STANDARDIZATION OF AGROTECHNIQUES FOR PRECISION FARMING IN WATERMELON [*Citrullus lanatus* (Thunb.) Matsum. & Nakai]

by

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(2013-22-101)

THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"STANDARDIZATION OF AGROTECHNIQUES FOR PRECISION FARMING IN WATERMELON [*Citrullus lanatus* (Thunb.) Matsum. & Nakai]"** 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, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis, entitled **"STANDARDIZATION OF AGROTECHNIQUES FOR PRECISION FARMING IN WATERMELON [*Citrullus lanatus* (Thunb.) Matsum. & Nakai]"** is a record of research work done independently by Ms. Nisha S. K. (2013-22-101) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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Nisha

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LIST OF ABBREVIATIONS

ANOVA	-	Analysis of variance
CD (0.05)	-	Critical difference at 5 per cent level
cm	-	Centimetre
DAT	-	Days after transplanting
d.f.	-	Degrees of freedom
et al.	-	Co-workers/ Co-authors
ECPGR	-	European Cooperative Programme for Plant Genetic Resources
FAO	-	Food and Agriculture Organization
Fig.	-	Figure
g	-	Gram
GCV	-	Genotypic coefficient of variation
ha	-	Hectare
ha^{-1}	-	Per hectare
IARI	-	Indian Agricultural Research Institute
IIHR	-	Indian Institute of Horticultural Research
K	-	Potassium
KAU	-	Kerala Agricultural University
kg	-	Kilogram
kg ha^{-1} mm^{-1}	-	Kilogram per hectare per millimeter
l	-	Litre
m	-	Metre
mg	-	Milligram
mg 100 g^{-1}	-	Milligram per 100 gram
mm	-	Millimetre
N	-	Nitrogen
No.	-	Number

NS	-	Non significant
P	-	Phosphorus
PCV	-	Phenotypic coefficient of variation
POP	-	Package of practices
RD	-	Recommended dose
SEm	-	Standard error of mean
t	-	Tonnes
TSS	-	Total soluble solids
viz.,	-	Namely
WUE	-	Water use efficiency

LIST OF SYMBOLS

@	-	at the rate of
β	-	Beta
°C	-	Degree Celsius
%	-	Per cent

Introduction

1. INTRODUCTION

A considerable development in protected cultivation as well as precision farming has been observed in Kerala during the last few years. The popularity was mainly due to the financial support provided by the Government for promoting hi-tech interventions in agriculture, to make the state self sufficient in vegetable production. Modified naturally ventilated polyhouses and rain shelters are the recommended structures for protected cultivation in Kerala. Rain shelters, being low cost units compared to polyhouses can be utilized in homesteads for off season cultivation as well as early planting of many vegetables. There is 40 to 100 per cent increase in yield in rain shelters compared to open field cultivation (Narayanankutty *et al*., 2014).

Watermelon [*Citrullus lanatus* (Thunb.) Matsum. & Nakai] is a popular dessert vegetable of the family Cucurbitaceae, cultivated all over the world. In India, it is grown in an area of 89,000 ha with a production of 21.45 lakh t (GOI, 2016b). In Kerala, watermelon is cultivated only in a very limited area of 20 ha with a production of 230 t (GOI, 2016a), even though the demand for the fruit is very high. Untimely rainfall is found to be a limiting factor in watermelon cultivation especially in southern Kerala. This could be overcome by growing them under protected structures. The studies conducted in the All India Co-ordinated Vegetable Improvement Project at Vellanikkara, Thrissur, proved the feasibility of watermelon cultivation in Kerala (AICVIP, 1994). KAU has also developed two seedless triploid hybrids, yellow fleshed Swarna and red fleshed Shonima (Pradeepkumar *et al*., 2013).

Watermelon is thought to have originated in southern Africa, because it is found growing wild throughout the area (De Candolle, 1882). David Livingstone, an explorer in a book on his expedition in South Africa in 1857 reported that in Kalahari desert, there were natural outgrowths of watermelon of various forms both edible and inedible. Three species of *Citrullus* are generally recognized: *C. lanatus*, *C. ecirhhosus* and *C. colocynthis* (Jeffrey, 1980). *C. colocynthis* (Colocynth) is considered to be the wild ancestor of watermelon. Colocynth is morphologically similar to *C. lanatus,* but with bitter fruit and small seeds. They have same chromosome number (2n = 2x = 22). Cultivated watermelon has a variant, citron or preserving melon (*C. lanatus* var. *citroides*) with small fruits having white flesh is considered as an intermediate domesticate between wild forms and modern cultivars. Zeven and De Wet (1982) regarded Hindustani center (India), as a secondary center of diversity.

A wide range of variability exists in the size of watermelon fruits. They can be classified as mini (1.5-4.0 kg), icebox (4.0-5.5 kg), small or pee-wee (5.5-8.0 kg), medium (8.1-11.0 kg), large (11.1-14.5 kg) and giant (>14.5 kg) (Gusmini and Wehner, 2007). Traditionally watermelon was considered as a seasonal fruit and market was dominated by bigger sized fruits. But now it is available round the year and consumer preference has shifted to smaller sized fruits. Mini and icebox watermelons are gaining popularity as they are ideal for nuclear families. The major nutritional components of the fruit are carbohydrates (6.4 g $100g^{-1}$), vitamin A (590 IU) and lycopene (4,100 μg $100g^{-1}$) (Wehner, 2008). Flesh colour is an important trait of watermelon which determines consumer acceptability. There are eight designated flesh colours in watermelon; white, salmon yellow, orange, crimson red, scarlet red, pale yellow, canary yellow and green (King *et al.,* 2009). Lycopene content in red fleshed watermelons is higher than that of fresh tomatoes. Citrulline, a non essential amino acid present in watermelon acts as an antioxidant and vasodilator (Perkins-Veazie, 2010).

Watermelon fruits make a delicious and refreshing dessert, especially esteemed in hot weather. They have served as an important source of water in the Kalahari Desert and other arid areas of Africa. The rind may be pickled or candied.

In Russia, beer is made from watermelon juice. Roasted seeds are eaten in the Orient and the Middle East, and some Chinese cultivars used for this purpose have been bred to have very large seeds (Robinson and Decker-Walters, 1997).

The latest edition of the United Nations World Water Development Report warns that the increased demand for water across the globe, along with climate change, is likely to cause fresh water scarcity in years to come (WWAP, 2016). Globally agriculture is the most water consuming activity. Irrigation along with livestock enterprise contributes to 91 per cent of the water withdrawal in India (FAO, 2012). So strategies to reduce water losses are the need of the hour. Use of micro irrigation facilities like drip system can play a major role towards this end. In drip irrigation, water is delivered near the plant root zone in a precise quantity so as to maintain soil moisture content close to field capacity. Drip irrigation also increases the uptake of plant nutrients (Deolankar *et al.*, 2004) and water use efficiency.

Precision farming in vegetables is gaining momentum in Kerala. Improved land management practices adopted in precision farming like deep ploughing and raised beds provides better aeration to root zone, develops efficient root system, effective drainage during rainy season and enhances moisture retention capacity of soil. The practice of mulching reduces soil moisture loss and regulates soil temperature. Availability of water soluble fertilizers has revolutionized the adoption of fertigation in various crops. Fertigation ensures supply of nutrients and water in a balanced manner according to the specific requirements of the crop. Fertigation management is aimed at maximizing grower's income and minimizing environmental pollution (Bar-Yosef, 1999).

Watermelon is traditionally cultivated by spreading horizontally on the ground. Recently, vertical training of vines has emerged as an alternative to horizontal training especially in polyhouse. Vertical training of watermelon increase the fruit yield per unit land area as more number of plants can be accommodated compared to horizontal training. Effective utilization of vertical space is possible through vertical training.

Watermelon is one of the highly priced vegetables having great market potential. It is especially most sought after during the summer season. Evaluation of the suitability of different watermelon genotypes for a specific area is of utmost importance for their successful cultivation. Being a high value crop, its exploitation on commercial scale under protected structure like rain shelter and open condition can generate handsome income to farmers.

In the light of the above, the present investigation was undertaken with the following objectives,

- To identify small to medium fruited watermelon with high yield and quality.
- To estimate genetic variability, heritability and genetic advance among the accessions.
- To analyse the degree and direction of association between various economic traits and to estimate the direct and indirect effects of various components on yield.
- To standardize the levels of fertilizer, irrigation and training for precision farming in watermelon under rain shelter.
- To standardize the levels of fertilizer, irrigation and training for precision farming in watermelon under open condition.

Review of Literature

2. REVIEW OF LITERATURE

Among cucurbits, watermelon [*Citrullus lanatus* (Thunb.) Matsum. & Nakai] is considered as a high value crop. Evaluation of the suitability of different watermelon genotypes for a specific area is of utmost importance for their successful cultivation. Optimal management of land, nutrients and water are essential not only for enhancing crop yield but also for sustainable development. The literature pertaining to genetic variability studies, precision farming, protected cultivation, nutrient management, irrigation and training in watermelon is reviewed in this chapter. Wherever literature on watermelon is limited, other cucurbits are also reviewed.

2.1 GENETIC VARIABILITY STUDIES

2.1.1 Variability

Genetic improvement in any crop mainly depends upon the amount of genetic variability present in the population. Phenotypic variability in a population is also of great importance as it reflects the presence of genetic diversity among the genotypes of such a population. Knowledge of availability and extent to which the genetic diversity is heritable is essential for effective selection.

In cultivated varieties of watermelon, the genetic diversity has been found to be very low, while genetic similarity is more (Maggs-Kolling *et al.*, 2000; Levi *et al.*, 2001). However, variation in morphological characteristics like rind colour, rind thickness, flesh colour, fruit shape, flesh texture, seed colour and seed shape is extensive among watermelon cultivars. Likewise wide variation in resistance to diseases and days to fruit maturity also exists.

2.1.1.1 Vegetative and Flowering Characters

The presence of wide range of variability for various characters in watermelon has been reported by many workers. Evaluation of twenty watermelon genotypes for eighteen characters under Vellayani condition revealed wide variability for vine length, node to first female flower (9.70 to 39.00) and days to first female flower (24.70 to 60.00) (Shibukumar, 1995). Prasad *et al.* (2002) reported a range of 43.00 to 61.00 for days to first female flower. Similar differences were also reported by Sundaram *et al.* (2011) and Choudhary *et al.* (2012) in watermelon.

Evaluation of forty two landraces of culinary melon revealed significant difference for all characters studied except the number of primary branches and node of first male as well as female flower (Rakhi and Rajamony, 2005).

In bitter gourd, Yadav *et al.* (2008) reported a range of 27.00 to 40.00 days for first male flower and 25.33 to 42.33 days for first female flower. Wide range was also recorded for days to first female flower and days to first male flower in cucumber (Yadav *et al.*, 2009) and in ridge gourd (Samadia, 2011). Selvi *et al.* (2013) obtained a range of 42.00 to 56.37 days for first female flower and 13.87 to 20.87 for node to first female flower in pumpkin.

Varietal variation in vine length, primary branches, nodes vine^{-1} and intermodal length was reported in bitter gourd (Yadav *et al.*, 2008; Resmi, 2009).

2.1.1.2 Fruit and Yield Characters

Gusmini and Wehner (2005) reported a large amount of genetic variation for number of fruits, fruit yield and fruit weight among a diverse set of 80 watermelon cultivars.

Genetic analysis showed widest range for number of fruits plant^{-1} (96.30 to 185.30) and narrowest range for diameter of full grown fruit (2.30 to 4.20 cm) in *Luffa* sp (Ram *et al.*, 2006). Evaluation of fifty genotypes of muskmelon showed differences between genotypic and phenotypic variance in characters such as fruit length, fruit weight and moisture percentage, and stressed the role of environment in the expression of these characters (Tomar *et al.*, 2008).

In bitter gourd, Yadav *et al.* (2008) reported wide range for fruit length (7.33 to 20.50 cm), fruit weight (28.33 to 175.00 g) and fruits vine $^{-1}$ (6 to 24). Similarly Yadav *et al.* (2009) observed wide variability for fruit weight and days to first harvest (43.24 to 58.10) in cucumber.

Zhang and Zhang (2010) observed obvious differences between edible seeded watermelons and flesh watermelons in phenotypic characteristics, especially in seed size and growth period of fruit. The RAPD results showed that the genetic distances between edible seeded and flesh watermelon were not beyond the biggest genetic distance among flesh watermelon.

In watermelon, Sundaram *et al.* (2011) reported high variability among twenty F_1 hybrids for days to final harvest (68.87 to 93.07) and yield vine^{-1} (4.62 kg to 15.70 kg). The range of variation was highest for number of seeds fruit^{-1} (155.67 to 893.40) followed by fruit yield plant^{-1} (7.20 to 22.75 kg) (Choudhary *et al.*, 2012).

Thangamani and Pugalendhi (2013) revealed the presence of variability for sixteen characters in 90 F_1 hybrids of bitter gourd obtained by crossing ten genetically diverse inbred lines through diallel mating. Selvi *et al.* (2013) reported wide range for days to first harvest (100.62 to 134.25) in pumpkin.

Studies to evaluate the genotypic variability of five Moroccan landraces and four commercial watermelon varieties revealed considerable variation for fruit weight, rind thickness, fruit length and fruit width (Said and Fatiha, 2015).

2.1.1.3 Quality Characters

Study on lycopene in watermelon has gained importance with the understanding of the beneficial effects of lycopene in human health (Collins *et al.*, 2006).

Carotenoids are responsible for the different flesh colours in watermelon fruit. Watermelon is a natural source of lycopene, an antioxidant with anticarcinogenic properties. Lycopene content in red fleshed watermelons is higher than that of fresh tomatoes. Genetic studies on flesh colours revealed that only few gene loci were associated with colour determination, each having two or three alleles. Red, orange and salmon yellow flesh colours are controlled by Y, y^o and y. Y (red) is dominant to both y^o (orange) and y (salmon yellow), and y^o is dominant to y (Henderson, 1989).

Perkins - Veazie *et al.* (2001) observed that lycopene content varied widely among watermelon cultivars, in red fleshed cultivars the highest lycopene content was 75.72 $\mu g\ g^{-1}$ fresh weight (FW), the lowest 33.96 $\mu g\ g^{-1}$(FW), mean 50 $\mu g\ g^{-1}$ (FW) and the yellow fleshed varieties had $<5\ \mu g\ g^{-1}$(FW) lycopene.

Varietal variation in qualitative traits like TSS, vitamin C, total sugar, reducing sugar and non reducing sugar was reported in pumpkin (Chaturvedi and Chaturvedi, 2001).

Prasad *et al.* (2002) observed wide variation in TSS content ranging from 4.25 to 11.00 per cent among 48 inbreds of watermelon. Maynard *et al.* (2002) reported higher TSS content in triploid watermelon cultivars compared to diploid.

Red, orange and yellow fleshed watermelon cultivars were found to have more fructose than glucose or sucrose (Perkins-Veazie *et al.*, 2002). Watermelon varieties with higher levels of fructose relative to sucrose are perceived sweeter.

Weidong *et al.* (2002) analysed the sugar content of diploid and tetraploid watermelon lines and reported that tetraploids had higher sugar content than the diploids. The average sugar content of the centre part was 8.86 per cent, and had the highest sugar content compared to other parts of the fruit. The sugar content of the ground-side part was significantly lower than the sunlight side part.

Leskovar *et al.* (2004) reported genetic variability for lycopene, vitamin C and sugar composition, primarily fructose, among diploid and triploid cultivars.

Triploid watermelon cultivars have more lycopene than diploid cultivars (Leskovar *et al.*, 2004). Perkins - Veazie *et al.* (2006) reported that the lycopene content of 50 commercial cultivars of seeded and seedless red fleshed watermelons varied from 33 to 100 mg kg^{-1}. Most of the seeded hybrid cultivars had average lycopene contents and seedless types had lycopene in high and very high ranges.

Seeded watermelons generally start colour development in the locule, followed by heart, intercellular and rind tissues at all ripening stages. In 'Dixie Lee', ripe fruit had 100 mg kg^{-1} and 71 mg kg^{-1} lycopene in locule and heart, respectively compared to 121 and 63 mg kg^{-1} in overripe fruit (Perkins-Veazie, 2007).

Zhang and Zhang (2010) observed significant differences between edible seeded watermelons and flesh watermelons for total soluble solid content.

In red fleshed watermelons lycopene constitutes the major pigment and β carotene the secondary. The predominant carotenoid in yellow fleshed watermelon is neoxanthin. Lycopene content in watermelon is related to genotype and ploidy level (Zhao *et al.*, 2013).

Studies on the nutritional quality of four icebox cultivars revealed that antioxidants such as lycopene, ascorbic acid and flavanols were more in the fruit of 'Beauty' followed by 'Suman 235' (Soumya and Rao, 2014).

2.1.2 Coefficients of variation

In crop improvement, it is imperative to determine the extent of genetic variation for a trait to be improved (Flores *et al.*, 1986). The variation present in the plant population are of three types *viz.*, phenotypic, genotypic and environmental. Of these the genetic variance can be further partitioned to additive, dominance and epistatic variance components. The genotypic coefficient of variation (GCV) provides a valid basis for comparing and assessing the range of genetic variability for quantitative characters and phenotypic coefficient of variation (PCV) measures the extent of total variation. The phenotypic expression of the character is the result of interaction between genotype and environment.

2.1.2.1 Vegetative and Flowering Characters

A narrow difference between PCV and GCV for various traits was reported by Prasad *et al.* (1988), Prasad *et al.* (2002), Sundaram *et al.* (2011) and Choudhary *et al.* (2012) in watermelon.

Prasad *et al.* (2002) reported high PCV for vine length in watermelon. In cucumber, Bisht *et al.* (2010) observed moderate GCV for vine length.

In watermelon, high PCV was observed for node to first male flower while, PCV was low for days to first male flower anthesis. High phenotypic coefficient of variation was reported for node to first female flower (Prasad *et al.*, 2002). Moderate estimates of GCV and PCV was reported for this character in muskmelon (Tomar *et al.*, 2008).

PCV was higher than GCV for all characters in cucumber (Yadav *et al.*, 2009). GCV was high for number of primary branches at maturity and number of nodes bearing female flowers plant^{-1}. But days to first male flower exhibited low GCV value.

In watermelon, Sundaram *et al.* (2011) and Choudhary *et al.* (2012) observed moderate genotypic coefficient of variation for days to first female flower. In cucumber Yadav *et al.* (2009) reported high GCV value for this character.

2.1.2.2 Fruit and Yield Characters

High PCV and GCV was reported for yield plant^{-1} by Somkuwar *et al.* (1997) and Tomar *et al.* (2008) in muskmelon; Sundaram *et al.* (2011) and Choudhary *et al.* (2012) in watermelon; Samadia (2011) and Varalakshmi *et al.* (2015) in ridge gourd.

Number of fruits plant^{-1} exhibited moderate PCV in ridge gourd (Karuppiah *et al.*, 2002) and muskmelon (Tomar *et al.*, 2008) while, PCV and GCV were high for the character in cucumber (Bisht *et al.*, 2010).

Prasad *et al.* (2002) reported high phenotypic coefficient of variation for rind thickness and yield plot^{-1} in watermelon.

Karuppiah *et al.* (2002) and Narayanankutty *et al.* (2006) reported high PCV and GCV for seeds fruit^{-1} in ridge gourd and snake gourd respectively. The difference between PCV and GCV was narrow.

High GCV and PCV were observed for fruit weight in culinary melon ((Rakhi and Rajamony, 2005) and ridge gourd (Varalakshmi *et al.*, 2015).

Gusmini and Wehner (2007) observed that large fruited parents had higher phenotypic variance than small fruited parents in watermelon.

In muskmelon, Tomar *et al.* (2008) reported low GCV and PCV for flesh thickness, fruit girth and days to first harvest. Yadav *et al.* (2009) also observed low GCV for days to first harvest in cucumber.

In ridge gourd, high PCV and GCV were recorded for fruit length (Samadia, 2011; Varalakshmi *et al.*, 2015).

In watermelon, Sundaram *et al.* (2011) reported highest PCV and GCV values for 100 seed weight while it was lowest for fruit diameter. Similar result was also reported by Choudhary *et al.* (2012). The phenotypic coefficient of variation ranged between 17 per cent for fruit width and 43 per cent for fruit weight (Said and Fatiha, 2015).

2.1.2.3 Quality Characters

Study on the adaptive responses and diversity pattern in 48 watermelon inbreds, revealed moderate PCV value for total soluble solids content (Prasad *et al.*, 2002).

Tomar *et al.* (2008) observed moderately high GCV and PCV for acidity percentage and total soluble sugars in muskmelon. Moderately low estimates were observed for total soluble solids and moisture percentage.

In watermelon, Choudhary *et al.* (2012) reported high GCV and PCV values for total soluble solids content. Said and Fatiha (2015) also observed high phenotypic coefficient of variation for TSS content.

2.1.3 Heritability and Genetic Advance

To improve complex (quantitative) traits like yield, understanding variances and heritability behaviours of yield and its components is paramount. Burton and De Vane (1952) suggested that genetic variability along with heritability should be considered for effective selection.

2.1.3.1 Vegetative and Flowering Characters

High heritability coupled with high genetic advance was observed for main vine length in pumpkin (Kumaran *et al.*, 1997), roundmelon (Dahiya *et al.*, 2001), snapmelon (Reddy *et al.*, 2005) and watermelon (Sundaram *et al.*, 2011). Prasad *et al.* (2002) noticed high heritability and low GA for vine length in watermelon.

In watermelon, high heritability and genetic advance was observed for days to first female flower (Prasad *et al.*, 2002), while Sundaram *et al.* (2011) reported high heritability with moderate GA estimates for this character.

Tomar *et al.* (2008) observed high heritability combined with high genetic advance for node at which first female flower appeared in muskmelon.

Heritability estimate was highest for node to first male flower and lowest heritability was observed for days to first female flower in cucumber (Yadav *et al.*, 2009). Maximum genetic advance was recorded for days to first female flower while, lowest genetic advance as per cent of mean was recorded for vine length.

Bisht *et al.* (2010) recorded high heritability for number of nodes on main shoot in cucumber. High heritability coupled with high genetic advance as per cent of mean was observed for number of primary branches plant^{-1}.

In watermelon, high estimates of heritability and GA were recorded for number of female flowers vine^{-1} while, days to first female flower and node to first female flower exhibited high heritability with moderate GA estimates (Sundaram *et al.*, 2011).

High heritability along with high genetic advance was recorded for node to first female flower and number of branches in ridge gourd (Varalakshmi *et al.*, 2015).

2.1.3.2 Fruit and Yield Characters

High heritability and genetic advance for fruit weight was reported by Kumaran *et al.* (1997) in pumpkin; Dahiya *et al.* (2001) in roundmelon; Yadav *et al.*

(2009) in cucumber and Sundaram *et al.* (2011) in watermelon. Choudhary *et al.* (2012) recorded high heritability and low genetic advance for fruit weight in watermelon.

In muskmelon, Somkuwar *et al.* (1997) observed medium heritability and high genetic advance for number of fruits plant^{-1}, while Tomar *et al.* (2008) noticed high values. High heritability coupled with high genetic advance for this character was reported in watermelon (Prasad *et al.*, 2002; Sundaram *et al.*, 2011) and cucumber (Kumar *et al.*, 2008; Bisht *et al.*, 2010).

High heritability coupled with high genetic advance was reported for seeds fruit^{-1} in ridge gourd (Karuppiah *et al.*, 2002), snake gourd (Narayanankutty *et al.*, 2006) and watermelon (Choudhary *et al.*, 2012).

In watermelon, Prasad *et al.* (2002) observed high heritability and genetic advance for yield plot^{-1}. But for fruit length and fruit breadth heritability was high and GA was low.

High heritability combined with high GA was noticed for yield vine^{-1} in muskmelon (Prasad *et al.*, 2004; Tomar *et al.*, 2008), bottle gourd (Ram *et al.*, 2005), cucumber (Bisht *et al.*, 2010), ridge gourd (Samadia, 2011) and watermelon (Sundaram *et al.*, 2011). Varalakshmi *et al.* (2015) recorded moderate levels of heritability and genetic advance for this character.

High heritability coupled with high genetic advance was noted for fruit length, 1000 seed weight and average fruit weight in culinary melon (Rakhi and Rajamony, 2005).

Gusmini and Wehner (2007) recorded low to intermediate estimates of broad and narrow sense heritability for fruit size in watermelon.

In the case of 100 seed weight, high heritability combined with high genetic advance was noted in bottle gourd (Kumar *et al.*, 2007) and cucumber (Kumar *et al.*, 2008).

Yadav *et al.* (2009) reported highest heritability estimate for fruit length at edible stage and high genetic advance for days to first harvest in cucumber.

In watermelon, days to final harvest and fruit diameter had high heritability but low genetic advance as per cent of mean (Sundaram *et al.*, 2011). Choudhary *et al.* (2012) also observed high heritability and moderate genetic advance for days to first fruit harvest while, rind thickness exhibited low genetic advance.

2.1.3.3 Quality Characters

Prasad *et al.* (2002) and Choudhary *et al.* (2012) reported high heritability and low genetic advance for total soluble solids in watermelon. Tomar *et al.* (2008) also observed similar estimates for TSS in muskmelon.

High heritability coupled with high genetic advance was noted for keeping quality of fruits in culinary melon (Rakhi and Rajamony, 2005).

In muskmelon, very high heritability estimates were obtained for total soluble sugars and acidity percentage (Tomar *et al.*, 2008).

2.1.4. Correlation Studies

In a breeding programme, selection of plants based on yield alone is not completely reliable since, yield as a whole is a complex entity determined by a number of factors. At the same time, selections based on the components of yield would pay better. Correlation analysis helps in the evaluation of relationship existing between yield and its components along with the interrelationship among the yield components.

Positive correlation of fruit yield with main vine length, primary branches plant^{-1}, fruits plant^{-1}, nodes plant^{-1} and number of female flowers plant^{-1} were reported by Prasad *et al.* (1988); Gopal *et al.* (1996) and Rolania *et al.* (2003) in watermelon.

Singh and Singh (1988) reported a negative correlation between fruit yield and average fruit weight in watermelon, whereas a positive correlation was observed in ridge gourd (Rao *et al.*, 2002), snake gourd (Narayanankutty *et al.,* 2006) and ash gourd (Resmi and Sreelathakumary, 2012).

Correlation studies with sixteen divergent types of pointed gourd indicated that fruit weight, fruit diameter and number of primary branches plant^{-1} were positively correlated with yield plant^{-1} at genotypic and phenotypic levels (Sarkar *et al.*, 1999).

A high negative correlation between fruits plant^{-1} and fruit yield were reported by Lovely (2001) and Resmi (2004) in ash gourd.

In snake gourd, seeds fruit^{-1} had significant negative correlation with days to first male flower and days to first harvest (Ashok and Rajan, 2004), while Narayanankutty *et al.* (2006) reported that seeds fruit^{-1} had significant positive correlation with days to first male and female flowers, fruit girth and fruit weight.

Choudhary *et al.* (2004) reported that yield plant^{-1} had significant positive correlation with fruit weight, fruits plant^{-1}, rind thickness and vine length in muskmelon.

In cucumber Rao *et al.* (2004) observed that yield was positively correlated with fruit weight, fruit length and flesh thickness at phenotypic and genotypic levels.

Fruit diameter, flesh thickness, vine length and fruits plant^{-1} exhibited positive and highly significant correlation with yield in pumpkin. Whereas, the correlation was negative and significant with days to first male and female flowers (Kumar *et al.*, 2005).

Vine length was positively associated with diameter of full grown fruit, fruits plant^{-1} and 100 seed weight, while it was negatively correlated with seed weight fruit^{-1} in *Luffa* sp (Ram *et al*., 2006). The days to first fruit harvest was positively and significantly correlated with vine length and average fruit weight.

Significant positive correlations were observed for days to first fruit harvest with days to first male and female flower anthesis; fruit weight with fruit length; number of nodes bearing female flowers plant^{-1} with number of nodes to first male flower and days to first female flower anthesis in cucumber (Kumar *et al*., 2008).

In muskmelon, fruit weight showed positive and significant genotypic and phenotypic association with fruit yield plant^{-1}, fruit length, fruit girth, flesh thickness and moisture percentage, while negative and significant correlation was seen with TSS. Fruit yield was positively correlated with fruit weight, fruit girth, flesh girth, flesh thickness and fruits plant^{-1} (Tomar *et al*., 2008).

Kumar and Wehner (2011) studied the performance of two watermelon populations developed from crosses between obsolete cultivars with high yield and elite modern cultivars. Fruit yield was reported to be correlated with component traits such as fruit count and fruit size. Total fruit weight and marketable fruit weight were highly positively correlated, while, fruit number was negatively correlated with fruit size.

Days to first harvest exhibited significant positive correlation with days to first male flower, days to first female flower and node to first fruit set in ridge gourd. Fruit yield plant^{-1} was positively correlated with fruits plant^{-1}, fruit weight and fruit diameter (Samadia, 2011). Similar findings were reported by Hanumegowda *et al.* (2012), Rabbani *et al.* (2012) and Varalakshmi *et al*. (2015).

Yield vine^{-1} showed significant positive correlation with fruit weight (0.924), flesh weight (0.918), fruit diameter (0.856), fruits vine^{-1} (0.855) and vine length (0.558) in watermelon (Sundaram *et al.*, 2011). Days to first female flower exhibited positive and significant correlation with node to first female flower and days to first harvest. Days to first harvest exhibited negative and significant correlation with number of fruits vine^{-1}, fruit weight and flesh weight. Similarly, Choudhary *et al.* (2012) also reported positive and highly significant correlation for node to first female flower and number of primary branches plant^{-1}.

Soumya and Rao (2014) evaluated the nutritional quality of watermelon fruits during their development and ripening in four icebox cultivars. A strong positive correlation was observed between total polyphenols and lycopene with total antioxidant activity.

Significant positive correlation of fruit weight with fruit length (0.92) and fruit width (0.83) was reported in watermelon by Said and Fatiha (2015). TSS had significant positive genotypic correlation with fruit weight, fruit length and fruit width. There was no genotypic and phenotypic correlation between rind thickness and other characters.

2.1.5 Path Coefficient Analysis

Path coefficient analysis is used to separate correlation coefficient into components of direct and indirect effects.

Varalakshmi and Reddy (1994) studied the association between yield and yield attributes in 58 genotypes of ridge gourd from diverse source. Path analysis revealed that vine length, node to first female flower, node to first male flower and fruit length had positive direct effect on yield. The contribution of fruit diameter and fruit weight was mostly indirect through vine length, node to first female flower, female flower number, fruits plant^{-1} and fruit length.

Fruit breadth showed highest positive direct effect on yield followed by days to opening of first male flower, days to opening of first female flower, vine length, seed number and seed/flesh ratio in bitter gourd (Parhi *et al.*, 1995). High negative indirect effects on yield were exhibited by 100 seed weight, days to first harvest, fruit weight and node number bearing first female flower.

In watermelon, Gopal *et al.* (1996) and Rolania *et al.* (2003) reported that the days to first fruit harvest and node at which first female flower appeared had negative direct effect on yield at genotypic level but the association was positive and significant with yield plant^{-1}.

Somkuwar *et al.* (1997) reported that average fruit weight and average fruit number exerted maximum direct effect on total yield plant^{-1} at phenotypic and genotypic levels in muskmelon. Days to first harvest had negative direct effect on yield plant^{-1}.

Path analysis revealed that fruit volume followed by fruit weight and fruit diameter has maximum positive direct effects on yield in pointed gourd. The indirect effects of all the components through fruit volume were relatively high in magnitude irrespective of direction (Sarkar *et al.*, 1999).

Fruit weight, fruits plant^{-1}, rind thickness, TSS and flesh thickness showed positive direct effect on yield plant^{-1} in muskmelon (Choudhary *et al.*, 2004).

Path analysis revealed that fruit weight, fruits plant^{-1}, flesh thickness and node number of first female flower are highly dependable and reliable for selection to improve yield in cucumber (Rao *et al.*, 2004).

Kumar *et al.* (2005) reported that flesh thickness, node to first female flower, days to first female flower, fruit diameter and vine length exhibited positive direct effect on yield in pumpkin.

In snake gourd, fruit weight and fruits plant^{-1} had the maximum positive direct effect on yield and the indirect contribution of other characters was mainly through days to first harvest, seeds fruit^{-1} and 100 seed weight (Narayanankutty *et al.*, 2006).

Ram *et al.* (2007) reported that highest positive direct effect was exerted by vine length followed by fruit weight and days to first flowering in bottle gourd.

In muskmelon, Tomar *et al.* (2008) observed that fruits plant^{-1} and moisture percentage were the main yield attributing characters. TSS exhibited positive direct effect on fruit yield. Fruit weight showed positive direct effect on yield while, negative indirect effect was shown through TSS and acidity percentage.

Fruit weight had the highest direct effect on fruit yield ha^{-1} followed by number of fruits plant^{-1} in watermelon (Choudhary *et al.*, 2012). Similar findings were reported by Rabbani *et al.* (2012) in ridge gourd and Resmi and Sreelathakumary (2012) in ash gourd.

Node to first female flower, vine length, fruit length and fruit girth exhibited negative direct effect on yield in ridge gourd (Varalakshmi *et al.*, 2015).

2.2 PRECISION FARMING, PROTECTED CULTIVATION, NUTRIENT AND IRRIGATION MANAGEMENT

2.2.1. History and Development of Precision Farming

Precision farming refers to the management of each crop production input by recognizing site specific differences within the field and taking management actions accordingly to reduce waste, increase profits and maintain the quality of environment (Goovaerts, 2000). What distinguishes precision farming from traditional agriculture is that instead of managing an entire field based upon some hypothetical average condition, which may not exist anywhere in the field, management is customized for small areas within fields. The main goal of precision farming is management of crop and soil variability to optimize yield with minimum input and reduced environmental pollution (Mondal and Basu, 2009).

Advanced precision farming technologies emerged in developed countries in early 1980s. Historically the concept of precision farming emanated from the marketing strategies adopted by North American fertilizer producers and dealers that required intense soil sampling, and presented fertilizer recommendations in the form of a map (Sparovek and Schnug 2001). This origin is probably the reason why, the main focus of precision agriculture has been on material inputs such as plant protection chemicals, fertilizers as well as various amendments, with the goal of reducing negative impact on environment (Haneklaus and Schnug, 1998).

The development of a global positioning system (GPS), geographic information system (GIS), in-field and remote sensors system, and variable rate technology have enabled site-specific management of farm operations (Chan, 2006). In developed nations, the adoption of precision farming has been relatively more quick and widespread. The progress of precision farming in Europe is less advanced than in United States and Canada, due to relatively small size of farms in most European countries (Tran and Nguyen, 2008). Among the developing countries, Argentina, Brazil, China, India, Malaysia and others have begun to adopt some precision farming components, based on availability and need, but the adoption is very limited (Mondal and Basu, 2009). It was introduced into Brazilian cropping zones in later part of 1990s. Argentineans have been using precision techniques, especially those related to soil maps and yield monitoring since past decade. In Malaysia site specific methods are getting accepted rapidly.

Precision farming is a fairly recent introduction into South African cropping zones. Resource poor farmers in South Africa prefer site specific nutrient management and variable rate application of nutrients to reduce costs on fertilizer and improve efficiency (Maine *et al.*, 2005). Precision farming has been accepted as a method to improve yield and revise resource allocation in most parts of Asian dry lands (Krishna, 2013).

The conventional definition of precision farming is suitable when the land holdings are large and enough variability exists between the fields. In India, the average land holdings are very small and precision farming is to be redefined in the context of Indian farming. Hence precision farming could be defined as, precise application of agricultural inputs based on soil, weather and crop requirement to maximize sustainable productivity, quality and profitability. In India, precision farming is practiced in Punjab, Uttar Pradesh, Haryana, Madhya Pradesh, Tamil Nadu, Karnataka etc. Major success story in India is Tamil Nadu Precision Farming Project, a Tamil Nadu State sponsored turnkey project, initially implemented at Dharmapuri and Krishnagiri districts. It adopted a location specific, field specific and crop specific approach (TNAU, 2016). It recorded 60-80 per cent higher yield, 90 per cent marketable quality and 30-40 per cent water economy.

2.2.2 Protected Cultivation

Protected cultivation provides many fold advantages over open field vegetable cultivation. This technology is highly productive, amenable to automation, conserves water, fertilizer and land (Singh and Sirohi, 2006), environmental control necessary for crop growth, ease of mechanization, better management of pests and diseases, efficient use of space and higher quality of produce (Syed, 2006). Rain shelters are more favourable for hot and humid conditions than greenhouses (Takakura, 2006). Compared to open field conditions, the yield of vegetables per unit area is 2 - 4 times higher in rain shelters (Sharif *et al.*, 2008). Several authors have reported higher vegetative growth (Sharma and Tiwari, 1993; Ganesan, 2002; Hazarika and Phookan, 2005; Rajasekar *et al.*, 2013), yield (Bhatnagar *et al.*, 1990; Kamaruddin *et al.*, 2006; Kumar and Arumugam, 2010; Parvej *et al.*, 2010) and quality (Ahluwalia *et al.*, 1996; Mahajan and Singh, 2006; Vattakunnel, 2014) under protected condition than open field for various vegetables. Narayanankutty *et al.* (2014) reported 40 to 100 per cent increase in yield in rain shelters compared to open cultivation.

Mostly, cucumber is grown inside protected structures in Northern Europe like Britain, Netherlands, Germany etc., Northern states of USA and Canada. Meanwhile, in Korea, Japan, China and Middle East, in most plastic houses watermelon is also grown besides cucumber (Seshadri and More, 2009). Growers remove all but two fruits plant^{-1}, to facilitate increase in fruit size and uniformity in watermelon. The superfluous fruits are pinched off at the young and developing stage. As the fruits enlarge, plastic strings are tied to support their increasing weight.

Campagnol (2012) reported that pruning the main stem of vertically trained watermelon to 2 m height gave highest yield and quality under greenhouse. It was also the least expensive training height.

2.2.3 Nutrient Management

The mineral nutrition of watermelon is one of the factors that mostly contribute to the yield and quality of this crop. Hegde (1989) reported that increase in N application (60 to 180 kg ha^{-1}) significantly increased dry matter and fruit yield (32 per cent) only up to 120 kg N ha^{-1}. Hollow heart in fruit flesh and excessive vine growth can be caused by heavy doses of N fertilizers.

Singh and Naik (1989) studied the response of watermelon cv. Arka Manik to four levels of N (50, 100, 150 and 200 kg ha^{-1}) and three levels of P (50, 100 and 150 kg ha^{-1}). Marked reduction in fruit yield was observed when N dose was raised above 50 kg ha^{-1}. The average fruit weight and number of fruits ha^{-1} were also higher at lower levels of N. Appreciable increase in yield and fruit weight was observed in the application of P up to 150 kg ha^{-1}. The TSS and rind thickness of fruits were not significantly influenced by N and P levels.

In watermelon, intensive K application should be there during flowering and fruit setting to ensure uniform fruits with high TSS content (Khade *et al.*, 1995; Locascio and Hochmuth, 2002). Increased levels of potassium fertilizers increased fruit weight as well as fruit yield (Grangerio and Filho, 2006; Hendricks *et al.*, 2007). El- Bassiony *et al.* (2012) investigated the response of two watermelon cultivars to four levels of potassium (100, 125, 150 and 175 Kg K_2O $acre^{-1}$). K levels showed highly significant effect on fruit weight, total yield and biochemical characters. By increasing K levels, all fruits characters except mean fruit weight were increased gradually. The highest K level of 175 kg $acre^{-1}$ registered highest TSS, fruit length and fruit diameter. Total yield and mean fruit weight were highest with 150 kg $acre^{-1}$. The interaction between cultivar and K levels showed significant effects on fruit diameter, fruit weight, rind thickness and yield. Nascimento *et al.* (2016) reported that potassium is the nutrient required in greatest quantity by watermelon, especially during the reproductive phase and most extracted from 45 to 65 days after transplanting.

