STANDARDISATION OF POPULATION DENSITY IN WATERMELON [*Citrullus lanatus* (Thunb.) Mansf.]

By

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THESIS
SUBMITTED IN PARTIAL FULFILMENT OF
THE REQUIREMENT FOR THE DEGREE OF
MASTER OF SCIENCE IN HORTICULTURE
FACULTY OF AGRICULTURE
KERALA AGRICULTURAL UNIVERSITY

DEPARTMENT OF HORTICULTURE
COLLEGE OF AGRICULTURE
VELLAYANI, THIRUVANANTHAPURAM

2000

Dedicated

to my beloved

Parents

DECLARATION

I hereby declare that this thesis entitled **"Standardisation of population density in watermelon** [*Citrullus lanatus* (Thunb.) Mansf.]" is a *bonafide* record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled **"Standardisation of population density in watermelon** [*Citrullus lanatus* (Thunb.) Mansf.]" is a record of research work done independently by **Ms. BINDUKALA. A. R.** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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ACKNOWLEDGEMENT

With profound pleasure, I place my gracious thanks to Dr. M. Abdul Vahab, Associate Professor of Horticulture, College of Agriculture, Vellayani and Chairman of the Advisory Committee for his personal attention, keen interest, constant inspiration and valuable guidance during the course of this work and preparation of this thesis. My sincere heartfelt gratitude ever remains with him.

I extend my sincere thanks to Dr. L. Rajamony, Associate Professor and Head, Department of Olericulture, College of Agriculture, Vellayani and member of the Advisory Committee for extending his help and assistance during the course of study.

I wish to express my profound gratitude and appreciation to Dr. Vijayaraghavakumar, Associate Professor, Department of Agricultural Statistics, College of Agriculture, Vellayani for his inestimable co-operation, periodic suggestion, guidance during the planning of experiments at various stages of this investigation.

I convey my heartiest gratitude to Dr. K. Rajmohan, Associate Professor, Plant Molecular Biology and Biotechnology Centre, College of Agriculture, Vellayani and member of the Advisory Committee for his generous help, valuable suggestions, keen interest and constructive criticism for the preparation of this thesis.

I remember with thanksfulness the help rendered by Sri. C. E. Ajithkumar, Programmer, Department of Agricultural Statistics, College of Agriculture, Vellayani for the immense help extended to me for the analysis of research data.

I place on record my gratefulness to Dr. Venugopal, Professor and Head, Department of Soil Science and Agricultural Chemistry and Dr. George Thomas, Assistant Professor, Department of Soil Science and Agricultural Chemistry for rendering the timely help and guidance for chemical analysis required for this work.

With ardent gratitude, I remember the inspiration, whole hearted co-operation and good will bestowed on me by all the members of the teaching and non-teaching staff of the Department of Horticulture, College of Agriculture, Vellayani in all my endeavors.

I should specially mention Mrs. Ann Alex, Mrs. Geetha, Mrs. Nirmalatha, Mrs. Rakhi Anilkumar, Mrs. Priya, Ms. Sudha, Ms. Rani Susheel, Ms. Jyothilakshmi, Mr. K.P. Sairaj, Mr. K. Dineshbabu for their unrelenting and indispensable help and company which is always a matter of joy to be remembered.

The instrument of my acknowledgement would remain complete if Maharashtra Seed Company and Instructional Farm, Vellayani is not thanked for their co-operation and assistance, without which the investigation would not have materialized.

Sincere thanks to M/s. Athira Computers, Kesavadasapuram, Thiruvananthapuram for the prompt computerized typesetting and documentation work of this thesis.

I sincerely thank the Kerala Agricultural University for granting me a fellowship for the M.Sc. programme.

Words fail to express my deep sense of gratitude and indebtness to my parents for their love, moral support and encouragement which enabled me to complete this work.

Above all, every gesture of help obtained me in thought, word and deed is a clear manifestation of God's love. It is He who moves my heart in many a guice and many a rapture of joy and sorrow.

Bindukala. A.R.

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Introduction

INTRODUCTION

Cucurbits were among the first group of plants used by man. They include dessert, salad, pickling and culinary types. Among the dessert types, watermelon [*Citrullus lanatus* (Thunb.) Mansf.] is the most important crop in the tropical regions of the world. It is used in many ways. In desert areas the fruit is used as a substitute for drinking water. The juice is delicious and nourishing and exerts a cooling effect in the hot summer months. Watermelon is the richest source of iron among the cucurbits. It is considered as common man's fruit and is relished by the rich and the poor alike. They are mostly eaten fresh, but the rind is often candied or pickled. The juice extracted by crushing the pulp is served after adding a pinch of salt and black pepper. Seeds are roasted and the kernals are used in various sweets and delicacies.

Watermelon is grown in the hot as well as in the sub-tropical regions. In India it is a major crop especially in the river beds of Uttar Pradesh, Rajasthan, Gujarat, Maharashtra and Andhra Pradesh.

In Kerala, watermelon is cultivated mainly in the northern parts especially in the river beds of Bharathapuzha. There is high demand for dessert vegetables, especially in the summer months. In fact no dessert vegetable other than watermelon is available in the market. At present, large quantities of watermelon are being sold in every parts of the Kerala, more than 95 per cent being imported from neighbouring states as the cultivation of this crop is yet to be popularised in the state. This is mainly due to non availability of suitable varieties and lack of improved management practices for watermelon.

Studies conducted in Kerala Agricultural University proved the feasibility of watermelon cultivation in the state and identified certain varieties and hybrids (AICVIP, 1994). From a varietal trial, Shibukumar (1995) also found Sugar Baby as the promising variety under Vellayani conditions. However, the management practices of watermelon have not been standardised for the Kerala conditions. The systems of planting as well as the population density vary from region to region. It is well known that the yield and quality in terms of total soluble solids (TSS) depend on the planting systems, population density and varieties / hybrids to a great extent. As the fruits of watermelon are harvested at the fully mature stage, the number of fruits per plant is usually not altered. This suggests scope for increasing the population density so as to maximise the yield without impairing the quality. Information on the optimum plant density for maximum returns with optimum benefit cost ratio would attract farmers towards watermelon cultivation. The present recommended spacing for Kerala (3x2 m) appears to be very wide when compared to other states. The total number of fruits and thereby the yield per hectare depends on the spacing and management practices. Optimisation of spacing is very important for maximisation of yield as the number of marketable fruits per unit area is a function of number of plants per unit area and other cultural practices. In this context the present study is conducted with the following specific objectives :

i) To standardise the population density of varieties and hybrids in watermelon for maximising yield and quality.

ii) To study the interaction effect of varieties and population density in water melon and

iii) To work out the optimum benefit : cost ratio in watermelon.

Review of Literature

2. REVIEW OF LITERATURE

Watermelon [*Citrullus lanatus* (Thunb.) Mansaf] is an important crop among the cucurbits in the tropical regions of the world. It is mainly used as a dessert. Watermelon has very high demand during summer season. The fruits vary in size, shape, colour and are considered nutritious. It is the richest source of iron among the cucurbits.

Possible improvement in yield through the use of good varieties, improved cultural practices such as optimum population density, fertilizer application etc. have been standardised in many countries. The yield and quality depend on the population density, varieties and hybrids to a great extent.

Information on planting density in watermelon for maximum returns with optimum benefit cost ratio are rather limited in the country. The available literature on cucurbitaceous vegetable pertaining to the present study is reviewed under the following subheads.

2.1 Growth, flowering and fruit set

Bach and Hruska (1981) reported in cucumber that when planted at different densities (56 and 77 cm between plants), low density had greater values for most of parameters such as vine length, leaf area, number of flowers than plants at higher densities. But leaf area alone was increased at high density planting.

Population density affects plant growth, flowering pattern and fruit set in any crop. In parthenocarpic cucumber the best plant growth, development, photosynthesis and yield were obtained when plants were grown at 1.5 plants per m^2 (Karataev and Salnikova, 1983)

The effect of population density varies with hybrids, open pollinated varieties and pathenocarpic cucumbers. In an experiment with hybrids and open pollinated varieties of cucumber, Lower *et al.* (1983) observed less pistillate flowers by increasing density and more staminate flowers per plant in hybrids. However in open pollinated varieties population density had no effect on sex expression.

In an experiment with muskmelon, Nerson *et al.* (1984) observed faster vegetative growth per unit area with a population of 31250 plants than with 13,500 plants per hectare. There were more leaves per m^2, higher leaf area index and more dry matter accumulation with higher population density.

Kasrawi (1989) in an experiment with parthenocarpic cucumber cv. Marbasen to planting density reported that the timing of fruit production, sex expression and flower abortion were not affected by planting density. However, the shoot dry weight per plant decreased linearly and quadratically with the increase in plant density.

Arora and Malik (1990) conducted work in *Luffa acutangula* cv. Pusa Nasdar and revealed that when seeds were sown at 12, 9 and 6 plants/bed and were grown at a population density of 11250 per hectare, the spacing of nine plants per bed gave the longest plants with highest secondary branches. It also resulted in early appearance of pistillate flowers and gave the highest number and weight of fruits.

Effect of population density on the performance of bittergourd was investigated by Parekh (1990) using three levels of spacing (1.5 x 0.5 m, 1.5 x 1.0 m and 1.5 x 1.5 m). He observed that the wider spacing of 1.5 x 1.5 m gave the maximum main vine length and number of primary branches per plant. The spacing 1.5 x 1.0 m produced the wider sex ratio. The different levels of spacing showed non-significant effects on days to appearance of first female flower.

Effect of population density on the performance of squash melon was investigated by Bikramjit Singh (1990) using two spacing *viz.*, 90 x 22.5 cm and 90 x 45 cm. He observed that closer spacing of 90 x 22.5 cm helped in inducing early female flowers. But spacing of 90 x 45 cm produced more vine length, branches and leaves.

Response of slicing cucumber (*Cucumis sativus* L.) to different planting densities was studied by Renji (1998). The study revealed that planting at the widest spacing of 2x1.5 m were the earliest for the male and female flower production.

2.2 Yield and yield components

Effect of plant population densities on performance of pickling cucumber was studied in the variety Spartan Dawan using three spacings by Wiebe (1965). Closer spacing resulted in increased yield per acre.

Cucumber yields were higher in weight and number from beds spaced 1.20 m apart than from beds 1.50 or 1.80 m apart in the studies of Hallig and Amsen (1967).

Population density and spacing affect yield and its components to a great extent. In watermelon, Petkov (1970) observed higher yield at closer spacing with negligible effect on fruit size.

Borrelli (1971) observed increased yield per m^2 in melons but the yield per plant and the individual fruit weight fell with increasing density. The rate of ripening and the refractive index of the fruit were inversely related to the number of plants in the row. It was also seen that among the three melon cultivars Vedrantais, Rafon and Ogen, Vedrantais performed best for close spacing.

Belik and Veselovskii (1972) observed that in trials with the cv. Melitopol'skii 142 of watermelon, when planted from 1700 to 20,400 plants per hectare, leaf area, photosynthesis and total yield increased with planting density but greatest yield of marketable fruits was obtained from plots with 5000 to 10,000 plants per hectare.

In a field trial with watermelon variety Sugar Baby at Agriculture College Farm, Dapoli by Patil and Bhosale (1973) revealed that row spacing of 2.4 x 2.4 m resulted in low yield, but as the spacing was reduced to 1.8 x 1.8 m, the yield of fruit per ha significantly increased. It still increased when the spacing was reduced to 1.2 x 1.2 m. But the average fruit weight, however was decreased as the spacing was narrowed.

Pickling cucumber cv. Chicago were planted at 1, 2 and 3 plants per hill with spacings of 20, 40 or 60 cm between and row width of 1m. The greatest number of fruits of acceptable size per hectare was obtained with 40 cm between hills and 3 plants per hill. (Garica *et al.*, 1973).

In a trial with the pickling cucumber cultivars Wisconsin, SMR and Pioneer and spacings of 30 x 30 cm to 15 x 15 cm, Hogue and Hemey (1974) obtained highest yield from those plants spaced at 15 x 15 cm.

When the cultivars of pickling cucumber Pioneer and Premier were grown at 50 and 70 cm between the rows, yield and returns were higher at 70 cm row spacing with Pioneer. However in Premier the 50 cm spacing was preferable (Kretchman, 1974). In another trial with cultivars Earlipik, Peerfectoverde and Pioneer spaced at 1, 2 or 3-4 feet within the row, yields and returns of all cultivars were highest at the closest spacing.

High yield of 31.7 t per ha was obtained from cucumber cultivar Ashely spaced at 1.4 x 0.4 m (Marin Hautrive and Peres Guerra, 1976)

In a spacing cum varietal trials using three varieties of pumpkin and three levels of spacing, Noon (1977) obtained highest yield, highest number of mature fruits and lowest number of immature fruits per plant from 'Lady Godiva' at the closest spacing of 1m x 1m.

Ko *et al.* (1978) planted *Luffa cylindrica* (*aegyptica*) at 90 and 60 cm apart and in rows 150 cm and observed the optimum spacing as 150 x 90 cm.

Response of watermelon cv 'Charleston Gray' to within row and between row spacing was studied with identical experiments at two locations viz. Gainesville and Leesburg by Brinen *et al.* (1979). In both the locations they observed decreased fruit yield and increased fruit size as between row spacing was increased from 1.5m to 4.5m and within row spacing from 50cm to 250cm.

Effect of population density on the performance of cucumber was investigated by Mangal and Yadava (1979) using two spacings *viz.* 100cm x 60cm and 100cm x 90cm. They observed maximum yield per hectare at closer spacing of 100cm x 60cm.

In a trial with cucumber cultivars Stereo, Corona and Sandra, Enthoven (1980) reported that the fruit number and yield per m^2 increased with increase in closer spacing. Though vines were spaced at 80 and 50 cm, the closely spaced plants of 50 x 50cm gave the highest fruit number.

Bianco and Miccols (1980) observed that when the pickling cucumber cultivars were spaced at the rate of 11 to 66 plants per m^2, increase in planting density also increased the number of small fruits and the gynoecious hybrid cultivar Pioneer was more productive upto 554 q ha^{-1} than the cultivar SMR-18 which produced 446 q ha^{-1}.

Burgmans (1981) conducted an experiment in gherkins to study the effect of spacing on growth and yield using two varieties *viz*. "Green Spear" and "SG-812". From the results of three years trial he observed highest salable and total yield with highest plant population (1,20,000 plants ha^{-1}).

According to Bach and Hruska (1981) cucumbers when planted at different densities (56 and 77cm between plants), low density showed greater value for fruit yield.

Liebig (1981) reported that when five weeks older plants of the cucumber cv. Pepinese were planted at 1.1 to 4.9 plants per m^2, fruit yield increased with plant density but allowing for the cost of transplants, the advantageous spacing was 2 plants/m^2.

Tesi *et al.* (1981) observed that Albatross, F_1 hybrid of Courgettes when grown at different spacings of 2.5, 1.48, 1.2 plants per m^2, the widely spaced plants gave the heaviest but shortest individual fruits.

