STANDARDISATION OF POPULATION DENSITY AND TRAILING SYSTEMS IN GHERKIN (*Cucumis sativus* L.)

By

SAIRAJ. K.P.

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Dedicated to

My daughter, Karthika

DECLARATION

I hereby declare that this thesis entitled "**Standardisation of population density and trailing systems in gherkin (*Cucumis sativus* L.)**" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

Vellayani,
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SAIRAJ. K.P.

CERTIFICATE

Certified that this thesis entitled **"Standardisation of population density and trailing systems in gherkin (*Cucumis sativus* L.)"**is a record of research work done independently by Mr. Sairaj. K.P. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

Vellayani,
12.10 -2001

Dr. M. Abdul Vahab
(Chairman, Advisory Committee)
Associate Professor
Department of Olericulture
College of Agriculture, Vellayani
Thiruvananthapuram

APPROVED BY:

CHAIRMAN

Dr. M. ABDUL VAHAB

MEMBERS

1. **Dr. L. RAJAMONY**

2. **Dr. K. RAJMOHAN**

3. **Dr. K. UMAMAHESWARAN**

EXTERNAL EXAMINER

S. RAMACHANDRAN NAIR
Professor of Hort. (retired)
Remya, Valiasala TVM

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Introduction

1. INTRODUCTION

The word 'gherkin' is used to denote either small cucumber (*Cucumis sativus* L.) or cucumber like fruit of West Indian gherkin or ber gherkin (*Cucumis anguria* L.). But most of the gherkin currently sold are small cucumbers of special pickling cultivars (Brouk, 1975). Cucumbers of 5.00 to 7.00 cm length are also referred to as gherkin. These may be divided in to further size grades designated as number one, number two and number three gherkin averaging approximately 260, 225 and 160 numbers per 4.5 litre respectively. Many times gherkins are also known as pickling cucumbers.

Gherkins are cultivated extensively in countries like Spain, Turkey Morocco, Bulgaria, West Indies, Brazil, USA etc. It is extensively consumed in these countries as pickling. Because of high labour cost and other related problems, the European countries are now popularizing its cultivation to some of the developing countries. The Asian countries have ideal climatic condition for gherkin. India has been identified as one of the potential countries for gherkin production due to favourable climatic conditions in many states (Veeraraghavathatham *et al.*, 1998).

At present gherkin is grown in few southern states like Tamil Nadu, Kerala, Karnataka and in West Bengal. This has become a profitable export oriented crop with practically no domestic consumption. In India only 0.5 per cent of fruits and vegetables produced is processed as compared to 83 per cent in Malaysia, 80 per cent in South Africa, 70 per cent in Brazil and 65 per cent in USA (Ponnuswami and Mohamed Ali, 2001). There are more than a dozen countries to which India exports gherkin, important being Spain, Belgium, France, UK, USA, Australia, Canada, Switzerland, Holland, Brazil, Argentina etc.

Gherkin cultivation was attempted on experimental basis by some private exporters in some parts of central Kerala, mainly in Thiruvalla area of the Pathanamthitta district. Personal survey in these area revealed that the farmers are very enthusiastic in gherkin cultivation and marketing. However, scientific management of the crop in respect of trailing, plant spacing, fertilizers, manures and crop protection measures are lacking with them. This pointed out to the need for standardisation of certain management practices in gherkin.

Generally in cucumber, most of the yield parameters are affected by the density of planting. This in turn depends greatly on the type of the cucumber namely slicing, pickling or fresh market. Variation in plant population density affects sex expression, fruit quality, earliness etc. Therefore, standardisation of population density in respect of maximum yield and quality would be an important contribution on the cultivation of gherkin.

There exists different systems of trailing namely trailing on ground, mulch, pandals, trellis etc. in the cultivation of gherkin. The size, shape, yield, growth, development, sex expression, quality etc. are influenced by the systems of trailing. Uniformly long fruits without crooked neck constitute marketable yield in gherkin. Other quality attributes like intact carpels without hollow spots and tender seeds at edible maturity stage are important criteria in deciding marketable yield. Hence staking is one of the most important tools that can be employed to increase yield and quality of gherkin. Information on optimum trailing system under different plant population is of utmost importance.

Under the above circumstances the present study was undertaken with following objectives.

i. To standardise the trailing system for maximum marketable yield in gherkin

ii. To arrive at optimum population density for maximum marketable yield in gherkin and

iii. To study the interaction effect of trailing systems with population density in gherkin.

Review of Literature

2. REVIEW OF LITERATURE

The productivity and full potential of any crop depends primarily on its genetic architecture. But the full expression of its potential yield is possible only when the crop is grown in the best environment. For viny crops like cucurbits, the population density, the method of trailing etc. are very important in achieving optimum yield and quality. The trailing systems affect photosynthesis, pollination, uniform development of fruits, fruit yield, flowering, sex expression, fruit quality, size, shape etc. Various cultural operations like fertilizer application, irrigation, weeding, plant protection, harvesting etc. are also affected by the method of trailing. So most suitable trailing system under different plant populations is very important. The population density also affects the above vegetative and reproductive characters and also varies with hybrids, open pollinated varieties and parthenocarpic cucumbers. The available literature on cucurbitaceous vegetables pertaining to the present study is reviewed under the following sub heads.

2.1 Trailing systems

2.2 Population density

2.1 Trailing system

2.1.1 Earliness, Growth, Flowering and Fruit set

Cucurbits are trailed in different systems which affect their growth, yield and quality. In glass house cucumbers, Kooistro (1967) reported that male flowers were comparatively less numerous on the vines topped at the fourth axillary joint, and also the three stem plants appeared to have no advantage in this respect.

It has been reported that vertical training in cucumbers resulted in slight loss of earliness as compared with the conventional flat system (Anon., 1969).

An increase in the earliness in cucumber was observed by Vogel *et al.* (1971) by pinching back lower side shoots to 1 to 2 leaves. But, temporary increase in leaf area was also reported (Kobza and Stambera, 1972) by cutting back the main axis above the first and fourth leaf. Different pruning methods studied by Yurina and Gnaichkina (1975) changed the plant branching habit, and the short pinching method improved leaf photosynthetic productivity.

In an experiment to study the influence of trailing system on the productivity of green house cucumbers, early harvest has been reported under pergola system by Stan *et al.* (1980).

Arora and Mallik (1989) studied different pruning systems in ridgegourd cultivar 'Pusa Nasdar' to leave two, four or six primary branches with no pruning as control. They found that plants pruned to six primary branches gave highest number of secondary branches. But the duration of fruit maturation and flowering were shorter when pruned in summer season (Gobiel and Gossel in, 1989).

Matiar Rahman and Monowar Hossain (1989) investigated the performance of three advanced bottlegourd lines viz. BG-0009, BG-0011 and BG-0003 under trellis and non-trellis and reported that plants on trellis produced flower earlier than those on non-trellis. They also reported that in all the three lines, the length of the main vine ranged from 6.03 to 8.20 m with trellis and 4.05 to 6.07 m in non-trellis.

Yadav *et al.* (1989) reported that in pointed gourd, flowering was initiated earlier when plants were trained. The number of days for first picking of fruits was significantly less in flat system than that of bower.

In an experiment on bittergourd Joshi *et al.* (1994) reported earlier appearance of female flowers in bower and kniffin systems than in bush and ground systems.

Subedi *et al.* (1997) also proved that trailing of cucumber using jute strings improved the number of marketable fruits when compared to tree branches or twigs.

Renji (1998) studied the response of slicing cucumber to different population densities, trailing systems and nutrients and found that plants trailed on mulches were earlier for male and female flower opening. First harvesting was in pandal grown plants.

2.1.2. Morphological traits

In an experiment pruning of all secondary shoots of cucumber upto 5th node gave significantly higher yield than unpruned control (Managal and Yadv, 1979). The average weight, diameter and fruit length were slightly more in the case of fruits harvested from pruned plants.

Hanna and Adams (1984) reported greater plant weight, greater weight and dimension of leaves in staked cucumber plants though the number of female flowers did not vary between staked and unstaked plants. Vertical training system recorded significantly increased fruit set.

In a field trial with bottlegourd cv 'Pusa Summer Prolific Long', female flowers, branches and fruits per plant were least in treatments where branching on the main shoot was allowed from the 9th to 15th mode (Sharma *et al*, 1988). Yadav *et al.* (1989) observed longest vines in trained pointed gourd plants. The favourable response of training was observed on branching pattern. Varieties FP-4 and FP-3 produced higher number of branches.

Joshi *et al.* (1994) studied the growth and flowering of bittergourd cv. 'Co-White' as influenced by different training systems viz. bower, kniffin, bush and ground. They recorded vigorous vine length, and more number of branches per plant on bower system.

2.1.3 Yield and yield attributes

Hosslin (1966) reported higher per plant yield in comparison of cordon cucumber with vertical wire espaliers which also resulted in greater amount of marketable fruits.

Raether (1966) reported higher yield per vine in cucumber with two shoots per plant with fruits left on main stem and lowest with no pruning. Light pruning also resulted in considerably higher yield and more uniform cropping (Kurki, 1972 and Wikesjo, 1971).

In a three year trial Konsler and Strider (1973) proved that the marketable yields of trellised cucumbers were double compared to those obtained with ground culture.

In one experiment, vertical training in cucumber had given higher yield, than oblique training system (Santos and Diaz, 1974).

Yurina and Ganichkina (1975) observed that training of shoots by various systems reduced yield by 40.5 to 69.1 per cent compared with untrained cucumbers.

According to Singh *et al.* (1982), the training of pruned muskmelon plants on bamboos and reduction in plant to plant spacing to 30 cm resulted in further increase in fruit yield. Duyn (1984) opined that retention of growing point in cucumber resulted in greater number of fruits.

In a five year trial with the cultivar 'Parifin F_1', yield components were in positive correlation with the number of main roots, vine and leaf numbers and vine length. Mulching greatly improve yield compared with non-mulched and open field conditions (Cerene, 1984).

Ganikhozhdaeva (1984) reported that out of three systems tried in plastic-clad greenhouses during spring season, training plants with single stem produced highest early and total yields. Hanna and Adams (1984) stated that vertical training increased the marketable yield of cucumbers more than double in the normal cultivar and also observed increased fruit length.

In field trials, 19 gherkin cultivars planted at 40 x 20 cm and trained as cordons were harvested from 19th July to 28th August, and graded by size into 4 classes. Frequent harvesting stimulated cropping and produced the desirable small (3-6cm) fruits. The most productive cultivar 'B 80', harvested every day and every second day yielded 714g and 576g fruits/plant respectively (Botos *et al.*, 1985).

Pruning of muskmelon varieties, Punjab Sunehri, Punjab Hybrid, Pusa Sharbati and Hara Madhu upto third, fourth, sixth and seventh node respectivly enhanced the fruit yield (Mangal and Pandita, 1985). In cucumber pruning enhanced the total yield per m2 of cultivar 'Lucinde', but depressed the early yields of cultivar 'Corona' (Moerman, 1985).

In a trial with cucumber cv. Selection No. 713 in different substrates including new gordan rockwool mats, old steamed gordan mats in 2 layers, new multifrow rockwool mats or new agrofoam plastic mats, the total yields were highest on new gordan mats, amounting to 10.6 kg/m2 which is 300 g/m2 higher than yields on multigrow mats (Uffelen and Van, 1986). In the same trial with cv. Lucinde and Selection No. 713 grown with 1 or 2 stems/plant, early yields were usually higher with 1 stem/plant, but there were only slight differences in total yields between the systems.

Two cucumber production methods, the double V and 4 row systems were compared by Hendrix (1987) and found that yields in the 4-row system were no higher than the double V.

Successful cultivation of the medium fruit size, early cucumber cultivars Crimson Sweet, Sweetmeat II W.R., Baby Fun and Ruban, on vertical trailing system was reported rather than the traditional flat system (Ruggeri, 1987). Average total fruit yields of Sweetmeat II W.R., Bady Fun and Ruban were 11.92 ton/ha under polyethylene, compared with 7.9 ton/ha in the open.

Uffelen and Van (1987) studied the effects of growing cucumbers with 1 or 2 stems per plant (the spacing of the latter being about 70 per cent wider). The total yields with cv. Lucinde, were 1 kg/m2 higher with the 2 stem system. In the same trial with cv. Corona, yields were 1.8 kg/m2 higher with the 1 stem system. Moreover, in this trial with autumn early hot house and cold culture, the 2 stem systems were found more cost effective, especially with early hot house and warm-air cultures.

In a study to find the effect of pruning method on the yield of field grown trellised cucumber, Botos *et al.* (1988) reported that the removal of laterals reduced early yields and total yields and returns. In another experiment it was observed that shoot pruning alone did not increase fruit yield (Duranti *et al.*, 1988). The shoot pruning along with traditional treatments gave the highest yields (4.8 Kg to 5.7 Kg), the earliest ripening and greatest profit.