Muruganandam and Anburani (2010) showed that application of nitrogen @ 75 kg ha^{-1} along with *Azospirillum* @ 200g kg^{-1} of seeds recorded the highest fruit length (38.65 cm), fruit girth (46.72 cm), fruit weight (5.80 kg), fruits $vine^{-1}$ (4.66) and fruit yield ha^{-1} (53.64 t) in watermelon.

The effect of NPK fertilizer and spacing levels on growth and yield of watermelon revealed that application of 200 kg NPK ha^{-1} gave the longest vine length and 100 kg NPK ha^{-1} gave the highest number of flowers. The highest yield (63.6 t/ha) was obtained from the combination of 150 kg ha^{-1} with 1.0×1.5 m spacing (Sabo *et al.*, 2013).

Goncalves *et al.* (2016) reported that quality of watermelon fruit was not influenced by the level of P fertilizer and varietal variation was there in the response to P doses. Maximum economic return was achieved with a dose of 49.37 kg P ha^{-1}. Maluki *et al.* (2016a) reported enhanced fruit quality with increased P level. Fruits with high TSS, low acidity and thin rind were obtained at 50 kg P ha^{-1}. Nitrogen has positive effect on days to flowering, sex expression ratio, fruits plant^{-1}, fruit weight and fruit yield. The number of fruits, fruit weight, fruit yield and TSS were highest in 120 kg N ha^{-1} followed by 80 kg ha^{-1} (Maluki *et al.*, 2016b).

2.2.4 Fertigation

Fertigation is the method of application of soluble fertilizers to the crops through an irrigation system. Supplying nutrients in small quantities helps to save labour, reduce compaction in the field and increases productivity (NCPAH, 2015).

To avoid reductions in both yield and quality, vegetable crops require an adequate supply of nutrients throughout the growth period (Burns, 1996). Conventional broadcast applications of granular fertilizer are not always effective at optimising the early nutrition of many vegetable crops. The nutrients may not become available quickly to the roots of developing seedlings. Precision placement techniques including the injection of small amounts of NPK solution either below or close to the side of the crop row are more effective at providing an uninterrupted supply of nutrients and maximising the early growth of vegetable seedlings and transplants (Burns *et al.*, 2010).

Fertigation allows nutrient placement directly into root zone around plants through a pipe network with the help of emitters near plant roots during critical periods of nutrient requirement (Imas *et al.*, 1997). Fertigation allows an accurate and uniform application of nutrients to the wetted area where most active roots are concentrated. Extended harvest is possible with fertigation. Fertigation can improve nutrient use efficiency by supplying nutrients and water precisely avoiding excess concentrations of fertiliser in the soil and consequent leaching (Papadopoulos, 1986; Bar-Yosef, 1999). Choudhari and More (2002), reported that application of fertilizers through drip irrigation was superior to sole solid fertilizer application under furrow as well as drip.

The utilization of P by the plants was poor under conventional surface application (Blane *et al*., 2000). But in fertigation, the continuous application of P through irrigation water increases the uptake and improves mobility and availability of P by creating a favourable moisture condition in soil. Guler and Ibrikci (2002) reported that drip fertigated plots had higher soil K than the furrow irrigated plots, and application of high doses of nitrogen also gave rise to an increase in soil K. The nutrient use efficiency of fertigation is about 90 per cent compared to that of conventional methods, where it is only 40-60 per cent (Solaimalai *et al*., 2005). Drip fertigation is highly profitable as it saves input, labour and energy to about 54 per cent than that of conventional methods (Bhat and Sujatha, 2006). The application efficiency of water and nutrients is improved by drip fertigation. At the same time marketable yield is maintained or improved (Monaghan *et al*., 2010).

2.2.4.1 Yield and Yield Attributes

In watermelon, application of 1680 kg ha^{-1} NPK mixed fertilizer promoted female flower production (Brinen *et al*., 1979). Goreta *et al*. (2005) reported that average fruit weight and fruit size of watermelon were unaffected by N fertigation levels. Andrade Junior *et al*. (2009) also reported similar result, but the effects were significant for number of fruits, total and marketable yield. Highest yield was obtained with N level 120 kg ha^{-1}.

Feltrim *et al*. (2011) studied the effects of N and K fertigation and spacing on the productivity of the hybrid seedless watermelon 'Shadow'. Nitrogen and potassium doses significantly influenced K foliar content only and the interactions were not significant. Filho *et al.* (2015) reported there was no increase in watermelon yield on increasing N and K doses by fertigation.

Prabhakar *et al.* (2013) observed that application of water soluble fertilizer 70: 70: 70 kg NPK ha^{-1} through fertigation gave significantly high vine length, fruits plant^{-1} and fruit weight than conventional soil application of fertilizers in watermelon. The fertigation treatments recorded an increase in average marketable yield by 7.22 to 26.4 per cent over conventional fertilizers.

In a study to evaluate the effect of different irrigation and nitrogen fertigation frequencies on watermelon revealed that the highest yield of 80.69 t ha^{-1} was obtained with 64 fertigations in a cycle (Fernandes *et al.*, 2014).

2.2.4.2 Quality

El-Beheidi *et al.* (1990) reported that fruit quality parameters like total soluble solids and pH were unaffected by nitrogen fertigation levels in watermelon. Andrade Junior *et al.* (2009) also reported that various levels of fertilizers supplied through fertigation had no influence on watermelon fruit quality.

Fruit K and Mg contents were not affected by fertigation, whereas Ca content increased by about ten times in watermelon (Battilani and Solimando, 2006). Prabhakar *et al.* (2013) showed that TSS did not differ significantly with fertigation.

2.2.5 Irrigation

Increase in yield and saving of water with drip irrigation over furrow method has been reported by earlier workers (Sharanappa and Gowda, 1995; Raina *et al.*, 1999; Imtiyaz *et al.*, 2000; Lingaiah *et al.*, 2005; Kushwah and Dwivedi, 2013). The uptake of nutrients by plants is also increased by drip irrigation (Deolankar *et al.*, 2004). Drip irrigation maintains moisture content at near about field capacity in one hand and eliminates water loss on the other (Bhunia *et al.*, 2014). Water application efficiency is high in drip irrigation because of reduced surface evaporation and deep percolation (Sandal and Kapoor, 2015).

In watermelon, drip irrigation offers the potential for precise water management with flexible scheduling, efficient application of fertilizers, increasing yields, plant and fruit growth (Bhella, 1988). Srinivas *et al.* (1989b) reported that, watermelon being a widely spaced crop, large quantity of water is wasted when conventional irrigation or sprinkler system was used. Water management is essential for the success of vegetable crops. Water stress may increase the incidence of blossom-end rot (Maynard and Hopkins, 1999) and result in lower yield, while excessive field moisture may cause losses of nutrients, such as nitrate N and K out of the root zone.

2.2.5.1 Yield and Yield Attributes

Desai and Patil (1984) reported highest yield in watermelon with irrigation IW/CPE ratio (irrigation water/cumulative pan evaporation ratio) of 1.0. The consumptive use and water requirement were 196.9 and 540 mm, respectively under clay loam soils of Parbhani. Hegde (1987) reported that highest dry matter production and fruit yield (35.58 t ha^{-1}) was obtained upon irrigating watermelon when soil matric potential at 15 cm depth reached -25 kPa. Under arid conditions of Bikaner, single lateral lines (12-16 mm) at 1.5 to 2.0 m distance with on line drippers (4 l hr^{-1}) at 50 cm distance were found to increase yield in watermelon (mateera) by 25 to 30 per cent compared to channel irrigation (Srinivas *et al.*, 1989b).

A study on irrigation scheduling and moisture conservation in watermelon by Ajith (2000) revealed that incorporation of moisture conservation materials increased yield attributes like weight of fruit and fruits $plant^{-1}$. Among moisture conservation methods, surface mulch and uniform incorporation of paddy waste were found superior. Lu *et al.* (2003) found that watermelon under high intensity management using trickle irrigation and plastic mulch produced 100 per cent greater marketable fruit yield per unit area, marketable fraction of total fruit and higher fruit weight than those under low intensity management. Leskovar *et al.* (2004) reported almost two fold increase in yield at 1.0 ET compared with watermelon grown at 0.5 ET. Reducing the irrigation rate to 0.75 ET also decreased the individual fruit length, fruit diameter and rind thickness. Simsek *et al.* (2004) also found similar reduction in yield when quantity of irrigation was reduced. Application of irrigation at 1.25 IW/CPE by drip system in a four day irrigation frequency was found optimal for watermelon grown in semi arid regions.

Water deficit has been shown to adversely affect yield, biomass production, leaf mineral composition, and leaf water status of watermelon, but reduced water use. Rouphael *et al.* (2008) reported that marketable yield decreased linearly in response to an increase in water stress. The net assimilation of CO_2, stomatal conductance, relative water content, leaf, and osmotic potential decreased under water stress conditions.

A two-year study conducted in North Florida to develop and test a crop factor for watermelons grown with plasticulture and daily drip-irrigation revealed that the highest watermelon yield was achieved with irrigation scheduled in real-time using a crop factor with values of 0.24, 0.48, 0.84, 1.08, and 0.84 for period 1–2, 3–4, 5–8, 9–11 and 12–13 weeks after transplanting, respectively. The effect of N rate and the interaction effects of irrigation × N rate were not significant on total marketable yield and individual fruit weight (Gioia *et al.*, 2009).

The knowledge of the evapotranspiration (ETc) and crop coefficient (Kc) is fundamental to plan and to manage the irrigation of any crop for higher yield. Bastos *et al.* (2012) studied the daily and hourly evapotranspiration of drip irrigated watermelon and crop coefficient (Kc) in each crop development phase in Brazil. The Kc of the drip irrigated watermelon was 0.18 in the initial stage of crop growth; 0.18

to 1.3 in crop development stage; 1.3 in the intermediate stage and 0.43 in the final stage.

Significant influence of irrigation frequency on marketable yield, fruit weight, polar diameter, equatorial diameter and rind thickness was reported by Fernandes *et al.* (2014). Highest productivity of 69.79 t ha^{-1} was recorded in treatments receiving twice daily irrigation. The irrigation frequencies greater than one day significantly reduced the productivity of watermelon grown in sandy soil under drip irrigation.

2.2.5.2 Quality

Hegde (1989) found that TSS content of juice was not influenced by irrigation. Leskovar *et al.* (2004) reported that lycopene and vitamin C content was unaffected by deficit irrigation in watermelon and in some treatments, lycopene was higher during deficit irrigation. Flesh firmness is an important characteristic of internal fruit quality. Fruit flesh was slightly firmer at 0.5 ET compared to 0.75 ET. Both, glucose and fructose contents increased with deficit irrigation. Davis *et al.* (2006) suggested that restriction of fruit growth has significant influence on the lycopene content of watermelon. Withholding irrigation prior to harvesting increases sugar content and avoid fibrous flesh. Fernandes *et al.* (2014) also reported significant influence of irrigation frequencies on soluble solids content.

Gioia *et al.* (2009) reported that the effect of N rate and the interaction effects of irrigation × N rate were not significant on total soluble solids content in watermelon.

2.2.5.3 Water use efficiency

Water use efficiency (WUE) is the measure of a cropping systems capacity to convert water into plant biomass.

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Hegde (1987) reported that field water use efficiency (FWUE) increased by 15 per cent with decreasing irrigation frequency. Increase in N application (60 to 180 kg ha^{-1}) significantly increased FWUE (32 per cent) only up to 120 kg N ha^{-1} (Hegde, 1989).

Srinivas *et al.* (1989a) studied plant water relations, yield, water use efficiency (WUE) of watermelon under drip and furrow irrigation system. Drip irrigation with one emitter per two plants resulted in higher relative water content, osmotic potential, yield and WUE, compared to furrow irrigation. Replenishment of 25 per cent evaporation losses under drip irrigation and 50 to 75 per cent evaporation losses under furrow irrigation were optimum for getting high yields.

Srinivas *et al.* (1989b) reported that frequent irrigations in watermelon with 100 per cent evaporation replenishment resulted in highest WUE, under drip irrigation over furrow irrigation treatments. Simsek *et al.* (2004) found that the values of WUE ranged from 9.6 to 11.7 kg m^{-3} under semi condition.

2.2.6 Training and Pruning

The importance of providing supports to the vines of cucurbits has been emphasized by a number of workers (Abusaleha and Dutta, 1994a; Abusaleha and Dutta, 1994b; Joshi *et al.*, 1994; Ranpise *et al.*, 2010; Campagnol *et al.*, 2012). The advantages of these supports are attributed to efficient pest and disease management, easy chemical application, improved plant ventilation, easy harvesting and improved quality of fruits besides high yield.

Watermelon is conventionally trained horizontally on the ground. Recently, vertical training has emerged as an alternative to horizontal training due to the reduced crop management labour involved (Watanabe, 2014). Moreover, the number of plants that can be accommodated per unit area is more in vertical training, hence more yield. The vines are trained upward on supports and fruits are suspended by strings and/or nets, so that growers can perform many tasks standing rather than crouching. In order to meet the current marketing trends for small fruits, vertical training systems provide potential, especially for intensively protected cultivation.

In the temporary trellis system, where plants are initially trained vertically and later when desired number of fruits develops, the trellis wires were cut and allowed to grow horizontally, the average weight of triploid watermelon fruits was significantly reduced compared to horizontally trained crop. But with increase in planting density the number of commercial fruits per unit area was increased under temporary trellis system (Nunez *et al.*, 2008).

Campagnol *et al.* (2012) studied the response of vertically trained watermelon to training height and plant density. Three training heights of 1.7 m, 2.2 m and 2.7 m was evaluated at two planting densities. Highest commercial yield was obtained in the training height of 2.7 m, whereas fruit weight, marketable yield and all quality characteristics were on par with that of 2.2 m. There was no significant reduction in the average weight of fruits in polyhouse. However, Watanabe (2014) reported that in vertically trained plants the fruit weight was significantly lower compared to those horizontally trained, even when the total leaf area was similar.

In horizontally trained watermelon in greenhouse, Choi *et al.* (2012) studied the impact of secondary-lateral branch removal practices. Until three weeks after pollination, the rate of fruit growth and sucrose accumulation in fruit were much slower in partial removal of secondary branches. But accumulation of sucrose started to increase steeply four weeks after pollination, and reached the highest concentration. Oga and Umekwe (2015) reported that pruning of lateral branches of watermelon produced longest vines, more number of flowers and fruits compared to unpruned melons.

Materials and Methods

3. MATERIALS AND METHODS

The present investigation entitled 'Standardization of agrotechniques for precision farming in watermelon [*Citrullus lanatus* (Thunb.) Matsum. & Nakai]' was carried out during 2014 to 2016. The study consisted of the following experiments:

3.1 Evaluation of varieties / hybrids of watermelon

3.2 Standardization of agrotechniques for precision farming under rain shelter and open condition

3.1 EVALUATION OF VARIETIES / HYBRIDS OF WATERMELON

3.1.1 Experimental site

The experiment was conducted in the field of Department of Olericulture, College of Agriculture, Vellayani, located at 8°25' 53.7" N latitude and 76°59' 15.8" E longitude at an altitude of 29 m above mean sea level. The soil type of the experimental site is red loam of Vellayani series, texturally classified as sandy clay loam. The area enjoys a humid tropical climate.

3.1.2 Materials

The basic material for the study consisted of 20 accessions (three varieties and 17 hybrids) of watermelon collected from public and private sectors. The details of the accessions are presented in Table 1 and Plate 1.

3.1.3 Methods

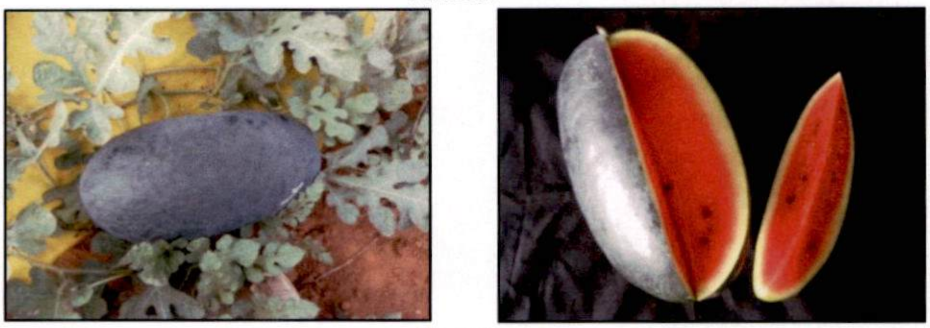
3.1.3.1 Design and layout

Twenty accessions of watermelon were evaluated for yield and quality during December 2014 to April 2015. The crop was raised as per the package of practices recommendations of Kerala Agricultural University (KAU, 2011) (Plate 2).

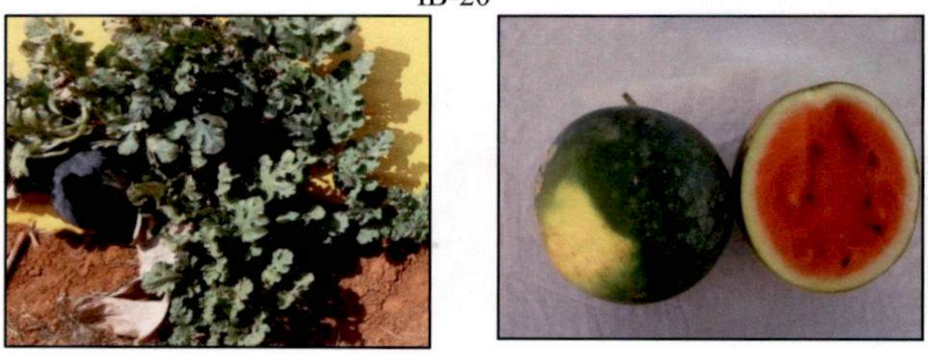
Table 1. Details of watermelon accessions used for evaluation

Treatment No.	Accession Number	Name	Source
T1	CL 1	Anmol	Known-You Seed (India) Pvt. Ltd., Pune
T2	CL 2	IB-20	Namdhari Seeds Pvt. Ltd., Bengaluru
T3	CL 3	Arka Muthu	IIHR , Bengaluru
T4	CL 4	Swarna	Kerala Agricultural University, Thrissur
T5	CL 5	Patanegra	Indo-American Hybrid Seeds, Bengaluru
T6	CL 6	Arka Akash	IIHR , Bengaluru
T7	CL 7	Arjun	Indo-American Hybrid Seeds, Bengaluru
T8	CL 8	Shonima	Kerala Agricultural University, Thrissur
T9	CL 9	Sumo	Indo-American Hybrid Seeds, Bengaluru
T10	CL 10	Kiran	Known-You Seed (India) Pvt. Ltd., Pune
T11	CL 11	IB-16	Namdhari Seeds Pvt. Ltd., Bengaluru
T12	CL 12	Arka Manik	IIHR , Bengaluru
T13	CL 13	Simran	Known-You Seed (India) Pvt. Ltd., Pune
T14	CL 14	NS-295	Namdhari Seeds Pvt. Ltd., Bengaluru
T15	CL 15	IB-23	Namdhari Seeds Pvt. Ltd., Bengaluru
T16	CL 16	Prachi	Known-You Seed (India) Pvt. Ltd., Pune
T17	CL 17	Sugar Baby	IARI, New Delhi
T18	CL 18	Agri Sweet Honey	Indica Hybrid Seeds, New Delhi
T19	CL 19	Saraswati	Known-You Seed (India) Pvt. Ltd., Pune
T20	CL 20	Devyani	Known-You Seed (India) Pvt. Ltd., Pune

Anmol



IB-20



Arka Muthu

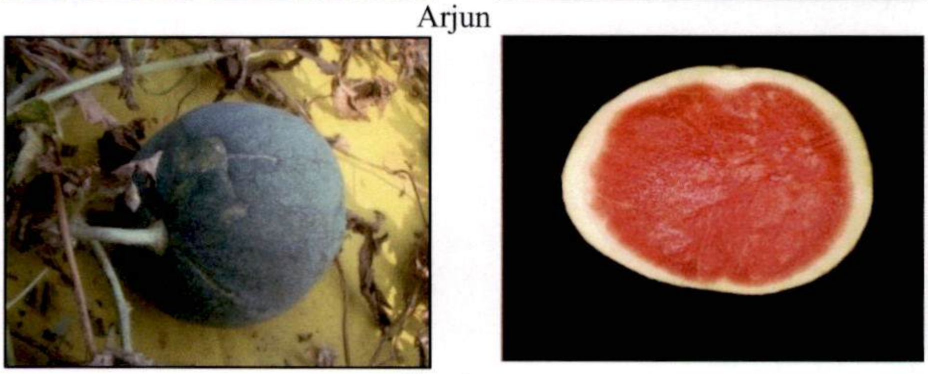
Swarna

Plate 1. Fruits of twenty accessions of *C. lanatus* (Experiment I)

Patanegra

Arka Akash

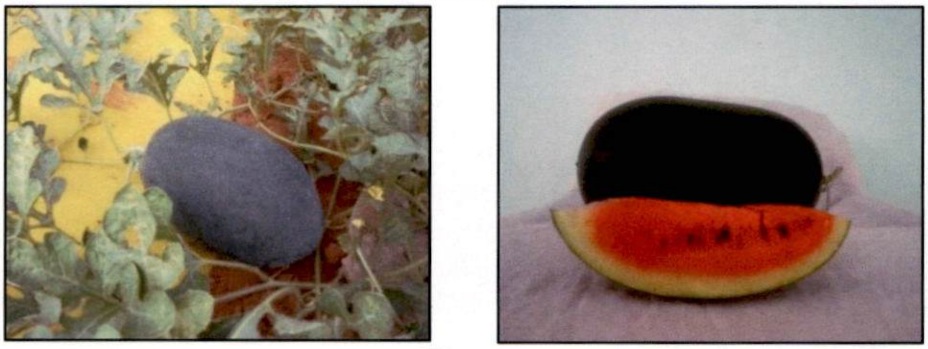
Arjun



Shonima

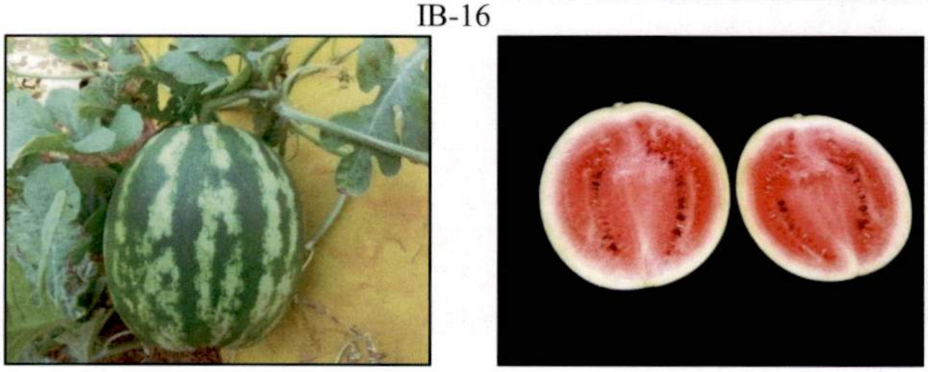
Plate 1. Continued

Sumo



Kiran

IB-16

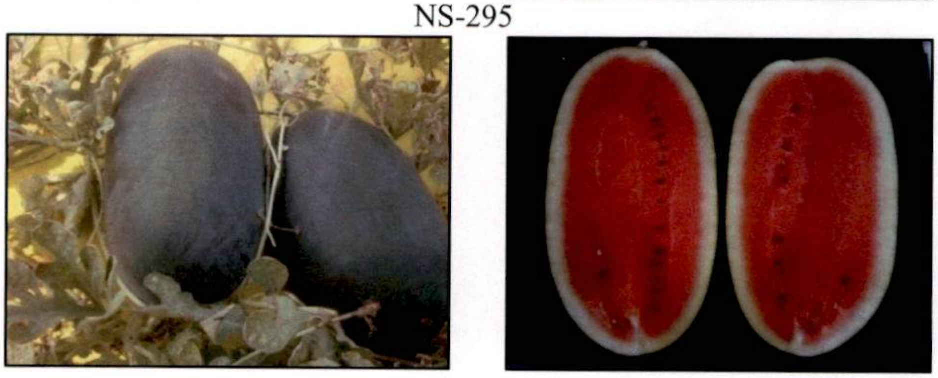


Arka Manik

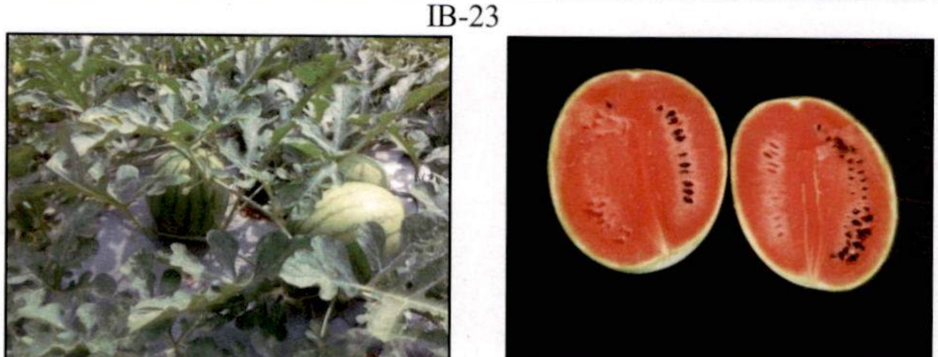
Plate 1. Continued

Simran

NS-295



IB-23



Prachi

Plate 1. Continued

Sugar Baby

Agri Sweet Honey

Saraswati

Devyani

Plate 1. Continued

Plate 2. General view of experimental field (Experiment I)

However, the spacing adopted was 2m x 1m with one plant per pit. The experiment was laid out as follows,

Design	: RBD
Treatments	: 20
Replication	: 2
Spacing	: 2 m x 1 m
Plot size	: 16 m^2 (8 plants/plot)

3.1.4 Observations

The observations were recorded from five plants selected at random in each replication and the mean worked out. For recording observations on fruit characters, five fruits were selected at random from the selected plants in each replication.

3.1.4.1 Vegetative and Flowering Characters

3.1.4.1.1 Vine length (m)

The length of vine from the cotyledonary node to the tip of the main vine after the final harvest was recorded.

3.1.4.1.2 Days to first male flower

The number of days taken from transplanting to the opening of the first male flower.

3.1.4.1.3 Node to first male flower

The node at which the first male flower appeared was recorded and the average worked out.

3.1.4.1.4 Days to first female flower

The number of days taken from transplanting to the bloom of the first female flower.

3.1.4.1.5 Node to first female flower

The node at which the first female flower appeared was recorded and the mean was worked out.

3.1.4.2 Fruit and Yield Characters

3.1.4.2.1 Fruit equatorial diameter (cm)

Fruits were cut horizontally and the diameter of the fruits was measured at the broadest point.

3.1.4.2.2 Fruit polar diameter (cm)

The fruits were cut longitudinally and the diameter was measured from the fruit stalk to the tip.

3.1.4.2.3 Rind thickness (cm)

The fruits were cut into two halves and thickness of rind was measured using scale.

3.1.4.2.4 Fruit weight (kg)

Weight of five fruits from each accession from each replication was taken and average worked out.

3.1.4.2.5 Days to first harvest

Number of days from the date of transplanting to the harvest of first fruit was recorded.

3.1.4.2.6 Fruits plant^{-1}

The total number of fruits harvested per plant till last harvest was recorded and the mean worked out.

3.1.4.2.7 Yield plant^{-1} (kg)

The weight of all fruits harvested from each plant per harvest was recorded and total worked out.

3.1.4.2.8 Yield plot^{-1} (kg)

The weight of fruits from each plot (16 m^2) per harvest was recorded and expressed in kilogram.

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

The weight of marketable fruits from each plot at each harvest was taken and total expressed in kilogram.

3.1.4.2.10 Days to final harvest

Number of days from the date of transplanting to the harvest of last fruit from the observational plants was recorded and the average was worked out.

3.1.4.2.11 Seeds fruit^{-1}

Average number of seeds per fruit was recorded.

3.1.4.2.12 Weight of 100 seeds (g)

The dry weight of randomly selected 100 seeds was taken.

3.1.4.3 Quality Characters

3.1.4.3.1 Total Soluble Solids (°Brix)

Total Soluble Solids (TSS) of watermelon fruits was recorded using hand refractometer (Erma – 0 to 32).

3.1.4.3.2 Lycopene (mg 100g^{-1})

Lycopene content of the fruits was estimated by following the method suggested by Sadasivam and Manickam (2008).

3.1.4.3.3 Ascorbic acid (mg 100g^{-1})

Ascorbic acid was estimated by visual titration method based on the reduction of 2, 6-Dichlorophenol indophenol as adopted by Freed (1966) and expressed in mg 100g^{-1}of fresh sample.

The fruit pulp of one gram was crushed in mortar with 5 ml of 4 per cent oxalic acid and centrifuged at 3000 rpm for 10 minutes. The supernatant liquid was made up to 25 ml with 4 per cent oxalic acid. An aliquot of 5 ml extract with 10 ml of 4 per cent oxalic acid was taken and titrated against the standard indophenol dye till the solution changed to pink colour.

Ascorbic acid content was calculated from the following formula,

$$\frac{\text{Dye factor x titer value}}{\text{Weight of the sample (1g)}} \text{ x } 100$$

The dye factor was obtained by standardization of dye. Five ml of standard ascorbic acid was titrated against the dye solution which was taken in the burette till the appearance of light pink colour which should persist for 15 seconds. The dye factor *ie*., mg of ascorbic acid per ml of the dye was determined using the formula,

$$\text{Dye factor} = \frac{0.5}{\text{Titer value}}$$

3.1.4.3.4 Reducing sugar

Fruit juice of the observation plants was extracted and reducing sugar was estimated as per Sadasivam and Manickam (2008) and expressed as per cent on fresh weight basis.

3.1.4.3.5 Non-reducing sugar

From the fruit juice of observation plants non-reducing sugar was estimated as per Sadasivam and Manickam (2008) and expressed as per cent on fresh weight basis.

3.1.5 Sensory Evaluation of Watermelon Accessions

Watermelon slices from different accessions were evaluated for sensory characteristics *viz.*, appearance, colour, flavour, taste, texture and overall acceptability by ten members. Each attribute was given score from 1 to 9 according to Hedonic rating (Ranganna, 1986) (Appendix I). The score was statistically analyzed using Kruskal-Wallis test (Chi square value) and ranked (Shamrez *et al.*, 2013).

3.1.6 Incidence of Pests and Diseases

The watermelon accessions were monitored for incidence of pests and diseases in field condition. Major disease noticed was Fusarium wilt and the pest was pumpkin caterpillar.

3.1.6.1 Fusarium Wilt *(Fusarium oxysporum* f. sp. *niveum)*

Wilting symptom first develop on single laterals expressed as flaccidity of leaves. A long narrow brown streak may develop on one side of the stem near the soil level extending upward. The diseased plant may bear large number of fruits, which ultimately shrivel before attaining full size.

Data on the severity of Fusarium wilt was recorded following 1-4 rating scale (Tziros *et al.*, 2007) where,

1- Apparently healthy plant

2 - Slight chlorosis of lower leaves, slight wilt of plant

3 - Necrosis, falling of lower leaves yellow areas on upper leaves

4- Dead plant

Based on the scores assigned to each diseased plant, severity (Percentage disease index) was worked out using the formula described by Mc Kinney (1923).

$$\text{Percentage Disease Index} = \frac{\text{Sum of individual ratings}}{\text{Total number of plants observed}} \times \frac{100}{\text{Maximum grade}}$$

3.1.6.2 Pumpkin caterpillar [*Diaphania indica* (Saunders)]

The young caterpillars lacerate and feed on chlorophyll of foliage. Later, they fold and web together the leaves and feed within. The caterpillars also scrape the green matter from the rind of developing fruits, leaving a feeding scar.

The pest could be effectively managed by spraying Flubendiamide 39.35 EC (Fame) @ 0.1 ml l^{-1}.

3.1.7 Genetic Cataloguing

IPGRI descriptor was not available for watermelon. Hence, the accessions were described morphologically using the descriptor developed by European Cooperative Programme for Plant Genetic Resources (ECPGR, 2008) and International Union for the Protection of New Varieties of Plants (UPOV, 2012) (Appendix II).

3.1.8 Statistical Analysis

The data recorded were processed using the following statistical procedures.

3.1.8.1 Analysis of variance (ANOVA)

The observations recorded were subjected to ANOVA (Panse and Sukhatme, 1985) for comparison among various treatments and to estimate variance components.

ANOVA for each character

Sources of variation	Degrees of freedom	Mean sum of squares	F ratio
Replication	r-1	MSR	MSR/MSE
Treatment	t-1	MST	MST/MSE
Error	(r-1) (t-1)	MSE	
Total	rt-1		

Where, r = number of replications

t = number of treatments

MSR = mean sum of replication

MST = mean sum of treatments

MSE = mean sum of error

Critical difference (CD) = $t_{\alpha}\sqrt{\frac{2MSE}{r}}$

Where, t_{α} = Student's 't' table value at error degrees of freedom at α level of significance.

3.1.8.2 Estimation of Genetic Parameters

3.1.8.2.1 Genetic component of variance

The phenotypic and genotypic variances were calculated by utilizing the respective mean square values (Johnson *et al.*, 1955).

i) Genotypic variance (V_G)

$$V_G = \frac{MST-MSE}{r}$$

ii) Environmental variance (V_E)

V_E = MSE

iii) Phenotypic variance (V_P)

$V_P = V_G + V_E$

3.1.8.2.2 Coefficient of variation

The genotypic and phenotypic coefficients of variation are calculated as per Burton (1952).

i) Phenotypic coefficient of variation (PCV)

$$PCV = \frac{\sqrt{V_P}}{\overline{X}} \times 100$$

ii) Genotypic coefficient of variation (GCV)

$$GCV = \frac{\sqrt{V_G}}{\overline{X}} \times 100$$

$\overline{X}$ = General mean of characters

Categorization of the range of variation was followed as proposed by Sivasubramanian and Menon (1973).

Low : Less than 10 per cent

Moderate : 10 to 20 per cent

High : More than 20 per cent

3.1.8.3 Heritability

Heritability in the broad sense refers to the proportion of genotypic variance to the total observed variance in the total population. Heritability in broad sense was estimated for various characters and expressed in percentage (Allard, 1960).

$$\text{Heritability } (h^2) = \frac{V_G}{V_P} \times 100$$

As suggested by Johnson *et al.* (1955) heritability in broad sense estimates were categorized as,

Low : Less than 30 per cent

Moderate : 30 to 60 per cent

High : More than 60 per cent

3.1.8.4 Genetic Advance

Genetic advance refers to the expected genetic gain or improvement in the next generation by selecting superior individuals under certain amount of selection pressure. It depends upon standardized selection differential, heritability and phenotypic standard deviation (Allard, 1960). The genetic advance was calculated in per cent by the formulae suggested by Johnson *et al.* (1955).

Genetic advance (GA) = $k \times h^2\sqrt{V_P}$

GA as percentage of mean = $\frac{GA}{\bar{X}} \times 100$

where, k = standardized selection differential (2.06 at 5% selection intensity)

h^2 = heritability

The range of genetic advance as per cent of mean was classified as suggested by Johnson *et al.* (1955).

Low : Less than 10 per cent

Moderate : 10 to 20 per cent

High : More than 20 per cent

3.1.8.5 Correlation Analysis

Phenotypic and genotypic correlation coefficients were calculated using the respective variance and covariance of the characters which showed significant variation in ANOVA.

Phenotypic correlation coefficient, $(r_{PX,Y}) = \frac{Cov_P\,(X,Y)}{\sqrt{V_P\,(X).V_P\,(Y)}}$

Genotypic correlation coefficient, $(r_{GX,Y}) = \frac{Cov_G\,(X,Y)}{\sqrt{V_G\,(X).V_G\,(Y)}}$

where, Cov_P (X,Y) = phenotypic variance between two traits X and Y

Cov_G (X,Y) = genotypic covariance between two traits X and Y

$V_P(X)$ and $V_P(Y)$ = phenotypic variance for X and Y respectively

$V_G(X)$ and $V_G(Y)$ = genotypic variance for X and Y respectively

3.1.8.6 Path Coefficient Analysis

To study the cause and effect relationship of yield and its component characters, direct and indirect effects were analyzed using path coefficient analysis as suggested by Dewey and Lu (1959).

3.2 STANDARDIZATION OF AGROTECHNIQUES FOR PRECISION FARMING UNDER RAIN SHELTER AND OPEN CONDITION

3.2.1 Experimental site

Two simultaneous experiments were conducted under rain shelter and open condition at Department of Olericulture, College of Agriculture, Vellayani. The site of rain shelter was located at 8°25'53.5"N latitude and 76°59'14.9"E longitude at an altitude of 29 m above mean sea level. The location of open field was 8°25'53.7"N latitude and 76°59'15.8"E longitude (Plate 3).

3.2.2 Soil

The soil of experiment site is red loam of Vellayani series, texturally classified as sandy clay loam. Chemical properties of soil under rain shelter and open are summarized in Table 2.

3.2.3 Season and Weather Conditions

The experiment was conducted from December 2015 to April 2016. The data on weather parameters (maximum temperature, minimum temperature, relative humidity, monthly rainfall, number of rainy days per month and evaporation) during the cropping period are presented in Fig. 1 and in Appendix III.

3.2.4 Materials

The rain shelter of 266 m^2 area (38 m x 7m) in east-west direction, with centre height 4.30 m and gutter height 3.00 m was used. The framework is made of GI pipes of 3 mm thickness. The roof is covered with UV stabilized polyethylene sheet of 200 μ thickness. Green shade net (50 per cent) is used to give side covering up to 2 m height from the ground (Plate 4).