Mangal *et al.* (1981) conducted spacing experiment on the watermelon cv. Sugar Baby. The plants spaced at 30cm gave the best results with regard to yield (32.2-41.2 kg), and showed slight delay in ripening.

Baljeet Singh *et al.* (1982) in trials with muskmelon cultivar Haramadhu found that the yield loss of 151.8 q ha^{-1} at 60cm spacing and 333.6 q ha^{-1} at 30cm spacing but the quality parameters like Total Soluble Solids (TSS), vitamin C, reducing sugar contents and pulp thickness remained unchanged.

Lazin and Simonds (1982) reported that, two cultivars namely Early Dew and Tam Dew of melons when spaced at 1, 2 and 3 feet within row spacing, decrease in spacing increased the number of fruits per plant. But the mean fruit size and weight of the fruit was decreased.

Al-Khayer (1982) studied the effect of spacing with two hybrids of salad cucumber Ksalata F_1 and Fembaby F_1. He found that, of the different spacing 1.5, 2.0, 2.5 and 3.0 plants per m^2, increase in plant densities increased the fruit number and weight per plot in both the hybrids.

Douglas *et al.* (1982) observed the performance of Buttercup squash (*Cucurbita maxima*) planted in 1.5 and 3 cm row and spaced at

29-100 cm and 17-87 cm. The highest yield of 27 t ha^{-1} was obtained at the closest spacing. It was also observed that increase in density gave a progressive decline in the size of the individual plant and in number and weight of the fruit. Significant numbers of fruits weighing more than 2 kg were only achieved at low populations but with a considerable loss of potential yield.

Mcgowan and Slak (1982) in a trial with two Buttercup squash cultivars spaced at 0.26 to 1.5 m^2 per plant observed higher total yields with increase in plant density. Marketable yields, however, was highest at 0.38 m^2 per plant.

Nelson *et al.* (1983) conducted an experiment in Buffalogourd to study the effect of population density on root yield. They found that a maximum yield of 34,500 kg was obtained from the highest density of 5,55,000 plants per hectare.

Wehner and Miller (1983) compared the performance of determinate and indeterminate cultivars of cucumber under varying planting densities. They reported that, higher optimum density gave higher yield for the indeterminate cultivar 'Table green 65'.

The yield and quality of musk melon as affected by various levels of spacings was investigated by Prabhakar *et al.* (1985) at Bangalore. In the study with the cv. Haramadhu using various levels of spacing, they observed highest yield of 45 q ha^{-1} when plants were spaced at 60 x 60 cm compared to other spacings. In addition to the yield increase the total soluble solids were increased.

In a spacing trial of watermelon cultivars such as Baby Fun, Minilee and Mickylee, fruit yields were highest when plants were grown at 24 inches in rows spaced at 5 ft. apart rather than 16 or 32 inches of the same row spacing (Elmstrom and Crall, 1986). Minilee fruits were smaller than Mickylee. Fruits of all the cultivars matured 7-10 days earlier than the traditional cultivars and were productive for a longer period and had good fruit quality.

Nerson *et al.* (1986) in their experiment with *Cucurbita pepo* cv. Goldy at different plant densities ranging from 10.000 to 66,666 plants per ha, obtained highest yield with densities ranging from 40,000 to 50,000 plants per ha. There was no delay in the time of first harvest at high densities compared with lower densities, but yield, quality and number of fruits was low at the lowest planting density. Fewer oversize and virus affected fruits were produced at higher densities, where as fewer off shape fruits were produced at the lower densities.

The yield of bottlegourd was affected by various levels of spacing in the investigations of Shukla and Prabhakar (1987). In a study with the cv. 'Arka Bahar' at various levels of spacing, they observed highest yield (38.5 t ha^{-1}) when plants were spaced at 300 x 45 cm with three plants per hill compared to other spacings.

Gilreath *et al.* (1988) in their studies with cultivars of water melon, Baby Fun and Minilee, highest yields for both the cultivars were obtained at 1.5 ft in row spacing. However the highest proportions of optimum sized fruits were produced at one feet row spacing for Baby Fun and two feet in row spacing for Minilee.

Silva *et al.* (1988) in the study with pickling cucumber, seeds of female cultivars namely Ging A.77 and Score were sown at four densities (13,333 - 80,000 plants per ha). The highest commercial yield (15.6 to 15.8 t/ha) were obtained at the densities of 80,000 plant per ha.

Aurin and Rasco (1988) observed in *Luffa cylindrica*, that with an increase in the plant density from 40,000 to 1,06,666 plants ha^{-1} increased both the yield (from 17.5 to 37.1 t ha^{-1}) and the marketable fruits.

The responses of parthenocarpic cucumber cv. Marbason to planting density and row arrangements were investigated in plastic green house by Kasrawi (1989) over two growing seasons with four planting densities. It was found that the yield per unit area increased linearly when the population density was increased from 2.4 to 5.4 plants per m^2.

Yadav *et al.* (1989) conducted an experiment at vegetable research farm of Narendra Deva University of Agriculture and Technology, Faizabad to study the influence of spacing and methods of training on different varieties of pointed gourd. Three varieties viz. FP-1, FP-3, FP-4 and two spacings *viz*., 1.5 x 1.5 m and 3 x 1.5 m were considered for study. Maximum yield of 110.32 q ha^{-1} was recorded under bower system of planting with narrow spacing (1.5 x 1.5 m) in the variety FP-4.

In a two season trial with *Cucumis melo* var. flexuosus and different densities, it was found that fruit yield increased with planting density, highest being in 30 cm spacing in one season and 15 cm in the other season (Mohammed *et al.*, 1989).

In the study of cultivar response and different planting densities Widders and Price (1989) reported that leaf lamina and fruit tissues exhibited largest reduction in tissues, when planting density was increased from 4.5 to 20 plants per m^2 (45,000 to 200,000 plants per hectre). Lower fruit productivity per plant at higher plant densities resulted from fewer fruitset per plant and lower fruit shoot ratio. But unit leaf area was not affected by plant spacing. Increased densities resulted in vegetative growth above ground. Total fruit yield with a single harvest did not increase above 77,000 plants per ha for both cultivars.

Edelstein *et al.* (1989) in field trials with two *Cucurbita pepo* which were spaced 1000, 2000, 3000 and 4000 plants per unit area, observed that total yield remained unaffected by population density but there was negative relationship between plant densities and number of fruits per plant. In plants of vine type, increase in plant density decreased the ratio of large to small fruits, where as in bush type plants, their ratio remain unaffected.

Singh and Naik (1989) opined that in a two year trial with cultivar 'Arka Manik' of watermelon and different spacings, the optimum conditions for higher yields of 253.2-282.5 q ha^{-1} in first year and 467.0 to 507.3 q ha^{-1} in the next year was obtained at 2.0 x 1.2m spacing.

Effect of four plant spacings (3m x 60 cm, 4m x 60cm, 3m x 75cm and 4m x 75cm) on growth yield and quality of pumpkin was studied by Kulbir Singh *et al.* (1990) in the loamy sand soils of Punjab Agricultural University. The different spacings did not change the number of fruits per vine but the fruit yield per plant was increased significantly with increase in intra row spacing from 60 cm to 75 cm. The closer spacing of 3m x 60 cm produced the maximum yield of 108.12 q per ha and the closer spacing induced early female flowers.

Different planting densities have desirable effects with respect to yield and vegetative characters Bikramjit Singh (1990) reported that a closer spacing of 90 x 22.5 cm helped to induce early female flowers and total fruit yield in squash melon but spacing of 90 x 45 cm produced more vine length, branches, leaves, fruit number and yield per plant.

EL-Aidy (1991) reported that cucumber cultivar Sahara F_1 when grown at different plant densities of 2, 2.5 and 3.3 plants per m^2 did not differ significantly from each other in their yields.

Effect of high plant density on performance of cucumber was studied by Staub *et al.* (1992). They reported that although the number and weight of fruits per hectre increased with increasing plant density, fruit weight per plant decreased with increased in plant density.

Wann (1993) conducted an experiment to identify adapted cultivars, optimum population density and plant special arrangement in cucumber. The cultivars were grown in population densities ranging from 26,000 to 130,000 plants per acre. The study indicated increased yield at densities above 26,000 plants per acre, but no increase was observed above 65,000 plants per acre.

Islam *et al.* (1994) reported that tuberous roots of *Momordica dioica* when planted at 3.0m x 3m spacing have the highest yield of 26.2 t ha^{-1}.

Choiyounghah *et al.* (1995) in their work with cucumber cv. Japanese White Spined, reported that planting densities of 45,000 plants per hectare produced the maximum yield of 3,80,020 kg ha^{-1} and also had the highest yield of marketable fruits.

In a trial with spinegourd by Puzari (1997) the results revealed that, there was a significant interaction between tuber size and spacing only in the main crop where the yield was 13.1 t ha^{-1}. The ratoon crop produced 9 t ha^{-1} but was more susceptible to fungal pathogens and physiological degeneration.

In a trial with root cuttings of pointedgourd cv. 'Damodar' Pandit *et al.* (1997) reported that total number of fruits per plant and fruit length increased with plant spacing. Total and early fruit yields were highest (101.71 and 169.82 q ha^{-1}) when plants were spaced at 60cm apart in rows.

Nerson (1998) concluded from the experiment at Bet Hashita (1992) and Neweyaar (1993) Israel that the two near Isogenic Cucumber Lines viz., WI 1983G Normal and WI 1983G Little Leaf when planted at the closest spacing of five plants per m^2, gave the highest yield.

Elizabeth and Dennis (1998) in their field studies during 1993 and 1994 to determine the optimal plant spacings for muskmelon cv. 'Superstar' production reported that yield and number of fruits per ha generally increased as plant population increased from 3074 to 10,764 plants per ha, but the number of fruits harvested per plant and average fruit mass decreased linearly as in-row spacing decreased.

Botwright *et al.* (1998) did experiment with *Cucurbita maxima* to find the effect of density on growth, development and yield. It was observed that marketable yield increased to a maximum of 18 t ha^{-1} at 1.1 plants/m^2 and declined at higher densities because of the increased number of undersized fruits. High plant density reduced the vegetative growth and also the yield was found to be less due to less female flower and increased abortion per plant.

In an experiment done with the slicing cucumber *Cucumis sativus* (Renji, 1998) reported that highest yield per plot (43.46 kg) was obtained from the highest density of 13,333 plants per hectare (1.5 x 0.5 m).

2.3 Quality parameters

By increasing the density of green house cucumber from 2.0 to 2.6 plants per m^2 kretschmer (1970) observed enhanced fruit quality.

In an experiment with Cantaloupe cultivars PMR-45 and 'Top mark' planted at population densities of 7000, 16,000, 28,000 and 63,000 plants per acre Zahara (1972) reported increased sucrose content of mature fruits at wider spacing. The number of marketable melons were also greater with PMR-45 at the population density of 16,000 plants per acre.

Effect of planting density and shading on fruit curvature in cucumber was studied by Kanahama and Saito (1984). Cucumber plants were grown at densities 7.3, 5.5 and 2.2 plants per m^2 and shaded with one, two or three layers of cheese cloth. They observed that the angle of curvature of fruits was not affected by planting densities but increased by increased shading.

Parekh (1990) in an experiment with bittergourd and three different population density reported that the wider spacing of 1.5 x 1.5 m gave maximum TSS. But non significnat effect was observed between the population density and vitamin C content.

In squash melon significant effect of wider spacing on the quality aspects *viz.*, TSS, ascorbic acid and minerals was reported by Bikramjit Singh (1990).

Materials and Methods

3. MATERIALS AND METHODS

A field investigation was carried out during February-May 1999 to find out the response of three watermelon varieties to different population densities on yield and quality. The materials used and methods adopted are given below.

3.1 Materials

3.1.1 Experimental site

The experiment was carried out at the Instructional Farm, College of Agriculture, Vellayani. It is situated at 8.5°N latitude, 76.9°E longitude at an altitude of 29m above mean sea level. Soil of the experiment site was lateritic red loam belonging to Vellayani series.

3.1.2 Planting material

Two open pollinated varieties namely Sugar Baby, Arka Manik and a hybrid MHW-6 were used for the study. The source of varieties is given in the Table 3.1 (Plate 1, 2 and 3 respectively).

Plate 1. Variety Sugar Baby

Plate 2. Hybrid MHW-6

Plate 3. Variety Arka Manik

Table 3.1. Source of watermelon varieties

Variety	Sources
Sugar Baby	Instructional Farm, College of Agriculture, Vellayani.
MHW 6	Maharashtra Hybrid seed Company, Jalna.
Arka Manik	Indian Institute of Horticultural Research, Bangalore.

3.2 Methods

3.2.1 Design and layout

The experiment was laid out in a split plot design with population densities in the main plots and varieties in the subplots. The details of lay out were as follows.

Net plot size = $24m^2$ (6m x 4m)

Number of main plots = 6

Number of subplots / main plot = 3

Replications = 3

3.2.2 Treatments

Main plot (6 population densities)

D_1 – 3 x 2m (1666 plants/ha)

D_2 – 2 x 2m (2500 plants/ha)

D3 – 3 x 1m (3333 plants/ha)

D_4 – 2 x 1 m (5000 plants/ha)

D_5 – 3 x 0.5 m (6666 plants/ha)

D_6 – 2 x 0.5 m (10000 plants/ha)

Subplot (3 varieties)

V_1 – Sugar Baby

V_2 – MHW-6

V_3 – Arka Manik

3.3 Field culture

3.3.1 Land preparation

The land was prepared as per the Package of Practices Recommendations of Kerala Agricultural University (KAU, 1996). The field was dug twice, stubbles burned, clods broken and the experimental plot was made into main plots and sub plots as per treatments. The different planting densities were assigned in the main plot and the three varieties to the subplots.

3.3.2 Manures and Fertilizer application

Basal dose of farm yard manure at the rate of 20 tons ha^{-1} was uniformly applied in all treatments. From the recommended dose of 70:25:25 kg ha^{-1}, half nitrogen, full potassium and phosphorus were applied as basal dressing. The remaining nitrogen was applied 30 days after sowing.

3.3.3 Seeds and sowing

Well dried seeds were selected for sowing. Two seeds per hill were sown in channels as per the treatment spacings. Later, only one per hill was retained.

3.3.4 After cultivation

Dried coconut leaves and banana leaves were spread on the interspaces of the channels and vines were allowed to trail on it. Regular weeding operations were carried out to keep the plot free of weeds and crops were irrigated everyday. Earthing up was done at the time of the top dressing.

3.3.5 Plant protection

To prevent the infection of damping off Dithane M-45 at the rate of 0.4 per cent was drenched at 2-3 leaf stage. Malathion at the rate of 2 kg ai ha^{-1} against Aulachophora beetle and Rogor 0.03 per cent was sprayed twice before and after fruit set to control mites. Later, the fruit fly attack was controlled by hanging banana fruit traps. Trap was prepared in coconut shells by applying Carbofuran granules on the slices of ripe banana fruit cv. Palayankodan.

