CHARACTER ASSOCIATION OF SEEDS ON PLANT MORPHOLOGY IN SNAKEGOURD
(*Trichosanthes anguina* L.)

By

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THESIS

Submitted in partial fulfilment of the requirement for the degree

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Department of Olericulture

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DECLARATION

I hereby declare that this thesis entitled **"Character association of seeds on plant morpholgoy in snakegourd (*Trichosanthes anguina* L.)"** 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, fellowship or other similar title, of any other University or Society.

Vellanikkara
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CERTIFICATE

Certified that this thesis, entitled **"Character association of seeds on plant morpholgoy in snakegourd (*Trichosanthes anguina* L.)"** is a record of research work done independently by **Mr.P.Ashok,** 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 him.

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We, the undersigned members of the Advisory Committee of **Mr.P.Ashok,** a candidate for the degree of **Master of Science in Horticulture** with major in **Olericulture**, agree that the thesis entitled **"Character association of seeds on plant morpholgoy in snakegourd (*Trichosanthes anguina* L.)"** may be submitted by Mr.P.Ashok, in partial fulfilment of the requirement for the degree.

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Dedicated to

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CONTENTS

LIST OF TABLES

LIST OF PLATES

LIST OF FIGURES

INTRODUCTION

INTRODUCTION

Vegetables are important as protective foods providing vitamins and minerals. Among different vegetables, those belonging to Cucurbitaceae family consist of the largest number of cultivated vegetable crops. Snakegourd (*Trichosanthes anguina* L.), belonging to cucrbitaceae family, occupies a pride of place among vegetables particularly in South India. The crop is supposed to be a native of Indian Archipelago. The fruits are harvested and cooked green and have fairly good nutritive value. The edible portion constitutes 98 per cent of the fruit. Every 100 g of fruit contains 94.6 g of moisture, 0.5 g of protein, 0.3 g fat, 0.5 g minerals, 0.8 g of fibre, 3.3 g of carbohydrate and 160.01 IU of vitamin A (Gopalan *et al.*, 1982). Snakegourd is a highly cross pollinated crop. Many varieties of snakegourd have been evolved through selection. It is one of the rare cucurbits having medicinal properties. The 'compound Q', which is an active principle extracted in 1989 from snakegourd, received a lot of attention when medical professionals began to study it as a treatment against the human immunodeficiency virus (HIV) (Robinson and Deckerwalter, 1997).

The crop improvement necessitates information on various production factors. The seed being the primary factor calls for elaborate information. Effect of seed characters on vegetative characters as well as production traits has attracted the attention of the research workers for many years. Importance of seed characters influencing crop stand and uniform crop growth and ultimate yield behaviour is immensely realized in commercial seed production.

Snakegourd exhibits wide variation in seed coat colour. Morphological characters of seeds such as seed coat colour, nature of seed surface and seed size have been invariably used by plant breeders to group plant varieties. Such information are lacking in snakegourd. Hence the present study was undertaken to distinguish snakegourd varieties by utilizing morphological characters as well as seed characters. The main objectives of the studies were,

1. To find out the association of various seed characters on the vegetative characters of snakegourd
2. To identify marker characters, if any, in snakegourd genotypes
3. To formulate keys for varietal identification.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

The studies on various seed characters like seed coat colour, seed size, seed weight, seed dormancy and classification of varieties based on seed characters and correlation between these characters are reviewed hereunder.

2.1 Seed coat colour

West and Harris (1963) observed that brownish seed coat colour of alfalfa seeds, records higher germination and vigour and they reported that the seed coat colour had certain effect on seed quality.

John (1974) conducted field tests involving 47 pairs of snap bean breeding lines. In eleven yield comparisons between seeds of coloured and white seeded lines, the coloured seeded lines out yielded their white seeded counterparts by an average of 67 per cent. The results suggested that differences in seed colour were a major factor affecting the yield.

Gugani *et al.* (1975) observed higher seed quality of reddish brown and brown seed coat colour of cauliflower when compared to yellowish brown or light brown.

Morris and Payne (1977) revealed that soybean varieties could be distinguished from each other on the basis of morphological characteristics of seeds namely seed size, seed coat colour and hilum colour.

Macda *et al.* (1980) reported the superiority of grey yellow green over grey green coloured seeds of bhindi in seed weight, germination and seedling root and shoot length compared to black.

Baumaunk (1981) observed that the green pea seeds had higher vigour than the yellowish green and latter was better than yellow ones.

Harisingh and Gill (1983) reported that the quality of okra seed lot could be judged directly from seed coat colour. They classified the seed lot into different colour groups namely yellow green group, grey green group and black group. They stated that as the proportion of black seeds increases the seed quality decreases.

Wayke (1987) reported that higher vigour was characterized by the greenish yellow seeds in peas. Chakrabarty and Agrawal (1989) examined sixteen black gram varieties based on seed coat colour and seed surface and the varieties were classified into black or brownish black and shiny or dull groups respectively. Studies on these seed characteristics revealed that both seed size and seed colour are important diagnostic physical characteristics. For the preparation of seed keys these varieties were first divided into various seed colour groups. Varieties within each seed colour group were then divided into various seed size groups.

Agrawal and Pawar (1990) classified thirteen varieties of soybean based on seed coat colour, out of thirteen varieties twelve were yellow seeded and one was black seeded. The twelve yellow seeded varieties could be classfied into three hilum colour groups, namely black hilum, yellow hilum and brown hilum. They stated that the differences in morphological, chemical and physiological characteristics of seeds and seedlings were used to develop seed keys to distinguish soybean varieties.

Paramsivan (1990) reported that the greenish yellow seeds were superior in seed quality to yellow colour seeds in garden pea.

Philip verghese (1991) found a white patch on the seeds of snakegourd as a marker character to identify its genotype TA 102.

Seed coat colour differences in *Brassica napus* viz. yellow brown and black was reported by Deynze and Pauls (1994).

Omokanye (1995) reported that seeds of horsegram (*Macrotyloma uniflorum*) having varied seed coat colours were separated into grey, dark brown and black seed groups from unclassified seeds, floated and sunken seeds in water.

Proportion of above seed types were estimated on weight basis. Floating seeds contained a very high proportion (85.8%) of black seed coat types whereas grey and dark brown seed coat types were higher in unclassified and sunken seeds. Germination, emergence and other plant characteristics were studied in different testa colour groups. Germination was maximum in grey and brown seed coat types (94.1%) it was followed by sunken seeds (83.8%). Black seed coat types had 56.3 per cent germination and it was least in floated seeds (16.4%). Emergence and 1000-seed weight showed the same pattern as germination percentage. Other growth parameters were better in grey dark brown seed coats as well as in sunken seeds.

2.2 Seed size

On reviewing literature exhaustively on crops like cereals, root crops, fodders, leaf crops and cotton, Kidd and West (1918) made the following points.

(i) There was strong correlation between the size of the germ and the vigour of the resulting seedlings. This vigour continued throughout its life and the plants produced from seed with the largest germs exhibited higher drought tolerance. (ii) The plants from plump seeds produced a larger number of flowers which produced more numerous and larger fruits. Earlier maturity, in the case of peas, was achieved by selecting large seeds. (iii) With the increasing age, the superiority of plants from larger seeds decreased and was gradually lost in perennial plants. (iv) In the case of oats, wheat and rye, higher germination was observed for larger seeds.

The productiveness of cabbage was reported not to be dependent on the seed size. The small seeds, however, produced better quality heads (Kotowski, 1926) large seeds of alfalfa, sweet clover, rice and groundnut have been reported to give higher germination (Tseng, 1962).

Hewston (1964) found that many vegetable species almost invariably produce larger seedlings when grown from larger seeds.

Wester (1964) studied that the possibility of increasing yields of bush limabean by sizing the seed before planting, and by planting the various seed grades separately to eliminate over crowding of small plants.

According to Whalley *et al.* (1966) considerable variation in seed size existed in seeds produced from same plant.

Elsaeed (1967) obtained higher percentage of emergence from larger seeds in broadbeans.

Yield of beans (Ries, 1971) was not found to be related with seed size.

Decrease in the emergence of small seeds of wheat (cv. Kalyansona) under late sowing (due to low temperature) was observed despite no differences in the germination capacity of various seed grades in laboratory (Randhawa, 1972).

Singh *et al.* (1972) observed no definite trend of seed size either in the laboratory or in the field, except in one year when smaller seeds of cv. Clark 63 exhibited significantly higher emergence in the field.

Studies of Gelmon (1972) showed that size differences in seeds influence germination, seeding vigour, plant growth and yield characteristics.

Larger seeds of soybean exhibited superiority over the small seeds in dry matter production of three week old shoots in the green house and four weeks old shoots in the growth chamber and in the field. But the superiority was lost with respect to the dry weight of roots, total dry matter production and root-shoot ratio at four weeks of age in the growth chamber. Significantly taller plants at three weeks, and nonsignificantly taller at four week of age and final plant height stage were produced by the larger seeds, which showed some increase in the seed weight. These attributes had no significant influence on the grain yield (Dhillon, 1973).

In the case of *Brassica campestris* L. (cv. Toria) plants from larger seeds produced more fruit per plant, heavier seeds and higher seed yield per plant than those from small seeds, but had few seeds per fruit (Ahmed and Zuberi, 1973).

Higher emergence speed in small seeds of barley, triticale, pigeonpea, moong G 65 and soybean was recorded. But in black gram and groundnut (cv. PG-1 and M-145), medium seeds showed the highest speed, where as in groundnut (cv. M-13), the large seeds showed the highest emergence speed (Dhillon *et al.*, 1976).

The study on the effect of seed size on crop production conducted thus so far has not been conclusive. However, the following generalization made by Dhillon and Kler (1976) are relevant:

i) The seedlings from the large seeds, in general, show early superiority, which is eventually lost with the advance in the growing season, particularly in case of crops or varieties of longer duration. The use of large seeds may prove advantageous in short duration crops like spring cereals and vegetables and/or under some unfavourable conditions like low temperature and low soil fertility.

ii) The emergence speed of large seeds is certainly slower than those of small seeds.

iii) In most of the cases, it is possible to obtain higher and similar yields with smaller seeds as with their ungraded bulk seeds. For forage crops however, large seeds appear to perform better.

iv) The slow rate of emergence in large seeds appears to be due to increased length of the diffusion path. But the exceptions to this in the case of groundnut, blackgram and ML-1 variety of green gram needs to be further investigated.

v) Seed size is a relative term that can be interpreted differently. One research worker may define a particular seed size, for example as medium, which the other worker may define as large or small according to the class size chosen by him. This may lead to misinterpretation of the conclusion drawn, unless the size of the seed is mentioned.

vi) Plants from small seeds, in general, appear to be more efficient users of their environment and resources either as a result of their extensive root systems, higher photosynthetic efficiency or some differences in their rhizosphere and phyllosphere which calls for some further detailed studies on these aspects to draw the final conclusion.

Dhillon *et al.* (1982) conducted field experiments in cowpea and revealed that small seeds tended to give slightly higher yield.

Association of seed, pod, leaf size and seeds per pod in 48 genotypes of lentil revealed that seed size was significantly and positively correlated with leaf and pod size and negatively with seeds per pod. Leaf and pod size were also positively correlated (Tyagi and Sharma, 1984).

Panditta and Randhawa (1992) reported that bold seeds gave the highest emergence (90.8%) followed by medium (81.6%) and small (73.1%) size seed lots in case of radish.

2.3 Seed weight

Importance of seed weight seems to be the greatest during the earlier stages of plant growth (Oexeman, 1942).

The size of the cotyledons in the case of soybean was reported to be positively correlated to the weight of the seeds. But the cotyledonary area, when calculated on the basis of the unit seed weight, increased with decrease in seed size (Edward and Hartwig, 1970).

Studies on soybean had shown that heavier seeds exhibited superior emergence, embryo size and fresh weight for roots, shoots and total plants. They also excelled in vigour, height, stem diameter, number of branches and pods per plant dry weight and grain yield (Burris *et al.*, 1973).

Rajan Paul and Ramaswamy (1979) reported that the seed weight exhibited linear relationship with seed size. In cowpea (Co-1) significant differences were recorded for length of shoot and hypocotyl vigour index and dry matter production among grades of seeds and these parameters positively correlated with seed weight.

Harisingh and Gill (1983) classified seed lots of bhindi into different groups based on the correlation between seed weight and seed coat colour.

Patil and Bangal (1984) studied the influence of seed weight on germination and seedling vigour in safflower cultivars and they revealed that germination per cent or vigour was not correlated significantly with seed weight.

Correlation studies on lentil revealed that seed number per pod had a significant negative correlation with 1000 grain weight (Tyagi and Sharma, 1984).

Palaniswamy and Ramaswamy (1985) revealed that the associations between seed weight and seedling vigour in three grades of bhindi seeds were positive and significant.

Ravendranath and Gopalsingh (1991) reported a positive association between seed size and weight of achene in sunflower.

Hooda and Rajbahadur (1993) conducted observation on twelve strains of subabul and revealed that seed length, breadth, thickness and weight were found to be positively correlated with each other and seed length had the highest direct effect on seed weight.

Omokamye (1995) classified seeds of horsegram into grey, dark brown and black seeds groups. He observed that there was a reduction in 1000 seed weight in the case of black seed coat types compared to dark brown and grey.

2.4 Classification of varieties based on seed characters

Davis and Heywood (1963) reported that seeds are relatively stable in their external morphology considered in terms of colour, size, surface ornamentation, outline and shape index. Variations in seed characters may occur from one species to another. As these differences are taxonomically constant, they are important and helpful in identifying species.

On the basis of seed characters Datta *et al.* (1970) first prepared an artificial key for identification of the different species studied.

Ghosh and Datta (1975) classified two species of corchorus based on the surface outline of the seed, ornamentation, seed colour, 100 seed weight and seed size.

In Kentucky blue grass seed length and width measurement, seed characteristics and drawings are used to describe 21 cultivars (Wiseman and Koszykowski, 1976).

Higgins *et al.* (1988) published a classification of 117 varieties of *Vicia faba* L. using four qualitative characters and five quantitative characters for use by breeders when entering varieties for national listing in the U.K.

Higgins and Sparks (1989) reported single seed weight and 100 seed weight in fababean could be used as key for identification of cultivars.

Martinello (1992) used different morphological characteristics related to stem, leaf, flower and frutiferous organs, seed yield and 1000 seed weight for checking genetic purity in pea, common vetch bean (*Vicia sativa* L.) and broad bean (*Vicia faba* L.).

Ninety two *Vicia sativa* accessions were studied for various varietal characters and among them seed length and width could be used as the parameters for varietal identification (Gill and Cubero, 1993).

