods plant^{-1}had narrow genetic variability. Characters with broad genetic variability and high heritability can be used as sources in soybean variety improvement. The positive correlation between number of branches plant^{-1}with number of reproductive nodes plant^{-1}and number of filled pods plant^{-1} were significant.

Manav and Arora (2017) studied the genetic variability of yield and seedling characters of forty five germplasm accessions of soybean at CCSHAU, Hisar during *kharif*2014. Accessions exhibited wide range of variability for different characters studied. Maximum variability was recorded for number of pods per plant and minimum variability was recorded for seedling dry weight. There was close agreement between GCV and PCV for number of days to maturity, plant height and number of branches per plant.

2.2 Heritability and genetic advance

Basavaraja *et al.* (2005) reported that significant heritable variation was observed in vegetable soybean genotypes for yield and its component traits. Among the vegetable genotypes studied, Himso 1563, a released vegetable soybean variety produced highest seed yield with highest pod length, pod width, bolder seeds, dwarf stature and early attainment of physiological maturity.

The genetic variability, broad sense heritability and expected genetic advance of seed yield and its component traits was evaluated in 55 diverse genotypes of soybean (*Glycine max* (L.) Merr.) by Gohil *et al.*(2006). The highest genotypic coefficient of variation was observed for number of pods per plant followed by seed yield per plant.

High heritability with high genetic advance was observed for plant height, number of clusters per plant, number of pods per plant and seed yield per plant and suggested that these four traits are under the control of additive gene action and can be improved through simple selection procedures.

Karnwall and Singh (2009) evaluated twenty elite breeding lines of soybean for genetic variability, correlation and path coefficient for eighteen economically important traits. Six genotypes *viz.* PK-1272, PK-1274, PK-1281, PK-1283, PK-1284 and PK-1286 were found significantly superior in yield and other major yield contributing characters. The broad sense heritability estimates was observed high for pods per plant, followed by plant height, primary branches per plant and seed yield per plant whereas, pods per plant and plant height revealed high genetic advance.

Dilnesaw *et al.* (2013) evaluated forty eight soybean genotypes for genetic variability, heritability and genetic advance of nine important traits. They reported that high heritability (78.24) and moderate genetic advance (10.65) for days to 50 percent flowering, whereas, high broad sense heritability and genetic advance were found for plant height (73.49 cm, 40.76 cm respectively).

Reni and Raob (2013) reported high heritability coupled with high genetic advance as percent of mean was observed for days to 50percent flowering, plant height, branches per plant, pods per plant, pod length, seeds per pod, 100 seed weight, biological yield, harvest index and seed yield per plant indicating additive gene action and scope for improvement of these traits through simple selection.

Mahbub *et al.* (2015) evaluated twenty eight soybean genotypes for eleven morphological characters and reported significant differences between the genotypes for all the traits. Highest heritability was recorded for days to maturity followed by plant height, seed yield per plant, branches per plant, number of seeds per pod, number of pods per plant and 100seed weight. These characters were controlled by additive gene action and selection for improvement of these traits would be more effective.

Mishra *et al.* (2015) reported high heritability coupled with high genetic advance for seed yield per plant, number of seeds per plant, biological yield per plant, and number of pods per plant which could be attributed to the predominance of additive gene action in fifty soybean genotypes.

Thakur (2015) studied the genetic variability, broad sense heritability and genetic advance for seed yield and its component traits in 40 diverse genotypes of soybean (*Glycine max* (L.) Merrill). The results revealed that high significant differences among varieties for all the characters except for number of primary branches per plant and number of seeds per pod. Among all the traits, pod length exhibited highest estimate of PCV and GCV whereas, highest PCV was observed for number of pods per plant. High heritability coupled with high genetic advance was observed for 100-seed weight, pod length and plant height. These three traits are under the control of additive gene action and can be improved through simple selection procedures.

Ekka and Lal (2016) assessed the soybean genotypes for heritability and genetic advance. Maximum heritability was observed for grain yield per plant (95%) and number of pods per plant (94%). Moderate values of genetic advance was observed for pods per plant (13.25) followed by days to maturity (12.69).

Kuswantoro (2017) reported high broad sense heritability for the characters of days to flowering, days to maturity, the number of filled pods plant^{-1} and grain weight per 100 seeds in soybean. Moderate broad sense heritability was recorded for number of branches plant^{-1}andnumber of reproductive nodes plant^{-1}and low broad sense heritability was reported for plant height and grain yield ha^{-1}.

Manav and Arora (2017) evaluated forty five germplasm accessions of soybean for yield and seedling characters and reported for number of pods per plant.

Stobaugha *et al.* (2017) studied variability of soybean genotypes for yield, plant height, maturity, seed protein and oil concentrations. The results revealed that the genotype x year x location effect was significant for all traits studied, except maturity. Protein and oil concentrations were negatively correlated (−0.91) and highly heritable (0.89–0.93 and 0.82–0.83, respectively). Four promising high-yielding genotypes with moderately high to high protein or oil levels were identified: R05-4682 (high protein) and R05-4256 (high oil) in the MG IV test, R05-1772 (high protein) and R05-71 (high oil) in the MG V test.

2.3 Correlation and path coefficient analysis

Kumar (2004) reported that in soybean seed yield was positively correlated with total biomass per plant, number of pods per plant, plant height, harvest index, days to maturity, days to 50 per cent flowering, number of branches per plant and seeds per pod. The path coefficient analysis revealed that seed yield had positive direct effect on plant height, number of pods per plant, total biomass per plant and harvest index.

Basavaraja *et al.* (2005) observed heritable variation in soybean for yield and its component. They also reported that seed yield had positive correlation with pod length, hundred seed weight and harvest index.

Mebrahtu and Mohamed (2006) reported that pod length had correlation with sucrose (0.598) and total sugar (0.447) and pod length was positively correlated (0.766) with hundred pod weight and hundred pod weight was positively correlated with sucrose and total sugar content. Pod length could be used an indirect selection criterion to identify genotypes with high sucrose and total sugar content.

Malik *et al.* (2007) conducted correlation study of 27 genotypes of soybean and reported that bean yield had positive correlation with leaf area, first pod height, days to flowering, days to maturity, plant height and number of branches per plant. Path coefficient analysis revealed that days to flowering had maximum direct contribution to yield followed by days to pod initiation, chlorophyll content, number of pods per plant and plant height and suggested that these characters could be considered as selection criteria in improving the bean yield of soybean genotypes.

There was no correlation of TIA with days to maturity, oil content, protein content and seed yield (Manjaya *et al.*2007).

Sirohi *et al.* (2007) conducted correlation and path analysis in 25 genotypes of soybean and found positive correlation between seed yield with days to 50 per cent flowering (0.417^{*}), number of pods per plant (0.640^{**}), days to maturity (0.645^{**}), plant height (0.609^{**}) and biological yield per plant (0.968^{**}). They also found positive direct effect for biological yield (0.965^{**}) and protein on seed yield.

Karnwall and Singh (2009) reported that of soybean seed yield had significant positive correlation with total dry matter weight per plant, primary branches per plant, pods per plant, seed yield efficiency, 100 seed weight and harvest index. Protein and oil contents showed significant and negative association with each other. Path coefficient analysis indicated major role of pods per plant, total dry matter weight per plant, primary branches per plant, seed yield efficiency and 100 seed weight both directly and indirectly influenced seed yield.

Iqbal *et al.* (2010) reported that oil content was positively and significantly correlated with grain yield, 100 seed weight, and harvest index, while significantly negative correlation were observed with days to maturity, plant height and number of branches per plant in 139 soybean genotypes. Significantly positive correlation was observed for days to maturity, plant height and number of branches per plant; number of branches per plant and number of pods per plant; number of pods per plant and biological yield per plant and harvest index.

Ramteke *et al.* (2010) studied correlation in soybean varieties and observed negative correlation between days to flowering and maturity and seed weight was negatively correlated with days to flowering, maturity, plant height, nodes but positively with oil content. Protein content was positively correlated with number of branches and days to 50 per flowering but negatively with oil content.

Grain yield per plant had strong significant and positive genetic correlation with plant dry matter content, number of primary branches per plant, number of pods per plant and harvest index (Aditya, 2011).

Patil *et al.* (2011) reported highly significant and positive correlation for plant height, pods per plant, days to 50 per cent flowering and days to maturity with seed yield per plant. Path analysis revealed highest positive direct effect of pod per plant on seed yield per plant followed by plant height. The studies suggest that selection for pods per plant, seed yield and plant height can be used to identify high yielding varieties of soybean.

Positive and significant phenotypic correlation of seed yield with number of branches per plant, pods per plant, pod weight, number of seeds per plant, biomass and harvest index was reported by Salimath *et al.* (2011).

Bello *et al.* (2012) reported significant correlations of days to flowering and maturity, plant height and number of pods per plant with seed yield in 56 genotypes of soybean.

Sarutayophat and Songklanakarin (2012) studied 22 genotypes of the vegetable soybean to determine the association of yield and its components with correlation coefficient and path coefficient analysis to estimate direct and indirect effects of each character on pod yield. The results revealed that positive and significant correlation existed between the plant height and number of marketable pods per plant (0.821^{**}), plant height and marketable pod yield (0.520^{*}), and number of marketable pods per plant and marketable pod yield (0.822^{**}). Negative and significant correlation was seen between the plant height and green pod weight (-0.620^{**}), and number of marketable pods per plant and green pod weight (-0.588^{**}). Direct effects of the number of marketable pods per plant and green pod weight on marketable pod yield were positive and significant with path coefficients of 1.310^{**} and 0.707^{**}, respectively. Indirect effect of the plant height on marketable pod yield through its association with number of marketable pods per plant was positive and significant (1.075^{**}). The results of this study suggested that the number of marketable pods per plant, green pod weight and plant height were important characters that should be taken into account as selection criteria in improving marketable pod yield of the vegetable soybean.

Sultan *et al.* (2012) reported positive and significant correlation of branches per plant, clusters per plant, pods per cluster, pods per plant and pod width with seed yield per plant in guar. Days to flower initiation, 50% flowering, days to maturity and plant height were significantly and negatively correlated with seed yield per plant in guar.

Tyagi *et al.* (2012) studied path analysis of 40 genotypes of soybean. The path analysis indicated high positive direct effect of total seedling dry weight and total seedling length on seed yield and protein content. They reported that two seedling characters may be used as early indicators in selection programmes in soybean. Ashraf *et al.* (2013) found positive correlation of seed yield ha^{-1} of soybean with number of branches $plant^{-1}$, number of pods $plant^{-1}$, 1000 seed weight and seed yield $plant^{-1}$.

Bahadur *et al.* (2013) studied genotypic and phenotypic correlation among different characters like plant height, number of primary branches, number of inflorescence, number of flowers, number of pods, pod length, pod weight showed positive significant correlation with pod yield per plant at genotypic level and phenotypic level in dolichos bean.

Chaudhari *et al.* (2013) studied forty vegetable dolichos bean genotypes for variability, correlation and path analysis. Green pod yield was highly significantly and positively correlated with number of branches per plant at both genotypic and phenotypic levels. Path coefficient analysis indicated that high positive direct effect for number of pods per plant followed by number of seeds per pod and number of days to last picking.

Ghodrati (2013) observed high broad sense heritability (81, 76 and 74%) and genetic advance (0.35, 0.20 and 0.40) for the number of nodes plant^{-1}, days to flowering and plant height respectively. The correlation studies recorded significant positive correlation ($r = 0.61^{*}$) between plant height and seed yield. The plant height is positively correlated with number of nodes plant^{-1}, number of pods plant^{-1}, number of seeds pod^{-1}, number of seeds plant^{-1} and protein yield. It was concluded that simultaneous selection for improving seed yield through increasing the number of nodes plant^{-1}, number of pods per plant and plant height would be an effective approach to increase seed yield as well as protein content.

Lil *et al.* (2013) evaluated thirty vegetable soybean and the results showed that fresh pod yield was positively correlated with 3-seed pod per plant (0.81^{**}), 2-seed pod per plant (0.76^{**}), 2-seed pod width (0.59^{**}) and 100-fresh seed weight (0.47^{**}), and negatively correlated with plant height (-0.75^{**}) and 2-seed pod length (-0.64^{**}). Path coefficient analysis also revealed that 3-seed pod per plant (0.58) had the greatest direct positive effect on fresh pod yield, followed by 2-seed pod per plant (0.56), 2-seed pod width (0.31), and 100 fresh seed weight (0.23), whereas plant height (-0.36) and 2-seed length (-0.35) had negative direct effect on fresh pod yield. It was concluded that more considerations should be given to the number of seedpod per plant, 2-seed pod width, 100-fresh seed weight, plant height, and 2-seed pod length when selecting higher fresh pod yield of vegetable soybean.

Magalingam *et al.* (2013) evaluated twenty-three genotypes of hyacinth bean for correlation and path analysis. They reported that individual green pod weight, percentage of pod set, number of flowers per cluster and number of pods per plant exhibited significant positive correlation and direct positive effect on yield.

In dolichos bean, Parmar *et al.* (2013) reported significant positive phenotypic correlations between yield and yield components including days to first pod set, days to 50% flowering, number of pods per plant, weight of 10 green pods and length of pod.

Salim *et al.* (2013) reported that seed yield per plant was positively and significantly correlated with days to first flowering, days to 50% flowering, days to first pod setting, number of pods per plant, pod yield per plant in dolichos bean. Path coefficient analysis showed that days to first flowering, days to 50% flowering, number of pods per plant, 20 pod weight, pod yield per plant, pod length, number of seeds per pod, number of seeds per plant, 100-seed weight influenced the seed yield per plant directly in positive direction.

Asaduzzaman *et al.* (2014) studied fourteen genotypes of lablab bean for sixteen yield and yield contributing characters. Seed yield per plant showed positive and significant correlation with days to maturity, number of raceme per plant, raceme length, pod length, green pod yield per plant, green test weight and shelling percentage and significant negative correlation with days to maturity, number of seeds per pod and protein content at both phenotypic and genotypic levels.

Kiran *et al.* (2014) reported that number of pods per plant, pod width, pod weight and pod length had positive correlation with pod yield per plant. The characters like number of branches and leaf length showed positive relation with total yield. However, days to 50% flowering and days to first picking showed negative effect on yield in dolichos bean.

In Indian bean, Ravinaik *et al.* (2014) observed that pod yield per plant was significant and positively correlated with plant height, number of branches per plant, number of flowers per cluster, number of pods per cluster, pod length, pod width and number of pods per plant at both phenotypic and genotypic levels, but days to 50% flowering had kept significant and negative correlation with pod yield per plant at both phenotypic and genotypic levels.

The Indian bean genotypes can be improved by simultaneous selection through spikes per plant, days to first flowering, days to 50% flowering, days to first pod harvest, pod length, pod width, pod girth and test weight (Sharma *et al.* 2014)

Das *et al.* (2015) observed interrelation among component characters and reported pod yield had significant and positive correlation with number of pods per plant at both genotypic and phenotypic levels in pole type of dolichos bean. However, positive correlation with pod yield was depicted by pod length, pod width and number of seeds per pod in pole type and number of pods per plant in bush type.

Dubey *et al.* (2015) evaluated 50 soybean genotypes and found highly significant positive correlation for number of pods node^{-1}, number of seeds plant^{-1}, biological yield plant^{-1}, number of nodes plant^{-1} and harvest index on seed yield. The path analysis revealed that number of pods node^{-1} had the high positive direct effect on seed yield plant^{-1} followed by number of nodes plant^{-1}, number of seed yield plant^{-1}, biological yield plant^{-1} and harvest index. Traits *viz.,* number of pods plant^{-1}, days to 50 per cent flowering, days to maturity had negative direct effect on seed yield plant^{-1}. The other traits had indirect effect via number of branches plant^{-1}, number of pods plant^{-1} and 100 seed weight.

Jain *et al.* (2015) studied correlation and path coefficient analysis in soybean for seed yield per plant and its components. The study revealed that seed yield per plant showed positive and significant association with biological yield, pods per plant and 100 seed weight. The path coefficient analysis revealed that biological yield, number of pods per plant and 100 seed weight were major characters influencing seed yield directly and indirectly. The results indicated that biological yield is responsible for improving of seed yield in soybean.

Kumar *et al.* (2015) found significant correlation between yield and its component traits in forty two soybean accessions. Path analysis revealed that number of clusters (0.402) and number of pods (0.313) had highest direct effect on grain yield and thus selection based on these traits would be quite fruitful.

Mahbub *et al.* (2015) reported correlation and path analysis in soybean genotypes. Seed yield was positively correlated with plant height, pod length, number of seeds per pod, number of pods per plant, hundred seed weight, branches per plant and number of seeds per pod. Path analysis showed positive direct effect for seeds per pod, hundred seed weight, pod length, days to maturity and plant height on yield.

Singh *et al.* (2015) studied twenty four dolichos bean genotypes. They found that pod length, number of seeds per pod, number of pods per plant and pod yield per plant had positive and significant correlation with pod yield. Path coefficient analysis revealed maximum direct effect of days to 50% flowering, pod width, number of pods per plant and pod yield per plant on pod yield indicating characters of importance for yield improvement

Bhartiya and Aditya (2016) evaluated twenty two elite breeding lines of black seeded soybean for 14 morphological traits and found highly significant positive phenotypic and genotypic correlation of grain yield with traits *viz.*, dry matter weight per plant (0.95 and 1.0) followed by 100 seed weight (0.75 and 0.87) and number of pods per plant (0.52 and 0.50). The study revealed dry matter content per plant and 100 seeds weight along with days to maturity can be considered as key traits that can play a crucial role in the genetic improvement of black seeded soybean genotypes.

Chavan *et al.* (2016) reported correlation and path coefficient analysis in thirty genotypes of soybean for eleven characters. The correlation analysis revealed that seed yield per plant showed highly significant positive association with 100 seed weight (0.4996),followed by number of pods per plant (0.2919) and protein content (0.2589). Branches per plant (-0.0074) and seeds per pod (-0.0013) showed negative and non-significant association with seed yield per plant. Path coefficient analysis showed that 100 seed weight (0.4996), number of pods per plant (0.2919), oil content (0.2176), days to 50 per flowering (0.2068), and days to maturity (0.0531) had high positive direct effect on seed yield per plant. The plant height (-0.1208) and protein content (-0.0539) had negative direct effect on seed yield per plant.

The results of correlation analysis in soybean conducted by Prateek *et al.* (2016) showed that significant positive correlation of pods per plant (0.748^{**}), seed index (0.665^{**}), clusters per plant (0.489^{**}), plant height (0.485^{**}) and pod length (0.481^{**}) with grain yield per plant.

Kuswantoro (2017) reported significant positive correlation between number of branches plant^{-1} with number of reproductive nodes plant^{-1}and number of filled pods plant^{-1}in soybean lines. They also found negative correlation between days to flowering with grain yield.

2.4 Genetic divergence and selection index

Kumar *et al.* (2004) studied the genetic diversity of eighty four soybean genotypes by using Mahalanobis D^2 statistic. These genotypes were grouped into thirteen clusters. The pattern of distribution of genotypes from different regions in various clusters was at random, indicating that geographical separation may not be the only factor causing genetic diversity. Plant height, protein content, days to maturity, 100 seed weight, total biomass per plant and oil content contributed maximum towards total genetic divergence in soybean. Based onthe divergence studies, crosses may be made between the genotypes of cluster 2 *viz.,* LSb23, PK 1029, JS 335, LSb 28 and Cluster 8 *viz.,* LSb 1 followed by cluster 13 *viz.*, AVRDC 516, RSC 1, WC 67, IC 15768, IC 15961 and cluster 8 *viz.,* LSb 1 to obtain new recombinants in soybean.

Sood *et al.* (2006) reported the extent of genetic diversity present among 61 soybean genotypes. Cluster analysis grouped 90 germplasm into eleven different clusters based on the degree of divergence between the genotypes. Clustering pattern revealed non-parallelism between genetic diversity and geographical distribution. Maximum inter-cluster distance was found between clusters II and IX (D=150.36) followed by that between clusters II and XI (D=129.64), II and VIII (D=124.78), X and XI (D=117.46), IV and IX (D=101.49) and IV and XI (D=100.02) indicating that these groups were highly divergent from each other. Number of cluster per plant (33.61) followed by plant height (23.28) and oil content (10.27) were contributed 67.16 per cent of the total divergence.

Manish *et al.* (2009) studied thirty three genotypes of French bean and reported that 18 appeared in cluster II. The higher order of divergence was recorded between clusters II and I. Genotypes included in cluster I were good source of yield per plant, number of seeds per pod, number of pods per plant and seed length, number of seeds per pod and number of fruits set accounted for 93% of the total divergence. Thus, these characters hold great promise in breeding strategy.

Olivia *et al.* (2010) studied twelve genotypes for divergence in pea and grouped them into four clusters. Cluster I retained the maximum number of genotypes while cluster II and cluster III also had three genotypes of each and while, cluster IV each accommodated only one genotype. The maximum value of inter cluster distance was observed for cluster I. Cluster IV showed the maximum value of cluster mean for length of pods, breadth of pods, number of seeds per pod, number of pods per plant, pod yield per plant, seed yield per plant and shelling percent. This cluster consist of only one genotype i.e. PSM-3. This strain is suitable for creating much variability for these characters in further hybridization programme.

Devendra *et al.* (2011) studied thirty two genotypes of dolichos bean for nine yield and its contributing characters by Mahalanobis's D^2 analysis. Thirty two genotypes were grouped into five clusters the highest intra cluster distance was observed for cluster III followed by cluster V, cluster IV and cluster II. The highest inter cluster distance was observed between the clusters III and cluster I followed by cluster IV and I and cluster V and I. The minimum inter cluster distance was noted in between IV and II. The genotypes collected from same geographical location fall in different clusters, revealed that geographical distance do not contribute to genetic divergence.