Plate 3. Location of the experiment

Table 2. Chemical characteristics of soil prior to experiment

Particulars	Value		Method used
	Rain shelter	Open	
Soil reaction (pH)	4.8 (Very strongly acid)	4.9 (Very strongly acid)	pH meter with glass electrode (Jackson, 1973)
Electrical conductivity (dS m^{-1})	0.18 (Normal)	0.28 (Normal)	Digital conductivity meter (Jackson, 1973)
Organic C (%)	1.70 (High)	1.60 (High)	Walkley and Black rapid titration method (Jackson, 1973)
Available N (kg ha^{-1})	282.33 (Medium)	273.40 (Medium)	Alkaline $KMnO_4$ method (Subbiah and Asija, 1956)
Available P (kg ha^{-1})	148.87 (High)	181.30 (High)	Bray's colorimetric method (Jackson, 1973)
Available K (kg ha^{-1})	198.00 (Medium)	243.60 (Medium)	Ammonium acetate method (Jackson, 1973)
Available Ca (ppm)	440.00 (Sufficiency)	750.00 (Sufficiency)	EDTA method (Jackson, 1973)
Available Mg (ppm)	127.00 (Sufficiency)	123.00 (Sufficiency)	
Available S (ppm)	11.00 (Sufficiency)	27.00 (Sufficiency)	$CaCl_2$ extraction method (Tabatabai, 1982)
Available Fe (ppm)	184.80 (Sufficiency)	215.30 (Sufficiency)	DTPA extraction method (Lindsay and Norwell, 1978)
Available Mn (ppm)	33.30 (Sufficiency)	12.60 (Sufficiency)	
Available Zn (ppm)	2.36 (Sufficiency)	1.56 (Sufficiency)	
Available Cu (ppm)	1.30 (Sufficiency)	1.20 (Sufficiency)	
Available B (ppm)	0.63 (Sufficiency)	0.56 (Sufficiency)	Hot water extraction method (Gupta, 1967)

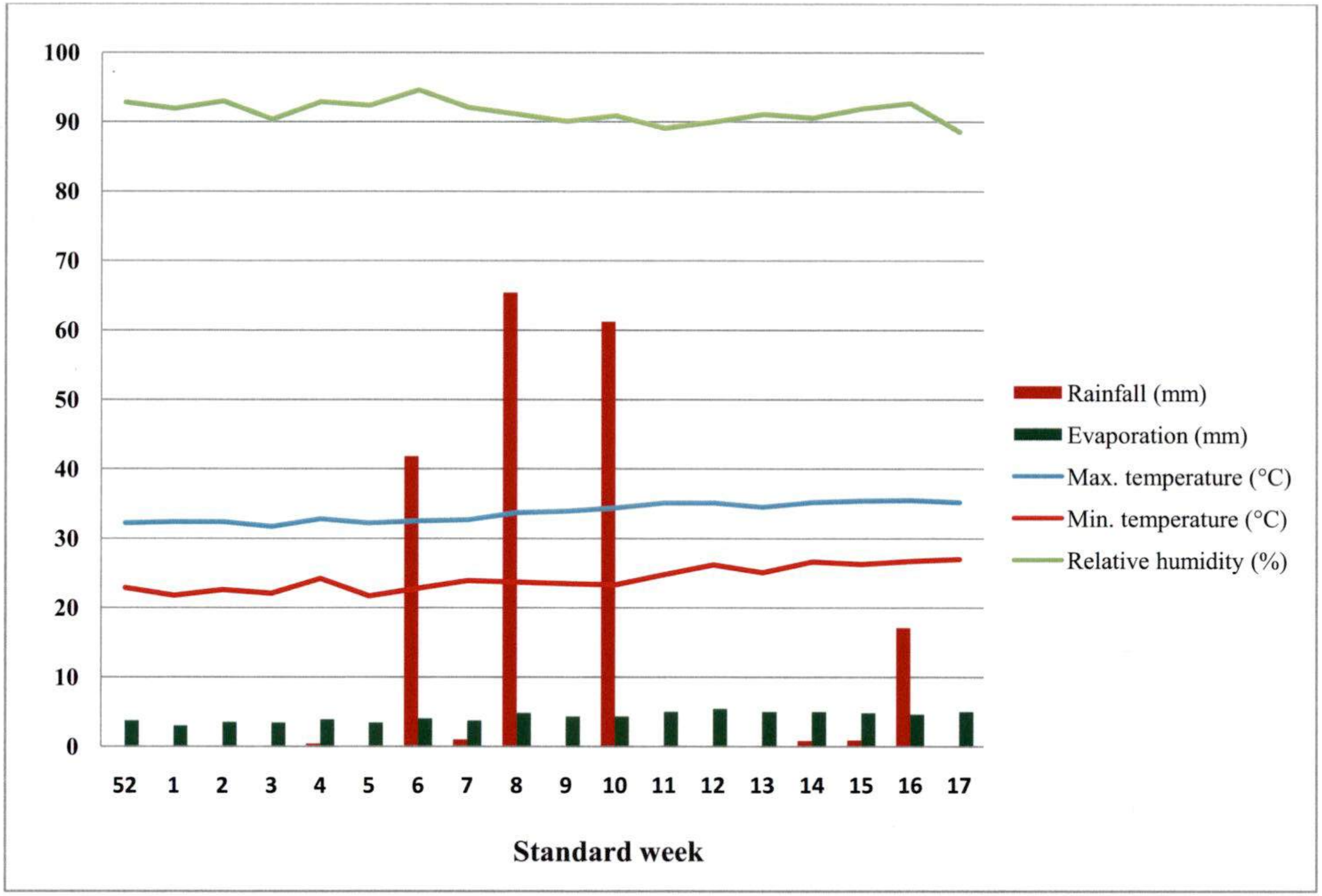
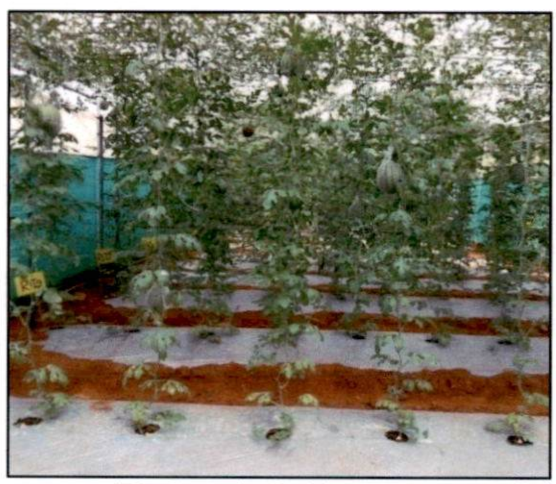


Fig. 1. Weather parameters during the cropping period (December 2015 - April 2016)

4A. Rain shelter used in Experiment II

4B. Crop in early stage



4C. Crop in fruiting stage

Plate 4. Inside and outside view of rain shelter

The best accession from Experiment I, Prachi (F_1) of Known You Seed (India) Pvt. Ltd., Pune, was used for both rain shelter and open condition.

3.2.5 Methods

3.2.5.1 Design and layout

Two separate experiments were conducted simultaneously under rain shelter and open condition using the hybrid Prachi during December 2015 to April 2016. The treatments included three levels of fertilizers, two levels of drip irrigation and two levels of training along with two controls.

Design : Factorial RBD

Treatments : 14

Replications : 2

Spacing : 1.5 m x 0.6 m

Plot size : 9 m^2 (10 plants/plot)

3.2.5.2 Treatments

(a) Fertilizer – 3 levels

F_1 - 75 per cent of recommended dose (52.50: 37.50: 90.00 kg NPK ha^{-1})

F_2 - 100 per cent of recommended dose (70: 50: 120 kg NPK ha^{-1})

F_3 -125 per cent of recommended dose (87.50: 62.50: 150.00 kg NPK ha^{-1})

(Since no specific recommendation for watermelon is available in the KAU *Ad hoc* POP for precision farming (KAU, 2013), a modified recommendation based on cucumber was adopted).

(b) Irrigation – 2 levels

I_1- 80 per cent Epan

I_2- 60 per cent Epan

(Epan – Pan evaporation rate in mm recorded from U. S. class A open pan evaporimeter)

(c) Training – 2 levels

T_1- Nipping to one vine

T_2- Nipping to two vines

Control (2)

Control 1: KAU *Ad hoc* recommendation (modified) for precision farming (70: 50: 120 kg NPK ha^{-1}, irrigation at 100 per cent Epan and pruning laterals only up to 60 cm height).

Control 2: KAU POP (Basin irrigation without mulching at POP level of fertilizer application, 70:25:25 kg NPK ha^{-1}).

Plants were trained vertically under rain shelter and horizontally in open condition.

3.2.5.3 Field Preparation and Planting

The experimental area was deeply ploughed up to 50 cm and weeds and stubbles were removed. Farm yard manure @ 25 t ha^{-1} and Rock phosphate (125 kg ha^{-1}) was applied before last ploughing. Raised beds of one meter width and one foot height were taken with channels of 50 cm between beds; so that the row to row spacing was 1.5 m. Drip lines were laid with a lateral per bed and online drippers with a discharge rate of 2 l hour^{-1} spaced every 60 cm. The beds were covered with silver on black polyethylene mulch of 50 μ thickness. Holes were punched at 60 cm spacing for transplanting (Plate 5).

Seedlings were raised in protrays using cocopeat and vermicompost as media. Seeds germinated in 3-4 days. Twelve days old seedlings at 2-3 true leaf stage were transplanted to main field at 60 cm spacing.

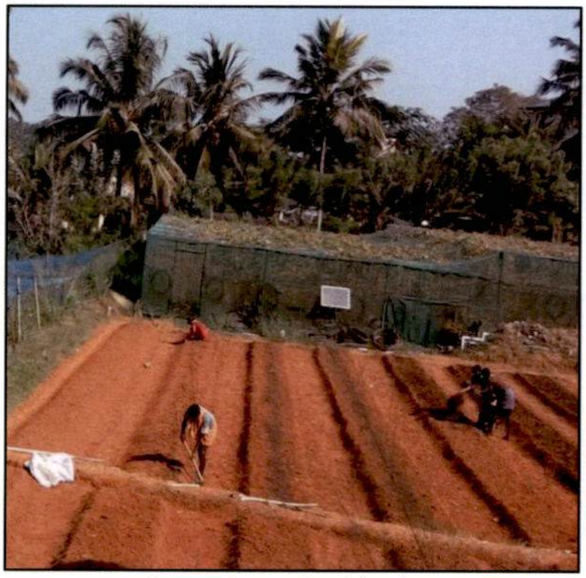
3.2.5.4 Training and Pruning

The plants were trained vertically under rain shelter (Plate 6). The tip of the main vine was nipped off at about 10-12 DAT and two vigorously growing laterals were allowed to grow as main vines in T_2 (nipping to two vines). In T_1 (nipping to one vine) only the main vine was allowed to grow. In rain shelter, plants were trailed on plastic strings tied on steel wires raised over the cropping rows 2.5 m height. The first three secondary branches were removed as soon as they appeared and the rest were pruned periodically after the third leaf (Campagnol *et al.*, 2012). In the case of Control 1 (*Ad hoc*) all laterals up to 2 feet only were removed and rest were trained vertically without pruning. In Control 2 (KAU POP) no pruning was adopted and plants were trailed horizontally over dried coconut fronds.

The plants were trained horizontally under open condition (Plate 7). Nipping was done as in rain shelter, but pruning of laterals was done only for about a month. Field view of the experiment under rain shelter and open are given in Plate 4 and Plate 8 respectively.

3.2.5.5 Drip irrigation scheduling

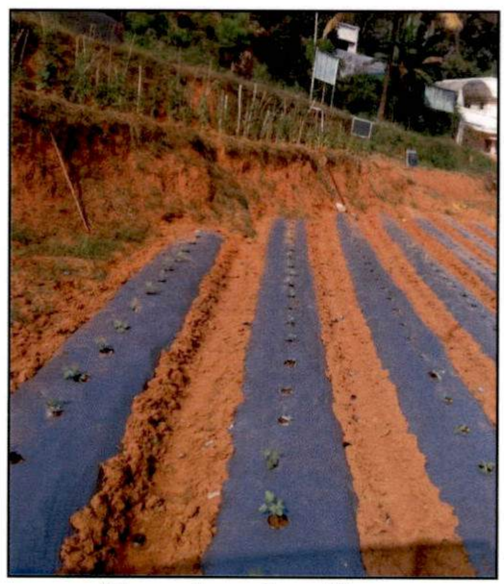
Uniform irrigation was given to the seedlings up to one week after transplanting. Irrigation scheduling was started from first week onwards. Drip irrigation was scheduled daily to meet the crop water requirement.



Preparing raised beds

Beds covered with polyethylene mulch

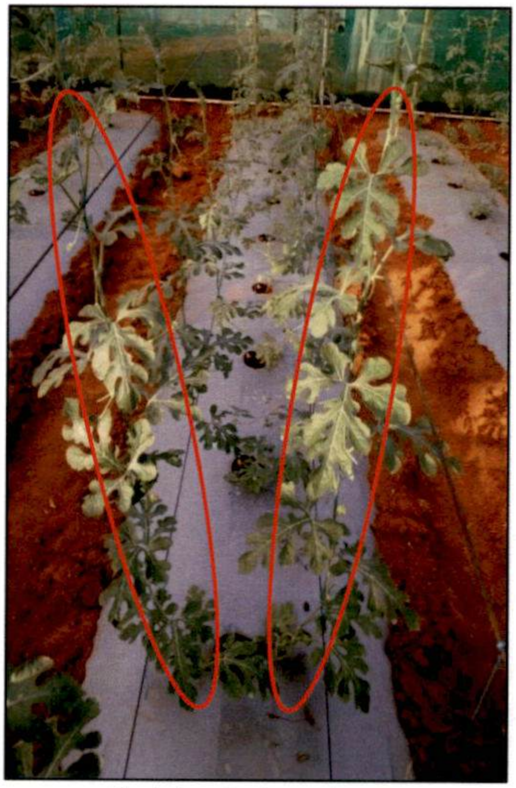
Protray seedlings



Transplanted seedlings

Plate 5. Land preparation and transplanting

Training to one vine

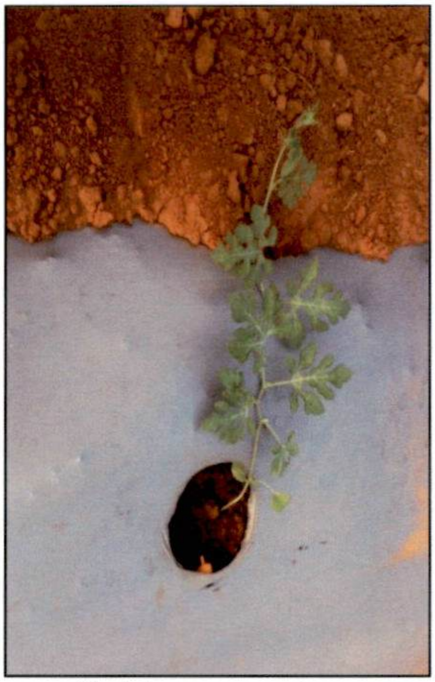


Training to two vines

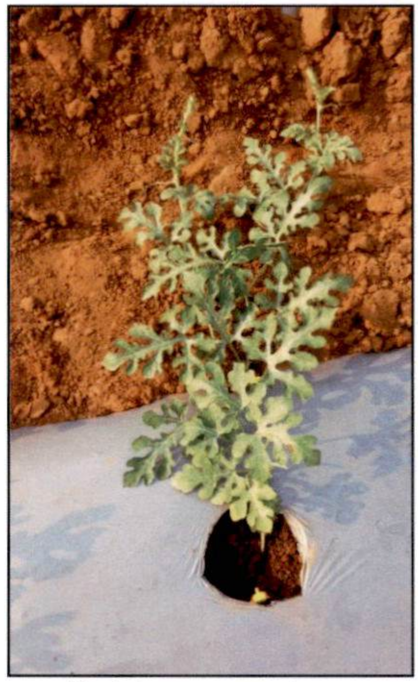
One vine- Fruiting stage

Two vines- Fruiting stage

Plate 6. Training of vines in rain shelter



Training to one vine



Training to two vines

Plate 7. Training of vines under open condition

Plate 8. Field view of open cultivation (Experiment II)

Based on the pan evaporation data of previous day, irrigation water requirement through drip (volume in litre plant^{-1} day^{-1}) was computed using the following relationship,

V = Epan x Kp x Kc x A (Biswas, 2015)

where,

V = Volume of water applied to each plant (litre plant^{-1} day^{-1})

Epan = Pan evaporation rate (mm) from U. S. class A open pan evaporimeter

Kp = Pan co-efficient (0.75)

Kc = Crop co-efficient (initial - 0.40; mid stage - 1.00; late stage - 0.75) (FAO, 1998)

Since polythene mulch was used, a 10 per cent reduction in Kc value (mid stage and late stage) was given (FAO, 1998).

A = Area allotted per plant (1.50 m x 0.60 m)

For Control 2 (KAU POP) basin irrigation was given. Measured quantity of water was applied once in 3 to 4 days initially and in alternate days during flowering. During fruit ripening stage irrigation was given in 3 to 4 days interval.

3.2.5.6 Fertigation

Fertigation was done at three days interval using fertigation pump (Plate 9). Water soluble fertilizers 19:19:19, 13:0:45, Urea and 12:61:0 were used. The fertigation schedule (KAU, 2013) is furnished in Table 3 and Appendix IV.

Nutrient solution for fertigation was prepared by dissolving required quantity of fertilizers in water. The tube attached to the fertigation pump was immersed in the nutrient solution and the system was operated to supply the nutrients along with irrigation water. Flushing of sub mains and laterals were done before the start of

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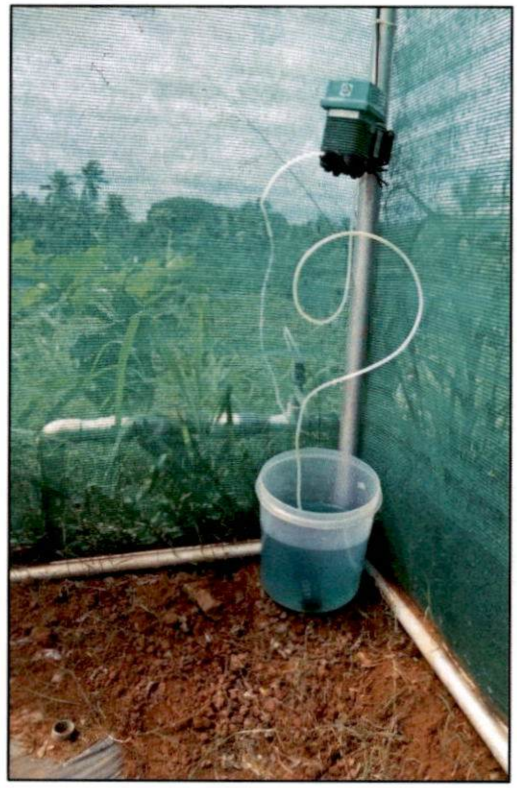

Plate 9. Fertigation using fertigation pump

fertigation. After every fertigation, drip irrigation was continued for five to ten minutes. Periodic cleaning of disc filter and screen filter was also carried out.

For Control 2 (KAU POP), manual application of fertilizer was done. Half dose of nitrogen and full doses of phosphorus and potassium were applied as basal. Remaining half dose of nitrogen was applied in two equal splits at vining and full bloom stage.

Table 3. Fertigation schedule at 3 days interval for 200 m^2 area

Item	Period (DAT)	Fertilizers to be used each time (Water Soluble) (g)				No. of split applications
		19:19:19	13:0:45	Urea	12:61:0	
F_1 (75% RD)	3 to 18	66.0	57.0	51.0	1.8	6
	21 to 90	33.0	120.0	21.0	12.0	24
F_2 (100% RD)	3 to 18	88.0	76.0	68.0	2.4	6
	21 to 90	44.0	160.0	28.0	16.0	24
F_3 (125% RD)	3 to 18	110.0	95.0	85.0	3.0	6
	21 to 90	55.0	200.0	35.0	20.0	24

Rock Phosphate @1.9 kg (F_1), 2.5 kg (F_2) and 3.1 kg (F_3) as basal dose

3.2.5.7 Plant Protection

The pest and disease occurrence were under control by the adoption of proper plant protection measures. Pumpkin butterfly [*Diaphania indica* (Saunders)] was seen in the initial stage of crop growth and spraying of Flubendiamide 39.35 EC (Fame) @ 0.1 ml l^{-1} effectively controlled them. Drenching of carbendazim + mancozeb 75 WP (Saaf) @ 3 g l^{-1} and pseudomonas @ 20 g $l^{-1}$was used as a protective measure against fusarium wilt. Cue-lure trap was used to control fruit flies (*Bactrocera cucurbitae* Coq.).

3.2.5.8 Harvesting

The fruits were harvested periodically on full maturity. The edible maturity stage was judged from the dried up tendril on the node of fruit attachment, a dull sound made when tapping the fruit with a finger compared to metallic sound in the case of immature and yellowish colour of the ground spot.

3.2.6 Observations

As in Experiment I (given in 3.1.4).

3.2.7 Water Requirement and Water Use Efficiency (WUE)

Total water requirement (WR) in each treatment was estimated directly by adding up the quantity of water supplied through irrigation with the quantity of effective rainfall and moisture contribution from soil profile. Moisture contribution from soil profile was not considered in the present calculation as this was negligible.

Total water requirement = Irrigation requirement + Effective rainfall

[Effective rainfall = 70 per cent of total seasonal rainfall (Dastane, 1974). Value reduced to 50 per cent due to polyethylene mulch (Leskovar *et al.*, 2004)].

Water use efficiency was estimated using the following formula and expressed as kg $ha^{-1}mm^{-1}$.

$$\text{Water Use Efficiency (WUE)} = \frac{\text{Yield (kg ha}^{-1}\text{)}}{\text{Total water requirement (mm)}}$$

3.2.8 Soil Analysis after the Experiment

Soil samples were collected after the experiment from both rain shelter and open condition. The composite samples drawn from the individual plots were air dried, powdered, sieved through 2mm sieve and analysed for N, P and K as per the methods mentioned in Table 2 and expressed in kg ha^{-1}.

3.2.9 Statistical Analysis

The data was analysed statistically by applying the techniques of analysis of variance (Panse and Sukhatme, 1985). Wherever the effects were found to be significant, CD values were calculated using standard techniques.

Results

4. RESULTS

The present investigation was conducted at the Department of Olericulture, College of Agriculture, Vellayani during December 2014 to April 2016 to evaluate the performance of watermelon varieties/ hybrids for yield and quality characteristics and to standardize agrotechniques for precision farming in watermelon under rain shelter and open. The experimental data were analyzed statistically and the results are presented below.

4.1 EXPERIMENT I

EVALUATION OF VARIETIES / HYBRIDS OF WATERMELON

4.1.1 Analysis of Variance

The analysis of variance revealed highly significant differences among the twenty accessions for all the characters studied. The mean sum of squares for twenty two characters is presented in Table 4.

4.1.2 Mean Performance of Watermelon Accessions

The mean performance of twenty watermelon accessions for twenty two characters is given below.

4.1.2.1 Vegetative and Flowering Characters

The mean values for vegetative and flowering characters like vine length, days to first male flower, node to first male flower, days to first female flower and node to first female flower are furnished in Table 5.

4.1.2.1.1 Vine length

Significant difference was noticed among the accessions for vine length. The mean vine length ranged from 1.20 m to 6.29 m. Arka Muthu (T3) recorded the

Table 4. Analysis of variance for characters in watermelon (Mean squares are given)

Source	df	Vine length	Days to first male flower	Node to first male flower	Days to first female flower	Node to first female flower	Fruit equatorial diameter
Replication	1	0.697	2.500	2.025	5.625	3.025	1.190
Treatment	19	2.237**	37.995**	6.183**	29.814**	12.183**	13.858**
Error	19	0.232	1.763	0.762	0.678	1.130	1.651

Source	df	Fruit polar diameter	Rind thickness	Fruit weight	Days to first harvest	Fruits plant^{-1}	Yield plant^{-1}
Replication	1	0.144	0.072	0.002	3.600	0.008	0.168
Treatment	19	44.738**	0.311**	3.164**	172.035**	1.454**	17.513**
Error	19	4.215	0.021	0.185	1.123	0.108	0.328

Source	df	Yield plot^{-1}	Marketable yield plot^{-1}	Days to final harvest	Seeds fruit^{-1}	Weight of 100 seeds
Replication	1	13.642	0.465	6.399	319.225	0.012
Treatment	19	634.711**	569.551**	169.082**	25835.025**	10.899**
Error	19	19.449	28.228	8.979	429.014	0.274

Source	df	TSS	Lycopene	Ascorbic acid	Reducing sugar	Non reducing sugar
Replication	1	0.002	0.100	0.256	0.003	0.015
Treatment	19	2.395**	8.558**	1.088**	0.168**	0.181**
Error	19	0.111	0.134	0.077	0.020	0.024

** Significant at 1 per cent level

Table 5. Mean performance of watermelon accessions for vegetative and flowering characters

Treatments		Vine length (cm)	Days to first male flower (DAT)	Node to first male flower	Days to first female flower (DAT)	Node to first female flower
T1	Anmol	4.60	36.01	8.50	40.00	17.50
T2	IB-20	3.83	36.50	9.00	37.50	18.50
T3	Arka Muthu	1.20	27.50	5.50	36.50	15.00
T4	Swarna	6.06	35.50	8.50	40.53	18.50
T5	Patanegra	3.60	34.00	8.50	37.50	18.50
T6	Arka Akash	4.50	38.50	8.50	46.50	22.50
T7	Arjun	3.38	37.50	9.00	41.50	23.00
T8	Shonima	4.77	38.50	9.52	42.50	18.50
T9	Sumo	4.58	39.02	11.00	42.50	22.00
T10	Kiran	3.40	37.00	8.50	47.00	17.00
T11	IB-16	3.75	28.50	8.50	36.00	20.50
T12	Arka Manik	3.70	40.50	13.00	46.00	21.50
T13	Simran	3.68	35.00	10.01	37.00	18.50
T14	NS-295	6.29	42.00	12.00	45.00	23.50
T15	IB-23	3.90	35.51	8.50	43.01	20.03
T16	Prachi	3.30	27.50	6.50	35.00	14.50
T17	Sugar Baby	4.16	35.00	11.50	39.50	19.00
T18	Agri Sweet Honey	4.55	34.00	10.00	38.00	20.50
T19	Saraswati	3.42	30.50	10.50	38.00	17.00
T20	Devyani	3.80	42.50	8.50	46.00	19.51
Mean		4.02	35.55	9.28	40.78	19.28
SEm (±)		0.341	0.939	0.617	0.582	0.752
CD (0.05)		1.009	2.779	1.827	1.723	2.225

shortest vine length (1.20 m) followed by T16 (3.30 m). T14 (NS-295) produced the longest vine of 6.29 m. Of the twenty accessions, twelve accessions were having vine length lesser than the general mean of 4.02 m.

4.1.2.1.2 Days to first male flower

The accessions T16 and T3 were the earliest to produce male flower (27.50 days) which were on par with T11 (28.50 days). The accession T20 was late and took 42.50 days for flowering which was on par with T14 (42.00 days).

4.1.2.1.3 Node to first male flower

The node in which first male flower appeared varied from 5.50 to 13.00. Lowest node number was recorded in T3 (5.50) and the accession T16 (6.50) on par with it. The highest node number of 13.00 was recorded in T12. The accessions T14 (12.00) and T17 (11.50) were on par with T12.

4.1.2.1.4 Days to first female flower

T16 (Prachi) was the earliest in female flowering with 35.00 days followed by T11 (36.00) and T3 (36.50). T10 flowered late (47.00) and was on par with T6 (46.50), T20 (46.00) and T12 (46.00). The average number of days for female flowering was 40.78 days. Among the twenty accessions, eleven flowered earlier than the general mean.

4.1.2.1.5 Node to first female flower

The accessions differed significantly for first female flowering node with an average of 19.28. The lowest node number was registered by T16 (14.50) which was statistically on par with T3 (15.00). The highest node number was recorded in T14 (23.50) which was on par with T7 (23.00). Eleven accessions produced female flower in nodes lower than the average for this character.

4.1.2.2 Fruit and Yield Characters

Table 6 depicts the mean values for fruit and yield characters like fruit equatorial diameter, fruit polar diameter, rind thickness, fruit weight, days to first harvest, fruits plant^{-1}, yield plant^{-1}, yield plot^{-1}, marketable yield plot^{-1}, days to final harvest, seeds fruit^{-1} and weight of 100 seeds.

4.1.2.2.1 Fruit equatorial diameter

Significant difference was noticed among the accessions for fruit equatorial diameter. Highest diameter was observed in T17 (23.50 cm) and was on par with T5 (21.50 cm). The lowest equatorial diameter of 12.65 cm was recorded in T7. The average equatorial diameter was 17.16 cm.

4.1.2.2.2 Fruit polar diameter

The fruit polar diameter exhibited a wide range of 15.00 cm to 31.00 cm. Lowest diameter was expressed by T6 (15.00 cm) which was statistically on par with T8 (15.50 cm), T3 (16.50 cm), T16 (17.25 cm), T4 (18.00 cm) and T1 (18.25 cm). Highest diameter was recorded in T9 (31.00 cm) and was on par with T15 (30.65 cm).

4.1.2.2.3 Rind thickness

The lowest value for rind thickness was recorded in T16 and T20 (0.75 cm) while T2 recorded the highest rind thickness of 2.20 cm. The average rind thickness was 1.41 cm. Eight accessions had lesser rind thickness than the general mean.

4.1.2.2.4 Fruit weight

There was significant difference between accessions with respect to fruit weight. It ranged from 1.55 kg to 6.38 kg with a mean of 3.24 kg. Accession T17

Table 6. Mean performance of watermelon accessions for fruit and yield characters

Treatments		Fruit equatorial diameter (cm)	Fruit polar diameter (cm)	Rind thickness (cm)	Fruit weight (kg)
T1	Anmol	16.75	18.25	0.90	2.27
T2	IB-20	18.01	29.50	2.20	4.29
T3	Arka Muthu	16.00	16.50	1.51	2.21
T4	Swarna	17.52	18.00	1.42	2.55
T5	Patanegra	21.50	22.53	1.50	3.69
T6	Arka Akash	14.50	15.00	1.65	2.41
T7	Arjun	12.65	20.25	1.00	1.55
T8	Shonima	15.50	15.50	1.55	1.93
T9	Sumo	18.50	31.00	1.75	5.24
T10	Kiran	14.50	25.75	1.55	2.42
T11	IB-16	18.01	21.50	1.60	3.02
T12	Arka Manik	17.50	22.00	2.00	3.85
T13	Simran	14.50	21.01	1.50	2.42
T14	NS-295	16.75	21.50	1.20	2.96
T15	IB-23	17.10	30.65	1.45	4.41
T16	Prachi	14.25	17.25	0.75	1.85
T17	Sugar Baby	23.50	26.00	1.80	6.38
T18	Agri Sweet Honey	20.75	22.50	1.20	4.67
T19	Saraswati	17.00	23.25	1.00	3.33
T20	Devyani	18.50	20.50	0.75	3.33
Mean		17.16	21.92	1.41	3.24
SEm (±)		0.909	1.452	0.103	0.305
CD (0.05)		2.690	4.297	0.305	0.900

(Sugar Baby) ranked first in weight (6.38 kg) followed by T9 (5.24 kg). Lowest weight of 1.55 kg was recorded in T7 (Arjun).

4.1.2.2.5 Days to first harvest

Accessions varied significantly for days to first harvest. It ranged from 54 days to 91.50 days. T16 (Prachi) exhibited the lowest value of 54.00 days followed by T3 (65.50 days). The accession T8 took maximum days for first harvest (91.50 days). Among the twenty accessions, fourteen accessions were earlier to first harvest than the general mean of 74.90 days.

4.1.2.2.6 Fruits plant^{-1}

The number of fruits was highest in T16 (4.47) followed by T13 (3.39) which was statistically on par with T20 (3.25), T15 (3.22), T19 (3.18), T11 (3.15), T1 (3.13), T2 (2.94) and T10 (2.89). The treatments T17 (Sugar Baby) and T6 (Arka Akash) recorded the lowest fruit number of 1.25. The accessions T14 (1.36), T9 (1.67) and T3 (1.92) were on par with the accessions producing lesser number of fruits plant^{-1}. Ten accessions had more number of fruits plant^{-1} than the general mean of 2.50.

4.1.2.2.7 Yield plant^{-1}

The accessions differed significantly for yield plant^{-1} with a general mean of 7.68 kg. The highest yield (14.17 kg) was recorded for T15 (IB-23) followed by T2 (11.85 kg), T19 (10.35 kg) and T 20 (10.31 kg). The lowest yield of 3.01 kg was recorded for T6 (Arka Akash). Among the twenty accessions evaluated, eleven registered higher yield plant^{-1} than the overall mean.

Table 6. Continued

Treatments		Days to first harvest (DAT)	Fruits plant^{-1}	Yield plant^{-1} (kg)	Yield plot^{-1} (kg)
T1	Anmol	73.01	3.13	7.06	51.28
T2	IB-20	68.50	2.94	11.85	58.12
T3	Arka Muthu	65.50	1.92	4.23	33.57
T4	Swarna	88.50	2.29	5.83	41.29
T5	Patanegra	76.52	2.50	9.21	65.93
T6	Arka Akash	88.50	1.25	3.01	20.45
T7	Arjun	73.51	2.25	3.47	24.51
T8	Shonima	91.50	2.00	3.88	28.29
T9	Sumo	76.50	1.67	8.66	65.26
T10	Kiran	75.00	2.89	7.07	53.15
T11	IB-16	66.00	3.15	9.35	54.91
T12	Arka Manik	82.00	1.95	7.49	52.25
T13	Simran	68.00	3.39	8.04	57.18
T14	NS-295	81.00	1.36	3.94	26.81
T15	IB-23	71.00	3.22	14.17	77.87
T16	Prachi	54.00	4.47	8.25	60.07
T17	Sugar Baby	70.50	1.25	8.04	61.67
T18	Agri Sweet Honey	78.00	1.95	9.08	57.11
T19	Saraswati	66.50	3.18	10.35	81.65
T20	Devyani	84.00	3.25	10.31	73.24
Mean		74.90	2.50	7.68	52.23
SEm (±)		0.750	0.348	0.684	4.591
CD (0.05)		2.222	0.697	1.194	9.223

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4.1.2.2.8 Yield plot^{-1}

Highest yield plot^{-1} of 81.65 kg was recorded in T19 (Saraswati). Two accessions, viz., T15 (77.87 kg) and T20 (73.24 kg) were on par with it. The lowest yield plot^{-1} was observed in T6 (20.45 kg). The average yield plot^{-1} was 52.23 kg with thirteen accessions having more yields plot^{-1} than the mean.

4.1.2.2.9 Marketable yield plot^{-1}

Marketable yield plot^{-1} exhibited a range of 14.19 kg to 76.77 kg. The highest marketable yield was obtained from T19 (76.77 kg) followed by T15 (60.44 kg) which was statistically on par with T20 (60.24 kg), T16 (56.43 kg), T5 (54.79 kg), T17 (53.51 kg), T9 (53.38 kg) and T13 (52.05 kg). The lowest marketable yield was recorded in T8 (14.19 kg).

4.1.2.2.10 Days to final harvest

The accession T8 took maximum days for final harvest (109.50 days) which was on par with T4 (107.00 days). The lowest duration of 74.00 days was expressed by T16.

4.1.2.2.11 Seeds fruit^{-1}

The number of seeds varied from 0.00 to 366.50. The highest number was observed in T9 (366.50) which was on par with T17 (361.50), T18 (353.00), T19 (352.00), T5 (333.50) and T2 (327.00). T4 (Swarna) and T8 (Shonima) were seedless.

4.1.2.2.12 Weight of 100 seeds

The treatment T14 recorded the highest 100 seed weight of 11.85 g, while T6 had the lowest weight of 2.20 g. Five accessions viz., T9 (2.30 g), T10 (2.90 g), T5 (3.13 g), T18 (3.22 g) and T15 (3.30g) were on par with T6.

Table 6. Continued

Treatments		Marketable yield plot^{-1} (kg)	Days to final harvest (DAT)	Seeds fruit^{-1}	Weight of 100 seeds (g)
T1	Anmol	43.80	95.50	145.50	4.25
T2	IB-20	45.71	95.52	327.00	3.80
T3	Arka Muthu	31.64	82.50	280.00	3.68
T4	Swarna	29.85	107.00	0.00	3.75
T5	Patanegra	54.79	95.01	333.50	3.13
T6	Arka Akash	14.24	99.50	201.50	2.20
T7	Arjun	20.29	83.50	99.50	3.35
T8	Shonima	14.19	109.50	0.00	3.60
T9	Sumo	53.38	88.00	366.50	2.30
T10	Kiran	44.59	84.50	251.52	2.90
T11	IB-16	42.21	94.00	294.00	3.63
T12	Arka Manik	39.26	99.00	241.01	4.88
T13	Simran	52.05	83.00	181.50	3.35
T14	NS-295	19.73	95.01	237.00	11.85
T15	IB-23	60.44	94.50	267.00	3.30
T16	Prachi	56.43	74.00	302.50	3.75
T17	Sugar Baby	53.51	95.00	361.50	5.05
T18	Agri Sweet Honey	46.03	95.50	353.00	3.22
T19	Saraswati	76.77	79.00	353.00	3.36
T20	Devyani	60.24	82.50	116.00	4.35
Mean		42.94	91.60	232.53	3.99
SEm (±)		4.806	2.119	14.646	0.373
CD(0.05)		11.116	6.276	43.356	1.108

4.1.2.3 Quality Characters

Mean values for quality characters like TSS, lycopene, ascorbic acid, reducing sugar and non reducing sugar are furnished in Table 7.

4.1.2.3.1 TSS

The TSS ranged from 9.30° Brix in T14 to 13.30° Brix in T16 (Prachi). The average TSS content was 10.71°B with eleven accessions having more TSS than the mean.

4.1.2.3.2 Lycopene

Significant difference was noticed among the accessions for lycopene content with the highest (7.95 mg $100g^{-1}$) being recorded by T8 (Shonima) and lowest by T4 (0.53 mg $100g^{-1}$). Among the twenty accessions, eleven recorded higher lycopene content than the general mean of 4.51 mg $100g^{-1}$.

4.1.2.3.3 Ascorbic acid

The ascorbic acid content was highest in T1 (Anmol) with a value of 5.85 mg $100g^{-1}$ followed by T20 (4.85 mg $100g^{-1}$) and T2 (4.75 mg $100g^{-1}$). T10 recorded the lowest value of 3.00 mg $100g^{-1}$.

4.1.2.3.4 Reducing sugar

In respect of reducing sugar content of fruits, the treatment T19 recorded the highest value of 3.18 per cent which was on par with T16 (3.09 per cent), T15 (3.04 per cent), T17 (2.99 per cent) and T10 (2.88 per cent). The lowest value was observed in T14 (2.16 per cent).

Table 7. Mean performance of watermelon accessions for quality characters

Treatments		TSS (°Brix)	Lycopene (mg 100g^{-1})	Ascorbic acid (mg 100g^{-1})	Reducing sugar (%)	Non reducing sugar (%)
T1	Anmol	9.50	0.78	5.85	2.23	3.11
T2	IB-20	11.30	7.38	4.75	2.60	3.51
T3	Arka Muthu	11.11	6.24	3.50	2.62	3.49
T4	Swarna	9.50	0.53	4.55	2.74	3.50
T5	Patanegra	9.85	3.74	3.35	2.58	3.29
T6	Arka Akash	9.35	3.94	3.25	2.29	2.78
T7	Arjun	11.05	5.17	3.25	2.62	3.35
T8	Shonima	9.65	7.95	3.70	2.71	3.38
T9	Sumo	10.10	5.05	3.15	2.44	3.42
T10	Kiran	11.50	4.74	3.00	2.88	3.41
T11	IB-16	10.65	5.71	3.95	2.80	3.42
T12	Arka Manik	11.00	5.97	3.20	2.49	3.06
T13	Simran	11.50	4.26	3.25	2.54	3.23
T14	NS-295	9.30	4.27	3.25	2.16	2.69
T15	IB-23	11.75	5.05	4.00	3.04	3.68
T16	Prachi	13.30	6.33	4.00	3.09	3.91
T17	Sugar Baby	11.35	3.88	3.30	2.99	3.65
T18	Agri Sweet Honey	10.75	3.82	3.35	2.73	3.24
T19	Saraswati	12.20	6.22	4.00	3.18	3.76
T20	Devyani	9.55	0.54	4.85	2.39	3.20
Mean		10.71	4.51	3.78	2.65	3.35
SEm (±)		0.244	0.258	0.188	0.103	0.104
CD(0.05)		0.726	0.773	0.556	0.309	0.312

4.1.2.3.5 Non reducing sugar

The treatment T16 recorded the highest non reducing sugar content of 3.91 per cent which was on par with T19 (3.76 per cent), T15 (3.68 per cent) and T17 (3.65 per cent). The lowest value was recorded in T14 (2.69 per cent).

4.1.3 Genetic Variability Parameters

The genetic parameters such as phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability and genetic advance of twenty accessions were studied. The population means, range, GCV, PCV, heritability and genetic advance are presented in Table 8, Fig. 2 and Fig. 3.

4.1.3.1 Vegetative and Flowering Characters

4.1.3.1.1 Vine length

A high estimate of PCV (27.61) and GCV (24.88) were recorded for vine length. This trait also exhibited high heritability (81.19 per cent) and high genetic advance (46.18 per cent).

4.1.3.1.2 Days to first male flower

Moderate PCV and GCV values (12.54 per cent and 11.97 per cent respectively) coupled with high heritability (91.13 per cent) and high genetic advance (23.54 per cent) was evident for days to first male flowering.

4.1.3.1.3 Node to first male flower

Node to first male flower exhibited high PCV (20.09) and moderate GCV (17.75) values with high heritability (78.06 per cent) as well as genetic advance estimates (32.31 per cent).