Nagapadma *et al.* (1996) prepared a key for characterising 23 inbred lines of maize based on seed colour, seed texture and 100 grain weight.

Craftons (1997) classified *Vicia faba* L. varieties based on the seed testa colour and the different proportion of the two principal hilum colour.

Surendraprakash and Singhal (1997) studied six vegetable pea cultivars for various morphological characters, both qualitative and quantitative for two year. They revealed that it was possible to identify the individual cultivars on the basis of morphological characters. A list of key characters useful in variety identification was prepared.

2.5 Correlation of plant characters with seed

Edelstein *et al.* (1987) reported that seed size had no effect on subsequent leaf and stem fresh weight, number of internodes and plant height in case of *Cucurbita pepo*.

Singh *et al.* (1987) reported that yield in parwal was significantly correlated with length of the fruit, diameter of the fruit and weight of seed. Days to flowering were negatively correlated with seed size. Length of the fruit was significantly correlated with fruit diameter, fruit weight, and seed number per fruit, diameter of fruit with fruit weight, seed size and seed weight, pulp thickness of the fruit with seed number per fruit and weight of seed. Days to flowering, fruit diameter, fruit weight and size and weight of the seed were thought to have direct effect on yield while fruit length pulp thickness and seed number per fruit had indirect effect.

In bittergourd percentage of mature seeds was the greatest in larger fruits but seed to fruit ratio was greater in smaller fruits, but the percentage of germination was not significantly effected by fruit size (Supe *et al.*, 1990).

Prasad and Singh (1990) studied on the morphological and agronomical components of pointed gourd and revealed positive correlation of yield with lateness in flowering and number of seeds per fruit with fruit weight.

In sponge gourd, Abusaleha and Dutta (1991) observed that yield per vine was positively correlated with fruits per vine, fruit length and branches per vine at genotypic level, and negatively correlated with days to female flower appearance.

High correlation were observed between seed weight per fruit and fruit weight or fruit length in short fruited lines of cucumber, but these traits were poorly correlated in the slicing lines (Milotary *et al.*, 1991).

Correlation studies in 16 parental lines of bottle gourd indicated that yield per plant was positively correlated with average fruit weight of edible fruit and number of fruits per plant. The yield per plant was negatively associated with the node bearing first female flower, days to first harvest and vine length (Kumar and Singh, 1998).

In *Trichosanthes cucumerina* large fruits had the highest number of seeds, but seed size did not significantly influence germination percentage (Devadas *et al.*, 1998).

In pumpkin total number and dry weight of seeds per fruit and 100 seed weight were maximum in big fruits and that of medium and small fruits. The weight of the fruit was significantly correlated with polar and equitorial diameter of fruit, total number and dry weight of seeds per fruit and 100 seed weight (Devadas, *et al.*, 1999).

2.6 Principal component analysis

Thirstone (1931) described a more generally applicable method of factor analysis which had no restrictions as regards to group factors and which did not restrict the number of general factors that are operative in producing the intercorrelation.

According to Hotelling (1933) principal components are linear combinations of statistical variables which have special properties in terms of variance.

Girskick (1936) has shown that principal components are linear functions of variables, which have least variance ascribable to errors of measurement, and factor loadings of principal components are maximum likelihood statistics.

Kutzbach (1961) principal component analysis to determine the relationship between various meteorological variables.

Dempster (1963) extended the stepwise testing methods of multivariate analysis of variance to the linear combination of variable resulting from principal component analysis.

Pearce (1967) described an interesting application of principal component analysis in apple for the prediction of the tree weight on the basis of relevant size measurements of individual tree.

Pochop *et al.* (1975) performed principal component analysis using climatological data, which consisted of 42 variables for eight countries and 45 years.

Principal component analysis was performed on twenty two morphological characters and yield determining characters of sixteen cultivars and strains of dry beans by Denis and Adams (1978). Variables with the highest positive loadings on the first axis were seed weight, pod thickness, pod breadth, pod length and internodal length.

Tikka and Asawa (1978) used correlations of twenty eight genotypes for factor analysis and only two factors were found important in explaining the variations in the seven traits.

Johnston (1978) has summarized the advantage of principal component analysis as (1) to identify groups of uncorrelated variables, (2) to reduce number of variables, (3) to remove multicollinearity.

Mahajan *et al.* (1981) applied the analysis through the principal component technique and showed that the most of the variations in late duration cultures of rice could be explained by ear bearing tillers or grain number per panicle and 100 grain weight in a set of six variations.

2.7 Seed dormancy

Crocker and Davis (1914) showed that the seed coat of *Alisma plantago* prevented the complete inhibition of embryo so that the seed with a partly swollen embryo could lie for years in its aquatic environment, unable to germinate.

Miller (1956) investigated the effects of cytokinins on the germination of lettuce seeds. The dormancy of lettuce seeds could be overcome by supplying kinetin in darkness.

In lettuce Ikuma and Thimann (1963) demonstrated that the mechanical properties of the endosperm layer prevented radicle elongation in seeds which had not received an irradiation treatment sufficient to bring about germination.

Belboa-Zavala and Dennis (1977) monitored the germination ability of isolated embryo's of apple seeds during seed development and found that neither free nor bound ABA levels in the embryonic axes and cotyledons showed any consistent correlation with the acquisition of dormancy.

According to Thomas (1977), cytokinins act by counteracting the effect of inhibitors, especially ABA, when applied simultaneously.

Seeds of species belonging to the genus *Acacia* showed a negative relationship between seed coat thickness and susceptability to softening (Tran, 1979).

Bewley and Black (1982) suggested that the coat-imposed dormancy in rice and other cereals is caused by the consumption of oxygen by the peroxidases present in the hull, limiting the amount of oxygen reaching the embryo.

Seed dormancy is initiated during seed development, the process being influenced by the parental and zygotic phenotype (Simpson, 1990).

Hilhorst *et.al.* (1992) concluded that ABA plays a pivotal role during the development of primary dormancy and gibberellins are involved in the induction of germination.

Suryavamsi *et al.* (1996) conducted seed dormancy studies in cucumber and they recorded the highest percentage of germination when cucumber seeds are treated with 1000 ppm GA_3.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The study was undertaken during the period from February 1999 to April 2000 in the Research Farm of the Department of Olericulture, College of Horticulture, Vellanikkara. The experimental site is located at an attitude of 22.5 m above M.S.L. between 70°32' N latitude and 75°16' E longitude. The whole experiment consisted of the following parts.

3.1 Collection and cataloguing of snakegourd genotypes

3.2 Selfing of genotype and collection of selfed seeds

3.3 Raising of crop from the selfed seeds and recording various seed characters and plant characters

3.1 Collection and catalouging of snakegourd genotypes

Twenty five accessions collected from different parts of the country were genetically catalogued as per IBPGR descriptor list (Table 1 and Table 2).

3.2 Selfing of genotype and collection of selfed seeds

3.2.1 Experimental materials

The experimental materials consisted of 25 accessions collected from different parts of India.

3.2.2 Methods

The experiment was laid out in a randomized block design with two replications. Each replication consisted of 25 plots, one for each type. Planting was done at a spacing of 2 m x 2 m. The genotypes were raised during August 1999 to November 1999 for selfing. Various seed characters were recorded before sowing of the seeds.

Table 1. Source of Snakegourd accession used in the study

Sl. No.	Accession Number	Source
1	TA 102	Guntur, Andhra pradesh
2	TA 103	Trichur, Kerala
3	Co-2	Coimbatore, Tamil Nadu
4	MDU-1	Madurai, Tamil Nadu
5	TA 104	NBPGR, Trichur, Kerala
6	TA 105	,,
7	TA 19	,,
8	TA 106	,,
9	TA 107	,,
10	TA 108	Anakayam, Kerala
11	TA 109	Muvattupuzha, Kerala
12	Kaumudi	Trichur, Kerala
13	Co-1	Coimbatore, Tamil Nadu
14	TA 95	Trichur, Kerala
15	TA 110	Ernakulam, Kerala
16	TA 111	NBPGR, Trichur, Kerala
17	TA 112	,,
18	TA 113	,,
19	TA 114	Mavellikara, Kerala
20	TA 115	NBPGR, Trichur, Kerala
21	TA 116	Pappanipara, Kerala
22	TA 117	Madurai, Tamil Nadu
23	TA 118	NBPGR, Trichur, Kerala
24	PKM-1	Periyakulam, Tamil Nadu
25	TA 119	NBPGR, Trichur, Kerala

Table 2. Genetic cataloging of snakegourd (*Trichosanthes anguina*)

1. Plantcharacters	
1. Vegetative	
1.1 Growth habit	- Bushy/Intermediate/Prostrate
2. Leaf shape	- Ovate/Orbicular/Reniform
3. Leaf size	- Small/Intermediate/Large
4. Leaf lobes	- Absent/Shallow/Intermediate/Deep
5. Leaf colour	- Light green/Green/Darkgreen
6. Leaf pubescence	- No Hairs/Sparse/Intermediate/Dense
7. Leaf pubescence type	- Smooth/Dented
8. Leaf Margin	- Present/Absent
9. Tendils	- Short (upto 5 cm)/Intermediate (6-10 cm)
10. Internodal length	
11. Stem shape	- Rounded/Angular
12. Stem colour	- Light green/Thick green
2. Inflorescence and Fruit	
2.1 Main vine length (m)	
2. Days to first male flower anthesis	
3. Days to first female flower opening	
4. Male flowers per plant	
5. Female flower per plant	
6. Sex ratio	
7. Flowering habit	- Simple/clusters
8. Sex type	- Monoecious/Dioecious/Hermophrodite
9. Peduncle length	- Short/Intermediate/Long
10. Blossom end of fruit	- Depressed/Flattened/Rounded/Pointed
11. Fruit skin colour	- Green/White/Green with white Stripes/White with green stripes
12. Fruit skin colour	- Soft/Intermediate/Hard
13. Fruit texture	- Matt/Intermediate/Glossy
14. Internal aroma	- Absent/Present
15. Flesh colour	
16. Flesh thickness	
17. Fruit length	- Small/Medium/Large
18. Fruit girth	
19. Fruit weight	
20. Days to fruit maturity	
21. Days to first harvest	
22. Fruits per plant	
23. Yield per plant	

Table 2. continued

3. Seed	
3.1 Seed surface	- Smooth/Wrinkled/Pitted/Creased
2. Seed surface lustre	- Dull/Intermediate/Glossy
3. Seed coat colour	- White/Tan/Brown/Gray/Black
4. Seed shape	- Round/Elliptical/Oval/Acorn/Cone
5. 100 seed weight	
6. Seed length	
7. Seed width	
8. Seed margin	
9. Seed dormancy	

The selfed seeds collected from each genotype were used to raise the second crop during January 2000 to April 2000. Various seed characters and plant characters were recorded. The cultural practices, plant protection measures and fertilizer application were adopted according to the Pakcage of Practices Recommendation 1996 of the Kerala Agricultural University.

3.2.3 Observations

Different quantitative as well as qualitative characters were taken from the selfed seeds and the resultant plants. The average values of the plant characters and that of seeds for every genotype were worked out and were used for further statistical analysis.

a) Vine length (m)

The plants were pulled out after the final harvest and the length was measured from the collar region to the tip of the main vine.

b) Tendril length (cm)

The length of the tendril was calculated by taking the average of three tendrils randomly selected.

c) Internodal length (cm)

The length of the internode at three different points of the vine was recorded, and average was worked out.

d) Days to first male flower opening

The number of days was counted from the date of germination to the date when the first male flower opened.

e) Days to first female flower opening

The number of days was counted from the date of germination to the date of opening of the first female flower.

f) Number of male flowers per plant

The number of male flowers was counted every day as and when they open, starting from the day of opening of first male flower.

g) Number of female flowers per plant

The number of female flowers was counted every day as and when they opened, starting from the day of opening of the first female flower.

h) Sex ratio

This was calculated as a ratio of the number of male flowers to female flowers per plant.

i) Peduncle length (cm)

The length of the peduncle from three fruits was recorded, and average was taken.

j) Fruit length (cm)

The length of the first six fruits harvested from each plant was recorded and the average worked out.

k) Fruit girth (cm)

Girth at the middle of first six fruits from each plant was recorded and the average was worked out.

l) Flesh thickness (mm)

The fruits were cut and the thickness of the flesh at the middle of the fruit was measured.

m) Average fruit weight (g)

The weight of first six fruits harvested from each plant was recorded and the average was worked out.

n) Days to fruit maturity

The number of days taken was counted starting from the day of female flower opening up to vegetable harvest pertaining to first six fruits.

o) Days to first harvest for seed

The number of days taken for the first fruit to harvest for seed, was counted starting from the day of female flower opening.

p) Fruits per plant

The number of fruits in each plant was counted as and when the fruits were harvested and finally added together.

q) Yield per plant (kg)

The weights of all the harvested fruits from each plant were recorded and added up to get the total yield per plant.

r) Number of seeds per plant

Number of seeds was counted from the first six fruits harvested from each plant and the average was worked out.

s) 100 seed weight (g)

The seeds obtained from first five fruits were taken for estimating the 100 seed weight.

t) Seed length, seed width and seed thickness (mm)

Seed length, seed width and seed thickness was measured with vernier calipers and average of five seeds was recorded.

v) Seed size index

Seed size index was obtained by multiplying seed length by seed width.

w) Seed dormancy

Seeds after extraction from fruit were subjected to germination test and number of days taken for germination was counted.

3.4 Statistical analysis

The data obtained from the studies were subjected to following types of statistical analysis.

i) Correlation analysis

Simple correlation coefficient between pairs of characters were worked out to know the degree and nature of association between relevant characters and their statistical significance tested using the student's 't' test.

ii) Principal component analysis

Principal component analysis consists of transforming a given set of variables to a new set which are linear combination of the original variables by an orthogonal transformation.

The first principal component is that linear combination of the several original variables which accounts for a maximum amount of the total variation or individual differences represented in the complete set of original variables. In general, the r^{th} principal component is that weighed combination which of all possible weighed combinations independent of the first (r-1) account for a maximum amount of the remaining variation among the observations of the original data. The properties of statistical orthogonality and maximization of variance uniquely define principal components. The principal components indicate the intrinsic relationships within a single set of variables and are helpful in reducing the dimensionality of the set of variables without as little loss of information as possible.

The second principal component and the associated variance are obtained in the same way as that described for the first component (Tabachnick and Fidell, 1989).

In the present study co-variance matrix of seed, growth and yield characteristics of plants were used for the extraction of major components through principle component analysis. This analysis was performed in computer by using MSTAT-C package.

RESULTS

4. RESULTS

The data obtained from the studies are presented under the following subtitles.