Patil *et al.* (2011) evaluated sixty eight advanced lines of soybean and analysed genetic diversity using Mahalanobis D^2 statistic. They were grouped in to fourteen clusters for seed yield and its components. Maximum inter cluster distance was obtained between clusters II and VIII followed by clusters VIII and IX. These clusters included the genotypes Himso 1610, Himso 1629, Himso 1630, Himso 1631, Himso 1606, Himso 1655, Himso 1636, Himso 1650, Himso 1609 and Himso 1669 derived from the crosses Himso 330 x Punjab-I, Himso 1520 x Himso 330, Punjab -I x DS 74-22, P7-1-1 x PunjabI,PK 1053 x Punjab-I and Himso 330 x Hardee.

Chaitanya *et al.* (2013) reported the genetic divergence for 19 characters among 48 genotypes of Indian bean. Genotypes were grouped into eight clusters on the basis of relative magnitude of D^2 values. The highest number of genotypes (14) appeared in cluster III. The maximum inter cluster distance was observed between cluster IV and cluster VI followed by cluster IV and VIII. The minimum inter cluster distance was observed between cluster I and cluster IV. Maximum intra cluster distance was in cluster V followed by cluster III. The mean value for most of the traits was highest in cluster VIII. Among the yield contributing characters, the maximum contribution towards divergence was made by protein content followed by number of flowers per inflorescence, pod length and number of pods per plant. Hybridization between cluster IV and VI could be utilized for getting the superior recombinants or transgress segregants in segregating generations.

Pawar *et al.* (2013) fifty eight diverse genotypes of lablab were evaluated for their genetic divergence for grain yield and yield contributing characters. The genotypes were grouped into seven clusters on the basis of relative magnitude of D^2 values. The maximum genetic distance was observed between cluster IV and cluster VII (45.798) followed by cluster IV and cluster VI (42.723) and cluster III and cluster VII (40.680). Cluster II and cluster III displayed lowest degree of divergence. The maximum intra cluster distance was exhibited by cluster I (22.432) followed by cluster VI (17.807) and cluster V (16.872), whereas minimum was recorded by cluster III. The maximum mean value for grain yield per plant was recorded in cluster III due to maximum number of inflorescences per plant. Protein content followed days to 50% flowering and days to maturity contributed maximum towards total divergence.

Adrull and Monpara (2014) studied variability and selection indices involving 100 germplasm lines of soybean. The study revealed that almost all the selection indices were found to be more efficient than straight selection based on seed yield alone. The index consisting of all the six traits gave the highest genetic gain and selection efficiency. Inclusion of pods per plant in selection index appears to increase its relative efficiency and is mainly based on four characters, *viz*., clusters per plant, pods per plant, biological yield per plant and harvest index.

Kachhadia (2014) studied the genetic divergence among 115 soybean accessions by clustering the genotypes into six groups and their inter-group distances revealed that genotypes in Cluster III comprised of BARI Soybean 5, G00083, BARI Soybean 6, G00342, BD 2338, BD 2355, BD 2329, BD 2340, AGS 95, G00056, AGS 129, BD 2336, BGH 02026, BGM 02093, Galarsum, BD 2350, G00084, BD 2331, G00103 indicated better performance which could be marked for the selection of yield potential genotypes through further evaluation.

Ananya *et al.* (2015) undertaken to ascertain the extent of genetic diversity present among 90 Indian bean genotypes using D2 statistic. Cluster analysis grouped

90 germplasm into sixteen clusters based on the degree of divergence between the genotypes. Clustering pattern revealed non-parallelism between genetic diversity and geographical distribution. Maximum intra-cluster distance was observed in cluster IV indicating greater genetic divergence between the genotypes belonging to this cluster. Number of green pods yield per plant, number of green pods per branch, number of green pods per plant, and green pod weight contributed 80.68 per cent to total divergence. Maximum inter-cluster distance was recorded between clusters XV and XVI followed by clusters VII and XV indicating wide genetic diversity and it may be used in Indian bean hybridization programme for improving yield.

Baruah *et al.* (2015) evaluated thirty six genotypes of soybean obtained from different eco geographical regions of India, for eleven characters. The D^2 values ranged from 33.64 to 379.08 indicating substaintial genetic diversity. The clustering pattern revealed that genetic diversity was not necessarily associated with geographical diversity in this crop. The hybridization programme was suggested on the basis of inter cluster divergence and cluster means for the character studied.

Dhillon and Ajay Kumar (2015) studied 30 genotypes of dolichos for genetic divergence studies, the genotypes were grouped into 11 clusters on the basis of relative magnitude of D^2 values. Maximum inter cluster distance was recorded between Clusters VII and I, indicating a wide diversity among these two clusters. Minimum inter cluster distance was observed between Clusters IX and VIII, indicating their close relationship. Thus, Clusters VII and I were generally the most divergent from the other clusters. Intra-cluster value was highest for Cluster IX. Intra-cluster distance was least for Clusters VI and X. Among the genotypes, SC-5, SC-7, SC-11, SC-16 and SC-17 were the best in traits related to yield compared to the Check (PS-2).

Verma *et al.* (2016) evaluated twelve genotypes of dolichos bean for their genetic diversity using Mahalanobis D^2 statistic and were grouped in to four clusters. The maximum genetic distance was observed between cluster I and cluster III followed by cluster II and Cluster III. Cluster I and cluster II displayed lowest degree of divergence. The maximum intra cluster distance was exhibited by cluster III followed by cluster IV. The mean value for most of the traits was highest in cluster II. Geographical and genetic diversity were observed to be unrelated as genotypes from diverse geographical regions were placed in the same cluster, while genotypes from the same centre were grouped into different clusters.

Mahesh *et al.* (2017) reported the genetic divergence of 11 important characters in forty genotypes of soybean using Mahalanobis's D2 Statistics. The genotypes were grouped into six clusters. The cluster III was the largest cluster with thirteen genotypes. The highest inter cluster distance was observed between cluster I and cluster VI followed by between V & VI and V and VI respectively. The genotypes JS 20-89 having diverse genetic base for yield contributing components (cluster VI) was identified for yield characters primary branches per plant (3.67), number of pods per plant (111.67), number of seeds per pod(2.78), number of three seeded pods per plant(95.33), harvest index (35.21) and seed yield per plant. Whereas genotypes RVS 2000-4, KDS 72, NRC 107, RVS 2002-22, RVS 2002-19, MAUS613 can be used for shorter maturity duration and plant height (cluster I) was identified for early maturity with early flowering habit and average plant height. Genotypes included in these two clusters can be utilized for future crop improvement programme.

Manav and Arora (2017) studied forty five germplasm accessions of soybean for genetic variability. Genetic advance as percent of mean was maximum for number of pods per plant. Thus, it may be concluded that a great amount of variability existed in the present material and it would be desirable to give emphasis on number of branches per plant, number of pods per plant and number of seeds per pod traits for selection of high yielding genotypes in soybean.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present study entitled "Performance analysis of vegetable soybean (*Glycine max* L.) in humid tropics" was carried out at research fields of Department of Vegetable Science, College of Horticulture, Vellanikkara which is located at an altitude of 23 m above MSL and between 10° 32"N latitude and 76° 16" E longitude. The experiment was conducted during October to December 2017 with an objective, to evaluate the performance of vegetable soybean accessions for yield and quality in the humid tropics of Kerala. The materials used and methods adopted for undertaking the study are described in this chapter.

3. A. EXPERIMENTAL MATERIALS AND METHODS

3. A. 1. Cataloguing of soybean genotypes

Twenty eight genotypes collected from IIHR, Bangalore were catalogued (Table 2) based on the descriptor for soybean.

3. A. 2. Experimental Materials

Experimental materials consisted of 28 vegetable soybean (*Glycine max*) genotypes, collected from Indian institute of Horticultural Research, Bangalore (Table 1).

Table 1. Source of vegetable soybean accessions used in the study

Sl. No.	Genotype	Accession Number	Source
1	GM-1	EC771156	IIHR, Bangalore
2	GM-2	EC771205	IIHR, Bangalore
3	GM-3	EC771208	IIHR, Bangalore
4	GM-4	EC771223	IIHR, Bangalore
5	GM-5	EC771190	IIHR, Bangalore
6	GM-6	EC771240	IIHR, Bangalore
7	GM-7	EC771215	IIHR, Bangalore
8	GM-8	EC771217	IIHR, Bangalore

9	GM-9	EC771211	IIHR, Bangalore
10	GM-10	EC771167	IIHR, Bangalore
11	GM-11	EC771146	IIHR, Bangalore
12	GM-12	EC771155	IIHR, Bangalore
13	GM-13	EC771169	IIHR, Bangalore
14	GM-14	EC771173	IIHR, Bangalore
15	GM-15	EC771213	IIHR, Bangalore
16	GM-16	EC771187	IIHR, Bangalore
17	GM-17	EC771224	IIHR, Bangalore
18	GM-18	EC771188	IIHR, Bangalore
19	GM-19	EC771176	IIHR, Bangalore
20	GM-20	EC771189	IIHR, Bangalore
21	GM-21	EC771200	IIHR, Bangalore
22	GM-22	EC771161	IIHR, Bangalore
23	GM-23	EC771166	IIHR, Bangalore
24	GM-24	EC771171	IIHR, Bangalore
25	GM-25	EC771233	IIHR, Bangalore
26	GM-26	EC771194	IIHR, Bangalore
27	GM-27	EC771183	IIHR, Bangalore
28	GM-28	EC771191	IIHR, Bangalore

Table 2. Descriptor of vegetable soybean

1.Vegetative characters		
1.1	Growth habit	Determinate/Semi determinate/Indeterminate
1.2	Leaf shape	Lanceolate/Pointed ovate/Rounded ovate
1.3	Leaf colour	Green/Dark green
2. Floral characters		
2.1	Flower colour	White/Purple
3. Pod characters		
3.1	Pod colour	Light green/Green/Dark green
3.2	Pod pubescence	Absent/present
3.3	Pod shape	Straight/Slightly curved/curved

3. A.3 Experimental methods

The experiment was laid out in a randomized block design with three replications during Oct-Dec, 2017 in research field of Department of Vegetable Science. Each replication consisted of twenty eight plots and there were twenty plants per plot per genotypes. Crop was raised in one season, during October to December, 2017. Farmyard manure was applied basally at the rate of 16.2 kg per plot and mixed thoroughly with the soil. Basal dose of fertilizers was also applied at the rate of 16.2 g N, 24.3 g P and 6.5 g K per plot. Seeds were sown at a spacing of 45 cm X 45 cm and started germination in 4 to 6 days. During cropping period various cultural operations and prophylactic plant protection measures were adopted as per KAU package of practices (2016).

3. B. MORPHOLOGICAL CHARACTERS STUDIED

Observations on morphological characters were recorded as per NBPGR descriptor. Five plants were selected randomly from each plot to record observations on plant height, days to 50% flowering, days to first harvest, days to vegetable maturity, pod length, pod width, pod yield per plant, number of pods per plant, pod weight, number of harvests and the average was calculated for further statistical analysis.

3. B. 1. Morphological characters

Observation on leaf shape, leaf colour, flower color, growth habit, pod color, pod pubescence and pod shape were recorded as per the NBPGR descriptor for soybean (*Glycine max* L.).

1. Plant height (cm)

The height of the plant was measured from ground level to the tip of the plant at 60 days after sowing using meter scale.

2. Days to 50 per cent flowering

Number of days taken from the date of sowing to the day on which 50% of the plants started flowering was recorded.

3. Days to first harvest

The number of days from the date of sowing to the date of first harvest of the pods at vegetable maturity was recorded.

4. Days to vegetable maturity

The number of days taken from flower opening to vegetable maturity of the pod in selected plants were recorded.

5. Pod length (cm)

Length of five randomly selected pods at vegetable maturity was measured.

6. Pod width (cm)

The width was recorded on the pods which were used for measurement of length.

7. Pod yield per plant (g)

The pod yield per plant at every harvest from each of the selected plant was recorded and average was calculated.

8. Number of pods per plant

The number of pods present on main stem and branches in each of the five selected plants were recorded and average was calculated.

9. Pod weight (g)

The weight of five pods from each genotype was recorded separately and average was worked out.

10. Number of seed per pod

The number of seeds per pod was counted from the five randomly selected pods in each genotype.

18. Number of harvests

The total number of harvests from the five randomly selected plants were recorded and average was calculated.

19. Number of root nodules per plant

The number of root nodules per plant was counted from five randomly selected plants in each replication.

20. Incidence of pests and diseases

3. B. 2. Quality parameters

1. Starch

The starch content was analyzed colorimetrically using anthrone reagent as suggested by Sadasivam and Manickam (1997). Starch content was estimated by hydrolysing starch into simple sugars. The sample (0.5g) was treated with 80 per cent ethanol to remove sugars and then starch was extracted with perchloric acid. Sample extract (0.2ml) was pipetted and tubes with one ml water served as blank. To each test tube including blank, anthrone reagent (4ml) was added. The tubes were kept in boiling water bath for 8 minutes and cooled rapidly. This compound formed a green coloured product and its absorbance was measured at 630 nm which was expressed as percentage.

2. Carbohydrates

Estimation of carbohydrates by anthrone method suggested by Sadasivam and Manickam (1997) was used to estimate the carbohydrate in fresh pods of vegetable soybean.

Fresh pods of vegetable soybean were taken and 100mg weighed into a boiling tube, added 5ml of 2.5N HCl and kept in water bath for three hours to hydrolyze the sample completely. After cooling it to the room temperature sodium carbonate was used to neutralize the solution where end point will be attained with the ceasing of effervescence upon adding sodium carbonate with the help of spatula and later volume was made up to 100ml with distilled water. Supernatant collected after filtering was taken in two different test tubes as 0.5ml and 1ml aliquots. Standards of 0, 0.2, 0.4, 0.6, 0.8 and 1ml of the working standards were taken in different test tubes and volume was made up to 1ml in all the test tubes including sample. '0' served as blank with distilled water alone.

Four ml of anthrone reagent was added to all the test tubes, heated for 8 minutes in boiling water bath and cooled rapidly followed by reading in UV-Spectrophotometer at 630nm. Concentration of total sugars in samples was calculated by plotting concentration of standards on X- axis and absorbance at 630nm on Y-axis in the graph. Total sugar will be expressed as %.

$$\text{Amount of total sugars present in 100 mg of pods} = \frac{\text{mg of total sugars}}{\text{Volume of test}} x100$$

3. Protein

The protein content of vegetable soybean was determined by Lowry's method. The sample (0.5g) was ground well in a mortar and pestle with 5-10ml of phosphate buffer. It was centrifuged and supernatant used for protein estimation was pipetted out into a series of test tubes. Sample extract (0.2ml) was pipetted out in other test tubes. Tubes with one ml water served as blank.

To each test tube including blank, Reagent C (5ml) was added. It was mixed well and allowed to stand for 10 minutes. To all test tubes Reagent D (0.5ml) was added, mixed well and incubated at room temperature in the dark for 30 minutes till blue colour was developed. Optical density values were recorded in a spectrophotometer at 660nm. A standard graph was drawn and the amount of protein in the sample was calculated.

4. Crude fibre

Crude fibre content of the sample was estimated by acid-alkali digestion method.

A known weight of the sample was first treated with acid and subsequently with alkali. The residue obtained after final titration was weighed, incinerated, cooled and weighed again. The crude fibre was given by the difference in weight and expressed as percentage.

5. Vitamin C

Vitamin C in pods was estimated by using 2, 6 dichloro indophenol dye. 10ml of clarified extracted sample was taken and made up to 100 ml with 2 per cent oxalic acid. This sample was diluted again. 10 ml was pipetted into conical flask and titrated against 2,6dichloro indophenol dye until the solution changes its colour from colourless to light pink. The ascorbic acid content was calculated by using the formula given below (Sadasivam and Manickam, 1997)

$$\text{mg of ascorbic acid } 100\ g^{-1} = \frac{\text{Titer value}}{\text{Aliquot of extract taken for estimation}}\ x\ \frac{\text{dye factor}}{\text{vol. of sample takenfor estimation}}\ x100$$

6. Polyphenols

Polyphenols estimation was carried out with Folin- Ciocalteau reagent. Phenols react with phosphomolybdic acid in alkaline medium and produce a blue coloured complex (Molybdenum blue).

The sample (1 g) was ground well in a mortar and pestle with 10-15ml of 80 per cent ethanol. It was centrifuged and the residue was re-extracted twice and pooled. The supernatant was evaporated to dryness. The residue was dissolved with 5ml of distilled water. The supernatant used for total phenol estimation was pipetted out into a series of test tubes. Sample extract (0.2ml) was pipetted out in other test tubes.

To each test tube including blank, 3ml distilled water was added. It was mixed with 0.5 ml Folin-Ciocalteau reagent. It was mixed well and allowed to stand for 3 minutes. To all test tubes, 20 per cent sodium carbonate (2ml) was added, mixed thoroughly and kept for 1 hour. All the tubes were kept in boiling water for exactly one minute and cooled. Optical density values were recorded in a spectrophotometer at 650nm. A standard graph was drawn and the amount of total phenol in the sample was calculated.

7. Phosphorous, Calcium and Iron

7.1 Collection and digestion of pod samples

At the time of harvesting, pods were collected from five randomly selected five plants were kept in an oven @ 60^{0}C for 10days. Later these samples were powdered and stored in polythene covers. These samples were digested using microwave digester. Phosphorus, calcium and iron content were suggested by Jackson (1973) and Piper (1966).

<table>
<tr><th>Parameter</th><th>Method</th><th>Reference</th></tr>
<tr><td>Phosphorus</td><td>Vanado–molybdo–phosphoric(Barton’s reagent) yellow colour</td><td>Jackson, 1973</td></tr>
<tr><td>Calcium</td><td rowspan="2">Digested in microwave and estimated by ICP-OES</td><td rowspan="2">Piper, 1966</td></tr>
<tr><td>Iron</td></tr>
</table>

3. C. Organoleptic evaluation

A panel of 15 judges were selected using triangle test (Jellinek, 1985) and organoleptic qualities were evaluated using 9 point hedonic scale.

The cooked pods were evaluated using a nine-point hedonic scale to assess the colour and appearance, flavour, taste, texture, after taste and overall acceptability of the products by a panel of 15 judges. Selection of best genotypes was done by using statistical analysis.

3. D. Statistical analysis

The mean of the values observed on five plants in each replication were taken for statistical analysis. The data thus obtained were processed for analysis of variance, genotypic and phenotypic variances, heritability, genetic advance, genetic gain, genotypic and phenotypic co-efficient of variation, genotypic and phenotypic correlation coefficients and path coefficients. The analysis techniques suggested by Fisher (1954) was employed for estimation of various genetic parameters.

3. D.1 Phenotypic, genotypic and environmental variance

The variance components were estimated using the formula suggested by Burton (1952).

Phenotypic variance (V_p) = Vg + Ve

Where,

Vg	=	Genotypic variance
Ve	=	Environmental variance

Genotypic variance (Vg) = (V_T - V_E) / N

Where,

V_T	=	Mean sum of squares due to treatments
V_E	=	Mean sum of squares due to error
N	=	Number of replications

Environmental variance (V_e) = V_E

3. D. 2 Phenotypic and genotypic coefficient of variation

The phenotypic and genotypic coefficient of variation were calculated by the formula suggested by Burton and Devane (1953).

Phenotypic coefficient of variation (pcv) = ($V_p^{1/2}$ / X) x 100

Where,

V_p	=	Phenotypic variance
X	=	Mean of characters under study

Genotypic coefficient of variation (gcv) = ($V_g^{1/2}$ / X) x 100

Where,

V_g	=	Genotypic variance
X	=	Mean of characters under study

3. D. 3 Heritability

Heritability in the broad sense was estimated by the formula suggested by Burton and Devane (1953).

$$\mathbf{H^2} = (V_g / V_p) \times 100$$

Where,

V_g	=	Genotypic variance
V_p	=	Phenotypic variance

The range of heritability was categorized as suggested by Robinson *et al.* (1949) as

0-30 per cent	-	low
31-60 per cent	-	moderate
61 per cent and above	-	high

3. D.4 Expected genetic advance

The genetic advance expected for the genotype at five per cent selection pressure was calculated using the formula by Lush (1949) and Johnson *et al.* (1955) with value of the constant K as 2.06 as given by Allard (1960).

Expected genetic advance GA $= (V_g / V_p) \times K$

Where,

V_g	=	Genotypic variance
V_p	=	Phenotypic variance
K	=	Selection differential

3. D.5 Genetic gain (genetic advance as percentage of mean)

Genetic advance (GA) calculated by the above method was used for estimation of genetic gain.

Genetic gain, GG $= (GA / X) \times 100$

Where,

GA	=	Genetic advance
X	=	Mean of character under study

45

The genetic gain was classified according to Johonson *et al.* (1955) as follows

1-10 per cent	-	low
11-20 per cent	-	moderate
21 per cent and above	-	high

3. D.6 Phenotypic, genotypic and environmental correlation coefficients

The phenotypic, genotypic and environmental correlation coefficients were worked out to study the extent of association between the characters. The phenotypic, genotypic and environmental covariances were worked out in the same way as the variances were calculated. Mean product expectations of the covariance analysis are analogous to the mean square expectations of the analysis of variances.

3. D.7 Correlation

Genotypic (r_g) and phenotypic (r_p) correlation coefficients were estimated as suggested by Al-Jibourie*et al.* (1958).

Genotypic correlation $= r_{xy}(g) = \dfrac{Cov_{xy}(G)}{\sqrt{V_x(G) \text{ x } V_y(G)}}$

Phenotypic correlation $= r_{xy}(p) = \dfrac{Cov_{xy}(P)}{\sqrt{V_x(P) \text{ x } V_y(P)}}$

Where,

$Cov_{xy}(G)$	=	Genotypic covariance between x and y
$Cov_{xy}(P)$	=	Phenotypic covariance between x and y
$V_x(G)$	=	Genotypic variance of character 'x'
$V_x(P)$	=	Phenotypic variance of character 'x'
$V_y(G)$	=	Genotypic variance of character 'y'
$V_y(P)$	=	Phenotypic variance of character 'y'

The test of significance for association between characters was done by comparing table r values at n-2 error degrees of freedom for phenotypic and genotypic correlations with estimated values, respectively.

3. D.8 Path coefficient analysis

Path co-efficient analysis suggested by Wright (1921) and Dewey and Lu (1959) was carried out to know the direct and indirect effect of the morphological traits on plant yield. The following set of simultaneous equations were formed and solved for estimating various direct and indirect effects.