Gherkins grown as double row vertical system gave the yield of 80 ton/ha compared with 75 ton/ha in the single row vertical system (Poll *et al.*, 1988). It is suggested that growing gherkins on a double row string increases labour costs. The unfavorable effect of pruning methods on yield of bottlegourd was reported by Sharma *et al.*, 1988.

Hanna *et al.* (1989) reported that the marketable yield was slightly lower when tomato stakes were reused for cucumber growing. Double cropping cucumber and tomatoes was suggested to minimise the cost of staking cucumbers.

In one experiment the outdoor cucumbers trained by traditional twine method produced more fruits although the fruits were shorter than those supported by nylon netting (Makus, 1989).

Matiar Rahman *et al* (1989) observed more fruits per plant on trellis than on those without trellis in bottlegourd. The fruit size and weight were also increased on trellis compared to non trellis. They also observed that fruits borne in bottlegourd plants without trellis had white spot in portion touching the ground and were susceptible to insect damage. The fruits of non trellis have poor market quality.

Derevencha *et al.* (1990) proved that Growing cucumber hybrid cv 'Levina' in a field trained on the used vine yard espaliers yielded 48.6 ton/ha and 46 ton/ha in 1987 and 1988 respectively, compared with the average yield of 17.2 ton/ha from the conventionally grown crops.

Nylon trellis netting was evaluated for its effects on yields of cucumber cultivar's Dasher II, Marketmore 76 and Peto Triple Mech at Oklahoma (Russo *et al.*, 1991). Trallising increased marketable yield to 32.84 ton/ha and 65.10 ton/ha at Lane and Wilburton, respectively compared with 26.93 ton/ha and 52.11 ton/ha for ground culture. Trellising also increased total yields. Peto Triple Mech was evaluated as a fresh market cultivar rather than as a pickling cucumber. The average fruit weight of marketable fruits was not affected by trellising, but was affected by cv at Lane, with Peto Triple Mech producing the heaviest fruits.

Hanna and Adams (1993) observed increased cucumber yields and quality with vertical training. The increased yields were attributed to increased fruit set and development to marketable size and reduction in fruit rot. Black or white polyethylene mulches increased yields compared with bare ground. The standard system gave higher total yields. But the increase was due to more number two grade fruits. Cucumbers could be double cropped with tomatoes to minimise the cost of staking cucumbers without reducing premium yields.

Klieber *et al.* (1993) applied various training systems to green house grown 'Mustang' cucumber at two production stages. Training system determined the number of stem per plant, orientation of laterals, and leaf fruit ratio.

Joshi *et al.* (1994) reported that in bittergourd cv. 'Co-white long' bower system resulted in maximum number of fruits per vine followed by kniffin (60), ground (45) and bush (40) systems. Bower system recorded higher yield (143 per cent) than ground and bush systems.

The effects of plant density and training methods were studied by Choi *et al.* (1995) in Japanese cucumbers. Of the three methods of training viz. pruning plants to one lateral bud, main shoot and one lateral shoot and three lateral shoot, the last method gave the higher yield (380 ton/ha).

In a trial yields were mostly between 80 ton/ha and 100 ton/ha, which is considered high, due to the vertical growing system and experimental conditions (Titulaer, 1996).

The effect of staking system (bamboo sticks or tree branches, staking using jute strings or no staking) on the yield of cucumbers was investigated by Subedi *et al.* (1997) at five research sites in Nepal during 1996-97. Staking using the farmers method (bamboo sticks or tree branches) produced significantly more fruits at the 2 sites which were irrigated. The farmers method of staking produced 5.6 and 82 per cent more fruits at Yamphant and 5 and 60.8 per cent more fruits at Dhanubase than the use of jute string and no string, respectively. Staking did not influence yield to such an extent at the other sites. On average staking with jute string gave 5.6 and 29 per cent more marketable fruits than the farmers practice of staking and no staking respectively.

In another experiment 18 cucumber cultivars were grown on trellis and flat bed production system during spring and summer seasons of 1995 in North Carolina, USA. Vine flower and yield traits were measured. When cultivars were grown on trellis support, fruit shape, vine length, incidence of powdery mildew (*Sphaerotheca fuliginea*), marketable yield and per cent of culled fruits were higher (Shetty *et al.*, 1998). Anthracnose (*Colletotricum orbiculare*) damage, fruit length, fruit diameter, average fruit mass, fruit colour, overall impression, fruit shrivelling, seed cell size, branch number, percentage of staminate nodes and total yield were not significantly affected by the production system.

2.1.4 Quality

Konsler and Strider (1966) reported that in cucumber fruit colour and shape were better on the trellised plants and more thorough harvesting could be carried out than from the ground plots. They also reported 63 per cent greater top grade total yield from trellis than plants of ground culture.

Fruit quality was much higher with trellised cucumbers compared to ground culture, by improved control of scab and eliminated losses by fungi (Konsler and strider, 1973).

Hanna and Adams (1984) reported significantly decreased fruit rot incidence when cucumber was grown on vertical training system.

In an investigation into the cultural systems and pruning of cucumbers the cv 'Corona' recorded best coloured fruits with a hedge system both initially and after storage (Moerman, 1985).

In an experiment by Mc Feeters and Lovdal (1987) during fruit development in the pickling cv Calypso, the glucose content (relative to total sugars) of the cell walls remained constant whereas contents of galactose, xylose and mannose decreased slightly. Galactouronic acid : rhamnose and galactouronic acid : arabinose ratios and the degree of pectin methylation, increased during maturation. A positive correlation was observed between mesocarp firmness and the total cell wall sugar content of the fresh tissue. Peel tissue contained 4 to 5 fold higher cell wall sugar concentrations than either the mesocarp or endocarp.

Hanna *et al.* (1989) opined that the percentage of culled fruits and of rotten fruits of cucumber were unaffected by staking system.

Klieber *et al.* (1993) proved that training system permitting high canopy penetration resulted in darker fruit and a longer shelf life. Shelf life was positively correlated to rapid fruit growth in experiment I, but not in experiment II. Training systems to achieve a long shelf life of green house grown long English cucumbers were also studied by them.

In an experiment fruit quality was found higher when cucumber varieties were trailed on trellis (Shetty and Wehner, 1998). But fruit colour, fruit shrivelling, etc. were not affected by the production systems.

2.2 Population density

2.2.1 Earliness, growth, flowering and fruit set

The effect of population density varies with hybrids, open pollinated varieties and parthenocarpic cucumbers. In an experiment with hybrids and open pollinated varieties of cucumber, Lower *et al.* (1983) found that by increasing density the pistillate flowers per plant were reduced and staminate flowers increased in hybrids. However in open pollinated varieties population density had no effect on sex expression.

Increasing number of plants per hill reduced the percentage of pistillate nodes per plant in all hybrids (Nienhuis *et al.*, 1984). The number of flowering nodes in both gynoecious inbred lines and their hybrids, and the per cent of gynoecious plants in both gynoecious inbred lines, and in their hybrids reduced with increasing number of plants per hill.

Arora and Mallik (1989) observed early appearance of pistillate flowers and highest number and weight of fruits when the plants were grown at a population density of 11250 per hectare. The plants were pruned to leave two, four or six primary branches with a no pruning control. Plants pruned to 6 primary branches gave the longest plants with highest number of secondary branches and showed early appearance of pistillate flowers.

The timing of fruit production, sex expression and flower abortion were not affected by plant density and row arrangement in the parthenocarpic cucumber cv. Marboson (Kasrswi, 1989).

In an experiment with pumpkin (*Cucurbita moshata* Duch ex Poir), the closer spacing of 3mX75cm resulted in earlier production of female flowers than with wide spacing (Kulbir Sing *et al.*, 1990).

2.2.2 Morphological traits

In an experiment with forcing cucumbers Kobza *et al.* (1972) reported temporary increase in leaf area of cutting back the main axis above the first and fourth leaf.

Karataev *et al.* (1983) opined that in cucumber the best plant growth, development, photosynthesis and greatest yields were obtained when plants were grown at 1.5 plants per m2.

2.2.3. Yield and yield attributes

Plant density affects yield and Yield components in any crop. In an experiment Weichold (1967) observed that plant density affected the yield of the cordon cucumbers.

Halling and Amsen (1970) recorded highest yield when the number of plants was increased and distance between the rows was shortened at same time.

In an experiment with watermelon, Petkov (1970) observed that closer spacing produced higher yield with negligible effect on fruit size.

Zahara (1972) reported that the number of marketable melons were greater with cv. 'PMR-45' at a population density of 16,000 plants per acre.

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

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

Enthoven (1980) reported that the fruit numbers differed slightly between single stem and double stem vines spaced at 86cm, but closely spaced two stem plants gave highest fruit numbers.

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 3 years trial he observed highest sailable and total yield with highest plant population of 1,20,000 plants per ha.

Karataev *et al.* (1983) opined that density of population affects plant growth, flowering pattern and fruit set in any crop. In cucumber the best plant growth, development, photosynthesis and greatest yields were obtained when plants were grown at 1.5 plants per m^2.

Wehner *et al.* (1983) compared the performance of determinate and indeterminate cultivars of cucumber under varying plant densities. They observed higher optimum population density for higher yield in the case of indeterminate cultivar 'Table green 65' than that of the determinate cultivars.

Nerson *et al.* (1984) in muskmelon observed faster vegetative growth per unit area with the population of 31250 plants than with 3500 plants per hectare. There were more leaves per m2, higher leaf area index and more dry matter accumulation per m2 with higher population density.

Experiments were conducted in Cucumber for 2 years on 3 soil types with plant densities 95000 and 1,43,000 per hectare by Paschold *et al.* (1984). But seasonal differences affected yields more than other factors.

Srinivas and Prabhakar (1984) reported that muskmelon (Hara Madhu) yields were highest at 300 x 60 cm and decreased with wider spacings. Interactions between spacing and nutrients were also significant.

An investigation proved that higher crop population density in cucumbers resulted in smaller plants, earlier competition from weeds and therefore a shorter period of weed infestation without yield loss (Weaver, 1984).

Yakimenko (1984) reported a plant stand of 1,00,000 to 1,25,000 per hectare for optimal yields after an extensive trial with various varieties and hybrids.

Plants of the cv. Corona, planted at 0.7 to 3.1/m2 were trained on the V-system or as cordons (Bakker and Vooren, 1985). Highest productivity was obtained with 'V' system at high density but mean fruit weight decreased in all cases.

Swamy *et al.* (1985) reported a range of 1.20 to 3.90 with a mean of 2.20 for number of fruits per plant with the total yield per plant ranging from 349 to 3061g with a mean of 1999g.

In a trail with cucumbers, cv. Lucinde, the young plants raised in rockwool blocks were spaced at 12,14,16 or 18/m^2 in the nursery before being planted in the glasshouse on rockwool matting on 12th August. The differences in early and total yields and average fruit weight between the spacing systems were slight. Total yields amounted to about 11.5 kg/m^2 (Uffelen and Van, 1986).

In another experiment cucumbers were planted with 0.5m between rows and either 0.2m (Low density) or 0.1m (High density) between plants within rows. Cucumber yields in both monoculture and polyculture were improved at their high planting densities, and when irrigated. But the interaction between cucumber densities and irrigation in polyculture cucumbers is not significant, but suggestive of increased yield with irrigation at high densities (Brian *et al.*, 1987).

In a trial with 3 cultivars of green house cucumbers, maximum leaf area increased as plant spacing decreased (1,2,3 or 5 plants/m^2) (Heissner *et al.*, 1987).

Successful cultivation of the medium fruit size early cultivars Crimson sweet, Sweetmeat II W.R., Baby fun and Rulan developed on a higher plant density (2 plants/m^2) than that used in the open (0.6 plants/m^2) and on training the plants by a vertical rather than the traditional flat system (Ruggeri, 1987).

Uffelen and Van (1987) studied the effects of growing cucumber with 1 or 2 stems per plant (the spacing of the latter being about 70 per cent wider). The widely spaced system scored higher yield (1.8kg/m^2).

Effects of spacing was studied in bottlegourd cv. Arka Bahar, spaced differently and with either 1 or 2 plants/hill by Vishnu and Prabhakar (1987). Spacing the plants at 300X45 cm with 1 plant per hill gave the highest average yield of 384.54 Q/ha.

Seedlings of Zucchini (Cucurbita pepo L. var. giromontiina) were planted in unheated and heated greenhouse with 1.6m between rows and 0.6, 0.8 or 1.2m within rows in an experiment (Vogel and Lanckow, 1987). After 23 weeks cultivation, marketable yields were 8.8, 8.7 and 7.7. kg/m2 in the heated house and 11.1, 9 and 7.9 kg/m2 in the unheated house at the 3 spacings, respectively.