4.1 Genetic cataloguing of snakegourd

Twenty five accessions of snakegourd were genetically catalogued based on the descriptor depicted in Table 2. Various characters of the genotypes like growth, yield and seed characters are presented in Tables 3, 4 and 5, respectively.

4.1.1 Growth characters

The growth habit varied from bushy to intermediate, leaf size varied from small to large, and leaf colour varied from light green to dark green. Leaf shape of all the accessions was orbicular. Leaf lobes varied from shallow to deep, leaf pubescence noted was smooth or dented. The stem shape was either rounded or angular, and stem colour varied from dark green to light green (Table 3).

4.1.2 Yield characters

Days to first male flower anthesis, days to first female flower opening, female flowers per plant, sex ratio, days to fruit maturity, fruits per plant and yield per plant varied with all the accessions (Table 4).

Fruit skin colour, fruit skin texture, fruit lustre, flesh thickness, fruit length, fruit girth, and fruit weight were varied with all accessions (Table 4).

4.1.3 Seed characters

The seed coat colour varied from tan (two accessions), brown (16 accessions) and grey (seven accession), seed shape was either elliptical (21

Table 3. Vegetative characters in snakegourd accessions

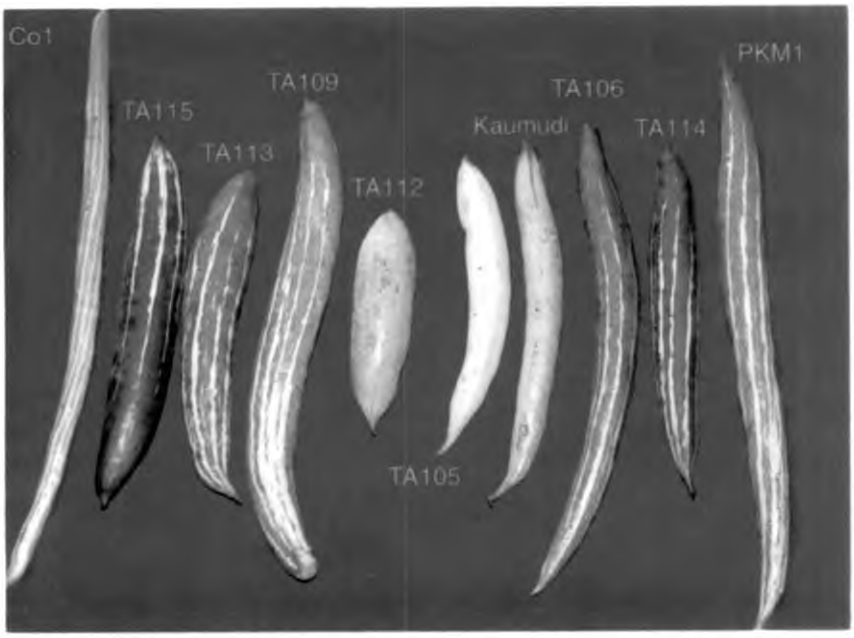
Accession No.	Growth habit	Leaf shape	Leaf size	Leaf lobes
TA102	Intermediate	Orbicular	Intermediate	Intermediate
TA103	Intermediate	Orbicular	Large	Shallow
CO2	Intermediate	Orbicular	Large	Shallow
MDU1	Bushy	Orbicular	Intermediate	Deep
TA104	Intermediate	Orbicular	Intermediate	Intermediate
TA105	Intermediate	Orbicular	Small	Deep
TA19	Intermediate	Orbicular	Intermediate	Deep
TA106	Intermediate	Orbicular	Intermediate	Shallow
TA107	Intermediate	Orbicular	Large	Shallow
TA108	Intermediate	Orbicular	Large	Shallow
TA109	Intermediate	Orbicular	Intermediate	Shallow
KAUMUDI	Intermediate	Orbicular	Intermediate	Shallow
CO1	Intermediate	Orbicular	Large	Shallow
TA95	Intermediate	Orbicular	Intermediate	Deep
TA110	Intermediate	Orbicular	Large	Shallow
TA111	Intermediate	Orbicular	Large	Deep
TA112	Intermediate	Orbicular	Large	Deep
TA113	Intermediate	Orbicular	Intermediate	Deep
TA114	Intermediate	Orbicular	Intermediate	Deep
TA115	Intermediate	Orbicular	Intermediate	Shallow
TA116	Intermediate	Orbicular	Large	Shallow
TA117	Intermediate	Orbicular	Intermediate	Deep
TA118	Intermediate	Orbicular	Large	Shallow
PKM1	Intermediate	Orbicular	Intermediate	Intermediate
TA119	Intermediate	Orbicular	Large	Shallow

Table 3. Continued

Accession No.	Leaf colour	Leaf pubescence	Leaf Pubescence type	Leaf margin	Stem shape	Stem colour
TA102	Green	Sparse	Smooth	Present	Rounded	Light green
TA103	Dark green	Sparse	Smooth	Present	Angular	Thick green
CO2	Green	Dense	Dented	Present	Angular	Thick green
MDU1	Green	Sparse	Smooth	Present	Angular	Green
TA104	Dark green	Sparse	Dented	Present	Angular	Light green
TA105	Dark green	Sparse	Smooth	Present	Angular	Light green
TA19	Dark green	Sparse	Smooth	Present	Angular	Light green
TA106	Green	Sparse	Dented	Present	Angular	Light green
TA107	Green	Sparse	Smooth	Present	Angular	Light green
TA108	Green	Sparse	Smooth	Present	Angular	Thick green
TA109	Green	Sparse	Smooth	Present	Angular	Thick green
KAUMUDI	Dark green	Intermediate	Dented	Present	Angular	Thick green
CO1	Green	Intermediate	Dented	Present	Angular	Thick green
TA95	Green	Sparse	Dented	Present	Angular	Green
TA110	Green	Sparse	Smooth	Present	Angular	Thick green
TA111	Green	Dense	Dented	Present	Angular	Thick green
TA112	Green	Sparse	Dented	Present	Angular	Green
TA113	Dark green	Intermediate	Dented	Present	Angular	Green
TA114	Green	Intermediate	Smooth	Present	Angular	Light green
TA115	Green	Intermediate	Dented	Present	Angular	Green
TA116	Green	Dense	Dented	Present	Angular	Green
TA117	Dark green	Dense	Dented	Present	Angular	Thick green
TA118	Green	Orbicular	Smooth	Present	Angular	Light green
PKM1	Green	Orbicular	Dented	Present	Angular	Thick green
TA119	Green	Orbicular	Smooth	Present	Angular	Light green

Table 4. Inflorescence and fruit characters of snakegourd

Accession No.	Flowering habit	Sex type	Blossom end of the fruit	Fruit skin colour
TA102	Clusters	Monoecious	Pointed	White
TA103	Clusters	Monoecious	Pointed	Green with White stripes
CO2	Clusters	Monoecious	Pointed	Green
MDU1	Clusters	Monoecious	Pointed	Green with White stripes
TA104	Clusters	Monoecious	Pointed	White with green stripes
TA105	Clusters	Monoecious	Pointed	White
TA19	Clusters	Monoecious	Pointed	Green with White stripes
TA106	Clusters	Monoecious	Pointed	Green with White stripes
TA107	Clusters	Monoecious	Pointed	Green
TA108	Clusters	Monoecious	Pointed	Green with White stripes
TA109	Clusters	Monoecious	Pointed	Green with White stripes
KAUMUDI	Clusters	Monoecious	Pointed	White with green stripes
CO1	Clusters	Monoecious	Pointed	Green with White stripes
TA95	Clusters	Monoecious	Pointed	White with green stripes
TA110	Clusters	Monoecious	Pointed	White
TA111	Clusters	Monoecious	Pointed	Green
TA112	Clusters	Monoecious	Pointed	Green
TA113	Clusters	Monoecious	Pointed	Green with White stripes
TA114	Clusters	Monoecious	Pointed	Green with White stripes
TA115	Clusters	Monoecious	Pointed	Green with White stripes
TA116	Clusters	Monoecious	Pointed	Green with White stripes
TA117	Clusters	Monoecious	Pointed	Green with White stripes
TA118	Clusters	Monoecious	Pointed	Green
PKM1	Clusters	Monoecious	Pointed	Green with White stripes
TA119	Clusters	Monoecious	Pointed	Green



TA108

TA111

TA118

Plate 1. Variability in snakegourd

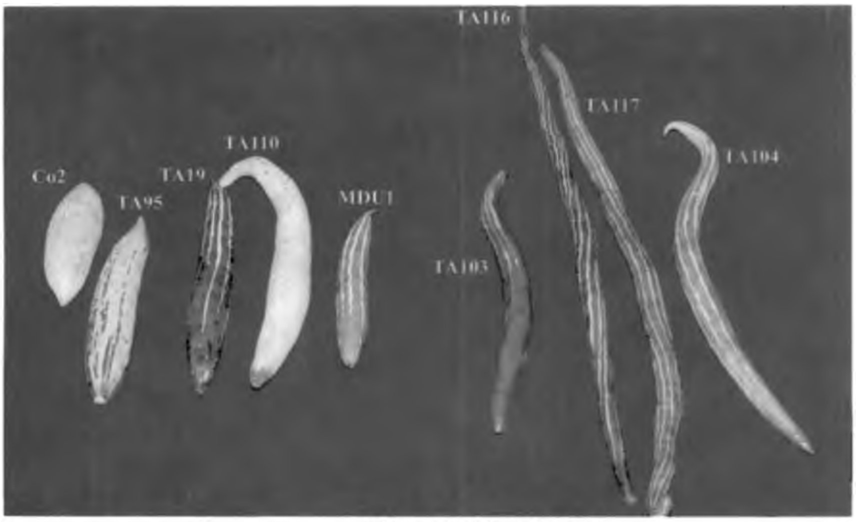


Plate 1. Continued

Plate 2. TA 102 – accession with maximum fruit length (115.80 cm) and fruit weight (767.5 g)

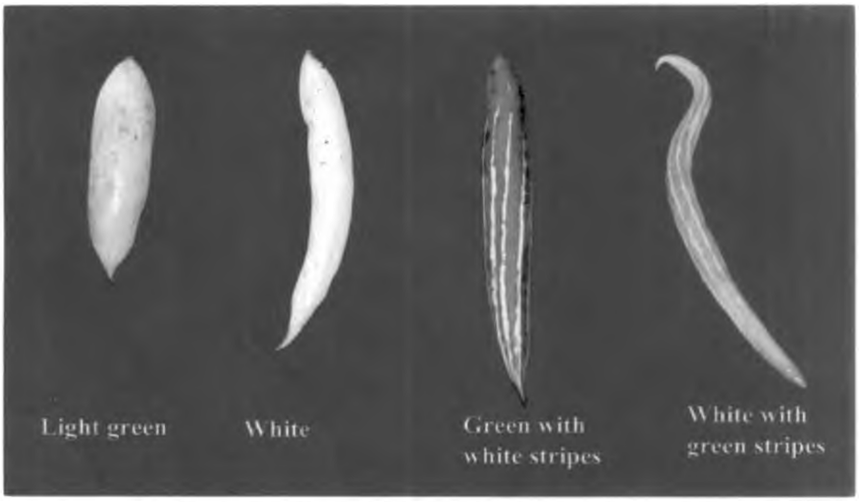


Plate 3. Variability in fruit skin colour

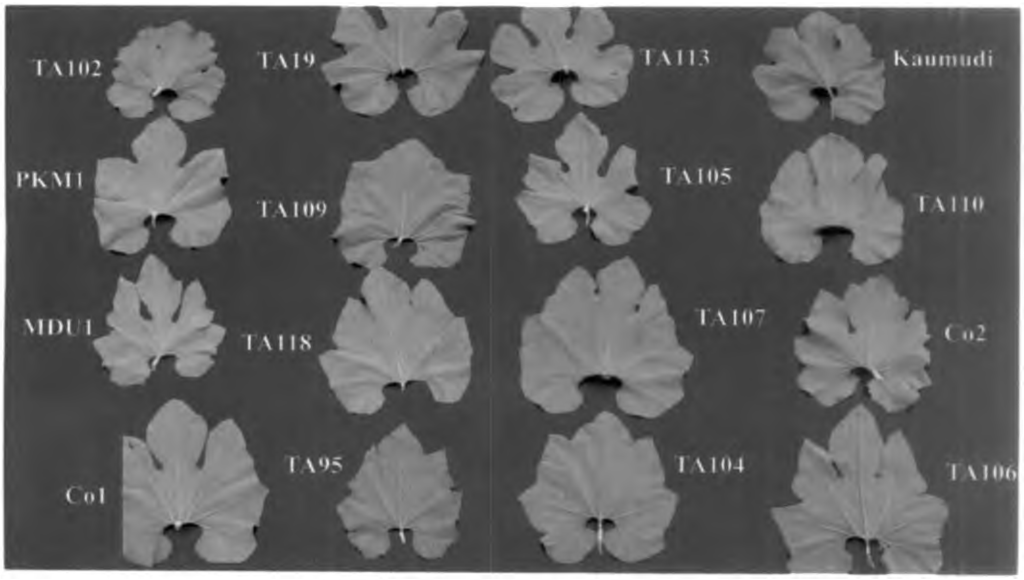


Plate 4. Variability in leaf lobes

Table 4. Continued

Accession No.	Fruit skin texture	Fruit lustre	Internal aroma	Flesh colour
TA102	Soft	Glossy	Present	White
TA103	Intermediate	Intermediate	Present	Light green
CO2	Intermediate	Matt	Present	Light green
MDU1	Soft	Intermediate	Present	Light green
TA104	Intermediate	Intermediate	Present	Light green
TA105	Intermediate	Intermediate	Present	White
TA19	Intermediate	Intermediate	Present	Light green
TA106	Intermediate	Intermediate	Present	Light green
TA107	Intermediate	Matt	Present	Light green
TA108	Soft	Intermediate	Present	Light green
TA109	Intermediate	Intermediate	Present	Light green
KAUMUDI	Soft	Intermediate	Present	White
CO1	Soft	Intermediate	Present	Light green
TA95	Intermediate	Glossy	Present	White
TA110	Soft	Glossy	Present	White
TA111	Intermediate	Intermediate	Present	Light green
TA112	Intermediate	Matt	Present	Light green
TA113	Intermediate	Intermediate	Present	Light green
TA114	Intermediate	Intermediate	Present	Light green
TA115	Soft	Intermediate	Present	Light green
TA116	Intermediate	Intermediate	Present	Light green
TA117	Soft	Intermediate	Present	Light green
TA118	Soft	Intermediate	Present	Light green
PKM1	Soft	Intermediate	Present	Light green
TA119	Soft	Glossy	Present	Light green

accessions) or oval (four accessions) and seed surface lustre was dull (nine accessions) or intermediate (16 accessions) (Table 5).