$r_{1y} = a + r_{12}b + r_{13}c + \ldots\ldots\ldots + r_{1Ii}$

$r_{2y} = a + r_{21}a + b + r_{23}c + \ldots\ldots\ldots + r_{2Ii}$

$r_{3y} = r_{31}a + r_{32}b + c + \ldots\ldots\ldots + r_{3Ii}$

$r_{1y} = r_{11}a + r_{12}b + r_{13}c + \ldots\ldots\ldots + I$

Where,

r_{1y} to 1_{1y} = Co-efficient of correlation between causal factors 1 to I with dependent characters y.

r_{12} to r_{1I} = Co-efficient of correlation among causal factors

a, b, c.......i = Direct effects of characters 'a' to 'I' on the dependent character 'y'

Residual effect (R) was computed as follows.

Residual effect (R) = $1 - \sqrt{a^2 + b^2 + c^2 + \ldots i^2 + 2abr_{12} + 2acr_{13} + \ldots}$

Lenka and Mishra (1973) have suggested a scale for the importance of direct and indirect effects values as given below:

Values of direct and indirect effects	Rate of scale
0.00-0.09	Negligible
0.10-0.19	Low
0.20-0.29	Moderate
0.30-0.99	High
More than 0.99	Very high

3. D.9 Genetic divergence

3. D.9.1 Mahalanobis D^2 analysis

Mahalanobis (1936) D^2 statistics was used for assessing the genetic divergence between populations comprising 28 vegetable soybean genotypes. The original correlated unstandardized character mean values were transformed into standardised uncorrelated values to simplify the computational procedure. The D^2 values were obtained as the sum of squares of the differences between the pairs of corresponding uncorrelated (Ys) values of any two genotypes (Rao, 1952). A total of $\frac{n(n-1)}{2}$ D^2 values were calculated.

Where, n = number of genotypes.

3.6.9.2 Clustering of genotypes

Using all D^2 values, the genotypes were grouped into clusters using Tocher's method as described by Rao (1952).

3.6.9.3 Intra and Inter-cluster distances

The intra- and inter-cluster distances were calculated by the formula given by Singh and Chaudhary (1977).

$$\text{Intra-cluster distance} = \sqrt{\frac{D_i^2}{n}}$$

Where D_i^2 is the sum of D^2 values between all possible combinations of the genotypes included in cluster 'i'.

$$\text{Inter-cluster distance} = \sqrt{\frac{D_{ij}^2}{n_i n_j}}$$

Where, D_{ij}^2 is the sum of distances between all possible combinations ($n_i n_j$) of the genotypes included in the clusters 'i' and 'j'.

n_i = number of genotypes in cluster 'i'

n_j = number of genotypes in cluster 'j'.

EXPERIMENTAL RESULTS

4. EXPERIMENTAL RESULTS

The present investigation on "Performance analysis of vegetable soybean (*Glycine max* L.) in humid tropics" was aimed at understanding the performance of vegetable soybean in humid tropics and to study the genetic variability, heritability, correlation and path analysis and genetic divergence present in vegetable soybean genotypes. The results of the experiment are presented in this chapter.

4.1 Cataloguing of soybean

Twenty eight accessions of soybean were catalogued based on the descriptor. Morphological characters like leaf shape, leaf colour, flower colour, growth habit, pod colour, pod pubescence and pod shape were recorded (Table 3).

Table 3. Morphological characters of vegetable soybean accessions

Accession number	Leaf shape	Leaf colour	Flower colour	Growth habit	Pod colour	Pod pubescence	Pod shape
GM-1	Pointed ovate	Green	Purple	Determinate	Green	Absent	Slightly curved
GM-2	Lanceolate	Dark green	Purple	Semi determinate	Green	Absent	Straight
GM-3	Pointed ovate	Green	White	Semi determinate	Dark green	Absent	Straight
GM-4	Lanceolate	Dark green	Purple	Determinate	Green	Absent	Slightly curved
GM-5	Pointed ovate	Green	Purple	Semi determinate	Green	Absent	Curved
GM-6	Pointed ovate	Green	White	Semi determinate	Green	Absent	Slightly curved
GM-7	Lanceolate	Green	Purple	Indeterminate	Green	Absent	Slightly curved
GM-8	Pointed ovate	Dark green	White	Determinate	Dark green	Absent	Slightly curved
GM-9	Pointed ovate	Green	Purple	Indeterminate	Green	Absent	Slightly curved
GM-10	Pointed ovate	Green	Purple	Determinate	Green	Absent	Slightly curved
GM-11	Round ovate	Dark green	Purple	Determinate	Green	Present	Slightly curved

GM-12	Lanceolate	Green	Purple	Indeterminate	Green	Absent	Curved
GM-13	Round ovate	Dark green	White	Determinate	Green	Absent	Straight
GM-14	Lanceolate	Green	Purple	Determinate	Green	Absent	Straight
GM-15	Lanceolate	Dark green	Purple	Semi determinate	Green	Absent	Slightly curved
GM-16	Round ovate	Green	Purple	Determinate	Green	Present	Straight
GM-17	Pointed ovate	Green	Purple	Indeterminate	Green	Absent	Curved
GM-18	Round ovate	Green	Purple	Determinate	Green	Absent	Slightly curved
GM-19	Lanceolate	Green	Purple	Semi determinate	Green	Present	Curved
GM-20	Lanceolate	Green	Purple	Semi determinate	Green	Absent	Straight
GM-21	Pointed ovate	Green	Purple	Indeterminate	Green	Absent	Slightly curved
GM-22	Round ovate	Dark green	Purple	Determinate	Dark green	Absent	Slightly curved
GM-23	Pointed ovate	Green	Purple	Semi determinate	Green	Absent	Slightly curved
GM-24	Round ovate	Green	Purple	Determinate	Green	Absent	Straight
GM-25	Round ovate	Dark green	Purple	Determinate	Green	Present	Slightly curved
GM-26	Pointed ovate	Dark Green	Purple	Indeterminate	Green	Absent	Curved
GM-27	Pointed ovate	Green	Purple	Indeterminate	Green	Present	Slightly curved
GM-28	Pointed ovate	Green	Purple	Indeterminate	Green	Absent	Curved

The leaf shape was lanceolate, pointed ovate and rounded ovate. Most of the accessions had pointed ovate leaf shape, except GM-2, GM-4, GM-7, GM-12, GM-14, GM-15, GM-19 and GM-20 had lanceolate leaf shape and GM-11, GM-13, GM-16, GM-18, GM-22, GM-24 and GM-25 had rounded ovate leaf shape (Plate 1).

The leaf colour varied from green to dark green. All the accessions were green leaf colour except accessions like GM-2, GM-4, GM-8, GM-11, GM-13, GM-15, GM-22, GM-25 and GM-26 (Plate 2).

The flower colour was purple for all the accessions except GM-3, GM-6, GM-8 and GM-13 had white flower colour (Plate 3).

The growth habit of the accessions were determinate, semi determinate and indeterminate and was observed in the experimental plot view (Plate 4 and 8).

The pod pubescence of all the accessions were absent except GM-11, GM-16, GM-19 and GM-25 (Plate 6).

The pod colour (Plate 5) varied from light green to dark green and pod shape was straight, slightly curved and curved in the accessions (Plate 7).

4.2 Genetic variability

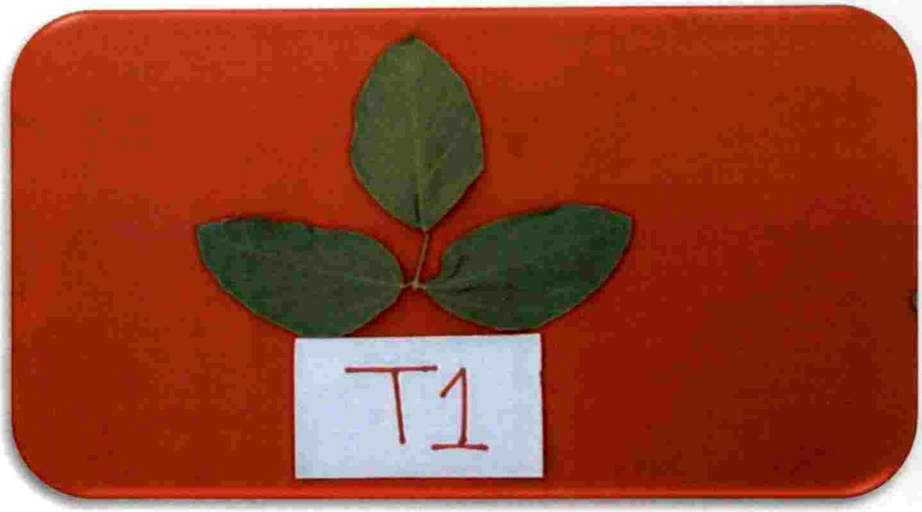
The results of the analysis of variance for 21 characters are presented in Table 4 and 6. There was significant difference between the soybean genotypes for all the characters studied except number of seeds per pods and number of root nodules.

With a view to understand the extent to which the observed variations are due to genetic factors, the range, mean, phenotypic variance (PV), genotypic variance (GV), phenotypic coefficient of variation (PCV), genotypic coefficient (GCV), broad sense heritability (H^2), genetic advance (GA) and genetic advance as percentage of mean (GAM) were worked out and are presented in Table 5 and 7. The data revealed that, existence of large amount of variability to most of the characters studied.

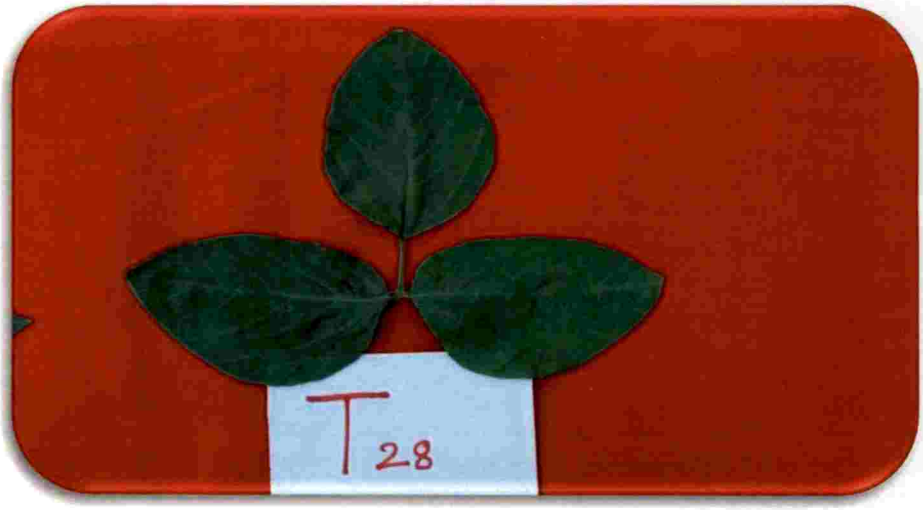
4.2.1 Variability in morphological and quality parameters in vegetable soybean genotypes

4.2.1.1 Plant height

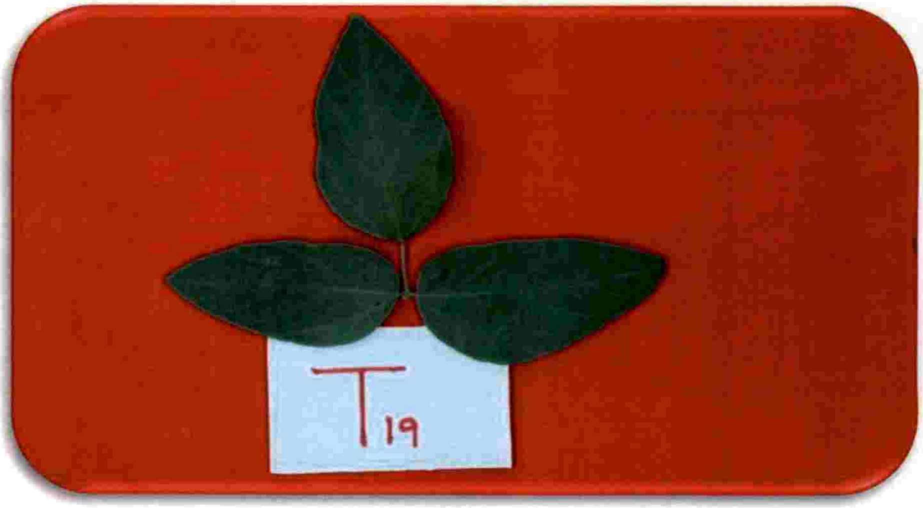
The plant height ranged from 20.53 cm (Gm-24) to 83.03 cm (Gm-27) with mean of 45.85 cm. Very high estimates of GV (392.73) and PV (394.78) with high GCV (43.21 %) and PCV (43.33%) and very high heritability (99.46%) along with high GA (40.71) and high GAM (88.77 %) were observed for plant height.



Pointed ovate

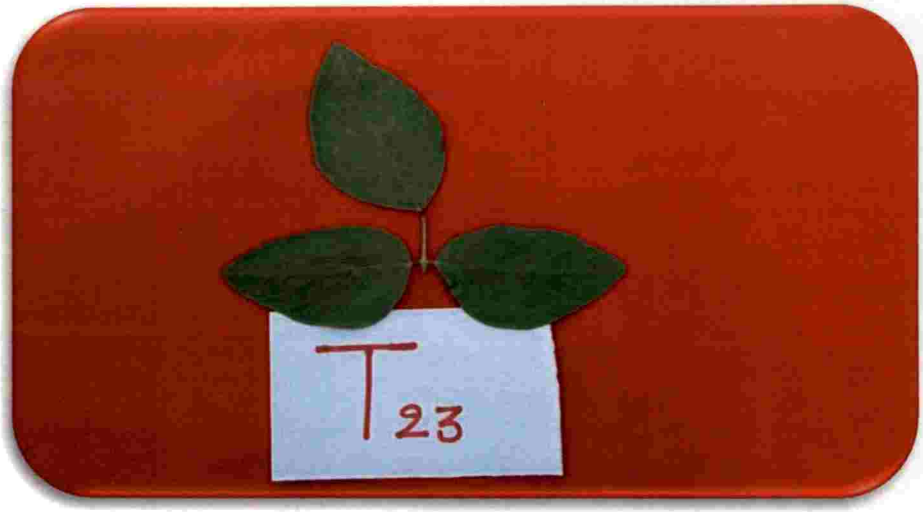


Round ovate



Lanceolate

Plate 1. Variability for leaf shape



Green

Dark Green

Plate 2. Variability for leaf colour

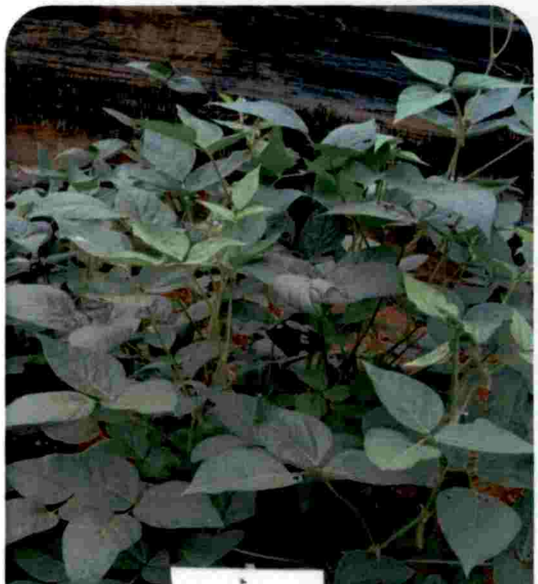
Purple

White

Plate 3. Variability in flower colour

Determinate

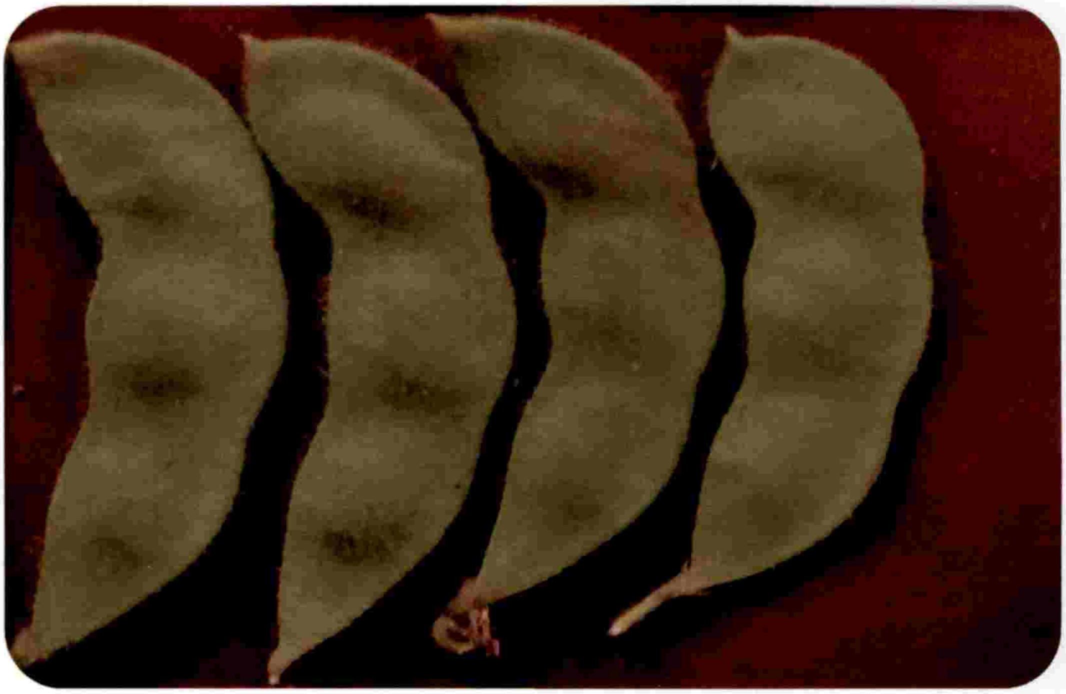
Semi determinate



Indeterminate

Plate 4. Variability for growth habit

Light green



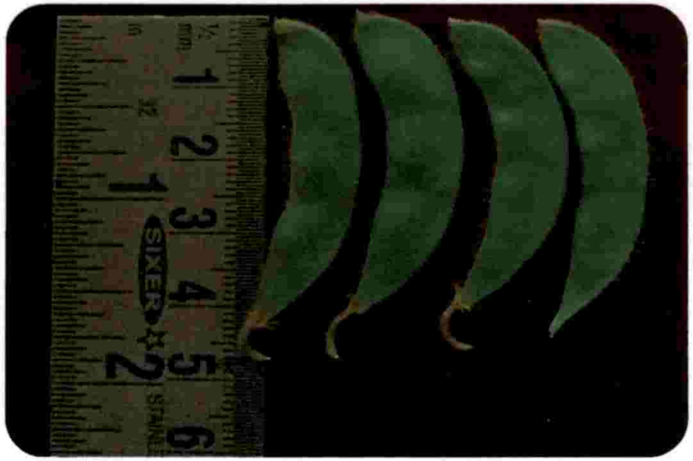
Green

Plate 5. Variability in pod colour

Pubescence present

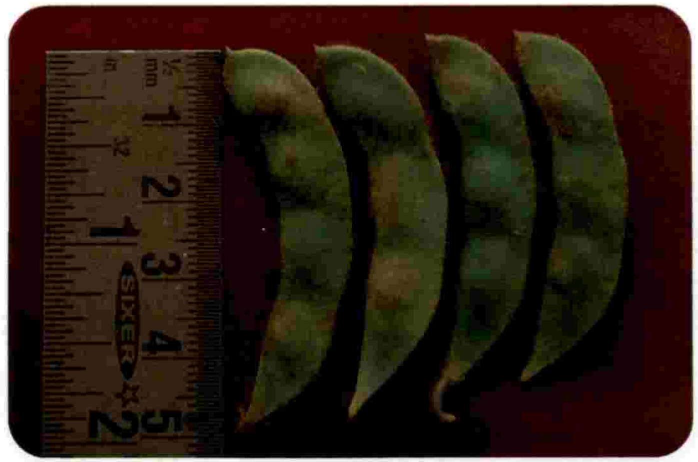
Pubescence absent

Plate 6. Variability in pod pubescence



Straight

Slightly curved



Curved

Plate 7. Variability in pod shape

Plate 8. Field view of an experimental plot

4.2.1.2 Days to 50% flowering

The genotype GM-12 took lowest number of days (27.00) to 50% flowering while, GM-23 took maximum number of days (42.00) to 50% flowering. On an average vegetable soybean genotypes attained 50% flowering in 34.13 days. The GV and PV were 12.89and 14.20 respectively. The estimates of PCV (11.05 %) was higher than GCV (10.51 %). High estimate of heritability (90.46 %) with very low GA (7.03) and moderate GAM (20.59 %) were observed for the trait.

4.2.1.3 Days to first harvest

Among the genotypes Gm-12 took minimum days to first pod harvest (35.00 days) and GM-23 took maximum days to first harvest (55.66 days). On an average genotype was ready for first harvest in 45.49 days. The PV (22.93) was greater than GV (19.87) and lower estimates of GCV (9.79%) and PCV (10.54 %) were observed. High estimate of heritability (86.23%) coupled with very low estimates of GA (8.52) and moderate GAM (18.73 %) were recorded for the trait.

4.2.1.4 Days to vegetable maturity

The genotype Gm-12 took minimum days to attain vegetable maturity (8.90 days) and Gm-23 took maximum days to attain vegetable maturity (15.97 days) and average was 12.69 days. The PV (3.37) was greater than GV (2.90) and lower estimates of GCV (13.41%) and PCV (14.49 %) were observed. High estimate of heritability (85.58%) coupled with very low estimates of GA (3.24) and high GAM (25.55 %) were also observed for the trait.

4.2.1.5 Pod length (cm)

The length of the pod ranged from 3.07 cm (GM-21) to 5.88 cm (GM-25) with a mean of 4.67 cm. The GV and PV were 0.36 and 0.36, respectively and PCV and GCV were 12.91 % and 12.88 % respectively. Very high estimates of heritability (99.64 %) coupled with low GA (1.23) and high GAM (26.50 %) for the trait.