Table 8. Estimates of genetic parameters for various characters in watermelon

Character	Range	Mean	PCV	GCV	Heritability (%)	Genetic Advance	GA as per cent of mean
Vine length	1.20 - 6.29	4.02	27.61	24.88	81.19	1.86	46.18
Days to first male flower	27.50 - 42.50	35.55	12.54	11.97	91.13	8.37	23.54
Node to first male flower	5.50 - 13.00	9.28	20.09	17.75	78.06	2.99	32.31
Days to first female flower	35.00 - 47.00	40.78	9.62	9.31	93.68	7.57	18.57
Node to first female flower	14.50 - 23.50	19.28	13.39	12.20	83.02	4.41	22.89
Fruit equatorial diameter	12.65 - 23.50	17.16	16.23	14.40	78.71	4.52	26.31
Fruit polar diameter	15.00 - 31.00	21.92	22.57	20.54	82.78	8.44	38.49
Rind thickness	0.75 - 2.20	1.41	28.85	26.95	87.24	0.73	51.85
Fruit weight	1.55 - 6.38	3.24	39.99	37.70	88.88	2.37	73.23
Days to first harvest	54.00 - 91.50	74.90	12.42	12.34	98.70	18.92	25.26
Fruits plant^{-1}	1.25 - 4.47	2.50	35.18	32.93	87.66	1.59	63.52
Yield plant^{-1}	3.01 - 14.17	7.68	38.97	38.24	96.34	5.93	77.33
Yield plot^{-1}	20.45 - 81.65	52.23	35.22	32.96	87.54	33.18	63.52
Marketable yield plot^{-1}	14.19 - 76.77	42.94	40.86	37.67	84.99	30.72	71.55
Days to final harvest	74.00 - 109.5	91.60	10.30	9.77	89.92	17.48	19.08
Seeds fruit^{-1}	0.00 - 366.5	235.53	48.66	47.85	96.73	228.35	96.96
Weight of 100 seeds	2.20 - 11.85	3.98	50.64	48.88	93.17	3.87	97.19
TSS	9.30 - 12.90	10.71	10.46	9.95	90.51	2.09	19.50
Lycopene	0.53 - 7.95	4.51	45.36	44.63	96.81	4.08	90.47
Ascorbic acid	3.00 - 5.85	3.78	20.12	18.85	87.74	1.37	36.36
Reducing sugar	2.16 - 3.18	2.65	11.43	10.03	77.07	0.48	18.14
Non reducing sugar	2.69 - 3.91	3.35	9.57	8.50	78.94	0.52	15.57

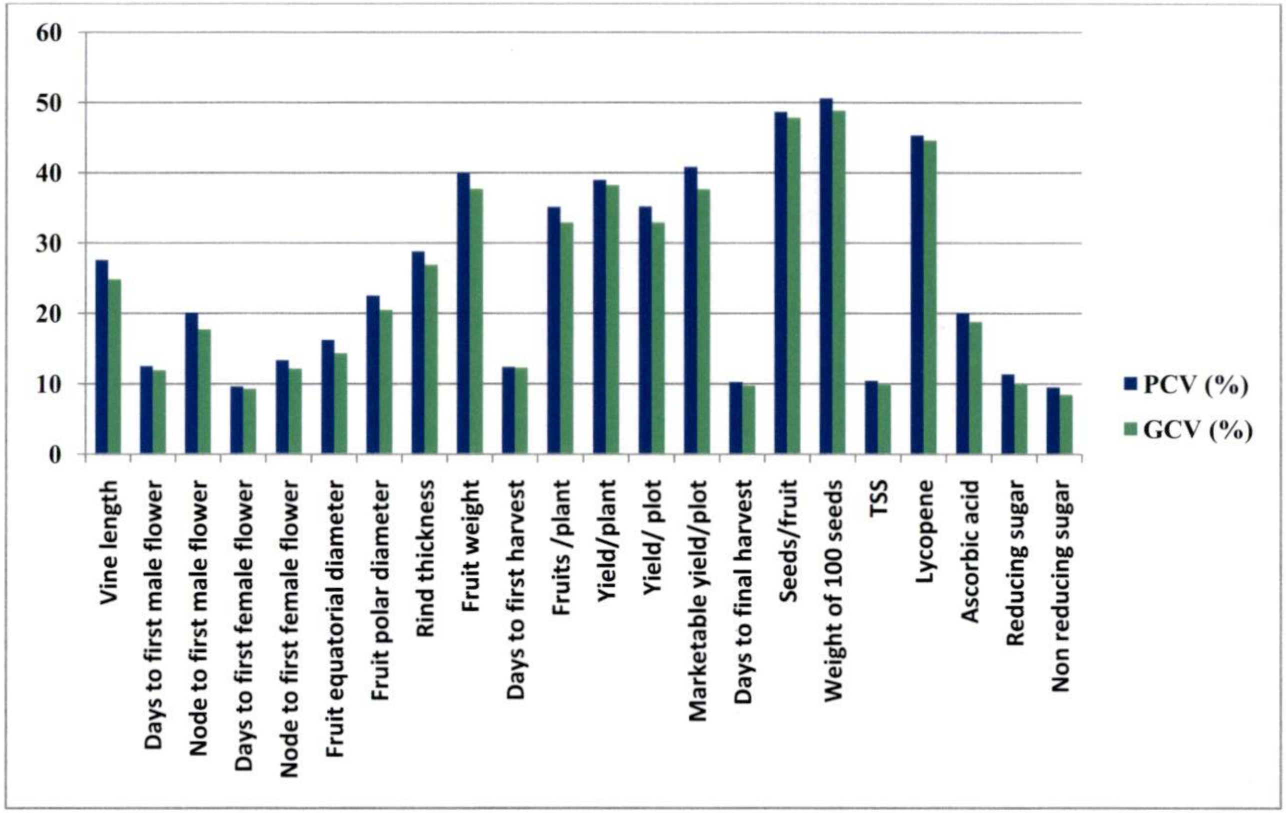


Fig. 2. Phenotypic and genotypic coefficients of variation for twenty two characters in *C. lanatus*

4.1.3.1.4 Days to first female flower

Low PCV and GCV values with narrow difference between them (9.62 per cent and 9.31 per cent respectively) coupled with high heritability (93.68 per cent) and moderate genetic advance (18.57 per cent) were recorded for days to first female flower.

4.1.3.1.5 Node to first female flower

Node to first female flower exhibited a moderate PCV (13.39 per cent) and GCV (12.20 per cent) with high estimates for both heritability (83.02 per cent) and genetic advance (22.89 per cent).

4.1.3.2 Fruit and Yield Characters

4.1.3.2.1 Fruit equatorial diameter

A moderate PCV and GCV were noticed (16.23 per cent and 14.40 per cent respectively) with high heritability (78.71 per cent) and high genetic advance (26.31 per cent) for this trait.

4.1.3.2.2 Fruit polar diameter

Greater variability was evident by a wide range from 15.00 cm to 31.00 cm for fruit polar diameter. The estimates of PCV (22.57 per cent) and GCV (20.54 per cent) were high coupled with higher estimates for heritability (82.78 per cent) and genetic advance as per cent of mean (38.49 per cent).

4.1.3.2.3 Rind thickness

High PCV and GCV were noticed (28.85 per cent and 26.95 per cent respectively) with high heritability (87.24 per cent) and high genetic advance (51.85 per cent) for this trait.

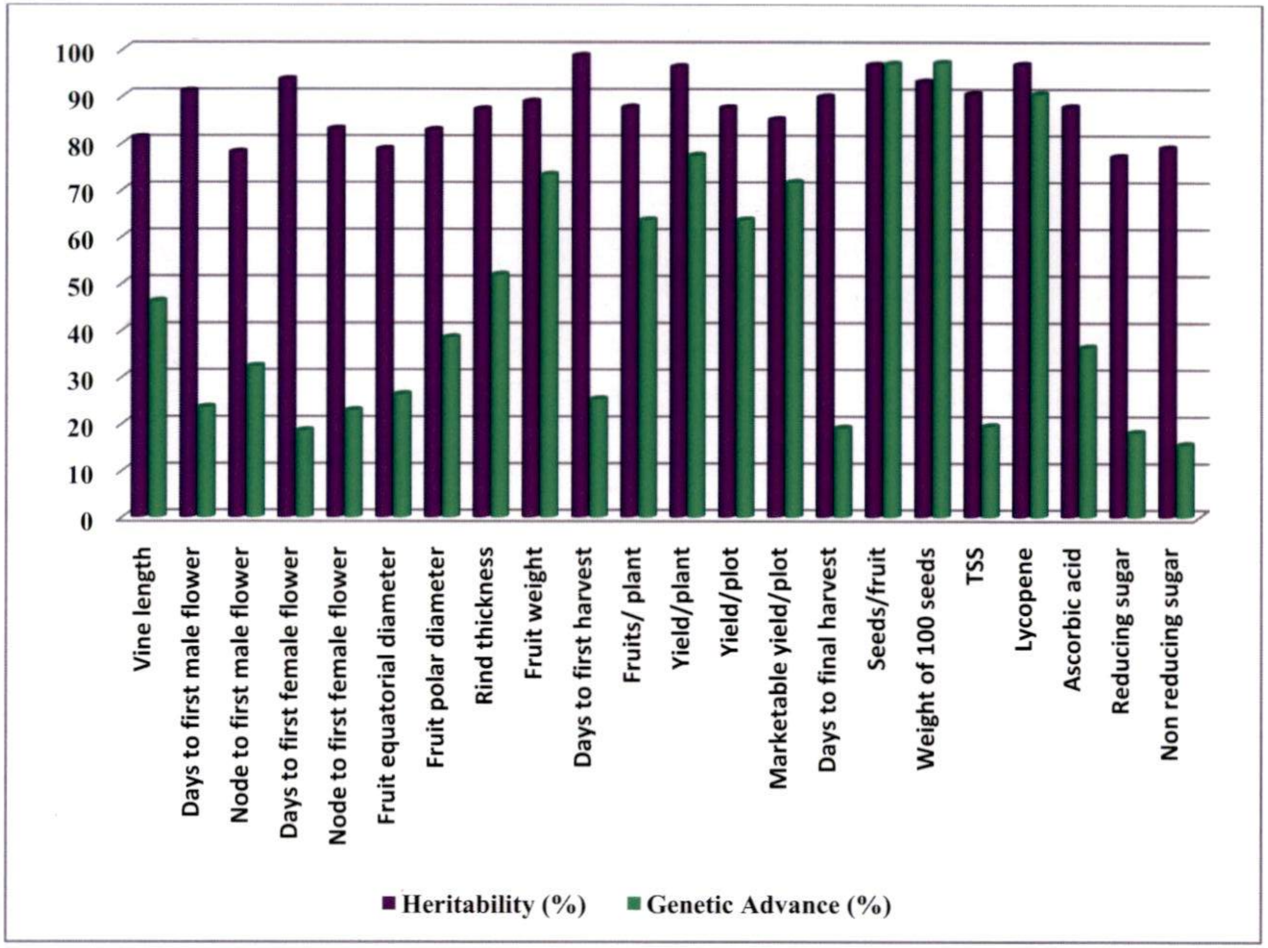


Fig. 3. Heritability and genetic advance for twenty two characters in *C. lanatus*

4.1.3.2.4 Fruit weight

Fruit weight exhibited high PCV (39.99 per cent) and GCV (37.07 per cent) along with high heritability estimates (88.88 per cent) and high genetic advance (73.23 per cent).

4.1.3.2.5 Days to first harvest

A moderate PCV of 12.42 per cent and GCV of 12.34 per cent were recorded. The estimates of heritability and genetic advance (98.70 per cent and 25.26 per cent respectively) were high for days to first harvest.

4.1.3.2.6 Fruits plant^{-1}

Greater variability was expressed by number of fruits per plant with a range of 1.25 to 4.47. The estimates of PCV (35.18 per cent) and GCV (32.93 per cent) were high along with higher estimates of heritability (87.66 per cent) and genetic advance (63.52 per cent).

4.1.3.2.7 Yield plant^{-1}

High PCV and GCV with narrow difference between them (38.97 per cent and 38.24 per cent respectively) along with higher heritability (96.34 per cent) and genetic advance (77.33 per cent) was expressed by yield per plant.

4.1.3.2.8 Yield plot^{-1}

The estimates of PCV (35.22 per cent) and GCV (32.96 per cent) were high. A high heritability (87.54 per cent) and genetic advance (63.52 per cent) were also recorded.

4.1.3.2.9 Marketable yield plot^{1}

Marketable yield per plot exhibited a high PCV (40.86 per cent) and GCV (37.67 per cent) with high heritability and genetic advance estimates (84.99 per cent and 71.55 per cent respectively).

4.1.3.2.10 Days to final harvest

A moderate estimate of PCV (10.30 per cent) along with low GCV (9.77 per cent) was recorded for days to final harvest. High heritability (89.92 per cent) and moderate genetic advance (19.08 per cent) was exhibited.

4.1.3.2.11 Seeds fruit^{1}

The PCV and GCV estimates were high (48.66 per cent and 47.85 per cent respectively). A high heritability of 96.73 per cent and a higher genetic advance of 96.96 per cent were noticed.

4.1.3.2.12 Weight of 100 seeds

A comparatively higher PCV (50.64 per cent) and GCV (48.88 per cent) were noticed with high heritability (93.17 per cent) and a higher genetic advance as per cent of mean (97.19 per cent) for weight of 100 seeds.

4.1.3.3 Quality Characters

4.1.3.3.1 TSS

A moderate PCV (10.46 per cent) and low GCV (9.95 per cent) was recorded along with high heritability (90.51 per cent) and moderate genetic advance (19.50 per cent) for TSS.

4.1.3.3.2 Lycopene

Lycopene content showed high value for PCV (45.36 per cent) and GCV (44.63 per cent) along with high heritability (96.81 per cent) and genetic advance (90.47 per cent) estimates.

4.1.3.3.3 Ascorbic acid

High PCV (20.12 per cent) with moderate GCV (18.85 per cent) was recorded for ascorbic acid content. Estimates of heritability (87.74 per cent) and genetic advance (36.36 per cent) were high.

4.1.3.3.4 Reducing sugar

Moderate PCV (11.43 per cent) and GCV (10.03 per cent) estimates coupled with high heritability (77.07 per cent) and moderate genetic advance (18.14 per cent) was exhibited by this character.

4.1.3.3.5 Non reducing sugar

The estimates of PCV (9.57 per cent) and GCV (8.50 per cent) were low. A high heritability (78.94 per cent) and moderate genetic advance (15.57 per cent) were also recorded.

4.1.4 Correlation Analysis

Genotypic and phenotypic correlation coefficients between yield and various yield components and interrelationship among the traits were computed and are presented in Table 9 and Table 10. In general, genotypic correlation coefficients were higher than the phenotypic correlation coefficients.

The fruit yield plant^{-1} had significant positive association at genotypic level with fruit equatorial diameter (0.469), fruit polar diameter (0.755), fruits plant^{-1}

Table 9. Genotypic correlation coefficients between yield and yield components

Character	Vine length	Days to 1^{st} female flower	Node to 1^{st} female flower	Fruit equatorial diameter	Fruit polar diameter	Fruits $plant^{-1}$	Fruit weight	Days to first harvest	Seeds $fruit^{-1}$	Weight of 100 seeds	Yield $plant^{-1}$
	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}
X_1	1.000	0.368	0.542**	0.166	-0.029	-0.357	0.165	0.632**	-0.363	0.173	-0.163
X_2		1.000	0.564**	-0.183	0.078	-0.435*	-0.014	0.712**	-0.349	0.161	-0.273
X_3			1.000	0.092	0.222	-0.587**	0.223	0.544**	-0.099	0.324	-0.200
X_4				1.000	0.379	-0.324	0.932**	0.076	0.511**	0.115	0.469*
X_5					1.000	0.045	0.805**	-0.249	0.621**	0.123	0.755**
X_6						1.000	-0.294	-0.619**	0.002	-0.150	0.546**
X_7							1.000	-0.024	0.659**	0.149	0.587**
X_8								1.000	-0.594**	-0.179	-0.405
X_9									1.000	0.325	0.503**
X_{10}										1.000	-0.033
X_{11}											1.000

* Significant at 5 per cent level ** Significant at 1 per cent level

Table 10. Phenotypic correlation coefficients between yield and yield components

Character	Vine length	Days to 1st female flower	Node to 1st female flower	Fruit equatorial diameter	Fruit polar diameter	Fruits plant^{-1}	Fruit weight	Days to first harvest	Seeds fruit^{-1}	Weight of 100 seeds	Yield plant^{-1}
	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}
X_1	1.000	0.331	0.493*	0.168	0.049	-0.288	0.106	0.557**	-0.315	0.160	-0.138
X_2		1.000	0.496*	-0.182	0.043	-0.392	0.004	0.682**	-0.333	0.128	-0.230
X_3			1.000	0.018	0.165	-0.569**	0.236	0.497*	-0.073	0.294	-0.194
X_4				1.000	0.421	-0.267	0.752**	0.059	0.437*	0.119	0.411*
X_5					1.000	0.011	0.680**	-0.221	0.536**	0.153	0.663**
X_6						1.000	-0.355	-0.575**	0.004	-0.157	0.528**
X_7							1.000	-0.030	0.605**	0.145	0.534**
X_8								1.000	-0.578**	-0.178	-0.399
X_9									1.000	0.298	0.479*
X_{10}										1.000	-0.045
X_{11}											1.000

* Significant at 5 per cent level   ** Significant at 1 per cent level

(0.546), fruit weight (0.587) and seeds fruit^{-1} (0.503). Vine length, days to first female flower, node to first female flower, days to first harvest and weight of 100 seeds had a negative but not significant relationship with yield. Similar trend in association of characters with yield was obtained at the phenotypic level also.

Regarding the inter association of various yield components at the genotypic and phenotypic levels; vine length had a significant association with node to first female flower (0.542 and 0.493) and days to first harvest (0.632 and 0.557).

The days to first female flower exhibited significant positive genotypic correlation with node to first female flower (0.564) and days to first harvest (0.712), while it had a significant negative correlation with number of fruits plant^{-1} (-0.435). At the phenotypic level also the relationship was similar except that the number of fruits plant^{-1} was not significant.

The first female flowering node had significant positive genotypic and phenotypic correlation with days to first harvest (0.544 and 0.497), while it had significant negative association with fruits plant^{-1} (-0.587 and -0.569).

The fruit equatorial diameter had significant positive genotypic correlation with fruit weight (0.932) and number of seeds fruit^{-1} (0.511). Similar trend of association was observed through phenotypic correlation coefficients.

Fruit polar diameter had significant and positive genotypic association with fruit weight and number of seeds fruit^{-1} with correlation values of 0.805 and 0.621 respectively. The phenotypic correlation coefficients followed a similar trend.

The number of fruits plant^{-1} exhibited a highly significant negative correlation with days to first harvest (-0.619), node to first female flower (-0.587) and days to first female flowering (-0.435) at the genotypic level. But at the phenotypic level, days to first female flowering was not significant.

Fruit weight manifested a highly significant positive genotypic and phenotypic correlation with number of seeds fruit^{-1} (0.659 and 0.605), fruit equatorial diameter (0.932 and 0.752) and fruit polar diameter (0.805 and 0.680).

At both genotypic and phenotypic level, days to first harvest had highly significant positive correlation with vine length (0.632 and 0.557), days to first female flower (0.712 and 0.682) and node to first female flower (0.544 and 0.497). The correlation was significant and negative with number of seeds fruit^{-1} (-0.594 and -0.578).

Number of seeds fruit^{-1} exhibited significant positive correlation with fruit equatorial diameter (0.511 and 0.437), fruit polar diameter (0.621 and 0.536) and fruit weight (0.659 and 0.605) at genotypic and phenotypic levels. But a significant negative correlation was associated with days to first harvest (-0.594 and -0.578).

The genotypic and phenotypic correlation coefficients of weight of 100 seeds with all other characters were non- significant.

4.1.5 Path Coefficient Analysis

Genotypic correlation coefficients of yield plant^{-1} with yield contributing characters were partitioned into different components to find the direct and indirect contribution of each character to yield. Vine length, days to first female flower, node to first female flower, fruit equatorial diameter, fruit polar diameter, fruits plant^{-1}, fruit weight, seeds fruit^{-1} and weight of 100 seeds were selected for path coefficient analysis in watermelon. The results are furnished in Table 11. and Fig. 4 .

Among the various yield components, fruit weight exerted the highest direct effect (0.8583) on yield plant^{-1} followed by number of fruits plant^{-1} (0.8321). The days to first female flower (0.0174), node to first female flower (0.1423) and fruit polar diameter (0.0577) also had positive direct effect on yield. Vine length

Table 11. Direct and indirect effects of yield components on fruit yield

Character	Vine length (m)	Days to 1st female flower	Node to 1st female flower	Fruit equatorial diameter (cm)	Fruit polar diameter (cm)	Fruits plant^{-1}	Fruit weight (kg)	Seeds fruit^{-1}	Weight of 100 seeds (g)	Genotypic correlation with yield
Vine length	**-0.1060**	0.0064	0.0771	-0.0051	-0.0017	-0.2967	0.1417	0.0290	-0.0077	-0.163
Days to 1st female flower	-0.0389	**0.0174**	0.0802	0.0056	0.0045	-0.3502	-0.0118	0.0278	-0.0072	-0.273
Node to 1st female flower	-0.0574	0.0098	**0.1423**	-0.0028	0.0128	-0.4885	0.1914	0.0079	-0.0144	-0.200
Fruit equatorial diameter	-0.0176	-0.0032	0.0130	**-0.0305**	0.0219	-0.2693	0.8002	-0.0407	-0.0051	0.469
Fruit polar diameter	0.0031	0.0013	0.0315	-0.0115	**0.0577**	0.0373	0.6906	-0.0496	-0.0055	0.755
Fruits plant^{-1}	0.0378	-0.0073	-0.0835	0.0099	0.0026	**0.8321**	-0.2522	-0.0002	0.0067	0.546
Fruit weight	-0.0176	-0.0002	0.0317	-0.0284	0.0464	-0.2446	**0.8583**	-0.0518	-0.0066	0.587
Seeds fruit^{-1}	0.0385	-0.0061	-0.0141	-0.0156	0.0359	0.0020	0.5566	**-0.0798**	-0.0145	0.503
Weight of 100 seeds	-0.0183	0.0028	0.0461	-0.0035	0.0071	-0.1249	0.1280	-0.0259	**-0.0445**	-0.033

Residual effect = 0.2585   Bold values indicate direct effects

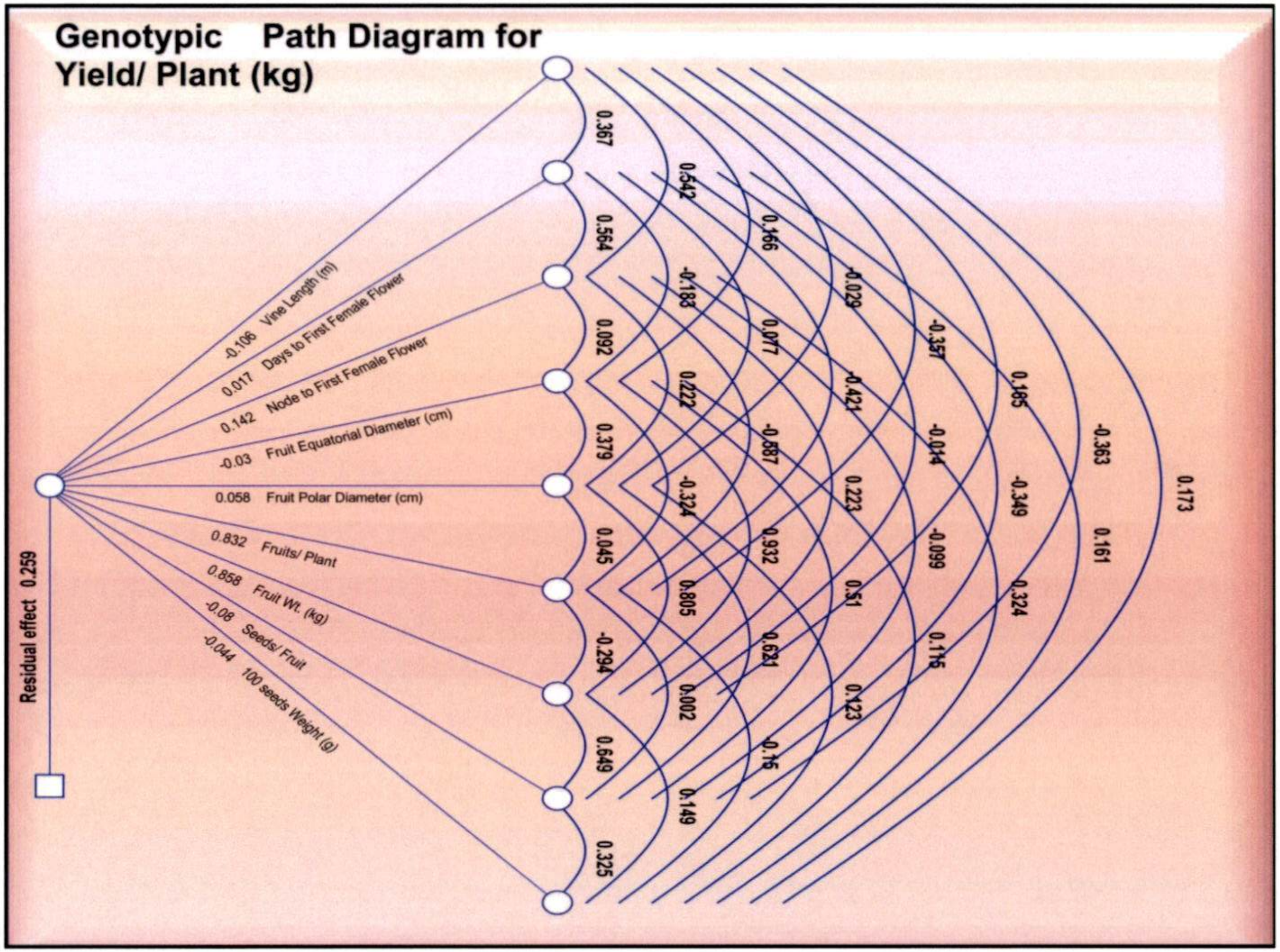


Fig. 4. Genotypic path diagram

(-0.1060), fruit equatorial diameter (-0.0305), seeds fruit^{-1} (-0.0798) and weight of 100 seeds (-0.0445) exhibited negative direct effect on yield plant^{-1}.

Regarding the indirect effects, vine length had positive effects through days to first female flower (0.0064), node to first female flower (0.0771), fruit weight (0.1417) and seeds fruit^{-1} (0.0290) and negative indirect effects via. fruit equatorial diameter (-0.0051), fruit polar diameter (-0.0017), fruits plant^{-1} (-0.2967) and weight of 100 seeds (-0.0077).

The days to first female flowering exerted positive indirect effect through node to first female flower, fruit equatorial diameter, fruit polar diameter and seeds fruit^{-1} and negatively through number of fruits plant^{-1}, fruit weight and weight of 100 seeds.

Indirect influence of first female flowering node on yield was observed through days to first female flowering (0.0098), fruit polar diameter (0.0128), fruit weight (0.1914) and seeds fruit^{-1} (0.0079) in the positive direction and through vine length (-0.0574), fruit equatorial diameter (-0.0028), fruits plant^{-1} (-0.4885) and weight of 100 seeds (-0.0144) in the negative direction.

The indirect effect of fruit equatorial diameter was positive through node to first female flower, fruit polar diameter and fruit weight (0.8002). The effect was negative through other characters.

The fruit polar diameter positively influenced yield via. vine length, days to first female flower, node to first female flower, fruits plant^{-1} and fruit weight (0.6906) and negatively through rest of the characters.

Indirect effects of fruits per plant were positive through vine length (0.0378), fruit equatorial diameter (0.0099), fruit polar diameter (0.0026) and weight of 100 seeds (0.0067). The effect was negative through days to first female flower, node to first female flower, fruit weight and seeds fruit^{-1}.

The fruit weight positively influenced yield indirectly through node to first female flower (0.0317) and fruit polar diameter (0.0464) and the effect was negative through other characters.

The indirect effect of seeds fruit^{-1} it was positive through vine length, fruit polar diameter, fruits plant^{-1} and fruit weight (0.5566). It was negative through other characters.

The 100 seed weight exhibited positive indirect effect through days to first female flower, node to first female flower, fruit polar diameter and fruit weight.

4.1.6 Evaluation of Sensory Parameters of Watermelon Accessions

Sensory parameters were statistically analysed using Kruskal - Wallis test and found that the accessions showed significant difference in organoleptic qualities and acceptability (Table 12). Evaluation of organoleptic qualities of watermelon accessions showed highest mean score for appearance, taste, colour, flavour and texture for the accession Prachi (T16). The yellow fleshed accessions, Devyani (T20) and Anmol (T1) ranked second and third in appearance and colour. But for the parameters flavour, taste and texture, the accessions Saraswati (T19) and Simran (T13) were in second and third positions. Regarding overall acceptability, the highest mean score was recorded by the accession Prachi (9.00) followed by Saraswati (8.75) and Simran (8.50).

4.1.7 Pest and Disease Incidence

The crop was monitored for the incidence of pests and diseases during the cropping period (Plate 10). At the initial stage of crop growth, incidence of pumpkin

Table 12. Evaluation of sensory parameters of watermelon accessions

Treatments		Sensory parameters					
		Appearance		Colour		Flavour	
		Mean score	Rank	Mean score	Rank	Mean score	Rank
T1	Anmol	8.25	3	8.50	3	6.75	9
T2	IB-20	7.00	8	7.00	8	7.50	6
T3	Arka Muthu	7.25	7	7.25	7	7.75	5
T4	Swarna	5.50	14	5.50	14	5.50	14
T5	Patanegra	4.75	18	4.75	18	4.75	18
T6	Arka Akash	4.50	19	4.50	19	4.50	19
T7	Arjun	5.75	13	5.75	13	5.75	13
T8	Shonima	6.25	11	6.25	11	6.25	11
T9	Sumo	5.00	17	5.00	17	5.00	17
T10	Kiran	6.75	9	6.75	9	7.25	7
T11	IB-16	5.25	15	5.25	15	5.25	15
T12	Arka Manik	6.00	12	6.00	12	6.00	12
T13	Simran	7.75	5	7.75	5	8.50	3
T14	NS-295	4.25	20	4.25	20	4.25	20
T15	IB-23	7.50	6	7.50	6	8.00	4
T16	Prachi	8.75	1	9.00	1	9.00	1
T17	Sugar Baby	6.50	10	6.50	10	6.50	10
T18	Agri Sweet Honey	5.25	16	5.25	16	5.25	16
T19	Saraswati	8.00	4	8.00	4	8.75	2
T20	Devyani	8.50	2	8.75	2	7.00	8
Chi square (KW test)		58.02**		55.84**		56.55**	

** Significant at 1 per cent level

Table 12. Continued

Treatments		Sensory parameters					
		Taste		Texture		Overall acceptability	
		Mean score	Rank	Mean score	Rank	Mean score	Rank
T1	Anmol	7.25	9	7.00	8	7.00	9
T2	IB-20	8.00	6	7.50	6	7.75	6
T3	Arka Muthu	8.25	5	7.75	5	8.00	5
T4	Swarna	5.75	14	5.50	14	5.50	14
T5	Patanegra	4.75	18	4.50	18	4.50	18
T6	Arka Akash	4.50	19	4.25	19	4.25	19
T7	Arjun	6.25	13	5.75	13	5.75	13
T8	Shonima	6.75	11	6.25	11	6.50	11
T9	Sumo	5.00	17	4.75	17	4.75	17
T10	Kiran	7.75	7	7.25	7	7.50	7
T11	IB-16	5.50	15	5.25	15	5.25	15
T12	Arka Manik	6.50	12	6.00	12	6.00	12
T13	Simran	8.75	3	8.25	3	8.50	3
T14	NS-295	4.25	20	4.00	20	4.00	20
T15	IB-23	8.50	4	8.00	4	8.25	4
T16	Prachi	9.25	1	8.75	1	9.00	1
T17	Sugar Baby	7.00	10	6.50	10	6.75	10
T18	Agri Sweet Honey	5.25	16	5.00	16	5.00	16
T19	Saraswati	9.00	2	8.50	2	8.75	2
T20	Devyani	7.50	8	6.75	9	7.25	8
Chi square (KW test)		59.46**		53.89**		59.35**	

** Significant at 1 per cent level

caterpillar [*Diaphania indica* (Saunders)] was noticed and was effectively controlled by spraying Flubendiamide 39.35 SC (Fame) @ 0.1ml l^{-1}.

There was incidence of Fusarium wilt (*Fusarium oxysporum* f.sp. *niveum*) and the percentage disease index (PDI) was calculated and given in Table 13. Among the accessions evaluated, seven showed incidence of Fusarium wilt, while 13 were free from the disease. PDI ranged from 9.38 per cent (Arjun) to 46.88 per cent (IB-23).

4.1.8 Genetic Cataloguing

Twenty accessions of watermelon were morphologically catalogued for vegetative, fruit and seed characters as per ECPGR (2008) and UPOV (2012) descriptor list (Table 14, Plate 11 & 12).

Among the twenty accessions, all except Arka Muthu had viny growth habit. Arka Muthu was bushy in nature with an average vine length of 1.20 m. The degree of lobing of leaf blades ranged from medium to strong.

Wide variability was noticed for fruit characters. Fruits were round, broad elliptical, elliptical, pyriform or oblong. Variability was pronounced in the colour of skin and pattern of stripes. The colour ranged from very light green to dark green, with majority having dark green colour. The rind thickness varied from very thin to thick. The flesh colour was yellow, orange, pinkish red, red and dark red.

Variation was also noticed in seed characters. Most of the accessions had cream coloured seeds, while few had brown and black seeds. The two triploids Swarna and Shonima were seedless. Fifty per cent of accessions exhibited over colour of testa (colour that develops over time upon the ground color of testa and appears as black spots).

10A. Caterpillar of *Diaphania indica* and its feeding symptom

10B. Fusarium wilt

Plate 10. Incidence of pest and disease

Table 13. Intensity of Fusarium wilt among watermelon accessions

Treatments		Percentage Disease Index
T1	Anmol	0.00
T2	IB-20	28.13
T3	Arka Muthu	0.00
T4	Swarna	12.35
T5	Patanegra	0.00
T6	Arka Akash	14.84
T7	Arjun	9.38
T8	Shonima	13.63
T9	Sumo	0.00
T10	Kiran	0.00
T11	IB-16	15.63
T12	Arka Manik	0.00
T13	Simran	0.00
T14	NS-295	0.00
T15	IB-23	46.88
T16	Prachi	0.00
T17	Sugar Baby	0.00
T18	Agri Sweet Honey	0.00
T19	Saraswati	0.00
T20	Devyani	0.00

Table 14. Genetic cataloguing of watermelon accessions used for the study

Accessions		Plant habit	Leaf blade: degree of lobing	Fruit				
				Shape in longitudinal section	Shape of apical part	Depression at apex	Ground colour of skin	Conspicuousness of veining
T1	Anmol	2	7	2	3	2	6	3
T2	IB-20	2	7	6	5	2	8	1
T3	Arka Muthu	1	5	2	3	2	8	1
T4	Swarna	2	5	3	1	3	8	3
T5	Patanegra	2	7	3	3	2	8	1
T6	Arka Akash	2	5	5	1	2	2	3
T7	Arjun	2	5	5	3	2	8	1
T8	Shonima	2	5	3	1	3	8	3
T9	Sumo	2	7	5	3	2	2	3
T10	Kiran	2	7	4	5	2	6	3
T11	IB-16	2	7	3	1	2	8	1
T12	Arka Manik	2	5	3	1	2	5	2
T13	Simran	2	7	4	5	2	7	2
T14	NS-295	2	7	5	3	2	2	3
T15	IB-23	2	7	6	5	2	8	1
T16	Prachi	2	7	3	1	2	5	2
T17	Sugar Baby	2	7	3	3	2	8	3
T18	Agri Sweet Honey	2	7	3	3	2	8	1
T19	Saraswati	2	7	3	3	2	2	4
T20	Devyani	2	7	3	1	3	5	2

Table 14. Continued

Treatments		Fruit				Seed	
		Width of stripes	Concpicuo-usness of stripes	Thickness of pericarp	Flesh colour	Ground colour of testa	Over colour of testa
T1	Anmol	3	3	3	2	2	9
T2	IB-20	1	1	7	7	2	9
T3	Arka Muthu	1	1	5	7	7	9
T4	Swarna	3	3	5	2	-	-
T5	Patanegra	1	1	5	7	2	9
T6	Arka Akash	3	4	5	5	2	1
T7	Arjun	1	1	3	7	7	1
T8	Shonima	3	3	5	6	-	-
T9	Sumo	5	4	5	5	2	1
T10	Kiran	1	2	5	7	7	1
T11	IB-16	1	1	5	7	7	1
T12	Arka Manik	7	3	7	7	6	9
T13	Simran	5	3	5	7	7	1
T14	NS-295	3	4	5	5	2	9
T15	IB-23	1	1	5	7	2	9
T16	Prachi	1	4	1	7	7	1
T17	Sugar Baby	1	2	5	6	6	9
T18	Agri Sweet Honey	1	1	5	7	2	1
T19	Saraswati	1	3	3	7	7	1
T20	Devyani	5	4	1	3	2	9

Plant growth habit

Bushy

Runner

Leaf blade: Degree of lobing

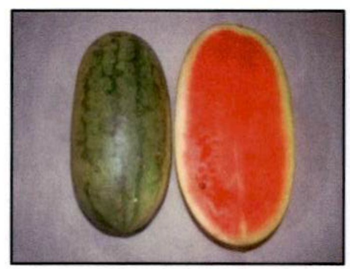
Medium

Strong

Fruit shape

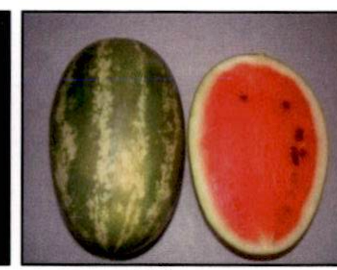
Round

Broad elliptical



Elliptical

Pyriform



Oblong

Plate 11. Variability in plant and fruit characters

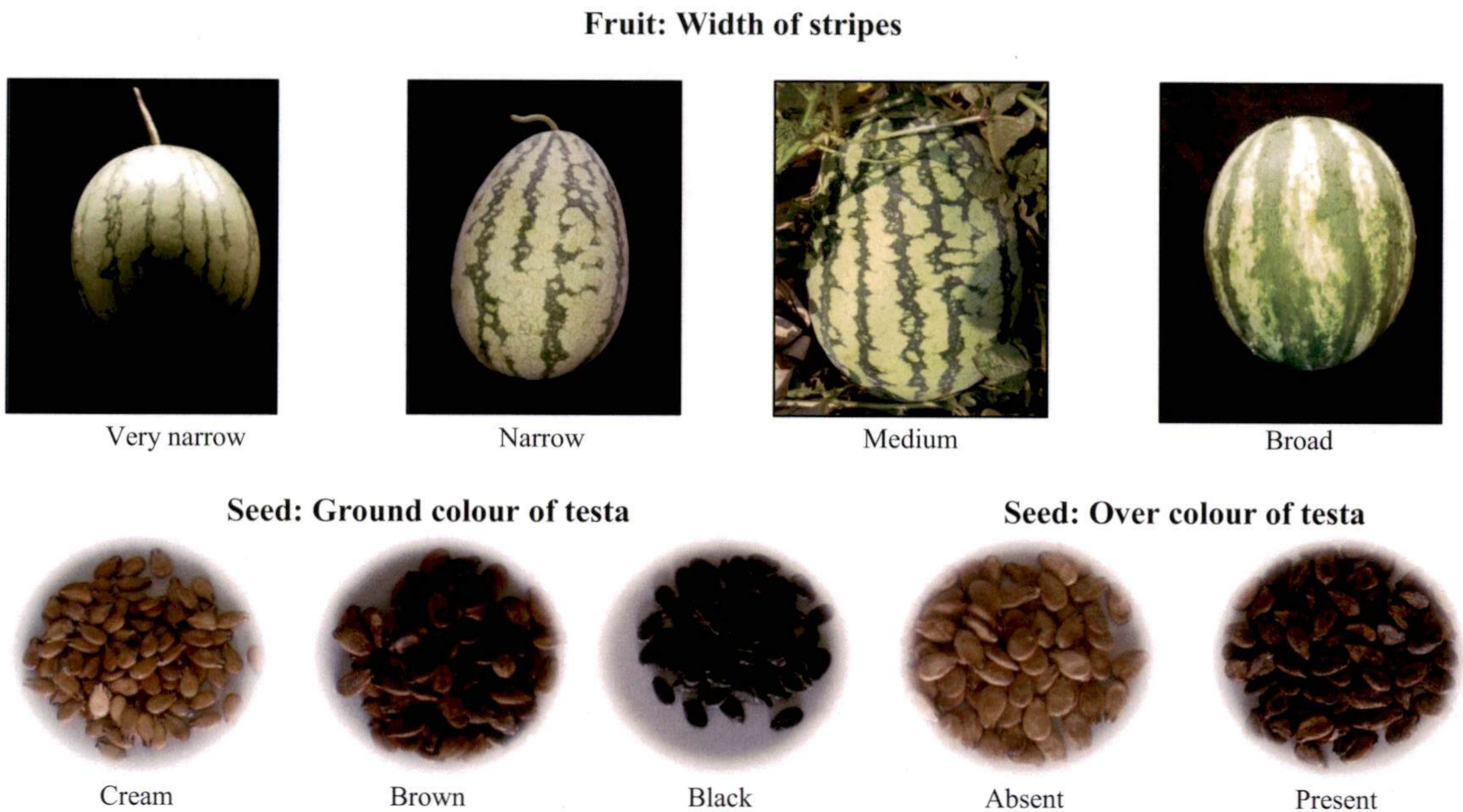


Plate 12. Variability in fruit and seed characters

4.2 EXPERIMENT II

A) STANDARDIZATION OF AGROTECHNIQUES FOR PRECISION FARMING IN WATERMELON UNDER RAIN SHELTER

4.2.1 Vegetative and Flowering Characters

The effect of three fertilizer levels (F), two irrigation levels (I), two levels of training (T) and their interactions on vegetative and flowering characters like vine length, days to first male flower, node to first male flower, days to first female flower and node to first female flower are presented in Table 15 and Table 16.