In a study with pickling cucumbers by Silva *et al.* (1988), seeds of the female cultivars Ginga Ag. 77 and Score were direct sown on 5 dates to give 4 seedling densities (13333 to 80000 plants/ha). The highest commercial yields (15.6 to 15.8 t/ha) were obtained by sowing in September to October at a density of 80,000 plants/ha.

Arora and Mallik (1989) observed early appearance of pistillate flowers and highest number and weight of fruits of ridge gourd when the plants were grown at a population density of 11250 per hectare.

In a field trail, plants of the 2 Cucurbita pepo types were spaced at 1000, 2000, 3000 or 4000 plants per unit area. The total yield was not affected significantly by population density, but there was a negative relationship between plant density and the number of fruits/plant. In plants of the vine type, increased plant density decreased the ratio of large to small fruits whereas in bush type plants, this ratio was almost unaffected (Edelstein *et al.*, 1989).

Two growing seasons with 4 planting densities were compared by Kasrswi (1989). The yield per unit area was increased linearly when the population density was increased from 2.4 to 5.4 plants per m2 and the increase was greater in a 2 row arrangement than in 3 or 4 row arrangements. However shoot dry weight per plant decreased linearly or quadratically with increasing plant density.

In a 2-season trail with *Cucumis melo* var. flexuoses, the fruit yield increased with planting density, being highest at 30 cm spacing in one year and at 15 cm in the other year. (Mohammed *et al.*, 1989)

A study on effects of plant density on growth and biomass partitioning in pickling cucumbers by Widders and Price (1989) was conducted in which cultivars Tamor and Castle Pink were direct seeded at 6 plant densities using 2 between row spacings (71 and 36cm) and 3 within row spacings (29, 14 and 11cm). Compared to the 29cm within row spacing, the 11 and 14cm spacings resulted in significantly lower total above ground plant dry weight growth rates and total leaf areas for both cultivars as early as 21 to 27 days after sowing. Lower fruit productivity per plant at higher plant densities resulted from fewer fruit set, plant and lower fruit : shoot ratios. Total fruit yield with a single harvest did not increase above 77000 plants/ha for both cultivars. A higher correlation (r=0.877) between leaf lamina DW and fruit growth rate indicated that net photosynthetic capacity might be limiting fruit production potential in pickling cucumbers.

In an experiment with pointed gourd, the highest yields (136.3q/ha) were obtained at the closer spacing with the bower system (Yadav *et al.*, 1989).

The different spacing 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 60cm to 75cm. The closer spacing of 3mX60cm produced the maximum yield of 108.12 q per ha (Kulbir singh *et al.*, 1990).

Four seed plants of the hybrid cv. Stella, grown in winter spring on the lower volga region recorded 2.2 plant/m^2 spacing as most suitable (Suchtova *et al.*, 1990). In a summer-autumn crop the best results were obtained with 2.2 to 2.3 plants per m^2.

Kanavel (1991) made a comparison study between short internode (NI) musk melon with main dwarf and normal internode (NT) cultivar at various plant densities and found that at double the population, SI plants produced approximately 35 per cent fewer fruit than NI cultivar grown at one half the population density. Spacing had no effect on average fruit weight, but increasing plant density of SI genotypes decreased the number of fruit per plant. Generally doubling the density reduced leaf area and total plant dry weight, but had minimal effect on the amount of shaded leaf area.

Higher plant populations achieved by decreasing within row spacing from 12-6 inches further increased premium and total yields in most crops. In cucumber, plants spaced at 9 or 12 inches produced higher premium and total yields that those spaced at 18 inches (Hanna and Adams, 1993).

Wann (1993) conducted an experiment to identify adapted cultivars, optimum population density and plant special arrangement of cucumber. The cultivars were grown in population densities ranging from 26000 to 130000 plants per acre. The study indicated increased yield at densities above 26000 plants per acre, but no increase was observed above 65000 plants per acre.

In an experiment with Japanese White Spined Cucumber cultivar, the highest yield (380020 kg/ha) was obtained from treatment with three lateral shoots planted at a density of 45000 plants/ha (Choi *et al.*, 1995).

Ishii *et al.* (1997) reported that the problems of declining yield in the second half of the season were overcome in cucumber cultivar 'ona' by allowing 4 laterals to develop per plant when the crop was planted at 148 plants/a or 6 lateral shoots when the plant density was 111 plants/a.

2.2.4 Quality

In many trailing crops, the quality is often affected by the population density. The quality in terms of size, shape, appearance, colour, nutrients, etc. are affected by population density. Zahara (1972) reported increased sucrose content in the mature fruits of cantaloupes at wider spacing. The number of marketable melons were also greater with PMR-45 at population density of 16,000 plants per acre.

By increasing the density of green house cucumber from 2 to 2.6 plants per m2, Kretschmer (1970) observed enhanced fruit quality.

Gurdeep Kaur *et al.* (1977) reported that the reducing sugars in muskmelon ranged from 2.52 to 4.76 per cent.

In a cucumber plant spacing trial, Janse (1984) observed that a reduction on light influences the colour and firmness of the harvested product in cucumber. He compared the effects of plant spacings of 70 and 50 cm. The wider spacing increased the subsequent shelf life from 13.5 to 15.8 days. The fruit colour was enhanced by wider spacing.

Cucumber plants were grown at densities 7.3, 5, 5 and 2.2 plants per m2 and shaded with one, two or, three layers of cheese cloth (Kanahama *et al.*, 1984). It was observed that the angle of curvature of fruit was not affected by planting density but increased with increased shading.

The periods of low light intensity during May-June resulted in poor furit colour and shelf life (Janse, 1985).

Swamy *et al.* (1985) observed a range of 1.20 to 3.90 with a mean of 2.20 for number of fruits per plant and reported the total yield per plant which ranged between 349 and 3061g with a mean of 1999g. They recorded a range of 4.7 to 15.3 per cent TSS with a mean of 10 per cent.

Illustrating the production technology of vegetable crops, Sing (1989) has recommended a spacing of 1.2 to 1.5 x 60 to 90 cm.

In an experiment to study the effects of plant density, highest yield of marketable fruits was obtained at density of 45,000 plants/ha (Choi *et al.*, 1995).

Everaarts *et al.* (1998) suggested that the amount of K in the crop was not influenced by plant density. But depended on the planting date.

Materials and Methods

3. MATERIALS AND METHODS

The experiment was carried out during January-March 2000 to know the response of pickling cucumber to trailing systems and population densities.

3.1 Experimental site

The experiment was carried out at the instructional farm, College of Agriculture, Vellayani. It is situated at 8.5^0N latitude, 76.9^0E longitude at an altitude of 29m above mean sea level. The experimental site had lateritic red loam soil under the Vellayani series.

3.2 Season

The crop was raised as summer crop during January-March 2000.

3.3 Materials

3.3.1 Planting material

The locally available monoecious pickling cucumber 'Thiruvalla Local' was collected from the gherkin growers of Thiruvalla panchayat, Kerala and used for this experiment.

3.3.2 Trailing materials

Bamboo twigs of six feet height with branches were used for trailing on twigs. Casuarina poles of six feet height and coir ropes used for making pandals. Dried coconut leaves were used for trailing on ground.

3.4 Method

3.4.1 Design and lay out

Split plot design with four replications was adopted for the lay out of the experiment, with trailing systems as main plot treatments and population densities as sub plot treatments. The details of the lay out were as follows.

Net plot size	6m2
No. of main plots	3
No. of sub plots	6
Replication	4
Total no. of plots	72

The lay out is shown in Fig. 1

3.4.2 Treatments

Main plot	4 (Trailing systems)
Sub plot	6 (Population densities)
Total	24

3.4.2.1 Trailing methods

T_1 - Trailing on ground

T_2 - Trailing on twigs/trellises

T_3 - Trailing on pandals

3.4.2.2 Population density

D_1 - 13,000 plants/ha (spacing 1.50X0.50 m)

D_2 - 26,666 plants/ha (spacing 1.50X0.25 m)

D_3 - 20,000 plants/ha (spacing 1.00X0.50 m)

D_4 - 40,000 plants/ha (spacing 1.00X0.25 m)

D_5 - 26,000 plants/ha (spacing 0.75X0.50 m)

D_6 - 53,333 plants/ha (spacing 0.75X0.25 m)

3.4.3 Field culture

3.4.3.1 Land preparation

The experimental field was dug twice, weeds removed, clods broken and levelled and the field was laid into main plots and sub plots. Each main plot had 24 sub plots, where various population densities were assigned.

3.4.3.2 Fertilizer and Manure application

Package of practice recommendations of Kerala Agricultural University (KAU, 1996) were followed for fertilizer and manure application. The entire dose of phosphorus and potassium and half dose of nitrogen were applied as basal dressing. Remaining half dose of nitrogen was applied after twenty five days of sowing.

3.4.3.3 Seeds and sowing

The seeds were sown in channels as per the spacings assigned to the sub plot treatments.

3.4.3.4 After cultivation

Fifteen days after sowing, the population density was adjusted to one in each hill, in the sub plot. The vines were trailed under different trailing systems given, when they started trailing.

The vines were trailed on dried coconut leaves which were spread on the interspaces of the channels for the first treatment (T1). For T2 each plant was allowed to trail on branched bamboo twigs of 6 feet height. In T3, vines were trailed on the pandals in a regular fashion after making pandals, using casuarina poles of 6 feet height and coir ropes.

The plot was kept free of weeds, by regular weeding operations. The field was irrigated every day.

3.4.3.5 Plant Protection

Thiride at the rate of 1g/litre was drenched at 2-3 leaf stage as a prophylactic measure against damping off. Immediately after sowing carbofuran was used at the rate of 0.5 kg/ha against insects during the early stages of growth. After the flowering stage, no plant protection chemicals were used.

3.4.3.6 Harvesting

Harvesting was done two days after pollination when the fruits attained the size of 5-7 cms. The fruits were harvested every day based on visual observations of maturity.

3.4.4 Observations

Four plants from each plot were taken, observations made average worked and recorded as follows.

3.4.4.1 Days to first male flower opening

The number of days taken from sowing to opening of first male flower was recorded.

3.4.4.2 Days to first female flower opening

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

3.4.4.3 Node to first female flower

Observations made from the basal portion of the plant to the one at which the first female flower opened.

3.4.4.4 Days to first harvest

Observation of the duration from sowing to first harvest of the fruits from two observation plants in each treatment was made and recorded in days.

3.4.4.5 Branches per plant

The number of branches/plant was counted, after the final harvest.

3.4.4.6 Main vine length (cm)

After the final harvest the vine was earthened up and the length from the collar region to the tip of the main vine was measured, using measuring tape and expressed in centimetres.

3.4.4.7 Fruits/plot

Observations of the total number of fruits from each plot were taken and averages worked out.

3.4.4.8 Fruits/plant

Observations of the total number of fruits from each plant in each plot were taken and average worked out.

3.4.4.9 Marketable fruits

The total number of marketable fruits without any crooked, bent, curved shapes, disease or insect damaged fruits were separately counted in each plot and average recorded.

3.4.410 Unmarketable fruits

The total number of unmarketable fruits, such as of crooked, bent, curved, diseased or insect damaged fruits were separately counted in each plot and average recorded.

3.4.4.11 Average fruit weight (g)

Average weight of two fruits each from observation plants were wroked out at third harvest and expressed in grams.

3.4.4.12 Fruit length (cm)

After removal of the dried up corolla, average length of the fruit was measured from the tip to the stalk end and expressed in centimetres.

3.4.4.13 Fruit volume (cm^3)

The same fruits used for length and girth measurements were immersed in water in a measuring jar one by one and the initial and final readings of the water levels were recorded. The difference was calculated by subtraction and expressed in centimeter cube.

3.4.4.14 Fruit diameter (cm)

The fruits used for measuring the fruit volume were cut in to two halves and the diameter at the middle measured and averages worked out and expressed in centimetre.

3.4.4.15 Rind thickness (mm)

The same fruits used for length measurement were taken and cut at the middle and average rind thickness recorded using vernier callipers and expressed in millimetres.

3.4.4.16 Flesh thickness (cm)

The same fruits used for rind measurement were taken and cut at the middle and average flesh thickness recorded using ordinary measuring scale and expressed in centimetres.

3.4.4.17 L/B ratio of fruit

The length/breadth ratio was worked out for the same fruits which were used for the rind thickness measurement.

3.4.4.18 Seeds/fruit

Two fruits in each plot were retained and allowed to ripen and average number of seeds obtained from each plot were recorded after harvest and seed extraction. Only physical method of extraction was undertaken.

3.4.4.19 100 seed weight (g)

The same fruits used for measuring number of seeds were taken. Using an electronic balance, 100 randomly selected seeds from each fruit were weighed and average worked out and recorded in grams.

3.4.4.20 Marketable Yield /plot (Kg)

Observations of total weight of marketable fruits from each plot from all harvests were recorded and expressed in kilograms.