4.2 Variability in snakegourd

The results of analysis of variance for 24 characters of 25 snakegourd accessions are presented in Table 6. The analysis showed significant difference among the accessions for all the characters studied except seed thickness. The population mean and range are given in Table 7. The mean performance of 25 accessions is presented in Tables 8 and 9.

a) Main vine length

The mean length of main vine ranged from 4.25 m (TA 104) to 6.6 m (TA 102, TA 117 and TA 119) with a mean value of 5.26 m.

b) Internodal length

The mean of internodal length ranged from 15.25 cm (TA 104 and TA 105) to 26.00 cm (MDU-1) with a mean value of 18.8 cm.

c) Tendril length

The mean of tendril length ranged from 25.20 cm (TA 113) to 41.80 cm (TA 118) with a mean value of 32.48 cm.

d) Peduncle length

The mean of peduncle length ranged from 8.5 cm (TA 95) to 35.50 cm (TA 104) with a mean value of 19.12 cm.

e) Days to first male flower anthesis

The mean number of days to first male flower anthesis ranged from 36.5 (TA 106) to 43.00 (TA 102) with a mean value of 38.48 cm.

Table 5. Seed characters in snakegourd accessions

Accession No.	Seed surface	Seed surface lustre	Seed coat colour	Seed Shape	Seed margin
TA102	Creased	Dull	Grey	Elliptical	Undulated
TA103	Pitted	Intermediate	Grey	Elliptical	Undulated
CO2	Creased	Intermediate	Brown	Elliptical	Undulated
MDU1	Creased	Dull	Tan	Elliptical	Undulated
TA104	Creased	Intermediate	Brown	Oval	Undulated
TA105	Pitted	Intermediate	Brown	Oval	Undulated
TA19	Pitted	Intermediate	Brown	Elliptical	Undulated
TA106	Pitted	Dull	Brown	Elliptical	Undulated
TA107	Creased	Intermediate	Brown	Elliptical	Undulated
TA108	Creased	Dull	Brown	Elliptical	Undulated
TA109	Creased	Intermediate	Tan	Elliptical	Undulated
KAUMUDI	Creased	Intermediate	Grey	Oval	Undulated
CO1	Creased	Intermediate	Grey	Elliptical	Undulated
TA95	Pitted	Intermediate	Grey	Oval	Undulated
TA110	Pitted	Intermediate	Brown	Elliptical	Undulated
TA111	Creased	Dull	Brown	Elliptical	Undulated
TA112	Creased	Dull	Brown	Elliptical	Undulated
TA113	Creased	Intermediate	Brown	Elliptical	Undulated
TA114	Pitted	Intermediate	Brown	Elliptical	Undulated
TA115	Pitted	Intermediate	Brown	Elliptical	Undulated
TA116	Pitted	Intermediate	Brown	Elliptical	Undulated
TA117	Creased	Intermediate	Brown	Elliptical	Undulated
TA118	Creased	Dull	Grey	Elliptical	Undulated
PKM1	Creased	Dull	Grey	Elliptical	Undulated
TA119	Creased	Dull	Brown	Elliptical	Undulated

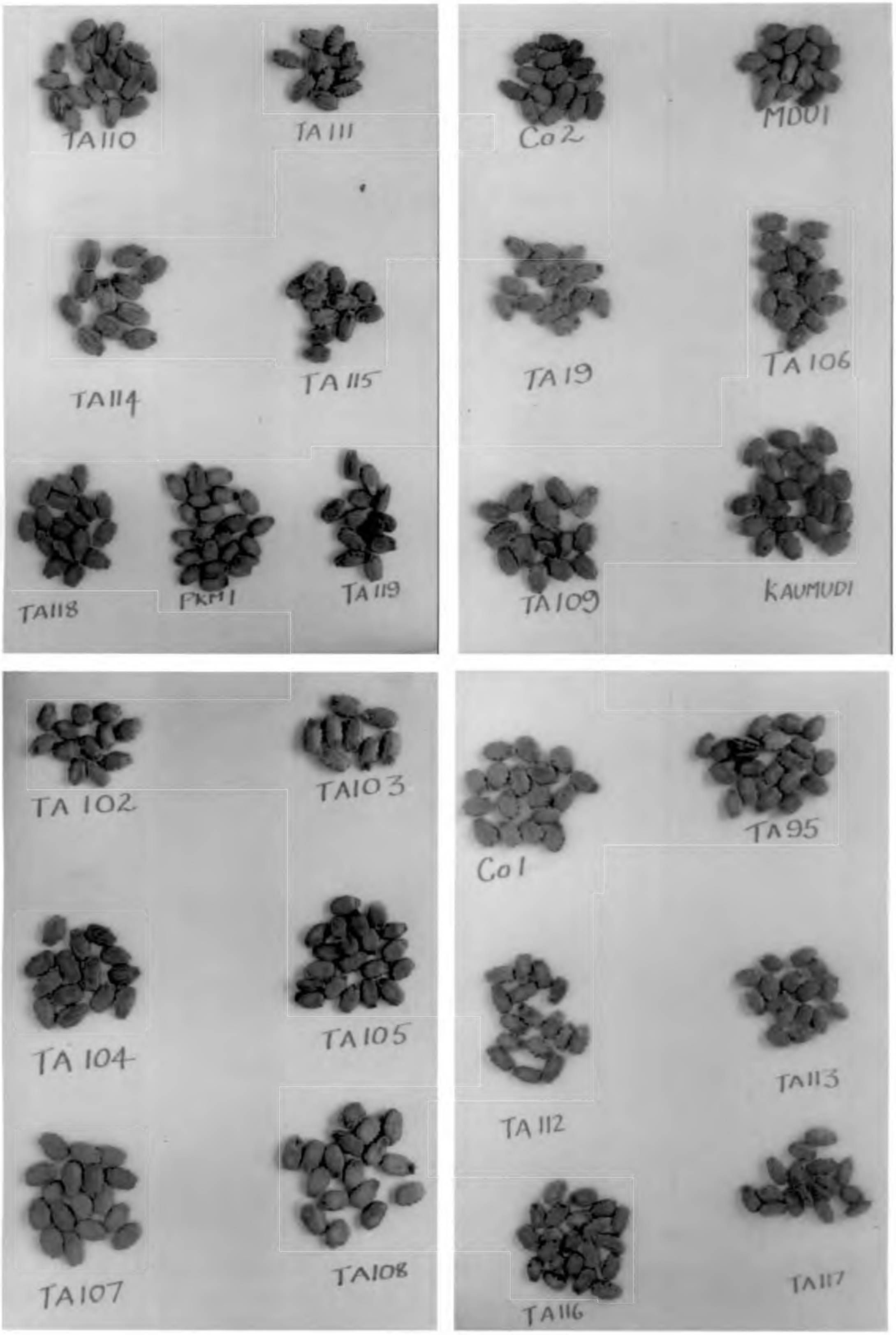


Plate 5. Variability in seed coat colour

Table 6. Analysis of variance for 24 characters in 25 accessions of snakegourd

Source of variation	Mean sum of squares												
	DF	Main vine length (m)	Internodal length (cm)	Peduncle length	Days to first male flower antheses	Days to first female flower opening	Male flower per plant	Female flower per plant	Sex ratio	Days to fruit maturity	Days to first harvest for seed	Fruit length (cm)	Fruit girth (cm)
Replication	1	2.213	0.423	6.480	0.320	0.080	5491.520	0.040	1.941	0.720	0.180	20.737	0.001
Treatment	24	0.784**	11.924**	102.928**	4.228**	8.000**	282268.180**	54.167**	80.415*	3.030**	17.203**	959.219**	37.039**
Error	24	0.039	0.591	0.230	1.278	0.661	3932.020	0.747	2.888	0.470	0.680	3.868	0.033
CD (0.05)		0.4076	1.587	0.9898	2.333	1.681	129.4	1.778	3.507	1.415	1.702	4.059	0.3749

Source of variation	Mean sum of squares											
	DF	Flesh thickness (cm)	Fruits per plant	Fruit weight (g)	Yield per plant (kg)	Seeds per fruit	100 seed weight (g)	Seed length	Seed width	Seed thickness	Seed size index	Seed dormancy
Replication	1	0.020	19.220	274.248	0.601	3.591	0.080	0.032	0.003	0.049	0.503	2.880
Treatment	24	0.563**	12.353**	33327.956**	3.761*	291.455**	15.920**	1.162**	0.474**	0.141	758.937**	37.113**
Error	24	0.103	0.220	195.76	0.081	0.570	0.413	0.032	0.026	0.105	7.377	0.547
CD (0.05)		0.6624	0.9681	28.88	0.5874	1.558	1.322	0.3692	0.332	NS	5.606	0.4828

*P = 0.05 **P = 0.01

Table 7. Range and mean of different characters in snakegourd

Sl.No.	Character	Range	Mean ± SE
1	Main vine length	4.250 - 6.6	5.266 ± 0.19
2	Internodal length	15.25 - 26.00	18.80 ± 0.76
3	Tendril length	25.20 - 41.80	32.48 ± 0.50
4	Peduncle length	8.5 - 35.50	19.12 ± 0.47
5	Days to first male flower anthesis	36.5 - 43.00	38.48 ± 1.13
6	Days to first female flower opening	44.5 - 53.00	48.00 ± 0.81
7	Male flowers per plant	643.0 - 2181	1286.56 ± 62.69
8	Female flowers per plant	27.50 - 46.50	37.80 ± 0.861
9	Sex ratio	21.75 - 47.95	33.51 ± 1.699
10	Days to fruit maturity	8.00 - 14.50	10.16 ± 0.68
11	Days to first harvest for seed	36.50 - 47.50	40.18 ± 0.82
12	Fruit length	31.10 - 115.8	79.70 ± 1.96
13	Fruit girth	10.30 - 23.55	17.02 ± 0.18
14	Flesh thickness	4.00 - 6.00	5.14 ± 3.12
15	Fruits per plant	7.5 - 16.5	10.98 ± 0.468
16	Fruit weight	261.3 - 767.5	474.446 ± 13.99
17	Yield per plant	2.9 - 7.7	4.833 ± 0.284
18	Seeds per fruit	32.30 - 71.80	49.74 ± 0.75
19	100 seed weight	22.0 - 32.50	27.72 ± 0.04
20	Seed length	15.55 - 17.65	16.11 ± 0.17
21	Seed width	8.95 - 10.7	9.95 ± 0.16
22	Seed thickness	4.4 - 5.45	5.002 ± 0.324
23	Seed size index	140.60 - 178.60	159.60 ± 2.71
24	Seed dormancy	6.00 - 18.50	10.16 ± 0.233

f) Days to female flower opening

The mean number of days to female flower opening ranged from 44.5 (TA 117) to 53.00 (TA 102) with a mean value of 48.

g) Male flowers per plant

The mean number of male flowers per plant ranged from 643 (TA 117) to 2181 (TA 114) with a mean value of 1286.56.

h) Female flowers per plant

The mean of female flowers per plant ranged from 27.5 (TA 105) to 46.50 (TA 111, TA 95, TA 107 and TA 114) with a mean value of 37.8.

i) Sex ratio

The mean of sex ratio ranged from 21.75 (TA 117) to 47.95 (TA 114) with a mean value of 33.518.

j) Days to fruit maturity

The mean number of days to fruit maturity ranged from 8.00 (Kaumudi) to 14.50 (TA 102) with a mean value of 10.16.

k) Days to first harvest for seed

The mean number of days to first harvest for seed ranged from 36.50 (PKM-1) to 47.50 (TA 116) with a mean value of 40.18.

l) Fruits per plant

The mean of fruits per plant ranged from 7.5 (TA 119) to 16.5 (TA 95 and TA 105) with a mean value of 10.98.

m) Fruit length

The mean of fruit length at vegetable stage ranged from 31.10 cm (Co-2) to 115.80 cm (TA 102) with a mean value of 79.7.

n) Fruit girth

The mean of fruit girth ranged from 10.31 cm (TA 102) to 23.55 cm (TA 109, TA 107 and MDU-1) with a mean value of 17.026 cm.

o) Flesh thickness

The mean of flesh thickness ranged from 4.00 mm (TA 103) to 6.00 mm (TA 19, TA 112, TA 105, TA 111 and TA 108) with a mean value of 5.14 mm.

p) Fruit weight

The mean of the fruit weight ranged from 261.3 g (MDU-1) to 767.5 g (TA 102 and TA 104) with a mean value of 474.44 g.

q) Yield per plant

The mean of the yield per plant ranged from 2.9 kg (TA 115) to 7.7 kg (TA 112) with a mean value of 4.88 kg.

r) Number of seeds per fruit

The mean number of seeds per fruit ranged from 32.30 (TA 108) to 71.80 (TA 109) with a mean value of 49.74.

s) 100 seed weight

The mean of 100 seed weight ranged from 22.00 g (TA 117) to 32.50 g (TA 110 and TA 114) with a mean value of 27.72 g.

Table 8. Treatment means of snakegourd genotypes (seed characters)

Accession No.	Mean of seed characters						
	Seeds/fruit	100 Seed weight (g)	Seed length (mm)	Seed width (mm)	Seed dormancy	Seed size index (mm^2)	Seed thickness (mm)
TA102	34.9	28.5	15.68	9.69	7.0	151.92	5.11
TA103	41.8	30.0	15.85	10.38	8.0	164.52	5.45
CO2	62.9	28.0	15.72	9.98	8.0	156.80	4.88
MDU1	43.1	26.5	16.54	9.86	8.5	163.09	4.39
TA104	56.9	24.5	14.90	9.73	7.5	144.97	4.72
TA105	35.9	24.5	15.78	9.60	14.5	83.91	5.22
TA19	38.3	26.5	16.47	10.69	8.5	176.09	5.40
TA106	52.7	24.5	16.59	10.29	8.5	170.71	5.13
TA107	49.9	30.0	15.11	9.31	6.5	140.60	4.96
TA108	32.3	30.0	17.39	10.28	7.5	178.63	5.01
TA109	71.8	25.5	16.42	9.73	7.5	159.67	5.43
KAUMUI	53.1	28.0	15.56	9.90	8.0	154.04	5.05
CO1	35.9	28.5	15.78	9.43	6.0	148.68	5.27
TA95	71.2	22.5	15.20	8.97	7.5	136.26	4.82
TA110	61.4	32.5	17.66	9.47	15.0	167.13	5.33
TA111	43.3	26.0	15.65	9.48	6.0	148.36	5.08
TA112	69.8	30.0	16.63	10.42	8.5	173.25	4.63
TA113	47.6	30.0	15.73	10.46	15.5	164.49	4.96
TA114	38.8	32.0	15.49	10.36	8.5	160.48	4.83
TA115	50.3	30.0	16.67	10.57	18.0	176.05	4.99
TA116	56.5	27.5	17.66	9.55	18.5	168.53	5.06
TA117	61.8	22.0	15.70	9.35	7.5	146.72	4.73
TA118	54.6	25.5	16.63	10.51	7.5	174.79	4.81
PKM1	35.8	30.0	15.33	10.43	17.5	159.80	4.71
TA119	42.9	30.0	16.66	10.42	18.0	173.55	5.12
CD (0.05)	1.558	1.322	0.3692	0.332	0.4828	5.606	NS

Table 9. Mean performance of snakegourd genotypes for growth and yield characters.