3.3.6 Harvesting

Harvesting started when fruit reached mature stage as judged by visual observations. The maturity indices were changing the colour of the fruit portion touching the ground to yellow, drying of the nearest tendrils and hearing a dull sound on tapping the fruits.

3.4 Observations

Four plants were selected at random from each treatment and the following observations were made by adopting standard procedures and the average values were worked out.

3.4.1 Flowering and earliness

(a) Days to first male flower opening

Number of days taken from sowing to the blooming of first male flower was recorded.

(b) Days to first female flower opening

The number of days taken from sowing to the blooming of first female flower was recorded.

(c) Node to first female flower opening

The nodes were counted from the lowest portion to the one at which the first female flower opened and recorded.

(d) Days to first harvest

Duration from sowing to first harvest of the fruits from each treatment was recorded.

(e) Crop duration (Days)

Number of days taken by three varieties from sowing to the harvest of the last fruit was considered as duration of crop.

(f) Number of female flowers plant^{-1}

The total number of female flowers per plant was counted and average worked out

3.4.2 Vegetative characters

(a) Branches plant^{-1}

The number of main branches per plant was counted after the last harvest and the average worked out.

(b) Main vine length (cm)

Length from the collar region to the tip of the main vine was measured using the measuring tape after pulling out the vine and expressed in centimetres.

3.4.3 Yield

(a) Total fruits plant^{-1}

The total fruits from observation plants were counted and average worked out.

(b) Total fruits plot^{-1}

The total number of fruits from each plot in each treatment were counted and total worked out.

(c) Marketable fruits plant^{-1}

The number of saleable fruits were counted from observation plants and average recorded.

(d) Marketable fruits plot^{-1}

The number of fruits saleable from each plot and each treatment was recorded and average worked out.

(e) Marketable yield plot^{-1} (kg)

The weight of marketable fruits from each plot at each harvest was taken using a balance and total expressed in kilograms.

(f) Unmarketable fruits plot^{-1}

Deformed and diseased fruits were counted and average worked out.

3.4.4 Fruit characters

For observation on fruit characters, four fruits per replication were taken and average worked out.

(a) Average fruit weight (kg)

The fruits from each plot were taken, weighed and their average worked out and expressed in kilograms.

(b) Fruit length (cm)

The length of the fruit was measured from the stalk end to the tip in all the observational fruits and expressed in centimetres.

(c) Fruit diameter (cm)

After cutting the fruits into two halves diameter at the middle of the fruits including the rind was worked out and expressed in centimetres.

(d) Flesh thickness (cm)

After cutting the fruits into two halves the diameter at the middle of the fruit excluding the rind was measured using scale, the average worked out and expressed in centimetres.

(e) Rind thickness (mm)

The difference between the fruit diameter and flesh thickness was calculated and expressed in millimetres.

(f) Fruit girth (cm)

Fruit girth was measured by encircling a twine around the middle portion of the fruits and the twine length was measured using a scale and expressed in centimetres.

(g) Seeds fruit^{-1}

The number of seeds from each of the four observations fruits were counted and the average worked out.

(h) 100 Seed weight (g)

100 fully developed seeds of the observational fruits were weighed and recorded in grams.

3.4.5 Quality

(a) Total soluble solids

Using refractometer the total soluble solids from the fruits of each treatment were taken, average worked out and expressed as percentage.

(b) Total sugars

Fruit juices of the observation plants were extracted and the total sugars were estimated as per Sadasivam and Manikam (1992).

(c) Reducing sugars

The extracted fruit juices of the observation plants were subjected for reducing sugar estimation as perSadasivam and Manikam (1992).

(d) Non-reducing sugar

From the fruit juices of observation plants non reducing sugars were estimated as per Sadasivam and Manikam (1992).

(e) Iron content (mg/100g)

The iron content from fruits of observational plants of each treatment analysed by Atomic Absorption Spectrophotometer, model SL-173, wave length 248.3 nm and average worked out.

3.4.6 Incidence of pest and diseases

The incidence of the important pests (fruit fly, *Aulochophora* beetle and mites) and the diseases (*Fusarium* rot) through out the crop period was recorded the severity was scored using an index scale.

Incidence of pests and diseases

0	No incidence
Below 50%	Mild incidence
Above 50%	Severe incidence

3.4.7 Economics of cultivation

The economics of cultivation was worked out from the total cost and total income. The total cost of produciton was based on various operations and inputs. This included labour charges, cost of seeds, fertilizers, plant protection charges etc. The total cost of production ha^{-1} was computed from the cost $plot^{-1}$. The total income ha^{-1} was arrived at by multiplying the total computed yield with average price kg^{-1} (Rs.3/-) and the benefit cost ratio arrived as follows.

Net income (Rs. ha^{-1}) = Gross income - cost of cultivation

$$\text{Benefit cost ratio} = \frac{\text{Gross income}}{\text{Cost of cultivation}}$$

3.4.8 Statistical analysis

The experimental data were analysed statistically by applying the technique of analysis of variance for split plot design (Gomez and Gomez, 1984).

In cases where the effects were significant, critical differences were calculated for making multiple comparisons among the means. The critical difference for comparison of all the main effects and interaction effects were also computed based on the formula for split plot design. Break up of total degree of freedom in the analysis of variance of the present study is as given below.

Source	df
Replications	2
Main plot (population densities)	5
Error (a)	10
Subplot (varieties)	2
Interaction between population densities x varieties	10
Error (b)	24
Total	53

Treatment combinations

D_1V_1 - T_1

D_2V_1 - T_2

D_3V_1 - T_3

D_4V_1 - T_4

D_5V_1 - T_5

D_6V_1 - T_6

D_1V_2 - T_7

D_2V_2 - T_8

D_3V_2 - T_9

D_4V_2 - T_{10}

D_5V_2 - T_{11}

D_6V_2 - T_{12}

D_1V_3 - T_{13}

D_2V_3 - T_{14}

D_3V_3 - T_{15}

D_4V_3 - T_{16}

D_5V_3 - T_{17}

D_6V_3 - T_{18}

Replication - I

T_1	T_7	T_{13}
T_3	T_9	T_{15}
T_5	T_{11}	T_{17}
T_2	T_8	T_{14}
T_4	T_{10}	T_{16}
T_6	T_{12}	T_{18}

Replication - II

T_5	T_8	T_{15}
T_3	T_7	T_{13}
T_2	T_6	T_{14}
T_1	T_9	T_{18}
T_4	T_{12}	T_{16}
T_{10}	T_{11}	T_{17}

Replication - III

T_5	T_{10}	T_{13}
T_3	T_8	T_{15}
T_4	T_9	T_{14}
T_2	T_7	T_{16}
T_1	T_{12}	T_{18}
T_6	T_{11}	T_{17}

Fig. 1. Layout of the experiment

Results

4. RESULTS

The results of the present experiment depicting the response of three varieties of watermelon [*Citrullus lanatus* (Thunb.) Mansf] to different population densities are presented in this chapter. The data on biometric observations, quality and yield characters were statistically analysed, their direct and interaction effects worked out and presented in the Tables 4.1 to 4.29.

4.1 Flowering and Earliness

4.1.1 Days to first male flower opening

4.1.1.1 Effect of population density

Perusal of the data revealed that there was no significant effect among different population densities on days to first male flower opening (Table 4.1).

4.1.1.2 Effect of varieties

Varieties showed significant differences on the days to first male flower opening. Among the three varieties, V_3 was the earliest (22.69 days) followed by V_1 (31.90 days) and V2 (46.36 days).

4.1.1.3 Effect of D x V interaction

The interaction effect between population density and variety was not significant on days to first male flower opening.

Table 4.1. Effect of population density, varieties and their interactions on days to first male flower opening

	V_1	V_2	V_3	Mean (D)
D_1	32.00	45.67	21.67	33.11
D_2	32.08	44.17	22.00	32.75
D_3	31.67	48.08	22.83	34.19
D_4	31.08	45.42	23.50	33.33
D_5	32.33	46.83	21.58	33.58
D_6	32.25	48.00	24.58	34.94
Mean (V)	31.90	46.36	22.69	

CD (D) = NS
CD (V) = 0.95
CD (D x V) = NS

4.1.2 Days to first female flower opening

4.1.2.1 Effect of population density

Days to first female flower opening was not significantly affected by the different population densities (Table 4.2). The values had a narrow range of 42.61 (D_1) days to 43.53 (D_5) days.

4.1.2.2 Effect of varieties

There was significant difference among the varieties on days to first female flower opening. V_3 was the first to flower (30.99 days) followed by V_1 (38.39 days) and V_2 (59.11 days).

4.1.2.3 Effect of D x V interaction

The density and variety interaction seemsto have no significant effect on days to first female flower opening.

Table 4.2. Effect of population density, varieties and their interaction on days to first female flower opening

	V_1	V_2	V_3	Mean (D)
D_1	38.92	59.25	29.67	42.61
D_2	40.00	59.17	30.42	43.19
D_3	39.67	58.75	31.00	43.14
D_4	38.33	59.67	31.33	43.11
D_5	39.25	59.50	31.83	43.53
D_6	40.17	58.33	31.67	43.39
Mean (V)	38.39	59.11	30.99	

CD (D) = NS

CD (V) = 0.96

CD (D x V) = NS

4.1.3 Node to first female flower

4.1.3.1 Effect of population density

The different population density did not produce any significant effect on node to first female flower opening (Table 4.3).

4.1.3.2 Effect of varieties

Highly significant effect was observed among the three varieties on node to first female flower opening. Variety V_1 showed the lowest node (12.61) followed by V_3 (13.89) and V_2 (14.43).

Table 4.3. Effect of population density, varieties and the interaction on node to first female flower opening

	V_1	V_2	V_3	Mean (D)
D_1	12.58	14.33	13.58	13.50
D_2	13.67	13.83	14.08	13.69
D_3	12.67	14.58	13.58	13.61
D_4	12.42	14.25	14.00	13.56
D_5	12.83	14.92	14.50	13.92
D_6	12.50	14.67	13.58	13.58
Mean (V)	12.61	14.48	13.89	

CD (D) = NS
CD (V) = 0.34
CD (C x V) = NS

4.1.3.3 Effect of D x V interaction

Node to first female flower opening was not significantly affected with density and variety interaction

4.1.4 Days to first harvest

4.1.4.1 Effect of population density

Days to first harvest significantly differed with different population densities (Table 4.4). Significantly early harvest (71.92 days) was obtained in D_1 which was on par with D_3 where as in plants at closer spacing, harvesting was late as in D_6 (74.09 days) and D5 (73.29 days).

4.1.4.2 Effect of varieties

It was evident that varieties showed highly significant variation on days to first harvest. V_3 was the first to harvest (57.50 days) followed by V_1 (69.13 days) and V_2 (91.58 days).

4.1.4.3 Effect of D x V interaction

There was significant interaction between population density (D) and variety (V) on days to first harvest. Among the various treatments D_4V_3 was significantly earlier to first harvest (55.96 days). The plants at D_6V_2 treatment were the last to harvest (93.25 days).

Table 4.4. Effect of population density, variety and their interaction on days to first harvest

	V_1	V_2	V_3	Mean (D)
D_1	67.33	89.75	58.67	71.92
D_2	67.92	93.17	56.86	72.65
D_3	67.75	90.08	58.04	71.96
D_4	70.00	91.58	55.96	72.52
D_5	70.00	91.67	58.21	73.29
D_6	71.75	93.25	57.27	74.09
Mean (V)	69.13	91.58	57.50	

CD (D) = 1.35
CD (V) = 0.62
CD (D x V) = 1.52

4.1.5 Crop duration (days)

4.1.5.1 Effect of population density

From Table 4.5, the different population densities exerted a considerable influence on crop duration. Maximum crop duration was observed in D_6 (94.69 days) and minimum (91.31 days) in D_1.

4.1.5.2 Effect of varieties

Varieties varied significantly on crop duration. Maximum crop duration of 109.04 days was seen in V_2 followed by V_1 (88.83 days) and V_3 (81.98 days).

4.1.5.3 Effect of D x V interaction

The interaction of D x V was not significant on crop duration.

Table 4.5. Effect of population density, variety and their interaction on crop duration

	V_1	V_2	V_3	Mean (D)
D_1	87.50	107.08	79.33	91.31
D_2	87.17	110.83	83.27	93.57
D_3	88.42	111.25	82.17	93.94
D_4	90.25	107.25	82.58	93.36
D_5	88.83	108.50	81.17	93.94
D_6	90.83	109.83	83.42	94.69
Mean (V)	88.83	109.04	81.98	

CD (D) = 1.56
CD (V) = 1.36
CD (D x V) = NS

4.1.6 Female flowers plant^{-1}

4.1.6.1 Effect of population density

There was a marked variation on number of female flower plant^{-1} due to population density (Table 4.6). Maximum number of female flowers was observed in D_6 (14.32) and minimum in D_2 (13.47).

4.1.6.2 Effect of varieties

The varieties varied significantly on number of female flowers plant^{-1}. Maximum female flowers were in V_1 (14.17) which was on par with V_3 (14.08).

4.1.6.3 Effect of D x V interaction

The female flowers plant^{-1} was not significantly affected by the interactions between varieties and population density.

Table 4.6. Effect of population density, variety and their interaction on female flowers plant^{-1}

	V_1	V_2	V_3	Mean (D)
D_1	13.75	12.92	13.92	13.53
D_2	13.75	13.00	13.67	13.47
D_3	13.75	13.33	13.75	13.61
D_4	14.25	13.75	13.83	13.94
D_5	14.75	13.50	14.42	14.22
D_6	14.73	13.33	14.92	14.32
Mean (V)	14.17	13.31	14.08	

CD (D) = 0.53
CD (V) = 0.27
CD (D x V) = 0.66 (NS)

4.2 Vegetative characters

4.2.1 Branches plant^{-1}

4.2.1.1 Effect of population density

There was significant variation on the number of branches plant^{-1} due to difference in population density (Table 4.7). The number of branches was maximum in D_3 (5.16) and minimum at D_2 (4.80).

4.2.1.2 Effect of varieties

Significant difference on the branches plant^{-1} was observed among varieties. Maximum branches was seen in V_1 (5.18) which was on par (5.00) in V_3 and the lowest was in V_2 (4.74).

Table 4.7. Effect of population density, variety and their interaction on branches plant^{-1}

	V_1	V_2	V_3	Mean (D)
D_1	5.33	5.17	4.83	5.11
D_2	4.75	4.75	4.92	4.80
D_3	5.56	4.58	5.33	5.16
D_4	5.42	4.75	4.83	5.00
D_5	4.83	4.58	5.33	4.92
D_6	5.17	4.58	4.75	4.83
Mean (V)	5.18	4.74	5.00	

CD (D) = 0.23 CD (V) = 0.19 CD (D x V) = 0.47

4.2.1.3 Effect of D x V interaction

Interaction effect between population densities (D) and varieties (V) was significant with regard to branches plant^{-1} (Table 4.7). The D_3V_1 interaction showed the maximum branches (5.56) and the interaction D_3V_2 had the minimum branches (4.58) which was on par with D_5D_6.