3.4.4.21 Marketable Yield/plant (Kg)

Observations of total weight o marketable fruits from each observation plant in each plot from all harvests were recorded and expressed in kilograms.

3.4.4.22 T.S.S. (%)

Total Soluble Solids in four randomly selected fruits from all plots were observed using a hand refractometer and expressed in percentage.

3.4.4.23 Incidence of pest and diseases

Visual observations of the attack of fruit fly and diseases were made through out the duration of the crop and the number of unmarketable fruits per plot due to pest and disease incidence, is taken as a measure of the degree of pest and disease attack.

3.4.4.24 Total sugar (%)

Six randomly selected fruits from the observation plant of each plot were taken and chemically analyzed to know the total sugars and expressed in percentage.

3.4.4.25 Reducing sugar (%)

Six randomly selected fruits from the observation plant of each plot were taken and chemically analyzed to know the reducing sugars and expressed in percentage.

3.4.4.26 Non reducing sugar (%)

Six randomly selected fruits from the observation plant of each plot were taken and chemically analyzed to know the non reducing sugars and expressed in percentage.

3.4.4.27 Crop duration (days)

Duration of the four observation plant of each plot was counted from date of sowing to the date of final harvest was recorded and averages worked out and expressed in days.

3.4.4.28 Economics of cultivation

The economics of cultivation was worked out based on the various input cost.

$$\text{Net income (Rs. ha}^{-1}\text{)} = \text{Gross income} - \text{Cost of cultivation}$$

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

3.4.4.29 Statistical analysis

The technique of analysis of variance for split plot design (Gomez and Gomez, 1984) was used for analyzing the experimental data and results tabulated.

Critical differences (5% and 1% levels) were worked out for multiple comparisons among the means, whenever the effects turned significant. Main plot effects, sub plot effects, and their interaction effects were compared using the multiple comparisons of their respective means. The break up of the degrees of freedom (Df) in the analysis of variance with reference to the present study is furnished.

Source	Df
Replications	3
Main Plot	
Trailing systems (T)	2
Error (a)	6
Sub plot	
Population density (D)	5
Interactions	
Trailing systems X Population density (T X D)	10
Error (b)	45
Total	**71**

Treatment Combinations

T_1	-	T_1D_1	T_7	-	T_2D_1	$T1_3$	-	T_3D_1
T_2	-	T_1D_2	T_8	-	T_2D_2	T_{14}	-	T_3D_2
T_3	-	T_1D_3	T_9	-	T2D3	T_{15}	-	T_3D_3
T_4	-	T_1D_4	T_{10}	-	T2D4	T_{16}	-	T_3D_4
T_5	-	T_1D_5	T_{11}	-	T2D5	T_{17}	-	T_3D_5
T_6	-	T_1D_6	T_{12}	-	T_2D_6	T_{18}	-	T_3D_6

Fig.1 Lay out of the experiment

Replication I

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

Replication II

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

Replication III

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

Replication IV

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

Results

4. RESULTS

The experimental results showing the response of gherkin (*Cucumus sativus* L.) to various trailing systems (T) and population densities (D) are furnished in this chapter. The data on earliness, morphological traits, yield and yields attributes were statistically analysed and their direct and interaction effects worked out and furnished in the Tables 1 to 29. The results are categorized under the following subheads.

Earliness and flowering

Morphological characters

Yield and yield characters

Quality characters

4.1 Earliness and flowering

4.1.1 Days to first male flower opening

4.1.1.1 Effect of trailing systems

Different trailing systems exerted significant influence on earliness and flowering of gherkins. Plants trailed on twig system (T_2) (Plate 2) which was on par with those on ground system (T_1) (Plate 1) were earlier than those (Table 1) trailed on pandals (T_3) (37.28) (Plate 3).

4.1.1.2 Effect of population density

Population density levels were not significantly different for days to male flower opening.

Plate 1 Treatment T_1 – Trailing on mulched ground

Plate 2 Treatment T_2 – Trailing on twigs

Plate 3 Treatment T_3 – Trailing on pandals

Plate 4 Different stages – male flower, female flower, opened female flower, female flower after pollination, gherkin, deshaped gherkin and overgrown fruit

4.1.1.3 Effect of T x D interaction

The T x D interaction was not significantly different for days to first male flower opening.

4.1.2 Days to first female flower opening

4.1.2.1 Effect of trailing system

Various trailing systems significantly influenced the days to first female flower opening in gherkins (Table 2). Plants trailed on twigs (T_2) were earliest (42.22) while those trailed on mulches (T_1) were latest (43.99).

4.1.2.2 Effect of population density

Population density significantly affected the days to first female flower opening in gherkin. Plants at densities at 26,666 plants/ha (D_2) 40,000 plant/ha (D_4) and 26,000 plant /ha (D_5) were significantly earlier and were on par. Population densities at 53,333 plants/ha (D_6), 13,00 plants/ha (D_1) and 20,000 plants /ha (D_3) were significantly late for days to first female flower opening (Fig. 2).

4.1.2.3 Effect of T X D interaction

The interactions among various treatment combinations were significant for days to first female flower opening.

Analysis of the experimental data showed that among the T_1 treatment combinations, T_1D_1 was earliest (42.83) and on par with T_1 D_2 and T_1D_5. The treatment combinations T_1D_1 and T_1D_3 were significantly later.

Table 1 Effect of trailing systems, population density and their interaction on days to first male flower opening

	D_1	D_2	D_3	D_4	D_5	D_6	Mean (T)
T_1	36.15	36.69	36.40	36.44	36.81	36.86	36.56
T_2	36.64	36.80	36.94	36.82	36.65	36.84	36.78
T_3	37.75	37.22	36.94	37.41	37.22	37.17	37.28
Mean (D)	36.85	36.90	36.76	36.89	36.89	36.95	

C.D. (P=0.05)
Trailing systems (T) – 0.42
Population density (D) – N.S.
T x D – N.S.

Table 2 Effect of trailing systems, population density and their interaction on days to first female flower opening (day)

	D_1	D_2	D_3	D_4	D_5	D_6	Mean (T)
T_1	45.08	43.50	45.00	42.83	43.67	43.89	43.99
T_2	42.53	41.61	42.55	42.31	42.44	41.89	42.22
T_3	42.50	42.50	42.89	42.66	42.80	43.83	42.86
Mean (D)	43.37	42.54	43.48	42.60	42.97	43.20	

C.D. (P=0.05)
Trailing systems (T) – 0.63
Population density (D) – 0.52
T x D –0.90

Table 3 Effect of trailing systems, population density and their interaction on the node to first female flower opening

	D_1	D_2	D_3	D_4	D_5	D_6	Mean (T)
T_1	14.83	10.33	9.61	9.75	10.50	14.44	11.58
T_2	7.44	7.72	9.39	9.69	8.40	8.89	8.59
T_3	12.05	14.50	9.89	12.11	12.97	10.78	12.05
Mean (D)	11.44	10.85	9.63	10.51	10.62	11.37	

C.D. (P=0.05)
Trailing systems (T) – 2.86

Population density (D) – N.S.
T x D – 1.67

Table 4 Effect of trailing systems, population density and their interaction on the days to first harvest

	D_1	D_2	D_3	D_4	D_5	D_6	Mean (T)
T_1	51.00	48.67	49.33	48.67	48.67	51.00	49.55
T_2	45.33	46.67	46.33	45.00	46.00	46.00	45.89
T_3	47.00	46.67	46.00	47.00	46.67	46.67	46.67
Mean (D)	47.78	47.33	47.22	46.89	47.11	47.89	

C.D. (P=0.05)
Trailing systems (T) – 1.19

Population density (D) – N.S.
T x D – N.S.

Among the T_2 treatment combinations, T_2D_2 (41.61) was earliest for days to first female flower opening and was on par with T_2D_5, T_2D_4 and T_2D_6. The interaction T_2D_3 and T_2D_1 were (42.55), (42.53) latest and on par.

Among the T_3 treatment combinations T_3D_1 and T_3D_2 (42.50) were earlier for days to first female flower opening and were on par with other interactions except T_3D_6 (43.83) which was the latest compared to all other interactions.

4.1.3 Node to first female flower opening

4.1.3.1 Effect of trailing system

Plants trailed on the twig system (T_2) had first female flowers on the lower nodes (8.59) than T_1 and T_3 which were on par (Table 3).

4.1.3.2 Effect of population density

The differences between various population densities were insignificant on the node to first female flower opening.

4.1.3.3 Effect of T x D interaction

In ground system (T_1), the interaction effects T_1D_1 and T_1D_6 significantly differed for node to first female flower opening. T_1D_3 (9.61) recorded lowest node for first female flower opening and was on par with all other interaction effects except T_1D_1 and T_1D_6 which recorded highest nodes for first female flower opening.

In twig system (T_2) the interactions T_2D_2, T_2D_1, T_2D_5 and T_2D_6 were on par and lower for node to first female flower opening than T_2D_3 (9.39) and T_2D_4 (9.69).

4.1.4 Days to first harvest

4.1.4.1 Effect of trailing system

The differences among the trailing systems were statistically significant for days to first harvest in gherkin. The plants trailed in the twig system (T_2) recorded minimum days to first harvest (45.89). The plants trailed in the ground system (T_1) recorded maximum days to first harvest (49.55) (Table 4).

4.1.4.2 Effect of population density

The difference among various population density levels were not significant for days to first harvest.

4.1.4.3 Effect of T x D interaction

T x D interaction was not significant for days to first harvest.

4.2 Morphological characters

4.2.1 Branches / plant

4.2.1.1 Effect of trailing system

All the trailing systems significantly influenced the number of branches per plant (Table 5). Plants trailed in the pandal system (T_3) recorded maximum branches (2.0). Branches were minimum (1.59) in plants trailed on ground (T_1).

4.2.1.2 Effect of population density

Differences among various population density levels were not significant for number of branches per plant.

4.2.1.3 Effect of T x D interaction

The differences among T x D interaction were not significant.

4.2.2 Vine length

The vine length was unaffected by the trailing systems, population densities and their interactions (Table 6).

4.3 Yield and yield components

4.3.1 Fruits/ plot

4.3.1.1 Effect of trailing system

Plants trailed on Twigs (T_2) recorded maximum fruits /plot (182.67) and were on par with pandal system (T_3). Plants trailed on mulches (T_1) recorded least number of fruits / plot (84.00) (Table 7 and Fig. 4).

4.3.1.2 Effect of population density

Fruits /plot were significantly affected by the population density. Maximum number of fruits (217.78) was obtained from the plots with the highest density of population (D_3) followed by D_4 and D_5.

4.3.1.3 Effect of T x D interaction

The interaction between trailing system and population density was significant for fruits /plot. In all the trailing systems plots with the highest population density had maximum number of fruits. Plants trailed on twigs with the highest population density (T_2D_6) had maximum fruits/plot (264) among all the treatment combinations.

4.3.2 Fruits / plant

4.3.2.1 Effect of trailing system

Plants trailed on pandal system (T_3) which was on par with Twig system (T_2) recorded maximum fruits/ plant (15.2) than those trailed on ground (6.00) (Table 8 and Fig. 3).

4.3.2.2 Effect of population density

The population density significantly affected the number of fruits per plant. It was maximum at the lower levels and minimum at the highest levels.

4.3.2.3 Effect of T x D interaction

Interaction effect was also significant for fruits/plant. Maximum fruits/plant (25.50) was observed on pandal grown plants at the second lowest level of population density followed by the plants on twigs at the same population. Fruits/plant were in general less in ground trailed plants at all population levels, the highest density having the least value (4.60).

4.3.3 Unmarketable fruits/plot

4.3.3.1 Effects of trailing system

The ground system (T_1) recorded least number of unmarketable fruits / plot (50.43). This was followed by the pandal system (69.17). Maximum unmarketable fruits/plot was obtained from plants trailed on twigs (92.78) (Table 9).

4.3.3.2 Effect of population density

Population density significantly affected the presence of unmarketable fruits/plot. It was minimum (35.11) in plots having the lowest density. The

Table 5 Effect of trailing systems, population density and their interaction on the number of branches per plant

	D_1	D_2	D_3	D_4	D_5	D_6	Mean (T)
T_1	1.58	1.42	1.42	1.43	2.27	1.45	1.59
T_2	3.42	1.10	2.25	1.45	1.48	1.47	1.86
T_3	2.98	2.38	1.50	1.50	1.38	2.23	2.00
Mean (D)	2.66	1.63	1.46	1.46	1.71	1.72	

C.D. (P=0.05)
Trailing systems (T) – 0.09
Population density (D) – N.S.
T x D – N.S.

Table 6 Effect of trailing systems, population density and their interaction on the vine length (m)

	D_1	D_2	D_3	D_4	D_5	D_6	Mean (T)
T_1	1.77	1.83	1.83	1.80	1.97	1.67	1.81
T_2	1.77	1.76	1.93	1.83	1.57	1.67	1.75
T_3	1.62	1.88	1.63	1.67	1.83	1.57	1.70
Mean (D)	1.72	1.82	1.80	1.77	1.79	1.63	

C.D. (P=0.05)
Trailing systems (T) – N.S.
Population density (D) – N.S.
T x D – N.S.