Accession No.	Tendril length (cm)	Internodal length (cm)	Main vine length (m)	Days to male flower opening	Days to female flower opening	Male flowers/ plant	Female flowers/ plant	Sex ratio	Peduncle length (cm)	Flesh thickness (mm)	Fruit girth (cm)	Fruit length (cm)	Days to fruit maturity	Days to first harvest	Fruits/ plant	Fruit weight (g)	Yield/ plant (kg)
TA102	28.70	17.75	6.61	43.0	53.0	1212.0	39.0	31.1	15.8	5	10.30	115.80	14.5	38.5	9.5	767.5	6.71
TA103	34.65	15.75	4.97	38.5	47.5	1525.0	38.0	40.2	14.8	4	17.40	66.45	10.5	43.5	8.0	359.3	3.065
CO2	29.35	17.00	5.74	39.0	49.5	1676.5	41.5	40.4	18.8	5.5	22.14	31.10	9.5	43.5	13.5	510.0	6.065
MDU1	30.95	26.00	5.41	37.5	46.5	1005.0	38.5	26.1	12.8	5	23.19	55.05	10.5	41.5	13.5	261.3	3.795
TA104	35.90	15.25	4.26	37.5	45.0	1051.5	35.5	29.6	35.5	5	16.73	106.45	10.5	41.5	11.5	763.5	7.365
TA105	32.95	17.00	4.82	37.5	46.5	896.0	27.5	32.6	13.0	6	15.24	61.35	9.5	38.5	16.5	292.7	4.7
TA19	29.60	16.75	5.40	38.5	49.0	701.0	31.5	22.2	15.5	6	20.10	68.90	10.5	38.5	8.0	467.0	3.555
TA106	28.80	18.00	4.79	36.5	46.5	1192.0	37.5	31.8	11.5	5	21.66	78.95	11.0	38.0	8.5	611.2	5.135
TA107	37.10	22.70	5.46	38.5	46.5	1723.5	45.5	37.9	23.8	5	23.27	76.85	8.5	36.5	11.5	407.5	4.55
TA108	33.20	21.50	5.64	41.0	50.5	1222.0	37.5	32.6	26.8	6	16.18	98.15	10.5	41.5	11.5	639.5	6.525
TA109	33.85	18.75	4.40	37.0	48.5	1204.5	40.5	29.7	23.3	5	23.55	87.50	9.5	36.5	7.5	506.9	3.525
KAUMUDI	32.60	18.75	5.48	37.0	47.5	986.0	36.5	27.0	16.3	5	14.15	95.75	8.0	37.5	10.5	458.7	4.6
Co-1	30.45	22.75	4.56	38.0	49.5	1595.0	39.5	40.4	34.5	5	12.61	68.75	10.5	39.5	12.5	615.3	6.945
TA95	31.20	16.75	5.55	37.5	48.5	1747.5	45.5	38.4	8.5	4.5	14.96	90.20	9.0	40.5	16.5	541.4	7.715
TA110	35.15	17.00	4.85	37.5	47.5	921.0	29.5	31.2	14.0	5	18.09	55.90	10.5	40.0	12.5	464.6	5.66
TA111	34.20	19.65	5.35	41.0	50.5	1626.5	46.5	35.0	11.0	6	14.80	64.75	9.0	41.0	9.5	480.5	4.45
TA112	33.25	18.00	4.68	38.5	48.5	1605.5	41.0	39.2	19.5	6	22.28	34.80	9.5	36.5	12.5	391.6	4.615
TA113	25.20	19.50	4.46	39.5	51.0	1599.0	39.0	41.0	27.0	5	15.53	86.05	9.5	41.0	10.5	406.8	4.735
TA114	32.15	18.25	5.86	39.0	47.0	2181.0	45.5	47.9	24.5	5	22.65	76.25	10.5	38.5	11.0	356.6	3.735
TA115	33.60	19.75	5.45	38.5	49.5	1305.0	35.5	36.7	17.5	4.5	12.42	90.20	10.5	36.5	8.0	390.1	2.905
TA116	27.60	18.00	4.85	38.0	47.5	1435.0	39.5	36.3	26.0	5	11.70	110.40	9.5	47.5	12.5	502.9	5.925
TA117	40.00	16.75	6.42	39.0	44.5	643.0	29.5	21.8	14.0	4.5	12.39	94.80	10.5	42.5	10.5	398.5	3.85
TA118	41.80	20.50	4.94	38.5	47.5	837.0	31.0	27.0	24.5	5	14.20	79.20	9.5	39.5	9.5	420.2	3.87
PKM1	29.75	18.50	5.47	38.5	45.5	1105.0	34.5	32.0	13.0	5	11.05	105.40	11.5	46.5	11.5	339.7	4.3465
TA119	30.00	19.50	6.29	37.0	46.5	1168.5	39.5	29.6	16.5	5.5	19.05	93.70	11.0	39.5	7.5	508.5	3.74
CD (0.05)	2.343	1.587	0.4076	2.333	1.681	129.4	1.778	3.507	0.9898	0.6624	0.3749	4.059	1.415	1.702	0.9681	28.88	0.5874

t) Seed length

The mean of seed length ranged from 15.55 mm (Kaumudi) to 17.65 mm (TA 110, TA 116 and TA 108) with a mean value of 16.11 mm.

u) Seed width

The mean of seed width ranged from 8.95 mm (TA 95) to 10.70 mm (TA 19) with a mean value of 9.95 mm.

v) Seed size index

The mean of the seed size index ranged from 140.60 mm^2 (TA 105) to 178.60 mm^2(TA 108) and with a mean value of 157.722 mm^2.

w) Seed thickness

No significant difference between the different accessions for this character was observed. The mean of the seed thickness ranged from 4.40 mm (MDU-1) to 5.45 mm (TA 103, TA 109 and TA 19) with mean value of 5.00 mm.

x) Seed dormancy

The mean number of days to germination ranged from 6.0 (Co-1 and TA 111) days to 18.5 (TA 116) days with a mean value of 10.16 days.

4.3 Correlation studies

The estimates of correlation for different pairs are presented in Table 10. It was observed that seed characters were significantly correlated with growth and yield characters.

4.3.1 Correlation of seed characters with growth and yield characters

Seeds per fruit was found to be significantly and negatively correlated with days to male flower opening and days for fruit maturity ($r = -0.407*$ and $r = -0.441*$).

Table 10. correlation coefficients among seed, growth and yield characters.

	Seeds/fruit	Seed surface	Seed surface lustre	Seed coat colour	Seed shape	100 seed weight	Seed length	Seed width	Seed dormancy	Growth habit	Leaf size	Leaf lobes	Leaf colour	Leaf pubescence
Seed surface	0.005													
Seed surface lustre	0.270	-0.389*												
Seed coat colour	-0.217	-0.029	-0.029											
Seed shape	0.167	-0.127	0.327	0.231										
100 seed weight	-0.329	-0.016	-0.046	0.061	-0.449*									
Seed length	0.072	-0.264	-0.233	-0.330	-0.439*	0.254								
Seed width	-0.306	-0.051	-0.314	-0.008	-0.369	0.411*	0.253							
Seed dormancy	-0.097	-0.307	0.048	-0.089	-0.081	0.346	0.379	0.276						
Growth habit	0.115	-0.153	0.272	0.433*	0.089	0.090	-0.117	0.039	0.080					
Leaf size	0.108	0.236	-0.206	0.125	-0.501**	0.417*	0.363	0.012	-0.111	0.144				
Leaf lobes	-0.063	-0.040	-0.040	-0.168	0.194	-0.299	-0.351	-0.072	-0.116	-0.256	-0.490*			
Leaf colour	-0.096	-0.089	0.468*	0.094	0.457*	-0.275	-0.333	0.082	-0.034	0.127	-0.441*	0.301		
Leaf pubescence	0.019	-0.005	0.234	-0.020	-0.119	0.137	0.004	-0.092	0.126	0.129	0.264	-0.077	-0.138	
Leaf pubescence type	0.308	0.089	0.089	-0.094	0.029	-0.112	-0.231	0.024	0.098	-0.127	-0.031	0.085	-0.008	0.393*
Tendril length	0.257	0.150	0.038	0.037	0.081	-0.229	-0.067	-0.177	-0.361	0.085	0.172	-0.102	0.085	-0.326
Internodal length	-0.307	0.418*	-0.354	-0.237	-0.340	0.198	0.157	-0.010	-0.100	-0.614**	0.216	-0.110	-0.442*	0.035
Stem shape	0.256	-0.153	0.272	-0.289	0.089	-0.058	0.118	0.112	0.153	-0.042	0.144	-0.035	0.127	0.129
Stem colour	0.411*	0.226	0.226	0.146	0.105	-0.112	-0.322	-0.314	-0.236	0.009	0.130	0.157	0.074	0.300
Main vine length	-0.262	0.119	-0.240	0.164	-0.173	0.055	-0.121	-0.026	-0.040	-0.048	-0.020	0.113	-0.156	-0.024
Days to male flower anthesis	-0.407*	0.282	-0.303	0.203	-0.339	0.207	-0.095	0.030	-0.231	0.140	0.159	0.210	-0.116	0.190
Days to female flower opening	-0.192	0.106	-0.128	0.144	-0.251	0.260	0.133	0.085	-0.145	0.156	0.180	-0.011	-0.227	0.337
Male flowers/plant	0.039	-0.073	0.137	0.070	-0.138	0.381	-0.281	-0.083	-0.133	0.156	0.302	0.042	-0.388*	0.466*
Female flowers/plant	0.107	0.167	-0.078	-0.055	-0.133	0.182	-0.291	-0.187	-0.303	-0.028	0.326	0.036	-0.473*	0.396*
Sex ratio	-0.025	-0.211	0.231	0.145	-0.112	0.483*	-0.197	0.011	0.049	0.244	0.251	-0.018	-0.289	0.441*
Peduncle length	-0.053	0.318	0.247	-0.044	-0.050	0.206	-0.020	0.057	-0.105	0.185	0.260	-0.282	0.027	0.171
Fruit skin colour	-0.003	-0.281	0.396*	0.101	0.434*	-0.248	-0.158	-0.081	-0.006	-0.100	-0.517**	0.091	0.394*	-0.100
Fruit skin texture	0.280	-0.329	0.342	-0.256	0.167	-0.192	-0.255	-0.069	-0.167	0.230	-0.085	0.282	0.194	0.213
Fruit luster	-0.141	-0.259	-0.101	0.241	0.174	-0.061	0.165	-0.177	0.258	0.015	-0.188	0.013	-0.047	-0.265
Flesh colour	-0.066	0.250	-0.167	-0.354	-0.600**	0.094	0.091	0.449*	-0.028	-0.102	0.354	-0.087	-0.134	0.172
Flesh thickness	-0.228	0.202	-0.359	-0.299	-0.013	0.048	0.214	0.163	-0.038	0.055	0.082	0.255	-0.082	0.106
Fruit girth	0.262	-0.020	0.010	-0.624**	-0.182	0.130	0.067	0.158	-0.289	-0.298	0.104	0.029	-0.161	-0.172
Fruit length	-0.186	0.073	-0.033	0.265	0.178	-0.139	-0.098	-0.072	0.226	0.235	-0.258	-0.165	0.090	-0.126
Days to fruit maturity	-0.441*	-0.004	-0.384*	0.158	-0.329	0.157	0.074	0.200	0.093	-0.058	-0.152	0.005	-0.157	-0.321
Days to fruit harvest	-0.111	0.003	-0.026	0.162	-0.103	-0.047	0.054	-0.078	0.296	-0.094	0.202	-0.004	0.054	0.300
Fruits/plant	0.135	-0.092	0.182	0.061	0.496*	-0.187	-0.168	-0.540**	-0.006	-0.211	-0.154	0.336	-0.050	0.064
Fruit weight	0.027	0.187	-0.099	0.202	0.137	-0.161	-0.033	-0.219	-0.306	0.344	0.147	-0.308	-0.123	-0.002
Yield/plant	0.106	0.096	0.047	0.290	0.394	-0.180	-0.136	-0.532**	-0.214	0.165	0.099	-0.059	-0.153	0.089
Seed size index	0.072	0.069	-0.326	-0.079	-0.639**	0.421*	0.548**	0.603**	0.104	-0.057	0.495*	-0.340	-0.324	0.049
Seed thickness	-0.169	-0.386*	0.337	0.104	-0.085	0.142	0.229	-0.004	0.049	0.480*	0.093	-0.399*	0.175	0.021

* = 5% level of significance

** = 1% level of significance

Table 10. continued.