4.2.2 Main vine length (cm)

4.2.2.1 Effect of population density

The vine length of watermelons was significantly influenced by different populations densities (Table 4.8). It ranged from 397.53 cm in D_6 to 404.36 in density D_2.

4.2.2.2 Effect of varieties

Table 4.8 showed significant difference in vine length with the varieties. Maximum vine length was observed in V_2 (462.42 cms) followed by V_3 (370.94 cms) which was on par in the V_1 (370.38 cms).

4.2.1.3 Effect of D x V interaction

Vine length was significantly different with regard to population density and variety interaction (Table 4.8). Maximum vine length was noticed in D_1V_2 combination (474.00 cm) and the minimum in D_1V_1 (356.90cm).

Table 4.8. Effect of population density, variety and their interaction on main vine length (cm)

	V_1	V_2	V_3	Mean (D)
D_1	356.90	474.00	392.00	400.97
D_2	368.67	469.17	375.25	404.36
D_3	369.00	471.25	372.50	404.25
D_4	371.25	455.17	377.25	401.22
D_5	378.33	454.44	364.67	399.14
D_6	378.08	450.50	364.00	397.53
Mean (V)	370.38	462.42	370.94	

CD (D) = 2.05
CD (V) = 2.16
CD (D x V) = 5.29

4.3 Yield

4.3.1 Total fruits plant^{-1}

4.3.1.1 Effect of population density and D x V interaction

Different planting density and the interaction of D x V had no effect on total fruits plant^{-1} (Table 4.9).

4.3.1.2 Effect of varieties

There was significant variation in total fruits plant^{-1} among the three varieties (Table 4.9). V_1 produced significantly higher number of fruits (1.99) plant^{-1} than V_3 (1.25) and V_2 (1.13).

Table 4.9. Effect of population density, variety and their interaction on total fruits plant^{-1}

	V_1	V_2	V_3	Mean (D)
D_1	2.25	1.08	1.25	1.53
D_2	1.92	1.17	1.33	1.47
D_3	2.17	1.17	1.25	1.53
D_4	1.92	1.25	1.25	1.47
D_5	2.00	1.08	1.25	1.44
D_6	1.67	1.00	1.67	1.28
Mean (V)	1.99	1.13	1.25	

CD (D) = 0.23 (NS)
CD (V) = 0.16
CD (D x V) = 0.39 (NS)

4.3.2 Total fruits plot^{-1}

4.3.2.1 Effect of population density

Significant difference was observed in total fruits plot^{-1} with different population density. Maximum fruits plot^{-1} was observed in D_6 (24.78) and the minimum in D_1 (6.11).

4.3.2.2 Effect of varieties

Varieties varied significantly in total fruit plot^{-1} maximum fruits plot^{-1} being in V_1 (20.89) followed by V_3 (13.11) and V_2 (9.56).

4.3.2.3 Effect of D x V interaction

The interaction between population density (D) and variety (V) on the total fruits plot^{-1} was significant (Table 4.10). The combination D_6V_1 recorded the maximum number of fruits plot^{-1} (35.00) while D_1V_2 had the minimum (4.33).

Table 4.10. Effect of population density, variety and their interaction on total fruits plot^{-1}

	V_1	V_2	V_3	Mean (D)
D_1	9.00	4.33	5.00	6.11
D_2	11.33	6.67	7.33	8.44
D_3	17.00	7.33	8.33	10.89
D_4	24.67	10.33	14.33	16.44
D_5	28.33	18.67	19.33	20.44
D_6	35.00	15.00	24.33	24.78
Mean (V)	20.89	9.56	13.11	

CD (D) = 2.98
CD (V) = 2.29
CD (D x V) = 5.61

4.3.3 Marketable fruits plant^{-1}

4.3.3.1 Effect of population density and D x V interaction

The different population densities and their interaction with varieties were not significant on marketable fruits plant^{-1} from (Table 4.11).

4.3.3.2 Effect of varieties

Only varieties were found to have significant difference for marketable fruits plant^{-1} (Table 4.11). Maximum marketable fruits plant^{-1} (1.44) was observed in V_1 followed by V_3 (1.18) and V_2 (0.90).

Table 4.11. Effect of population density, variety and their interaction on marketable fruits plant^{-1}

	V_1	V_2	V_3	Mean (D)
D_1	1.50	1.00	1.67	1.22
D_2	1.50	0.83	1.25	1.19
D_3	1.50	1.00	1.25	1.25
D_4	1.42	0.92	1.25	1.19
D_5	1.42	1.00	1.17	1.19
D_6	1.32	0.67	1.00	1.00
Mean (V)	1.44	0.90	1.18	

CD (D) = NS
CD (V) = 0.15
CD (D x V) = NS

4.3.4 Marketable fruits plot^{-1}

4.3.4.1 Effect of population density

The marketable fruits plot^{-1} differed significantly with population densities (Table 4.12). Maximum marketable fruits plot^{-1} was observed in D_6 (21.33) and minimum (4.67) in D_1.

4.3.4.2 Effect of varieties

The varieties varied significantly on marketable fruits plot^{-1}. Among them V_1 produced maximum marketable fruits plot^{-1} of (16.33) followed by V_3 of (12.22) and V_2 (8.00).

4.3.4.3 Effect of D x V interaction

D x V interaction effect was significant with regard to marketable fruits plot^{-1} (Table 4.12) in which maximum number (29.00) was observed in D_6V_1. The minimum number of fruits was seen in D_1V_2 (3.67) which was on par with D_3V_3.

Table 4.12. Effect of population density, variety and their interaction on marketable fruits plot^{-1}

	V_1	V_2	V_3	Mean (D)
D_1	5.67	3.67	4.67	4.67
D_2	8.33	4.33	7.00	6.56
D_3	12.00	6.33	8.00	8.78
D_4	18.33	9.33	13.33	13.67
D_5	24.67	11.67	18.00	18.11
D_6	29.00	12.67	22.33	21.33
Mean (V)	16.33	8.00	12.22	

CD (D) = 2.75 CD (V) = 1.82 CD (D x V) = 4.46

4.3.5 Marketable yield plot^{-1} (kg)

4.3.5.1 Effect of population density

The population densities had significant effect on marketable yield plot^{-1} (Table 4.13). Maximum yield of 108.33 kg was observed at D_6 and a minimum of 30.43 kg at D_1.

4.3.5.2 Effect of varieties

There was significant variations between the varieties on marketable yield plot^{-1}. V_1 showed the highest marketable yield of 84.03 kg followed by V_3 (58.52 kg) and V_2 (57.78 kg).

Table 4.13. Effect of population density, variety and their interaction on marketable yield plot^{-1} (kg)

	V_1	V_2	V_3	Mean (D)
D_1	40.13	27.77	23.89	30.43
D_2	45.14	34.19	34.20	37.85
D_3	62.95	43.80	39.81	48.85
D_4	104.21	73.64	63.11	80.32
D_5	119.75	80.19	84.63	94.86
D_6	132.00	87.04	105.96	108.33
Mean (V)	84.03	57.78	58.52	

CD (D) = 17.59 CD (V) = 10.36 CD (D x V) = NS

4.3.5.3 Effect of D x V interaction

The D x V interaction was not significant.

4.3.6 Unmarketable fruits plot^{-1}

4.3.6.1 Effect of population density, variety and their interaction

The population density and then interaction did not influence significantly on unmarketable fruits plot^{-1}.

Table 4.14. Effect of population density, variety and their interaction on unmarketable fruits plot^{-1}

	V_1	V_2	V_3	Mean (D)
D_1	2.03	1.24	1.14	1.47
D_2	1.95	1.82	1.14	1.64
D_3	2.38	1.38	1.14	1.63
D_4	2.70	1.38	1.38	1.82
D_5	2.09	1.66	1.33	1.70
D_6	2.64	1.73	1.66	2.01
Mean (V)	2.30	1.54	1.30	

CD (D) = NS
CD (V) = NS
CD (D x V) = NS

4.4 Fruit characters

4.4.1 Average fruit weight (kg)

4.4.1.1 Effect of population density

The population densities showed a profound influence on average fruit weight (Table 4.15). It was highest at D_1 (6.12 kg) and the lowest at D_6 (5.11 kg). The average fruit weight decreased with increase in planting density.

4.4.1.2 Effect of varieties

Significant difference between the varieties on average fruit weight was observed. It was highest in V_2 (7.34 kg) followed by V_1 (5.25 kg) and V_3 (4.85 kg).

Table 4.15. Effect of population density, variety and their interaction on average fruit weight (kg)

	V_1	V_2	V_3	Mean (D)
D_1	5.74	7.58	5.02	6.12
D_2	5.39	7.91	4.88	6.06
D_3	5.25	6.98	4.97	5.72
D_4	5.69	7.90	4.74	6.11
D_5	4.85	6.89	4.70	5.48
D_6	4.55	6.86	4.76	5.11
Mean (V)	5.25	7.34	4.85	

CD (D) = 0.15 CD (V) = 0.11 CD (D x V) = 0.26

4.4.1.3 Effect of D x V interaction

The interaction effect between population densities and varieties produced marked difference in average fruit weight (Table 4.15). The average fruit weight of D_2V_2 (7.91 kg) was higher than other combinations. Minimum fruit weight was recorded in D_6V_1 (4.55 kg).

4.4.2 Fruit length (cm)

4.4.2.1 Effect of population density

The fruit length was significantly influenced by population densities (Table 4.16). It was longest (33.17 cm) in D_3 and shortest (28.33 cm) in D_6.

4.4.2.2 Effect of varieties

Significant difference was seen among varieties for fruit length. Maximum fruit length (38.03 cm) was observed in V_2 followed by V_1 (29.71 cm) and V_3 (26.10 cm).

4.4.2.3 Effect of D x V interaction

The interaction between population density and variety on fruit length was significant (Table 4.16). Maximum fruit length was noticed in D_5V_2 (42.73 cm). The D_6V_3 had minimum fruit length of 24.91 cm.

Table 4.16. Effect of population density, variety and their interaction on fruit length (cm)

	V_1	V_2	V_3	Mean (D)
D_1	31.45	41.87	27.08	33.47
D_2	29.88	34.97	26.04	30.29
D_3	30.16	42.19	27.15	38.17
D_4	28.99	33.57	25.52	29.36
D_5	29.01	42.73	25.91	32.55
D_6	28.77	32.83	24.91	28.33
Mean (V)	29.71	38.03	26.10	

CD (D) = 0.62
CD (V) = 0.36
CD (D x V) = 0.89

4.4.3 Fruit diameter (cm)

4.4.3.1 Effect of population density

Population densities differed significantly for fruit diameter. Maximum diameter of 17.46 cm was observed in D_1 and minimum (15.06 cm) at D_6 density (Table 4.17).

4.4.3.2 Effect of varieties

Varieties also differed significantly on fruit diameter. Maximum diameter (17.20 cm) was noted in V_1 followed by V_2 (16.51 cm) and V_3 (14.48 cm).

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4.4.3.3 Effect of D x V interaction

Significant interaction was found between population densities and varieties for fruit diameter (Table 4.17). Maximum diameter was observed in Sugar Baby variety grown at the lowest population density (D_1V_1 - 19.97 cm) and minimum in Arka Manik (D_5V_3 - 14.04 cm).

Table 4.17. Effect of population density, variety and their interaction on fruit diameter (cm)

	V_1	V_2	V_3	Mean (D)
D_1	19.97	17.38	15.04	17.46
D_2	15.94	16.29	14.41	15.55
D_3	19.06	17.10	14.92	17.03
D_4	16.13	16.21	14.25	15.53
D_5	16.96	16.21	14.04	15.74
D_6	15.14	15.85	14.19	15.06
Mean (V)	17.20	16.51	14.48	

CD (D) = 0.14
CD (V) = 0.12
CD (D x V) = 0.29

4.4.4 Flesh thickness (cm)

4.4.4.1 Effect of population density

Population density exerted a considerable influence on flesh thickness (Table 4.18). It was maximum in D_1 (15.33 cm) and minimum (13.09 cm) in D_6.

4.4.4.2 Effect of varieties

Varietal variation was significant for flesh thickness. Highest flesh thickness was observed in V_1 (15.08 cm), followed by V_2 (14.43 cm) and V_3 (12.39 cm).

4.4.4.3 Effect of D x V interaction

The flesh thickness was significantly influenced by DxV interaction (Table 4.18). Maximum flesh thickness was noticed in D_1V_1 (17.78 cm) and was minimum in D_5V_3 (11.99 cm) which was on par with D_2V_3 (12.15 cm) and D_6V_3 (12.28 cm).

Table 4.18. Effect of population density, variety and their interaction on flesh thickness

	V_1	V_2	V_3	Mean (D)
D_1	17.78	15.30	12.89	15.33
D_2	13.73	14.15	12.15	13.34
D_3	17.00	15.08	12.76	14.95
D_4	13.94	14.06	12.29	13.43
D_5	14.89	14.15	11.99	13.67
D_6	13.14	13.85	12.28	13.09
Mean (V)	15.08	14.43	12.39	

CD (D) = 0.17
CD (V) = 0.14
CD (D x V) = 0.35

4.4.5 Rind thickness (mm)

4.4.5.1 Effect of population density

Rind thickness was significantly influenced by different population densities. Maximum rind thickness of 21.39 mm was observed in D_4 and minimum (20.22 cm) in D_6 (Table 4.19).

4.4.5.2 Effect of varieties

Varietal difference in rind thickness was not significant.

Table 4.19. Effect of population density, variety and their interaction on rind thickness (mm)

	V_1	V_2	V_3	Mean (D)
D_1	21.50	21.33	21.08	21.31
D_2	22.08	21.42	20.50	21.33
D_3	20.75	20.17	21.67	20.86
D_4	22.00	21.50	20.67	21.39
D_5	20.75	19.92	20.50	20.39
D_6	20.00	20.17	20.50	20.22
Mean (V)	21.18	20.75	20.82	

CD (D) = 0.67

CD (V) = NS

CD (D x V) = 1.11

4.4.5.3 Effect of D x V interaction

The table 4.19 showed a significant difference in rind thickness due to interaction between population density and variety. The rind thickness was maximum in D_2V_1 (22.08 mm) and minimum in D_5V_2 (19.92 mm).

4.4.6 Fruit girth (cm)

4.4.6.1 Effect of population density

The effect of various planting densities on fruit girth was highly significant (Table 4.20). The plants at D_1 showed maximum girth of 54.76 cm and those at D_6 showed the minimum (47.87 cm).

4.4.6.2 Effect of varieties

The fruit girth was significantly different among the varieties. V_1 showed a maximum of 54.22 cm followed by V_2 51.77 cm and V_3 of 45.49 cm.

4.4.6.3 Effect of D x V interaction

Significant difference was observed in fruit girth with DxV interaction (Table 4.20). D_1V_1 (62.64 cm) gave the maximum fruit girth. Minimum fruit girth was noticed in D_5V_3 (44.11 cm) combination.