Table 7 Effect of trailing systems, population density and their interaction on the total number of fruits per plot

	D_1	D_2	D_3	D_4	D_5	D_6	Mean (T)
T_1	44.00	82.67	56.00	114.67	77.33	129.33	84.00
T_2	93.33	169.33	150.67	222.67	196.00	264.00	182.67
T_3	92.00	153.33	120.00	225.33	205.33	260.00	176.00
Mean (D)	76.44	135.11	108.89	187.55	159.55	217.78	

C.D. (P=0.05)
Trailing systems (T) – 37.78
Population density (D) – 21.75
T x D – 26.50

Table 8 Effect of trailing systems, population density and their interaction on the total number of fruits per plant

	D_1	D_2	D_3	D_4	D_5	D_6	Mean (T)
T_1	7.3	5.9	6.3	5.4	6.5	4.6	6.0
T_2	15.5	18.6	16.7	10.7	16.3	10.5	14.7
T_3	15.3	25.5	13.3	10.6	17.1	9.3	15.2
Mean (D)	12.7	16.7	12.1	8.9	13.3	8.1	

C.D. (P=0.05)
Trailing systems (T) – 2.86
Population density (D) – 2.1
T x D – 2.3.

Table 9 Effect of trailing systems, population density and their interaction on the number of unmarketable fruits per plot

	D_1	D_2	D_3	D_4	D_5	D_6	Mean (T)
T_1	24.00	47.00	32.67	66.25	51.00	81.67	50.43
T_2	45.33	86.00	75.00	112.33	99.67	138.33	92.78
T_3	36.00	57.67	44.33	87.00	83.00	107.00	69.17
Mean (D)	35.11	63.35	50.67	88.53	77.89	109.00	

C.D. (P=0.05)
Trailing systems (T) – 17.20
Population density (D) – 15.70
T x D – N.S.

Table 10 Effect of trailing systems, population density and their interaction on the number of marketable fruits per plot

	D_1	D_2	D_3	D_4	D_5	D_6	Mean (T)
T_1	26.00	29.67	32.33	41.50	38.67	63.67	38.64
T_2	48.00	83.33	75.67	110.33	96.33	125.67	89.89
T_3	56.00	95.67	75.67	138.33	122.33	153.00	106.83
Mean (D)	43.33	69.55	61.22	96.72	85.78	114.11	

C.D. (P=0.05)
Trailing systems (T) – 23.06
Population density (D) – 22.1
T x D – N.S.

Fig. 2 Effect of trailing systems, population density and their interaction on days to first female flower opening

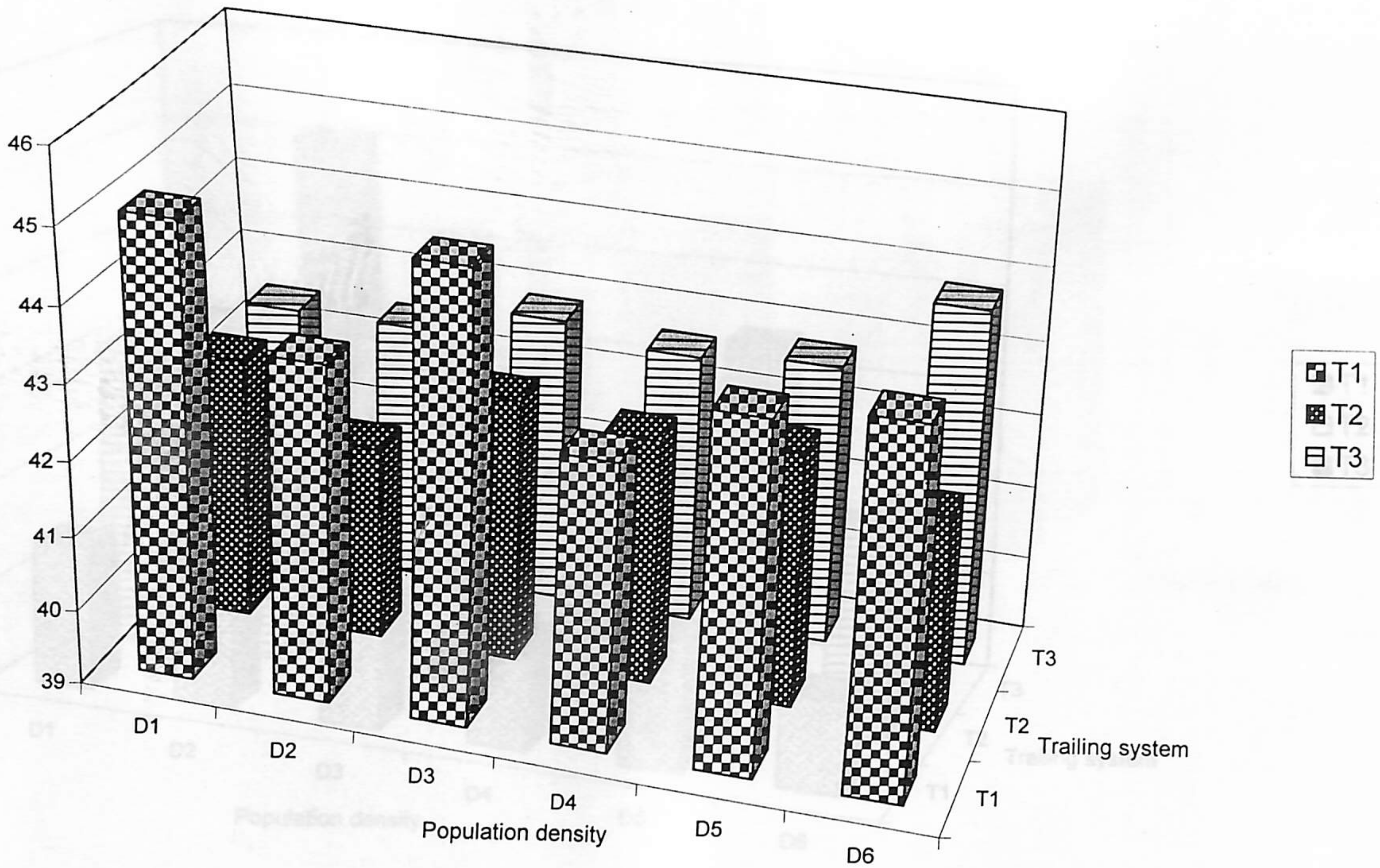


Fig. 3 Effect of trailing systems, population density and their interaction on the total number of fruits per plant

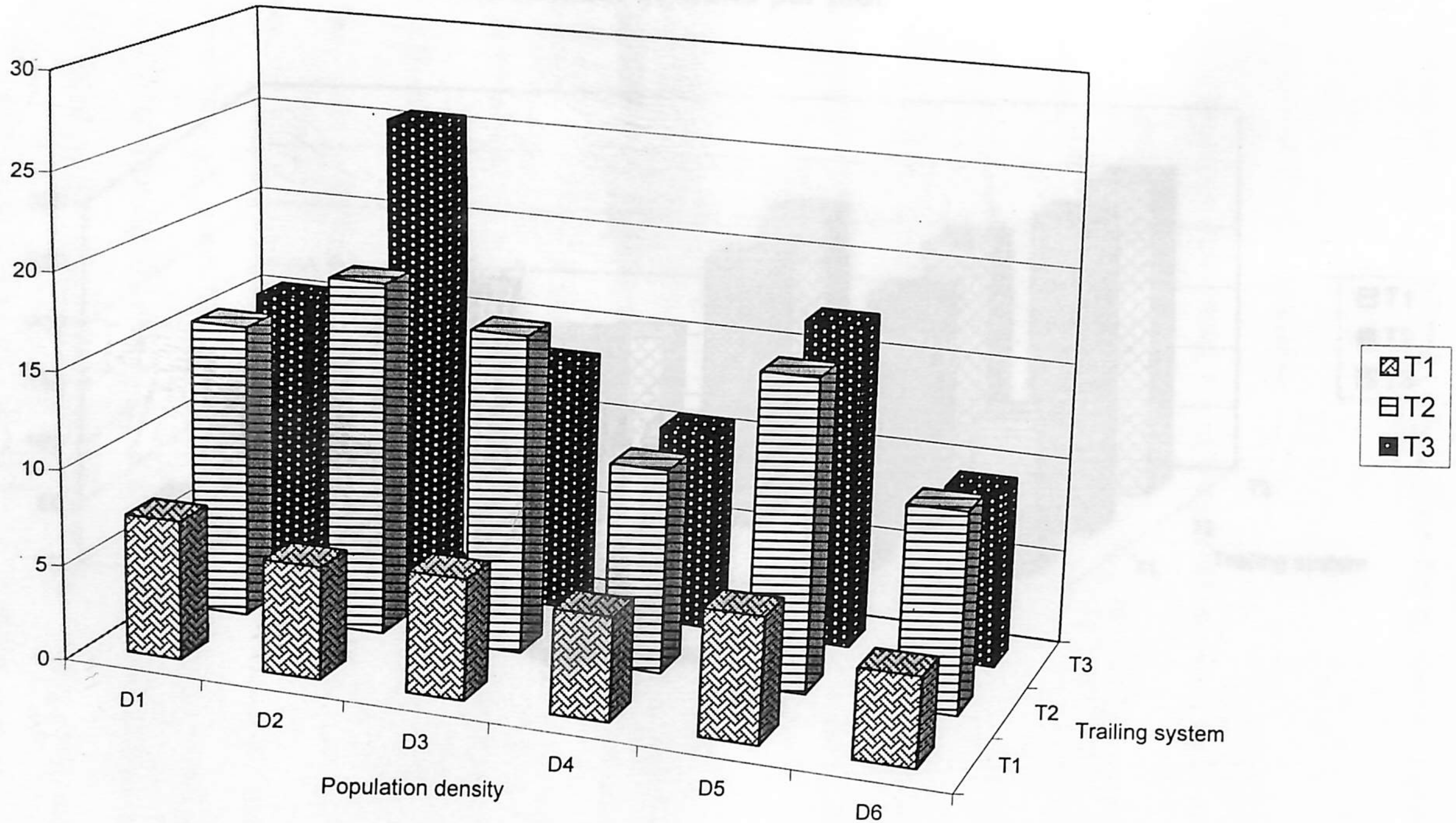
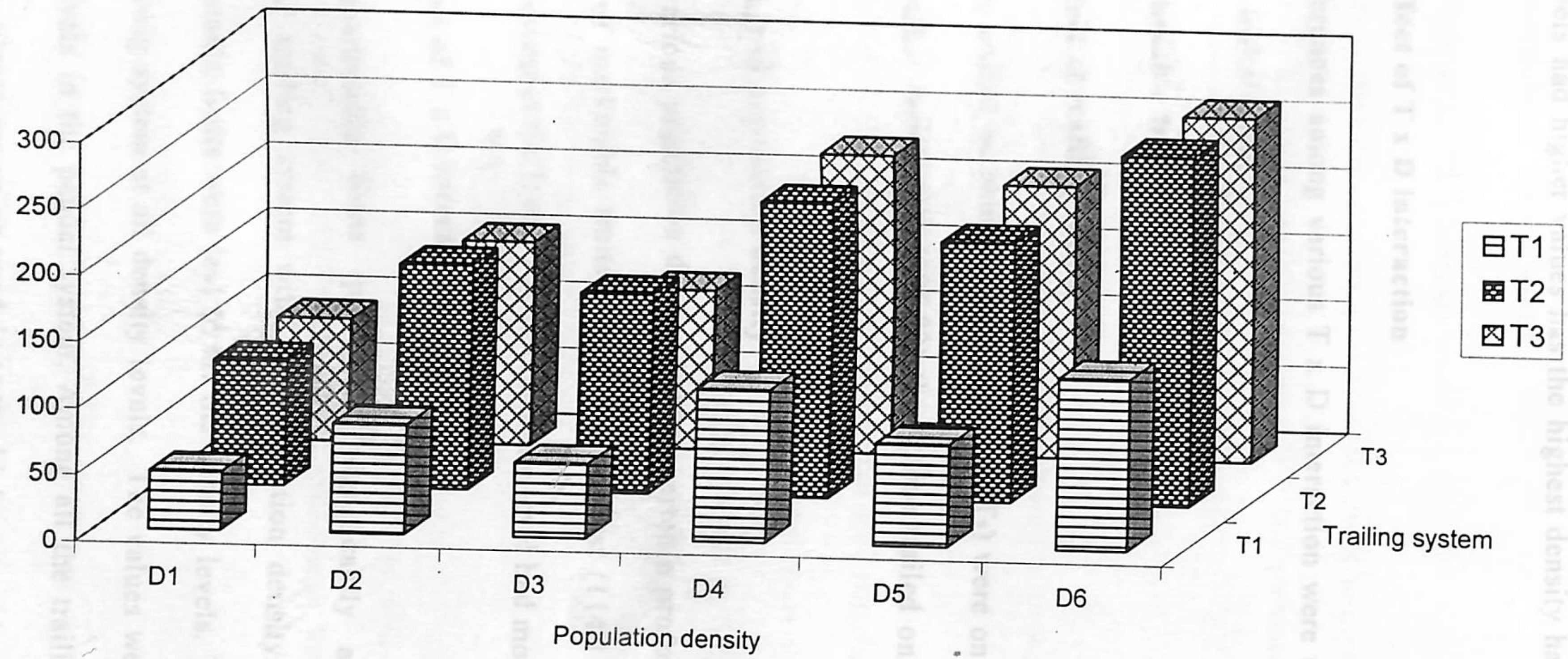


Fig. 4 Effect of trailing systems, population density and their interaction on the total number of fruits per plot



highest levels had higher values has the highest density had the higher value (109).