	Leaf pubescence type	Tendril length	Internodal length	Stem shape	Stem colour	Main vine length	Days to male flower anthesis	Days to female flower anthesis	Male flowers/ plant	Female flowers/ plant	Sex ratio	Peduncle length	Fruit skin colour	Fruit skin texture	Fruit lustre
Tendril length	-0.269														
Internodal length	-0.059	-0.009													
Stem shape	0.327	0.209	0.090												
Stem colour	0.642**	0.013	-0.184	0.244											
Main vine length	-0.121	0.006	0.034	-0.447*	-0.152										
Days to male flower anthesis	-0.321	-0.058	0.044	-0.648**	-0.112	0.454*									
Days to female flower opening	-0.205	-0.406*	0.121	-0.521**	-0.082	0.093	0.677**								
Male flowers/plant	0.361	-0.294	0.095	0.041	0.271	-0.036	0.191	0.313							
Female flowers/plant	0.404*	-0.282	0.252	-0.048	0.277	0.101	0.198	0.321	0.861**						
Sex ratio	0.286	-0.299	-0.005	0.080	0.215	-0.173	0.145	0.291	0.931**	0.627**					
Peduncle length	0.007	0.051	0.182	0.098	-0.068	-0.425*	0.038	0.072	0.215	0.104	0.263				
Fruit skin colour	0.329	-0.206	-0.171	0.108	0.209	-0.177	-0.263	-0.166	-0.119	-0.119	-0.104	0.109			
Fruit skin texture	0.165	-0.195	-0.401*	0.230	0.133	-0.417*	-0.126	0.000	0.471*	0.400*	0.429*	0.055	-0.023		
Fruit luster	-0.122	-0.147	-0.174	-0.371	-0.178	0.266	0.028	0.116	-0.256	-0.183	-0.253	-0.284	0.268	-0.391*	
Flesh colour	0.356	0.049	0.283	0.408*	0.023	-0.156	-0.007	-0.153	0.182	0.216	0.116	0.400*	-0.142	0.161	-0.531**
Flesh thickness	-0.346	-0.164	0.095	0.055	-0.233	-0.028	0.206	0.245	-0.084	-0.016	-0.116	0.019	-0.455*	0.161	-0.239
Fruit girth	0.038	0.012	0.157	0.326	-0.045	-0.167	-0.349	-0.186	0.245	0.321	0.135	-0.007	-0.240	0.452*	-0.401
Fruit length	0.007	-0.071	-0.098	-0.343	-0.221	0.225	0.162	-0.037	-0.202	-0.064	-0.256	0.190	0.483*	-0.285	0.470*
Days to fruit maturity	-0.176	-0.250	-0.105	-0.735**	-0.311	0.400*	0.444	0.216	-0.194	-0.195	-0.148	-0.080	0.031	-0.384*	0.461*
Days to fruit harvest	0.256	-0.205	-0.159	0.119	0.325	0.049	0.108	-0.190	-0.022	-0.075	0.025	0.004	0.165	-0.029	0.048
Fruits/plant	-0.078	-0.078	0.035	0.124	0.208	-0.108	-0.110	-0.126	0.168	0.017	0.241	-0.046	0.063	0.125	-0.077
Fruit weight	-0.097	-0.156	-0.213	-0.473*	-0.137	0.011	0.270	0.355	0.004	0.152	-0.074	0.371	0.159	-0.029	0.299
Yield/plant	-0.092	-0.236	-0.133	-0.278	0.089	-0.098	0.165	0.242	0.178	0.177	0.171	0.294	0.200	0.046	0.209
Seed size index	0.145	-0.110	0.167	0.062	-0.086	0.051	0.074	0.196	0.008	0.102	-0.053	0.138	-0.021	-0.251	0.002
Seed thickness	-0.282	-0.123	-0.289	-0.081	-0.126	-0.192	-0.043	0.298	-0.075	-0.144	0.011	-0.013	0.003	0.161	0.265

Table 10. continued.

	Flesh colour	Flesh thickness	Fruit girth	Fruit length	Days to fruit maturity	Days to first harvest	Fruits/ plant	Fruit weight	Yield/plant	Seed size index
Flesh thickness	0.038									
Fruit girth	0.294	0.225**								
Fruit length	-0.095	-0.332	-0.586							
Days to fruit maturity	-0.058	-0.115	-0.266	0.335						
Days to fruit harvest	0.205	-0.171	-0.380*	0.197	0.101					
Fruits/plant	-0.435*	0.144	-0.056	-0.267	-0.271	0.228				
Fruit weight	-0.121	0.058	-0.207	0.424*	0.387*	-0.040	-0.140			
Yield/plant	-0.370	0.078	-0.262	0.189	0.120	0.209	0.556**	0.722**		
Seed size index	0.500*	-0.083	0.151	0.055	0.183	0.064	-0.603**	0.107	-0.245	
Seed thickness	-0.196	0.031	-0.038	0.016	0.052	-0.199	-0.384*	0.205	-0.087	-0.035

* = 5% level of significance

** = 1% level of significance

Significant negative correlation was observed between seed coat colour and fruit girth (r = -0.624**).

Seed shape was found to be significantly and negatively correlated with leaf size (r = -0.501**) and positively correlated with leaf colour (r = 0.457*). Seed shape was also found to be significantly and positively correlated with fruits per plant and yield per plant (r = 0.496** and r = 0.394*).

Hundred seed weight was found to be significantly and negatively correlated with leaf size (r = -0.501**) and positively correlated with sex ratio (r = 0.483*).

Seed width was found to be significantly and negatively correlated with fruits per plant and yield per plant (r = -0.540** and r = -0.532**).

Seed thickness was found to be significantly and negatively correlated with leaf lobes and fruits per plant (r = -0.399* and r = -0.384*).

Seed size index was found to be significantly and positively correlated with leaf size (r = 0.495**) and negatively correlated with fruits per plant (r = -0.603**).

4.3.2 Correlation of growth characters with yield characters

Leaf colour was found to be significantly and negatively correlated with male flowers per plant and female flowers per plant (r = -0.388* and r = -0.473*).

Leaf pubescence was found to be significantly and positively correlated with male flowers per plant, female flowers per plant and sex ratio (r = 0.466*, 0.396* and 0.441* respectively).

Leaf pubescence type was found to be significantly and positively correlated with female flowers per plant (r = 0.404*).

Tendril length was found to be significantly and negatively correlated with days to female flower opening (r = -0.406*).

Main vine length was found to be significantly and positively correlated with days to fruit maturity (r = 0.400*).

4.3.3 Inter correlation between seed characters

Hundred seed weight was found to be significantly and positively correlated with seed width and seed size index (r = 0.411* and r = 0.421*).

Seed shape was found to be significantly and negatively correlated with 100 seed weight, seed length and seed size index (r = -0.499*, r = -0.439* and r = -0.639**, respectively).

4.3.4 Inter correlation between yield characters.

Days to male flower opening was found to be significantly and positively correlated with days to fruit maturity and days to female flower opening (r = 0.677** and r = 0.444*).

Female flowers per plant was significantly and positively correlated with male flowers per plant (r = 0.861**).

Sex ratio was found to be significantly and positively correlated with male flowers per plant and female flowers per plant (r = 0.931** and r = 0.627**).

Fruit length was found to be significantly and positively correlated with fruit weight and fruit lustre and negatively correlated with fruit girth (r = 0.424*, r = 0.470* and r = -0.586**, respectively).

Fruit skin texture was found to be significantly and negatively correlated with days to fruit maturity and fruit lustre (r = -0.384* and r = -0.391*).

Days to fruit maturity was found to be significantly and positively correlated with fruit weight and fruit lustre (r = 0.387* and 0.461*).

Yield per plant was significantly and positively correlated with fruits per plant and fruit weight (r = 0.566** and r = 0.722**).

4.4 Principal component analysis

Principal component analysis was conducted by using 11 characters of seed, 11 characters of growth and 18 characters of yield. Components were extracted from co-variance matrices.

From the principal component analysis of co-variance matrix formed from the seed characters, the first two components were accounted for 93.05 per cent of the total variation. The latent roots of the component loadings, percentage variance and cumulative variance explained by each component are presented in Table 11.

From the principal component analysis of co-variance matrix formed from the growth characters, major part of variation (86.43 %) was accounted by the first two components. The latent roots of the component loadings, percentage variance and cumulative variance explained by each component are presented in Table 12.

The principal component analysis based on the co-variance matrix formed from the yield characters, major part of variation (99.7%) was accounted by the first two components .The latent roots of the component loadings, percentage variance and cumulative variance are presented in Table 13.

The salient features of these three principle component analysis of seed characters (Table 11), growth characters (Table 12) and yield characters (Table 13) could be demonstrated by the first two components.

Table 11. Principal component analysis based on the seed characters : latent roots of component loadings percentage variance and cumulative variance accounted by each component

Sl.No.	Name of the variety	Component loadings	
		1	2
1	TA 102	92.208	127.774
2	TA 103	97.109	141.345
3	Co-2	77.245	151.956
4	MDU-1	94.892	141.430
5	TA 104	72.119	139.562
6	TA 105	91.691	128.913
7	TA 19	107.556	146.410
8	TA 106	93.87	153.572
9	TA 107	74.075	131.451
10	TA 108	113.674	143.587
11	TA 109	73.106	160.441
12	Kaumudi	81.718	142.806
13	Co-1	89.043	126.290
14	TA 95	56.062	144.448
15	TA 110	87.177	158.440
16	TA 111	83.636	131.576
17	TA 112	84.979	168.044
18	TA 113	94.161	146.365
19	TA 114	96.429	136.523
20	TA 115	101.132	156.274
21	TA 116	91.329	155.987
22	TA 117	69.891	144.372
23	TA 118	95.566	157.572
24	PKM-1	98.825	134.645
25	TA 119	104.227	149.108
	Latent roots	4150.165	3008.677
	Percentage variance	53.945	39.108
	Cumulative variance	53.945	93.052

Table 12. Principal component analysis based on the growth characters : latent roots of component loadings percentage variance and cumulative variance accounted by each component

Sl.No.	Name of the variety	Component loadings	
		1	2
1	TA 102	28.442	17.790
2	TA 103	34.434	15.706
3	Co-2	29.004	17.012
4	MDU-1	30.551	25.861
5	TA 104	35.628	15.179
6	TA 105	32.650	16.872
7	TA 19	29.341	16.661
8	TA 106	28.542	18.066
9	TA 107	36.829	22.856
10	TA 108	32.945	21.641
11	TA 109	33.571	18.690
12	Kaumudi	32.273	18.614
13	Co-1	30.108	22.686
14	TA 95	30.896	16.593
15	TA 110	34.942	17.122
16	TA 111	33.758	19.555
17	TA 112	32.952	17.892
18	TA 113	24.835	19.254
19	TA 114	31.763	18.172
20	TA 115	33.246	19.849
21	TA 116	27.248	18.055
22	TA 117	39.677	16.583
23	TA 118	41.533	20.711
24	PKM-1	29.461	18.367
25	TA 119	29.752	19.630
	Latent roots	342.563	146.015
	Percentage variance	60.604	25.832
	Cumulative variance	60.604	86.436

Table 13. Principal component analysis based on the yield characters : latent roots of component loadings percentage variance and cumulative variance accounted by each component

Sl.No.	Name of the variety	Component loadings	
		1	2
1	TA 102	1212.557	773.719
2	TA 103	1525.601	362.719
3	Co-2	1677.779	510.341
4	MDU-1	1005.537	264.484
5	TA 104	1052.229	769.419
6	TA 105	896.493	296.291
7	TA 19	701.611	470.864
8	TA 106	1192.767	614.937
9	TA 107	1724.104	411.595
10	TA 108	1222.648	644.929
11	TA 109	1205.072	511.829
12	Kaumudi	986.324	464.427
13	Co-1	1596.020	618.543
14	TA 95	1748.061	545.820
15	TA 110	921.807	467.296
16	TA 111	1627.274	483.394
17	TA 112	1606.561	392.626
18	TA 113	1599.498	411.763
19	TA 114	2181.566	360.489
20	TA 115	1305.342	395.426
21	TA 116	1435.306	509.474
22	TA 117	643.160	404.500
23	TA 118	837.474	425.063
24	PKM-1	1105.035	346.335
25	TA 119	1168.953	513.783
	Latent roots	3389110.303	402318.199
	Percentage variance	89.127	10.580
	Cumulative variance	89.127	99.707

4.4.1 Seed index

The seed index values for each accession (Table 11) were extracted from the first component, which accounted for 53.94 per cent of the variation. Maximum seed index value was recorded for the accession TA 108 and minimum for TA 95.

4.4.2 Growth index

The growth index values for each accession (Table 12) were extracted from the first component, which accounted for 60.6 per cent of the variation. Maximum growth index value was recorded for the accession TA 118 and the minimum for TA 113.

4.4.3 Yield index

The yield index values for each accession (Table 13) were extracted from the first component, which accounted for 89.12 per cent of the variation. Maximum yield index value was recorded for the accession TA 114 and the minimum for TA 117.

4.5 Grouping of varieties based on index values

4.5.1 Seed index

The accessions were grouped into six clusters based on the plotted points obtained from the component loadings of seed characters (Fig.1).

First cluster includes TA 115, TA 119, TA 19 and TA 108. Maximum values for seed length, seed width, 100 seed weight, seed size index and seed thickness were recorded for these accessions. Seed coat colour of all these varieties was brown.

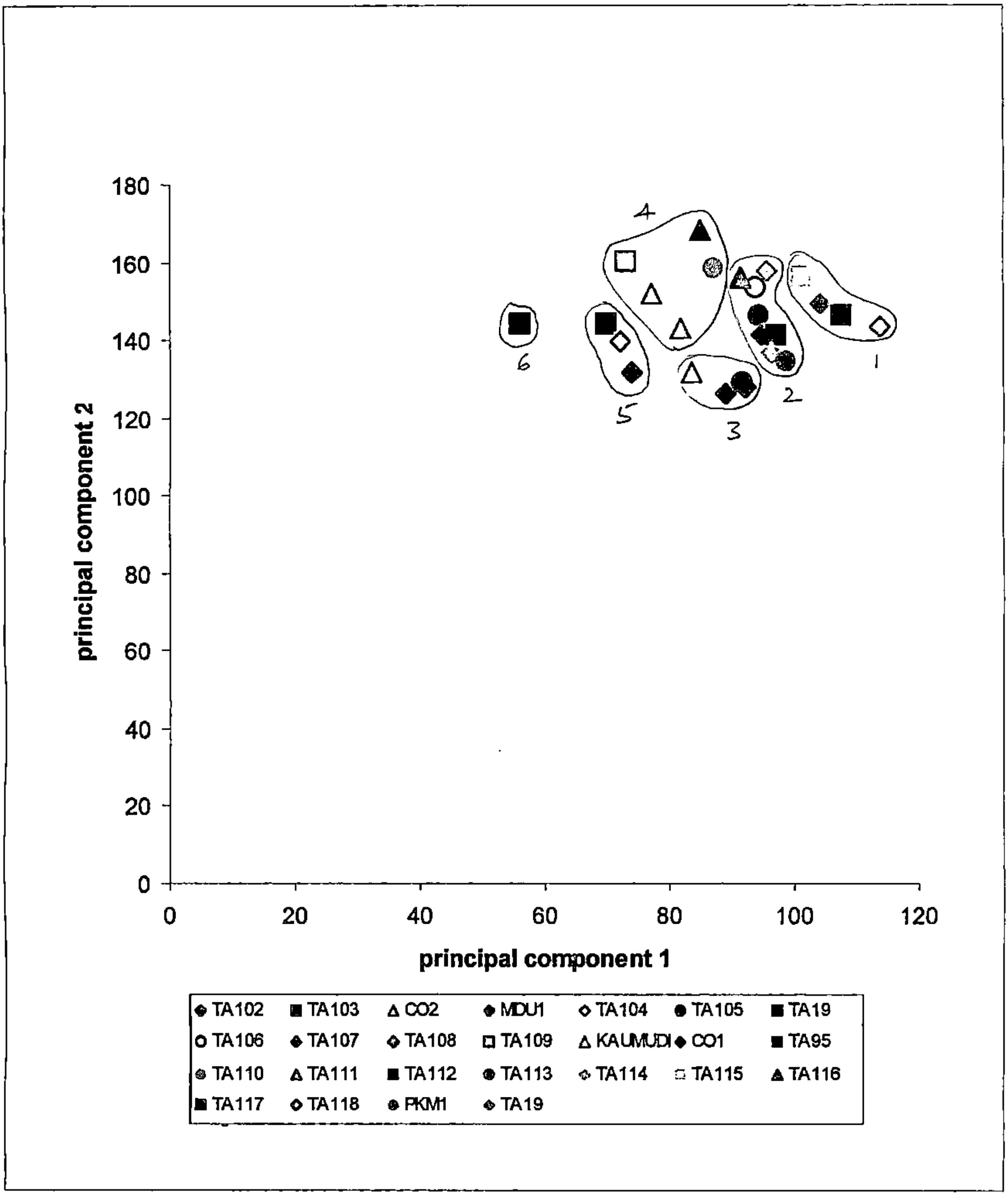


Figure 1. Clustering of snakegourd genotypes based on seed index

Second cluster includes TA 118, TA 116, TA 106, TA 113, TA 103, MDU-1, TA 114 and PKM-1. Seed length, seed width, 100 seed weight, seed size index and seed thickness values were slightly less when compared with first cluster but more number of seeds per fruit was recorded compared to first cluster.