Table 4.20. Effect of population density, variety and their interaction on fruit girth (cm)

	V_1	V_2	V_3	Mean (D)
D_1	62.64	54.28	47.36	54.76
D_2	50.85	51.08	44.60	48.84
D_3	59.83	53.77	46.86	53.49
D_4	50.18	50.91	45.10	48.73
D_5	53.07	50.65	44.11	49.28
D_6	48.75	49.94	44.92	47.87
Mean (V)	54.22	51.77	45.49	

CD (D) = 0.68
CD (V) = 0.54
CD (D x V) = 1.33

4.4.7 Seeds fruit^{-1}

4.4.7.1 Effect of population density

The number of seeds fruit^{-1} differed among population densities (Table 4.21). More seeds were observed (309.64) at D_2 and less (304.42) at D_3 which was on par with D_6.

4.4.7.2 Effect of varieties

Seeds fruit^{-1} varied significantly with varieties. Maximum seeds (362.35) were observed in V_1 followed by V_2 (322.57) and V_3 (234.21).

4.4.7.3 Effect of D x V interaction

The interaction effect between densities and varieties on seeds fruit^{-1} was not significant.

Table 4.21. Effect of population density, variety and their interaction on seeds fruit^{-1}

	V_1	V_2	V_3	Mean (D)
D_1	365.17	322.08	235.67	307.64
D_2	366.75	326.83	235.33	309.64
D_3	364.58	320.83	229.50	304.94
D_4	356.42	323.83	233.00	304.42
D_5	364.83	315.67	240.58	307.03
D_6	356.33	326.17	231.17	304.56
Mean (V)	362.35	322.57	234.21	

CD (D) = 5.90
CD (V) = 3.90
CD (D x V) = NS

4.4.8 100 Seed weight (g)

4.4.8.1 Effect of population density

The population densities showed significant differences for 100 seed weight (Table 4.22). It was higher (5.88 g) at D_3 density and lower at D_6 density (5.55 g).

4.4.8.2 Effect of varieties

There was significant variation in 100 seed weight among the varieties also. V_2 showed maximum weight of (8.34 g) followed by V_3 (5.09 g) and V_1 (3.67 g).

4.4.8.3 Effect of D x V interaction

Significant difference in 100 seed weight was observed among the interaction between population density and variety (Table 4.22). Maximum weight was recorded in D_1V_2 (8.85 g) and minimum in D_2V_1 (3.51 g).

Table 4.22. Effect of population density, variety and their interaction on 100 seed weight (g)

	V_1	V_2	V_3	Mean (D)
D_1	3.67	8.85	5.07	5.86
D_2	3.51	8.19	5.00	5.57
D_3	3.79	8.60	5.24	5.88
D_4	3.55	8.32	5.09	5.66
D_5	3.71	8.28	5.08	5.69
D_6	3.77	7.82	5.05	5.55
Mean (V)	3.67	8.34	5.09	

CD (D) = 0.22
CD (V) = 0.13
CD (D x V) = 0.33

4.4.9 Total soluble solids (%)

4.4.9.1 Effect of population density

There was marked variation in total soluble solids in fruits of varying population densities (Table 4.23). Maximum soluble solids of (10.57 %) was observed in D_4 which was on par with D_6. It was minimum (10.19 %) in D_5.

4.4.9.2 Effect of varieties

The varieties varied significantly on the total soluble solids. It was highest in V_3 (11.35 %) and V_1 (11.19 %) and lowest in V_2 (8.52 %).

Table 4.23. Effect of population density, variety and their interaction on total soluble solids (%)

	V_1	V_2	V_3	Mean (D)
D_1	11.05	8.37	11.41	10.28
D_2	11.14	8.27	11.38	10.26
D_3	11.19	8.38	11.35	10.31
D_4	11.47	8.87	11.37	10.57
D_5	11.03	8.31	11.25	10.19
D_6	11.31	8.98	11.33	10.52
Mean (V)	11.19	8.52	11.35	

CD (D) = 0.22 CD (V) = 0.16 CD (D x V) = NS

4.4.9.3 Effect of D x V interaction

The total soluble solids was not significantly affected by D x V interaction.

4.4.10 Total sugars (%)

4.4.10.1 Effect of population density

The population densities showed a profound influence on the total sugars (Table 4.24). Maximum total sugar was obtained at D_1 (6.31 %) and minimum (5.05 %) at D_6 density.

4.4.10.2 Effect of varieties

Significant difference in total sugars was observed with different varieties also. Highest value (6.09 %) was recorded in V_1 followed by V_3 (5.99 %) and lowest in V_2 (5.37 %).

4.4.10.3 Effect of D x V interaction

The DxV interaction was significant in total sugars (Table 4.24) which was highest in plants grown on 5000 plants ha^{-1} D_4V_1 (6.79%). Lowest percentage of total sugars was noticed in plants grown at 10000 plants ha^{-1} D_6V_2 (4.67%).

Table 4.24. Effect of population density, variety and their interaction on total sugars (%)

	V_1	V_2	V_3	Mean (D)
D_1	6.38	5.97	6.59	6.31
D_2	6.63	5.31	6.44	6.13
D_3	6.13	5.95	6.76	6.28
D_4	6.79	5.49	5.53	5.94
D_5	5.41	4.83	5.36	5.19
D_6	5.19	4.67	5.28	5.05
Mean (V)	6.09	5.37	5.99	

CD (D) = 0.26
CD (V) = 0.16
CD (D x V) = 0.39

4.4.11 Reducing sugars (%)

4.4.11.1 Effect of population density

The population densities had significant effect on reducing sugars (Table 4.25). The maximum value (2.92 %) was recorded in D_1 density and minimum (2.25 %) in D_5 density.

4.4.11.2 Effect of varieties

Reducing sugars was significantly influenced by different varieties. The highest (2.70 %) was observed in V_1, next in V_3 (2.61 %) and the least value (2.44 %) observed in V_2.

4.4.11.3 Effect of D x V interaction

Significant DxV interaction was observed for reducing sugar (Table 4.25). It ranged from 3.02 per cent in D_4V_1 to 2.09 per cent in D_6V_2 combinations.

Table 4.25. Effect of population density, variety and their interaction on reducing sugars (%)

	V_1	V_2	V_3	Mean (D)
D_1	2.97	2.95	2.83	2.92
D_2	2.88	2.13	2.99	2.67
D_3	2.80	2.29	2.74	2.81
D_4	3.02	2.43	2.38	2.61
D_5	2.26	2.20	2.29	2.25
D_6	2.88	2.09	2.40	2.26
Mean (V)	2.70	2.44	2.61	

CD (D) = 7.29
CD (V) = 7.90
CD (D x V) = 0.19

4.4.12 Non reducing sugars (%)

4.4.12.1 Effect of population density

Non reducing sugars was significantly different among the population densities (Table 4.26). The maximum of (3.37 %) in density D_2 and minimum of (2.75 %) in density D_6.

4.4.12.2 Effect of varieties

The effect of different varieties with respect to non reducing sugars was highly significant. V_3 showed the highest values (3.34 %) followed by V_1 (3.31 %) and the least by V_2 (2.85 %).

Table 4.26. Effect of population density, variety and their interaction on non reducing sugars (%)

	V_1	V_2	V_3	Mean (D)
D_1	3.22	3.00	3.83	3.35
D_2	3.70	3.00	3.40	3.37
D_3	3.29	2.93	3.87	3.36
D_4	3.54	3.02	2.97	3.18
D_5	3.24	2.61	3.13	2.99
D_6	2.89	2.53	2.83	2.75
Mean (V)	3.31	2.85	3.34	

CD (D) = 0.16
CD (V) = 0.16
CD (D x V) = 0.38

4.4.12.3 Effect of D x V interaction

DxV interaction exerted a greater influence on percentage of non reducing sugars (Table 4.26). D_3V_3 recorded the highest value (3.87%) which were on par with D_1V_3 (3.83%) and D_4V_1 (3.54%). Minimum value was recorded in D_6V_2 (2.53%).

4.4.13 Iron content (mg 100 g^{-1})

4.4.13.1 Effect of population density

The population densities exerted significant difference on iron content (Table 4.27). Maximum iron content (5.76 mg) was observed in D_5 density and minimum (5.43 mg) in D_3 density.

4.4.13.2 Effect of varieties

Iron content was significant among the varieties. Highest value for iron content was observed in V_3 (6.01 mg) followed by V_1 (5.85 mg) and the least in V_2 (4.91 mg).

4.4.13.3 Effect of D x V interaction

The interaction effect between population densities and varieties on iron content was found to be non significant.

Table 4.27. Effect of population density, variety and their interaction on iron content (mg 100 g^{-1})

	V_1	V_2	V_3	Mean (D)
D_1	5.78	4.76	6.07	5.54
D_2	5.81	4.87	6.14	5.61
D_3	5.80	4.87	5.63	5.43
D_4	5.85	4.95	5.97	5.59
D_5	5.98	5.21	6.09	5.76
D_6	5.88	4.79	6.14	5.60
Mean (V)	5.85	4.91	6.01	

CD (D) = 0.12
CD (V) = 0.13
CD (D x V) = NS

4.5 Incidence of pests and diseases

The incidence of important pests and diseases through out the the crop was observed. The severity of the pest and disease incidence was observed.

4.5.1 Incidence of fruit fly (*Dacus dorsalis*)

Incidence of fruit fly was mild in all the treatments. There was no incidence in the hybrid MHW-6 in all the population densities except D_2. In Arka Manik, the attack was nil in D_1, D_2 and D_5. In all densities of Sugar Baby mild attack of fruit fly was observed except D_4. (Table 4.28a).

Table 4.28a. Incidence of fruit fly - *Dacus dorsalis*

	V_1	V_2	V_3
D_1	M	N	N
D_2	M	M	N
D_3	M	N	M
D_4	N	N	M
D_5	M	N	N
D_6	M	N	M

4.5.2 Incidence of mite (*Polyphaga tarsonemus latus*)

One hundred per cent mite attack was observed in the hybrid which resulted in lower yields in all the population densities. But the attack was only mild in the other two varieties in all the population densities (Table 4.28b).

Table 4.28b. Incidence of mites - *Polyphaga tarsonemus latus*

	V_1	V_2	V_3
D_1	M	S	M
D_2	M	S	M
D_3	M	S	M
D_4	M	S	M
D_5	M	S	M
D_6	M	S	M

4.5.3 Incidence of *Fusarium* rot (*Fusarium oxysporum*)

Attack of *fusarium* rot was only mild in all the three varieties. The treatments *viz.*, D_4V_1, D_1V_2, D_5V_2, D_2V_3 were completely free from the attack (Table 4.28c).

Table 4.28c. Incidence of *Fusarium* rot (*Fusarium oxysporum*)

	V_1	V_2	V_3
D_1	M	N	M
D_2	M	M	N
D_3	M	M	M
D_4	N	M	M
D_5	M	N	M
D_6	M	M	M

M - Mild incidence
S - Severe incidence
N - No incidence

4.6 Economics of cultivation

Economics of crop production was worked out considering the cost of production, yield and net returns. In the present study the cost of production increased with increase in population density, as more man days were required for taking more channels at higher population densities.

Table 4.29. Economics of cultivation ha^{-1}

	Cost of cultivation	Yield t/ha	Gross income	B/C ratio
D_1V_1	39,000	16.72	50,156	1.28
D_2V_1	42,000	18.81	56,427	1.34
D_3V_1	44,000	26.24	78,725	1.79
D_4V_1	48,000	43.42	1,30,262	2.71
D_5V_1	52,000	50.00	1,49,687	2.86
D_6V_1	55,000	55.00	1,65,000	3.00
D_1V_2	40,000	11.57	34,708	0.87
D_2V_2	43,000	14.24	42,742	0.99
D_3V_2	46,000	18.25	54,750	1.19
D_4V_2	51,000	30.68	92,050	1.80
D_5V_2	57,000	33.41	1,00,244	1.76
D_6V_2	67,000	36.27	1,08,796	1.62
D_1V_3	39,000	9.75	29,246	0.75
D_2V_3	42,000	14.25	42,754	1.01
D_3V_3	44,000	16.58	49,750	1.13
D_4V_3	48,000	26.29	78,892	1.64
D_5V_3	52,000	35.26	1,05,792	2.03
D_6V_3	55,000	44.15	1,32,446	2.40

Similarly, the seed rate requirement was also higher at higher densities. In all the densities, the cost of hybrid seed was higher than that of open pollinated varieties. Considering all these the cost of production hectare^{-1} was computed, net returns worked out and the benefit cost ratio arrived at (Table 4.29).

In all the treatment combinations, the cost of production as well as the yield increased with increased in population density, mainly due to increase in cost of seed, labour requirement and after care. The highest yield of 55 t ha^{-1} and gross income of 1,65,000 with a benefit cost ratio of 3.00 : 1.00 was found in Sugar Baby at the highest population density. This was followed by the same variety at the second highest density with an yield of 50 t ha^{-1}, net income 1,49,687 with a benefit cost ratio of 2.86 : 1.00. Minimum yield was in Arka Manik (9.75 t ha^{-1}) grown at the widest spacing with minimum gross income of 29,246 and with minimum benefit cost ratio of 0.75 : 1.00.

Discussion

5. DISCUSSION

The production and productivity of any crop depends primarily on the genetic set up and the various management practices given for the crop. The potential yield of crops is fully expressed only when they are grown in the best environment. This emphasizes the need for optimum management practices specific for the crop. The best management is one which accommodates optimum number of plants per unit area, provides favourable growing conditions, judicious use of nutrients and plant protection chemicals. For viny crops like watermelon which produces only limited fruits, optimum planting density and suitable variety are very important in acheiving maximum yield and best quality.

Watermelon [*Citrullus lanatus* (Thunb.) Mansf.], an important cucurbitaceous crop is grown for their mature fruits which are mainly used as dessert. In desert areas it is used as a substitute for drinking water. Much work has been done and considerable improvement is made in this crop. The genetic variability, heritability, genetic advance and correlation of characters have been explored leading to the development of certain promising varieties / hybrids to suit specific purposes in different parts of the world. In our country also much improvement has been achieved in various institutes.

Despite its economic, medicinal and nutritional importance, its cultivation is yet to be popularised in Kerala, which warrants the need for standardisation of management practices of this vegetable. In watermelon, fruits are produced only in limited number per vine and are harvested when they are fully mature. Therefore the ultimate yield depends on varieties and cultivation practices, which include the optimisation of population density, manures and fertilizers, irrigation practices etc.

The present experiment was therefore carried out with the object of standardising population density for varieties and hybrids in watermelon for maximum yield and acceptable table quality with optimum benefit cost ratio. The experiment was laid out in a split plot design with six population densities as the main plot treatments and three varieties as sub plot treatments with three replications. Observations were recorded for various vegetative, yield and quality characters and the results presented in the tables (4.1 to 4.29) are discussed here.

Population density

Population density ie., the number of plants per unit area is an important criteria which decides the vegetative as well as the reproductive growth of plants. The final yield is decided by the number of plants per unit area as well as the management practices. In the present study, six population densities *viz.*, 1666, 2500, 3333, 5000, 6666 and 10000 plants per hectare were tried. The results revealed significant effects on majority of the characters.