4.3.3.3 Effect of T x D interaction

Differences among various T x D interaction were not significant for marketable fruits/ plant.

4.3.4 Marketable fruits/ plot

4.3.4.1 Effect of trailing system

Plants trailed on pandals (T_3) and twigs (T_2) were on par and recorded more marketable fruits/ plot (106.83) than those trailed on mulches (Table 10) (38.64).

4.3.4.2 Effect of population density

The various population density levels exerted a profound influence on the number of marketable fruits/plot. It was highest (114.11) at the highest density and lowest at the level. The intermediate level had moderate values.

4.3.4.3 Effect of T x D interaction

The marketable fruits /plot were significantly affected by the interaction of trailing system with the population density. Under ground system marketable fruits were less in all the density levels. The values were moderate in twig system at all density levels. The values were higher under all density levels in the pandal system. Among all the trailing systems and density levels, plants grown as pandals at the highest population level (T_3D_2) had the maximum number of fruits /plot (153)

4.3.5 Unmarketable fruits / plant

4.3.5.1 Effect of trailing system

Plants trailed on mulches (T_1) recorded least number of unmarketable fruits/ plant (2.95) plants trailed on twigs (T_2) and pandals (T_3) were on par for number of unmarketable fruits/plant (Table 11).

4.3.5.2 Effect of population density

Differences among various population densities were not significant.

4.3.5.3 Effect of T x D interaction

The interaction effects of trailing system and population density were significant for unmarketable fruits /plant. In general these values were less in all population levels under ground system, the lowest by T_1D_6 (2.47), highest value was observed in T_3D_2 (11.80) followed by T_3D_5 and T_2D_3.

4.3.6 Marketable fruits /plant

4.3.6.1 Effect of trailing system

Plants trailed on pandals (T_3) which was on par with twig system (T_2) recorded more marketable fruits/plant (7.78) than those trailed on mulches (T_1) (Table 12).

4.3.6.2 Effect of population density

Marketable fruits /plot were maximum (7.45) in plants grown at the second lower population level (D_2). It was minimum (4.10) at the highest density.

4.3.6.3 Effect of T x D interaction

The interaction between the trailing system and population density was also significant for marketable fruits /plant. Under ground system marketable fruits were (3.77) in plants grown at the lowest and minimum (2.13) at the highest density. Under pandal system highest value (13.73) was in T_3D_2 and the lowest (4.50) in T_3D_6. Among all the combinations T_3D_2 had the higher value (13.73).

4.3.7 Marketable yield /plot

4.3.7.1 Effect of trailing system

Plants trailed on pandals (T_3) was on par with twig system (T_2) and superior for marketable fruits/plot (1.67) to those trailed on mulches (T_1) (Table 13).

4.3.7.2 Effect of population density

Marketable yield/plot was significantly affected by the population density. Among the various levels D_6 recorded the highest yield (2.14) followed by D_4, D_5 and the lower levels.

4.3.7.3 Effect of T x D interaction

T x D interaction significantly influenced the marketable yield / plot. Under T_1 combination T_1D_6 had highest value (1.08) followed by T_1D_4 and T_1D_5. Under T_2 combination it was maximum (2.45) in T_2D_6 followed by T_2D_4. Among T_3 combination maximum yield (2.89) was in T_3D_6 followed by T_3D_4 (2.17) and T_3D_5 (2.07). Among all the combinations the highest yield was recorded from T_3D_6 (2.89) and the minimum (0.27) from T_1D_1.

4.3.8 Marketable yield/plant

4.3.8.1 Effect of trailing system

Plants trailed on twig system (T_2) which was on par with pandal system (T_3) recorded maximum marketable fruit yield per plant compared to those trailed on mulches (T_1) (Table 14).

4.3.8.2 Effect of population density

Population density significantly influenced marketable yield /plant. The higher values were observed in D_5 (122.18) followed by D_3 (96.37) which was on par with D_1 (95.07). The lower values were observed in D_4 (72.59) and D_6 (76.40).

4.3.8.3 Effect of T x D interaction

Marketable yield /plant was influenced by the interaction of trailing systems with population density levels. Under ground system highest value (53.70) was observed in T_1D_5 and lower values in T_1D_2, T_1D_4 and T_1D_6. In the T_2 combinations it was higher in T_2D_5 (131.42) and lowest in T_2D_6 (87.19). In T_3 combinations T_3D_5 had maximum values (176.61). Among all the combinations of trailing system and population density the highest value (176.61) was observed in T_3D_5.

4.3.9 Average fruit weight

Average fruit weight in gherkin was not influenced by trailing systems, population densities and their interactions ((Table 15).

Table 11 Effect of trailing systems, population density and their interaction on the number of unmarketable fruits per plant

	D_1	D_2	D_3	D_4	D_5	D_6	Mean (T)
T_1	3.57	2.63	3.03	2.93	3.07	2.47	2.95
T_2	7.80	5.17	8.03	5.27	7.77	4.80	6.47
T_3	7.63	11.80	6.57	4.87	8.73	4.80	7.40
Mean (D)	6.33	6.53	5.88	4.35	6.52	4.02	

C.D. (P=0.05)
Trailing systems (T) – 1.15
Population density (D) – N.S.
T x D – 1.20

Table 12. Effect of trailing systems, population density and their interaction on the number of marketable fruits per plant

	D_1	D_2	D_3	D_4	D_5	D_6	Mean (T)
T_1	3.77	3.23	3.23	2.47	3.47	2.13	3.05
T_2	7.73	5.40	8.70	5.40	8.57	5.67	6.91
T_3	7.70	13.73	6.77	5.67	8.33	4.50	7.78
Mean (D)	6.40	7.45	6.23	4.51	6.79	4.10	

C.D. (P=0.05)
Trailing systems (T) – 1.67
Population density (D) – 1.71
T x D – 1.20

Table 13 Effect of trailing systems, population density and their interaction on marketable yield per plot (kg)

	D_1	D_2	D_3	D_4	D_5	D_6	Mean (T)
T_1	0.27	0.49	0.42	0.83	0.66	1.08	0.62
T_2	0.53	1.41	1.16	2.12	1.64	2.45	1.55
T_3	0.76	1.09	1.05	2.17	2.07	2.89	1.67
Mean (D)	0.52	0.99	0.87	1.70	1.46	2.14	

C.D. (P=0.05)
Trailing systems (T) – 0.23
Population density (D) – 0.20
T x D – 0.25

Table 14 Effect of trailing systems, population density and their interaction on the marketable fruit yield per plant (g)

	D_1	D_2	D_3	D_4	D_5	D_6	Mean (T)
T_1	45.89	35.13	47.23	37.95	53.70	38.78	43.11
T_2	111.56	122.82	126.96	101.21	136.42	87.19	114.36
T_3	127.75	78.11	114.93	78.61	176.61	103.23	113.17
Mean (D)	95.07	78.68	96.37	72.59	122.18	76.40	

C.D. (P=0.05)
Trailing systems (T) – 18.54
Population density (D) – 19.40
T x D – 20.18

Table 15 Effect of trailing systems, population density and their interaction on the average fruit weight (g)

	D_1	D_2	D_3	D_4	D_5	D_6	Mean (T)
T_1	7.1	7.4	7.8	8.3	7.7	7.0	7.6
T_2	6.9	7.5	11.1	12.0	5.7	7.6	8.5
T_3	7.6	10.0	5.8	9.4	7.2	8.5	8.1
Mean (D)	7.2	8.3	8.2	9.9	6.9	7.7	

C.D. (P=0.05)
Trailing systems (T) – N.S. Population density (D) – N.S.
T x D – N.S.

Table 16 Effect of trailing systems, population density and their interaction on the fruit volume (cm^3)

	D_1	D_2	D_3	D_4	D_5	D_6	Mean (T)
T_1	6.0	6.8	7.9	7.0	8.0	6.8	7.1
T_2	6.6	7.5	11.2	11.5	5.4	6.9	8.2
T_3	7.0	9.5	6.0	7.8	6.8	8.2	7.5
Mean (D)	6.5	7.9	8.4	8.8	6.7	7.3	

C.D. (P=0.05)
Trailing systems (T) – N.S. Population density (D) – N.S.
T x D – N.S.

4.3.10 Fruit volume

Fruit volume in gherkin was not affected by various trailing systems, population densities and their interacting (Table 16).

4.3.11 Fruit diameter

Fruit diameter was not influenced by various trailing systems, population densities and their interactions (Table 17).

4.3.12 Flesh Thickness

Flesh thickness was unaffected by trailing system, population density and their interaction (Table 18).

4.3.13 Rind thickness

Rind thickness was not influenced by various trailing systems, population densities and their interacting (Table 19).

4.3.14 Fruit length

Fruit length was not influenced by various trailing system, population densities and their interactions (Table 20)

4.3.15 L/B ratio

L/B ratio of gherkin was not influenced by trailing systems, population densities and their interactions (Table 21).

4.3.16 Seeds/Fruit

4.3.16.1 Effect of trailing systems

Plants trailed on all the trailing systems different significantly for seeds/ fruit. Maximum seeds/ fruit was obtained from plants trailed on twigs (326.56) and minimum from plants trailed on mulches (T_1) (262.43) (Table 22).

Table 17 Effect of trailing systems, population density and their interaction on the fruit diameter (cm)

	D_1	D_2	D_3	D_4	D_5	D_6	Mean (T)
T_1	4.9	4.5	5.1	5.6	4.9	4.6	4.9
T_2	4.8	5.0	4.9	5.0	4.8	5.0	4.9
T_3	4.7	5.1	4.6	5.3	4.6	4.9	4.9
Mean (D)	4.8	4.9	4.9	5.3	4.7	4.8	

C.D. (P=0.05)
Trailing systems (T) – N.S.
Population density (D) – N.S.
T x D – N.S.

Table 18 Effect of trailing systems, population density and their interaction on the flesh thickness of fruit (cm)

	D_1	D_2	D_3	D_4	D_5	D_6	Mean (T)
T_1	0.85	0.90	0.87	0.98	0.85	0.93	0.90
T_2	0.92	0.93	0.88	1.13	0.87	0.93	0.94
T_3	1.00	1.05	0.87	0.95	0.87	1.00	0.95
Mean (D)	0.92	0.96	0.87	1.02	0.86	0.95	

C.D. (P=0.05)
Trailing systems (T) – N.S.
Population density (D) – N.S.
T x D – N.S.

Table 19 Effect of trailing systems, population density and their interaction on the rind thicknes (mm) of fruit

	D_1	D_2	D_3	D_4	D_5	D_6	Mean (T)
T_1	1.77	1.83	1.83	1.80	1.97	1.67	1.81
T_2	1.77	1.76	1.93	1.83	1.57	1.67	1.75
T_3	1.62	1.88	1.63	1.67	1.83	1.57	1.70
Mean (D)	1.72	1.82	1.80	1.77	1.79	1.64	

C.D. (P=0.05)
Trailing systems (T) – N.S.
Population density (D) – N.S.
T x D – N.S.

Table 20 Effect of trailing systems, population density and their interaction on the fruit length (cm)

	D_1	D_2	D_3	D_4	D_5	D_6	Mean (T)
T_1	5.23	5.13	6.37	5.87	5.53	5.47	5.60
T_2	5.55	6.43	5.80	5.60	5.83	6.09	5.88
T_3	5.77	6.04	5.30	5.77	5.42	5.77	5.68
Mean (D)	5.52	5.87	5.82	5.74	5.59	5.77	

C.D. (P=0.05)
Trailing systems (T) – N.S.
Population density (D) – N.S.
T x D – N.S.