Table 4. ***Per se*** **performance of vegetable soybean genotypes for morphological parameters**

Sl. No.	Genotypes	Plant height (cm)	Days to 50% flowering	Days to first harvest	Days to vegetable maturity	Pod length (cm)	Pod width (cm)	Pod yield/ plant(g)	No. of pods/ plant	Pod weight(g)	No. of harvests	No. of seeds per pod	No. of root nodules per plant
1	GM-1	37.80^{m}	35.00^{def}	48.00^{cd}	10.54^{mn}	5.01^{ef}	2.08^{ijk}	82.43^{abcd}	39.23^{def}	2.04^{c}	4.23^{def}	3	0
2	GM-2	41.80^{l}	31.00^{ijk}	43.66^{ghi}	12.27^{ghijk}	4.44^{k}	2.81^{ab}	59.97^{efg}	28.80^{hij}	2.03^{c}	4.67^{c}	2	0
3	GM-3	50.33^{j}	30.00^{ik}	41.00ij	11.77^{ijkl}	4.83^{g}	2.14^{fgh}	74.8^{bcde}	38.60^{def}	2.02^{c}	5.80^{b}	3	0
4	GM-4	22.73st	31.00^{ijk}	44.33^{fgh}	13.04^{fgh}	5.42^{b}	2.57^{c}	34.87^{ij}	15.43^{mn}	3.89^{a}	5.80^{b}	2	0
5	GM-5	51.00^{j}	38.00^{b}	52.00^{b}	15.66^{ab}	4.59^{ij}	2.06^{ijk}	75.10^{bcde}	34.70^{efg}	2.05^{c}	3.97^{fghi}	3	0
6	GM-6	58.03^{h}	34.33^{efg}	47.33^{cde}	14.26^{cde}	4.31^{l}	2.04^{jk}	70.70^{cde}	34.30^{efg}	2.05^{c}	4.53^{cd}	2	0
7	GM-7	70.47^{cd}	32.33^{hi}	44.66^{efgh}	12.04^{hijk}	4.43^{k}	2.14^{fgh}	59.80^{efg}	34.06^{fgh}	2.03^{c}	4.20^{defg}	2	0
8	GM-8	28.13^{r}	31.67^{ij}	44.33^{fgh}	14.74^{bcd}	5.47^{b}	2.76^{b}	37.50^{hij}	8.07^{op}	3.92^{a}	4.47^{cd}	2	0
9	GM-9	72.50^{c}	42.00^{a}	54.34^{ab}	10.34^{n}	4.97^{f}	2.24^{e}	53.47^{fgh}	28.73^{hijk}	2.05^{c}	3.33^{k}	2	0
10	GM-10	29.73^{op}	35.00^{def}	44.34^{fg}	11.50^{klm}	5.25^{d}	2.10^{ghi}	53.47^{fgh}	26.40^{ijk}	1.90^{c}	5.47^{b}	2	0
11	GM-11	28.67^{q}	36.00^{cde}	46.00^{cdef}	12.17^{hijk}	4.29^{lm}	2.15^{f}	84.57^{abc}	42.47^{cd}	1.95^{c}	5.40^{b}	3	0
12	GM-12	66.27^{ef}	27.00^{m}	35.00^{k}	8.90^{op}	5.32^{c}	2.18^{f}	88.67^{ab}	52.27^{b}	2.85^{b}	6.40^{a}	3	0
13	GM-13	24.60^{s}	29.33^{kl}	35.00^{k}	12.60^{ghij}	4.45^{k}	2.18^{f}	43.17^{hij}	11.93^{nop}	3.92^{a}	6.53^{a}	3	0
14	GM-14	32.37^{n}	34.00^{fgh}	45.66^{de}	10.73^{lmn}	4.65^{h}	2.15^{fg}	79.37^{abcd}	26.40^{kl}	3.93^{a}	4.20^{defg}	2	0

Contd..

Sl. No.	Genotypes	Plant height(cm)	Days to 50% flowering	Days to first harvest	Days to vegetable maturity	Pod length (cm)	Pod width (cm)	Pod yield/plant (g)	No. of pods/ plant	Pod weight (g)	No. of harvests	No. of seeds per pod	No. of root nodules
15	GM-15	57.33^{h}	28.00^{lm}	39.33^{j}	11.57^{klm}	4.66^{h}	2.17^{f}	45.53^{ghi}	42.23^{cd}	2.69^{b}	5.53^{b}	2	0
16	GM-16	23.80^{s}	37.00^{bc}	48.00^{cd}	11.63^{jklm}	4.03^{n}	2.84^{a}	67.87^{def}	59.60^{a}	1.11^{d}	4.40^{cde}	3	0
17	GM-17	63.93^{f}	36.33^{bcd}	48.66^{c}	12.77^{fghij}	5.04^{e}	2.09ij	83.93^{abcd}	43.17^{cd}	1.97^{c}	4.13^{defgh}	3	0
18	GM-18	21.27^{t}	37.00^{bc}	48.66^{c}	12.30^{ghijk}	4.61^{hi}	2.14^{fgh}	38.23^{hij}	20.37^{lm}	2.00^{c}	3.47^{jk}	3	0
19	GM-19	54.60^{i}	37.00^{bc}	47.00^{cd}ef	10.80^{lmn}	4.53^{j}	2.03^{k}	82.37^{abcd}	41.50^{cd}	2.11^{c}	3.47^{jk}	3	0
20	GM-20	52.51^{ij}	31.00^{ijk}	42.00^{hij}	12.17^{hijk}	4.96^{f}	2.08^{ijk}	75.63^{abcde}	39.63^{de}	2.88^{b}	4.00^{efghi}	2	0
21	GM-21	60.60^{g}	34.00^{fgh}	44.66^{efgh}	15.37^{abc}	3.07^{r}	1.19^{m}	37.80^{hij}	12.43^{nop}	2.93^{b}	4.16^{defg}	3	0
22	GM-22	20.53^{t}	32.00^{i}	45.00^{efg}	12.80^{fghj}	3.94^{op}	2.08^{ijk}	48.57^{ghi}	14.13^{n}	2.92^{b}	4.20^{defg}	2	0
23	GM-23	46.53^{k}	42.00^{a}	55.66^{a}	15.53^{ab}	3.97^{nop}	1.83^{l}	53.56^{fgh}	31.73^{ghi}	2.11^{c}	3.63^{ijk}	3	0
24	GM-24	20.53^{t}	36.00^{cde}	46.33^{cdefg}	15.97^{a}	5.23^{d}	2.24^{e}	84.53^{abc}	26.8^{ijk}	2.93^{b}	3.87^{fghij}	2	0
25	GM-25	20.80^{t}	37.00^{bc}	46.00^{cdefg}	13.40^{efg}	5.88^{a}	2.33^{d}	48.33^{ghi}	26.16^{jk}	2.07^{c}	3.80^{ghij}	2	0
26	GM-26	75.56^{b}	34.00^{fgh}	45.33^{defg}	12.80^{fghi}	4.25^{m}	2.10^{hi}	91.80^{a}	45.43^{c}	2.05^{c}	4.20^{defg}	2	0
27	GM-27	83.03^{a}	35.00^{def}	46.33^{cdefg}	13.83^{def}	3.88^{q}	1.83^{l}	91.66^{a}	54.10^{b}	2.11^{c}	3.73^{hijk}	2	0
28	GM-28	68.47^{de}	32.66^{ghi}	45.00^{efg}	13.77^{def}	5.24^{d}	2.16^{f}	26.87^{j}	15.57^{mn}	2.06^{c}	5.60^{b}	2	0
	Mean	**45.86**	**34.13**	**45.49**	**12.69**	**4.67**	**2.17**	**63.38**	**31.83**	**2.45**	**4.54**	**2.43**	**0**
	Range	20.53-83.03	27.00-42.00	35.00-55.67	8.90-15.97	3.07-5.88	1.19-2.84	26.87-91.80	8.07-59.60	1.11-3.93	3.33-6.53	2-3	0
	CD	3.18	2.54	3.88	1.52	0.08	0.06	21.89	7.17	0.46	0.55	0	0
	CV	3.18	3.41	3.91	5.50	0.77	1.37	15.85	10.34	8.71	5.57	0	0

Table 5. Estimates of components of variance, heritability, genetic advance and genetic advance over percentage of mean for morphological parameters in vegetable soybean

Sl. No.	Character	GV	PV	GCV (%)	PCV (%)	H^2	GA	GAM
1.	Plant height(cm)	392.73	394.78	43.21	43.33	99.46	40.71	88.77
2.	Days to 50% flowering	12.89	14.20	10.51	11.05	90.47	7.03	20.59
3.	Days to first harvest	19.87	22.93	9.79	10.54	86.23	8.52	18.73
4.	Days to vegetable maturity	2.90	3.37	13.41	14.49	85.58	3.24	25.55
5.	Pod length(cm)	0.36	0.36	12.88	12.91	99.64	1.23	26.50
6.	Pod width (cm)	0.09	0.09	14.49	14.56	99.11	0.64	29.73
7.	Pod yield per plant (g)	361.27	458.52	29.94	33.87	78.11	34.55	54.51
8.	Number of pods per plant	181.16	191.61	42.27	43.51	94.35	26.92	84.58
9.	Pod weight(g)	0.52	0.56	29.40	30.67	91.92	1.42	58.08
10.	Number of harvests	0.71	0.86	19.64	20.41	92.56	1.76	38.93

GV- Genotypic variance
H^2- Broad sense heritability
PV- Phenotypic variance
GA- Genetic advance
GCV- Genotypic co-efficient of variation
GAM- Genetic advance as percentage of mean
PCV- Phenotypic co-efficient of variation

Table 6. *Per se* performance of vegetable soybean quality parameters

Sl. No.	Genotypes	Starch (g/100g)	Carbohyd rate (g/100g)	Protein (g/100g)	Crude fibre (g/100g)	Vitamin C (mg/100g)	Iron (mg/100g)	Calcium (mg/100g)	Phosphorous (mg/100g)	Polyphenols (g/100g)
1	GM-1	1.45^{j}	11.37^{c}	14.66^{f}	2.09^{fgh}	12.52^{d}	6.84^{e}	14.34^{st}	601.33^{b}	6.30^{h}
2	GM-2	1.42^{j}	6.85^{n}	18.37^{b}	1.35^{m}	7.46^{j}	4.66^{i}	17.57^{n}	525^{fg}	7.37^{g}
3	GM-3	1.95^{g}	6.26^{r}	13.43^{g}	2.09^{fgh}	6.45^{m}	3.26^{nop}	16.49^{op}	753^{a}	3.67^{m}
4	GM-4	2.06^{f}	8.85^{h}	12.53^{h}	2.11^{fg}	14.43^{b}	7.62^{d}	13.85^{u}	476.66^{h}	9.70^{d}
5	GM-5	1.47^{j}	9.25^{g}	16.57^{d}	1.94^{hi}	9.15^{g}	8.59^{b}	27.82^{i}	550^{de}	5.43^{i}
6	GM-6	1.01^{opq}	9.85^{e}	15.56^{e}	1.64^{kl}	8.70^{h}	2.75^{q}	12.79^{x}	374.66^{k}	5.20^{i}
7	GM-7	2.17^{e}	12.20^{b}	12.47^{h}	2.15^{f}	14.75^{a}	2.76^{q}	26.55^{j}	452^{i}	2.43^{n}
8	GM-8	1.76^{h}	8.16^{jk}	10.60^{j}	1.65^{kl}	8.49^{hi}	3.92^{l}	14.10^{t}	352^{lm}	7.57^{g}
9	GM-9	1.06^{nop}	6.26^{r}	17.43^{c}	1.35^{m}	8.59^{hi}	3.12^{op}	15.62^{q}	332.66^{mn}	10.80^{b}
10	GM-10	1.55^{i}	5.66^{s}	13.63^{g}	2.16^{f}	13.79^{c}	5.13^{h}	37.46^{c}	570.66^{c}	2.73^{n}
11	GM-11	1.06^{nop}	6.65^{op}	12.60^{h}	1.96^{ghi}	10.45^{e}	8.19^{c}	18.53^{m}	534.00^{efg}	4.57^{jk}
12	GM-12	2.29^{d}	7.28^{l}	19.43^{a}	2.35^{e}	9.63^{f}	4.11^{k}	14.77^{r}	543.00^{def}	9.67^{d}
13	GM-13	2.77^{a}	8.46^{i}	11.43^{i}	2.55^{cd}	6.49^{m}	5.86^{f}	14.79^{r}	483.33^{h}	4.2^{l}
14	GM-14	1.16^{klm}	7.35^{l}	16.66^{d}	2.92^{a}	4.54^{q}	5.71^{fg}	13.50^{v}	613.66^{b}	11.3^{a}
15	GM-15	2.58^{b}	10.85^{d}	15.33^{e}	2.44^{de}	5.54^{n}	5.65^{g}	25.66^{k}	434.66^{ij}	4.77^{j}

16	GM-16	2.38^{c}	8.05^{k}	16.33^{d}	2.65^{bc}	3.78^{r}	10.76^{a}	37.71^{b}	520.00^{g}	9.53^{d}
17	GM-17	1.22^{kl}	8.27^{j}	6.70^{m}	1.86^{ij}	6.87^{l}	1.78^{t}	30.46^{g}	234.00^{q}	3.7^{m}
18	GM-18	1.06^{nop}	6.46^{q}	16.33^{d}	2.15^{f}	8.72^{h}	4.75^{i}	34.32^{e}	428.66^{j}	4.27^{kl}
19	GM-19	1.23^{k}	9.68^{f}	12.56^{h}	2.06^{fgh}	8.42^{i}	6.75^{e}	31.44^{f}	562.00^{cd}	8.37^{f}
20	GM-20	1.46^{j}	6.46^{q}	10.5^{j}	1.76^{jk}	10.57^{e}	1.86^{t}	40.85^{a}	439.00^{ij}	9.13^{e}
21	GM-21	0.95^{q}	8.27^{j}	9.70^{k}	1.35^{m}	9.39^{fg}	2.16^{s}	23.77^{l}	355.00^{kl}	7.5^{g}
22	GM-22	2.14^{e}	9.64^{f}	7.63^{l}	1.27^{m}	8.73^{h}	2.35^{r}	29.55^{h}	250.33^{op}	2.43^{n}
23	GM-23	1.07^{nop}	12.61^{a}	10.60^{j}	2.56^{cd}	7.16^{k}	2.66^{q}	35.62^{d}	369.66^{kl}	8.63^{f}
24	GM-24	1.15^{lm}	6.45^{q}	13.60^{g}	2.75^{b}	4.64^{op}	10.59^{a}	25.72^{k}	430.66^{j}	8.4^{f}
25	GM-25	1.06^{nop}	4.80^{t}	16.30^{d}	1.19^{m}	5.49^{n}	4.46^{j}	35.75^{d}	322.00^{n}	2.57^{n}
26	GM-26	1.17^{klm}	8.46^{i}	15.50^{e}	1.55^{l}	6.69^{lm}	3.43^{mn}	35.77^{d}	434.00^{ij}	5.53^{i}
27	GM-27	1.59^{i}	7.05^{m}	10.43^{j}	2.06^{fgh}	8.33^{i}	6.66^{e}	13.19^{w}	479.33^{h}	10.32^{c}
28	GM-28	1.11^{mn}	7.26^{l}	17.63^{c}	2.36^{e}	9.57^{f}	3.48^{m}	14.38^{s}	443.00^{ij}	4.37^{kl}
	Mean	**1.55**	**8.17**	**13.73**	**2.01**	**8.55**	**4.99**	**24.01**	**459.44**	**6.44**
	Range	1.02-2.77	4.80-12.61	6.70-19.43	1.19-2.92	3.78-14.75	1.78-10.76	12.71-40.85	234-753	2.43-11.30
	CD	0.09	0.15	0.49	0.21	0.36	0.24	0.34	26.69	0.48
	CV	2.89	0.86	1.65	4.82	1.92	2.22	0.64	2.66	3.40

Table 7. Estimates of components of variance, heritability, genetic advance and genetic advance over percentage of mean for quality parameters in vegetable soybean

Sl. No.	Character	GV	PV	GCV (%)	PCV (%)	H^2	GAM
1	Starch (g/100g)	0.29	0.29	35.54	34.66	99.30	70.91
2	Carbohydrate (g/100g)	3.84	3.85	23.99	24.01	99.87	49.39
3	Protein (g/100g)	10.52	10.57	23.61	23.67	99.51	48.53
4	Crude fibre (g/100g)	0.22	0.23	23.25	23.74	95.87	46.90
5	Vitamin C (mg/100g)	8.06	8.09	33.21	33.27	99.66	68.30
6	Iron (mg/100g)	6.29	6.30	50.19	50.24	99.80	100.00
7	Calcium (mg/100g)	90.12	90.14	39.53	39.54	99.97	81.43
8	Phosphorous (mg/100g)	13060.89	13205.34	24.87	25.01	98.86	50.94
9	Polyphenols (g/100g)	7.71	7.84	43.32	43.45	99.38	88.97

GV- Genotypic variance H^2- Broad sense heritability

PV- Phenotypic variance   GA- Genetic advance

GCV- Genotypic co-efficient of variation

GAM- Genetic advance as percentage of mean

PCV- Phenotypic co-efficient of variation

4.2.2.6 Pod width (cm)

Pod width ranged from 1.19 cm (GM-21) to 2.84 cm (GM-16) with an average of 2.17 cm. The GV was lower (0.098) than PV (0.099). The estimates of GCV and PCV were 14.49 % and 14.56 %respectively. High heritability (99.11 %) coupled with very low GA (0.64) and high estimate of GAM (29.73%) for the character.

4.2.2.7 Pod yield per plant (g)

The pod yield per plant in vegetable soybean genotypes ranged from 26.87 g (GM-28) to 91.80 g (GM-26) with a mean of 63.38g. The PV (458.52) was much higher than GV (361.27) along with high GCV (29.94 %) and PCV (33.87%), respectively. The estimates of heritability were high (78.11 %) along with high GA (34.55) and high GAM (54.51%) for the trait.

4.2.2.8 Number of pods per plant

Maximum number of pods were recorded in the genotype GM-8 (8.07) and minimum number of pods were recorded in GM-16 (59.60) with a mean of 31.83. Lower estimates of GV (1.48) and PV (1.79) with very lower estimates of GCV (4.03 %) and PCV (4.44 %) were observed. Higher estimates of heritability (82.68 %) coupled with very low estimates of GA (2.33) and GAM (7.73 %).

4.2.2.9 Pod weight (g)

The pod weight ranged from 1.11g (GM-16) to 3.93g (GM-14) with an average mean of 2.45g. The PV (0.56) slightly higher than GV (0.52) along with this moderate estimates of GCV (29.40 %) and PCV (30.67 %) were also observed. High heritability (91.92 %) along with lower estimates of GA (1.42) and high GAM (58.08 %) were observed among the genotypes for pod weight.

4.2.1.10 Number of harvest

Number of harvests ranged from 3.33 to 6.53. Maximum number of harvests was obtained in GM-14 (6.53) and the minimum in GM-9 (3.33). GCV and PCV values recorded for the character were 19.64% and 20.41% respectively. High heritability

(92.56%) along with lower estimates of GA (1.76) and high GAM (38.93%) were recorded for number of harvest.

4.2.1.11 Number of seeds per pod

Number of seeds per pod ranged from 2 to 3 with mean value of 2.43.

4.2.1.12 Number of root nodules per plant

None of the genotypes had root nodules even by 90th day of the crop.

4.2.1.13 Incidence of pest and disease

Incidence of *Spodoptera litura* was observed in the early stage of crop. *Rhizoctonia* collar rot varying from 7.1% to 18.75% was observed in GM-2, GM-3, GM-4, GM-6, GM-7, GM-10, GM-20, GM-24 and GM-27.

4.2.2 Variability in quality parameters in vegetable soybean genotypes

4.2.2.1 Starch content (g per 100g)

Starch content in vegetable soybean genotypes ranged from 1.01g (GM-17) to 2.77 g (GM-12) with a mean of 1.55 g. The PV (0.28) was higher than GV (0.29). The GCV and PCV were high (35.54 % and 34.66 %, respectively). Very high estimates for heritability (99.30 %) along with high GAM (70.91%) for this trait.

4.2.2.2 Carbohydrate content (g per 100g)

Carbohydrate content of pods in vegetable soybean genotypes ranged from 4.80g (GM-25) to 12.61 g (GM-23) with a mean of 8.17 g. The PV (3.85) was higher than GV (3.84). The GCV and PCV were high (23.99% and 24.01%, respectively). Very high estimates for heritability (99.87 %) and high GAM (49.39%) was recorded.

4.2.2.3 Protein content (g per 100g)

Protein content of pods in vegetable soybean genotypes ranged from 6.70g (GM-17) to 19.43 g (GM-12) and mean of 13.73 g. The PV (10.57) was higher than GV (10.52). The GCV and PCV were high (23.61 % and 23.67 %, respectively). Very high estimates for heritability (99.51 %) along with high GAM (48.53 %) for this trait.

4.2.2.4 Crude fibre (g per 100g)

Crude fibre in vegetable soybean genotypes ranged from 1.19 g (GM-25) to 2.92g (GM-14) and mean of 2.01g. Very low estimates of PV (0.23) and GV (0.22) along with higher estimates of GCV (23.25 %) and PCV (23.74 %) were also reported. High estimates of heritability (95.87%) coupled with high GAM (46.90%) for the character.

4.2.2.5 Vitamin C (mg per 100g)

Vitamin C content among the genotypes ranged from 3.78 mg (GM-16) to 14.7 mg (GM-7) with an average mean value of 8.55 mg. The PV (8.09) wasslightly greater than GV (8.06). The estimates of GCV (33.21%) and PCV (33.27%) were very high. The trait also had very high heritability (99.66%) and very high GAM (68.30 %) observed for this trait in vegetable soybean genotypes.

4.2.2.6 Iron content (mg per 100g)

Iron content of pods in the genotypes ranged from 1.78 mg (GM-17) to 10.76 mg (GM-16) and mean of 4.99 mg. The PV (6.29) was higher than GV (6.28). The GCV and PCV were high (50.19 % and 50.24 %, respectively). Very high estimates for heritability (99.80 %) along with high GAM (100%) for this trait.