Though a definite trend is not shown in respect of character of earliness, such as days to first male and female flower opening and node to first female flower, plants at wide spacing in general, were earlier for these characters. However in this present study days to first harvest was significantly affected by different planting density. The days to harvest ranged from 71.92 days in plots of lowest population density (1666 plants ha^{-1}) to 74.09 days in plots of highest population density (10,000 plants ha^{-1}). Earliness in respect of flowering is in general a varietal character and need not be affected by management practices and this could be the reason for the non response of varieties to the different level of population density tried in this present study. Fruit maturity is often decided by the vegetative growth, ground cover, irrigation, temperature, light, humidity, evaporation etc. It is also affected by the competition for the nutrients which affect their mobilisation to the economic parts. The enhanced maturity observed in the present study with wider spacing could be attributed to better sunlight, temperature, low humidity, lack of competition of nutrients etc. The findings of Pandey *et al.* (1996) that earliness in flowering is not always related to early harvest is in line with the present result. Maximum crop duration was observed in plots of higher population density (10,000 plants ha^{-1}) where the conditions for keeping the plants in the vegetative phase were favourable resulting in longer crop production.

Population density affects vegetative characters. The present study revealed profound influence on the number of branches per plant and main vine length. The plants at moderate and closest spacing had minimum number of branches compared to those at wider spacing. It is a general tendency in almost all crops to branch heavily under wider spacings due to sufficient availability of sunlight, moisture, aeration and lesser degree of mutual competition. Similar tendency of increased branching due to wider spacing have been reported in tomato also (Pandey *et al.*, 1996). The main vine length was also influenced by the population density. Though a definite trend was not observed for vine length with change in population density, longest vines were seen in plants of moderate population densities and the shortest vines were observed in plants of close spacing. Renji (1998) has also reported similar results in slicing cucumbers. The absence of a definite trend in vine length with increase or decrease in population density as observed in erect growing types of plants could be attributed to viny nature of water melon. The unfavourable condition of narrow spacings like insufficient ground area per plant, moisture, air and less availability of plant nutrients could have restricted the general growth and hence vine elongation.

The response of watermelon to population density for the number of female flower per plant was very significant. Maximum female flower production was observed at the highest population density and minimum at the moderate population density. It may be due to the favourable micro climate formed at the high density spacings. In cucurbits, the sex ratio is affected by the external factors like sunlight, temperature, humidity, soil nutrients etc. In general lower temperature, short days and high humidity enhance femaleness. Under high densities these factors may be in optimum combination resulting in more female tendency.

Plants did not differ in total fruits with change in population densities. Generally in cucurbits where the fruits are harvested at mature stage, the number of fruits will be less than those where the fruits are harvested at the tender stage. In watermelon, harvesting is done at fully mature stage and it is found that the average number of fruits per plant dosen't exceed two. However in the present study the number of fruits per plot varied significantly with population densities. Maximum number of fruits per plot was observed in high density (24.78) and minimum in the lowest density (6.11). This is due to more number of plants accommodated under high densities. The marketable fruits per plant was also not significant, however the marketable fruits per plot was significantly affected by the population densities. The maximum number of marketable fruits was (21.33) obtained from the highest density due to maximum number of plants per unit area. Marketable yield per plot was significantly influenced by planting density. Maximum yield of 108.3 kg was obtained from the highest population density and minimum 30.43 kg from the lowest. Nerson (1998) has also achieved similar results in pickling cucumber.

Fruit characters

The fruit parameters like weight, diameter, flesh thickness, length, rind thickness and girth were also influenced by population density. In the present study, values for fruit parameters were higher in plant grown at wider spacing. In lower population density, unit area per plant is more which facilitated better absorption of water and nutrients for proper growth and development of fruits. This also favours better pollination and consequent increase in size of fruits. All these might have contributed to better values for fruit parameters. The number of seeds per fruit in general is decided by the number of pollen grains falling on the stigmatic surface. Under optimum conditions of population density, proper pollination, pollen germination, pollen tube growth and fertilization takes place. The moderate population density is ideal for bee activities effecting proper pollination. Optimum condition also favours seed development, seed filling and seed maturation which finally decide the seed weight.

Quality

Quality attributes like total soluble solids, total sugars, reducing sugars, non reducing sugars and iron content were estimated in various population densities. Though a definite trend was not observed, these attributes except iron content were in general higher in plants of moderate to lower populations. The iron content was higher in the highest densities. These findings indicate that the conditions for better yield and fruit parameters need not be the same for the quality characters.

Varieties

In any crop, growth, yield, quality and reaction to pest and diseases vary with varieties. In watermelon also several varieties are available which vary in their vegetative, yield and productive characters. In the present study, two open pollinated varieties (Sugar Baby and Arka Manik) and one hybrid (MHW-6) were used to examine their response to various population densities. The management practices vary with varieties and hybrids. The analysis showed significant difference among three varieties for all the characters.

The attributes of earliness namely days to first male flower opening, first female flower opening, crop duration and days to first harvest were observed. Variety Arka Manik was earlier for majority of these characters. Watermelon being a cross pollinated crop due to monoecy, has considerable genetic diversity with respect to various traits. Hence the present variation is quite natural as these three varieties have been developed from three different centers. Such variations have also been reported by Shibukumar (1995). But Sugar Baby produced the highest number of female flowers at the lowest node (12.61).

The varieties varied significantly in vegetative, yield and fruit characters. Sugar Baby had more female flowers and more branches per plant. However the vine length was maximum in the hybrid MHW-6 (462.42 cm).

Of the three varieties tried, Sugar Baby had maximum values for total fruits per plant (1.99), total fruits per plot (20.89), marketable fruits per plant (1.44), marketable fruits per plot (16.33) and marketable yield per plot (84.03 kg) (Fig.2).

Fruit characters like fruit diameter, flesh thickness and rind thickness were also superior in Sugar Baby. This variety also had more seeds per fruit. Among the quality attributes, Sugar Baby had better values for total sugars and reducing sugars.

From the study the variety Sugar Baby is found superior with respect to most of the economic traits. The superiority of SugarBaby is well known as it is a very popular and established variety through out the country which has been recommended for cultivation at national level. This is evident from the annual reports of All India Co-ordinated Vegetable Improvement Project (AICVIP, 1994) and Shibukumar (1995).

Arka Manik was also superior in many characters such as

a) Total soluble solids (11.35°B)

b) Non reducing sugars (3.34 %)

c) Iron content (6.01 mg/100 g)

However at this present trial it ranked only second.

The performance of MHW-6 was superior in vine length, average fruit weight (7.34 kg), fruit length (38.03 cm) and seed weight (8.34 g). Its performance under Vellayani conditions indicates that MHW-6 being a hybrid needs better management than open pollinated varieties. In this experiment, attack of pest and disease was also high in MHW-6.

Interaction between population density and varieties

The study revealed significant population density and variety interactions for fifteen characters; one under earliness, two under vegetative characters, two under yield, seven under fruit characters and three under quality characters.

The interaction between population density and variety was significant for days to first harvest. Among the various treatment combinations, Arka Manik at moderate population density (5000 plants ha^{-1}) was significantly earlier to first harvest. The hybrid MHW-6 at the highest density of (10,000 plants/ha) took maximum number of 93.25 days (Fig. 3). In cucurbits flowering is governed by internal and external factors. Time taken for flowering is decided by the auxin content of the plant which in turn is governed by the environmental factors such as temperature, light, humidity and day length. There is also varietal difference for earliness under varying population densities. Similar differential responses to varying population densities for days to first harvest have also been reported in cucumber by Renji (1998).

Vegetative characters such as branches per plant and vine length were also influenced by the interaction of varieties and population densities. In this study, Sugar Baby under moderate population density (3,333 plants ha^{-1}) had maximum number of branches (5.56). Here the row to row spacing was more than plant to plant spacing. It indicates that the plants under moderate density and optimum density produce more branches when rows are spaced wider. The number of branches was minimum in the hybrid MHW-6 when grown under moderate to higher densities. This shows that the branching pattern in hybrid is better under lower densities indicating the need of wider spacing for hybrids than the open pollinated varieties.

Vine elongation was favoured by the interaction of varieties and population densities. Longest vines were in the hybrid MHW-6 when grown under widest spacing. It is suggested that hybrid needs wider spacing than open pollinated varieties for vine elongation. However in the case of open pollinated variety it need not be so, as evidenced in the present study where, Sugar Baby under widest spacing gave shortest vines (Fig. 4).

Under yield characters, total fruits per plot was significantly influenced by the interaction between population densities and varieties. Number of fruits were maximum under highest density in Sugar Baby, it was minimum in the hybrid at the lowest density. It is quite logical that under highest densities the maximum number of plants per plot produced the maximum number of fruits. This is true with respect to the marketable fruits per plot also (Fig. 5). The minimum number of fruits in the hybrid under widest spacing is attributed to the minimum number of plants. It is a general phenomenon that the number of fruits per unit area increases with the number of plants in the same area.

Interaction between population density and variety significantly affected the average fruit weight which was maximum in the hybrid at second lowest density. As the density increased the average fruit weight also decreased. Fruit weight was minimum in Sugar Baby at the highest density. Here also a decreased trend in fruit weight with increase in population density was observed. The increase in number of fruits is often at the expense of fruit weight. In general in any plant the size of fruit gets reduced when the number increases. This is true in the present study also (Fig. 6). Similar findings in this line were reported in slicing cucumber by Renji (1998).

Other fruit characters like fruit length, fruit diameter, flesh thickness, rind thickness and girth are also influenced by the interaction between population density and varieties. Fruit length was maximum in the hybrid at second high density (6666 plants ha^{-1}) and minimum in Arka Manik at the highest density. Fruit length in general is a varietal character and the response vary with population densities. Fruit diameter was maximum in Sugar Baby grown at lowest density and minimum for Arka Manik at second highest density. This also is a varietal character where plants at wider spacing had near round fruits. When the population increases the fruits show the tendency towards elongation resulting in oval fruits. Flesh and rind thickness are varietal characters which are also influenced by the management practices. In the present study the SugarBaby grown under wider spacing had fleshy fruits, where as it was less fleshy in Arka Manik at the second highest density. Rind thickness is governed mainly by varieties. It was maximum in Sugar Baby at the second lowest level of population and minimum in the hybrid at the second highest level of population. There is a general decrease in rind thickness with increase in population density. It shows that as the population density increases beyond the optimum, fruit characters like diameter, rind and flesh thickness get reduced resulting in smaller fruits and lower fruit weight.

Among the seed characters number and weight of seeds are genetically controlled which can be modified by management practices. In this study the interaction of population density and variety was significant only for seed weight. This is because seed weight depends on its development and maturation after fertilization. The internal and external conditions at the time of seed development and maturation determine the quality of seeds especially the seed weight. In the present study it was maximum in the hybrid at the lowest density indicating wider spacing for seed crop than the vegetable crops.

The quality parameters like total sugars, reducing sugars and non reducing sugars are significantly influenced by the interaction between varieties and population density. Total sugar was maximum for Sugar Baby grown at moderate spacing and minimum for hybrids at highest density (Fig. 7). The same is true for reducing sugars. With respect to non reducing sugars, Arka Manik at moderate spacing had highest value and hybrid at highest density had the minimum value. This means that for quality parametres open pollinated varieties are to be grown under moderate or optimum population density where as hybrid need wider spacing.

Incidence of pests and diseases

The treatment combinations of varieties and population densities were scored for the incidence of fruit fly, mites and *Fusarium* rot. Of these, the incidence of fruit fly and *Fusarium* rot was mild in most of the treatments. However, the mite attack was severe in all the population densities of hybrid MHW-6. This could be the reason for the poor performance at the higher two densities.

Economics of cultivation

All production decisions are basically economic decisions. Hence, a farmer ought to denote his resources in such a way as to maximise the net return. The most economic returns of a crop could be obtained either by increasing the yield or by reducing the cost of production. The present study suggested the scope for increasing the population density of watermelon for increasing the yield ha^{-1} without affecting the quality.

The study revealed that increasing the population density to the extent of 10,000 plants ha^{-1} resulted in maximum yield of 55 tons ha^{-1} with the highest benefit cost ratio of 3.00 : 1.00 in the watermelon variety Sugar Baby. Despite highest cost of production, this treatment gave highest economic returns owing to maximum yield ha^{-1}. However, in the hybrid, MHW-6 and the open pollinated variety Arka Manik, the benefit cost ratios were less indicating differential response of these varieties. The study suggested that, the spacing of the most popular watermelon variety Sugar Baby could be reduced to 2.00 m between channels and 50.00 cm between plants for maximum economic returns.

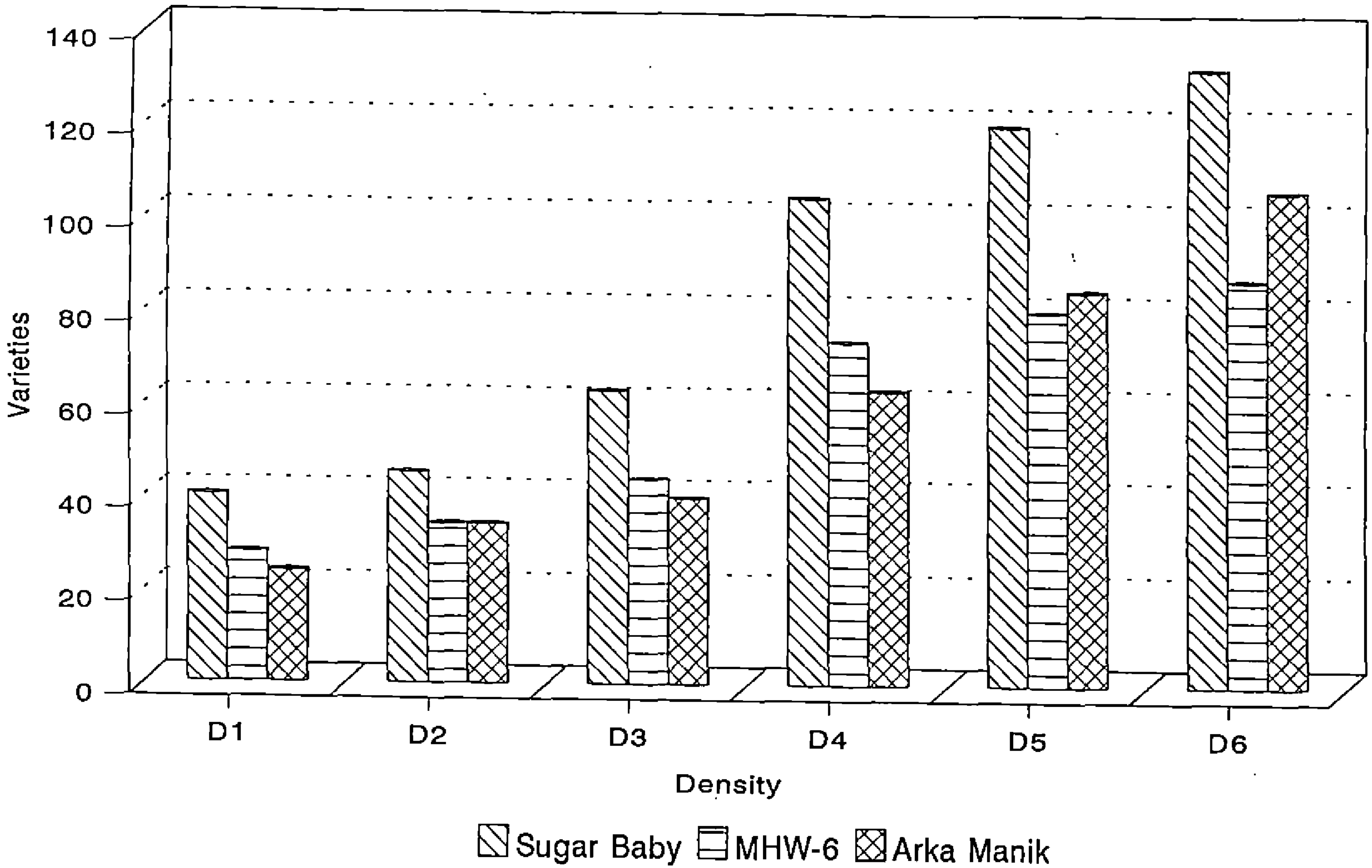

Fig. 2. Marketable yield per plot (kg)