Table 21 Effect of trailing systems, population density and their interaction on the L/B ratio of fruit

	D_1	D_2	D_3	D_4	D_5	D_6	Mean (T)
T_1	3.32	3.55	3.93	3.31	3.63	3.78	3.59
T_2	3.64	4.02	3.72	3.50	3.83	3.83	3.76
T_3	3.86	3.73	3.63	3.46	3.69	3.68	3.68
Mean (D)	3.61	3.77	3.76	3.42	3.72	3.76	

C.D. (P=0.05)
Trailing systems (T) – N.S.   Population density (D) – N.S.
T x D – N.S.

Table 22 Effect of trailing systems, population density and their interaction on the number of seeds per fruit

	D_1	D_2	D_3	D_4	D_5	D_6	Mean (T)
T_1	207.94	234.27	211.27	317.36	301.74	302.01	262.43
T_2	346.68	257.26	295.70	350.08	318.58	391.62	326.56
T_3	229.00	242.02	301.61	344.92	281.69	376.13	295.90
Mean (D)	261.21	244.52	269.35	337.45	300.67	356.59	

C.D. (P=0.05)
Trailing systems (T) – 1.82   Population density (D) – N.S.
T x D – N.S.

4.3.16.2 Effect of population densities

Differences among various population density levels were not significant for seeds/fruit.

4.3.16.3 Effect of T x D interaction

The T x D interactions were not significant for seeds/fruit.

4.3.17 100 seed weight

4.3.17.1 Effect of trailing system

Plants trailed on pandals (T_3) which was on par with twig system (T_2) recorded maximum value for 100 seed weight compared to those trailed on mulches (T_1) (2.13) (Table 23).

4.3.17.2 Effect of population densities

Differences among population density levels were not significant for 100 seed weight.

4.3.17.3 Effect of T x D interaction

There was no T x D interaction for 100 seed weight.

4.3.18 Crop duration

4.3.18.1 Effect of trailing system

Crop duration was less (81.83) in gherkins trailed on mulches (T_1) while it was long for plants trailed on pandals (T_3) (84.39) (Table 24).

4.3.18.2 Effect of population densities

Population density levels were not significantly different for crop duration.

Table 23 Effect of trailing systems, population density and their interaction on the weight of 100 seeds (g)

	D_1	D_2	D_3	D_4	D_5	D_6	Mean (T)
T_1	2.20	1.90	2.07	1.80	2.49	2.34	2.13
T_2	1.90	2.53	2.20	1.80	2.82	2.22	2.25
T_3	2.09	2.15	1.86	2.26	2.64	2.64	2.27
Mean (D)	2.06	2.19	2.04	1.95	2.65	2.40	

C.D. (P=0.05)
Trailing systems (T) – 0.05
Population density (D) – N.S.
T x D – N.S.

Table 24 Effect of trailing systems, population density and their interaction on the crop duration (days)

	D_1	D_2	D_3	D_4	D_5	D_6	Mean (T)
T_1	82.33	82.00	80.67	82.00	81.67	82.33	81.83
T_2	80.67	85.33	82.67	82.00	85.00	83.00	83.11
T_3	85.33	84.33	85.00	82.33	83.67	85.67	84.39
Mean (D)	82.78	83.89	82.78	82.11	83.44	83.67	

C.D. (P=0.05)
Trailing systems (T) – 0.56
Population density (D) – N.S.
T x D – N.S.

4.3.18.3 Effect of T x D interaction

Various T x D interaction were not significantly different for crop duration.

4.3.19 Percentage of unmarketable fruits / plot due to pests and diseases

4.3.19.1 Effect of trailing system

Plant trailed on pandals (T_3) had least percentage of unmarketable fruits /plot due to pests and diseases while those trailed on mulches (T_1) had highest (38.85) percentage of unmarketable fruits/plot (60.54). Twig system was intermediate in influencing the percentage of unmarketable fruits/plot (49.47) (Table 25).

4.3.19.2 Effect of population density

Population density levels were not significantly different for percentage of unmarketable fruits/plot due to pest and diseases.

4.3.19.3 Effect of T x D interaction

The interactions were not significantly different for percentage of unmarketable fruits/plot.

4.4 Quality characters

4.4.1 Total soluble solids

Total soluble solids in gherkins were not influenced by the trailing systems, population densities, and their interactions (Table 26).

Table 25 Effect of trailing systems, population density and their interaction on the percentage of unmarketable fruits per plot (%)

	D_1	D_2	D_3	D_4	D_5	D_6	Mean (T)
T_1	55.14	56.89	59.78	62.30	65.92	63.22	60.54
T_2	48.46	50.46	49.51	45.11	50.77	52.51	49.47
T_3	39.07	36.98	37.30	38.75	39.82	41.19	38.85
Mean (D)	47.55	48.11	48.86	48.72	52.17	52.31	

C.D. (P=0.05)
Trailing systems (T) – N.S. Population density (D) – N.S.
T x D – N.S.

Table 26 Effect of trailing systems, population density and their interaction on total soluble solids (per cent)

	D_1	D_2	D_3	D_4	D_5	D_6	Mean (T)
T_1	5.0	5.3	4.9	4.4	4.8	4.8	4.9
T_2	4.2	4.9	4.7	5.0	5.1	4.8	4.8
T_3	5.0	5.0	4.9	4.7	5.2	5.4	
Mean (D)	4.7	5.1	4.8	4.7	5.0	5.0	

C.D. (P=0.05)
Trailing systems (T) – N.S. Population density (D) – N.S.
T x D – N.S.

4.4.2 Total sugar

4.4.2.1 Effect of trailing system

Plants trailed on mulches (T_1) had higher percentage of total sugar content (7.18) than those trailed on twigs (T_2) and pandals (T_3) which were on par (Table 27).

4.4.2.2 Effect of population density

Differences among various population density leads were not significant for total sugar.

4.4.2.3 Effect of T x D interactions

The T x D interactions were not significant for total sugars.

4.4.3 Reducing sugar

Reducing sugar content was not influenced by the trailing system, population densities and their interactions (Table 28).

4.4.4 Non reducing sugar

Non reducing sugar content was not influenced by trailing systems, population densities and their interaction (Table 29).

4.4.5 Economics of production

Details of economic of production was furnished in Table 30. T_2D_6 recorded the highest benefit : cost ratio (2.18) closely followed by T_3D_6. The lowest benefit : cost ratio was observed in T_1D_1 (0.36).

Table 27 Effect of trailing systems, population density and their interaction on total sugar content of fruit (%)

	D_1	D_2	D_3	D_4	D_5	D_6	Mean (T)
T_1	7.14	7.20	7.24	7.18	7.19	7.15	7.18
T_2	7.10	7.12	7.17	7.14	7.14	7.14	7.14
T_3	7.18	7.10	7.14	7.16	7.06	7.16	7.14
Mean (D)							

C.D. (P=0.05)
Trailing systems (T) – 0.04
Population density (D) – N.S.
T x D – N.S.

Table 28 Effect of trailing systems, population density and their interaction on reducing sugar content of fruit (%)

	D_1	D_2	D_3	D_4	D_5	D_6	Mean (T)
T_1	4.56	4.62	4.66	4.65	4.63	4.61	4.62
T_2	4.57	4.61	4.63	4.61	4.60	4.61	4.60
T_3	4.60	4.59	4.61	4.61	4.59	4.58	4.60
Mean (D)	4.57	4.60	4.63	4.62	4.60	4.60	

C.D. (P=0.05)
Trailing systems (T) – N.S.
Population density (D) – N.S.
T x D – N.S.

Table 29 Effect of trailing systems, population density and their interaction on non-reducing sugar content of fruit (%)

	D_1	D_2	D_3	D_4	D_5	D_6	Mean (T)
T_1	2.58	2.58	2.58	2.53	2.56	2.54	2.56
T_2	2.53	2.51	2.54	2.53	2.54	2.53	2.53
T_3	2.58	2.51	2.53	2.55	2.47	2.58	2.54
Mean (D)	2.57	2.53	2.55	2.54	2.52	2.55	

C.D. (P=0.05)
Trailing systems (T) – N.S.
Population density (D) – N.S.
T x D – N.S.

Table 30 Economics of cultivation

Treatments	Cost of cultivation (Rs.)	Yield (T/ha)	Gross income (Rs.)	Benefit : Cost
T_1D_1	25000.00	0.45	9000.00	0.36
T_1D_2	25500.00	0.82	16400.00	0.64
T_1D_3	26000.00	0.70	14000.00	0.54
T_1D_4	26500.00	1.38	27600.00	1.04
T_1D_5	27000.00	1.10	22000.00	0.81
T_1D_6	27500.00	1.87	36000.00	1.31
T_2D_1	35000.00	0.88	17600.00	0.50
T_2D_2	35500.00	2.35	47000.00	1.32
T_2D_3	36000.00	1.93	38600.00	1.07
T_2D_4	36500.00	3.53	70600.00	1.93
T_2D_5	37000.00	2.73	54600.00	1.48
T_2D_6	37500.00	4.08	81600.00	2.18
T_3D_1	45000.00	1.27	25400.00	0.56
T_3D_2	45500.00	1.82	36400.00	0.80
T_3D_3	46000.00	1.75	35000.00	0.76
T_3D_4	46500.00	3.62	72400.00	1.56
T_3D_5	47000.00	3.45	69000.00	1.47
T_3D_6	47500.00	4.82	96400.00	2.03

Discussion

5. DISCUSSION

The phenotypic expression of a plant is the sum total of its genetic set up, environment and the genotype-environmental interaction. The performance of any crop plant in terms of yield, earliness and quality of produce can be improved by subjecting it to a favourable environment. This emphasizes the importance of the potential crop yield. The best management is one which accommodates optimum number of plants per unit area, provides favourable growing conditions and uses nutrients and other chemicals in a judicious manner. The management practices vary with crops for trailing crops like cucurbits, among other things methods of trailing and population density are important factors to be considered for achieving maximum economic returns. This is more so in the case of crops which are trailed on supports.

Gherkin (*Cucumis sativus* L.) is an important crop in Western and Gulf countries. In India also it is gaining importance as an export oriented crop. Experiences of few farmers of the central parts of the state in gherkin cultivation is encouraging. The soil and climatic conditions of the state are good for the growth and yield of gherkins. However, studies on the scientific cultivation, harvesting and processing of gherkin have not been conducted so far. Under this circumstances, the present experiments were undertaken with the objective of understanding the feasibility of gherkin cultivation in the state. As a preliminary study, the investigation aimed at standardizing the trailing system and population density for maximum yield and superior grades of gherkin. The treatments consisted six levels of population densities and three trailing systems. Their direct and interaction effects were studied on growth, yield and quality aspects in gherkin. The results of the experiments are discussed hereunder.

5.1 Trailing systems

The experiment consisted of three trailing system viz. mulched ground, twigs and pandals. The result showed that these systems of trailing profoundly influenced earliness, morphological characters and quality of gherkin.

Among the three methods of trailing earlier male flower opening was noticed in plants trailed on mulched ground and twigs than those trailed on pandals. Earlier female flower production was in plants trailed on twigs. Plants on twig system had female flowers on the lowest nodes. This resulted in earlier harvest also. In the case of trailing crops like gherkins, plants grown on pandals may have faster, vigorous and longer vegetative growth resulting in late initiation of reproductive phase. When compared to pandal systems, plants trailed on ground or twigs may experience some sort of restriction on vegetative growth favouring early onset of reproductive phase. Moreover plants trailed on twigs or mulches have better exposure and aeration resulting in early initiation of flowering. Late flowering in plants trailed on open ground as reported by Joshi *et al.* (1994) and Yadav *et al.* (1989) support the present findings. This also suggests that, flowering in gherkin is better when trailed on twigs, mulches or similar structures. Pandal system is not good enough for flowering. Similar findings are also reported in cucumber by Renji (1998).

Trailing systems affect the morphological characters as well. Plants trailed on pandals had maximum branches/plant and those on ground the minimum. This could be due to better branching conditions available in pandals. Similar findings of Yadav *et al.* (1989) in pointed gourd, Joshi *et al.* (1994) in bittergourd and Renji (1998) in cucumber support the present findings. However the vine length was not affected by the trailing systems.

Trailing systems exerted profound influence on yield and yield components. In the present experiment plants trailed on pandals and twigs yielded more fruit/plot. Fruits/plant also were more in these systems. Plants trailed on ground had minimum number of fruits. Increased number of fruits in plants trailed on twigs and pandals could be due to enhanced fruit set.

In pandals or twigs, plants may experience better microclimate, better photosynthesis and mobilization to fruits, better pollination by bees and better fruit development. All these have contributed to the present increased number of fruits. The earlier findings of more fruits/plant on supports in cucumber by Hosslin (1966); Makus (1989); Renji (1998) and in bittergourd by Joshi *et al.* (1994) support the present findings.