Third cluster includes TA 111, Co-1, TA 105 and TA 102. Maximum values for seed thickness and minimum number of seeds per fruit values were recorded for these accessions.

Fourth cluster includes TA 112, TA 110, TA 109, Co-2 and Kaumudi. Maximum number of seeds per fruit and 100 seed weight were recorded for these accessions.

Fifth cluster includes TA 117, TA 104 and TA 107. Minimum seed thickness and seed size index values were recorded for these accessions.

Sixth cluster includes only one accession TA 95. Maximum number of seeds per fruits, seed thickness and minimum hundred seed weight, seed size index were recorded for this accession. Seed coat colour of this accession was grey and seed shape was oval.

4.5.2 Yield index

From the scattered diagram (Fig. 2) the accessions were grouped into four clusters based on the plotted points obtained from the component loadings of yield characters.

First cluster has only one accession TA 114. This cluster characterised by maximum number of male flowers per plant, female flowers per plant, sex ratio and peduncle length. Fruit skin colour was green with white stripes.

171685

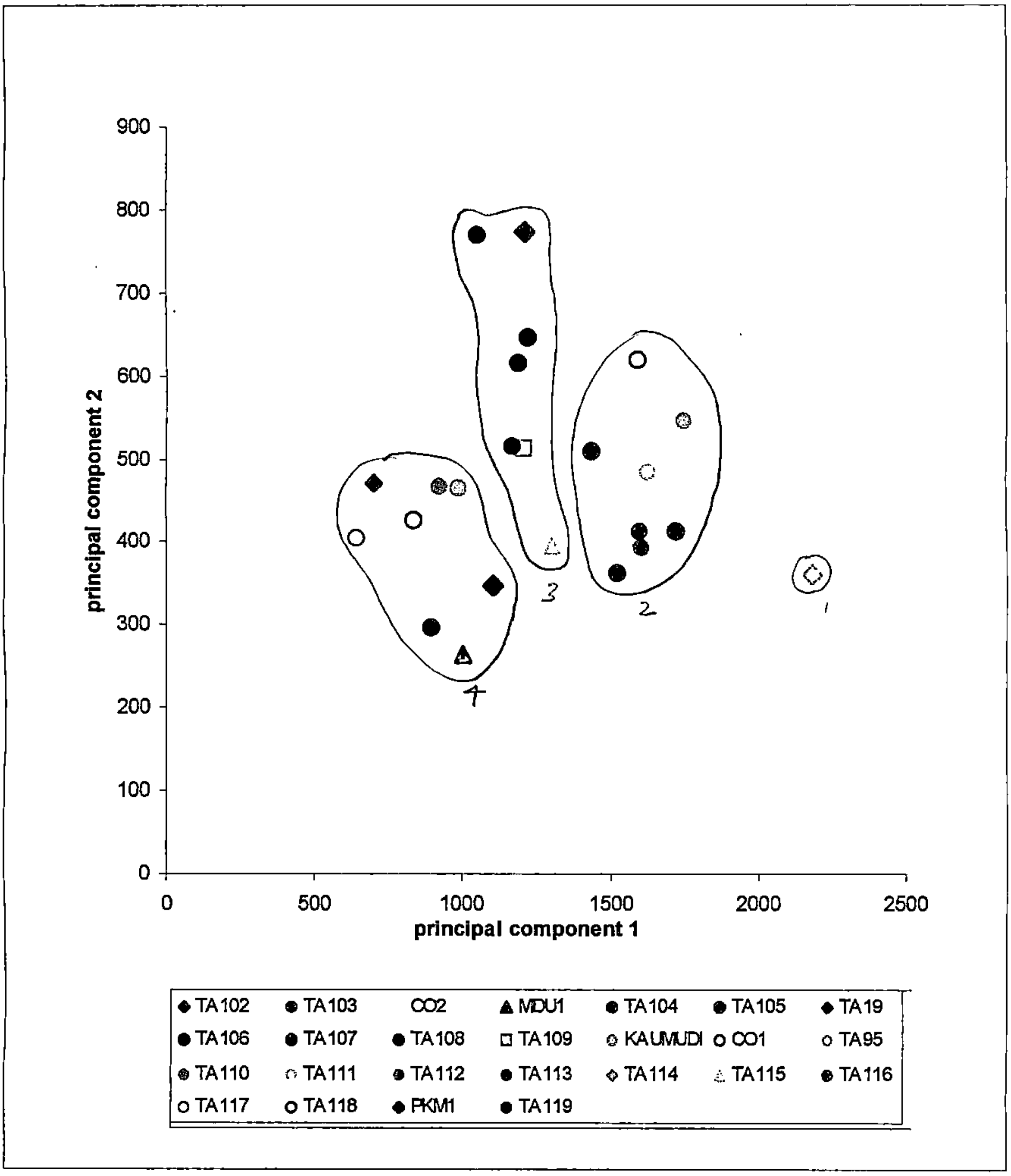


Figure 2. Clustering of snakegourd genotypes based on yield index

Second cluster includes TA 103, Co-2, TA 107, Co-1, TA 95, TA 111, TA 112, TA 113 and TA 116. Compared to first cluster slightly less values were recorded for male flowers per plant female flowers per plant, sex ratio and peduncle length. Maximum values for days to fruit maturity and days to first harvest for seed were recorded for these accessions.

Third cluster comprised of TA 102, TA 104, TA 106, TA 108, TA 109, TA 115 and TA 119. Maximum values were recorded for days to first female flower opening, fruit girth, fruit length and fruit weight. Maximum fruit length and fruit weight values were recorded for the accession TA 102 of this cluster.

MDU-1, TA 105, TA 19, Kaumudi, TA 110, TA 118 and PKM-1 formed the fourth cluster. Minimum values were recorded for male flowers per plant, female flowers per plant, days to first male flower anthesis, days to first female flower opening, sex ratio and fruit length and maximum for the fruits per plant.

4.5.3 Growth index

From the scattered diagram (Fig. 3) the accessions were grouped into six clusters based on the plotted points obtained from the component loadings of growth characters.

First cluster includes only one accession TA 118. Maximum value for tendril length and qualitative characters like dented pubescence and large leaf size was recorded for this accession.

Second cluster includes TA 117. Deep leaf lobes, dark green coloured leaves and dark green coloured stem were peculiar in this accession.

Third cluster includes TA 107. Maximum value for internodal length and qualitative characters like shallow lobbed leaves, pale green coloured leaves were most peculiar in this accession.

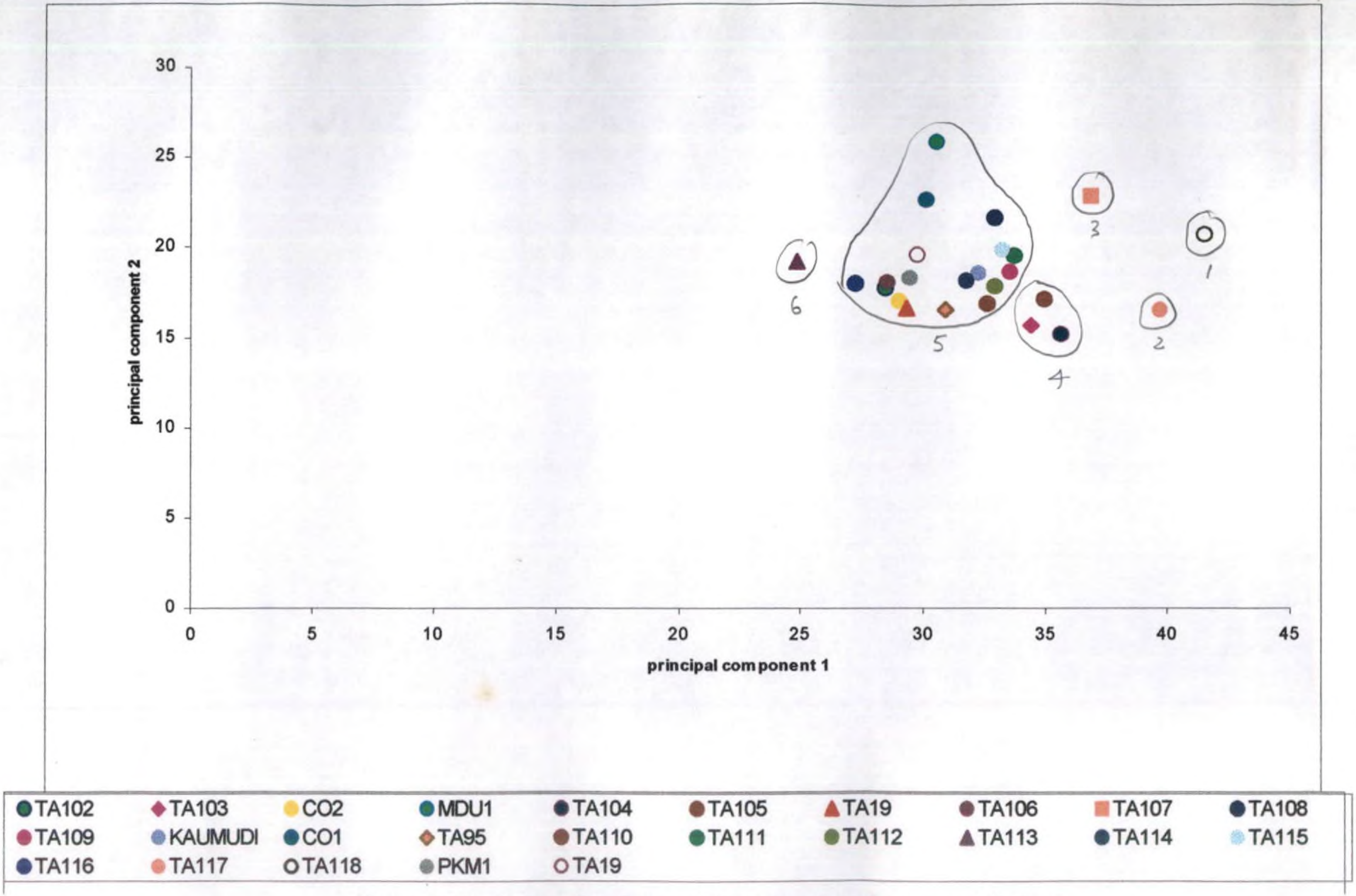


Figure 3.Clustering of snakegourd genotypes based on growth index

Fourth cluster includes TA 104, TA 103 and TA 110. These accessions were having slightly lesser values for internodal length and peduncle length but regarding qualitative characters there was not much similarity.

Fifth cluster includes TA 111, TA 109, TA 115, TA 108, TA 112, TA 105, TA 114, TA 95, Kaumudi, MDU-1, Co-1, TA 119, PKM-1, TA 19, Co-2, TA 106,TA 102 and TA 116. These accessions were showing similarity in their qualitative value recorded for internodal length and tendril length there is much similarity in qualitative characters also.

Sixth cluster includes TA 113. Minimum tendril length value was recorded for this accession.

4.6 Keys developed for varietal identification

Based upon the differences in seeds, growth and yield attributes of genotypes, keys were developed to distinguish 25 snakegourd included in the study. The rankings of these keys were developed based on the yield index values obtained from principal component analysis. The highest yield index value was obtained for the accession TA 114 (2181.566) followed by TA 95 (1748.06), TA 107 (1724.104), Co-2 (1677.779), TA 111 (1627.274), TA 112 (1606.561), TA 113 (1599.498), Co-1 (1596.020), TA 103 (1525.601), TA 116 (1435.306), TA 115 (1305.343), TA 108 (1222.64), TA 102 (1212.557), TA 109 (1205.072), TA 106 (1192.767), TA 119 (1168.953), PKM-1 (1105.035), Kaumudi (986.324), TA 110 (921.807), TA 105 (896.493), TA 118 (837.474), TA 19 (701.611) and TA 117 (643.160) (Table 14).

Growth characters (viz. Leaf lobes, leaf pubscence and tendril length), fruit characters (viz. Fruit skin colour, fruit length, fruit girth and fruit weight) and seed characters (viz. seed coat colour, seed size and 100 seed weight) were also taken into consideration for the development of the key.

a) Growth characters

Of the 25 accessions, nine accessions were having deep leaf lobed nature (36%), 12 accessions were having shallow leaf lobed nature (48%) and four accessions were having intermediate nature (16%). With respect to leaf pubescence type 17 accessions were dented (68%) and eight accessions were having smooth pubescence (32%). And with regard to tendril length seven accessions were having length ranging from 25 to 30 cm (28%) and 18 accessions were in a range of 30 to 42 cm (72%).

b) Fruit characters

Of the 25 accessions, the fruit skin colour of five accessions was green with white strips (62%), four accessions with white colour (16%) and three accessions was white with green strips (12%). Fruit girth of 17 accessions was in the range of 10-20 cm (68%) and eight accessions was in the range of 20-25 cm (32%). Fruit length of three accessions was medium with a range of 30-60 cm and 12 accessions was long with a range of 60-90 cm (48%) and 10 accessions were very long, i.e. above 90 cm (40%). Fruit weight of 20 accessions was in range of 300-600 g (80%) and five accessions was in a range of 600-800 g (20%).

c) Seed characters

Out of 25 accessions the seed size index of 12 accessions was in a range of 130-160 mm^2 (48%) and 13 accessions was in a range of 160-180 mm^2 (52%). Hundred seed weight of five accessions was in a range of 20-25 g (20%) and 20 accessions were in the range of 25-30 g (80%). The seed coat colour of 16 accessions was brown (64%) and seven accession was grey (28%) and two accessions of tan seed coat colour (8%).