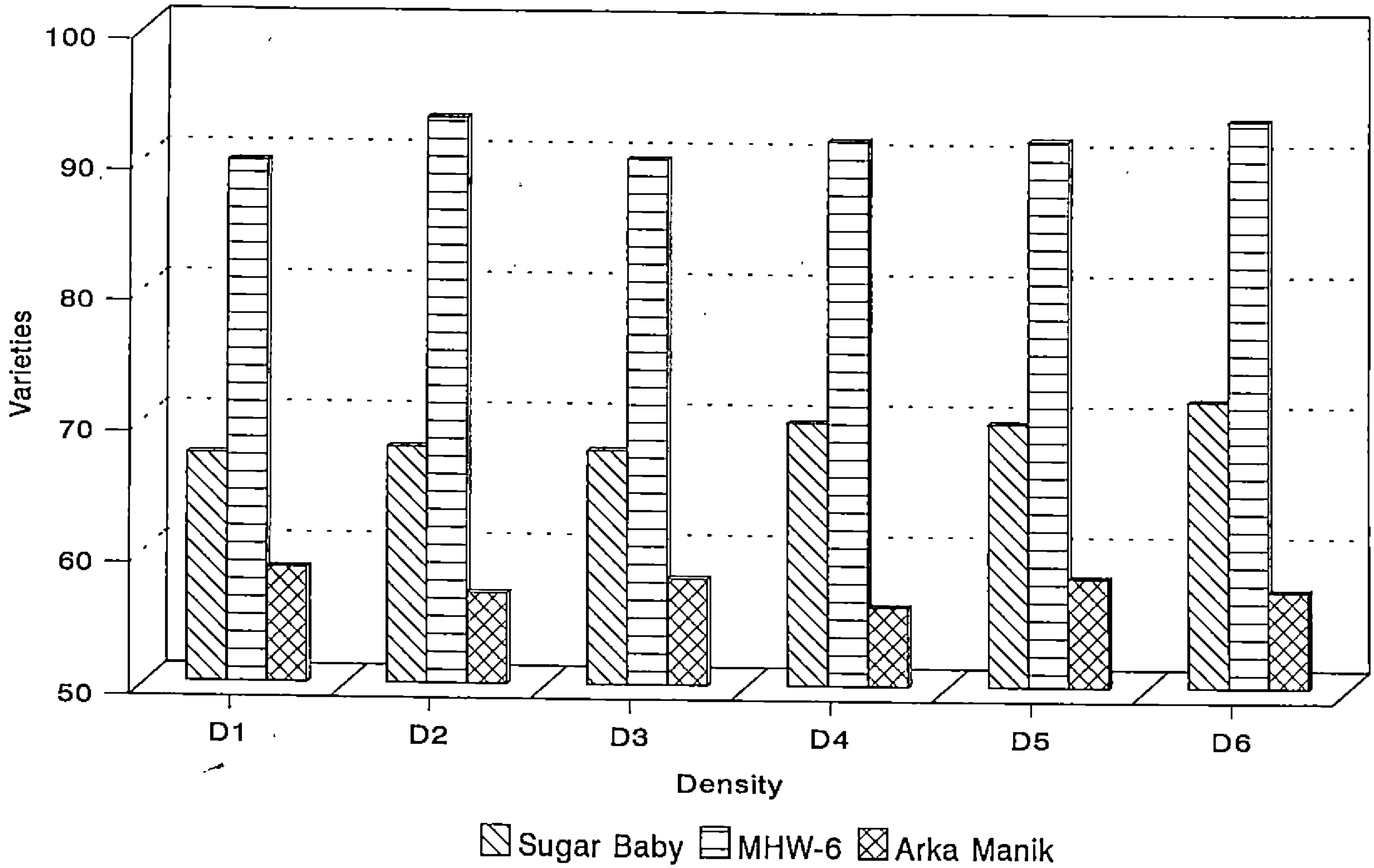

Fig. 3. Days to first harvest

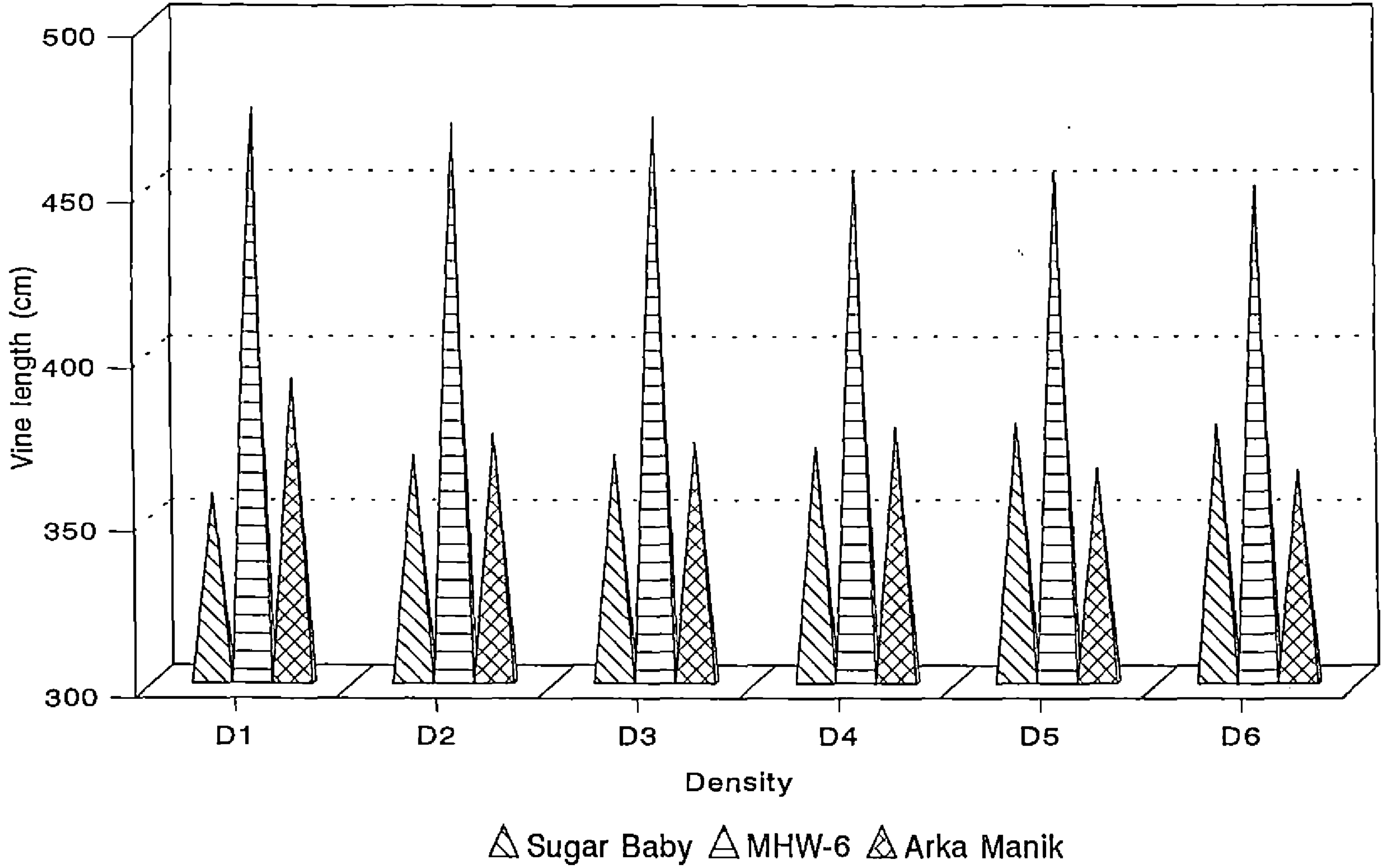

Fig. 4. Vine length (cm)

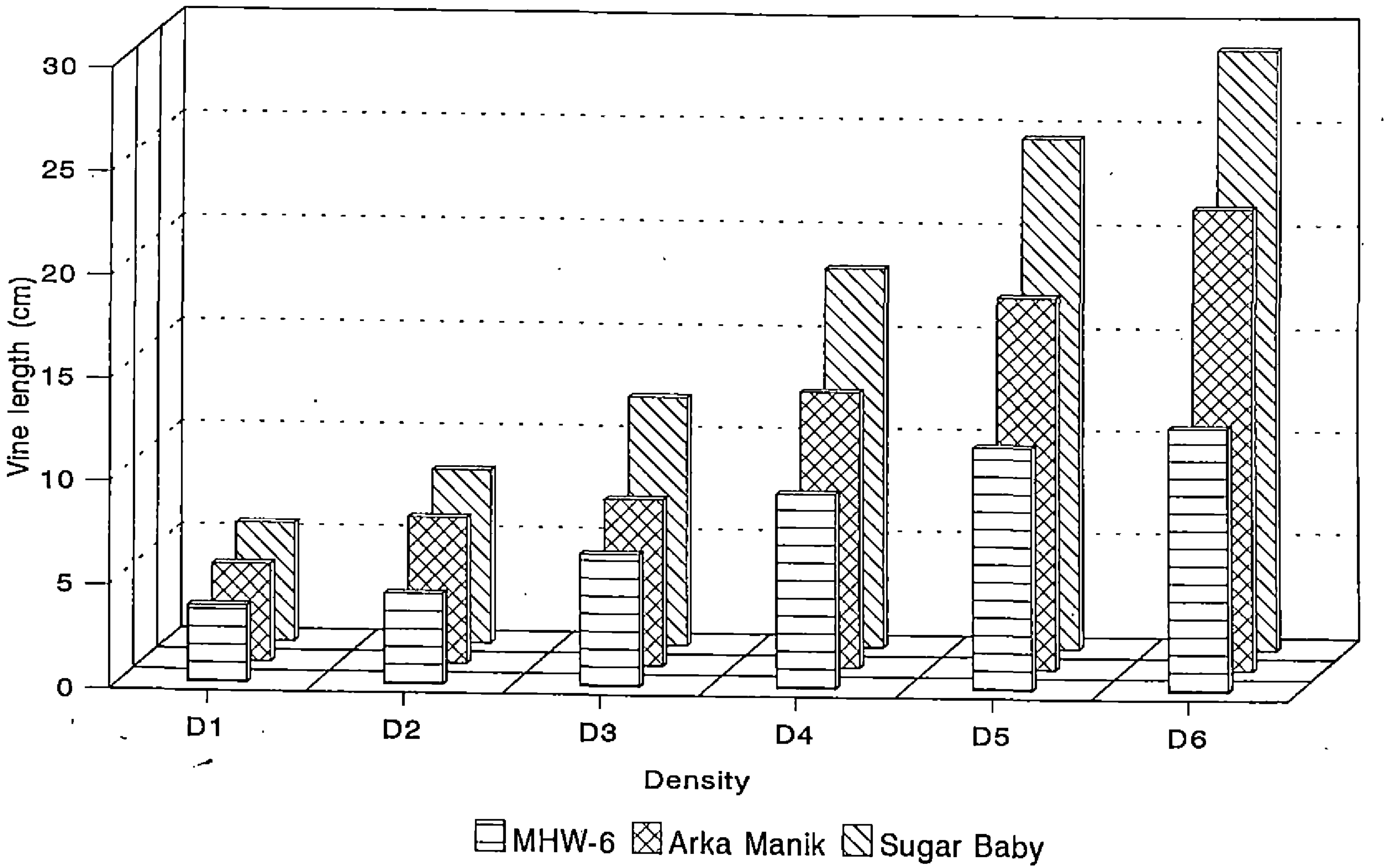

Fig. 5. Marketable fruits per plot

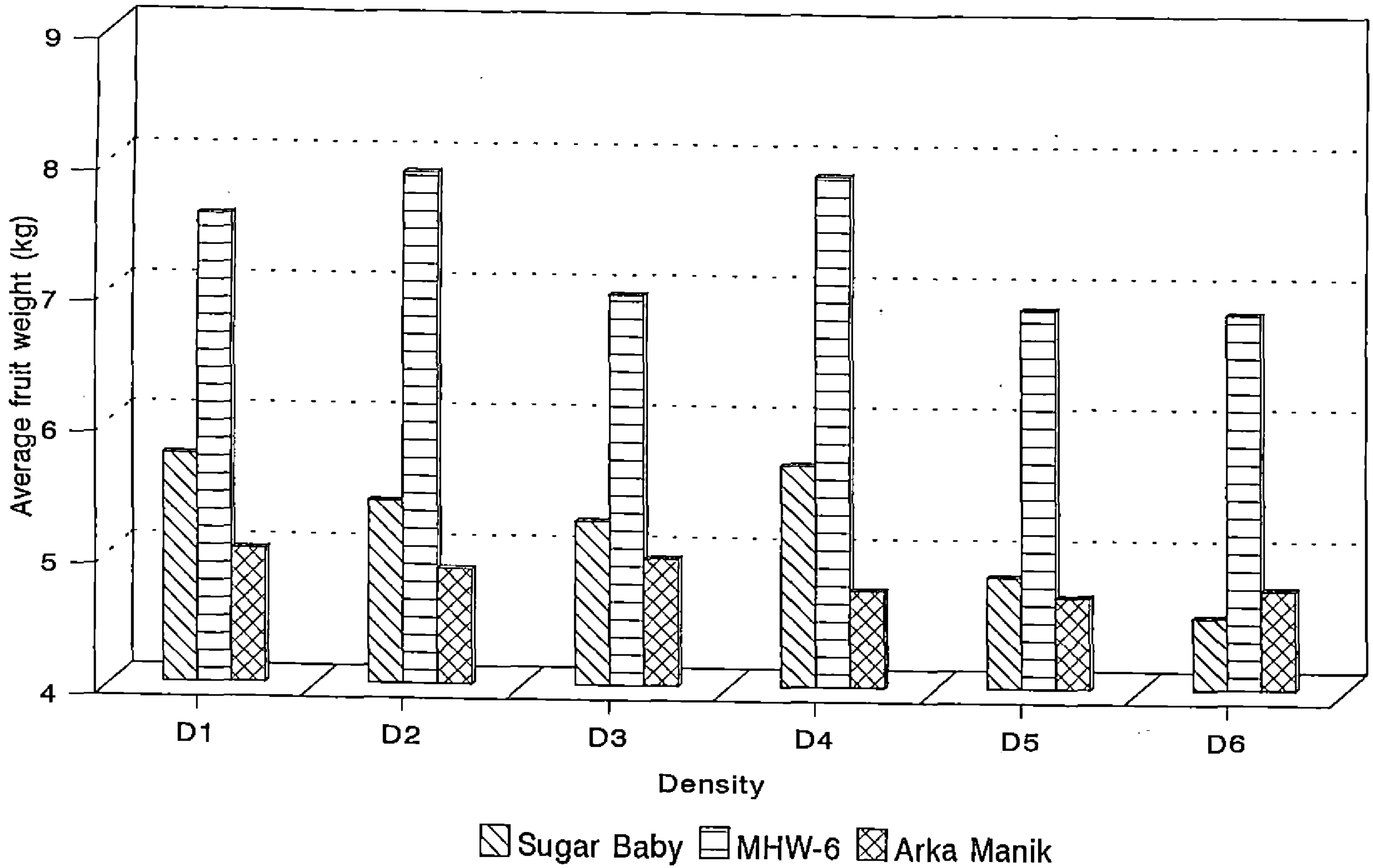

Fig. 6. Average fruit weight (kg)