4.2.1.1 Vine length

Different levels of fertilizer and irrigation had significant influence on vine length in watermelon (Table 15). Fertilizer at 125 per cent RD (F_3) recorded the highest vine length of 5.62 m and the treatments F_1 (75 per cent RD) and F_2 (100 per cent RD) were on par. Among the irrigation treatments, irrigation at 80 per cent Epan (I_1) registered higher vine length (5.36 m) than I_2 (60 per cent Epan). However, training levels did not show any significant effect.

Interactions had no significant influence (Table 16). The comparison between two controls C_1 (*Ad hoc*) and C_2 (KAU POP) revealed significant difference, with C_2 recording the longest vine (6.00 m). The difference was not significant between the treatments and controls.

4.2.1.2 Days to first male flower

Days to first male flower was significantly influenced by the levels of fertilizer (Table 15). Fertilizer at 100 per cent level (F_2) registered earliness in flowering (15.25 days) and it was on par with F_1 (75 per cent RD) (15.88 days). The levels of irrigation and training had no significant influence.

Table 15. Effect of fertilizer, irrigation and training on vegetative and flowering characters under rain shelter

Treatments	Vine length (m)	Days to first male flower	Node to first male flower	Days to first female flower	Node to first female flower
Fertilizer					
F_1 (75 per cent RD)	4.79	15.88	5.13	23.00	13.48
F_2 (100 per cent RD)	4.99	15.25	4.57	23.88	14.63
F_3 (125 per cent RD)	5.62	17.63	6.57	22.10	13.19
SEm (±)	0.144	0.219	0.157	0.192	0.254
CD (0.05)	0.447	0.680	0.490	0.596	0.789
Irrigation					
I_1 (80 per cent Epan)	5.36	16.30	5.17	23.07	13.83
I_2 (60 per cent Epan)	4.89	16.20	5.67	22.92	13.70
SEm (±)	0.116	0.178	0.130	0.155	0.207
CD (0.05)	0.360	NS	0.406	NS	NS
Training					
T_1 (one vine)	5.20	16.08	5.58	22.95	13.78
T_2 (two vines)	5.05	16.42	5.25	23.03	13.75
SEm (±)	0.116	0.178	0.130	0.155	0.207
CD (0.05)	NS	NS	NS	NS	NS

NS - Non significant

Table 16. Interaction effects of treatments on vegetative and flowering characters under rain shelter

Treatments	Vine length (m)	Days to 1st male flower	Node to 1st male flower	Days to 1st female flower	Node to 1st female flower
F x I					
f_1i_1 (75% F, 80% Epan)	5.10	15.75	4.88	23.38	13.38
f_1i_2 (75% F, 60% Epan)	4.49	16.00	5.38	22.63	13.58
f_2i_1 (100% F, 80% Epan)	5.18	14.88	4.00	24.25	15.25
f_2i_2 (100% F, 60% Epan)	4.80	15.63	5.13	23.50	14.00
f_3i_1 (125% F, 80% Epan)	5.82	18.25	6.63	21.58	12.88
f_3i_2 (125% F, 60% Epan)	5.42	17.00	6.50	22.63	13.50
SEm (±)	0.202	0.309	0.223	0.267	0.359
CD (0.05)	NS	0.963	0.693	0.832	NS
F x T					
f_1t_1 (75% F, one vine)	4.91	15.75	5.50	23.00	13.45
f_1t_2 (75% F, two vines)	4.68	16.00	4.75	23.00	13.50
f_2t_1 (100% F, one vine)	5.04	15.00	4.63	23.63	14.88
f_2t_2 (100% F, two vines)	4.93	15.50	4.50	24.13	14.38
f_3t_1 (125% F, one vine)	5.67	17.50	6.63	22.25	13.00
f_3t_2 (125% F, two vines)	5.57	17.75	6.50	21.95	13.38
SEm (±)	0.202	0.309	0.223	0.267	0.359
CD (0.05)	NS	NS	NS	NS	NS
I x T					
I_1t_1 (80% I, one vine)	5.43	16.17	5.17	23.00	13.83
i_1t_2 (80% I, two vines)	5.30	16.42	5.17	23.13	13.83
i_2t_1 (60% I, one vine)	4.98	16.00	6.00	22.92	13.72
i_2t_2 (60% I, two vines)	4.82	16.42	5.33	22.92	13.67
SEm (±)	0.165	0.253	0.181	0.221	0.291
CD (0.05)	NS	NS	NS	NS	NS

NS - Non significant

Table 16. Continued

Treatments	Vine length (m)	Days to first male flower	Node to first male flower	Days to first female flower	Node to first female flower
F x I x T					
$f_1i_1t_1$	5.16	16.00	5.00	23.25	13.25
$f_1i_1t_2$	5.03	15.50	4.75	23.50	13.50
$f_1i_2t_1$	4.65	15.50	6.00	22.75	13.65
$f_1i_2t_2$	4.32	16.50	4.75	22.50	13.50
$f_2i_1t_1$	5.25	14.50	4.00	24.00	15.75
$f_2i_1t_2$	5.10	15.25	4.00	24.50	14.75
$f_2i_2t_1$	4.83	15.50	5.25	23.25	14.00
$f_2i_2t_2$	4.76	15.75	5.00	23.75	14.00
$f_3i_1t_1$	5.88	18.00	6.50	21.75	12.50
$f_3i_1t_2$	5.76	18.50	6.75	21.40	13.25
$f_3i_2t_1$	5.45	17.00	6.75	22.75	13.50
$f_3i_2t_2$	5.38	17.00	6.25	22.50	13.50
SEm (±)	0.284	0.437	0.315	0.380	0.507
CD (0.05)	NS	NS	NS	NS	NS
Control 1 (*Ad hoc*)	4.65	19.00	7.25	29.50	14.85
Control 2 (KAU POP)	6.00	18.50	6.25	25.75	16.75
Between Controls	NS	NS	S	NS	NS
Controls *vs* Treatments	NS	S	S	NS	S

NS - Non significant S - Significant

Interactions due to F x I exerted significant influence on days to first male flower (Table 16). The combination f_2i_1 *ie.*, fertilizer at 100 per cent level and irrigation at 80 per cent Epan was earliest (14.88 days) and was on par with f_1i_1 (fertilizer at 75 per cent RD and irrigation at 80 per cent Epan) (15.75 days). Fertilizer at 125 per cent level and irrigation at 80 per cent Epan was late (18.25 days). F x T, I x T and F x I x T interactions had no significant influence.

In the case of controls, there was no significant difference in days to first male flower. But between treatments and controls, the difference was significant. The controls were late in flowering.

4.2.1.3 Node to first male flower

Node to first male flower was significantly influenced by the levels of fertilizer and irrigation, but training levels had no influence (Table 15). Fertilizer at 100 per cent RD (F_2) recorded the lowest node number of 4.57 and F_3 the highest (6.57). Among the irrigation levels, 80 per cent Epan (I_1) produced male flower in lowest node (5.17).

Among the interactions, only F x I interactions had significant influence, where f_2i_1 (fertilizer at 100 per cent RD and irrigation at 80 per cent Epan) registered the lowest node number (4.00). The combination f_3i_1 (125 per cent RD and 80 per cent Epan) recorded the highest node number to first male flower which was on par with f_3i_2 (125per cent RD and 60 per cent Epan).

There was significant difference between the controls (*Ad hoc* and KAU POP) as well as between the treatments and controls.

4.2.1.4 Days to first female flower

The results presented in Table 15. revealed that only the levels of fertilizer had significant influence on days to first female flower. Fertilizer at 125 per cent RD (F_3) was the earliest (22.10 days) followed by F_1 (75 per cent RD) (23.00 days).

Among the treatment combinations, F x I had significant influence on days to first female flowering (Table 16). Application of fertilizer at 125 per cent RD and irrigation at 80 per cent Epan (f_3i_1) resulted in earlier female flower production (21.58 days). The combination f_2i_1 was late in flowering (24.25 days). F x T, I x T and F x I x T had no significant influence on this character.

The controls (C_1 and C_2) exhibited no significant difference for this trait. Similar was the case between treatments and controls.

4.2.1.5 Node to first female flower

Among the treatments, different levels of fertilizers had significant influence on node to first female flowering (Table 15). Fertilizer at 125 per cent RD (F_3) recorded the lowest node number (13.19) and it was on par with F_1 (13.48). The levels of irrigation and training were not significant.

Treatment combinations had no significant influence on node to first female flower. There was also no significant difference between two controls (C_1 and C_2). But between the treatments and controls there was significant difference, with treatments producing female flowers in lower nodes.

4.2.2 Fruit and Yield Characters

The effects of fertilizers, irrigation, training and their interaction on fruit and yield characters are presented in Table 17 and Table 18.

Table 17. Effect of fertilizer, irrigation and training on fruit and yield characters under rain shelter

Treatments	Fruit equatorial diameter (cm)	Fruit polar diameter (cm)	Rind thickness (cm)	Fruit weight (kg)
Fertilizer				
F_1 (75 per cent RD)	14.57	17.22	0.70	1.98
F_2 (100 per cent RD)	15.87	19.09	0.68	2.13
F_3 (125 per cent RD)	14.23	16.73	0.55	1.77
SEm (±)	0.354	0.416	0.040	0.088
CD (0.05)	1.101	1.295	0.124	0.273
Irrigation				
I_1 (80 per cent Epan)	14.97	18.35	0.600	2.09
I_2 (60 per cent Epan)	14.80	17.00	0.683	1.84
SEm (±)	0.290	0.339	0.034	0.071
CD (0.05)	0.903	1.056	NS	0.220
Training				
T_1 (one vine)	14.97	18.17	0.65	2.04
T_2 (two vines)	14.80	17.18	0.63	1.88
SEm (±)	0.290	0.339	0.034	0.071
CD (0.05)	NS	NS	NS	NS

NS - Non significant

Table 18. Interaction effects of treatments on fruit and yield characters under rain shelter

Treatments	Fruit equatorial diameter (cm)	Fruit polar diameter (cm)	Rind thickness (cm)	Fruit weight (kg)
F x I				
f_1i_1 (75% F, 80% Epan)	15.20	18.13	0.68	2.20
f_1i_2 (75% F, 60% Epan)	13.93	16.30	0.73	1.77
f_2i_1 (100% F, 80% Epan)	17.10	20.38	0.60	2.25
f_2i_2 (100% F, 60% Epan)	14.63	17.80	0.75	2.00
f_3i_1 (125% F, 80% Epan)	14.10	16.58	0.53	1.81
f_3i_2 (125% F, 60% Epan)	14.35	16.88	0.58	1.73
SEm (±)	0.504	0.590	0.056	0.125
CD (0.05)	1.569	NS	NS	NS
F x T				
f_1t_1 (75% F, one vine)	14.75	17.70	0.68	2.07
f_1t_2 (75% F, two vines)	14.38	16.73	0.73	1.90
f_2t_1 (100% F, one vine)	16.38	19.65	0.75	2.22
f_2t_2 (100% F, two vines)	15.35	18.53	0.60	2.03
f_3t_1 (125% F, one vine)	13.78	17.15	0.55	1.84
f_3t_2 (125% F, two vines)	14.68	16.30	0.55	1.71
SEm (±)	0.504	0.590	0.056	0.125
CD (0.05)	NS	NS	NS	NS
I x T				
I_1t_1 (80% I, one vine)	15.43	18.77	0.60	2.21
i_1t_2 (80% I, two vines)	15.50	17.95	0.60	1.96
i_2t_1 (60% I, one vine)	14.50	17.57	0.72	1.87
i_2t_2 (60% I, two vines)	14.10	16.42	0.65	1.80
SEm (±)	0.408	0.479	0.047	0.104
CD (0.05)	NS	NS	NS	NS

NS - Non significant

Table 18. Continued

Treatments	Fruit equatorial diameter (cm)	Fruit polar diameter (cm)	Rind thickness (cm)	Fruit weight (kg)
F x I x T				
$f_1i_1t_1$	15.65	19.05	0.60	2.36
$f_1i_1t_2$	14.75	17.20	0.75	2.03
$f_1i_2t_1$	13.85	16.35	0.75	1.77
$f_1i_2t_2$	14.00	16.25	0.70	1.76
$f_2i_1t_1$	17.15	20.70	0.65	2.38
$f_2i_1t_2$	17.05	20.05	0.55	2.12
$f_2i_2t_1$	15.60	18.60	0.85	2.06
$f_2i_2t_2$	13.65	17.00	0.65	1.94
$f_3i_1t_1$	13.50	16.55	0.55	1.90
$f_3i_1t_2$	14.70	16.60	0.50	1.72
$f_3i_2t_1$	14.05	19.05	0.55	1.77
$f_3i_2t_2$	14.65	17.20	0.60	1.69
SEm (±)	0.711	0.833	0.080	0.179
CD (0.05)	NS	NS	NS	NS
Control 1 (*Ad hoc*)	14.50	16.50	0.75	1.95
Control 2 (KAU POP)	12.73	14.60	0.65	1.61
Between Controls	NS	NS	NS	NS
Controls *vs* Treatments	S	S	NS	NS

NS - Non significant S - Significant

4.2.2.1 Fruit equatorial diameter

Application of fertilizer at 100 per cent RD (F_2) was found to be significantly superior to other treatments in improving fruit equatorial diameter (Table 17). It recorded highest diameter of 15.87 cm followed by F_1 (75 per cent RD) (14.55 cm) which was on par with F_3 (125 RD) (14.23 cm). Irrigation treatments also had significant influence on fruit equatorial diameter where, irrigation at 80 per cent Epan (I_1) recorded the highest diameter (14.97 cm). But levels of training did not have any influence on fruit equatorial diameter.

Interactions due to fertilizer and irrigation had significant influence on fruit equatorial diameter (Table 18). Fertilizer level at 100 per cent RD along with irrigation at 80 per cent Ep (f_2i_1) recorded the highest value of 17.10 cm. All other treatment combinations were on par. F x T, I x T and F x I x T interactions were not significant.

There was no significant difference between the two controls. But between treatments and controls the difference was significant, with treatments having higher values.

4.2.2.2 Fruit polar diameter

Among the treatments, levels of fertilizer and irrigation had significant influence on fruit polar diameter (Table 17). Application of fertilizer at 100 per cent RD (F_2) recorded the highest diameter of 19.09 cm followed by F_1 (75 per cent RD) (17.22 cm) which was on par with F_3 (125 per cent RD) (16.73 cm). With respect to irrigation, I_1 (80 per cent Epan) registered the highest value of 18.35 cm.

The interaction effects were not significant (Table 18). The comparison of two controls revealed that there was no significant difference between the controls.

But between the treatments and controls the difference was significant, with treatments having higher values.

4.2.2.3 Rind thickness

Rind thickness was significantly influenced by fertilizers alone and levels of irrigation and training of vines had no effect (Table 17). Fertilizer application at 125 per cent RD (F_3) exhibited the lowest rind thickness (0.55 cm) followed by F_2 (0.68 cm) which was on par with F_1 (0.70 cm).

The interactions were not significant. Similarly there was no significant difference between the controls as well as between the treatments and controls.

4.2.2.4 Fruit weight

Fertilizer and irrigation levels significantly influenced fruit weight (Table 17). Fertilizer at 100 per cent RD (F_2) recorded the highest fruit weight of 2.13 kg. Among irrigation levels, I_1 (80 per cent Epan) registered the highest fruit weight (2.09 kg). Training of vines had no influence on fruit weight.

The treatment combinations were not significant (Table 18). Similarly there was no significant difference between the controls as well as between the treatments and controls.

4.2.2.5 Days to first harvest

Fertilizer levels had significant influence on days to first harvest in watermelon (Table 17). Fertilizer at 125 per cent RD (F_3) recorded early harvest (45.98 days) and it was on par with F_1 (75 per cent RD) (46.94 days). Irrigation treatments and training levels had no influence.

Table 17. Continued

Treatments	Days to first harvest (DAT)	Fruits plant^{-1}	Yield plant^{-1} (kg)	Yield plot^{-1} (kg)
Fertilizer				
F_1 (75 per cent RD)	46.94	5.49	10.02	98.30
F_2 (100 per cent RD)	47.94	5.64	10.99	107.35
F_3 (125 per cent RD)	45.98	5.37	9.10	88.48
SEm (±)	0.454	0.515	0.424	4.356
CD (0.05)	1.412	NS	1.321	13.555
Irrigation				
I_1 (80 per cent Epan)	47.03	5.77	11.10	108.92
I_2 (60 per cent Epan)	46.88	5.21	8.97	87.17
SEm (±)	0.372	0.209	0.347	3.557
CD (0.05)	NS	NS	1.079	11.068
Training				
T_1 (one vine)	47.00	4.90	9.34	91.32
T_2 (two vines)	46.90	6.09	10.73	104.77
SEm (±)	0.372	0.209	0.347	3.557
CD (0.05)	NS	0.651	1.079	11.068

NS - Non significant

Table 18. Continued

Treatments	Days to first harvest (DAT)	Fruits plant^{-1}	Yield plant^{-1} (kg)	Yield plot^{-1} (kg)
F x I				
f_1i_1 (75% F, 80% Epan)	47.25	5.81	11.47	113.40
f_1i_2 (75% F, 60% Epan)	46.63	5.16	8.57	83.20
f_2i_1 (100% F, 80% Epan)	48.25	6.06	12.34	120.85
f_2i_2 (100% F, 60% Epan)	47.63	5.21	9.64	93.85
f_3i_1 (125% F, 80% Epan)	45.58	5.44	9.50	92.50
f_3i_2 (125% F, 60% Epan)	46.38	5.29	8.70	84.46
SEm (±)	0.645	0.363	0.598	6.163
CD (0.05)	NS	NS	NS	NS
F x T				
f_1t_1 (75% F, one vine)	47.00	4.86	9.31	91.850
f_1t_2 (75% F, two vines)	46.88	6.11	10.73	104.75
f_2t_1 (100% F, one vine)	47.75	4.91	10.02	97.70
f_2t_2 (100% F, two vines)	48.13	6.36	11.95	117.00
f_3t_1 (125% F, one vine)	46.25	4.95	8.69	84.40
f_3t_2 (125% F, two vines)	45.70	5.78	9.51	92.55
SEm (±)	0.645	0.363	0.598	6.163
CD (0.05)	NS	NS	NS	NS
I x T				
I_1t_1 (80% I, one vine)	47.00	5.14	10.39	102.200
i_1t_2 (80% I, two vines)	47.05	6.39	11.81	115.63
i_2t_1 (60% I, one vine)	47.00	4.67	8.30	80.43
i_2t_2 (60% I, two vines)	46.75	5.77	9.64	93.90
SEm (±)	0.526	0.296	0.490	5.031
CD (0.05)	NS	NS	NS	NS

NS - Non significant

Table 18. Continued

Treatments	Days to first harvest (DAT)	Fruits plant^{-1}	Yield plant^{-1} (kg)	Yield plot^{-1} (kg)
F x I x T				
$f_1i_1t_1$	47.25	5.05	10.61	106.10
$f_1i_1t_2$	47.25	6.56	12.32	120.70
$f_1i_2t_1$	46.75	4.66	8.01	77.60
$f_1i_2t_2$	46.50	5.66	9.13	88.80
$f_2i_1t_1$	48.00	5.37	11.45	112.00
$f_2i_1t_2$	48.50	6.75	13.22	129.70
$f_2i_2t_1$	47.50	4.44	8.59	83.40
$f_2i_2t_2$	47.75	5.97	10.68	104.30
$f_3i_1t_1$	45.75	5.00	9.10	88.50
$f_3i_1t_2$	45.40	5.87	9.90	96.50
$f_3i_2t_1$	46.75	4.90	8.28	80.30
$f_3i_2t_2$	46.00	5.68	9.11	88.60
SEm (±)	0.911	0.515	0.849	8.712
CD (0.05)	NS	NS	NS	NS
Control 1 *(Ad hoc)*	53.50	4.60	9.21	92.10
Control 2 (KAU POP)	49.75	4.14	6.13	36.41
Between controls	S	NS	S	S
Controls *vs* Treatments	S	S	S	S

NS - Non significant S - Significant

The interaction effects were not significant. But there was significant difference between the controls (*Ad hoc* and KAU POP) as well as between the treatments and controls. In treatments first harvest was early compared to controls.

4.2.2.6 Fruits plant^{-1}

Different levels of fertilizer and irrigation had no significant influence on the number of fruits plant^{-1} (Table 17). But training levels favourably influenced the trait. Training to two vines (T_2) registered higher fruits plant^{-1} (6.09) than one vine (4.90).

The treatment combinations were not significant (Table 18). Between the controls (C_1 and C_2) also there was no significant difference for fruit number, whereas it was significant between the treatments and controls. The treatments had more fruits than the controls.

4.2.2.7 Yield plant^{-1}

Levels of fertilizer, irrigation and training exerted significant influence on yield plant^{-1} (Table 17). Fertilizer application at 100 per cent RD (F_2) recorded the highest yield (10.99 kg) and it was on par with the fertilizer at 75 per cent RD (10.02 kg). Regarding irrigation, I_1 (80 per cent Epan) was significantly superior to I_2 registering yields 11.10 kg and 8.97 kg respectively. In the case of training, highest yield of 10.73 kg was recorded in T_2 (two vines).

In the case of interactions, there was no significant influence on yield plant^{-1}. The comparison of two controls revealed significant difference, with *Ad hoc* yielding higher (9.21 kg) than KAU POP (6.13 kg). The difference between treatments and controls were also significant, with treatments yielding more.

4.2.2.8 Yield plot^{-1}

Different levels of fertilizer, irrigation and training had significant influence on yield plot^{-1}. Fertilizer level F_2 (100 per cent RD) recorded highest yield plot^{-1} (107.35 kg) which was on par with F_1 (98.30 kg). Irrigation level I_1 (80 per cent Epan) was significantly superior to I_2 (60 per cent Epan) registering yield of 108.92 kg and 87.17 kg respectively. In the case of training, highest yield plot^{-1}was recorded in T_2 (two vines) (104.77 kg) which was significantly superior to T_1 (91.32 kg).

The interaction effects had no significant influence on yield plot^{-1}. But there was significant difference between the controls (*Ad hoc* and KAU POP) as well as between the treatments and controls. Treatments gave higher yield than controls.

4.2.2.9 Marketable yield plot^{-1}

The marketable yield plot^{-1} was significantly influenced by the different levels of fertilizer, irrigation and training. Fertilizer at 100 per cent RD (F_2) recorded the highest marketable yield plot^{-1} (104.12 kg) and it was on par with the fertilizer level at 75 per cent RD (95.64 kg). Regarding irrigation, I_1 (80 per cent Epan) was significantly superior to I_2 with marketable yield of 105.75 kg and 84.30 kg respectively. In the case of training, T_2 (two vines) recorded significantly higher yield (101.42 kg) than T_1 (88.65 kg).

The treatment combinations had no significant influence. There was significant difference between the controls (*Ad hoc* and KAU POP) as well as between the treatments and controls, with treatments having higher yield.

4.2.2.10 Days to final harvest

Different levels of fertilizer and irrigation had significant influence on days to final harvest (Table 17). Fertilizer at 100 per cent RD (F_2) recorded the longest duration of harvest (118.02 days) which was on par with F_1 (116.59 days). Among the irrigation

Table 17. Continued

Treatments	Marketable yield $plot^{-1}$ (kg)	Days to final harvest (DAT)	Seeds $fruit^{-1}$	Wt. of 100 seeds (g)
Fertilizer				
F_1 (75 per cent RD)	95.64	116.59	193.88	3.67
F_2 (100 per cent RD)	104.12	118.02	205.13	3.65
F_3 (125 per cent RD)	85.34	112.01	200.75	3.67
SEm (±)	4.396	1.652	4.397	0.061
CD (0.05)	13.680	5.142	NS	NS
Irrigation				
I_1 (80 per cent Epan)	105.75	119.68	201.75	3.64
I_2 (60 per cent Epan)	84.30	111.39	198.08	3.68
SEm (±)	3.592	1.351	3.590	0.051
CD (0.05)	11.177	4.205	NS	NS
Training				
T_1 (one vine)	88.65	115.66	205.00	3.68
T_2 (two vines)	101.42	115.40	194.83	3.65
SEm (±)	3.592	1.351	3.590	0.051
CD (0.05)	11.177	NS	NS	NS

NS - Non significant

Table 18. Continued

Treatments	Marketable yield plot^{-1} (kg)	Days to final harvest (DAT)	Seeds fruit^{-1}	Wt. of 100 seeds (g)
F x I				
f_1i_1 (75% F, 80% Epan)	110.10	120.18	190.25	3.63
f_1i_2 (75% F, 60% Epan)	81.18	113.00	197.50	3.70
f_2i_1 (100% F, 80% Epan)	117.23	122.13	204.50	3.60
f_2i_2 (100% F, 60% Epan)	91.00	113.90	205.75	3.70
f_3i_1 (125% F, 80% Epan)	89.93	116.75	210.50	3.70
f_3i_2 (125% F, 60% Epan)	80.75	107.26	191.00	3.63
SEm (±)	6.219	2.232	6.220	0.089
CD (0.05)	NS	NS	NS	NS
F x T				
f_1t_1 (75% F, one vine)	89.70	116.88	199.25	3.68
f_1t_2 (75% F, two vines)	101.58	116.30	188.50	3.65
f_2t_1 (100% F, one vine)	95.08	118.28	207.00	3.63
f_2t_2 (100% F, two vines)	113.15	117.75	203.25	3.68
f_3t_1 (125% F, one vine)	81.15	111.86	208.75	3.73
f_3t_2 (125% F, two vines)	8 9.53	112.15	192.75	3.60
SEm (±)	6.219	2.342	6.220	0.089
CD (0.05)	NS	NS	NS	NS
I x T				
I_1t_1 (80% I, one vine)	99.38	119.63	208.66	3.65
i_1t_2 (80% I, two vines)	112.12	119.72	194.83	3.63
i_2t_1 (60% I, one vine)	77.90	111.70	201.33	3.70
i_2t_2 (60% I, two vines)	90.72	111.07	194.83	3.65
SEm (±)	5.077	1.911	5.078	0.073
CD (0.05)	NS	NS	NS	NS

NS - Non significant

Table 18. Continued

Treatments	Marketable yield plot^{-1} (kg)	Days to final harvest (DAT)	Seeds fruit^{-1}	Wt. of 100 seeds (g)
F x I x T				
$f_1i_1t_1$	103.45	120.15	196.00	3.65
$f_1i_1t_2$	116.75	120.20	184.50	3.60
$f_1i_2t_1$	75.95	113.60	202.50	3.70
$f_1i_2t_2$	86.40	112.40	192.50	3.70
$f_2i_1t_1$	109.10	121.25	212.00	3.55
$f_2i_1t_2$	125.35	123.00	197.00	3.65
$f_2i_2t_1$	81.05	115.30	202.00	3.70
$f_2i_2t_2$	100.95	112.50	209.50	3.70
$f_3i_1t_1$	85.60	117.50	218.00	3.75
$f_3i_1t_2$	94.25	116.00	203.00	3.65
$f_3i_2t_1$	76.70	106.21	199.50	3.70
$f_3i_2t_2$	84.80	108.30	182.50	3.55
SEm (±)	8.795	3.308	8.794	0.112
CD (0.05)	NS	NS	NS	NS
Control 1 *(Ad hoc)*	87.43	102.25	210.50	3.55
Control 2 (KAU POP)	33.84	96.75	208.50	3.75
Between controls	S	NS	NS	NS
Controls *vs* Treatments	S	S	NS	NS

NS - Non significant S - Significant

treatments, irrigation at 80 per cent Epan (I_1) registered longer duration (119.68 days) than at 60 per cent Epan (111.39 days). However, training levels were not significant.

Interaction effects had no significant influence on days to final harvest. There was no significant difference between the controls C_1 (*Ad hoc*) and C_2 (KAU POP). But the difference was significant between the treatments and controls, where treatments had more duration than controls.

4.2.2.11 Seeds fruit^{-1}

Different levels of fertilizer, irrigation and training had no significant influence on the seeds fruit^{-1} (Table 17). Treatment combinations also had no significant influence on this character.

The controls (C_1 and C_2) exhibited no significant difference for seeds fruit^{-1} in watermelon. Similar was the case between treatments and controls.

4.2.2.12 Weight of 100 seeds

The weight of 100 seeds was not influenced by different levels of fertilizer (F), irrigation (I) and training (T). Similarly the interactions were also not significant.

There was no significant difference between the controls (C_1 and C_2) and also between the controls and treatments.

4.2.3 Quality Characters

The effects of different levels of fertilizer, irrigation, training and their interactions on qualitative characters like TSS, lycopene, ascorbic acid, reducing sugar and non reducing sugar are presented in Table 19 and Table 20.

Table 19. Effect of fertilizer, irrigation and training on quality characters under rain shelter

Treatments	TSS (^{0}Brix)	Lycopene (mg 100g^{-1})	Ascorbic acid (mg 100g^{-1})	Reducing sugar (%)	Non reducing sugar (%)
Fertilizer					
F_1 (75 per cent RD)	12.70	7.56	4.69	3.32	4.25
F_2 (100 per cent RD)	13.08	7.82	4.83	3.36	4.24
F_3 (125 per cent RD)	12.77	7.58	4.85	3.34	4.24
SEm (±)	0.240	0.076	0.097	0.040	0.024
CD (0.05)	NS	NS	NS	NS	NS
Irrigation					
I_1 (80 per cent Epan)	12.87	7.53	4.63	3.35	4.24
I_2 (60 per cent Epan)	12.83	7.77	4.95	3.32	4.24
SEm (±)	0.195	0.059	0.077	0.035	0.021
CD (0.05)	NS	0.184	0.240	NS	NS
Training					
T_1 (one vine)	12.88	7.63	4.83	3.33	4.26
T_2 (two vines)	12.80	7.66	4.75	3.35	4.23
SEm (±)	0.195	0.059	0.077	0.035	0.021
CD (0.05)	NS	NS	NS	NS	NS

NS - Non significant

Table 20. Interaction effects of treatments on quality characters under rain shelter

Treatments	TSS (°Brix)	Lycopene (mg $100g^{-1}$)	Ascorbic acid (mg $100g^{-1}$)	Reducing sugar (%)	Non reducing sugar (%)
F x I					
f_1i_1 (75% F, 80% Epan)	12.60	7.75	4.85	3.38	4.24
f_1i_2 (75% F, 60% Epan)	12.80	7.37	4.53	3.26	4.25
f_2i_1 (100% F, 80% Epan)	13.03	7.86	4.98	3.36	4.24
f_2i_2 (100% F, 60% Epan)	13.13	7.77	4.68	3.35	4.24
f_3i_1 (125% F, 80% Epan)	12.98	7.70	5.03	3.31	4.24
f_3i_2 (125% F, 60% Epan)	12.55	7.45	4.68	3.37	4.23
SEm (±)	0.336	0.103	0.135	0.059	0.034
CD (0.05)	NS	NS	NS	NS	NS
F x T					
f_1t_1 (75% F, one vine)	12.58	7.55	4.78	3.33	4.27
f_1t_2 (75% F, two vines)	12.83	7.57	4.60	3.31	4.22
f_2t_1 (100% F, one vine)	13.18	7.83	4.88	3.37	4.22
f_2t_2 (100% F, two vines)	12.98	7.80	4.78	3.34	4.26
f_3t_1 (125% F, one vine)	12.90	7.53	4.83	3.29	4.28
f_3t_2 (125% F, two vines)	12.63	7.63	4.88	3.39	4.18
SEm (±)	0.336	0.103	0.135	0.059	0.034
CD (0.05)	NS	NS	NS	NS	NS
I x T					
I_1t_1 (80% I, one vine)	12.78	7.72	5.00	3.33	4.25
i_1t_2 (80% I, two vines)	12.95	7.82	4.90	3.37	4.22
i_2t_1 (60% I, one vine)	12.98	7.55	4.65	3.33	4.25
i_2t_2 (60% I, two vines)	12.67	7.50	4.60	3.32	4.21
SEm (±)	0.274	0.086	0.112	0.047	0.026
CD (0.05)	NS	NS	NS	NS	NS

NS - Non significant

Table 20. Continued

Treatments	TSS (^{0}Brix)	Lycopene (mg 100g^{-1})	Ascorbic acid (mg 100g^{-1})	Reducing sugar (%)	Non reducing sugar (%)
F x I x T					
$f_1i_1t_1$	12.25	7.75	5.00	3.37	4.24
$f_1i_1t_2$	12.95	7.75	4.70	3.39	4.24
$f_1i_2t_1$	12.90	7.35	4.55	3.29	4.30
$f_1i_2t_2$	12.70	7.38	4.50	3.23	4.19
$f_2i_1t_1$	13.05	7.85	5.00	3.39	4.22
$f_2i_1t_2$	13.00	7.87	4.95	3.33	4.26
$f_2i_2t_1$	13.30	7.80	4.75	3.34	4.21
$f_2i_2t_2$	12.95	7.73	4.60	3.35	4.27
$f_3i_1t_1$	13.05	7.55	5.00	3.22	4.30
$f_3i_1t_2$	12.90	7.85	5.05	3.40	4.18
$f_3i_2t_1$	12.75	7.50	4.65	3.35	4.26
$f_3i_2t_2$	12.35	7.40	4.70	3.38	4.19
SEm (±)	0.476	0.148	0.195	0.081	0.048
CD (0.05)	NS	NS	NS	NS	NS
Control 1 *(Ad hoc)*	12.75	7.55	4.50	3.28	4.19
Control 2 (KAU POP)	13.00	7.56	4.70	3.31	4.20
Between controls	NS	NS	NS	NS	NS
Controls *vs* Treatments	NS	NS	NS	NS	NS

NS - Non significant S - Significant

4.2.3.1 TSS (Total Soluble Solids)

Different levels of fertilizer, irrigation and training had no significant influence on TSS content. Similarly the interaction effects were also not significant.

There was no significant difference between the controls (C_1 and C_2) and also between the controls and treatments.

4.2.3.2 Lycopene

The lycopene content was not influenced by fertilizer levels and training levels (Table 19). But levels of irrigation had significant influence, with I_2 (60 per cent Epan) recording the highest value (7.77 mg $100g^{-1}$).

The treatment combinations had no significant influence on lycopene content. Similarly there was no significant difference between the controls as well as between the treatments and controls.

4.2.3.3 Ascorbic acid

Different levels of fertilizer and training had no influence on ascorbic acid content (Table 19). But irrigation levels had significant influence, with I_2 (60 per cent Epan) recording the highest value (4.95 mg $100g^{-1}$).

The interaction effects were not significant. Similarly there was no significant difference between the controls as well as between the treatments and controls.

4.2.3.4 Reducing sugar

The treatments as well as interactions had no significant influence on reducing sugar content. There was no significant difference between the controls as well as between the treatments and controls.

4.2.3.5 Non reducing sugar

The effects of treatments and interactions on non reducing sugar content were not significant. There was also no significant difference between the controls as well as between the treatments and controls.

4.2.4 Soil Nutrient Status after the Experiment

The effect of three fertilizer levels (F), two irrigation levels (I), two training levels (T) and their interactions on soil nutrient status are furnished in Table 21 and Table 22 respectively.

The available nitrogen (N), phosphorus (P) and potassium (K) status of soil were significantly influenced by fertilizer levels, with F_3 (125 per cent RD) recording the highest N (354.75 kg ha^{-1}) followed by F_2 (303.63 kg ha^{-1}). The P and K contents were also highest in F_3 (158.73 kg ha^{-1} and 184.43 kg ha^{-1} respectively). The lowest N (277.53 kg ha^{-1}), P (130.48 kg ha^{-1}) and K (111.48 kg ha^{-1}) were recorded in F_1 (75 per cent RD).

Irrigation and training levels had no significant influence. The interaction effects were also not significant.

The comparison between two controls revealed that there was significant difference between the controls, with Control 1 (*Ad hoc*) recording the highest N (349.10 kg ha^{-1}), P (171.00 kg ha^{-1}) and K (232.30 kg ha^{-1}). Between the controls and treatments, there was no significant difference for N, P and K contents.

4.2.5 Water Requirement and Water Use Efficiency (WUE)

The data on water requirement and water use efficiency as influenced by the treatments and their interactions are furnished in Table 23, Table 24 and Table 25 respectively.

Table 21. Effect of fertilizer, irrigation and training on soil nutrient status after the experiment under rain shelter (kg ha^{-1})

Treatments	Available N	Available P	Available K
Fertilizer			
F_1 (75 per cent RD)	277.53	130.48	111.48
F_2 (100 per cent RD)	303.63	144.10	130.83
F_3 (125 per cent RD)	354.75	158.73	184.43
SEm (±)	3.799	3.888	4.777
CD (0.05)	11.824	12.099	14.866
Irrigation			
I_1 (80 per cent Epan)	312.13	143.83	140.88
I_2 (60 per cent Epan)	311.80	145.03	143.60
SEm (±)	3.108	3.174	3.901
CD (0.05)	NS	NS	NS
Training			
T_1 (one vine)	312.80	144.27	146.77
T_2 (two vines)	311.13	144.60	137.72
SEm (±)	3.108	3.174	3.901
CD (0.05)	NS	NS	NS

NS - Non significant

Table 22. Interaction effects of fertilizer, irrigation and training on soil nutrient status after the experiment under rain shelter (kg ha^{-1})

Treatments	Available N	Available P	Available K
F x I			
f_1i_1 (75% F, 80% Epan)	278.70	129.250	115.45
f_1i_2 (75% F, 60% Epan)	276.35	131.70	107.50
f_2i_1 (100% F, 80% Epan)	300.75	149.40	126.70
f_2i_2 (100% F, 60% Epan)	306.50	138.80	134.95
f_3i_1 (125% F, 80% Epan)	356.95	152.85	180.50
f_3i_2 (125% F, 60% Epan)	352.55	164.60	188.35
SEm (±)	5.371	5.496	6.757
CD (0.05)	NS	NS	NS
F x T			
f_1t_1 (75% F, one vine)	277.750	128.950	112.350
f_1t_2 (75% F, two vines)	277.30	132.00	110.60
f_2t_1 (100% F, one vine)	306.00	144.30	138.00
f_2t_2 (100% F, two vines)	301.25	143.90	123.65
f_3t_1 (125% F, one vine)	354.65	159.55	189.95
f_3t_2 (125% F, two vines)	354.85	157.90	178.90
SEm (±)	5.371	5.496	6.757
CD (0.05)	NS	NS	NS
I x T			
I_1t_1 (80% I, one vine)	312.333	141.93	147.00
i_1t_2 (80% I, two vines)	311.93	145.73	134.76
i_2t_1 (60% I, one vine)	313.26	146.60	146.53
i_2t_2 (60% I, two vines)	310.33	143.46	140.66
SEm (±)	4.383	4.488	5.515
CD (0.05)	NS	NS	NS

NS - Non significant

Table 22. Continued

Treatments	Available N	Available P	Available K
F x I x T			
$f_1i_1t_1$	276.10	124.30	123.30
$f_1i_1t_2$	281.30	134.20	109.60
$f_1i_2t_1$	279.40	133.60	103.40
$f_1i_2t_2$	273.30	129.80	111.60
$f_2i_1t_1$	298.40	145.20	132.30
$f_2i_1t_2$	303.10	153.60	121.10
$f_2i_2t_1$	313.60	143.40	143.70
$f_2i_2t_2$	299.40	134.20	126.20
$f_3i_1t_1$	362.50	156.30	187.40
$f_3i_1t_2$	351.40	149.40	173.60
$f_3i_2t_1$	346.80	162.80	192.50
$f_3i_2t_2$	358.30	166.40	184.20
SEm (±)	7.600	7.772	9.551
CD (0.05)	NS	NS	NS
Control 1 *(Ad hoc)*	349.10	171.10	232.30
Control 2 (KAU POP)	274.80	123.40	209.60
Between controls	S	S	S
Controls *vs* Treatments	NS	NS	NS

NS - Non significant S - Significant

The water requirement of watermelon ranged from 179.63 mm to 344.50 mm under rain shelter. The highest requirement (344.50 mm) was registered under basin irrigation and lowest in I_2 (60 per cent Epan).