4.2.2.7 Calcium content (mg per 100g)

Calcium content ranged from 12.71 mg (GM-6) to 40.85 mg (GM-20) and mean of 24.01 mg. The PV (90.14) was higher than GV (90.12). The GCV and PCV were high (39.53% and 39.54%, respectively). Very high estimates for heritability (99.97 %) and high GAM (81.43 %) was recorded.

4.2.2.8 Phosphorous content (mg per 100g)

Phosphorous content in vegetable soybean genotypes ranged from 234 mg (GM-17) to 753 mg (GM-3) with a mean of 459.44 mg. The PV (13205.34) was higher than GV (13060.89). The GCV and PCV were high (24.87% and 25.01 %, respectively). Very high estimates for heritability (98.86%) and high GAM (50.94%) for this trait.

4.2.2.9 Polyphenol content (g per 100g)

Polyphenol content in vegetable soybean genotypes ranged from 2.43g (GM-7) to 11.30g (GM-14) and mean of 6.44 g. The PV (7.84) was higher than GV (7.71). The GCV and PCV were high (43.32 % and 43.45 %, respectively). Very high estimates for heritability (99.38 %) and high GAM (88.97 %) for this trait.

4. 3 Sensory evaluation (9 point hedonic scale)

The data pertaining to sensory evaluation scores of vegetable soybean are presented in Table 8. Stastical differences were recorded with respect to sensory evaluation scores (9 point hedonic scale) performed by panel of judges. The sensory traits *viz.,* appearance, colour, flavour, texture, taste and overall acceptability of 28 vegetable soybean genotypes were judged by 15 judges.

Table 8. Sensory evaluation parameters of different vegetable soybean genotypes

Treatment	Appearance	Colour	Flavour	Texture	Taste	Total score
GM-1	6.5333 (0.846)	6.1556 (1)	6.4444 (0.9)	6.2889 (0.916)	6.0667 (0.909)	4.571
GM-2	8.1333 (0.115)	8.1556 (0.3125)	7.0000 (0.7)	7.4444 (0.5)	6.4889 (0.818)	2.4455
GM-3	5.0889 (1)	6.8222 (0.875)	6.5556 (0.85)	5.5333 (1)	5.9111 (0.9545)	4.6795
GM-4	7.5111 (0.576)	8.1778 (0.3125)	7.4667 (0.45)	7.0222 (0.75)	7.2444 (0.6818)	2.7703
GM-5	8.0889 (0.153)	8.2222 (0.3125)	7.7111 (0.3)	7.6889 (0.33)	8.0444 (0.2272)	1.3227
GM-6	7.6667 (0.423)	7.7333 (0.5625)	8.0444 (0.1)	8.0000 (0.166)	8.0667 (0.1818)	1.4333
GM-7	7.1111 (0.769)	8.0667 (0.375)	6.8667 (0.75)	7.1778 (0.66)	6.5333 (0.818)	3.372
GM-8	7.3778 (0.653)	8.1556 (0.3125)	7.3778 (0.55)	7.3333 (0.583)	6.6889 (0.583)	2.9165
GM-9	7.2667 (0.73)	7.9111 (0.4375)	7.1556 (0.65)	6.9111 (0.7916)	6.8667 (0.7727)	3.3818
GM-10	5.6000 (0.923)	7.4889 (0.687)	6.4889 (0.9)	5.2889 (1)	5.6222 (1)	4.51
GM-11	7.7778 (0.346)	6.9556 (0.875)	7.6667 (0.35)	8.1111 (0.125)	8.1333 (0.136)	1.832
GM-12	7.9778 (0.192)	8.1778 (0.3125)	7.7333 (0.3)	8.1333 (0.125)	8.2444 (0.0909)	1.0204
GM-13	8.2667 (0.076)	8.4444 (0.1875)	7.7556 (0.25)	8.1556 (0.125)	8.1778 (0.136)	0.7745
GM-14	6.7333 (0.846)	8.0444 (0.4375)	7.6889 (0.35)	6.8000 (0.833)	6.9111 (0.7727)	3.2392

71

GM-15	7.8667 (0.269)	8.5778 (0.125)	7.8222 (0.2)	8.3111 (0.083)	8.1333 (0.136)	0.813
GM-16	7.8222 (0.307)	8.0667 (0.375)	7.7111 (0.3)	7.8222 (0.25)	7.7556 (0.3636)	1.5956
GM-17	7.6000 (0.5)	8.0444 (0.4375)	7.4889 (0.45)	7.4889 (0.5)	7.6222 (0.454)	2.3415
GM-18	7.6000 (0.5)	8.0444 (0.4375)	7.3778 (0.55)	8.0889 (0.125)	7.9111 (0.2727)	1.8852
GM-19	7.1333 (0.769)	7.5111 (0.6875)	7.4267 (0.5)	7.2000 (0.66)	7.6000 (0.5)	3.1165
GM-20	7.6000 (0.5)	8.1111 (0.375)	7.5556 (0.4)	7.4667 (0.5)	7.5778 (0.545)	2.32
GM-21	7.8000 (0.307)	8.1556 (0.3125)	7.4444 (0.5)	7.4889 (0.5)	6.9111 (0.7727)	2.3922
GM-22	8.0444 (0.153)	8.0222 (0.4375)	7.9778 (0.15)	8.0000 (0.166)	8.1111 (0.136)	1.0425
GM-23	7.4889 (0.576)	8.0222 (0.4375)	7.4222 (0.5)	7.9333 (0.2083)	7.8222 (0.318)	2.0398
GM-24	8.1333 (0.115)	8.1556 (0.3125)	7.0000 (0.7)	7.4444 (0.5)	6.4889 (0.818)	2.4455
GM-25	7.1111 (0.769)	8.0667 (0.375)	6.8667 (0.75)	7.1778 (0.66)	6.5333 (0.818)	3.372
GM-26	7.9111 (0.269)	7.9111 (0.4375)	7.6667 (0.35)	8.0667 (0.125)	7.4000 (0.59)	1.7715
GM-27	7.1111 (0.769)	7.3778 (0.75)	6.1333 (1`)	7.1556 (0.66)	7.9556 (0.2727)	3.4517
GM-28	7.3333 (0.692)	7.4000 (0.6875)	7.2000 (0.65)	7.6000 (0.416)	7.7556 (0.3636)	2.8091

*Values in parenthesis indicates mean ranking score

4.3. 1 Appearance

The genotype GM-13 was more appealing in appearance with highest rank of 0.076 followed by GM-24(0.115) and GM-2(0.115). The lowest rank of 1 was recorded for GM-3.

4.3. 2 Colour

The highest rank of 0.125 was recorded in GM-15 followed by GM-13(0.1875) and GM-4(0.3125) and lowest rank was recorded in GM-1(1.00).

4. 3. 3 Flavour

For flavour, the highest rank of 0.1 was observed for GM-6 followed by GM-22(0.15). The minimum rank for flavour was 1 observed by GM-27.

4. 3. 4 Texture

The highest rank score was of 0.083 was recorded in GM-15 followed by GM-13(0.125) and GM-12(0.125) and lowest score was recorded in GM-10(1.00).

4. 3. 5 Taste

The genotype GM-12 recorded highest rank of 0.0909 followed by GM-13 with a rank of 0.136. Lowest rank obtained with regard to taste was recorded in GM-10(1.00).

The genotype GM-13 registered highest rank score of 0.775 whereas the genotype GM-3 had lowest rank score of 4.6795.

4.4 Correlation studies

Correlation coefficient indicates the nature of association among the different traits. The characters that are positively correlated with yield are considerably important to plant breeder for selection purpose. The results are presented in Table 9 and 10.

4.4.1 Genotypic correlation

Plant height had positive and significant association with number of pods per plant (rG = 0.313) and pod weight (rG = 0.429). It was negatively and significantly correlated with pod width (rG = -0.426), pod length (rG = -0.237), number of harvest (rG = -0.300) and calcium content (rG = -0.433). However it was positively but non significantly correlated with days to first harvest (0.057), protein content (0.194), crude fibre (0.054), iron content (0.119) and pod yield per plant (0.143).

Positive and significant correlation was found for days to 50% flowering with days to first harvest (rG = 0.952), days to vegetable maturity (rG = 0.2838) and phosphorous (rG = 0.342) but it was significant and negatively correlated with number of harvests (rG = -0.493), starch content (rG = -0.746), carbohydrate content (rG = -0.658) and polyphenol content (rG = -0.2533). It was also positively but non significantly correlated with number of pods per plant (0.1215), pod weight (0.0909), protein content (0.0185), calcium content (0.1441) and pod yield per plant (0.1539).

Days to first harvest had significant and positive association with days to vegetable maturity (rG = 0.3545) and phosphorous content (rG = 0.256) but it was significantly and negatively correlated with number days to harvest (rG = -0.469), starch content (rG = -0.791), carbohydrate content (rG = -0.653) and polyphenol content (rG = -0.2887). It was also positively and non-significantly correlated with number of pods per plant (0.0700), pod weight (0.0511), protein content (0.1841), calcium content (rG = 0.0578) and pod yield per plant (0.1642).

Negative and significant association was observed between days to vegetable maturity and pod weight (rG = -0.386), carbohydrate content (rG = -0.3242), crude fibre (rG = -0.361) and polyphenol content (rG = -0.406). It was negatively and significantly associated with pod length (rG = -0.2275), pod width (rG = -0.2280), number of pods per plant (rG = -0.2719) and starch content (rG = -0.2746). It was also positively and non-significantly correlated with number of harvest (0.1096), protein content (0.1202), calcium (0.0390) and phosphorous content (0.1020).

Pod length was positively and significantly correlated with pod width (rG = 0.5044), crude fibre (rG = 0.2987) and starch content (rG = 0.2269). It was negatively and significantly correlated with protein content (rG = -0.370. It was also positively but non significantly correlated with number of harvest (0.1803), carbohydrate content (0.0256), vitamin C (0.0679), iron content (0.1274), calcium content (0.0773) and polyphenol content (0.0643).

Pod width had positive and significant correlation with carbohydrate content (rG = 0.343), crude fibre (rG = 0.359) and calcium content (rG = 0.3608). It was positively but non significantly correlated with pod weight (0.0258), number of harvest (0.0360), starch content (0.1935), vitamin C content (0.0735), polyphenol content (0.1180) and pod yield per plant (0.0951).

Number of pods per plant had positive and significant correlation with pod weight (rG = 0.779), polyphenol content (rG = 0.3704), calcium content (rG =0.2551) and pod yield per plant (rG = 0.2612). It was negatively and significantly associated with number of harvest (rG = -0.2986) and positively but non significantly correlated with crude fibre (0.0316), vitamin C content (0.1465) and phosphorous content (0.03518).

Table 9. Genotypic correlation coefficients among morphological and quality parameters in vegetable soybean

	1	2	3	4	5	6	7	8	9	10	11	`12	13	14	15	16	17	18	19
1	1**																		
2	-0.0116	1**																	
3	0.0567	0.952**	1**																
4	-0.0936	0.2838**	0.3545*	1**															
5	-0.2373*	-0.1459	-0.1665	-0.227*	1**														
6	-0.42**	-0.170	-0.1094	-0.228*	0.5044**	1**													
7	0.3125*	0.1215	0.0700	-0.271*	-0.090	-0.1113	1**												
8	0.429**	0.0909	0.0511	-0.385*	-0.135	0.0258	0.779**	1**											
9	-0.29**	-0.49**	-0.46**	0.1096	0.1803	0.0360	-0.29**	-0.61**	1**										
10	-0.1074	-0.74**	-0.78**	-0.274*	0.2269*	0.1935	-0.1770	-0.0780	0.3169**	1**									
11	-0.1378	-0.65**	-0.65**	-0.32**	0.0256	0.343**	-0.1490	0.1035	0.2811**	0.6042*	1**								
12	0.1941	0.0185	0.1841	0.1202	-0.370**	-0.2003	-0.0329	0.0650	0.0139	-0.0872	0.2510*	1**							
13	0.0543	-0.0227	-0.0441	-0.36**	0.2987**	0.359**	0.0316	0.1792	-0.2405*	0.1532	-0.0621	-0.2560*	1**						
14	-0.1639	-0.0854	-0.1514	-0.1203	0.06799	0.0735	0.1465	0.1877	0.1565	0.2973*	0.3093**	0.1840	0.15035	1**					
15	0.1186	-0.1258	-0.0197	-0.1398	0.1274	-0.1425	-0.17985	-0.1670	0.01312	0.1698	0.03289	0.2129	-0.1378	-0.18775	1**				
16	-0.43**	0.14410	0.0578	0.03904	0.0773	0.3608**	0.2551*	0.2472*	-0.0485	0.0635	0.1734	-0.0960	0.2684*	0.499**	-0.17443	1**			
17	-0.1489	0.3422*	0.2560*	0.10209	-0.0881	-0.0834	0.03518	0.21098	-0.404**	-0.41**	-0.1147	-0.00964	-0.1907	-0.0778	-0.1116	-0.0548	1**		
18	-0.0547	-0.2533*	-0.28**	-0.40**	0.6434	0.1180	0.3704**	0.30747*	-0.0793	0.388**	0.20198	-0.11098	0.410**	0.467**	0.0897	0.433**	-0.2409*	1**	
19	0.1433	0.1539	0.1642	-0.1088	-0.07891	0.09513	0.2612	0.2065	0.2709*	-0.2142	-0.10186	-0.0636	0.1741	0.2492*	-0.1717	0.2712*	-0.2475*	0.14668	1**

*Significant at 5% **Significant at 1%

1. Plant height
2. Days to 50% flowering
3. Days to first harvest
4. Days to vegetable maturity
5. Pod length
6. Pod width
7. Number of pods per plant
8. Pod weight
9. Number of harvests
10. Starch
11. Carbohydrate
12. Protein
13. Crude fibre
14. Vitamin C
15. Iron
16. Calcium
17. Phosphorous
18. Polyphenols
19. Pod yield per plant

Pod weight was positively and significantly associated with polyphenol content (rG = 0.3074) and calcium (rG = 0.2472). It was also positively but non significantly correlated with carbohydrate content (0.1035), protein content (0.0650), crude fibre (0.1792), vitamin C (0.1877), phosphorous content (0.21098) and pod yield per plant (0.2709).

Positive and significant association was found for number of harvests with starch content (rG = 0.3169), carbohydrate content (rG = 0.2811) and pod yield per plant (rG = 0.2709). It also negatively and significantly correlated with phosphorous content (rG = -0.404) and crude fibre (rG = -0.2405). It was positively but non significantly correlated with protein content (0.0139), vitamin C content (0.1565) and iron content (0.0131).

Positive and highly significantly correlation was found for starch content with number of harvest (rG = 0.317), carbohydrate content (rG = 0.605), vitamin C (rG = 0.298), polyphenol content (rG = 0.389) and pod length (rG = 0.227). It was also negatively and significantly associated with protein content (rG= -0.746) and phosphorous content (rG = -0.416) and negatively significantly correlated with days to vegetable maturity (rG = -0.275).

Positive and significant association was found for carbohydrate content with vitamin C (rG = 0.3093) and protein content (rG = 0.2510). It was positively and non-significantly correlated with iron content (0.033), calcium content (0.173) and polyphenol content (0.20198).

Protein content was negatively and significantly correlated with pod length (rG = -0.370) crude fibre (rG = -0.2510). It was also positively significantly associated with carbohydrate content (rG = 0.251) but non significantly correlated with vitamin C content (0.2129) and iron content (0.2129)

Crude fibre content was positively and significantly correlated with pod length (rG = 0.299), pod width (rG = 0.360), polyphenol content (rG = 0.410) and calcium content (rG = 0.26843).It was also positively but non significantly correlated with vitamin C content (0.15035) and pod yield per plant (0.1741).

Vitamin C content had significant and positive association with calcium content (rG = 0.499), polyphenol content (rG = 0.467) and pod yield per plant (rG = 0.24929).

Iron content is positively but non significantly correlated with polyphenol content (rG = 0.0897).

Calcium content was positively and significantly correlated with polyphenol (rG = 0.433).

Pod yield per plant was significantly and positively correlated with number of pods per plant (rG = 0.2612), vitamin C (rG = 0.249) and calcium content (rG = 0.27125) and number of harvest (rG = 0.256). It was also positively but non significantly correlated with plant height (0.1433), days to 50% flowering (0.1539), days to first harvest (0.1642), pod width (0.0951), pod weight (0.2065), crude fibre (0.1741) and polyphenol content (0.147).

4.4.2 Phenotypic correlation

At phenotypic level, plant height was found to have a positive and significantly association with number of pods per plant (rP = 0.279) and pod weight (rP = 0.4130). It was negatively and significantly correlated with pod width (rP = -0.422), number of harvest (rP = -0.292), pod length (rP = -0.235) and calcium (rP = -0.431). However, it was positively but non significantly correlated with days to first harvest (0.0506), protein content (0.1937), crude fibre (0.0544), iron content (0.117) and pod yield per plant (0.1433).

Positive and significant correlation was found for days to 50% flowering with days to first harvest (rP = 0.875), days to vegetable maturity (rP = 0.233) and phosphorous (rP = 0.326) but it was significant and negatively correlated with number of harvests (rP = -0.451), starch content (rP = -0.696) and carbohydrate content (rP = -0.615) and also negatively significant with polyphenol content (rP = -0.233). It was also positively but non significantly correlated with number of pods per plant (0.060), pod weight (0.073), protein content (0.014), calcium content (0.138) and pod yield per plant (0.1485)

Table 10. Phenotypic correlation coefficients among morphological and quality parameters in vegetable soybean

	1	2	3	4	5	6	7	8	9	10	11	`12	13	14	15	16	17	18	19
1	1**																		
2	0.013*	1**																	
3	0.050	0.875**	1**																
4	-0.086	0.233*	0.305**	1**															
5	-0.235*	-0.014	-0.153	-0.207	1**														
6	-0.42**	-0.160	-0.103	-0.217*	0.502**	1**													
7	0.279*	0.061	0.004	-0.185	-0.077	-0.100	1**												
8	0.413**	0.073	0.028	-0.34**	-0.129	0.024	0.729**	1**											
9	-0.29**	-0.45**	-0.42**	0.063	0.175	0.037	-0.253*	-0.56**	1**										
10	-0.100	-0.69**	-0.71**	-0.25*	0.220	0.188	-0.182	-0.076	0.287**	1**									
11	-0.137	-0.61**	-0.60**	-0.30**	0.026	0.341**	-0.136	0.099	0.274*	0.577**	1**								
12	0.194	0.013	0.171	0.107	-0.36**	-0.199	-0.034	0.062	0.012	-0.083	0.250*	1**							
13	0.054	-0.019	-0.039	-0.33**	0.297**	0.358**	0.026	0.175	-0.233*	0.487	-0.062	-0.255	1**						
14	-0.156	-0.071	-0.138	-0.097	0.065	0.077	0.127	0.174	0.144	0.286	0.30	0.179	0.146	1**					
15	0.117	-0.118	-0.022	-0.130	0.127	-0.142	-0.154	-0.159	0.016	0.161	0.033	0.212	-0.137	-0.182	1**				
16	-0.43**	0.138	0.052	0.030	0.077	0.358	0.224*	0.242*	-0.040	0.058	0.172	-0.095	0.267*	0.488**	-0.173	1**			
17	-0.148	0.326**	0.237*	0.094	-0.087	-0.083	0.031	0.205	-0.38**	-0.40**	-0.114	0.009	-0.190	-0.076*	-0.111	-0.054	1**		
18	-0.055	-0.233*	-0.257*	-0.37**	0.064	0.117	0.317**	0.294**	-0.068	0.368**	0.200	-0.109	0.406**	0.454**	0.088	0.429**	-0.239*	1**	
19	0.143	0.148	0.156	-0.106	-0.079	0.093	0.230*	0.202	0.256*	-0.206	-0.100	0.063	0.173	0.243*	-0.170	0.270*	-0.246*	0.145	1**

*Significant at 5% **Significant at 1%

1. Plant height
2. Days to 50% flowering
3. Days to first harvest
4. Days to vegetable maturity
5. Pod length
6. Pod width
7. Number of pods per plant
8. Pod weight
9. Number of harvests
10. Starch
11. Carbohydrate
12. Protein
13. Crude fibre
14. Vitamin C
15. Iron
16. Calcium
17. Phosphorous
18. Polyphenols
19. Pod yield per plant

Days to first harvest had significant and positive association with days to vegetable maturity (rP = 0.305) and phosphorous content (rP= 0.237) but it was significant and negatively correlated with number days to harvest (rP = -0.425), starch content (rP = -0.711), carbohydrate content (rP = -0.599) and polyphenol content (rP = -0.257). It was also positively but non significantly correlated with number of pods per plant (0.003), pod weight (0.028), protein content (0.170), calcium content (0.052) and pod yield per plant (0.156).

Negative and significant association was observed for days to vegetable maturity with pod weight (rP = -0.346), carbohydrate content (rP = -0.301), crude fibre (rP = -0.338) and polyphenol content (rP = -0.379). It was negatively and significantly associated with pod length (rP = -0.207), pod width (rP = -0.217), number of pods per plant (rP= -0.185) and starch content (rP = -0.25). It was also positively but non significantly correlated with number of harvest (0.063), protein content (0.108), calcium (0.035) and phosphorous content (0.095).

Pod length is positively and significantly correlated with pod width (rP = 0.502), crude fibre (rP = 0.298) and starch content (rP = 0.220). It was negatively and significantly correlated with protein content (rP = -0.369). It was also positively but non significantly correlated with number of harvest (0.175), carbohydrate content (0.026), vitamin C (0.066), iron content (0.1274), calcium content (0.0773) and polyphenol content (0.0643).

Pod width was positively and significantly correlated with carbohydrate content (rP = 0.341), crude fibre (rP = 0.358) and calcium content (rP = 0.359). It was also positively but non significantly correlated with pod weight (0.024), number of harvest (0.0369), starch content (0.188), vitamin C content (0.0767), polyphenol content (0.117) and pod yield per plant (0.093).