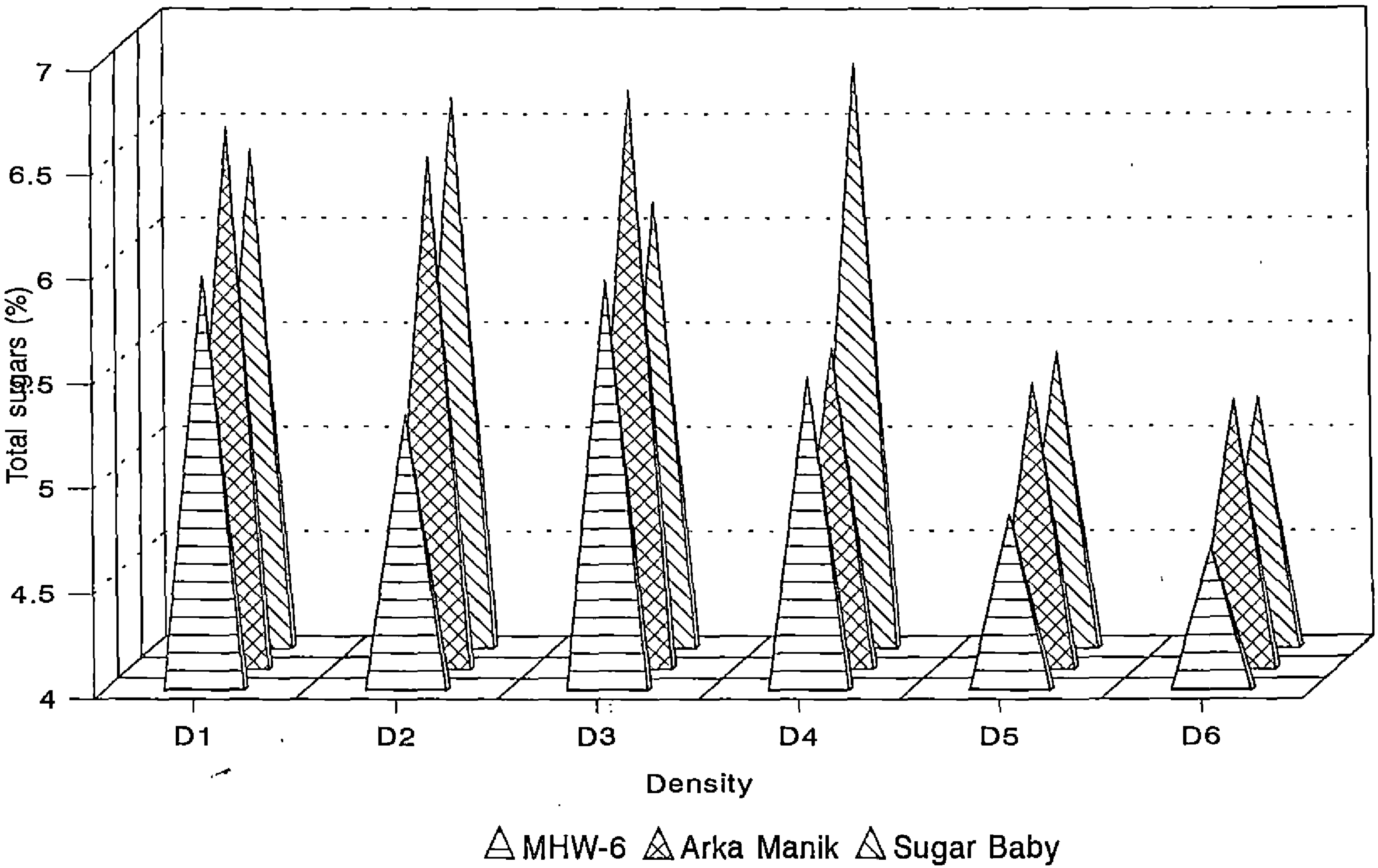

Fig. 7. Total sugars (%)

Summary

SUMMARY

The study entitled "Standardisation of population density in watermelon [*Citrullus lanatus* (Thunb.) mansf.]" was carried out at the Instructional Farm, College of Agriculture, Vellayani during February to May 1999. The main objective was standardisation of population density in watermelon for maximum yield and acceptable table quality with optimum benefit cost ratio.

The experiment was laid out in a split plot design with six spacings in the main plot and three varieties in the subplot thus constituting eighteen treatments with three replications. The population densities were 1666 plants ha^{-1} (D_1 - 3 x 2 m spacings) 2500 plants ha^{-1} (D_2 - 2 x 2 m spacing), 3333 plants ha^{-1} (D_3 - 3 x 1 m spacing), 5000 plants ha^{-1} (D_4 - 2 x 1 m spacing) 6666 plants ha^{-1} (D_5 - 3 x 0.5 m spacing), 10,000 plants ha^{-1} (D_6 - 2 x 0.5 m spacing). The varieties were V_1 (Sugar Baby), V_2 (MHW-6), V_3 (Arka Manik).

Observations were recorded on important morphological and yield attributes. The data generated were analysed, presented in tables and discussed in the previous chapters. The findings of the study are summarised below.

1. Among the three varieties, Arka Manik was earlier (22.69 days) in male flower opening. The different population density and their interaction with varieties did not affect the days to first male flower opening.

2. Arka Manik was significantly earlier for days to first female flower opening (30.99 days) and Sugar Baby had the female flowers in the lowest node (12.61). Population density and its interaction with variety did not produce any marked difference in these two attributes of earliness.

3. Harvesting was earlier (71.92 days) in plants grown at a density of 1666 plants ha^{-1} and among the three varieties Arka Manik was the earliest (57.50 days) to harvest. The population density and variety interaction influenced the days to first harvest. Arka Manik grown at a density of 5000 plants ha^{-1} was earliest (55.96 days) to harvest.

4. The direct effects of variety and population density were significant for the crop duration. It was shorter (91.31 days) in plants grown at the widest spacing of 1666 plants ha^{-1} and the variety Arka Manik was the earliest (81.98 days) to complete the crop. The population density and variety interaction did not affect the duration of the crop.

5. Population density influenced the number of female flowers plant^{-1} which was more (14.32) at the spacing of 10,000 plants ha^{-1}. Sugar Baby had more (14.17) female flowers plant^{-1}. Population density and variety interaction did not influence the production of female flowers plant^{-1}.

6. Among the vegetative characters, maximum branches plant^{-1} (5.16) was observed in plants grown at a density of 3333 plants ha^{-1} and the variety Sugar Baby had the maximum branches. The population density and variety interaction was significant. Sugar Baby at a density of 3333 plants ha^{-1} produced maximum number of (5.56) branches plant^{-1}.

7. Main vine length was maximum (404.36 cm) in plants grown at a density of 2500 plants ha^{-1} and the hybrid MHW-6 had longest vines. MHW-6 with 1666 plants ha^{-1} showed the maximum vine length (474.00 cm).

8. Yield varied significantly with varieties. Maximum total fruits plant^{-1} (1.99) was in Sugar Baby. The population density and its interaction with varieties was not significant for total fruits plant^{-1}.

9. The plants grown at the closest spacing of 10,000 plants ha^{-1} produced maximum (24.78) fruits plot^{-1}. Among varieties Sugar Baby

produced maximum fruits (20.89) plot^{-1}. The population density and variety interaction was significant and Sugar Baby (35.00) with 10,000 plants ha^{-1} spacing.

10. Varieties differed significantly for marketable fruits plant^{-1}. Sugar Baby having the maximum fruits plant^{-1} (1.44).

11. Marketable fruits plot^{-1} was maximum at 10,000 plants ha^{-1} (21.30). Among the varieties Sugar Baby had maximum marketable fruits (16.33). The population density and variety interaction was significant and Sugar Baby at the closest spacing of 10,000 plants ha^{-1} had maximum fruits (29.00).

12. Significant effect was observed among the population densities for marketable yield plot^{-1}. It was maximum (108.33 kg) at 10,000 plants ha^{-1} spacing and Sugar Baby produced the highest yield (84.03 kg).

13. Unmarketable fruits plot^{-1} was not affected by the population density variety and their interactions.

14. In the fruit characters, average fruit weight was highest (6.12 kg) in plants grown at the widest spacing of 1666 plants ha^{-1}. The hybrid MHW-6 had the maximum fruit weight (7.34 kg). In population density and variety interaction MHW-6 at a denisty of 2500 plants ha^{-1} had maximum fruit weight (7.91 kg).

15. Diameter and flesh thickness were maximum (17.46 cm, 15.33 cm) at the widest spacing of 1666 plants ha^{-1}. Sugar Baby showed the highest values for both these characters. The Sugar Baby at 1666 plants ha^{-1} had higher values (19.97 cm, 17.78 cm) for these traits.

16. The fruit length was maximum (38.17 cm) in plants grown at the density of 3333 plants ha^{-1} and the hybrid MHW-6 grown at the rate of 6666 plants ha^{-1} and the longest fruits (42.73 cm).

17. The rinds were thickest (21.73 mm) for the plants grown at a density of 5000 plants ha^{-1}. The varieties did not differ significantly. But Sugar Baby at the density of 2500 plants ha^{-1} had the thickest rinds (22.08 mm).

18. Fruit girth was maximum (54.76 cm) in plants grown at the rate of 1666 plants ha^{-1}. Sugar Baby showed the highest value (54.22 cm). Among the interaction effects Sugar Baby grown at the widest spacing had highest values (62.64 cm) for fruit girth.

19. Seeds per fruit was maximum (309.64) in plants grown at the rate of 2500 plants ha^{-1} and Sugar Baby had maximum seeds (362.35).

20. Hundred seed weight was maximum (5.88 g) at 3333 plants ha^{-1}. Among varieties MHW-6 showed the maximum value (8.34 g). MHW-6 at the widest spacing had highest seed weight (8.85 g).

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21. The total soluble solids showed maximum values at density of 5000 plants ha^{-1} (10.57 %). Among varieties Arka Manik had highest value (11.55 %) for total soluble solids.

22. Total sugars and reducing sugars were maximum (6.31%, 2.92%) at the widest spacing of 1666 plants ha^{-1} and among the varieties Sugar Baby had the maximum values (6.09%, 2.70%). In their interaction Sugar Baby with 5000 plants ha^{-1} had better values (6.76%, 3.02%).

23. Maximum values for non reducing sugars were observed at 2500 plants ha^{-1} density and Arka Manik showed highest value (3.34%) for this character.

24. Iron content was maximum in plants grown at the rate of 6666 plants ha^{-1} and for the variety Arka Manik (6.01 mg 100 g^{-1}). But their interaction was not significant for this character.

25. Sugar Baby with the highest population density of 10,000 plants ha^{-1} gave the highest (55 t ha^{-1}) returns and the maximum benefit cost ratio of 3.00 : 1.00.

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STANDARDISATION OF POPULATION DENSITY IN WATERMELON [*Citrullus lanatus* (Thunb.) Mansf.]

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ABSTRACT OF THE THESIS
SUBMITTED IN PARTIAL FULFILMENT OF
THE REQUIREMENT FOR THE DEGREE OF
MASTER OF SCIENCE IN HORTICULTURE
FACULTY OF AGRICULTURE
KERALA AGRICULTURAL UNIVERSITY

DEPARTMENT OF HORTICULTURE
COLLEGE OF AGRICULTURE
VELLAYANI, THIRUVANANTHAPURAM

2000

ABSTRACT

The present investigation on "Standardisation of population density in watermelon [*Citrullus lanatus* (Thunb.) mansf.]" was conducted at the Instructional Farm, College of Agriculture, Vellayani, Thiruvananthapuram during February - May, 1999. Three watermelon varieties *viz.*, Sugar Baby, Arka Manik and MHW-6 were tried under six population densities to find out their direct and indirect effects on vegetative yield and quality attributes in watermelon. Majority of the characters were significantly influenced by the direct as well as interaction effects of the population density and varieties.

Among the varieties, Arka Manik was earlier for male and female flower opening and for days to first harvest. However, the node to first female flower was in Sugar Baby which also had more female flowers plant^{-1}.

The population density significantly influenced majority of the vegetative characters. Lower to moderate population density had shorter crop duration, branches plant^{-1} and vine length.

Different density levels significantly influenced the yield characters. Total fruits plant^{-1}, Total fruits plot^{-1}, Marketable fruits plant^{-1},

Marketable fruits plot^{-1}, Marketable yield plant^{-1} were maximum in plants grown at highest density of 10000 plants ha^{-1}. The variety Sugar Baby was first in all these yield characters.

Sugar Baby also had the highest values for diameter, flesh thickness, rind thickness, fruit girth and seeds fruit^{-1}. The hybrid MHW-6 had maximum average fruit weight, fruit length and 100 seed weight.

Among the quality parameters, Sugar Baby had maximum values for total sugars and reducing sugars whereas, Arka Manik recorded the highest values for total soluble solids, non-reducing sugars and iron content. The plants at moderate spacings recorded highest values for the quality characters.

Majority of the characters were influenced by the interaction of population densities and varieties also. Sugar Baby at a moderate population density of 3333 plants ha^{-1} had maximum branches plant^{-1}. The number of fruits plot^{-1} was highest in Sugar Baby at the highest population of 10000 plants ha^{-1}. This treatment combination also had maximum marketable yield plot^{-1} registering maximum yield of 55 t ha^{-1} and maximum income of Rs. 165000 with the highest benefit cost ratio of 3.00 : 1.00.