Different levels of fertilizer and training had no influence on WUE. But irrigation levels had significant influence, with I_2 (60 per cent Epan) recording the highest value (544.59 kg ha^{-1} mm^{-1}). The interactions were not significant.

The comparison between two controls revealed that there was significant difference between the controls, with control 1 recording highest WUE (389.68 kg ha^{-1} mm^{-1}), and between controls and treatments, the difference was significant, with treatments having higher WUE than controls.

Table 23. Water requirement of watermelon under rain shelter (mm)

Treatments	Water Requirement (mm)	Mean WR (mm)
$f_1i_1t_1$	272.42	I_1= 272.27
$f_1i_1t_2$	272.26	
$f_2i_1t_1$	278.50	
$f_2i_1t_2$	286.38	
$f_3i_1t_1$	265.02	
$f_3i_1t_2$	259.02	
$f_1i_2t_1$	185.60	I_2= 179.63
$f_1i_2t_2$	182.96	
$f_2i_2t_1$	191.27	
$f_2i_2t_2$	182.54	
$f_3i_2t_1$	164.00	
$f_3i_2t_2$	171.41	
Control 1 *(Ad hoc)*	255.88	C_1= 255.88
Control 2 (KAU POP)	344.50	C_2= 344.50

Table 24. Effect of fertilizer, irrigation and training on water use efficiency (WUE) under rain shelter (kg ha^{-1} mm^{-1})

Treatments	WUE
Fertilizer	
F_1 (75 per cent RD)	483.61
F_2 (100 per cent RD)	518.35
F_3 (125 per cent RD)	480.53
SEm (±)	27.532
CD (0.05)	NS
Irrigation	
I_1 (80 per cent Epan)	443.73
I_2 (60 per cent Epan)	544.59
SEm (±)	22.481
CD (0.05)	69.961
Training	
T_1 (one vine)	460.98
T_2 (two vines)	527.35
SEm (±)	22.481
CD (0.05)	NS

NS - Non significant

Table 25. Interaction effects of fertilizer, irrigation and training on WUE under rain shelter (kg ha^{-1} mm^{-1})

Treatments	WUE
F x I	
f_1i_1 (75% F, 80% Epan)	462.44
f_1i_2 (75% F, 60% Epan)	504.79
f_2i_1 (100% F, 80% Epan)	474.82
f_2i_2 (100% F, 60% Epan)	561.89
f_3i_1 (125% F, 80% Epan)	393.97
f_3i_2 (125% F, 60% Epan)	567.10
SEm (±)	38.940
CD (0.05)	NS
F x T	
f_1t_1 (75% F, one vine)	451.43
f_1t_2 (75% F, two vines)	515.79
f_2t_1 (100% F, one vine)	465.86
f_2t_2 (100% F, two vines)	570.85
f_3t_1 (125% F, one vine)	465.65
f_3t_2 (125% F, two vines)	495.42
SEm (±)	38.940
CD (0.05)	NS
I x T	
I_1t_1 (80% I, one vine)	416.16
i_1t_2 (80% I, two vines)	471.32
i_2t_1 (60% I, one vine)	505.78
i_2t_2 (60% I, two vines)	583.39
SEm (±)	31.793
CD (0.05)	NS

NS - Non significant

Table 25. Continued

Treatments	WUE (kg ha^{-1} mm^{-1})
F x I x T	
$f_1i_1t_1$	432.14
$f_1i_1t_2$	492.74
$f_1i_2t_1$	470.73
$f_1i_2t_2$	538.84
$f_2i_1t_1$	446.46
$f_2i_1t_2$	503.17
$f_2i_2t_1$	485.25
$f_2i_2t_2$	638.52
$f_3i_1t_1$	369.90
$f_3i_1t_2$	418.04
$f_3i_2t_1$	561.39
$f_3i_2t_2$	572.80
SEm (±)	55.071
CD (0.05)	NS
Control 1 *(Ad hoc)*	389.68
Control 2 (KAU POP)	117.42
Between controls	S
Controls *vs* Treatments	S

S - Significant

4.3 EXPERIMENT II

B) STANDARDIZATION OF AGROTECHNIQUES FOR PRECISION FARMING IN WATERMELON UNDER OPEN CONDITION

4.3.1 Vegetative and Flowering Characters

The effect of three fertilizer levels (F), two irrigation levels (I), two levels of training (T) and their interactions on vegetative and flowering characters like vine length, days to first male flower, node to first male flower, days to first female flower and node to first female flower are presented in Table 26 and Table 27.

4.3.1.1 Vine length

The fertilizer levels significantly influenced vine length, with F_3 (Fertilizer at 125 per cent RD) recording the longest vine length (4.84 m) followed by F_1 (75 per cent RD) (3.41 m) which was on par with F_2 (100 per cent RD) (3.32 m) (Table 26). Irrigation levels were also significant. Irrigation at 80 per cent Epan (I_1) registered longer vine length (4.03 m) than I_2 (3.69 m). However, training levels had no significant effect.

The interactions were not significant. Similarly there was no significant difference between the controls as well as between the treatments and controls.

4.3.1.2 Days to first male flower

Days to first male flower was significantly influenced by the levels of fertilizer (Table 26). Fertilizer at 75 per cent level (F_1) registered earliness in flowering (16.19 days) and it was on par with F_2 (100 per cent RD) (16.25 days). The levels of irrigation and training had no significant influence on days to first male flower.

Table 26. Effect of fertilizer, irrigation and training on vegetative and flowering characters under open condition

Treatments	Vine length (m)	Days to first male flower	Node to first male flower	Days to first female flower	Node to first female flower
Fertilizer					
F_1 (75 per cent RD)	3.41	16.19	5.63	27.63	13.88
F_2 (100 per cent RD)	3.32	16.25	5.63	27.94	14.38
F_3 (125 per cent RD)	4.84	17.88	6.38	26.50	13.32
SEm (±)	0.093	0.431	0.271	0.518	0.372
CD (0.05)	0.288	1.342	NS	NS	NS
Irrigation					
I_1 (80 per cent Epan)	4.03	16.70	5.67	27.25	14.13
I_2 (60 per cent Epan)	3.69	16.83	6.08	27.45	13.58
SEm (±)	0.076	0.353	0.220	0.424	0.305
CD (0.05)	0.238	NS	NS	NS	NS
Training					
T_1 (one vine)	3.96	16.88	5.95	27.42	13.92
T_2 (two vines)	3.75	16.67	5.80	27.230	13.80
SEm (±)	0.076	0.353	0.220	0.424	0.305
CD (0.05)	NS	NS	NS	NS	NS

NS - Non significant

Table 27. Interaction effects of treatments on vegetative and flowering characters under open

Treatments	Vine length (m)	Days to 1st male flower	Node to 1st male flower	Days to 1st female flower	Node to 1st female flower
F x I					
f_1i_1 (75% F, 80% Epan)	3.50	16.00	5.37	27.41	13.87
f_1i_2 (75% F, 60% Epan)	3.32	16.37	5.87	27.29	13.87
f_2i_1 (100% F, 80% Epan)	3.46	15.87	5.12	27.41	14.88
f_2i_2 (100% F, 60% Epan)	3.17	16.62	6.12	27.29	13.87
f_3i_1 (125% F, 80% Epan)	5.11	18.25	6.50	27.41	13.62
f_3i_2 (125% F, 60% Epan)	4.56	17.50	6.25	27.29	13.00
SEm (±)	0.130	0.608	0.384	0.734	0.524
CD (0.05)	NS	NS	NS	NS	NS
F x T					
f_1t_1 (75% F, one vine)	3.52	16.37	5.75	27.75	14.00
f_1t_2 (75% F, two vines)	3.29	16.00	5.50	27.75	13.75
f_2t_1 (100% F, one vine)	3.42	16.00	5.62	28.50	14.25
f_2t_2 (100% F, two vines)	3.22	16.50	5.62	27.37	14.50
f_3t_1 (125% F, one vine)	4.92	18.25	6.50	26.00	13.50
f_3t_2 (125% F, two vines)	4.76	17.50	6.25	27.00	13.12
SEm (±)	0.130	0.608	0.384	0.734	0.524
CD (0.05)	NS	NS	NS	NS	NS
I x T					
I_1t_1 (80% I, one vine)	4.13	16.83	5.50	27.75	14.00
i_1t_2 (80% I, two vines)	3.92	16.58	5.83	26.75	14.25
i_2t_1 (60% I, one vine)	3.78	16.91	6.41	27.08	13.83
i_2t_2 (60% I, two vines)	3.59	16.75	5.75	27.83	13.33
SEm (±)	0.108	0.498	0.314	0.599	
CD (0.05)	NS	NS	NS	NS	NS

NS - Non significant

Table 27. Continued

Treatments	Vine length (m)	Days to first male flower	Node to first male flower	Days to first female flower	Node to first female flower
F x I x T					
$f_1i_1t_1$	3.61	16.50	5.25	28.25	13.75
$f_1i_1t_2$	3.39	15.50	5.50	26.50	14.00
$f_1i_2t_1$	3.44	16.25	6.25	27.25	14.25
$f_1i_2t_2$	3.20	16.50	5.50	28.50	13.50
$f_2i_1t_1$	3.59	15.50	5.00	28.50	14.75
$f_2i_1t_2$	3.34	16.25	5.25	27.00	15.00
$f_2i_2t_1$	3.25	16.50	6.25	28.50	13.75
$f_2i_2t_2$	3.10	16.75	6.00	27.75	14.00
$f_3i_1t_1$	5.19	18.50	6.25	26.50	13.50
$f_3i_1t_2$	5.04	18.00	6.75	26.75	13.75
$f_3i_2t_1$	4.65	18.00	6.75	25.50	13.50
$f_3i_2t_2$	4.48	17.00	5.75	27.25	12.50
SEm (±)	0.185	0.863	0.541	1.039	0.742
CD (0.05)	NS	NS	NS	NS	NS
Control 1 (*Ad hoc*)	4.47	18.00	6.25	28.25	16.00
Control 2 (KAU POP)	3.45	18.50	6.25	29.00	14.50
Between Controls	NS	NS	NS	NS	NS
Controls *vs* Treatments	NS	S	NS	NS	S

NS - Non significant S - Significant

The interaction effects were not significant. There was no significant difference between controls. But between treatments and controls, the difference was significant. The controls were late in flowering.

4.3.1.3 Node to first male flower

The treatments as well as interactions had no significant influence on node to first male flower. There was no significant difference between the controls as well as between the treatments and controls.

4.3.1.4 Days to first female flower

The levels of fertilizer, irrigation and training as well as their interactions had no significant influence on days to first female flower (Table 26). There was no significant difference between the controls as well as between the treatments and controls.

4.3.1.5 Node to first female flower

Fertilizer, irrigation and training levels as well as interactions were not significant.

There was no significant difference between two controls (C_1 and C_2). But between the treatments and controls there was significant difference, with treatments producing female flowers in lower nodes.

4.3.2 Fruit and Yield Characters

The effects of fertilizers, irrigation, training and their interaction on fruit and yield characters like fruit equatorial diameter, fruit polar diameter, rind thickness, fruit weight, days to first harvest, fruits plant^{-1}, yield plant^{-1}, yield plot^{-1}, marketable yield plot^{-1}, days to final harvest, seeds fruit^{-1} and weight of 100 seeds are presented in Table 28 and Table 29.

4.3.2.1 Fruit equatorial diameter

The fertilizer levels had no significant influence on fruit equatorial diameter (Table 28). Irrigation treatments were significant, with irrigation at 80 per cent Epan (I_1) recording the highest diameter (15.93 cm). But levels of training had no influence on fruit equatorial diameter.

The interactions were not significant (Table 29). There was no significant difference between the two controls. But between treatments and controls the difference was significant, with treatments having higher values.

4.3.2.2 Fruit polar diameter

Among the treatments, levels of fertilizer and irrigation had significant influence on fruit polar diameter (Table 28). Fertilizer at 100 per cent RD (F_2) recorded the highest value of 18.84 cm which was on par with F_1 (75 per cent RD) (17.69 cm). With respect to irrigation, I_1 (80 per cent Epan) registered the highest value of 18.42 cm.

The treatment combinations were not significant. The comparison of two controls revealed that there was no significant difference between the controls. But between the treatments and controls the difference was significant, with treatments having higher values.

4.3.2.3 Rind thickness

Rind thickness was significantly influenced by fertilizer levels (Table 28). Fertilizer at 125 per cent RD (F_3) exhibited the lowest rind thickness (0.58 cm) followed by F_2 (0.69 cm) which was on par with F_1 (0.75 cm). Levels of irrigation were also significant, with lowest rind thicknesss (0.63 cm) in I_1 (80 per cent Epan). However, training effects were not significant.

Table 28. Effect of fertilizer, irrigation and training on fruit and yield characters under open condition

Treatments	Fruit equatorial diameter (cm)	Fruit polar diameter (cm)	Rind thickness (cm)	Fruit weight (kg)
Fertilizer				
F_1 (75 per cent RD)	15.08	17.69	0.75	2.17
F_2 (100 per cent RD)	15.71	18.84	0.69	2.24
F_3 (125 per cent RD)	14.64	17.04	0.58	2.11
SEm (±)	0.380	0.427	0.033	0.097
CD (0.05)	NS	1.328	0.103	NS
Irrigation				
I_1 (80 per cent Epan)	15.93	18.42	0.63	2.28
I_2 (60 per cent Epan)	14.33	17.27	0.72	2.06
SEm (±)	0.309	0.349	0.028	0.083
CD (0.05)	0.962	1.085	0.086	NS
Training				
T_1 (one vine)	15.03	17.95	0.70	2.18
T_2 (two vines)	15.26	17.76	0.65	2.15
SEm (±)	0.309	0.349	0.028	0.083
CD (0.05)	NS	NS	NS	NS

NS - Non significant

Table 29. Interaction effects of treatments on fruit and yield characters under open condition

Treatments	Fruit equatorial diameter (cm)	Fruit polar diameter (cm)	Rind thickness (cm)	Fruit weight (kg)
F x I				
f_1i_1 (75% F, 80% Epan)	16.00	18.33	0.70	2.24
f_1i_2 (75% F, 60% Epan)	14.15	17.03	0.80	2.08
f_2i_1 (100% F, 80% Epan)	16.59	19.50	0.63	2.43
f_2i_2 (100% F, 60% Epan)	14.81	18.17	0.75	2.04
f_3i_1 (125% F, 80% Epan)	15.23	17.45	0.55	2.17
f_3i_2 (125% F, 60% Epan)	14.05	16.62	0.60	2.04
SEm (±)	0.538	0.604	0.050	0.138
CD (0.05)	NS	NS	NS	NS
F x T				
f_1t_1 (75% F, one vine)	15.12	17.59	0.75	2.14
f_1t_2 (75% F, two vines)	15.03	17.77	0.75	2.18
f_2t_1 (100% F, one vine)	15.62	19.12	0.75	2.25
f_2t_2 (100% F, two vines)	15.78	18.55	0.62	2.22
f_3t_1 (125% F, one vine)	14.32	17.12	0.57	2.15
f_3t_2 (125% F, two vines)	14.95	16.95	0.57	2.06
SEm (±)	0.538	0.604	0.050	0.138
CD (0.05)	NS	NS	NS	NS
I x T				
I_1t_1 (80% I, one vine)	15.87	18.45	0.62	2.26
i_1t_2 (80% I, two vines)	16.01	18.41	0.63	2.30
i_2t_1 (60% I, one vine)	14.17	17.44	0.76	2.09
i_2t_2 (60% I, two vines)	14.50	17.11	0.66	2.01
SEm (±)	0.438	0.495	0.041	0.112
CD (0.05)	NS	NS	NS	NS

NS - Non significant

Table 29. Continued

Treatments	Fruit equatorial diameter (cm)	Fruit polar diameter (cm)	Rind thickness (cm)	Fruit weight (kg)
F x I x T				
$f_1i_1t_1$	15.90	18.25	0.65	2.21
$f_1i_1t_2$	16.10	18.41	0.75	2.28
$f_1i_2t_1$	14.33	16.93	0.85	2.07
$f_1i_2t_2$	13.97	17.14	0.75	2.09
$f_2i_1t_1$	16.56	19.60	0.65	2.39
$f_2i_1t_2$	16.62	19.41	0.60	2.47
$f_2i_2t_1$	14.69	18.65	0.85	2.11
$f_2i_2t_2$	14.94	17.70	0.65	1.98
$f_3i_1t_1$	15.15	17.50	0.55	2.19
$f_3i_1t_2$	15.30	17.40	0.55	2.16
$f_3i_2t_1$	13.50	16.75	0.60	2.11
$f_3i_2t_2$	14.60	16.50	0.60	1.97
SEm (±)	0.761	0.853	0.069	0.998
CD (0.05)	NS	NS	NS	NS
Control 1 (*Ad hoc*)	14.35	16.75	0.75	2.22
Control 2 (KAU POP)	12.55	14.85	0.75	1.51
Between Controls	NS	NS	NS	S
Controls *vs* Treatments	S	S	NS	NS

NS - Non significant S - Significant

The interaction effects were not significant. Similarly there was no significant difference between the controls as well as between the treatments and controls.

4.3.2.4 Fruit weight

The treatments as well as interactions had no significant influence on fruit weight.

The comparison between two controls revealed the superiority of Control 1 (*Ad hoc* POP) with high fruit weight (2.22 kg) than Control 2 (1.51 kg). There was no significant difference between controls and treatments.

4.3.2.5 Days to first harvest

The treatments as well as interactions had no significant influence on days to first harvest. There was no significant difference between the controls as well as between the treatments and controls.

4.3.2.6 Fruits plant^{-1}

Different levels of fertilizer and irrigation had significant influence on the number of fruits plant^{-1} (Table 28). Fertilizer at 100 per cent RD (F_2) recorded highest number (4.13) which was on par with F_3 (3.76 kg). Among the irrigation treatments, I_1 (80 per cent Epan) registered the highest number (4.06). The training effects were not significant.

The interaction effects were not significant. Similarly there was no significant difference between the controls, and between the treatments and controls.

4.3.2.7 Yield plant^{-1}

Levels of fertilizer and irrigation exerted significant influence on yield plant^{-1} (Table 28). Fertilizer at 100 per cent RD (F_2) recorded the highest yield of 8.51

Table 28. Continued

Treatments	Days to first harvest (DAT)	Fruits plant^{-1}	Yield plant^{-1} (kg)	Yield plot^{-1} (kg)
Fertilizer				
F_1 (75 per cent RD)	51.57	3.59	7.55	72.38
F_2 (100 per cent RD)	51.94	4.13	8.51	82.00
F_3 (125 per cent RD)	50.57	3.76	7.52	72.10
SEm (±)	0.512	0.126	0.056	2.299
CD (0.05)	NS	0.393	0.715	7.154
Irrigation				
I_1 (80 per cent Epan)	51.20	4.06	8.42	81.23
I_2 (60 per cent Epan)	51.50	3.60	7.28	69.75
SEm (±)	0.419	0.101	0.187	1.878
CD (0.05)	NS	0.315	0.582	5.844
Training				
T_1 (one vine)	51.45	3.84	7.81	75.13
T_2 (two vines)	51.25	3.81	7.89	75.85
SEm (±)	0.419	0.101	0.187	1.878
CD (0.05)	NS	NS	NS	NS

NS - Non significant

Table 29. Continued

Treatments	Days to first harvest (DAT)	Fruits plant^{-1}	Yield plant^{-1} (kg)	Yield plot^{-1} (kg)
F x I				
f_1i_1 (75% F, 80% Epan)	51.13	3.85	8.18	78.75
f_1i_2 (75% F, 60% Epan)	52.00	3.35	6.90	66.00
f_2i_1 (100% F, 80% Epan)	51.75	4.40	9.17	88.70
f_2i_2 (100% F, 60% Epan)	52.12	3.85	7.83	75.30
f_3i_1 (125% F, 80% Epan)	50.75	3.90	7.93	76.25
f_3i_2 (125% F, 60% Epan)	50.37	3.61	7.10	67.95
SEm (±)	0.273	0.178	0.327	3.247
CD (0.05)	NS	NS	NS	NS
F x T				
f_1t_1 (75% F, one vine)	51.75	3.70	7.40	70.95
f_1t_2 (75% F, two vines)	51.37	3.48	7.68	73.80
f_2t_1 (100% F, one vine)	52.50	4.09	8.58	82.75
f_2t_2 (100% F, two vines)	51.37	4.16	8.43	81.25
f_3t_1 (125% F, one vine)	50.12	3.73	7.47	71.70
f_3t_2 (125% F, two vines)	51.00	3.77	7.55	72.50
SEm (±)	0.723	0.554	0.327	3.270
CD (0.05)	NS	NS	NS	NS
I x T				
I_1t_1 (80% I, one vine)	51.83	4.09	8.35	80.51
i_1t_2 (80% I, two vines)	50.58	4.01	8.50	81.95
i_2t_1 (60% I, one vine)	51.08	3.59	7.28	69.75
i_2t_2 (60% I, two vines)	51.91	3.60	7.28	69.75
SEm (±)	0.591	0.147	0.264	2.656
CD (0.05)	NS	NS	NS	NS

NS - Non significant

Table 29. Continued

Treatments	Days to first harvest (DAT)	Fruits plant^{-1}	Yield plant^{-1} (kg)	Yield plot^{-1} (kg)
F x I x T				
$f_1i_1t_1$	52.25	3.97	8.11	78.05
$f_1i_1t_2$	50.00	3.74	8.25	79.45
$f_1i_2t_1$	51.25	3.43	6.69	63.85
$f_1i_2t_2$	52.75	3.22	7.12	68.15
$f_2i_1t_1$	52.50	4.37	9.12	88.15
$f_2i_1t_2$	51.00	4.43	9.23	89.25
$f_2i_2t_1$	52.50	3.82	8.04	77.35
$f_2i_2t_2$	51.75	3.89	7.63	73.25
$f_3i_1t_1$	50.75	3.94	7.84	75.35
$f_3i_1t_2$	50.75	3.86	8.02	77.15
$f_3i_2t_1$	49.50	3.53	7.11	68.05
$f_3i_2t_2$	51.25	3.69	7.09	67.85
SEm (±)	1.027	0.253	0.46	4.601
CD (0.05)	NS	NS	NS	NS
Control 1 *(Ad hoc)*	52.25	3.59	7.87	78.70
Control 2 (KAU POP)	53.00	3.71	5.12	30.72
Between controls	NS	NS	S	S
Controls *vs* Treatments	NS	NS	S	S

NS - Non significant S - Significant

kg followed by F_1 (7.55 kg) which was on par with F_3 (7.52 kg). Regarding irrigation, highest yield (8.42 kg) was recorded in I_1 (80 per cent Epan). Training levels did not show any influence on yield plant^{-1}.

In the case of interactions (Table 29), there was no significant influence on yield plant^{-1}. The comparison between the two controls revealed significant difference, with C_1 (*Ad hoc*) registering higher yield (7.87 kg) than C_2 (5.12 kg). The difference between treatments and controls were also significant, with treatments giving higher yields.

4.3.2.8 Yield plot^{-1}

Different levels of fertilizer and irrigation had significant influence on yield plot^{-1}. Fertilizer level F_2 (100 per cent RD) recorded highest yield plot^{-1} (82.00 kg) followed by F_1 (72.38 kg) which was on par with F_3 (72.10 kg). Irrigation level I_1 (80 per cent Epan) was significantly superior to I_2 registering 81.23 kg and 69.75 kg respectively. In the case of training, the influence was not significant.

The interaction effects had no significant influence on yield plot^{-1}. But there was significant difference between the controls (*Ad hoc* and KAU POP) as well as between the treatments and controls. Control 1 registered higher yield (78.70 kg) than C_2 (30.72 kg). The treatments recorded higher yield than controls.

4.3.2.9 Marketable yield plot^{-1}

The marketable yield plot^{-1} was significantly influenced by the different levels of fertilizer and irrigation (Table 28). Fertilizer at 100 per cent RD (F_2) recorded the highest marketable yield (77.86 kg) followed by F_1 (69.14 kg) which was on par with F_3 (67.89 kg). Regarding irrigation, I_1 (80 per cent Epan) was significantly superior to other treatment with marketable yield of 77.00 kg. Training levels were not significant.

Table 28. Continued

Treatments	Marketable yield plot^{-1} (kg)	Days to final harvest (DAT)	Seeds fruit^{-1}	Wt. of 100 seeds (g)
Fertilizer				
F_1 (75 per cent RD)	69.14	75.30	229.88	3.66
F_2 (100 per cent RD)	77.86	79.65	253.00	3.66
F_3 (125 per cent RD)	67.89	76.23	233.13	3.63
SEm (±)	2.058	1.478	5.332	0.065
CD (0.05)	6.406	NS	NS	NS
Irrigation				
I_1 (80 per cent Epan)	77.00	79.83	239.66	3.62
I_2 (60 per cent Epan)	66.25	74.28	237.66	3.67
SEm (±)	1.682	1.208	4.356	0.054
CD (0.05)	5.234	3.759	NS	NS
Training				
T_1 (one vine)	71.07	77.47	235.41	3.66
T_2 (two vines)	72.20	76.65	241.91	3.63
SEm (±)	1.682	1.208	4.354	0.054
CD (0.05)	NS	NS	NS	NS

NS - Non significant

Table 29. Continued

Treatments	Marketable yield plot^{-1} (kg)	Days to final harvest (DAT)	Seeds fruit^{-1}	Wt. of 100 seeds (g)
F x I				
f_1i_1 (75% F, 80% Epan)	74.80	77.25	247.25	3.62
f_1i_2 (75% F, 60% Epan)	63.46	73.35	212.50	3.70
f_2i_1 (100% F, 80% Epan)	83.95	83.50	240.25	3.60
f_2i_2 (100% F, 60% Epan)	71.77	75.80	265.75	3.70
f_3i_1 (125% F, 80% Epan)	72.27	78.75	231.50	3.65
f_3i_2 (125% F, 60% Epan)	63.50	73.70	234.75	3.62
SEm (±)	2.913	2.088	7.540	0.091
CD (0.05)	NS	NS	NS	NS
F x T				
f_1t_1 (75% F, one vine)	67.31	75.80	218.50	3.70
f_1t_2 (75% F, two vines)	70.95	74.80	241.25	3.62
f_2t_1 (100% F, one vine)	78.15	80.20	249.25	3.62
f_2t_2 (100% F, two vines)	77.57	79.10	256.75	3.67
f_3t_1 (125% F, one vine)	67.72	76.40	238.50	3.67
f_3t_2 (125% F, two vines)	68.05	76.05	227.75	3.60
SEm (±)	2.913	2.088	7.540	0.091
CD (0.05)	NS	NS	NS	NS
I x T				
I_1t_1 (80% I, one vine)	76.23	80.33	233.50	3.63
i_1t_2 (80% I, two vines)	77.78	79.33	245.83	3.61
i_2t_1 (60% I, one vine)	65.89	74.60	237.33	3.70
i_2t_2 (60% I, two vines)	66.60	73.96	238.00	3.65
SEm (±)	2.378	1.705	6.159	0.076
CD (0.05)	NS	NS	NS	NS

NS - Non significant

Table 29. Continued

Treatments	Marketable yield $plot^{-1}$ (kg)	Days to final harvest (DAT)	Seeds $fruit^{-1}$	Wt. of 100 seeds (g)
F x I x T				
$f_1i_1t_1$	74.00	78.50	231.00	3.70
$f_1i_1t_2$	75.60	76.00	263.50	3.55
$f_1i_2t_1$	60.62	73.10	206.00	3.70
$f_1i_2t_2$	66.31	73.60	219.00	3.70
$f_2i_1t_1$	82.95	84.00	244.50	3.55
$f_2i_1t_2$	84.95	83.00	236.00	3.65
$f_2i_2t_1$	73.35	76.40	254.00	3.70
$f_2i_2t_2$	70.19	75.20	277.50	3.70
$f_3i_1t_1$	71.75	78.50	225.00	3.65
$f_3i_1t_2$	72.80	79.00	238.00	3.65
$f_3i_2t_1$	63.70	74.30	252.00	3.70
$f_3i_2t_2$	63.30	73.10	217.50	3.55
SEm (±)	4.117	2.952	10.688	0.129
CD (0.05)	NS	NS	NS	NS
Control 1 *(Ad hoc)*	73.60	74.00	261.50	3.55
Control 2 (KAU POP)	27.36	69.60	249.00	3.75
Between controls	S	NS	NS	NS
Controls *vs* Treatments	S	S	NS	NS

NS - Non significant S - Significant

The treatment combinations were not significant. There was significant difference between the controls (*Ad hoc* and KAU POP) as well as between the treatments and controls. Marketable yield $plot^{-1}$ was high for Control 1 (73.60 kg) compared to Control 2 (27.36 kg).

4.3.2.10 Days to final harvest

Different levels of fertilizer and training had no significant influence on days to final harvest (Table 28). Irrigation effect was significant, with 80 per cent Epan (I_1) registering longest duration of 79.83 days (Table 28).

Interactions were not significant. Between the controls C_1 (*Ad hoc*) and C_2 (KAU POP) there was no significant difference, but the difference was significant between the treatments and controls. Treatments had longer duration than controls.

4.3.2.11 Seeds $fruit^{-1}$

Different levels of fertilizer, irrigation and training had no significant influence on the seeds $fruit^{-1}$. Treatment combinations also had no significant influence on this character.

The controls (C_1 and C_2) exhibited no significant difference for seeds $fruit^{-1}$. Similar was the case between treatments and controls.

4.3.2.12 Weight of 100 seeds

The weight of 100 seeds was not influenced by different levels of fertilizer (F), irrigation (I) and training (T). Similarly the interactions were also not significant.

There was no significant difference between the controls (C_1 and C_2) and also between the controls and treatments.

4.3.3 Quality Characters

The effects of different levels of fertilizer, irrigation, training and their interactions on qualitative characters like TSS, lycopene, ascorbic acid, reducing sugar and non reducing sugar under open condition is presented in Table 30 and Table 31.

4.3.3.1 TSS (Total Soluble Solids)

Different levels of fertilizer, irrigation and training had no significant influence on TSS content (Table 30). Similarly the interaction effects were also not significant.

There was no significant difference between the controls (C_1 and C_2) and also between the controls and treatments.

4.3.3.2 Lycopene content

The treatments as well as interactions had no significant influence on lycopene content.

Similarly there was no significant difference between the controls, and between the treatments and controls.

4.3.3.3 Ascorbic acid content

Different levels of fertilizer (F), irrigation (I) and training (T) had no influence on ascorbic acid content (Table 30).

The interaction effects were not significant (Table 31). Similarly there was no significant difference between the controls as well as between the treatments and controls.

Table 30. Effect of fertilizer, irrigation and training on quality characters under open condition

Treatments	TSS (^{0}Brix)	Lycopene (mg $100g^{-1}$)	Ascorbic acid (mg $100g^{-1}$)	Reducing sugar (%)	Non reducing sugar (%)
Fertilizer					
F_1 (75 per cent RD)	12.62	6.32	3.85	3.07	3.88
F_2 (100 per cent RD)	13.01	6.37	3.95	3.07	3.91
F_3 (125 per cent RD)	12.53	6.36	4.05	3.09	3.90
SEm (±)	0.230	0.006	0.147	0.046	0.018
CD (0.05)	NS	NS	NS	NS	NS
Irrigation					
I_1 (80 per cent Epan)	12.62	6.43	4.15	3.10	3.91
I_2 (60 per cent Epan)	12.81	6.28	3.75	3.06	3.87
SEm (±)	0.189	0.007	0.118	0.039	0.013
CD (0.05)	NS	NS	NS	NS	NS
Training					
T_1 (one vine)	12.74	6.37	3.97	3.08	3.89
T_2 (two vines)	12.70	6.32	3.93	3.07	3.88
SEm (±)	0.189	0.007	0.118	0.039	0.013
CD (0.05)	NS	NS	NS	NS	NS

NS - Non significant

Table 31. Interaction effects of treatments on quality characters under open condition

Treatments	TSS (^{0}Brix)	Lycopene (mg 100g^{-1})	Ascorbic acid (mg 100g^{-1})	Reducing sugar (%)	Non reducing sugar (%)
F x I					
f_1i_1 (75% F, 80% Epan)	12.38	6.38	4.05	3.09	3.88
f_1i_2 (75% F, 60% Epan)	12.86	6.27	3.65	3.05	3.86
f_2i_1 (100% F, 80% Epan)	12.98	6.45	4.15	3.09	3.91
f_2i_2 (100% F, 60% Epan)	13.03	6.27	3.75	3.06	3.89
f_3i_1 (125% F, 80% Epan)	12.52	6.44	4.25	3.12	3.92
f_3i_2 (125% F, 60% Epan)	12.52	6.28	3.85	3.07	3.88
SEm (±)	0.324	0.012	0.205	0.065	0.026
CD (0.05)	NS	NS	NS	NS	NS
F x T					
f_1t_1 (75% F, one vine)	12.46	6.36	3.80	3.07	3.88
f_1t_2 (75% F, two vines)	12.77	6.29	3.90	3.08	3.86
f_2t_1 (100% F, one vine)	13.20	6.36	4.00	3.08	3.90
f_2t_2 (100% F, two vines)	12.81	6.37	3.90	3.06	3.90
f_3t_1 (125% F, one vine)	12.54	6.40	4.10	3.10	3.90
f_3t_2 (125% F, two vines)	12.50	6.31	4.00	3.08	3.90
SEm (±)	0.324	0.012	0.205	0.065	0.026
CD (0.05)	NS	NS	NS	NS	NS
I x T					
I_1t_1 (80% I, one vine)	12.55	6.44	4.17	3.11	3.91
i_1t_2 (80% I, two vines)	12.70	6.40	4.13	3.09	3.89
i_2t_1 (60% I, one vine)	12.92	6.30	3.76	3.06	3.88
i_2t_2 (60% I, two vines)	12.69	6.25	3.73	3.05	3.87
SEm (±)	0.266	0.010	0.169	0.054	0.020
CD (0.05)	NS	NS	NS	NS	NS

NS - Non significant

Table 31. Continued

Treatments	TSS (°Brix)	Lycopene (mg 100g^{-1})	Ascorbic acid (mg 100g^{-1})	Reducing sugar (%)	Non reducing sugar (%)
F x I x T					
$f_1i_1t_1$	12.11	6.46	4.00	3.10	3.89
$f_1i_1t_2$	12.65	6.30	4.10	3.09	3.87
$f_1i_2t_1$	12.82	6.25	3.60	3.04	3.88
$f_1i_2t_2$	12.90	6.28	3.70	3.06	3.85
$f_2i_1t_1$	13.10	6.39	4.20	3.10	3.92
$f_2i_1t_2$	12.86	6.52	4.10	3.08	3.91
$f_2i_2t_1$	13.30	6.32	3.80	3.07	3.89
$f_2i_2t_2$	12.77	6.23	3.70	3.05	3.89
$f_3i_1t_1$	12.45	6.48	4.30	3.13	3.93
$f_3i_1t_2$	12.60	6.39	4.20	3.11	3.91
$f_3i_2t_1$	12.64	6.32	3.90	3.08	3.87
$f_3i_2t_2$	12.41	6.24	3.80	3.06	3.89
SEm (±)	0.457	0.016	0.290	0.095	0.034
CD (0.05)	NS	NS	NS	NS	NS
Control 1 *(Ad hoc)*	12.78	6.35	3.90	3.07	3.87
Control 2 (KAU POP)	12.93	6.32	3.80	3.05	3.90
Between controls	NS	NS	NS	NS	NS
Controls *vs* Treatments	NS	NS	NS	NS	NS

NS - Non significant S – Significant

4.3.3.4 Reducing sugar content

The treatments as well as interactions had no significant influence on reducing sugar content. There was also no significant difference between the controls as well as between the treatments and controls.

4.3.3.4 Non reducing sugar content

The treatments and the interactions were not significant. There was also no significant difference between the controls as well as between the treatments and controls.

4.3.4 Soil Nutrient Status after the Experiment

The data on effect of three fertilizer levels (F), two irrigation levels (I), two training levels (T) and their interactions on soil nutrient status are furnished in Table 32 and Table 33 respectively.

The available nitrogen (N), phosphorus (P) and potassium (K) status of soil were significantly influenced by fertilizer levels, with F_3 (125 per cent RD) recording the highest N (324.33 kg ha^{-1}) which was on par with F_2 (317.30 kg ha^{-1}). The P and K contents were also highest in F_3 (230.18 kg ha^{-1} and 268.13 kg ha^{-1} respectively). The lowest N (274.68 kg ha^{-1}), P (180.65 kg ha^{-1}) and K (229.48 kg ha^{-1}) were recorded in F_1 (75 per cent RD).

Irrigation and training levels had no significant influence. The interaction effects were also not significant for N and P. But for K, F x I interaction was significant, with f_3i_2 (125 per cent RD, 60 per cent Epan) recording highest content (272.85 kg ha^{-1}) which was on par with f_3i_1 (263.40 kg ha^{-1}).