Number of pods per plant had positively and significantly with pod weight (rP = 0.729), pod yield per plant (rP = 0.230), calcium content (rP =0.224) and polyphenol content (rP = 0.317). It was negatively and significantly associated with number of harvest (rP = -0.253). It was also positively but non significantly correlated with crude fibre (0.026), vitamin C content (0.127) and phosphorous content (0.031).

Pod weight is positively and significantly associated with polyphenol (rP = 0.294) and calcium content (rP = 0.242). It was also negatively significantly correlated with number of harvest (rP = -0.568) It was also positively but non significantly correlated with carbohydrate content (0.099), protein content (0.0618), crude fibre (0.175), vitamin C (0.174), phosphorous content (0.205) and pod yield per plant (0.202).

Positive and significant association was found for number of harvest with pod yield per plant (rP = 0.256), starch content (rP = 0.287) and carbohydrate content (rP = 0.274). It also negatively and significantly correlated (both at p = 0.01 and p=0.05) with phosphorous content (rP = -0.38) and negatively significant associated with crude fibre (rP = -0.233). It was also positively but non significantly correlated with protein content (0.012), vitamin C content (0.144) and iron content (0.016).

Positive and significant association was found for carbohydrate content with vitamin C (rP = 0.30) and protein content (rP = 0.250). It was positively and non-significantly correlated with iron content (0.033), calcium content (0.172) and polyphenol content (0.200).

Positive and highly significantly correlation was found for starch content with number of harvest (rP = 0.317), pod length (rG = 0.227), carbohydrate content (rP = 0.605), vitamin C (rP = 0.298) and polyphenol content (rP = 0.389). It was also negatively and significantly associated with protein content (rP= -0.746) and phosphorous content (rG = -0.416) and negatively significantly (p = 0.05) with days to vegetable maturity (rG = -0.275).

Protein content was negatively and significantly correlated with pod length (rP = -0.369) and crude fibre (rP = -0.255). It was positively significantly associated with carbohydrate content (rP = 0.251) but non significantly correlated with vitamin C content (0.179) and iron content (0.212).

Crude fibre content was positively and significantly correlated with pod length (rP = 0.297), pod width (rP = 0.358) polyphenol content (rP = 0.406) and calcium content (rP = 0.267).It was also positively but non significantly correlated with vitamin C content (0.146) and pod yield per plant (0.1729).

Vitamin C content had found significant and positive with calcium content (rP = 0.488), polyphenol content (rP= 0.454) and pod yield per plant (rP = 0.243).

Iron content is positively but non significantly correlated with polyphenol content (rP = 0.088).

Calcium content was positively and significantly correlated with polyphenol (rP = 0.429) and pod yield per plant (rP = 0.270)

Pod yield per plant was significantly (at p = 0.05) and positively correlated with number of pods per plant (rP = 0.230), vitamin C (rP = 0.249) and calcium content (rP = 0.270) and number of harvest (rP = 0.256). It was also positively but non significantly correlated with plant height (0.1433), days to 50% flowering (0.1539), days to first harvest (0.1642), pod width (0.0951), pod weight (0.202), crude fibre (0.1729) and polyphenol content (0.1451).

4.5 Path co-efficient analysis

The correlation coefficient would indicate only the relationship of independent variables with the dependent variable without specifying cause and effect. Using path coefficient analysis, it is possible to resolve the correlations, by subjecting the correlation co-efficient to path analysis for partitioning the correlation values into direct and indirect effect through alternate ways. The results showing the direct and indirect effect of various traits on pod yield per plant are presented in Table 11.

4.5.1 Direct effect on pod yield per plant

Days to 50% flowering (0.0387), days to first harvest (0.1874), pod length (0.10380), number of pods per plant (1.1017) and pod weight (0.4408) have shown positive direct effects on pod yield per plant while, plant height (-0.115), days to vegetable maturity (-0.0144) and pod width (-0.2330) have shown negative direct effects on pod yield per plant.

Table 11. Path coefficient analysis for pod yield and its components in vegetable soybean

	Plant height	Days to 50 % flowering	Days to first harvest	Days to vegetable maturity	Pod length	Pod width	Number of pods per plant	Pod weight	rG
Plant height	-0.115	-0.0004	0.0106	0.0013	-0.024	0.099	0.4737	-0.1322	0.143
Days to 50% flowering	0.0013	0.0387	0.1788	-0.0041	- 0.0151	0.0399	0.10042	-0.2175	0.157
Days to harvest	- 0.0065	0.0370	0.1874	-0.0051	- 0.0173	0.0255	0.0567	-0.2067	0.164
Days to vegetable maturity	0.0107	0.0110	0.0660	-0.0144	- 0.0236	0.0532	-0.4250	0.0486	-0.109
Pod length	0.0272	-0.0056	-0.0312	0.0033	0.1038	-0.1177	-0.1498	0.0795	-0.079
Pod width	0.0489	-0.0066	-0.0205	0.0033	0.0523	-0.233	0.0285	0.0158	0.095
Number of pods per plant	- 0.0493	0.0035	0.0096	0.0055	- 0.0141	-0.006	1.1017	-0.2706	0.261
Pod weight	0.0344	-0.0191	-0.0879	-0.0016	0.0187	-0.0084	-0.6763	0.4408	0.206

Legends: Negative direct effect; Positive direct effect; Positive indirect effect; Negative indirect effect

Diagonal indicates direct effect *Significant at 5% **Significant at 1% rG- Genotypic correlation with pod yield per plant
Residual = **0.269**

1. Plant height
2. Days to 50% flowering
3. Days to first harvest
5. Pod length
6. Pod width
7. Number of pods per plant

4.5.2 Indirect effect on pod yield per plant

Plant height had high positive indirect effect on pod yield per plant through number of pods per plant (0.4737), pod width (0.099), days to first harvest (0.0106) and days to vegetable maturity (0.0013).

Days to 50 % flowering had positive indirect effect on pod yield per plant through days to first harvest (0.1788), number of pods per plant (0.1004), pod width (0.0399) and plant height (0.0013).

Days to first harvest had positive indirect effect on pod yield per plant through number of pods per plant (0.0567), days to 50 % flowering (0.0370) and pod width (0.0255).

Days to vegetable maturity had positive indirect effect on pod yield per plant through days to first harvest (0.0660), pod width (0.0532), pod weight (0.0486), days to 50 % flowering (0.0110) and plant height (0.0107).

Pod length had positive indirect effect on pod yield per plant through pod weight (0.07952), days to vegetable maturity (0.0033) and plant height (0.0272).

Pod width had positive indirect effect on pod yield per plant through pod length (0.0523), plant height (0.0489), number of pods per plant (0.0285), pod weight (0.01587) and days to vegetable maturity (0.0033).

Number of pods per plant had positive indirect effect on pod yield per plant through days to first harvest (0.0096), days to vegetable maturity (0.0055) and days to 50% flowering (0.0035).

Pod weight had positive indirect effect on pod yield per plant through plant height plant height (0.0344) and pod length (0.0187).

4.6. Genetic divergence

Twenty eight vegetable soybean genotypes were evaluated for nineteen traits to study the divergence and the obtained data was subjected to D^2 analysis. As many as eight divergent clusters were grouped by using Trocher's method.

By adapting the method suggested by Trocher's (Rao, 1952), twenty eight genotypes were grouped into eight clusters from estimated D^2 values as the squares of generalized distances. The distribution pattern of genotypes into various clusters is given in Table 12.

Cluster II is the largest cluster having 8 genotypes followed by cluster V and cluster I including 4 genotypes, cluster III and IV containing 3 genotypes and remaining clusters VI, cluster VII and cluster VIII having two genotype each.

Table 12. Cluster composition based on D^2 statistics in vegetable soybean

Cluster	Number of genotypes	Genotypes included in the cluster
I	4	GM-10, GM-18, GM-20, GM-25
II	8	GM-2, GM-3, GM-8, GM-9, GM-12, GM-13, GM-14, GM-28
III	3	GM-7, GM-15, GM-21
IV	3	GM-5, GM-11, GM-19
V	4	GM-24, GM-22,GM-23, GM-26
VI	2	GM-1, GM-4
VII	2	GM-16, GM-24
VIII	2	GM-6, GM-27

Based on distance between clusters *i.e.* inter-cluster distances in Table 13, the maximum distance was observed between cluster VIII and I (D^2= 51828.79) followed by cluster VI and I (48046.45), cluster VIII and VII (45389.69), cluster VII and VI (38638.46), cluster II and I (38391.70). The least inter cluster distance was observed between cluster VIII and II (7406.18) followed by cluster VI and II (8460.01).

4.6.1Mean performance of characters in clusters

83

Cluster mean in nineteen characters are summarized in Table 14.

4.6.1.1 Plant height

The highest mean for plant height in vegetable soybean was observed in the cluster VIII (70.53) followed by cluster III (52.79). The lowest mean was observed in the cluster VII (22.16).

4.6.1.2 Days to 50% flowering

The highest vegetable soybean mean for days to 50% flowering was observed for the cluster IV (37.00) followed by cluster VII (36.50). The lowest cluster mean was observed for the cluster III (31.44) followed by cluster II (32.20).

4.6.1.3 Days to first harvest

The cluster mean for days to first harvest was highest in the cluster V (48.66) followed by cluster IV (48.33). The lowest cluster mean was observed in the cluster III (42.88).

4.6.1.4 Days to vegetable maturity

The cluster VIII (14.04) recorded highest cluster mean for days to vegetable maturity followed by cluster VII (13.79). The lowest cluster mean was observed for the cluster VI (11.78).

4.6.1.5 Pod length

The highest mean for pod length was observed for the cluster VI (5.21) followed by cluster I (5.17) and II (4.91). The lowest cluster mean was observed for the cluster III (4.05).

4.6.1.6 Pod width

The cluster mean for pod width was highest in the cluster VI (2.321) followed by cluster II (2.32). The lowest cluster mean was observed in the cluster III (1.83).

4.6.1.7 Pod yield per plant

Pod yield per plant in vegetable soybean, the highest mean was observed for the cluster VIII (81.18) followed by cluster IV (80.67). The lowest mean was observed in the cluster III (47.71).

Table 13. Intra cluster and inter cluster D^2 values in vegetable soybean genotype

	I	II	III	IV	V	VI	VII	VIII
I	4547.2							
II	38391.70	4803.65						
III	29809.72	13583.91	8670.44					
IV	16649.03	14415.14	11353.06	5775.88				
V	15181.24	24782.71	11393.79	11835.60	6673.43			
VI	48046.45	8460.01	16778.87	16696.90	31861.76	4687.86		
VII	13618.79	33276.50	29832.74	12636.91	20427.02	38638.46	10403.16	
VIII	51828.79	7406.18	13443.16	19404.79	28765.72	10702.37	45389.69	8084.77

Table 14. The mean of 19 characters for eight clusters in vegetable soybean genotypes

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
I	30.99	35	45.24	12.34	5.17	2.16	53.91	28.13	2.21	4.18	1.28	5.84	14.19	1.81	9.64	4.05	37.09	440.08	4.67
II	48.05	32.20	42.99	11.88	4.91	2.32	66.07	26.29	2.84	5.12	1.68	7.23	15.62	2.07	7.65	4.26	15.15	505.70	7.36
III	52.79	31.44	42.88	12.98	4.05	1.83	47.71	29.57	2.54	4.63	1.901	10.43	12.49	1.97	9.89	3.52	25.32	413.88	4.89
IV	44.75	37.00	48.33	12.87	4.46	2.08	80.67	39.55	2.03	4.27	1.253	8.52	13.90	1.98	9.34	7.84	25.93	548.66	6.12
V	51.63	36.08	48.66	13.47	4.61	2.02	69.46	33.61	2.26	3.94	1.39	9.74	10.10	1.80	7.36	2.55	32.84	321.99	5.07
VI	30.26	33.00	46.16	11.78	5.21	2.32	58.64	27.33	2.96	5.01	1.75	10.10	13.59	2.1	13.47	7.23	14.09	538.99	8.00
VII	22.16	36.5	47.16	13.79	4.62	2.54	76.19	43.2	2.02	4.13	1.76	7.24	14.96	2.70	4.21	10.6	31.71	475.33	8.9
VIII	70.53	34.66	46.83	14.04	4.09	1.93	81.18	44.2	2.07	4.13	1.29	8.44	12.99	1.84	8.51	4.70	12.99	426.99	7.75

1. Plant height	6. Pod width	11. Starch	16. Iron
2. Days to 50% flowering	7. Pod yield per plant	12. Carbohydrate	17. Calcium
3. Days to first harvest	8. Number of pods per plant	13. Protein	18. Phosphorous
4. Days to vegetable maturity	9. Pod weight	14. Crude fibre	19. Polyphenols
5. Pod length	10. Number of harvest	15. Vitamin C	

4.6.1.8 Number of pods per plant

The cluster VIII (44.2) showed highest cluster mean for number of pods per plant followed by cluster VII (43.2). The lowest cluster mean was observed for the cluster II (26.29).

4.6.1.9 Pod weight

The highest mean for pod weight was observed in the cluster VI (2.96) followed by cluster II (2.84). The lowest mean was observed in the cluster VII (2.02).

4.6.1.10 Number of harvest

For number of harvest, the highest mean was observed for the cluster II (5.12) followed by VI (5.01) followed by IV (4.27). The lowest mean was observed in the cluster V (3.94).

4.6.1.11 Starch content

The cluster III (1.901) showed highest cluster mean for starch content followed by cluster VII (1.76). The lowest cluster mean was observed for the cluster I (1.2).

4.6.1.12 Carbohydrate content

The highest mean for carbohydrate content in vegetable soybean was observed in the cluster III (10.43) followed by cluster VII (10.10). The lowest mean was observed in the cluster I (5.84).

4.6.1.13 Protein content

The cluster mean for protein content was highest in the cluster II (15.62) followed by cluster III (3.36). The lowest cluster mean was observed in the cluster V (0.97).

4.5.1.14 Crude fibre

The highest mean for crude fibre in vegetable soybean was observed in the cluster VII (2.70) followed by cluster VI (2.1). The lowest mean was observed in the cluster V (1.80).

4.5.1.15 Vitamin C content

The cluster VI (13.47) recorded highest cluster mean for vitamin C content followed by cluster III (9.89). The lowest cluster mean was observed for the cluster VII (4.21).

4.6.1.16 Iron content

For iron content in vegetable soybean, the highest mean was observed for the cluster VII (10.6) followed by IV (7.84). The lowest mean was observed in the cluster V (2.55).

4.6.1.17 Calcium content

The cluster I (37.09) showed highest cluster mean for calcium content followed by cluster V (32.84). The lowest cluster mean was observed for the cluster VIII (12.99).

4.6.1.18 Phosphorous content

The highest mean for phosphorous content in vegetable soybean was observed in the cluster IV (548.66) followed by cluster VII (538.99). The lowest mean was observed in the cluster V (321.99).

4.6.1.19 Polyphenol content

The cluster VII (8.9) recorded highest cluster mean for polyphenol content followed by cluster VI (8.00). The lowest cluster mean was observed for the cluster I (4.67).

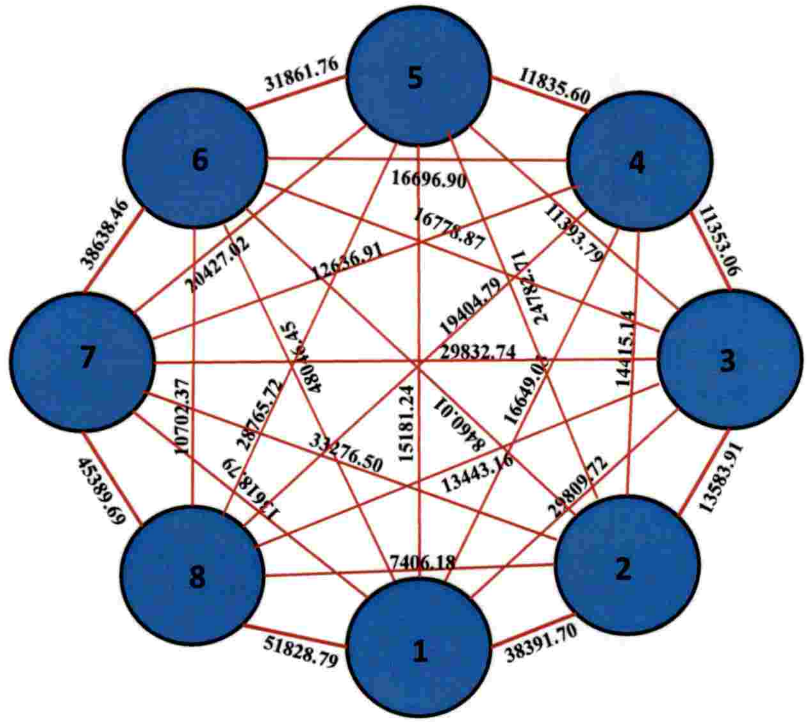


Fig. 1 Diagrammatic representation of inter cluster D^2 values in vegetable soybean genotypes

DISCUSSION

5. DISCUSSION

Vegetable soybean or Edamame is a specialty soybean (*Glycine max* L.) harvested as a vegetable when the seeds are immature (R6 stage) and have expanded to fill 80 to 90 per cent of the pod width. Like field-dried soybean, the seeds of edamame varieties are rich in protein and highly nutritious. Worldwide, it is a minor crop, but it is quite popular in East Asia. Vegetable soybean is popular in Japan, Korea, China and Taiwan and consumption is increasing rapidly. The green-shelled beans can be cooked to make a tasty and nutritious meal or snack. Grain soybean is widely cultivated in many countries of the tropics and subtropics and so the production of vegetable soybean can also be readily adopted. The cultivation practices for vegetable soybean and grain soybean are similar except that vegetable soybean is harvested when the pods are mature and green. The seeds of vegetable soybean are commonly bigger in size as compared to grain soybean.

Selection of genotypes/cultivars/varieties suited to a particular agro climatic region is more important when considerable variability exists in the germplasm. Hence, the present investigation was undertaken at the Department of Vegetable Science, College of Horticulture, Vellanikkara to study the performance of vegetable soybean genotypes in humid tropics to assess their yield and quality parameters. The experiment was laid out in randomized block design with three replications. The results obtained are discussed in this chapter.

5.1 Genetic variability, heritability and genetic advance

The analysis of variance revealed that significantly high variation existed between the genotypes for morphological and quality parameters of vegetable soybean. Since, sufficient genetic variability was present in the vegetable soybean genotypes evaluated, it is possible to identify high yielding genotypes for vegetable purpose and suited to the humid tropics. But, analysis of variance by itself is not enough and conclusive to explain all the inherent genotypic variances in the germplasm.

One of the ways by which variability present in the germplasm could be assessed, is through a simple approach of examining the range of variation. Significant differences observed between twenty eight soybean genotypes in the present study indicated the presence of sufficient variability in the germplasm for morphological and quality parameters. Basavaraja *et al.* (2005); Reni and Raob (2013) and Pagde *et al.* (2015) had also reported broad genetic variation in the germplasm of soybean. This will help in further selection of promising types.

The extent of variability present in germplasm includes genotypic, phenotypic and its interaction factors. Therefore, estimates of GCV and PCV were calculated. Significant values of GCV and PCV were observed for plant height, pod yield per plant, number of pods per plant, pod weight, starch, carbohydrate, protein, crude fibre, vitamin C, iron, calcium, phosphorous and polyphenol content confirmed existence of broad genetic base, which will be useful in further selection. Similar results were also reported by Mebrahtu and Mohamed (2006) for plant height and pod yield per plant, Basavaraja *et al.* (2005); Poornima *et al.* (2014); Ramya and Mummigatti (2015); Haruna *et al.* (2015); Reni and Raob (2013); Baraskar *et al.* (2014) for number of pods per plant and plant height; SureshRao *et al.* (2014); Mahbub *et al.* (2015); Mishra *et al.* (2015); Pagde *et al.* (2015) for pod yield per plant.

Moderate GCV and PCV were observed for days to vegetable maturity, pod length and number of harvest. This implied presence of additive and non-additive gene action for these traits. These results are in accordance with results of Basavaraja *et al.* (2005) and Sharma *et al.* (2013) for pod length.

Low GCV and PCV were observed for days to 50% flowering and days to first harvest. This indicated the narrow genetic base hence variability has to be generated for further improvement. These results are similar to results of Basavaraja *et al.* (2005); Haruna *et al.* (2015); Njoroge *et al.* (2015) and Kuswantoro (2017).

Genotypic and phenotypic coefficient of variation indicated only the extent of variability present in germplasm. Heritability estimates indicate the degree of variation of a phenotypic trait that is due to genetic variation between individuals in that population.

High heritability (>60 %) was observed for plant height, days to 50% flowering, days to first harvest, days to vegetable maturity, pod length, pod width, pod yield per plant, number of pods per plant, pod weight, number of harvests, starch, carbohydrate, protein, crude fibre, vitamin C, iron, calcium, phosphorous and polyphenol content. It indicated that these characters can be used to predict response to selection. Similar results were also reported by Basavaraja *et al.* (2005); Gohil *et al.* (2006) and Karnwall and Singh (2009) for plant height and number of pods per plant; Dilnesaw *et al.* (2013) for days to 50% flowering and plant height; Reni and Raob (2013) for days to 50% flowering, plant height, number of pods per plant, and pod length; Mahbub *et al.* (2015) for days to vegetable maturity, plant height and number of pods per plant; Mishra *et al.* (2015); Manav and Arora (2017); Ekka and Lal (2016) for number of pods per plant; Thakur (2015) for pod length; Kuswantoro (2017) for days to flowering and days to vegetable maturity.