In gherkin, fruit shape and appearance are important (Plate 4). Fruits damaged by insects and pests, deshaped fruits due to improper pollination etc. are not considered as marketable fruits. These unmarketable fruits were minimum in plants trailed on mulched ground. The number of marketable fruits were also less in mulched ground because of less number of total fruits. Despite more number of unmarketable fruits, the marketable fruits were maximum in the pandal and twig system. This is due to more increased total number of fruits in these systems. Eventhough, there is significant difference in total and marketable fruits between pandal and twig system, there were more unmarketable fruits in the twig than the pandal system. This could be due to uniform spread of vines and less chances for pests and diseases resulting in better pollination and consequent fruit development in the pandal system. In twig system there is crowded growth which hinders pollination of all flowers, besides harbouring more pests and disease organisms.

Expressing the figure on a percentage basis gives a better idea. The percentage of unmarketable fruits was least in the pandal system (38.85 %) as against 60.54 per cent in the mulched ground and 49.47 per cent on the twigs. Similar findings were made by Hosslin (1956) who obtained more marketable fruits in vertical espaliers in cucumber. In the present study, the marketable fruits per plot increase from mulched ground to twig and pandal systems. Subedi *et al.* (1997) also proved that, trailing of cucumber using jute strings improved the number of marketable fruits when compared to tree branches or twigs. This is in line with the present study. Shetty and Wehner (1998) also support the present observation.

Marketable yield is most important factor in any crop production. In the present study plants trailed on twigs and pandals had the highest values. As yield is a function of net photosynthates accumulated by plant, plants on pandal had better opportunity for proper photosynthesis and mobilization. Moreover, higher leaf area per vine, better pollination, fruit set and fruit development also contribute to more fruits per plant. This increased number of fruits per plant resulted in higher yield from plants trailed on pandals and twigs than those from flat or open ground. Similar higher yield from plants grown on support have also been reported by several workers confirming the present findings (Hosslin, 1966; Konsler and Strider, 1973; Bakker and Vooren, 1985; Poll *et al.*, 1988; Drevendra and Drevencha, 1990 and Renji, 1998).

Other yield components like average fruit weight, fruit length, fruit volume, fruit diameter, flesh thickness, L/B ratio and rind thickness were not influenced by trailing systems. Quality traits like total soluble solids, reducing and non-reducing sugar content etc. were also not influenced by trailing systems.

5.2 Population density

The number of plants /unit area is an important criteria which decides the vegetative as well as reproductive growth of plant. In the present study population density significantly affected the days to first female flower opening in gherkin. Plants at moderate levels of population density had earlier female flowers compared to highest and lowest levels. In cucurbits the sex expression and sex ratio are highly influenced by the micro-climate like temperature, sunlight and humidity. This is achieved through optimum levels of auxin which is dependent on environmental factors. The lowest as well as highest levels of plant population as observed in the present study are not favourable to early appearance of female flowers. This might have led to the early appearance of female flowers in the moderate population levels.

The population density affected the number of total, marketable and unmarketable fruits /plant. Total number of fruits / plant was maximum at the lowest and minimum at the highest population levels which is a general observation that when plants are grown at wider spacing they get better chances for root and crop growth resulting in more fruits /plant when compared to thickly grown plants. The findings of Renji (1998) that the number of fruits in individual plants decreases with increase in population density is in line with the present finding. Total number of fruits/plant was also influenced by the population density. The number of marketable and unmarketable fruits were also affected by population density. Marketable fruits /plant was more in plants grown at second lowest level of population. It was minimum at the highest density. When plants are grown at optimum or wider spacing. The tendency to produce quality fruits is more than when grown in crowded condition. This could be attributed to low incidence of pest or diseases and better exposure and aeration. This is inline with findings of Renji (1998).

Yield is the most important factor in any managemental study. In the present study marketable yield was significantly affected by population density. Among the various levels the highest density of population (53333 plants /ha) recorded the higher yield followed by the lower levels. This indicate that gherkins can be grown in still closure spacing as the fruits are harvested at very early stages. More number of plants /unit area has contributed the present observation of highest yield / plot with highest population density. Higher fruit yield at higher population density observed earlier in cucumber by Karataev and Salinikova (1983) and Renji (1998), watermelon by Petkov (1970) and pumpkin by Noon (1977) support the present findings.

Fruit and quality attributes were not significantly affected by population density. As gherkins are harvested at immature stage, changes in these attributes might not have developed at the harvest stage.

5.3 Interaction between trailing systems and population density

The effect of interaction between trailing system and population density was significant for days and node to first female flower opening, yield and yield parameters. Among the various treatment combinations plants trailed on twigs at the second lowest density levels flowered earlier. Flowering was late in ground trailed plants at the highest density. Node to first female flower opening was lower in plants trailed on twigs at the lowest density whereas it was in the upper nodes in ground trailed plants at the lowest as well as highest levels. This suggests that for earliness to flowering plants need better exposure and aeration an in the present finding plants trailed on twigs at lower densities were earlier in female flower opening.

Yield and yield components were affected significantly by the interaction of population density and trailing system. Among all the trailing systems, total number of fruits/plot was higher in plants on pandal and twigs at lower populating density levels. When expressed on a unit area basis fruit number was highest, at highest population density in all the trailing systems. This indicate that the increased number of plants at the highest population density levels has contributed to higher number of fruits/plot in the present study. This is in line with the earlier findings of Renji (1998) in cucumber.

The quality of fruits was also affected by the interaction of trailing systems with population densities. Marketable fruits / plot was maximum when plants were trailed on pandals at highest level of population density. It was least when trailed on ground at all density levels. This suggests that for gherkin the pandal system is better for quality products irrespective of population density. As far as marketable fruit yield /plot is concerned it was also highest when plants are grown on pandals at the highest population density. It was minimum in ground trailed plants at the lowest density. This is attributed to more marketable fruits/plant, under pandal system due to favourable plant and better photosynthesis and consequent nutrient mobilization and less incidence of pests and diseases. This is in line with the findings of Joshi *et al.* (1994) in bittergourd and Renji (1998) in cucumber.

In the present study the highest yield /plot with the highest benefit : cost ratio was (2.18) observed in plants trailed on pandals at the highest population density (T_2D_6). This appears to be a low yield with small benefit : cost ratio. The yield /plot in the present study appears to be very low in all the treatments. This may be due to pollination problems, inadequate nutrients, cultivar selected, seasonal effects etc. Gherkin is a new crop in the state, needs further study relating to these problems. Low benefit : cost ratio may also be due to the same level of nutrients applied to all levels of populations. This suggests that with increase in population, nutrient levels are also to be increased for the full expression of yield and yield components. In the present study the highest density of population considered was 53333 plants / ha whereas in other parts a population level exceeding one lakh plants/ha are practiced. This could be another reason for the low yield of gherkin in the present experiment.

Summary

6. SUMMARY

The study entitled 'standardisation of trailing systems and population densities in gherkin (*Cucumis sativus* L.) was carried out at the Instructional Farm, College of Agriculture, Vellayani during January to March 2000. The main objective of the study was the standardisation of trailing systems and population density in Gherkin for maximum yield and acceptable fruit quality.

The experiment was laid out in a split plot design with three trailing systems as the main plot treatment and six levels of population densities as the subplot treatments, constituting eighteen treatments with four replications. The trailing systems consisted of trailing on mulched ground (T_1), twigs (T_2) and pandal (T_3). The population densities were 13,000 plants/ha (D_1- 1.5 x 0.50 m spacing), 26,666 plants/ha (D_2-1.50 x 0.25m spacing), 20,000 plants ha (D_3-1.0 x 0.50 m spacing) 40,000 plants/ha (D_4 -1.0 x 0.25 m spacing), 26,000 plants /ha (D_5-0.75 x 0.50 m spacing) and 53,333 plants /ha (D_6-0.75 x 0.25 m spacing).

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. The direct effects of the treatment showed that plants trailed on twigs (T_2) and ground system (T_1) were earlier in male flower opening. Population density did not affect the days to first male flower opening.

   Interaction of trailing systems and population density (T x D interaction) did not produce any marked effect on the days to first male flower opening.

2. The direct effects of trailing systems were significant for female flower opening. It was early in plants trailed on twigs (T_2) and those at population density 26,666 plants/ha (D_2).

   Among T x D combinations, plants grown on twigs at a population density of 26,666 plants/ha (T_2 D_2) were earlier in female flower opening.

3. Plants trailed on twigs (T_2) had first female flowers on the lower nodes. Population density did not affect the nodes to first female flower opening.

   Interactions of Trailing systems and population density revealed that plants grown on twigs at a population density of 13,000 and 26,666, 26,000 and 53,333 plants/ha (T_2D_1, T_2D_2, T_2D_5 and T_2D_6) had first female flowers on the lower nodes.

4. Significantly earlier harvest was recorded in plants trailed on twigs (T_2). Population density did not affect the days to first harvest.

   T x D interaction was also not significant for days to first harvest.

5. Among morphological characters maximum branches/ plant was observed in pandal grown plants (T_3). Population density levels did not affect the number of branches/ plant.

   T x D interaction was not significant for number of branches/plant.

6. The trailing systems, population density and their interaction did not produce any marked difference on the vine length.

7. Yield and yield components varied significantly with trailing systems, population densities and their interactions. Total number of fruits were maximum in pandal (T_3) and twig (T_2) trailed plants. Among the population density levels it was minimum at the highest level (D_6) followed by D_4 and D_5.

   Among treatment combinations plants trailed on twigs with the highest density of 53,333 plants/ha (T_2D_6) gave the maximum number of fruits.

8. Deshaped and unmarketable fruits were minimum in plants trailed in mulched ground (T_1). It was minimum in plots having lowest density.

9. The trailing systems and population density significantly affected the number of marketable fruits/plot. It was highest at pandal system. Among density levels the highest density (D_6) had maximum marketable fruits/plot.

   Among the treatment combinations plants trailed on pandal at highest population level (T_3D_6) had maximum number of marketable fruits/plot.

10. The trailing system, population density and their interactions had significant effect on marketable yield/plot. Among the trailing systems, pandal grown plants (T_3) had highest marketable yield. The highest population density recorded the highest yield among the various levels.

Interaction between trailing system and population density showed that plants trailed on pandals at highest level had highest marketable yield /plot.

11. The fruit parameters like weight, volume, diameter, flesh thickness, rind thickness, length and L/B ratio etc. were not influenced by trailing systems, population density and their interaction.

12. Maximum seeds/fruit was obtained from plants trailed on twigs (T_2). Population density and its interaction with trailing system did not influence the number of seeds/fruit.

13. The trailing systems, population density and their interactions did not influence 100 seed weight in gherkin.

14. Crop duration was less in gherkins trailed on mulches (T1). Effect of population density and its interaction with the were not significant for crop duration.

15. The percentage of unmarketable fruits/plot due to pests and diseases was least in plants trailed on pandals (T_3). Population density and it's interaction with the trailing systems were not significant for percentage of unmarketable fruits/plot.

16. Among the quality attributes like total soluble solids, total sugar, reducing sugar and non-reducing sugar, only the total sugar varied significantly due to trailing systems. Plants trailed on mulched ground (T_1) had higher percentage of total sugar content.

    Various population density levels and their interaction with trailing system did not influence the quality characters.

17. The benefit : cost ratio was found to be highest in plants trailed on twigs at highest population density (T_2D_6), closely followed by pandal grown plants at highest population density (T_3D_6).

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STANDARDISATION OF POPULATION DENSITY AND TRAILING SYSTEMS IN GHERKIN (*Cucumis sativus* L.)

By

SAIRAJ. K.P.

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COLLEGE OF AGRICULTURE
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ABSTRACT

The present investigation on "Standardisation of trailing systems and population densities in gherkin (*Cucumis sativus* L.)" was conducted at the Instructional Farm, College of Agriculture, Vellayani, Thiruvananthapuram during January-March 2000. Gherkin cultivar Thiruvalla Local collected from Thiruvalla area of Pathanamthitta district was raised in a split plot design with four replications. Three trailing systems and six population densities were tried to understand their direct and interaction effects on morphological as well as yield attributes. Majority of the yield and yield attributes were significantly influenced by the systems of trailing, population density and their interaction effects.

Among trailing systems, plants trailed on twigs (T_2) were earlier in female flower opening at lower nodes. This system also had more number of total and marketable fruits with highest marketable yield / plot.

Among the population density levels lower level had early female flower protection. However, number of total and marketable fruits were more at the highest level of 53333 plants /ha. This level also had maximum yield of marketable fruits / plot.

The interaction of treatments showed that plants trailed on twigs at highest density of 53333 plants/ha had maximum total number of fruits/plot. However, marketable fruits and marketable yield /plot were maximum in pandal system at highest density.

The fruit parameters like weight, length, volume, flesh and rind thickness etc. were not affected by the treatments.

Among the quality attributes total sugar content was highest in fruits from ground trailed plants. Other attributes like total soluble solids, reducing sugar and non-reducing sugar were not affected by the treatments.

The highest benefit : cost ratio of 2.18 was observed in plants trailed on twig system with the highest population density of 53333 plants /ha followed by the pandal system (2.03) at the same density.