The comparison between two controls revealed that there was significant difference between the controls, with Control 1 (*Ad hoc*) recording the highest Nitrogen content

Table 32. Effect of fertilizer, irrigation and training on soil nutrient status after the experiment under open condition (kg ha^{-1})

Treatments	Available N	Available P	Available K
Fertilizer			
F_1 (75 per cent RD)	274.68	180.65	229.48
F_2 (100 per cent RD)	317.30	204.70	249.05
F_3 (125 per cent RD)	324.33	230.18	268.13
SEm (±)	3.510	3.311	3.043
CD (0.05)	10.922	10.305	9.469
Irrigation			
I_1 (80 per cent Epan)	301.58	202.30	249.48
I_2 (60 per cent Epan)	309.28	208.05	248.28
SEm (±)	2.867	2.705	2.134
CD (0.05)	NS	NS	NS
Training			
T_1 (one vine)	307.62	206.12	249.22
T_2 (two vines)	303.25	204.23	248.55
SEm (±)	2.867	2.705	2.134
CD (0.05)	NS	NS	NS

NS - Non significant

Table 33. Interaction effects of fertilizer, irrigation and training on soil nutrient status after the experiment under open condition (kg ha^{-1})

Treatments	Available N	Available P	Available K
F x I			
f_1i_1 (75% F, 80% Epan)	270.35	177.600	227.90
f_1i_2 (75% F, 60% Epan)	279.00	183.70	231.05
f_2i_1 (100% F, 80% Epan)	315.50	198.75	257.15
f_2i_2 (100% F, 60% Epan)	319.10	210.65	240.95
f_3i_1 (125% F, 80% Epan)	318.90	230.55	263.40
f_3i_2 (125% F, 60% Epan)	329.75	229.80	272.85
SEm (±)	4.964	4.683	4.229
CD (0.05)	NS	NS	13.380
F x T			
f_1t_1 (75% F, one vine)	276.500	181.050	229.95
f_1t_2 (75% F, two vines)	272.85	180.25	229.00
f_2t_1 (100% F, one vine)	321.00	202.85	247.70
f_2t_2 (100% F, two vines)	313.60	206.55	250.40
f_3t_1 (125% F, one vine)	325.35	234.45	270.00
f_3t_2 (125% F, two vines)	323.30	225.90	266.25
SEm (±)	4.964	4.683	4.229
CD (0.05)	NS	NS	NS
I x T			
I_1t_1 (80% I, one vine)	302.166	199.566	249.23
i_1t_2 (80% I, two vines)	301.00	205.03	249.73
i_2t_1 (60% I, one vine)	313.06	212.66	249.20
i_2t_2 (60% I, two vines)	305.50	203.43	247.37
SEm (±)	4.052	3.825	3.509
CD (0.05)	NS	NS	NS

NS - Non significant

Table 33. Continued

Treatments	Available N	Available P	Available K
F x I x T			
$f_1i_1t_1$	269.30	173.80	231.20
$f_1i_1t_2$	271.40	181.40	224.60
$f_1i_2t_1$	283.70	188.30	228.70
$f_1i_2t_2$	274.30	179.10	233.40
$f_2i_1t_1$	319.60	188.10	253.10
$f_2i_1t_2$	311.40	209.40	261.20
$f_2i_2t_1$	322.40	217.60	242.30
$f_2i_2t_2$	315.80	203.70	239.60
$f_3i_1t_1$	317.60	236.80	263.40
$f_3i_1t_2$	320.20	224.30	263.40
$f_3i_2t_1$	333.10	232.10	276.6
$f_3i_2t_2$	326.40	227.50	269.1
SEm (±)	7.020	6.623	6.082
CD (0.05)	NS	NS	NS
Control 1 *(Ad hoc)*	348.40	256.20	264.90
Control 2 (KAU POP)	256.30	94.80	223.10
Between controls	S	S	S
Controls *vs* Treatments	NS	S	NS

NS - Non significant S – Significant

(348.40 kg ha^{-1}), P (256.20 kg ha^{-1}) and K (264.90 kg ha^{-1}). Between the controls and treatments, there was no significant difference for N and K, while the difference was significant for P.

4.3.5 Water Requirement and Water Use Efficiency (WUE)

The water requirement and water use efficiency as influenced by the treatments and their interactions are furnished in Table 34, Table 35 and Table 36 respectively.

Table 34. Water requirement of watermelon under open condition (mm)

<table>
<tr><th>Treatments</th><th>Water Requirement (mm)</th><th>Mean WR (mm)</th></tr>
<tr><td>$f_1i_1t_1$</td><td>233.08</td><td rowspan="6">I_1=239.79</td></tr>
<tr><td>$f_1i_1t_2$</td><td>225.12</td></tr>
<tr><td>$f_2i_1t_1$</td><td>257.20</td></tr>
<tr><td>$f_2i_1t_2$</td><td>253.60</td></tr>
<tr><td>$f_3i_1t_1$</td><td>234.64</td></tr>
<tr><td>$f_3i_1t_2$</td><td>235.10</td></tr>
<tr><td>$f_1i_2t_1$</td><td>181.48</td><td rowspan="6">I_2= 184.02</td></tr>
<tr><td>$f_1i_2t_2$</td><td>181.15</td></tr>
<tr><td>$f_2i_2t_1$</td><td>190.06</td></tr>
<tr><td>$f_2i_2t_2$</td><td>185.47</td></tr>
<tr><td>$f_3i_2t_1$</td><td>184.63</td></tr>
<tr><td>$f_3i_2t_2$</td><td>181.33</td></tr>
<tr><td>Control 1 (Ad hoc)</td><td>250.52</td><td>C_1= 250.52</td></tr>
<tr><td>Control 2 (KAU POP)</td><td>330.86</td><td>C_2= 330.86</td></tr>
</table>

Table 35. Effect of fertilizer, irrigation and training on water use efficiency (WUE) under open condition (kg ha^{-1} mm^{-1})

Treatments	WUE
Fertilizer	
F_1 (75 per cent RD)	393.55
F_2 (100 per cent RD)	416.25
F_3 (125 per cent RD)	387.22
SEm (±)	12.037
CD (0.05)	NS
Irrigation	
I_1 (80 per cent Epan)	376.83
I_2 (60 per cent Epan)	421.88
SEm (±)	9.826
CD (0.05)	30.581
Training	
T_1 (one vine)	394.83
T_2 (two vines)	403.19
SEm (±)	9.826
CD (0.05)	NS

NS - Non significant

Table 36. Interaction effects of fertilizer, irrigation and training on WUE under open condition (kg ha^{-1} mm^{-1})

Treatments	WUE
F x I	
f_1i_1 (75% F, 80% Epan)	381.25
f_1i_2 (75% F, 60% Epan)	405.86
f_2i_1 (100% F, 80% Epan)	385.67
f_2i_2 (100% F, 60% Epan)	446.83
f_3i_1 (125% F, 80% Epan)	361.49
f_3i_2 (125% F, 60% Epan)	412.95
SEm (±)	17.024
CD (0.05)	NS
F x T	
f_1t_1 (75% F, one vine)	382.76
f_1t_2 (75% F, two vines)	404.35
f_2t_1 (100% F, one vine)	417.29
f_2t_2 (100% F, two vines)	415.21
f_3t_1 (125% F, one vine)	384.42
f_3t_2 (125% F, two vines)	390.02
SEm (±)	17.024
CD (0.05)	NS
I x T	
I_1t_1 (80% I, one vine)	370.34
i_1t_2 (80% I, two vines)	391.92
i_2t_1 (60% I, one vine)	419.31
i_2t_2 (60% I, two vines)	424.45
SEm (±)	13.901
CD (0.05)	NS

NS - Non significant

Table 36. Continued

Treatments	WUE (kg ha^{-1} mm^{-1})
F x I x T	
$f_1i_1t_1$	371.68
$f_1i_1t_2$	390.80
$f_1i_2t_1$	393.83
$f_1i_2t_2$	417.88
$f_2i_1t_1$	380.65
$f_2i_1t_2$	390.68
$f_2i_2t_1$	453.92
$f_2i_2t_2$	439.73
$f_3i_1t_1$	358.69
$f_3i_1t_2$	364.31
$f_3i_2t_1$	410.17
$f_3i_2t_2$	415.73
SEm (±)	24.075
CD (0.05)	NS
Control 1 *(Ad hoc)*	335.67
Control 2 (KAU POP)	103.16
Between controls	S
Controls *vs* Treatments	S

S - Significant

The water requirement of watermelon ranged from 184.02 mm to 330.86 mm. The highest requirement was registered under basin irrigation and lowest in I_2 (60 per cent Epan).

Different levels of fertilizer and training had no influence on WUE. But irrigation levels had significant influence, with I_2 (60 per cent Epan) recording the highest value (421.88 kg ha^{-1} mm^{-1}). The interactions were not significant.

The comparison between two controls revealed that there was significant difference between the controls, with Control 1 recording highest WUE (335.67 kg ha^{-1} mm^{-1}), and between controls and treatments, the difference was significant, with treatments having higher WUE than controls.

4.3.6 Pest and Disease Incidence

There was no serious pest and disease occurrence due to the timely application of plant protection measures. At the initial stage of crop growth, incidence of pumpkin caterpillar [*Diaphania indica* (Saunders)] was noticed and was effectively controlled by spraying Flubendiamide 39.35 SC (Fame) @ 0.1ml l^{-1}. Mild attack of fruit fly (*Bactrocera cucurbitae* Coq.) during the fruiting stage was controlled using fruit fly traps.

4.4 POOLED ANALYSIS

The influence of fertilizer, irrigation, training, growing conditions (rain shelter and open) and their interactions on pooled fruits plant^{-1}, days to final harvest and yield plant^{-1} are furnished in Tables 37 to 39.

4.4.1 Fruits plant^{-1}

Different levels of irrigation and training significantly enhanced fruits plant^{-1} in watermelon, while the effect of fertilizer was not significant (Table 37). Irrigation at 80 per cent Epan (I_1) produced higher number than I_2 (60 per cent Epan) under both rain shelter and open. Among training levels, T_2 (two vines) produced highest number (4.94) compared to T_1 (4.37). It was also observed that there was significant variation between two growing conditions. The fruits plant^{-1} was significantly higher under rain shelter (5.49) compared to open condition (3.82).

The interaction effects of treatments on pooled fruits plant^{-1} are presented in Table 38 and Table 39.

The interactions F x I, F x T, I x T and F x I x T were not significant. Whereas, in combination of treatments with growing conditions, g_1t_2 (rain shelter and training to two man vines) registered the highest fruit number of 6.08 followed by g_1t_1 (rain shelter, one vine) (4.90). The lowest number was recorded in g_2t_2 (open, two main vine) (3.81) which was on par with g_2t_1 (3.84).

4.4.2 Days to final harvest

The data on days to final harvest (Table 37) revealed that different levels of fertilizer and irrigation significantly increased the days to final harvest. Longest crop duration (98.83 days) was recorded in F_2 (100 per cent RD) which was on par with F_1 (95.94). In irrigation levels, I_1 (80 per cent Epan) recorded significantly longer duration (99.76 days) compared to I_2 (92.83 days). In the case of training there was

Table 37. Effect of fertilizer, irrigation, training and growing condition on pooled fruits plant^{-1}, days to final harvest and yield plant^{-1}

Treatments	Fruits plant^{-1}	Days to final harvest (DAT)	Yield plant^{-1} (kg)
Fertilizer			
F_1 (75 per cent RD)	4.54	95.94	8.81
F_2 (100 per cent RD)	4.88	98.83	9.75
F_3 (125 per cent RD)	4.56	94.11	8.31
SEm (±)	0.141	1.084	0.241
CD (0.05)	NS	3.172	0.705
Irrigation			
I_1 (80 per cent Epan)	4.91	99.76	9.79
I_2 (60 per cent Epan)	4.41	92.83	8.12
SEm (±)	0.115	0.885	0.197
CD (0.05)	0.337	2.590	0.575
Training			
T_1 (one vine)	4.37	96.57	8.60
T_2 (two vines)	4.94	96.01	9.31
SEm (±)	0.115	0.885	0.197
CD (0.05)	0.337	NS	0.575
Growing condition			
G_1 (rain shelter)	5.49	115.53	10.05
G_2 (open)	3.82	77.06	7.85
SEm (±)	0.115	0.885	0.197
CD (0.05)	0.334	2.590	0.575

NS - Non significant

Table 38. Interaction effect of fertilizer, irrigation and training on pooled fruits plant^{-1}, days to final harvest and yield plant^{-1}

Treatments	Fruits plant^{-1}	Days to final harvest (DAT)	Yield plant^{-1} (kg)
F x I			
f_1i_1 (75% F, 80% Epan)	4.83	98.71	9.89
f_1i_2 (75% F, 60% Epan)	4.24	93.18	7.74
f_2i_1 (100% F, 80% Epan)	5.23	102.81	10.76
f_2i_2 (100% F, 60% Epan)	4.53	94.85	8.74
f_3i_1 (125% F, 80% Epan)	4.67	97.75	8.72
f_3i_2 (125% F, 60% Epan)	4.45	90.48	7.90
SEm (±)	0.199	1.533	0.341
CD (0.05)	NS	NS	NS
F x T			
f_1t_1 (75% F, one vine)	4.28	96.34	8.42
f_1t_2 (75% F, two vines)	4.80	95.55	9.21
f_2t_1 (100% F, one vine)	4.50	99.24	9.30
f_2t_2 (100% F, two vines)	5.26	98.43	10.19
f_3t_1 (125% F, one vine)	4.34	94.13	8.08
f_3t_2 (125% F, two vines)	4.78	94.10	8.53
SEm (±)	0.199	1.533	0.341
CD (0.05)	NS	NS	NS
I x T			
I_1t_1 (80% I, one vine)	4.617	99.98	9.41
i_1t_2 (80% I, two vines)	5.20	99.53	10.16
i_2t_1 (60% I, one vine)	4.13	93.15	7.79
i_2t_2 (60% I, two vines)	4.69	92.52	8.46
SEm (±)	0.163	1.252	0.278
CD (0.05)	NS	NS	NS

NS- Non significant

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Table 38. Continued

Treatments	Fruits plant^{-1}	Days to final harvest (DAT)	Yield plant^{-1} (kg)
F x I x T			
$f_1i_1t_1$	4.51	99.33	9.49
$f_1i_1t_2$	5.15	98.10	10.29
$f_1i_2t_1$	4.05	93.35	7.35
$f_1i_2t_2$	4.44	93.00	8.13
$f_2i_1t_1$	4.87	102.63	10.29
$f_2i_1t_2$	5.59	103.00	11.23
$f_2i_2t_1$	4.13	95.85	8.32
$f_2i_2t_2$	4.93	93.85	9.16
$f_3i_1t_1$	4.47	98.00	8.47
$f_3i_1t_2$	4.87	97.50	8.96
$f_3i_2t_1$	4.22	90.26	7.70
$f_3i_2t_2$	4.69	90.70	8.10
SEm (±)	0.282	2.168	0.482
CD (0.05)	NS	NS	NS

NS - Non significant

Table 39. Interaction effect of growing condition, fertilizer, irrigation and training on pooled fruits plant^{-1}, days to final harvest and yield plant^{-1}

Treatments	Fruits plant^{-1}	Days to final harvest (DAT)	Yield plant^{-1} (kg)
G x F			
g_1f_1 (rain shelter, 75% F)	5.48	116.59	10.08
g_1f_2 (rain shelter, 100% F)	5.63	118.01	10.99
g_1f_3 (rain shelter, 125% F)	5.36	112.00	9.10
g_2f_1 (open, 75% F)	3.59	75.30	7.54
g_2f_2 (open, 100% F)	4.13	79.65	8.51
g_2f_3 (open, 125% F)	3.76	76.23	7.52
SEm (±)	0.199	1.533	0.341
CD (0.05)	NS	NS	NS
G x I			
g_1i_1 (rain shelter, 80% I)	5.77	119.68	11.14
g_1i_2 (rain shelter, 60% I)	5.22	111.39	8.97
g_2i_1 (open, 80% I)	4.05	79.83	8.43
g_2i_2 (open, 60% I)	3.60	74.28	7.28
SEm (±)	0.163	1.252	0.278
CD (0.05)	NS	NS	NS
G x T			
g_1t_1 (rain shelter, one vine)	4.90	115.67	9.38
g_1t_2 (rain shelter, two vines)	6.08	115.40	10.73
g_2t_1 (open, one vine)	3.84	77.47	7.82
g_2t_2 (open, two vines)	3.81	76.65	7.89
SEm (±)	0.163	1.252	0.278
CD (0.05)	0.477	NS	0.814

NS- Non significant

Table 39. Continued

Treatments	Fruits $plant^{-1}$	Days to final harvest (DAT)	Yield $plant^{-1}$ (kg)
G x F x I			
$g_1f_1i_1$	5.81	120.18	11.59
$g_1f_1i_2$	5.16	113.00	8.57
$g_1f_2i_1$	6.06	122.13	12.34
$g_1f_2i_2$	5.21	113.90	9.64
$g_1f_3i_1$	5.44	116.75	9.50
$g_1f_3i_2$	5.29	107.26	8.70
$g_2f_1i_1$	3.86	77.25	8.18
$g_2f_1i_2$	3.33	73.35	6.91
$g_2f_2i_1$	4.40	83.50	9.18
$g_2f_2i_2$	3.86	75.80	7.84
$g_2f_3i_1$	3.90	78.75	7.93
$g_2f_3i_2$	3.61	73.70	7.10
SEm (±)	0.282	2.168	0.482
CD (0.05)	NS	NS	NS

NS - Non significant

Table 39. Continued

Treatments	Fruits plant^{-1}	Days to final harvest (DAT)	Yield plant^{-1} (kg)
G x F x T			
$g_1f_1t_1$	4.86	116.88	9.44
$g_1f_1t_2$	6.11	116.30	10.73
$g_1f_2t_1$	4.91	118.28	10.02
$g_1f_2t_2$	6.36	117.75	11.95
$g_1f_3t_1$	4.95	111.86	8.69
$g_1f_3t_2$	5.78	112.15	9.51
$g_2f_1t_1$	3.70	75.80	7.40
$g_2f_1t_2$	3.48	74.80	7.69
$g_2f_2t_1$	4.10	80.20	8.58
$g_2f_2t_2$	4.16	79.10	8.43
$g_2f_3t_1$	3.74	76.40	7.48
$g_2f_3t_2$	3.78	76.05	7.56
SEm (±)	0.282	2.168	0.482
CD (0.05)	NS	NS	NS

NS - Non significant

Table 39. Continued

Treatments	Fruits plant^{-1}	Days to final harvest (DAT)	Yield plant^{-1} (kg)
G x I x T			
$g_1i_1t_1$	5.14	119.63	10.47
$g_1i_1t_2$	6.39	119.73	11.81
$g_1i_2t_1$	4.67	111.70	8.29
$g_1i_2t_2$	5.77	111.07	9.64
$g_2i_1t_1$	4.09	80.33	8.36
$g_2i_1t_2$	4.01	79.33	8.50
$g_2i_2t_1$	3.59	74.60	7.28
$g_2i_2t_2$	3.60	73.97	7.28
SEm (±)	0.231	1.770	0.393
CD (0.05)	NS	NS	NS

NS - Non significant

Table 39. Continued

Treatments	Fruits plant^{-1}	Days to final harvest (DAT)	Yield plant^{-1} (kg)
G x F x I x T			
$g_1f_1i_1t_1$	5.05	120.15	21.72
$g_1f_1i_1t_2$	6.56	120.20	24.64
$g_1f_1i_2t_1$	4.66	113.60	16.02
$g_1f_1i_2t_2$	5.66	112.40	18.26
$g_1f_2i_1t_1$	5.37	121.25	22.90
$g_1f_2i_1t_2$	6.75	123.00	26.44
$g_1f_2i_2t_1$	4.44	115.30	17.18
$g_1f_2i_2t_2$	5.97	112.50	21.36
$g_1f_3i_1t_1$	5.00	117.50	18.20
$g_1f_3i_1t_2$	5.87	116.00	19.80
$g_1f_3i_2t_1$	4.90	106.21	16.56
$g_1f_3i_2t_2$	5.68	108.30	18.22
$g_2f_1i_1t_1$	3.97	78.50	16.22
$g_2f_1i_1t_2$	3.74	76.00	16.50
$g_2f_1i_2t_1$	3.43	73.10	13.38
$g_2f_1i_2t_2$	3.22	73.60	14.24
$g_2f_2i_1t_1$	4.37	84.00	18.24
$g_2f_2i_1t_2$	4.43	83.00	18.46
$g_2f_2i_2t_1$	3.82	76.40	16.08
$g_2f_2i_2t_2$	3.89	75.20	15.26

$g_2f_3i_1t_1$	3.94	78.50	15.68
$g_2f_3i_1t_2$	3.86	79.00	16.04
$g_2f_3i_2t_1$	3.53	74.30	14.22
$g_2f_3i_2t_2$	3.69	73.10	14.18
SEm (±)	0.400	3.066	0.681
CD (0.05)	NS	NS	NS

NS - Non significant

was no significant influence. There was significant variation in days to final harvest between rain shelter and open, with g_1 (rain shelter) registering the longest duration of 115.53 days compared to 77.06 days under open condition (g_2).

The interaction effects were not significant.

4.4.3 Yield plant^{-1}

Fertilizer, irrigation and training levels significantly enhanced yield plant^{-1} in watermelon (Table 37). Among the fertilizer levels, F_2 (100 per cent RD) recorded highest yield (9.75 kg) followed by F_1 (8.81 kg) which was on par with F_3 (8.31 kg). Irrigation at 80 per cent Epan (I_1) produced highest yield (9.79 kg) than I_2 (60 per cent Epan) under both rain shelter and open. Among training levels, T_2 (two vines) produced highest yield (9.31 kg) compared to T_1 (8.60 kg). It was also observed that there was significant variation between two growing conditions. The yield plant^{-1} was significantly higher under rain shelter (10.05 kg) compared to open condition (7.85 kg).

The interaction effects of treatments on pooled yield plant^{-1} are presented in Table 38 and Table 39.

The interactions F x I, F x T, I x T and F x I x T were not significant. Whereas, in the combination of treatments with growing conditions, g_1t_2 (rain shelter and training to two vines) registered the highest fruit yield of 10.73 kg followed by g_1t_1 (rain shelter, one vine) (9.38 kg). The lowest yield was recorded in g_2t_1 (open, one vine) (7.82 kg) which was on par with g_2t_2 (7.89 kg).

Discussion

5. DISCUSSION

Hi-tech interventions like protected cultivation and precision farming in vegetables is gaining momentum in Kerala. These are mainly adopted in few crops like cucumber, capsicum, tomato, cowpea and few leafy vegetables. Compared to polyhouses, rain shelters are low cost structures and are more suited to hot humid conditions. Watermelon is one of the highly priced vegetables having great market potential. It is the most sought after fruit during the summer season. The production of watermelon is very limited in Kerala and almost the entire requirement is met from other states. Being a high value crop, its exploitation on commercial scale under protected structures like rain shelters and also in open can generate handsome income to farmers. Currently the preference is for small to medium sized fruits to cater the needs of nuclear families. Watermelon is essentially a cross pollinated crop and there exists great diversity in morphological as well as quality traits.

The present investigation was carried out at the Department of Olericulture, College of Agriculture, Vellayani, during 2014-2016 to evaluate watermelon accessions for yield and quality and to standardize agrotechniques for precision farming. The study comprised of two experiments.

5.1 EXPERIMENT I

EVALUATION OF VARIETIES / HYBRIDS OF WATERMELON

Planning and execution of a breeding programme for the improvement of quantitative attributes depends, to a great extent, upon the magnitude of genetic variability. The improvement of any crop depends on the available variability, heritability and genetic advance of the character under selection. Knowledge on nature and extent of genetic variation and diversity available in the germplasm helps the breeder for planning sound breeding programmes. Thus evaluation of diverse genotypes under uniform conditions is a pre-requisite for any breeding programme.

Experiment I was conducted during 2014-2015 to identify small to medium fruited watermelon with high yield and quality. The experiment was laid out in RBD with twenty accessions and two replications. The salient results of the experiment are briefly discussed here.

5.1.1 Variability Studies

The success of breeding programme depends upon the quantum of variability present among the available genotypes.

Analysis of variance revealed that difference due to genotypes was significant for all the characters studied. This indicates sufficient genetic variability to be exploited in a breeding programme. Similar results have also been reported by Gusmini and Wehner (2005), Sundaram *et al.* (2011) and Choudhary *et al.* (2012) in watermelon.

The characters having higher range of variation have a better scope of improvement through selection. Wide range of variability was shown by number of seeds fruit^{-1}, days to first harvest, fruit polar diameter, days to first male flower, days to first female flower, weight of 100 seeds and yield plant^{-1}, which has been reported by Prasad *et al.* (2002) and Sundaram *et al.* (2011). Choudhary *et al.* (2012) observed higher range for number of seeds fruit^{-1}and fruit yield plant^{-1}.

There was remarkable difference among the accessions for vine length with a range of 1.20 m in the variety Arka Muthu to 6.29 m in the hybrid NS 295. Such varietal variation in vine length was also reported by Samadia (2007) in round melon; Yadav *et al.* (2008) in bitter gourd; Bisht *et al.* (2011) in cucumber; Sundaram *et al.* (2011) in watermelon, which might be due to specific genetic constitution and vigour of different genotypes.

The number of days taken for first appearance of male and female flowers as well as their nodal positions plays an important role in deciding the earliness of crop. Arka Muthu and Prachi were the earliest to produce male flower and also in the lower nodes compared to other accessions. The hybrid Prachi was significantly superior to other accessions in earliness to female flowering (35 days) and was closely followed by IB-16 (36 days), Arka Muthu (36.5 days) and Simran (37 days). Similarly Prachi exhibited earliest harvest also, which differed significantly from other accessions. Earliness in terms of days to first harvest is an important criterion to select varieties or hybrids to fetch premium price for fruits in early market. Such varietal variation was also reported by Kumar *et al.* (2008), Yadav *et al.* (2008), Bisht *et al.* (2011) and Choudhary *et al.* (2012).

Significant difference was noticed among the accessions for fruit equatorial and polar diameters. Prasad *et al.* (2002) reported sufficient variation for fruit size in watermelon genotypes. Rind thickness is an important character associated with availability of edible flesh. The lowest rind thickness of 0.75 cm was recorded in the hybrids Prachi and Devyani. The hybrid IB-20 recorded the highest rind thickness (2.20 cm).

Fruit weight is a primary trait to be considered in any crop improvement programme, as it directly contributes towards yield. The data pertaining to fruit weight revealed significant differences among accessions. The variation in fruit weight ranged from 1.55 kg to 6.38 kg. Sugar Baby recorded the maximum weight and the hybrid Arjun registered the minimum. Since the present day market is having more inclination towards small to medium sized fruits, preference was given to select accessions producing more number of fruits plant^{-1} with lesser weight. Among the twenty accessions, Prachi ranked first in terms of fruits per plant with 4.47 fruits followed by Simran with 3.39. Such varietal variation in number of fruits per plant was also reported by Selvi *et al.* (2013). The highest yield plant^{-1} was recorded in the hybrid IB-23 (14.17 kg) followed by IB-20 (11.85 kg), Saraswati (10.35 kg) and Devyani (10.31 kg). The significant variation in fruit yield plant^{-1} might be due to difference in fruit weight and number of fruits plant^{-1}. These findings were supported by Yadav *et al.* (2008) in bitter gourd and Varalekshmi *et al.* (2015) in ridge gourd.

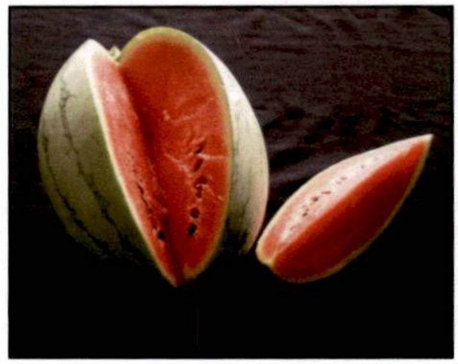
Eventhough IB-23 and IB-20 recorded higher yield, it may be attributed to high fruit weight (> 4kg), which is less desirable as per our objective. Moreover, they exhibited high incidence of Fusarium wilt.

The days to final harvest determines the crop duration. It ranged from 74 days to 109.5 days. Shonima took maximum days for final harvest and the minimum duration by the hybrid Prachi. A considerable variability was observed for number of seeds fruit^{-1}. Shonima and Swarna were seedless and the hybrids Saraswati and Agri Sweet Honey recorded the highest number of seeds per fruit (353). The weight of 100 seeds ranged from 11.80 g in NS-295 to 2.20 g in Arka Akash.

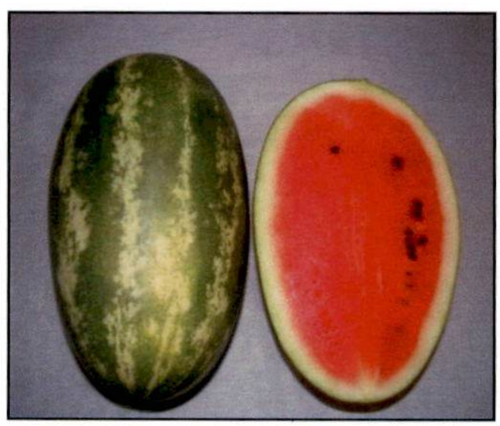
In watermelon, TSS is an important character determining quality and market preference. TSS is a measure of the concentration of the reducing sugars fructose and glucose and the non reducing sugar sucrose. The present study revealed that the hybrid Prachi was significantly superior to other accessions with a TSS of 13.30°B followed by Saraswati (12.20°B). Such variation in TSS has been reported by Prasad *et al*. (2002), Perkins-Veazie *et al*. (2007) and Zhang and Zhang (2010) in watermelon.

Red fleshed triploid watermelons contain high quantities of lycopene, a carotenoid that imparts the red color. The triploid Shonima recorded highest lycopene content and lowest by yellow fleshed Devyani. This is in confirmation with the findings of Perkins-Veazie *et al.* (2001). Development of superior hybrids with improved carotene content was recorded by Moon *et al.* (2006) in muskmelon. Presence of high reducing and non reducing sugar in watermelon is a preferred quality trait. The relative concentration of these sugars is influenced by cultivar and stage of maturity. Variations in sugar content in different cultivars have been reported by Maynard *et al*. (2002) and Weidong *et al.* (2002).

As the consumer preference is more for small sized fruits with high TSS content, it can be concluded that the hybrids Prachi, Simran and Saraswati (Plate 12)



Prachi



Saraswati

Simran

Plate 13. Best performing hybrids

are promising under South Kerala conditions. These accessions were also early in flowering and harvesting and also had more number of fruits.

Coefficients of variation (GCV and PCV) are better indices for comparison of characters with different units of measurements. In the present study, even though phenotypic coefficient of variation was higher than the corresponding genotypic coefficient of variation for all the characters, only a slight difference was observed between PCV and GCV. This revealed greater stability of the characters against environmental fluctuation, thus the selection based on phenotypic performance will be reliable. A major portion of PCV was contributed by GCV for most of the characters suggesting that the observed variation was mainly due to genetic factors. This similarity between PCV and GCV was reported earlier by Prasad *et al*. (2002), Sundaram *et al*. (2011) and Choudhary *et al.* (2012) in watermelon; Samadia (2011) and Varalakshmi *et al*. (2015) in ridge gourd.

High GCV and PCV were recorded for fruit weight, yield plant^{-1}, yield plot^{-1}, fruits plant^{-1}, rind thickness, vine length, fruit polar diameter, lycopene content, marketable yield plot^{-1}, weight of 100 seeds and number of seeds fruit^{-1} clearly indicating that selection will be rewarding. These results are in agreement with those of Somkuwar *et al*. (1997) and Bisht *et al* (2010). High magnitude of GCV was reported for number of seeds fruit^{-1} and yield plant^{-1} by Sundaram *et al*. (2011) and Choudhary *et al*. (2012) in watermelon.

Moderate PCV and GCV were recorded for fruit equatorial diameter, node to first female flower, days to first male flower, days to first harvest and reducing sugar content. Similar results were reported by Tomar *et al*. (2008) and Yadav *et al.* (2009) for number of fruits plant^{-1}. The genotypic coefficient of variation was quite low for days to first female flower and days to final harvest. Sundaram *et al*. (2011) and Choudhary *et al*. (2012) reported moderate GCV value for days to first female flower in watermelon.

5.1.2 Heritability and Genetic Advance

The genotypic coefficient of variation does not offer full scope to estimate the variation that is heritable and, therefore, estimation of heritability becomes necessary. The knowledge of heritability along with genetic advance aid in drawing valuable conclusions for effective selection based on phenotypic performance (Johnson *et al.*, 1955).

In the present investigation high heritability was observed for all the characters studied. The magnitude of heritability ranged from 78.06 to 98.70%. Highest heritability was recorded for days to first harvest followed by lycopene content, seeds fruit^{-1}, yield plant^{-1}, weight of 100 seeds, days to first female flower, days to first male flower, fruit weight, ascorbic acid and fruits plant^{-1}. High value of heritability indicates that phenotype of the trait strongly reflects the genotype and suggests the major role of genotypic constitution in the expression of the character. Therefore, reliable selection could be made for these traits on the basis of phenotypic expression. This is in agreement with the findings of Sundaram *et al*. (2011) and Choudhary *et al*. (2012). For total soluble solids (TSS), high heritability was observed in this study. Similar results were also reported by Kumar and Wehner (2011), Choudhary *et al*. (2012) and Said and Fatiha (2015) suggesting that genotypic components may play an important role in the improvement of this trait in watermelon.

High heritability combined with high genetic advance as per cent of mean was observed for characters like yield plant^{-1}, fruit weight, fruits plant^{-1}, lycopene content, yield plot^{-1}, marketable yield plot^{-1}, rind thickness, vine length, weight of 100 seeds and seeds fruit^{-1}. The result showed that these characters were controlled by additive gene effects and phenotypic selection for these characters is likely to be effective. Similar results were reported by Sundaram *et al*. (2011). Despite high heritability, genetic advance as per cent of mean was moderate for days to first female flower, days to final harvest, TSS, reducing sugar and non reducing sugar contents. Choudhary *et al*. (2012) reported high heritability combined with low GA for vine length, fruit weight, rind thickness and yield plant^{-1}.

5.1.3 Correlation Studies

Yield of watermelon is a result of interactions of a number of interrelated characters. For rational approach towards the improvement of yield, selection will be more rewarding when it is based on the components of yield. The efficiency of selection for yield mainly depends on the direction and magnitude of association between yield and its components and among themselves.

Correlation coefficient analysis measures the mutual relationship between various characters and is used to determine the component character on which selection can be done for improvement of yield. It also helps to understand the nature of inter relationships among the component traits.

In the present study, for all the characters, genotypic correlation coefficient was higher than respective phenotypic correlation coefficient, which may be ascribed to the low effect of environment on the character expression (Dey *et al*., 2005; Said and Fatiha, 2015).

Yield plant^{-1} was found to be significantly and positively associated with fruit equatorial diameter, fruit polar diameter, fruit weight, fruits plant^{-1} and seeds fruit^{-1} at genotypic and phenotypic levels. Positive correlation of fruit yield with fruits plant^{-1} and fruit weight has also been reported by Singh and Singh (1988), Gopal *et al*. (1996), Rolania *et al*. (2003), Sundaram *et al*. (2011), Kumar and Wehner (2011) and Choudhary *et al*. (2012) in watermelon. Vine length was positively and significantly correlated with days to first harvest and node to first female flower. Days to first female flower exhibited positive and significant correlation with days to first harvest and node to first female flower. This is in agreement with the findings of Singh and Singh (1988) and Sundaram *et al.* (2011) in watermelon. Days to first harvest exhibited significant negative correlation with fruits plant^{-1}. This view was supported by Choudhary *et al.* (2004) in muskmelon and Sundaram *et al.* (2011) in watermelon. The inter correlation involving fruit weight with fruit equatorial and polar diameters were positive and significant (Kumar and Wehner, 2011) while it was negative with days to first female flower and fruits plant^{-1}. Thus any improvement in the fruit weight would improve fruit equatorial and polar diameters but number of fruits would be reduced.

5.1.4 Path Coefficient Analysis

Correlation studies give an idea about the positive and negative associations of different characters with yield and also among themselves. However, the nature and extent of contribution of these characters towards yield is not obtained. The total correlation between yield and its component characters may sometimes be misleading, as it might be an over-estimate or under-estimate because of its association with other characters which are also associated with economic yield. Path coefficient analysis can provide a more realistic picture of relationships between different traits, as it takes into consideration direct as well as indirect effects of the different yield components. Determination of interrelationships between and among yield components and yield helps a plant breeder to easily identify traits that make the most significant contribution to yield.

In this study, path coefficient analysis was used to separate the genotypic correlation coefficients of yield plant^{-1} with vine length, days to first female flower, node to first female flower, fruit equatorial diameter, fruit polar diameter, fruits plant^{-1}, fruit weight, seeds fruit^{-1} and weight of 100 seeds, into direct and indirect effects.

Among yield attributes, fruit weight (0.858) exhibited the highest positive direct effect on fruit yield followed by fruits plant^{-1} (0.832). Fruit weight and fruits plant^{-1} also showed positive and significant correlation with yield plant^{-1}. This indicated that direct selection based on fruit weight and fruits plant^{-1} would result in appreciable improvement of yield plant^{-1}. These findings are in agreement with Somkuwar *et al.* (1997) and Choudhary *et al.* (2004) in muskmelon; Rao *et al.* (2004) in cucumber; Choudhary *et al.* (2012) in watermelon and Rabbani *et al.* (2012) in ridge gourd.

Days to first female flower, node to first female flower and fruit polar diameter also exerted positive direct effect on yield (Kumar *et al.*, 2005). Vine length, fruit equatorial diameter, seeds fruit^{-1} and weight of 100 seeds had negative direct effect on yield. Varalakshmi *et al.* (2015) also reported negative direct effect of vine length and fruit girth on yield. The path coefficient analysis revealed that fruit equatorial diameter and fruit polar diameter had the highest indirect positive effect on yield plant^{-1} through fruit weight. The indirect effects suggested that selection for any of these two characters would improve the yield through the associated character.

Therefore, it can be inferred that fruit weight and fruit plant^{-1} were the main yield contributing characters in fruit yield of watermelon because of its high, positive direct effect and positive correlation with fruit yield plant^{-1}. Since these characters also have high level of heritability and genetic advance, they can be considered dependable for improvement of yield in watermelon.

5.1.5 Sensory Evaluation of Watermelon Accessions

The sensory analysis of twenty watermelon accessions was conducted and chi-square test confirmed significant difference among the accessions. Mean sensory score values revealed that the hybrid Prachi was superior to other accessions in organoleptic qualities like appearance, taste, colour, flavour and texture (Fig. 5). Barrett *et al.* (2010) also reported that the color, flavor, texture, and the nutritional value of fresh-cut fruit and vegetable products are factors critical to consumer acceptance.

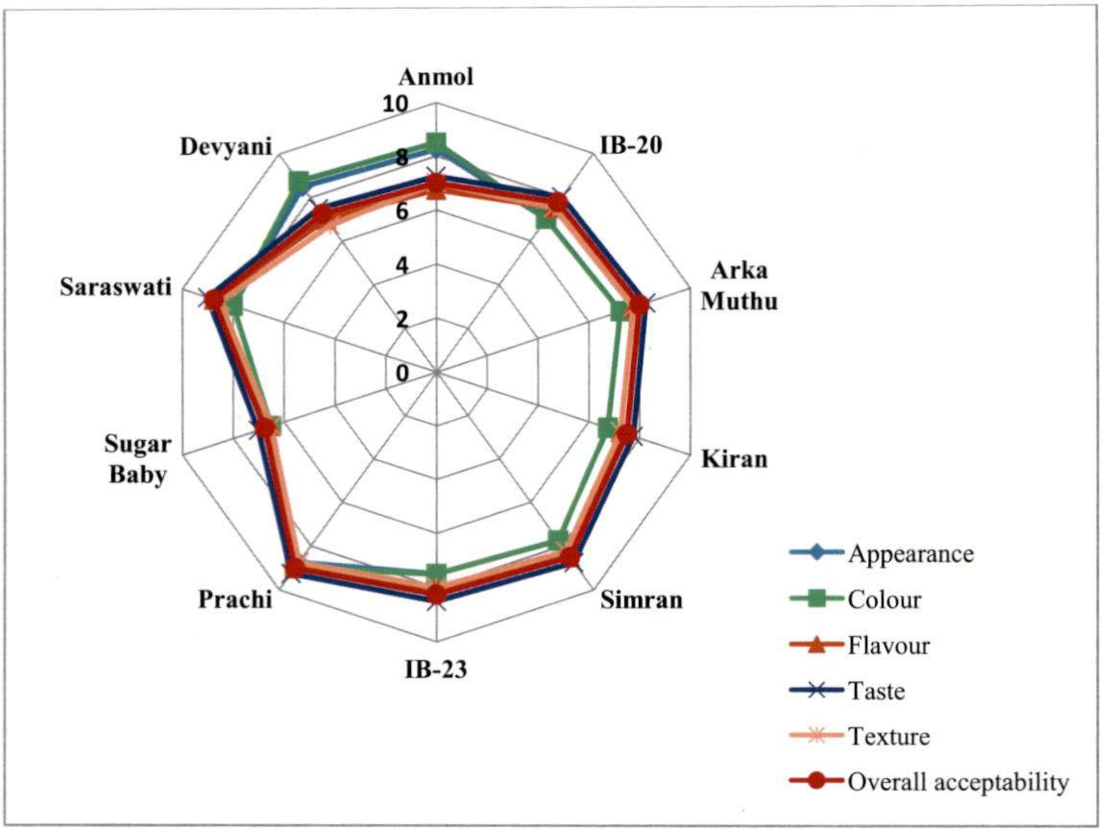


Fig. 5. Sensory evaluation of best ten accessions

5.1.6 Genetic Cataloguing

Genetic cataloguing based on standard descriptors helps to describe the morphological features of a genotype easily and thus helps in the exchange of information about new genotype in a more clearway.