The very high estimates of heritability coupled with high values of genetic advance over percent mean were observed for plant height, days to 50% flowering, days to vegetable maturity, pod length, pod width, pod yield per plant, number of pods per plant, pod weight, number of harvests, starch, carbohydrate, protein, crude fibre, vitamin C, iron, calcium, phosphorous and polyphenol content indicating that these characters are under the influence of additive gene action. Similar results were also obtained by Basavaraja *et al.* (2005); Gohil *et al.* (2006) and Karnwall and Singh (2009) for plant height and number of pods per plant in soybean; Dilnesaw *et al.* (2013) for days to 50% flowering and plant height in soybean; Reni and Raob (2013) for days to 50% flowering, plant height, number of pods per plant, and pod length; Mahbub *et al.* (2015) for days to vegetable maturity, plant height and number of pods per plant; Mishra *et al.* (2015), Manav and Arora (2017) and Ekka and Lal (2016) for number of pods per plant; Thakur (2015) for pod length; Kuswantoro (2017) for days to flowering and days to vegetable maturity.

High heritability (>60 %) with low genetic advance (0-10 %) for days to 50% flowering, days to first harvest, days to vegetable maturity, pod length, pod width, pod weight, number of harvests, starch, carbohydrate, protein, crude fibre, vitamin C, iron and polyphenol content. Therefore these characters are governed by non-additive gene action and influence of environment is also high.

Prevalence of high degree of additive components like high estimates of heritability coupled with high GAM and presence of high GCV and PCV for the traits like plant height, pod yield per plant, number of pods per plant, pod weight, number of harvest, starch, carbohydrate, protein, crude fibre, vitamin C, iron, calcium, phosphorous and polyphenol content indicated additive gene action. Therefore, genetic improvement of these traits can be achieved through selection in the existing germplasm.

5.2 Correlation studies

Correlation studies indicate the degree of inter-relationship of plant characters for improvement of yield as well as quality parameters in any breeding programme. Hence, understanding of the inter-relationship between pod yield and yield components is of vital importance because this would facilitate effective selection for simultaneous improvement in one or more yield components. In the present investigation, both genotypic and phenotypic correlations worked out for pod yield and its contributing characters. In general, genotypic correlation was higher than phenotypic correlations for most of the characters studied which indicated that the influence of environment was less for these characters.

Plant height was positively and significantly correlated with number of pods per plant and pod weight indicating that plant height is an important trait in selection of high yielding genotypes in vegetable soybean. Similar results were also reported by Sarutayophat and Songklanakarin (2012) for number of pods per plant.

Days to 50% flowering was positively and significantly correlated with days to first harvest, days to vegetable maturity and phosphorous content and was negatively and significantly correlated with number of harvest, starch content, carbohydrate content and polyphenol content. Similar findings were also reported by Basavaraja *et al.* (2005); Njoroge *et al.* (2015); Sharma *et al.* (1983); Aditya *et al.* (2011); Mallik *et al.* (2006) and Ramteke *et al.* (2010).

Days to first harvest had significant and positive correlation with days to vegetable maturity. Basavaraja *et al.* (2005) also reported similar results.

Negative and significant correlation was observed between days to vegetable maturity with pod weight, carbohydrate content, crude fibre and polyphenol content. Similar results were reported by Parmar *et al.* (2013) and Asaduzzaman *et al.* (2014) in dolichos bean for pod weight.

Significant positive correlation of pod length with pod width and crude fibre was observed, which was also reported by Basavaraja *et al.* (2005) and Sharma *et al.* (2013) in vegetable soybean.

Pod width was positively and significantly correlated with carbohydrate, crude fibre and calcium content. It was also positively but non-significantly correlated with pod weight, number of harvest, pod yield per plant, starch content, vitamin C content and polyphenol content. Similar results were also observed by Basavaraja *et al.* (2005), Sharma *et al.* (2013) in vegetable soybean; Sarangi and De (2010), Pandey *et al.* (2011) and Kumar *et al.* (2014) in French bean.

Number of pods per plant was positively and significantly correlated with pod weight, pod yield per plant, calcium and polyphenol content. It was also negatively and significantly associated with number of harvest. Similar results were also reported by Singh *et al.* (2015) in dolichos bean.

Pod yield per plant was significantly and positively correlated with number of pods per plant, number of harvest, vitamin C and calcium content. Since, these associated traits are in the desirable direction, it indicated that simultaneous selection for these traits would be useful in improving the vegetable pod yield. Kumar *et al.* (2004); Mallik *et al.* (2007); Bello *et al.* (2012); Lil *et al.* (2013); Kumar *et al.* (2015); Ramya and Mummigatti (2015), Basavaraja *et al.* (2005), Sciarappa *et al.* (2007) and Poornima *et al.* (2014) also reported similar results in vegetable soybean.

Positive and highly significantly correlation was found between starch content, number of harvests, carbohydrate, vitamin C and polyphenol content. Similar findings were observed by Sharma *et al.* (2013) in vegetable soybean.

Protein content was negatively and significantly correlated with pod length, crude fibre and carbohydrate content. Similar results were observed by Sharma *et al.* (2014), Salmani *et al.* (2012) and Sharma *et al.* (2013) in vegetable soybean and Sharma *et al.* (2016).

From the foregoing discussions, it can be concluded that improvement of pod yield per plant can be achieved by applying selection pressure on plant height, pod length, pod width, pod weight, number of pods per plant and number of harvests as these traits had significant and positive correlation with pod yield per plant.

5.2.2 Path coefficient analysis

Yield is a complex character and its component characters which contribute directly as well as indirectly through each other. The study of correlation alone when considered as the criteria for selection for high yield would be misleading. Path coefficient analysis helps to find out the direct and indirect influence of component characters on yield. The technique of path coefficient analysis developed by Wright (1921) and demonstrated by Dewey and Lu (1959) facilitated partitioning of the correlation coefficients into direct and indirect contribution of various characters to the yield.

Plant height exhibited positive correlation with pod yield per plant (rG= 0.1433) and but had negative direct effect through plant height (-0.115). The positive correlation is mainly through its high positive indirect effect through number of pod per plant, pod width, days to first harvest, days to vegetable maturity. Similar observations were reported by Joshi and Mehra (1984); Vaid *et al.* (1986); Shinde and Dumbre (2001); Roy *et al.* (2006); Bhushan *et al.* (2007); Mallik *et al.* (2007) in soybean; Golani *et al.* (2007); Mishra *et al.* (2009) in French bean; Patil *et al.* (2011); Singh *et al.* (2011); Bello *et al.* (2012); Pal and Singh (2012); Mehra and Singh (2012); Lil *et al.* (2013). Hence both direct and indirect effects showed to be considered for selection.

Days to 50% flowering had positive correlation with pod yield per plant (rG= 0.1539) and it had positive direct effect on pod yield per plant. Because it had positive indirect effect through days to first harvest, number of pods per plant, pod width and plant height. Similar results were observed by Verma *et al.* (2014) and Jayprakash *et al.* (2015).

Days to first harvest had positive correlation with pod yield plant (rG=0.1642) and had direct effect on pod yield per plant. The positive correlation was exhibited through number of pods per plant, days to 50 % flowering and pod width. Similar results were observed by Lil *et al.* (2013); Bello *et al.* (2012); Patil *et al.* (2011); Mallik *et al.* (2007).

Pod width had positive correlation with pod yield per plant and it had high negative direct effect on pod yield per plant. The positive correlation is mainly through indirect effect through plant height, days to vegetable maturity, pod length number of pods per plant and pod weight. Similar results were observed by Basavaraj *et al.* (2005).

Number of pods per plant exhibited significant positive correlation with pod yield per plant because it had high positive direct positive effect on pod yield per plant. Similar results were also reported by Malik *et al.* (2007); Sirohi *et al.* (2007) and Lil *et al.* (2013).

Pod weight had positive correlation with pod yield per plant and it had high positive direct effect. The positive indirect effect on pod yield per plant through plant height and pod length. Lil *et al.* (2013) also made similar observations.

In breeder's point of view, selection for yield in this crop can be achieved by employing the traits which had high direct and indirect effects like, plant height, days to 50% flowering, days to first harvest, days to vegetable maturity, pod length, pod width, number of pods per plant and pod weight.

5.3 Genetic divergence

The magnitude of D^2values indicated that presence of genetic diversity among twenty-eight genotypes of vegetable soybean. The genotypes were grouped into eight clusters which had considerably high inter-cluster D^2values.

Results of inter cluster distance revealed that, cluster VIII with 2 genotypes showed highest inter-cluster distance, indicating maximum diversity between cluster VIII and cluster I (D^2 = 51828.79) followed by clusters VI and I (48046.45), clusters VIII and II

(45389.69), clusters II and I (38391.70), clusters VII and II (33276.50). The lowest inter cluster distance was observed between clusters VIII and II (7406.18) followed by clusters VI and II (8460.01).

Out of 8 clusters, cluster VIII, with 2 genotypes, showed high mean values for plant height, days to vegetable maturity, pod yield per plant and number of pods per plant; moderate mean values for days to 50% flowering, days to first harvest, protein content, vitamin C, polyphenols content and crude fibre; low mean values for pod length, pod width, pod weight, number of harvest, starch, carbohydrate, iron content and calcium content.

Cluster V showed superiority for characters like days to first harvest and days to 50% flowering. Cluster VI exhibited higher cluster mean for pod length and pod weight. Cluster I showed superiority for calcium content.

Cluster II containing 8 genotypes, had high cluster means for number of harvest and protein content.

Crossing among divergent parents is likely to yield heterotic hybrids. In the present study maximum genetic distance was exhibited by cluster VIII and cluster I. The genotypes GM-6 and GM-27 are located in cluster VIII and GM-10, GM-18, GM-20 and GM-25 in cluster I. It showed that genotypes in these two clusters divergent for more number of characters.

The results of sensory evaluation in 9 point hedonic scale showed that highest rank recorded by GM-13 (0.7745) followed by GM-15 (0.813) and GM-12 (1.0204). The genotype GM-3 had lowest rank score of 4.6795.

According to Gopalan *et al.* 2012, pulse type soybean contains 20.9 g carbohydrate, 43.2 g protein, 3.7 g crude fibre, 10.4 mg iron, 240 mg calcium and 690 mg phosphorous.

The values obtained for the vegetable soybean, GM-13 which recorded highest rank in sensory evaluation also recorded carbohydrate (8.46 g), protein(11.43 g), crude fibre (2.55 g), iron (5.71 mg), calcium (13.50 mg) and phosphorous (613.66 mg) content.

Present study shows that based on yield and sensory evaluation, GM-12 is the promising genotype and it is the earliest genotype with respect to days to 50% flowering, days to first harvest and days to vegetable maturity.

SUMMARY

6. SUMMARY

The present study were conducted at the Department of Vegetable Science, College of Horticulture, Vellanikkara during October to December, 2017. The experiment material consisted of 28 soybean genotypes collected from IIHR, Bangalore. The 28 genotypes were sown in a randomized block design to study the performance of vegetable soybean genotypes in humid tropics to assess their yield and quality parameters.

The findings of the study are summarized as follows;

Twenty eight accessions of soybean were genetically catalogued vegetative, floral and pod characters based on NBPGR descriptor. The 28 genotypes differed significantly for all the characters except number of seeds per pod and number of root nodules per plant, which clearly indicates the existence of abundant variability among the genotypes selected for the study.

The earliest genotypes was GM-12 for days to 50% flowering, days to first harvest and days to vegetable maturity. Plant height recorded highest in the genotype GM-27 (83.03 cm) and lowest in GM-22 (20.53).

The genotype GM-26 recorded maximum pod yield per plant (90.80 g) followed by GM-27 (90.66g) and minimum in GM-28 (26.86 g). Number of pods per plant recorded highest in GM-27 (54.10) and lowest in GM-8 (8.07).

The extent of variability present in germplasm includes genotypic, phenotypic and its interaction factors. Therefore, estimates of GCV and PCV were calculated. Significant values of GCV and PCV were observed for plant height, pod yield per plant, number of pods per plant, pod weight, starch, carbohydrate, protein, crude fibre, vitamin C, iron, calcium, phosphorous and polyphenol content confirmed existence of broad genetic base, which will be useful in further selection.

The very high estimates of heritability coupled with high values of genetic advance over percent mean were observed for plant height, days to 50% flowering, days to vegetable maturity, pod length, pod width, pod yield per plant, number of pods per plant, pod weight, number of harvests, starch, carbohydrate, protein, crude fibre, vitamin C, iron, calcium, phosphorous and polyphenol content indicating that these characters are under the influence of additive gene action.

Pod yield per plant was significantly and positively correlated with number of pods per plant, number of harvest, vitamin C and calcium content. Since, these associated traits are in the desirable direction, it indicated that simultaneous selection for these traits would be useful in improving the vegetable pod yield.

The path analysis revealed that days to 50% flowering, days to first harvest, pod length, number of pods per plant and pod weight have shown positive direct effects on pod yield per plant while, plant height, days to vegetable maturity and pod width have shown negative direct effects on pod yield per plant.

The 28 genotypes of soybean were grouped into 8 clusters based on Mahalanobis D^2 statistic and clusters I, II, III, IV, V, VI, VII and VIII contained 4, 8, 3, 3, 4, 2 and 2 respectively. Out of eight clusters, Cluster VIII showed high mean value for plant height, days to vegetable maturity and number of pods per plant. In the present study maximum genetic distance was exhibited by cluster VIII and cluster I. The genotypes GM-6 and GM-27 are located in cluster VIII and GM-10, GM-18, GM-20 and GM-25 in cluster I. It showed that genotypes in these two clusters divergent for more number of characters.

The results of sensory evaluation in 9 point hedonic scale showed that highest rank recorded by GM-13 (0.7745) followed by GM-15 (0.813) and GM-12 (1.0204). The genotype GM-3 had lowest rank score of 4.6795. The values obtained for the vegetable soybean GM-13 which recorded highest rank in sensory evaluation also recorded carbohydrate (8.46 g), protein(11.43 g), crude fibre (2.55 g), iron (5.71 mg), calcium (13.50 mg) and phosphorous (613.66 mg) content.

Present study shows that based on yield and sensory evaluation, GM-12 is the promising genotype and it is the earliest genotype with respect to days to 50% flowering, days to first harvest and days to vegetable maturity.

REFERENCES

References

Abd El-Mohsen, A. A., Mahmoud, G. O., and Safina, S. A. 2013. Agronomical evaluation of six soybean cultivars using correlation and regression analysis under different irrigation regime conditions. *J. Plant. Breed. Crop Sci*. 5(5): 91-102.

Adasul, H. R. and Monpara, A. 2014. Genetic variability and selection indices for improving seed yield in soybean (*Glycine max* L. Merrill). *Electr. J. Plant Breed*. 5(4): 807-811.

Aditya, J. P., Bhartiya, P., and Bhartiya, A. 2011. Genetic variability, heritability and character association for yield and component characters in soybean (*Glycine max* (L.) Merrill). *J. Cent. Eur. Agric*. 12(1): 27-34.

Ali, A., Khan, S. A., Ehsanullah, M., Ali, N., and Hussain, I. 2016. Estimation of genetic parameters in soybean for yield and morphological characters. *Pak. J. Agric. Eng. Vet. Sci.* 32 (2): 162-168.

Al-jibouri, H. A., Miller, P. A., and Robinson, H. V. 1958. Genotypic and environmental variances and co-variances in an upland cotton cross of inter specific origin. *Agron. J.* 50: 633-636.

Allard, R. W. 1960. *Principles of Plant Breeding.* John wiley and Sons Inc., Newyork, p.89-98.

Amarasinghe, Y. P., Wijesinghe, G., and Pushpakumara R. R. 2015. Estimation of phenotypic diversity of soybean genotypes available in Sri Lanka for varietal improvement. *J. Agric. Res.* 2(2): 84-87.

Ananya, K. C., Patel, A. I., and Himani, P. 2015. Assessment of genetic diversity in dolichos bean (*Lablab purpureus* L.). *Trends Biosci.* 8(11): 2879-2882.

Ananya, K. C., Patel, A. I., and Himani, P. 2015. Genetic variability, correlation and path analysis for yield and yield attributing traits in Indian bean (*Lablabpurpureus* L.) genotypes. *Trends Biosci.* 8(11): 2883-2887.

Asaduzzaman, Bhuiyan, M. J. H., Hossain, M. A., and Raffi, S. A., 2014. Correlation and path coefficient analysis of fourteen different genotypes of Lablab bean (*Lablab purpureus* L.). *Bangladesh J. Plant Breed. Genetics* 27(1): 37-44.

Bahadur, V., Kumar, P., and Singh, D. 2013. Studies on genetic variability, heritability and character association in dolichos bean (*Lablab purpureus* L.). *Hort. Flora. Res. Spectrum* 2(3): 208-214.

Baraskar, V. V., Kacchadia, H. V., Vacchan, J. H., Barad, H. R., Patel, M. B., and Darwankar, M. S. 2014. Genetic variability, heritability and genetic advance in soybean [*Glycine max* (L.) Merrill]. *Electr. J. Plant Breed.* 5(4): 802-806.

Baruah, S., Sarma, M. K., Baishya, D., Sharmal, A. A., Bhuyan, Y., and Borah, R. 2015. Genetic variability, character association and genetic divergence in soybean [*Glycine max* (L.) Merrill] germplasm under rainfed situation of Assam. *Prog. Agric.* 15(1): 1-8.

Basavaraja, G. T., Naidu, G. K., and Salimath, P. M. 2005. Evaluation of vegetable soybean genotypes for yield and component traits. *Karnataka. J. Agric. Sci.* 18(1): 27-31.

Bello, L. L., Shaahu, A., and Vange, T. 2012. Studies on relationship between seed yield and yield components in soybean *(Glycine max L. Merrill)*. *Electr. J. Plant Breed.* 3(4): 1012-1017.

Bhartiya, A. and Aditya, J. P. 2016. Genetic variability, character association and path analysis for yield and component traits in black seeded soybean lines under rainfed condition of Uttarakhand hills of India. *Legume Res.* 39 (1): 31-34.

Bhushan, K. B., Singh, B. P., Dubey, R. K. and Ram, H. H., 2007. Correlation analysis for seed yield in french bean (*Phaseolus vulgaris*). *Pantnagar J. Res.,* 5(1): 104 -106.

Burton, C. W. and Devane, E. H. 1953. Estimating heritability in tall Festuca (*Restuca arundinaceae*) from donar material. *Agron. J.* 45: 1476-1481.

Burton, G. W. 1952. Quantitative inheritance in grass. 6th Int. Grassld Cong. Proc. 1:277-283.

Chaitanya, V., Reddy, R. V. S. K., Pandaravada, S. R., and Sujatha, M. 2013. Genetic divergence in dolichos bean genotypes (*Dolichos lablab* L. vartypicus) for yield and yield contributing traits. *Asian J. Hort.* 8(2): 733-736.

Chaudhari, P. P., Patel, A. I., Kadam, Y. R., and Patel, J. M. 2013. Variability, correlation and path analysis study in vegetable dolichos bean (*Lablab purpureus* L.). *Crop Res.* 45(1, 2 & 3): 229-236.

Chavan, B. H., Dahat, D. V., Rajput, H. J., Deshmuk, M. P., and Diwane, L. 2016. Correlation and Path Analysis in Soybean. *Int. Res. J. Multidisciplinary Stud.* 2(9): 2454-8499

Das, I., Shende, V. D., Seth, T., Yadav, Y., and Chattopadhyay, A. 2015. Genetic analysis and interrelationships among yield attributing traits in pole and bush type dolichos bean (*Lablab purpureus* L.). *J. Crop Weed* 11(2):72-77.

Devendra, U., Nandan, M., Jitendra, S., and Mayuri S. 2011. Genetic divergence in dolichos bean (*Lablab purpureus* L.). *Electr. J. Plant Breed.* 2(4): 552-554.

Dhillon, T. S. and Kumar, A. 2015. Variability, heritability, correlation and genetic divergence studies in dolichos bean (*Lablab purpureus* L.). *J. Hort. Sci.* 10(2).

Dilnesaw, Z., Abadi, S., and Getahun, A. 2013. Genetic variability and heritability of soybean (*Glycine max* (L.) Merrill) genotypes in Pawe district, Metekelzone, Benishangule Gumuz regional state, northwestern Ethiopia. *Wudpecker J. Agric. Res.* 2(9): 240-245.

Dubey, N., Shrivasthava, A. N., Avinashe, H. A., and Jaiwar, S. 2015. Genetic variability, correlation and path analysis for yield and yield contributing characters in soybean (*Glycine max* L.). *Electr. J. Plant. Breed.* 6(1): 318-325.

Dewey, D. R. and Lu, K. H. 1959. A correlation and path coefficient analysis of components of crested wheat grass seed production. *Agron. J.* 51: 515-518.

Ekka, P. K. and Lal, G. M. 2016. Study on genetic variability and character association in soybean [*Glycine max* (L.) Merrill] germplasm at Vindhyan zone of Uttar Pradesh. *Agric. Sci. Digest.* 36(1): 69-71.

Fehr, W. R., C. E. Caviness. 1977. *Stages of soybean development.* Iowa State University Cooperative Extension Service, Special Report 80.

Fisher, R. A. 1954. A fuller theory of "junctions" in breeding. *Heredity*. 8: 187-197

Ghodrati, G. 2013. Study of genetic variation and broad sense heritability for some qualitative and quantitative traits in soybean (Glycine max L.) genotypes. *Curr. Opin. Agric.* 2(1): 31-35.

Gohil, V. N., Pandya, H. M., and Mehta, D. R. 2006. Genetic variability for seed yield and its component traits in soybean. *Agric. Sci. Digest.* 26 (1): 73-74.

Golani, I. J., Naliyadhara, M. V., Mehta, D. R., Purohit and Padya, H. M., 2006, Genetic divergence in dolichos bean *(Lablab purpureus* L.). *Legume Res.,* 29(4): 286-288.

Gopalan, C., Sastri, B. V. R., and Balasubramanian, S. C., 2012, *Nutritive value of Indian foods*. National institute of nutrition, Hyderabad, pp. 47-58.

Gotoh, K. 1984. Historical review of soybean cultivation in Japan. *Trop. Agric. Res. Series* 17: 135-138.

Hanchinamani, N. C., 2004, Studies on genetic variability and genetic divergence in cluster bean (*Cyamopsis tetragonoloba* L.*). M. Sc. (Hort.) Thesis, Univ. Agric. Sci., Dharwad.*

Haruna, M. K., Turaki, Z. G. S., Bibinu, A. T. S and Wali, A. S., 2015, Soybean varietal evaluation in Northern Guinea Savanna. *J. Bio. Agric. Healthcare,* 5(9): 139-142.