Table 14. Keys developed for snakegourd (ranking based upon yield index)

Acc. No.	Growth characters			Fruit characters				Seed characters		
	Leaf lobes	Leaf pubescence	Tendril length (cm)	Fruit skin colour	Fruit girth (cm)	Fruit length (cm)	Fruit weight (g)	Seed size index (mm²)	100 seed weight (g)	Seed coat colour
TA 114	Deep	Dented	32.40	Green with white strips	22.65	76.25	356.6	160.48	32.0	Brown
TA 95	Deep	Dented	31.20	White with green strips	14.96	90.2	541.4	136.26	22.5	Grey
TA 107	Shallow	Smooth	37.10	Green	23.27	76.85	407.5	140.6	30.0	Brown
Co-2	Shallow	Dented	29.35	Green	22.14	31.10	510.0	156.80	28.0	Brown
TA 111	Deep	Dented	34.20	Green	14.8	64.75	480.5	148.36	26.0	Brown
TA 112	Deep	Dented	33.25	Green	22.28	34.8	391.6	173.25	30.0	Brown
TA 113	Deep	Dented	25.20	Green with white stripes	15.53	86.05	406.8	164.49	30.0	Brown
Co-1	Shallow	Dented	30.45	Green with white stripes	12.61	68.75	615.3	148.68	28.5	Grey
TA 103	Shallow	Dented	34.65	Green with white stripes	17.40	66.45	359.3	164.52	30.0	Grey
TA 116	Shallow	Dented	27.60	Green with white stripes	11.70	110.40	502.9	168.53	27.5	Brown
TA 115	Shallow	Dented	33.60	Green with white stripes	12.42	90.20	390.1	176.05	30.0	Brown
TA 108	Shallow	Smooth	33.20	Green with white stripes	16.18	98.15	639.5	178.63	30.0	Brown
TA 102	Intermediate	Smooth	28.70	White	10.30	115.80	767.5	151.92	28.5	Grey
TA 109	Intermediate	Dented	33.85	Green with white stripes	23.55	87.50	506.9	159.67	25.5	Tan
TA 106	Shallow	Dented	28.80	Green with white stripes	21.66	78.95	611.2	170.71	24.5	Brown
TA 119	Shallow	Dented	30.00	Green	19.05	93.70	508.5	173.55	30.0	Brown
PKM-1	Intermediate	Dented	29.75	Green with white stripes	11.05	105.40	339.7	159.80	30.0	Grey
TA 104	Intermediate	Dented	36.3	White with green stripes	16.8	105.5	776.9	144.97	24.5	Brown
MDU-1	Deep	Smooth	31.4	Green with white stripes	23.26	54.9	260.4	163.09	26.5	Tan
Kaumudi	Shallow	Dented	32.6	White with green stripes	14.05	95.75	458.7	154.04	28.0	Grey
TA 110	Shallow	Smooth	35.15	White	18.09	55.90	464.6	167.13	32.5	Brown
TA 105	Deep	Smooth	32.95	White	15.24	61.35	292.7	151.84	24.5	Brown
TA 118	Shallow	Smooth	41.80	White	14.20	79.20	420.2	174.79	25.5	Grey
TA 19	Deep	Smooth	29.60	Green with white stripes	20.1	68.9	467.0	176.09	26.5	Brown
TA 117	Deep	Dented	40.0	Green with white stripes	12.39	94.82	398.5	146.72	22.0	Brown

DISCUSSION

5. DISCUSSION

Cucurbitaecous vegetables are widely cultivated in India. Snakegourd (*Trichosanthes anguina* L.) is a common cucurbitaceous vegetable cultivated for its semimatured fruits and relished by many people of the south India. Its fruits are rich with fibre, minerals and other nutrients. Besides it has been found to contain medicinal properties also.

There was a wide variation with respect to seed characters like seed coat colour, seed length, seed breadth and seed thickness in the snakegourd accessions. And in fruits much contrast is seen for the characters like skin colour, length of fruit, fruit girth, weight of fruit and yield per plant. Hence it is interesting to know the relation, if any, between seed characters and other plant characters. An attempt to establish a possible relationship between these characters would be much helpful in identifying the varieties. The present study was undertaken with this objective. The results of the study are discussed hereunder.

5.1 Variability in snakegourd

The mean and range values for seed characters like seed size index, seed coat colour, seed length and seed width and number of seeds per fruit show significant variation.

Similarly significant variation was observed for plant characters like leaf size, leaf lobes, leaf colour, leaf pubescence, leaf pubescence type, tendril length, internodal length and main vine length.

The yield characters like days to female flower opening, number of female flowers per plant, sex ratio, days to fruit maturity, number of fruits per plant and yield per plant also differed significantly.

The characteristics of fruits like skin colour, fruit skin texture, lustre, flesh thickness, girth, length and weight were also shown significant difference.

Wide variation among genotypes in bhindi (Kirtisingh *et al.*, 1974), in watermelon (Takur and Nandpuri, 1974) and in bottle gourd (Ram *et al.*, 1996) have been reported as the germplasm were drawn from various sources. The twenty five genotypes constituted in the present investigation represent diverse sources and the variation observed are ascribed to this reason.

5.2 Correlation among plant traits

The seed characters were found to be significantly and positively correlated with growth and yield characters. Seeds per fruit was found to be significantly and negatively correlated with days for male flower opening and days for fruit maturity. Maximum value for number of seeds per fruit was recorded for TA 95, which took 38 days for male flower opening and nine days for fruit maturity.

Sharma and Tyagi (1977) suggested that seed quality has a definite effect on plant development leading to flowering and it is manifested as an interaction between seed quality and the genotype. The report of Singh *et al.* (1987) endorses on this aspect.

Seed size index and seed width were found to be significantly and negatively correlated with fruits per plant and yield per plant. Seed size index value was maximum for TA 115 but it has minimum fruits per plant (seven) and yield (2.81 kg). It reveals that genotypes with lower seed size indicative of higher yield per plant and fruits per plant. Similar reports were made in moogbean and maize, where it was seen that small seeds will give higher yield than bolder seeds (Dhillon *et al.*, 1978).

Both male and female flowers per plant were found to be significantly and positively correlated with sex ratio. But high correlation value (r = 0.931) was recorded for male flowers per plant. In the case of TA 114 the number of both male and female flowers per plant was 2280 and 46 respectively and its sex ratio was 49.5. It reveals that male flowers per plant should be more for effective pollination and to maintain a desirable sex ratio. Similar results were reported by Thamburaj and Kamalnathan (1973) in *Cucurbita moschata* and *Benincasa hispida.*

The snakegourd accessions of the present study indicated a significant positive correlation between fruit girth and fruit skin texture. The observations recorded from the individual accession reveals that the soft skin textured fruit has lesser fruit girth. The fruit skin texture of Co-1 was glossy and it was having lesser fruit girth (12.52 cm).

Fruit length was found to be significantly and positively correlated with fruit weight. It reveals that if length of the fruit increases, the weight of the individual fruit will also increase. Similar results were reported by Singh *et al.* (1987) in Parwal.

Yield per plant was significantly and positively correlated with number of fruits per plant and individual fruit weight. It indicates that number of fruits and average fruit weight should be given importance in the selection programme to improve yield. Kumar and Singh (1998) observed similar correlation between yield per plant with number of fruits per plant and individual fruit weight. Similar results were also reported by Indiresh (1982) in bittergourd.

5.4 Classification of varieties and formation of keys for varietal identification

Characterization of cultivars is helpful in maintaining their genetic purity during seed production. It also helps seed certification agencies, seed inspectors and others involved in seed production programmes.

The present study on 25 Indian snakegourd accessions attempted to find out the extent by which the morphological characters and seed characters could be used to differentiate the snakegourd varieties in varietal identification.

Morphological features of seed and plant parts are a major component of cultivar identifaction because they provide dependable data. Use of different morphological features in a sequential fashion is more useful and convenient to distinguish the varieties, rather than focussing on single morphological character.

The morphological characteristics utilized in the present study were typical for the accessions and were able to characterize the varieties during the field crop inspection. By the combination of two or more morphological characteristics belonging to different parts of the plant it is possible to characterize the varieties. Principal component analysis was used to make dent in this case.

With the help of principal component analysis all the characters of individual accession were combined to form indices. By locating these index values on a two dimensional chart, accessions were grouped into different clusters.

5.4.1 Grouping on seed index

Based on the seed characters, the accessions were gouped into six clusters. The accessions, which are having similar characters, are grouped together. First cluster (Fig.1) included TA 115, TA 119, TA 19 and TA 108. All these accessions are having maximum values for seed length, seed width, 100 seed weight, seed size index and seed thickness. Similarly sixth cluster included only one accession TA 95. Minimum value for 100 seed weight and seed size index were recorded for this cluster.

5.4.2 Grouping on yield index

Based on the yield index the accessions were grouped into four clusters (Fig.2). Here also the accessions, which are having similar characters, are grouped together. First cluster included only one accession TA 114. Maximum value for number of male flowers per plant, sex ratio and peduncle length was recorded for this accession. Similarly fourth cluster included MDU-1, TA 105, TA 19, kaumudi, TA 110, TA 118 and PKM-1. Minimum values for male flowers per plant, female flowers per plant, days to first male flower anthesis, sex ratio and fruit length and maximum for the fruits per plant. It indicates that the percentage of fruit set is more in these accessions.

5.4.3 Grouping on growth index

Based on the growth characters, the accessions were grouped into six clusters (Fig.3). Here also clusters are formed based on the similarity in their growth characters. First cluster included only one accession TA 118. Maximum value for tendril length was recorded for this accession. Similarly sixth cluster of Fig.2 includes only one accession TA 113. Minimum value for tendril length was recorded for this accession.

From this analysis the groups of varieties having desirable characters could be identified and they may be used for further improvement in breeding and to locate diverse types. Similar application was used by Devis and Adam (1978) for grouping of 16 cultivars of beans for different characters.

5.4.4 Keys developed for varietal identification in snakegourd

Keys were prepared based on the primary diagnostic characters of both seed and plant. The major diagnostic characters that were used for developing keys are leaf pubescence, nature of leaf lobing, tendril length, fruit skin colour, fruit girth, fruit length, fruit weight, 100 seed weight, seed size and seed coat colour. To draw a similarity, Chakrabarty *et al.* (1989) used different seed characters for varietal identification in black gram. The varietal identification keys suggested by Martinello (1992) using leaf characters and fruit characters in *Pisum sativum, vicia sativa* and *Vicia faba* are comparable in this case.

The summarized information prepared from the keys can be used as marker for distinguishing varieties for high yield, earliness, fruit size and fruit colour, pattern as depicted below.

Marker characters for varietal identification

Chief genotypic characters	Key characters
High yield	Low seed width (<10 mm) Low seed thickness (<5 mm) Dented pubescence
Early varieties	Plant with long tendrils (35-40 cm)
Long fruited varieties	Grey seed coat colour
Short to medium fruited varieties	Brown seed coat colour
Green fruits with white stripes/white fruits with green stripes	Dark green leaves/less number of female flowers
Light green fruits/white fruits	Large leaves with light green colour

SUMMARY

6. SUMMARY

The present investigation on character association of seeds on plant morphology in snakegourd (*Trichosanthes anguina* L.) was conducted in the Vegetable Research Farm of Department of Olericulture, College of Horticulture, Kerala Agricultural University, Vellanikkara during 1999-2000.

The salient findings are summarized.

1. Twenty five accessions of snakegourd collected from different parts of India were genetically catalogued based on the IBPGR descriptor list. Wide variation in seed characters, growth characters and yield characters were noted.
2. The accessions showed significant differences for tendril length, internodal length, main vine length, days to first male flower anthesis, days to first female flower opening, male and female flowers per plant, sex ratio, fruit girth, fruit length, fruit weight, days to fruit maturity, days to first harvest for seed, fruits per plant, yield per plant, number of seeds per fruit, 100 seed weight, seed length and width measurements, and seed size index.
3. Comparison of the different snakegourd types has revealed that the type TA 104 is the highest yielder (7.8 kg/plant) followed by TA 95 (7.34 kg/plant) and TA 102 (6.42 kg/plant).
4. Correlation studies have shown that the number of seeds per fruit was highly associated with days for male flower opening and days for fruit maturity. Seed size index was strongly associated with leaf size.
5. Intercorrelation studies revealed that there is strong association between yield and fruit characters and number of fruits per plant.
6. Principal component analysis revealed that the highest seed index values were obtained for the accessions TA 108 followed by TA 19, TA 119 and TA 115.

7. Highest growth index values were obtained for the accessions TA 118 followed by TA 117 and TA 107.
8. Highest yield index values were obtained for the type TA 114 followed by TA 95, TA 107 and Co-2.
9. Twenty five accessions were grouped into six clusters based upon seed index, four clusters based on growth index and six clusters based on the yield index.
10. Keys for varietal identification were developed based on the primary diagnostic characters like seed size index, 100 seed weight, seed coat colour, leaf lobes, leaf pubescence, tendril length, fruit skin colour, fruit girth, fruit length and fruit weight.

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CHARACTER ASSOCIATION OF SEEDS ON PLANT MORPHOLOGY IN SNAKEGOURD
(Trichosanthes anguina L.)

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ABSTRACT OF THE THESIS

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ABSTRACT

The research project `Character association of seeds on plant morphology in snakegourd (*Trichosanthes anguina* L.)' was carried out in College of Horticulture, Kerala Agricultural University, Vellanikkara, Thrissur during the period 1999-2000. The study envisaged to find out the association of various seed characters on the vegetative characters of snakegourd, classification of accessions based on the seed index, growth index and yield index as obtained from principal component analysis and to formulate keys for varietal identification.

The 25 accessions were catalogued based on the IBPGR descriptor list. Significant differences for various seed characters, growth characters and yield characters were noticed among the accessions.

Correlation studies have shown that the number of seeds per fruit strongly associated with days to male flower opening and fruit maturity. Seed size index was strongly associated with leaf size.

The highest seed index value for TA 108, the highest growth index value for TA 118 and the highest yield index value for TA 114 were obtained as revealed from principal component analysis.

Twenty five accessions were grouped into different clusters based on the seed index, growth index and yield index. Based upon the seed characters (seed size, seed coat colour and 100 seed weight), growth characters (leaf lobes, leaf pubescence and tendril length) and fruit characters (fruit skin colour, fruit girth, fruit length and fruit weight) keys were developed for varietal identification.