Iqbal, Z., Arshad, M., Ashraf, M., Naeem, R., Malik, M. M., and Waheed, A. 2010. Genetic divergence and correlation studies of soybean [*Glycine max* (l.) Merrill.] genotypes. *Pak. J. Bot.* 42(2): 971-976.

Jain, S., Srivastava, S. C., Singh, S. K., Indapurkar,Y. M., and Singh, B. K. 2015. Studies on genetic variability, character association and path analysis for yield and its contributing traits in soybean [*Glycine max* (L.) Merrill]. *Legume Res.* 38 (2): 182-184.

Jackson, M. L. 1973. *Soil Chemical Analysis*, Prentice Hall of India, Pvt. Ltd., New Delhi, 498p.

Jayprakash, Ram, R. B. and Meena, M. L., 2015, Genetic variation and characters interrelationship studies for quantitative and qualitative traits in french bean (*Phaseolus vulgaris* L.). *Legume Res.*, 38(4): 425-433.

Jellinek, G. 1985. Sensory Evaluation of Food: Theory and Practice. Ellis Horwood, Chichester, England, 596p.

Jian, Y. 1984. Situation of soybean production and research in China. *Trop. Agric. Res. Series* 17: 67-72.

Johnson, H. W., Robinson, H. F., and Comstock, R. E. 1955. Estimates of genetic and environmental variability in soybeans. *Agron. J.* 47: 314-318.

Joshi, B. D. and Mehra, K. L., 1984, Path analysis of productivity in French bean. *Prog. Hort.*, 16(1-2): 78-84.

Kachhadia, V. H., Barasar, V. V., Vachhani, J. H., Patil, M. B., and Barad, H. R. 2014. Genetic divergence in soybean [*Glycine max* (L.) Merrill.]. *Electr. J. Plant. Breed.* 5(3): 563-566.

Karnwal, M. K. and Singh, K. 2009. Studies on genetic variability, character association and path coefficient for seed yield and its contributing traits in soybean [*Glycine max* (L.) Merrill]. *Legume Res.* 32 (1): 70-73.

KAU [Kerala Agriculture University]. 2016. *Package of Practices Recommendation*: Crops (15th Ed.). Kerala Agricultural University, Thrissur, 200p

Keatinge, J. D. H., Easdown, W. J., Yang, R. Y., Chadha, M. L., and Shanmugasundaram, S. 2011. Overcoming chronic malnutrition in a future warming world: The key importance of mungbean and vegetable soybean. *Euphytica* 180: 129-141.

Kiran, T. M., Lavanya, G. R., and Babu, G. S. 2014. Association analysis for pod yield and component characters in dolichos bean (*Lablab purpureus* L.). Electr. *J. Plant Breed.* 5(4): 820-823.

Kono, S., 2000, Edamame. Theor. Appl. Genet., 71: 195-243.

Konovsky, J., Lumpkin, T. A., and Mcclary, D. 1994. Edamame: the vegetable soybean. In: O'Rourke A. D. (ed.), *Understanding the Japanese food and agrimarket: A multifaceted opportunity.* Haworth Press, Binghamton New York, pp. 173-181.

Kumar, A. P., Reddy, R. V. S., Pandravada, S. R., Rani, D. V. and Chaitanya, V., 2014, Phenotypic variability, correlation and path coefficient analysis in pole type French beans (*Phaseolus vulgaris* L.) *Plant Archives,* 14(1): 313-319.

Kumar, A., Pandey, A., and Pattanayak, A. 2015. Assessment of genotypic variation in soybean. *Legume Res.* 38 (2): 174-177.

Kumar, A., Pandey, A., Aochen, C., and Pattanayak, A. 2015. Evaluation of Genetic Diversity and Interrelationships of Agro-Morphological Characters in Soybean (*Glycine max*) Genotypes. *Proc. Nat. Acad. Sci. India Sect. B. Biol. Sci.* 85(2): 397-405.

Kumar, M. K. V., 2004, Physiological basis of yield variation in french bean (*Phaseolus vulgaris* L.) genotypes *M. Sc. (Agri.) Thesis*, *Univ. Agric. Sci., Dharwad.*

Kumar, V., Rani, A., Goyal, L., Pratap, D., Billore, S. D., and Chauhan, S. D. 2011. Evaluation of Vegetable-Type Soybean for Sucrose, Taste-Related Amino Acids, and Isoflavones Contents. *Int. J. Food Prop.* 14:1142–1151.

Kuswantoro, H. 2017. Genetic variability and heritability of acid-adaptive soybean promising lines. *Biodiversitas*. 18(1): 378-382.

Lenka, D. and Mishra, B. 1973. Path coefficient analysis of yield in rice varieties. *Indian J. Agric. Sci.* 43: 376-379.

Li, Y. S., Du, M., Zhang, Q. Y., Hashemi, M., Liu, X. B., and Hebert, S. J. 2013. Correlation and path coefficient analysis for yield components of vegetable soybean in northeast China. *Legume Res.* 36: 284-288.

Lowry, O. H., Rosebrough, N. J., Farr, A. L., and Randall, R. J. 1951. Protocol for protein estimation. *J. Boil. Chem.* 193: 265-275.

Lush, J. L.1949. *Animal breeding Plans.* Lown State University Press, Annes, p.473

Magalingam, V., Yassin, M., and Kumar, S. R. 2013. Genetic variability and character association in dolichos bean. *SAARC J. Agric.* 11(2): 161-171.

Mahalanobis, P. C. 1936. On the generalised distance in statistics. *Proc. Nat. Acad. Sci. (India).* pp. 79-85.

Mahbub, M. M., Rahman, M. M., Hossain, S., Mahmud, F., and Mir, M. M. 2015. Genetic variability, correlation and path analysis for yield and yield components in soybean. *Am.-Eur. J. Agric. Environ. Sci.* 15(2): 231-236.

Mahesh, M., Sudhanshu, J., and Bhadoria, V. S. 2017. Genetic divergence studies in soybean (*Glycine max* L. Merrill). *Int. J. Agric. Sci.* [e-Journal] 9(19). Available: http://www.einternational/content/ Volume9/Issue 19/full/index.html. ISSN: 0975-3710&E-ISSN: 0975-9107. [28 March 2017].

Malik, M. F., Asraf, M., Qureshi, A. S., and Ghafoor, A. 2007. Assessment of genetic variability, correlation and path analyses for yield and its components in soybean. *Pak. J. Bot.* 39(2): 405-413.

Manav and Arora, R. N. 2017. Genetic variability studies for yield and seedling traits in soybean [*Glycine max* (L.) Merrill]. *Indian Res. J. Genet. & Biotech.* 9(1): 78-110.

Manish, K. S., Smaranika, M., and Neerja, S. R. 2009. Genetic divergence in french bean (*Phaseolus vulgaris* L.). *Legume Res.* 32(3): 220-223.

Manjava, J. G., Gopalkrishna, T., Pawar, S. E., and Bapat, V. A. 2007. Genetic variability for trypsin inhibitor content in soybean [*Glycine max* (L.) Merrill.] and its correlation with oil and protein. *Indian J. Genet.* 67(1): 51-55.

Masuda, R. 1991. *Quality requirement and improvement of vegetable soybean. Research needs for production and quality improvement.* AVRDC. Taiwan. pp. 103-107.

Mathur, S. 2004. Soybean: The wonder legume. Beverage and Food world. *Genet. Res. Crop Evol.* 42: 97-108.

Mebrahtu, A. T. and Devine, T. E. 2010. Combining ability analysis for selected green pod yield components of vegetable soybean genotypes (*Glycine max*). *NewZealand J. Crop Hort. Sci.* 36: 97-105.

Mebrahtu, T. and Mohamed, A. 2006. Genetic variation for green pod yield and quality among vegetable soybean genotypes. *J. Crop. Improv.*16: 113-130.

Mehra, D. and Singh, D. K., 2012, Path analysis for pod yield in french bean (*Phaseolus vulgaris* L.). *Veg. Sci.,* 39(2): 192-194.

Mishra, S., Pancheshwar, D. K., Singh, P., and Jha, A. 2014. Study of Genetic Variability in Recently Evolved Genotypes of Soybean [*Glycine max* (L.) Merill]. *Trends Biosci.* 8(19).

Mishra, V. K., Shridhar, and Tripathi, S., 2009, Association between economic traits in french bean (*Phaseolus vulgaris* L.). *Prog. Hort.*, 41(1): 86-88.

Njoroge, J. N., Owouche, J. O. and Oyoo, M. E., 2015, Evaluation of (*Glycine max* (L.) Merrill) genotypes for agronomic and quality traits in Kenya. *Afr. J. Agric. Res.,* 10(12): 1474-1479.

Olivia, P. D., Pant, S. C., Rawat, S. S., Rana, D. K., and Indrakumar, N. S. 2010. Correlation coefficient and genetic divergence analysis in pea (*Pisum sativum* L.). *Indian J. Hort.* 67(Special issue): 160-165.

Pal, A. K. and Singh, S., 2012, Correlation and path analysis in garden pea (*Pisum sativum* L var. Hortense). *The Asian J. Hort.,* 7(2): 569-573.

Pandey, Y., Durgamani, G., Resham, B. T., Mohan, D. S. and Krishna, P., 2011, Variability of french bean (*Phaseolus vulgaris* L.) in the western mid hills of Nepal. *Kasetsart J. Nat. Sci.,* 45: 780-792.

Parmar, A. M., Singh, A. P., Dhillon, N. P. S. and Jamwal, M., 2013, Genetic variability studies for morphological and yield traits in dolichos bean (*Lablab purpureus* L.). *World J. Agri. Sci.*, 9(1): 24-28.

Pagde, L., Abubakkar, D., Ingole, G., and Dhuppe, M. V. 2015. Study of genetic variability for yield and yield contributing traits in soybean (*Glycine max* (L.) Merrill). *Bioinfolet.* 12 (1): 256 – 258.

Patil, S. S., Naik, M. R., Patil, A. B., Ghodke, U. R. 2011. Genetic diversity in soybean. *Legume Res.* 34 (1): 68-70.

Patil, S. S., Naik, M. R., Patil, P. P., and Shinde, D. A. 2011. Genetic variability, correlation and path analysis in soybean. *Legume Res.* 34(1): 36-40.

Pawar, R. M. and Prajapati, R. M. 2013. Genetic variability, correlation and path analysis in dolichos bean (*Lablab purpureus* L.). *Int. J. Agric. Sci.* 9(2): 615-619.

Pawar, R. M., Prajapati, R. M., Sawant, D. M., and Patil, A. H. 2013. Genetic divergence in Indian bean (*Lablab purpureus* L. Sweet). *Electr. J. Plant. Breed.* 4(2): 1171-1174

Piper, C. S. 1966. *Soil and Plant Analysis.* Hans Publishers, Bombay, 368p.

Poornima, R., Koti, R. V. and Nair, R. N., 2014, Physiological basis of yield variation in vegetable soybean and organoleptic test for acceptance. *Plant Archives,* 14: 51-54.

Ramteke, R., Kumar, V., and Muralidharan, P. 2010. Study on genetic variability and traits interrelationship among released soybean varieties of India [*Glycine max* (L.) Merrill]. *Electr. J. Plant Breed.* 1(6): 1483-1487.

Ramya, V. and Mummigatti, U. V. 2015. Characterization of vegetable soybean genotypes for phenological, physiological and yield attributing traits. *Karnataka J. Agric. Sci.* 28(4): 500-503.

Rao, C.R. 1952. *Advanced Statistical Methods in Biometrical Research.* John Wiley and Sons Ltd., London, p.301

Ravinaik, K., Hanchinamani, C. N., Patil, M. G., and Imamsaheb, S. J. 2014. Correlation and path co-efficient analysis in dolichos bean (Dolichos lablab L.) genotypes. *Asian J. Hortic.* 9(2): 396-399.

Reni, Y. P. and Raob, Y. K. 2013. Genetic variability in soybean [*Glycine max* (L.) Merrill]. *Int. J. Plant Ani. Environ. Sci.* 3(4): 2231-4490.

Roy, S. K., Md. Karim, A., Islam, A., Nasimul, B. M., Khaleque, M. A. M. and Hidaka, T., 2006. Relationship between yield and its component characters of bush bean (*Phaseolus vulgaris* L.). *South Specific Studies,* 27 (1): 13-23.

Sadarivam, S. and Manickam, A. 1996. *Biochemical methods for agricultural sciences - Estimation of starch by anthrone method.* Willey publishers, pp. 10-11.

Salim, M., Hossain, S., Alam, S., Rashid, J. A., and Islam, S. 2013. Variability, correlation and path analysis in lablab bean (*Lablab purpureus* L.). *Bangladesh J. Agric. Res.* 38(4): 705-717.

Salmani, Z., Vijayalakshmi. and Sajjan, J. T., 2012. Screening of selected vegetable soybean genotypes for nutrient and anti-nutrient factors. *J. Dairying, Foods & H.S.,* 31(2): 142-145.

Sarangi, S. K. and De, L. L., 2010. Varietal evaluation of french bean at mid hills of Arunachal Pradesh. *Indian J. Hill Farming*, 23(2): 53-54.

Sarutayophat, T., 2012, Correlation and path coefficient analysis for yield and its components in vegetable soybean. *Songklanakarin J. Sci. Technol.,* 34(3): 273-277.

Sciarappa, W. J., Hunsberger, L. K., Shen, D., Qing-Li Wu, Simon, J. and Hulme, B., 2007. *Evaluation of edamame cultivars in New Jersey and Maryland*. Fruits, Vegetables and Nursery crops. pp. 223-227.

Shadakshari, T. V., Kalaimagal, T., Senthil, N., Boranayaka, M. B., Gowda, R. K., and Rajesha, G. 2011. Genetic diversity studies in soybean [*Glycine max* (L.) Merrill] based on morphological characters. *Asian J. Biosci.* 6(1): 7-11.

Shanmugasundaram, S. and Yan, M. R. 1999. *Vegetable soybeans for nutritional quality income generation ad soil sustainability.* In: Proceedings of the world Soybean Research Conference VI held at Chicago, USA, Aug. 4-7, 1999, p. 450.

Shanmugasundaram, S. and Yan, M. R. 2004. *Global expansion of high value vegetable soybean.* World Soybean Research Conference 7th, pp.915-920.

Sharma, B. K., Kushwah, S. S., Verma, K. S. and Singh, O. P., 2013, Studies on french bean (*Phaseolus vulgaris* L.) varieties under different N, P, K and S levels for growth, yield and economics. *J. Hort. Sci.,* 8(2): 268-270.

Sharma, D. P., Dehariya, N. K., and Tiwari, A. 2014. Genetic variability, correlation and path coefficient analysis of dolichos bean genotypes (*Lablab purpureus* L.). *Int. J. Basic App. Agric. Res.* 12(2): 193-199.

Sharma, R. K., Kumar, S., Maji, S., Pandey, V. J., Singh, S., Dubey A. K. and Kumar, P., 2016. Genetic variability, heritability, correlation coefficient and path analysis in french bean (*Phaseolus vulgaris* L.). *The Bioscan*, 11(2): 1153-1153.

Shinde, S. S. and Dumbre, A. D., 2001. Correlation and path coefficient analysis in French bean. *J. Maharashtra Agric. Univ.*, 26(1): 48-49.

Shivakumar, M., Basavaraj, G. T., Salimath, P. M., Patil, P. V., and Talukdar, A. 2011. Identification of rust resistant lines and their genetic variability and character association studies in soybean [*Glycine max* (L.) Merr.]. *Indian J. Genet.* 71(3): 235-240.

Shurtleff, W. and Aoyagi, A. 1971. History of fresh green soybeans and vegetable-type soybeans. In: Shurtleff, W. and Aoyagi A. (eds), *History of Soybeans and Soyfoods.*

Singh, Pramod K., Rai, N., Lal, Hira, Bhardwaj, D.R. Singh, Rashmi. and Prakash A., 2011. Correlation, path and cluster analysis in hyacinth bean (*Lablab purpureus* L. Sweet). *J. Agri. Tech.*, 7(4): 1117-1124.

Singh, S., Singh, P. K., Singh, D. R., Pandey, V. B., and Srivastava, R. C. 2015. Genetic variability and character association study in dolichos bean. *Indian J. Hort.* 72(3): 343-346.

Sirohi, S. P., Malik, S., Singh, S. P., Yadav, R., and Meenakshi, S. 2007. Genetic variability, correlations and path coefficient analysis for seed yield and its components in soybean [*Glycine max* (l.) Merrill]. *Prog. Agric.* 7(12): 119-123.

Sood, V. K., Sood, V. P., Pathania, A., and Chandel, K. 2006. Exploiting Genotypic Variability in Relation to Genetic Divergence among Advanced Lines of Soybean [*Glycine max* (L) Merrill]. *Indian J. Plant. Genet. Res.* 19(1).

Stobaugha, B., Palaciosa, L. F., Chena, P., and Orazalya, M. 2017. Agronomic evaluation of high-protein and high-oil soybean genotypes for specialty markets. *J. crop. Improv.* 31(2): 247-260.

Sureshrao, S. S., Singh, V. J., Gampala, S., and Rangare, N. R. 2014. Assessment of genetic variability of the main yield related characters in soybean. *Int. J. Food Agric. Vet. Sci.* 4(2): 69-74.

Thakur, D. K. 2015. Study on genetic variability, heritability and genetic advance for seed yield and its attributing traits in soybean [*Glycine max* (L.) Merrill]. *Trends Biosci.* 8(8): 1994-1996.

Tyagi, S. D., Sethi, J., and Tyagi, V. 2012. Genetic variability for seedling vigour traits and their association with seed yield and protein content in soybean [*Glycine max* (L.) Merrill]. *Forage Res.* 38 (2): 96-101.

Vaid, K. S., Singh, R. M. and Gupta, V. P., 1986. Inter-relationship of yield and its component characters in dry beans (*Phaseolus vulgaris* L.). *Crop Improv.*, 13: 164-167.

Verma, A. K., Uma Jyothi, K., Singh, R. P., and Jhade, R. K. 2016. Genetic Divergence studies in hyacinth bean (*Lablab purpureus* L.) genotypes. *Environ. Ecol.* 34(2): 437-440.

Wright, S. 1921. Correlation and causation. *J. Agric. Res.* 20: 557-585.

Young, G., Mebrahtu, T., and Johnson, J. 2000. Acceptability of green soybeans as a vegetable entity. *Plant Foods Hum. Nutr.* 55: 323–333.

ABSTRACT

117

Performance analysis of vegetable soybean (*Glycine max* L.) in humid tropics

By

SHILPASHREE N.

(2016-12-021)

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the

Requirement for the degree of

Master of Science in Horticulture

(VEGETABLE SCIENCE)

Faculty of Agriculture

Kerala Agricultural University, Thrissur

DEPARTMENT OF VEGETABLE SCIENCE
COLLEGE OF HORTICULTURE
VELLANIKKARA, THRISSUR - 680 656
KERALA, INDIA
2018

Performance analysis of vegetable soybean (*Glycine max* L.) in humid tropics

ABSTRACT

An experiment was carried out in research field of Department of Vegetable Science, College of Horticulture, Vellanikkara during October to December 2017 to study the performance of vegetable soybean (*Glycine max* L.). The main objective was to evaluate the performance of vegetable soybean accessions for yield and quality in the humid tropics of Kerala. Twenty eight accessions were grown in randomized block design with three replications.

The accessions were catalogued based on the NBPGR descriptor for soybean. The analysis of variance revealed significant differences for characters like plant height, days to 50% flowering, days to first harvest, days to vegetable maturity, pod length, pod width, pod yield per plant, number of pods per plant, pod weight, number of harvests, starch, carbohydrate, protein, crude fibre, vitamin C, iron, calcium, phosphorous and polyphenol content except number of seeds per pod and number of root nodules per plant.

The accession GM-26 was found to be the highest yielder of pods (91.80 g/plant) with a mean of 45.43 pods per plants. The accession GM-27 had highest plant height (83.03 cm). GM-12 recorded early flowering (27 days) to flowering and early harvest (35days). Highest pod length was observed in GM-25 and lowest pod length and width was observed in GM-21. The quality parameters like protein and crude fibre content were recorded highest in GM-12 and GM-14 respectively.

High genotypic coefficient of variation and phenotypic coefficient of variation were observed for plant height, number of pods per plant, pod weight, pod yield per plant and calcium content. High heritability coupled with genetic gain was observed for all the morphological and quality parameters.

Pod yield per plant was significantly and positively correlated with number of pods per plant, number of harvests, vitamin C and calcium content. Since, these associated traits are in the desirable direction, it indicated that simultaneous selection for these traits would be useful in improving the vegetable pod yield.

Days to 50% flowering (0.0387), days to first harvest (0.1874), pod length (0.10380), number of pods per plant (1.1017) and pod weight (0.4408) have shown positive direct effects on pod yield per plant while, plant height (-0.115), days to vegetable maturity (-0.0144) and pod width (-0.2330) have shown negative direct effects on pod yield per plant.

Twenty eight genotypes were grouped into eight clusters from estimated D^2 values. Cluster II was the largest cluster having 8 genotypes followed by Cluster V and Cluster I with 4 genotypes, Cluster III and IV had 3 genotypes and Cluster VI, cluster VII and cluster VIII had two genotypes each. Based on distance between clusters *i.e.* inter-cluster distance, the maximum distance was observed between clusters VIII and I (D^2 = 51828.79) followed by clusters VI and I (48046.45), clusters VIII and VII (45389.69), clusters VII and VI (38638.46) and clusters II and I (38391.70). The lowest inter cluster distance was observed between cluster VIII and II (7406.18) followed by cluster VI and II (8460.01).

The values obtained for the vegetable soybean, GM-13 which recorded highest rank in sensory evaluation also recorded carbohydrate (8.46 g), protein (11.43 g), crude fibre (2.55 g), iron (5.71 mg), calcium (13.50 mg) and phosphorous (613.66 mg) content.

Present study shows that based on yield and sensory evaluation, GM-12 is the promising genotype and it is the earliest genotype with respect to days to 50% flowering, days to first harvest and days to vegetable maturity.