The twenty accessions of watermelon upon cataloguing showed distinct variation among each other with respect to vegetative, fruit and seed characters.

All the accessions were runners except Arka Muthu, which was bushy in habit. The degree of leaf lobing was strong in majority of the accessions. There was wide variation in size and shape of fruits. The shapes ranged from round, broad elliptical, elliptical, pyriform and oblong.

There was also variation in rind thickness. Some of the small fruited hybrids had very thin rind. The triploid Swarna and hybrids Anmol and Devyani were yellow fleshed. Variation was also noticed in seed size and seed colour among the accessions.

Wehner *et al.* (2001), Yadav and Asati (2005), Gichimu *et al.* (2009) and Choudhary *et al.* (2012) have earlier characterized the watermelon genotypes for different morphological traits.

5.2 EXPERIMENT II

STANDARDIZATION OF AGROTECHNIQUES FOR PRECISION FARMING IN WATERMELON UNDER RAIN SHELTER AND OPEN CONDITION

The experimental findings on the response of watermelon to different levels of fertilizer, irrigation and training under rain shelter and open condition are briefly discussed below.

5.2.1 Effect of Fertilizer, Irrigation and Training on Growth, Yield and Quality of Watermelon

The results indicated that vine length was influenced by fertilizer levels under both rain shelter and open field condition. Increasing the fertilizer dose resulted in significant increase in vine length. Longest vine length was recorded in treatment receiving 125 per cent RD of fertilizer (F_3) both under rain shelter and open. Significant response to the applied nutrients on growth and growth attributes was reported by Miller (1958), Lakshmi (1997) and Hari (2016).

The plants in rain shelter had longer vines than those under open field condition. This might be due to favourable micro climatic conditions that prevailed in the rain shelter. Plants under open environment are exposed to harmful ultra violet and infra red radiations, which bring changes in molecular level leading to cellular disorganization. While the UV stabilized covering of protected structures have UV and IR absorbing property and promotes growth (Hazra and Som, 1999). Better performance of growth characters under protected structures as compared to open condition was earlier reported by Hazarika and Phookan (2005), Kavita *et al*. (2009), Ganiger (2010), Rajasekar *et al.* (2013) and Rajasekar *et al*. (2014).

The results showed that among the irrigation treatments, drip irrigation at I_1 (80 per cent Epan) had significantly increased the length of vines, both under rain shelter and open. Cucurbits require considerable amount of moisture during their most vigorous growth phase and it extends up to the maturity of fruits (Whitaker and

Davis, 1962). The reduced growth in basin irrigation could be attributed to the movement of water and nutrients beyond the effective root zone leading to a reduction in the uptake of nutrients.

Fertilizer treatments significantly influenced male flowering both under rain shelter and open. F_2 (100 per cent RD) recorded earliness in male flower anthesis as well as flower production in the lowest node. In the case of female flowering, influence of fertilizer level was observed only under rain shelter, with F_3 (125 per cent RD) registering early flowering. Similar observation was also made by Maluki *et al.* (2016b). The early appearance of male and female flowers at higher levels of nitrogen application might be attributed to fast growth of vine which favoured flower forming hormone like Gibberellic acid thereby inducing production of more female flowers (Choudhari and More, 2002; Umamaheswarappa *et al.*, 2005). The interaction between fertilizer and irrigation was significant with respect to days to first female flower under rain shelter only. The optimum availability of moisture and nutrients from the early crop growth stage promoted early flowering in f_3i_1.

In general, the crop under rain shelter produced higher yield at all levels of fertilizer and irrigation, compared to open field condition (Fig. 6A and Fig. 6B). Higher yield in rain shelter could be ascribed to favourable environmental conditions which resulted in better growth and longer crop duration. These results are in agreement with Bhatnagar *et al.* (1990), Kamaruddin *et al.* (2006) and Ganiger (2010) who also observed better growth and yield increase in greenhouse crop.

Fertilizer treatments significantly influenced the characters contributing to fruit yield *viz.*, fruit equatorial diameter, fruit polar diameter and fruit weight under rain shelter. Fertilizer level at 100 per cent RD (F_2) significantly increased all these parameters. Nitrogen promotes vegetative growth and P stimulates root development. Better vegetative growth leads to enhanced chlorophyll content along with higher stomatal conductance and thereby increased photosynthesis. Moreover, sufficient

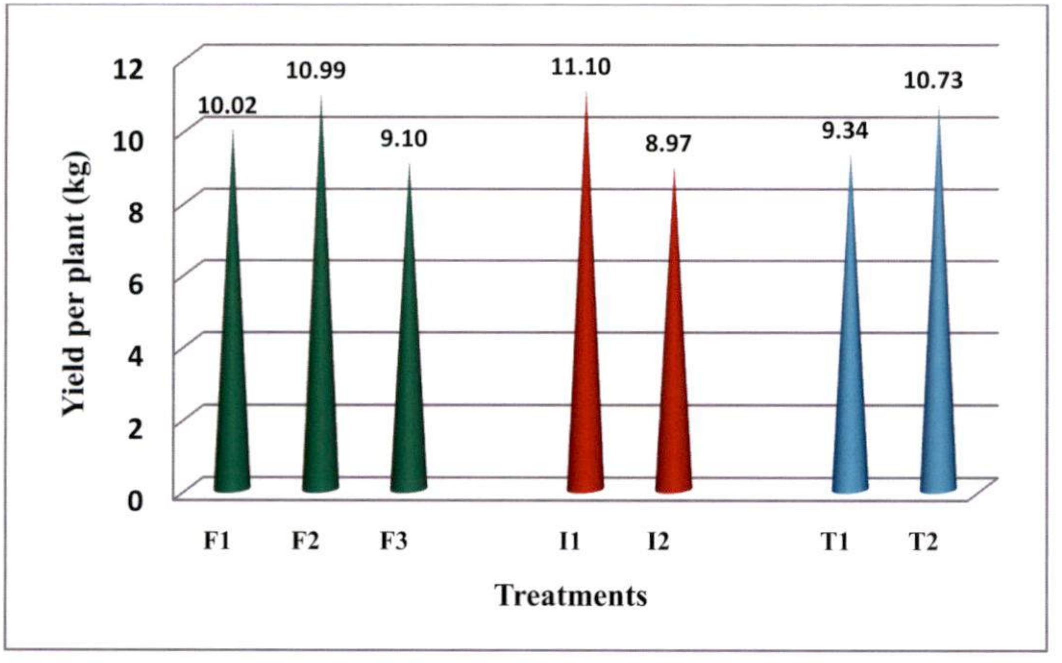


Fig. 6A. Yield plant^{-1} as influenced by fertilizer, irrigation and training under rain shelter

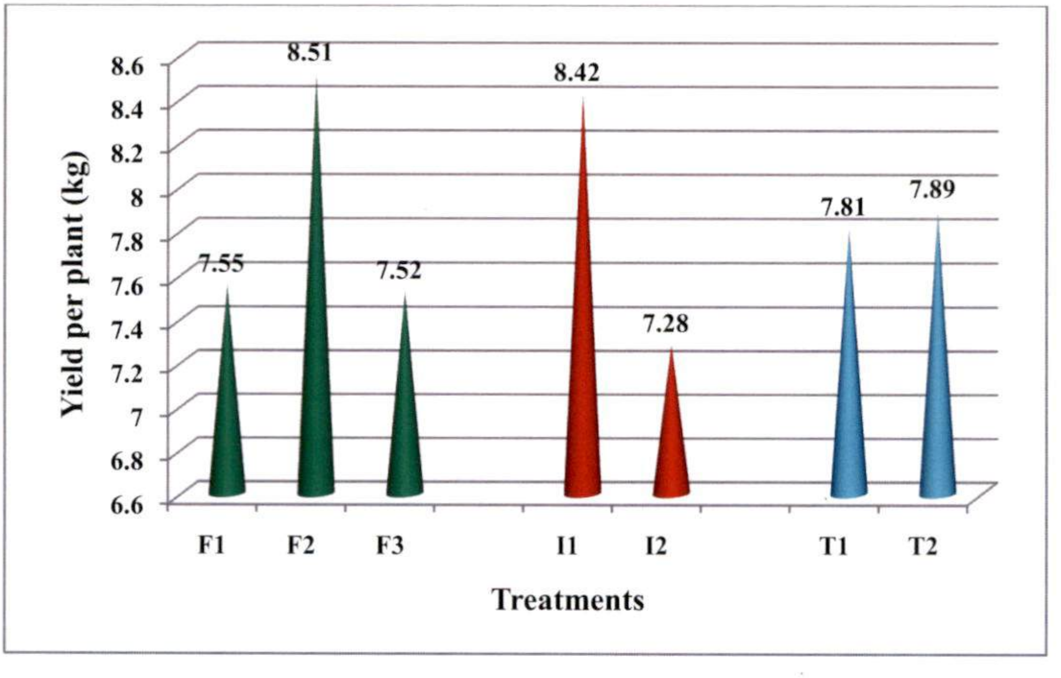


Fig. 6B. Yield plant^{-1} as influenced by fertilizer, irrigation and training under open condition

availability of K might have encouraged increased transport of photosynthates to the sink leading to higher yield (Maluki *et al*, 2016a, 2016b). Under open condition, fruit weight was not influenced by fertilizer dose. Similar result was reported by Andrade Junior *et al.* (2009), where fruit yield was more influenced by number of fruits than fruit weight. Hegde (1987) reported increase in both fruit weight and fruit number with increased nitrogen levels. The yield attributes like fruit weight, fruits plant^{-1} and yield plant^{-1} were decreased at the highest fertilizer level (125 per cent RD) tried (Fig. 7A and Fig. 7B). This might be attributed to early fruit set in lower nodes which resulted in competition between the fruit and vegetative parts during early fruit development. Moreover early formed fruits also recorded reduced fruit weight (Watanabe, 2014). Increased concentration of soluble fertilizers increases the osmotic potential of soil solution, causing reduction in water uptake by the plant roots (Maluki, 2016b)). The application of fertilizer through drip (fertigation) was found superior to conventional solid fertilizer application (Choudhari and More, 2002; Sharma *et al.*, 2011).

Increasing irrigation level from 60 per cent to 80 per cent Epan under drip system increased fruit equatorial diameter, fruit polar diameter and fruit weight under rain shelter. Increased vine length and yield attributes with increasing irrigation levels through drip irrigation thus, enhanced fruit yield of watermelon. The highest fruit yield of 11.10 kg and 8.97 kg was recorded at 80 per cent Epan (I_1) under rain shelter and open respectively, against 8.97 kg and 7.28 kg with irrigation at 60 per cent Epan. Proper balance of moisture in plants not only increases the photosynthesis but also helps in higher uptake of nutrients to meet accelerated rate of growth and ultimately yield (Parmar *et al.* 1999). The drip irrigation levels gave higher yield of watermelon than basin irrigation under both rain shelter and open field. Increase in yield with drip irrigation over conventional method has been reported by Sharanappa and Gowda (1995) and Kushwah and Dwivedi (2013). The increased yield under drip irrigation system might have resulted due to excellent soil-

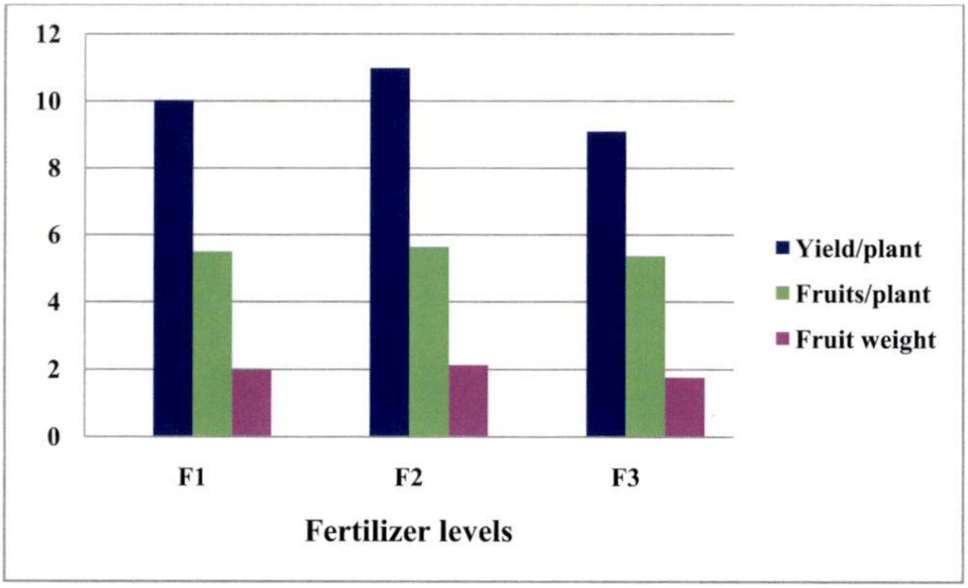


Fig. 7A. Yield and yield attributes as influenced by fertilizer levels under rain shelter

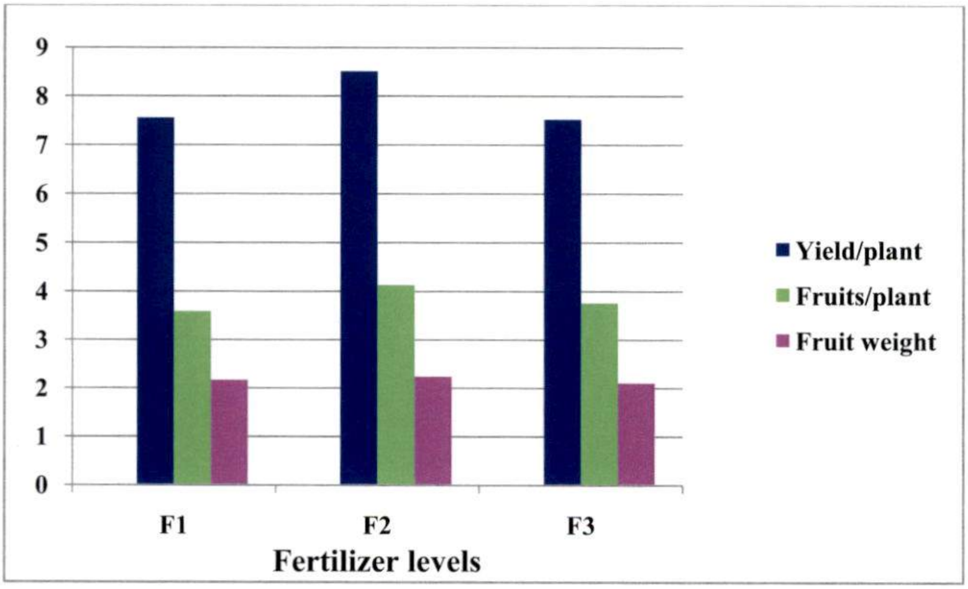


Fig. 7B. Yield and yield attributes as influenced by fertilizer levels under open condition

water-air relationship with higher oxygen concentration in the root zone (Gornat *et al.*, 1973), higher uptake of nutrients (Bafna *et al.*, 1993; Deolankar *et al.*, 2004) and continuous maintenance of higher soil moisture content to fulfill the evapotranspirational need of the crop (Lingiaiah *et al.*, 2005).

Rind thickness decreased significantly with increase in fertilizer level, with F_3 (125 per cent RD) recording the lowest value both under rain shelter and open. This is in corroboration with the findings of Maluki *et al.* (2016a) and (Maluki *et al.* (2016b). Nitrogen and phosphorus plays a role in photosynthesis, and the uptake of potassium and calcium is enhanced at higher levels of N and P. K and Ca are responsible for transporting photosynthates from leaves to the fruits. This increased transport might have led to good quality fruits with thinner rind. Irrigation treatment I_1 (80 per cent Epan) recorded lowest rind thickness.

The results revealed that number of fruits plant^{-1} increased significantly with increasing training level from one to two vines under rain shelter only. The highest number of 6.09 was recorded in T_2 (two vines). Increased vine length and longer crop duration inside rain shelter might have increased the fruit number. The fruit weight was lower in vertically trained plants than those of horizontally trained. This might be due to reduced light received by middle and lower leaves on vertical plants compared to horizontal ones (Watanabe, 2014).

Total crop duration was also significantly influenced by fertilizer and irrigation levels under rain shelter, with fertigation treatments registering longer duration compared to basin irrigation. This might be because of favourable conditions created by precise and timely application of irrigation water and fertilizer through fertigation which enhanced crop growth. The crop duration was significantly high under rain shelter (115.53 days) than open field (77.06 days).

Total soluble solids (TSS) is the most important quality parameter of watermelon. TSS content was not affected by the fertilizer, irrigation and training levels. El-Beheidi *et al*. (1990), Battilani and Solimando (2006), Andrade Junior *et al.* (2009) and Gioia *et al*. (2009) reported that total soluble solids was unaffected by fertigation levels in watermelon. However, increased TSS content with increase in application of N and P were reported by Maluki *et al*. (2016b) and Maluki *et al*. (2016a) respectively. Hegde (1989) found that TSS content of juice was not influenced by irrigation. According to Davis *et al*. (2006) withholding irrigation prior to harvesting increases sugar content and avoid fibrous flesh. Fernandes *et al*. (2014) also reported significant influence of irrigation frequencies on soluble solids content.

Lycopene and ascorbic acid contents were higher under rain shelter than open field condition. This might be due to favourable environment under protected condition, which helps in better development of fruit in different developmental phases. Similar improvement in quality characters under protected cultivation were reported by Ahluwalia *et al*. (1996), Mahajan and Singh (2006), Cheema *et al*. (2013) and Vattakunel (2014). Rajasekar *et al*. (2014) reported higher ascorbic acid content in field grown vegetables compared to protected condition. Among the treatments, only irrigation levels had influence on lycopene and ascorbic acid contents, where I_2 (60 per cent Epan) recorded higher contents than 80 per cent Epan under rain shelter. Leskovar *et al*. (2004) reported that vitamin C content was unaffected by deficit irrigation in watermelon and in some treatments, lycopene was higher during deficit irrigation. Lycopene content in watermelon is related to growth conditions, harvest maturity, accession and ploidy level (Zhao *et al*., 2013).

5.2.2 Effect of Fertilizer, Irrigation and Training on Soil Nutrient Status

Soil analysis after the experiment revealed that the fertilizer treatments showed significant influence on the nutrient status of soil. Treatments receiving 125 per cent RD (F_3) registered higher nutrient status compared to 100 and 75 per cent RD. The significant increase could be attributed to the direct effect of the applied fertilizers that was left unutilized by the crop. Similar findings were reported by

Bains (1967) and Mani and Ramanathan (1980). The final nutrient status in all treatments were medium for N and K and high for P. Bacon and Davey (1982) opined that drip fertigation would result in horizontal and vertical movement of native soil P near the outlet and remain near the soil surface and root zone. Similar increase in P content in soil has been reported by Shimi (2014) and Hari (2016). Guler and Ibrikci (2002) opined that drip fertigated plots had higher soil K compared to furrow irrigated plots and increasing nitrogen level also gave rise to an increase in soil K. On perusal of data between the two controls, it was found that the N, P and K status of soil was highest in Control 1 (*Ad hoc*).

5.2.3 Effect of Fertilizer, Irrigation and Training on Water Requirement and Water Use Efficiency

It was observed that water use was highest in conventional irrigation (Control 2) both under rain shelter (344.50 mm) and open condition (330.86 mm). The high water requirement under rain shelter was mainly due to enhanced crop duration under protected condition. This is in agreement with the findings of Mahajan and Singh (2006). Drip irrigation always resulted in reduced water requirement compared to basin irrigation. In drip irrigation, as water is applied directly to the root zone, it helps in conserving moisture and minimizes loss due to deep percolation (Bhogi *et al*., 2011). The results of this study also indicate considerable saving in irrigation water by drip irrigation. Maximum saving of water (47.86 per cent, 44.38 per cent) in I_2 (60 per cent Epan) was achieved with drip irrigation system over conventional irrigation (Control 2) under rain shelter and open respectively. This means, using the same quantity of water, about 47.86 per cent and 44.38 per cent additional area could have been brought under irrigation. A considerable saving in water under drip irrigation was reported by Sivanappan (2004), Suojala *et al*. (2006), Rekha and Mahavishnan (2008), Gupta *et al*. (2014), Hakkim and Chand (2014) and Patwardhan (2014).

Drip irrigation, both at I_1 (80 per cent Epan) and I_2 (60 per cent Epan) registered much higher water use efficiency as compared to conventional surface irrigation (Control 2) both inside and outside rain shelter. The WUE ranged from 117.42 kg ha^{-1} mm^{-1} to 544.59 kg ha^{-1} mm^{-1} under rain shelter and 103.16 kg ha^{-1} mm^{-1} to 421.88 kg ha^{-1} mm^{-1} in open field. The increase in WUE was due to enhanced yield registered for unit quantity of water used. Under drip system the rate of loss of water from soil surface was much lower compared to surface irrigation. Malik and Kumar (1996), Kushwah and Dwivedi (2013), Bhunia *et al.* (2014) and Patwardhan (2014) also reported similar results on WUE of drip irrigation. Lower water use efficiency in surface irrigation (Control 2) might be due to more water loss through percolation, infiltration or evapotranspiration. Application of excess quantity of water over the crop demand might have resulted in these losses.

The results of the present study revealed that the fertilizer level at 100 per cent RD (F_2) (70: 50: 120 kg NPK ha^{-1}) and daily irrigation at 80 per cent Epan (I_1) were found suitable for precision farming in watermelon both under rain shelter and open cultivation (Plates 14 and 15). Training of vines to two shoots vertically was found superior to single vine under rain shelter.

Plate 14. Best treatment under rain shelter ($f_2i_1t_2$)

Plate 15. Best treatment under open condition ($f_2i_1t_2$)

Summary

6. SUMMARY

The present investigation entitled 'Standardization of agrotechniques for precision farming in watermelon [*Citrullus lanatus* (Thunb.) Matsum. & Nakai]' was carried out at the Department of Olericulture, College of Agriculture, Vellayani during 2014-2016. The investigation comprised of two separate experiments.

In experiment I, twenty accessions of watermelon from public and private sectors were evaluated for small fruited varieties/hybrids with high yield and quality. The extend of variability, heritability and genetic advance of the accessions were assessed. The degree and direction of association between various traits and the direct and indirect effects of various components on yield were also analyzed.

The second experiment to standardize agrotechniques for precision farming in watermelon was conducted using the best hybrid Prachi selected from experiment I. The experiment II was laid out simultaneously under rainshelter and open condition with three levels of fertilizer (F_1 - 75 per cent of recommended dose (RD) (52.5: 37.5: 90 kg NPK ha^{-1}), F_2 - 100 per cent of RD (70: 50: 120 kg NPK ha^{-1}) and F_3 - 125 per cent of RD (87.5 : 62.5: 150 kg NPK ha^{-1}); two irrigation levels (I_1- 80 per cent Epan and I_2 - 60 per cent Epan) and two levels of training (T_1- nipping to one vine and T_2 - nipping to two vines) along with two controls (Control 1- *Ad hoc* recommendation for precision farming (70: 50: 120 kg NPK ha^{-1}) with irrigation at 100 per cent Epan and Control 2 - KAU Package of Practices recommendations). Vines were trained vertically under rain shelter and horizontally in open cultivation.

The salient findings of the study are summarized below:

- Analysis of variance revealed significant differences among the twenty accessions for all the characters studied *viz.*, vine length, days to first male flower, node to first male flower, days to first female flower, node to first female flower, fruit equatorial diameter, fruit polar diameter, rind thickness, fruit weight, days to first harvest, fruits $plant^{-1}$, yield $plant^{-1}$, yield $plot^{-1}$, marketable yield plot^{-1}, days to final harvest, seeds fruit^{-1}, weight of 100 seeds, TSS, lycopene, ascorbic acid, reducing sugar and non reducing sugar.

- The hybrids, Prachi, Saraswati and Simran were superior for fruits plant^{-1}, earliness in flowering, earliness in harvest and TSS content.
- The variety Arka Muthu was dwarf in nature with bushy vine having average vine length of 1.2 m.
- Among the accessions, IB-23 was the highest yielder (14.17 kg) followed by IB-20 and Saraswati. High yields in the hybrids IB-23 and IB-20 was due to high fruit weight (>4 kg).
- The assessed accessions contained sufficient variability and offered scope for selection based on characters like yield plant^{-1}, fruit polar diameter, days to first harvest, days to first male flower, days to first female flower, weight of 100 seeds and number of seeds fruit^{-1}.
- High genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were recorded for fruit weight, yield plant^{-1}, yield plot^{-1}, fruits plant^{-1}, fruit polar diameter, lycopene content, marketable yield plot^{-1}, rind thickness, vine length, weight of 100 seeds and number of seeds fruit^{-1}.
- Moderate PCV and GCV were recorded for fruit equatorial diameter, node to first female flower, days to first male flower, days to first harvest and reducing sugar content, whereas low GCV was recorded for days to first female flower and days to final harvest.
- The heritability estimates were high for all 22 characters studied. High heritability coupled with high genetic advance as per cent of mean was observed for yield plant^{-1}, fruit weight, fruits plant^{-1}, yield plot^{-1}, marketable yield plot^{-1}, lycopene content, rind thickness, vine length, weight of 100 seeds and seeds fruit^{-1}, indicating additive gene action and scope for improvement of these characters through selection.

- Correlation studies revealed that yield had positive and significant association with fruit equatorial diameter, fruit polar diameter, fruit weight, fruits plant^{-1} and seeds fruit^{-1} at both phenotypic and genotypic levels indicating that selection for these characters may improve yield.
- Path coefficient analysis revealed that fruit weight and fruits plant^{-1} exhibited high positive direct effect on fruit yield. Selection based on these characters would be effective for improving yield in watermelon.
- Incidence of fusarium wilt was high in IB-23 and IB-20, even though they were high yielders.
- Sensory evaluation of twenty watermelon accessions and chi-square test confirmed significant difference among the accessions. Mean sensory score values revealed that the hybrid Prachi was superior in organoleptic qualities like appearance, taste, colour, flavour and texture.
- Fertilizer, irrigation and training levels had varying influence on yield and yield attributes under rain shelter and open condition.
- Crop under rain shelter had longer vines than those in open. The fertilizer level 125 per cent RD (F_3) and irrigation at 80 per cent Epan (I_1) was found to produce longest vines.
- Fertilizer level had influence on earliness in female flowering only under rain shelter. Earliness in days to flowering as well as node number was observed in F_3 (125 per cent RD).
- The application of fertilizer through drip (fertigation) was found superior to conventional solid fertilizer application.
- The crop under rain shelter gave higher yield at all levels of fertilizer and irrigation, compared to open field condition.
- Fertilizer treatments significantly influenced the characters contributing to fruit yield *viz*., fruit equatorial diameter, fruit polar diameter and fruit weight

under rain shelter. Fertilizer level at 100 per cent RD (F_2) significantly increased all these parameters.

- Under open condition, fruit weight was not influenced by fertilizer dose.
- The irrigation level I_1 recorded the highest yield plant^{-1} under rain shelter (11.10 kg) and open (8.42 kg).
- Increasing irrrigation level from 60 per cent to 80 per cent Epan under drip system increased fruit equatorial diameter and fruit polar diameter under both rain shelter and open.
- Training to two vines significantly improved fruits plant^{-1} and yield plant^{-1} under rain shelter while training had no significant influence under open condition.
- Significantly higher fruit yield plant^{-1}, yield plot^{-1} and marketable yield plot^{-1} were recorded at fertilizer level F_2 (100 per cent) and irrigation level I_1 (80 per cent Epan). Under rain shelter F2 was on par with F1 (75 per cent RD).
- Fertilizer treatments significantly influenced rind thickness and minimum thickness was observed in fertilizer level F_3 (125 per cent RD) under both rain shelter and open.
- Fertigation treatments registered longer crop duration compared to conventional basin irrigation.
- The crop duration was significantly higher under rain shelter (115.53 days) than open condition (77.06 days).
- TSS content was not affected by the fertilizer, irrigation and training levels under both rain shelter and open.
- Lycopene and ascorbic acid contents were higher under rain shelter than open field condition.
- Irrigation levels had influence on lycopene and ascorbic acid contents, with I_2 (60 per cent Epan) recording higher contents than I_1 (80 per cent Epan) under rain shelter.

- Fertilizer treatments showed significant influence on the nutrient status of soil after the experiment. Treatments receiving 125 per cent RD (F_3) registered higher N, P and K contents.
- Water use was highest in conventional irrigation under both rain shelter and open condition. The lowest water requirement was registered in I_2 (60 per cent Epan). Maximum saving of water was achieved with drip irrigation than basin irrigation.
- The water requirement was 272.27 mm (I_1) and 179.63 mm (I_2) under rain shelter and 239.79 mm (I_1) and 184.02 mm (I_2) in open condition.
- Water use efficiency was influenced by irrigation levels and highest value was observed in I_2 (60 per cent Epan).

The results of the present study indicated that the hybrids Prachi, Saraswati and Simran, producing fruits having high TSS, small size and more number of fruits plant^{-1} are promising under Vellayani condition. It can also be inferred that the fertilizer dose of 70: 50: 120 kg NPK ha^{-1} and daily irrigation at 80 per cent Epan is found suitable for precision farming in watermelon both under rain shelter and open cultivation. Training of vines to two shoots vertically can be suggested for rain shelters.

FUTURE LINE OF WORK

The standardized protocol for precision farming in watermelon has to be evaluated for one more season for confirmatory results and later this can be recommended as Package of practice recommendation for precision farming in watermelon, under rain shelter and open condition.

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STANDARDIZATION OF AGROTECHNIQUES FOR PRECISION FARMING IN WATERMELON [*Citrullus lanatus* (Thunb.) Matsum. & Nakai]

by

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Abstract of the

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ABSTRACT

The investigation entitled "Standardization of agrotechniques for precision farming in watermelon [*Citrullus lanatus* (Thunb.) Matsum. & Nakai]" was carried out at the Department of Olericulture, College of Agriculture, Vellayani, during the period 2014-2016, to identify small fruited varieties / hybrids of watermelon with high yield and quality and to standardize the agrotechniques for precision farming in watermelon. The investigation comprised of two separate experiments.

The first experiment on 'Evaluation of varieties / hybrids of watermelon' was undertaken from December 2014 to April 2015. The experimental material consisted of 20 watermelon accessions, including three varieties and 17 hybrids. The experiment was laid out in RBD with two replications. The analysis of variance revealed highly significant differences among the twenty accessions for all the characters studied. The highest yield plant^{-1} was recorded in the hybrid IB-23 (14.17 kg) followed by IB-20 and Saraswati, while the highest fruits plant^{-1}, high TSS and earliness in flowering as well as harvest was observed in the hybrid Prachi. The variety Arka Muthu registered the lowest vine length of 1.20 m. High and moderate phenotypic and genotypic coefficients of variation (PCV and GCV) were noticed for most of the yield contributing characters. High estimates of heritability coupled with high to moderate genetic advance as per cent of mean was recorded for all the yield components, indicating additive gene action.

Yield had positive and significant correlation with the yield contributing characters such as fruit equatorial diameter, fruit polar diameter, fruits plant^{-1}, fruit weight and seeds fruit^{-1}. Path analysis revealed that fruit weight had the highest positive direct effect on yield plant^{-1} followed by fruits plant^{-1}. Fusarium wilt was the major disease observed in few accessions during the study. Sensory evaluation revealed the superiority of the hybrid Prachi over other accessions.

The second experiment on 'Standardization of agrotechniques for precision farming under rain shelter and open condition' was conducted simultaneously under

rain shelter and open condition, from December 2015 to April 2016, using the best hybrid Prachi. It was conducted in factorial RBD with twelve treatments and two controls, with two replications. The treatments were three levels fertilizer *viz.*, F_1 - 75% of recommended dose (RD) (52.5: 37.5: 90 kg NPK ha^{-1}), F_2 - 100% of RD (70: 50: 120 kg NPK ha^{-1}) and F_3 - 125% of RD (87.5 : 62.5: 150 kg NPK ha^{-1}); irrigation at two levels *ie.*, I_1- 80% Epan and I_2 - 60% Epan; and two levels of training *viz.*, T_1- nipping to one vine and T_2 - nipping to two vines. Vines were trained vertically under rain shelter and horizontally in open cultivation. The two controls were, Control 1- *Ad hoc* recommendation for precision farming (70: 50: 120 kg NPK ha^{-1}) with irrigation at 100% Epan and Control 2 - KAU Package of Practices recommendations (POP).

Fertilizer levels had significant influence on flowering and yield attributes of watermelon. The treatment F_2 registered highest yield plant^{-1} both under rain shelter and open condition, and was on par with F_1 under rain shelter. The effect of irrigation on vine length, fruit equatorial diameter, polar diameter and ascorbic acid content was also significant under both conditions. The irrigation level I_1 recorded the highest yield plant^{-1} under rain shelter (11.10 kg) and open (8.42 kg). Training to two vines significantly improved fruits plant^{-1} and yield plant^{-1} under rain shelter while training had no significant influence under open condition. The water requirement was 272.27 mm (I_1) and 179.63 mm (I_2) under rain shelter and 239.79 mm (I_1) and 184.02 mm (I_2) in open condition. Compared to conventional surface irrigation, drip irrigation registered higher water use efficiency at both levels of irrigation.

Pooled analysis also revealed that yield plant^{-1} was the highest in fertilizer level F_2, irrigation level I_1 and training level T_2. Among the growing conditions, rain shelter recorded the highest number of fruits plant^{-1} (5.49), yield plant^{-1} (10.05 kg) and maximum days to final harvest (115.53 DAT). Interaction effect of rain shelter with training to two main vines recorded the highest fruits plant^{-1} (6.08) and yield plant^{-1} (10.73 kg). Among the controls, *Ad hoc* recommendation for precision farming was significantly superior to KAU POP recommendation.

The present study revealed the superiority of fertilizer dose 70: 50: 120 kg NPK ha^{-1} (F_2) and daily irrigation at 80 per cent Epan (I_1) for watermelon under rain shelter and open condition for yield and quality. Training to two vines could be recommended for higher production under rain shelter. The hybrids Prachi, Saraswati and Simran producing fruits having high TSS, small size and more number of fruits were found promising under South Kerala condition.

Appendices

APPENDIX I

KeralaAgricultural University
College of Agriculture, Vellayani
Department of Olericulture

SCORE CARD FOR ORGANOLEPTIC EVALUATION OF WATERMELON

Name of student: Nisha S.K. (2013-22-101)

Title of Thesis: Standardization of agrotechniques for precision farming in watermelon [*Citrullus lanatus* (Thunb.) Matsum. & Nakai

Criteria	**SAMPLES**							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Appearance								
Colour								
Flavour								
Texture								
Taste								
Overall acceptability								

SCORE

Like Extremely -9
Like Very Much -8
Like Moderately -7
Like Slightly -6
Neither Like Nor Dislike -5
Dislike Slightly -4
Dislike Moderately -3
Dislike Very Much -2
Dislike Extremely -1

Date :

Name & Signature

APPENDIX II

MODIFIED DESCRIPTOR FOR WATERMELON (UPOV & ECPGR)

Sl. No.	Descriptor name	Descriptor state
1	Plant growth habit*	1 Bushy 2 Runner
2	Leaf blade: Degree of lobing	1 Absent or weak 3 Weak 5 Medium 7 Strong 9 Very strong
3	Fruit: shape in longitudinal section*	1 Flattened 2 Round 3 Broad elliptical 4 Elliptical 5 Pyriform 6 Oblong
4	Fruit: shape of apical part	1 Truncate 2 Truncate to rounded 3 Rounded 4 Rounded to acute 5 Acute
5	Fruit: depression at apex	1 Absent or very shallow 2 Shallow 3 Medium 4 Deep 5 Very deep
6	Fruit: ground colour of skin	1 Yellow 2 Very light green 3 Very light green to light green 4 Light green 5 Light green to medium green 6 Medium green 7 Medium green to dark green 8 Dark green 9 Dark green to very dark green 10 Very dark green

7	Fruit: conspicuousness of veining	1 Inconspicuous or very weakly conspicuous 2 Weak 3 Medium 4 Strong 5 Very strong
8	Fruit: width of stripes	1 Very narrow 3 Narrow 5 Medium 7 Broad 9 Very broad
9	Fruit: conspicuousness of stripes	1 Inconspicuous or very weakly conspicuous 2 Weak 3 Medium 4 Strong 5 Very strong
10	Fruit: thickness of pericarp	1 Very thin 3 Thin 5 Medium 7 Thick 9 Very thick
11	Fruit: flesh colour	1 White 2 Yellow 3 Orange 4 Pink 5 Pinkish red 6 Red 7 Dark red
12	Seed: ground colour of testa	1 White 2 Cream 3 Green 4 Red 5 Red brown 6 Brown 7 Black
13	Seed: over colour of testa	1 Absent 2 Present

* As per ECPGR (2008)

APPENDIX III

Standard week wise weather parameters during cropping period

(December 2015 to April 2016)

Standard week	Temperature (°C)		Relative humidity (%)	Rainfall (mm)	Evaporation (mm)
	Maximum	Minimum			
52	32.2	22.9	92.8	0.0	3.7
1	32.4	21.8	91.9	0.0	3.0
2	32.4	22.6	93.0	0.0	3.5
3	31.7	22.1	90.4	0.0	3.4
4	32.8	24.2	92.9	0.4	3.9
5	32.2	21.7	92.4	0.0	3.4
6	32.5	22.8	94.6	41.8	4.0
7	32.7	23.9	92.1	1.0	3.7
8	33.7	23.7	91.1	65.4	4.8
9	33.9	23.5	90.1	0.0	4.3
10	33.7	23.3	90.9	61.2	4.3
11	35.1	24.8	89.1	0.0	5.0
12	35.1	26.2	90.0	0.0	5.4
13	34.5	25.1	91.1	0.0	5.0
14	35.2	26.6	90.6	0.8	5.0
15	35.4	26.3	91.9	0.9	4.8
16	35.5	26.7	92.7	17.1	4.6
17	35.2	27.0	88.6	0.0	5.0

APPENDIX IV

FERTIGATION SCHEDULE FOR PRECISION FARMING IN WATERMELON

30 Split – 90 days

Sl. No.	Days of Fertigation	Fertiliser to be applied (Water Soluble)	Quantity	
			kg ha^{-1}	200 m^2 (g)
	Basal Dose P (kg/ha)		25.00	500
1	3rd Day after planting	19:19:19	4.30	88.00
		13:0:45	3.70	76.00
		Urea	3.25	68.00
		12:61:0	0.15	2.40
2	6th Day after planting	19:19:19	4.30	88.00
		13:0:45	3.70	76.00
		Urea	3.25	68.00
		12:61:0	0.15	2.40
3	9th Day after planting	19:19:19	4.30	88.00
		13:0:45	3.70	76.00
		Urea	3.25	68.00
		12:61:0	0.15	2.40
4	12th Day after planting	19:19:19	4.30	88.00
		13:0:45	3.70	76.00
		Urea	3.25	68.00
		12:61:0	0.15	2.40
5	15th Day after planting	19:19:19	4.30	88.00
		13:0:45	3.70	76.00
		Urea	3.25	68.00
		12:61:0	0.15	2.40
6	18th Day after planting	19:19:19	4.30	88.00
		13:0:45	3.70	76.00
		Urea	3.25	68.00
		12:61:0	0.15	2.40
7	21st Day after planting	19:19:19	2.20	44.00
		13:0:45	8.00	160.00
		Urea	1.40	28.00
		12:61:0	0.70	16.00
8	24th Day after planting	19:19:19	2.20	44.00
		13:0:45	8.00	160.00
		Urea	1.40	28.00
		12:61:0	0.70	16.00
9	27th Day after planting	19:19:19	2.20	44.00
		13:0:45	8.00	160.00
		Urea	1.40	28.00
		12:61:0	0.70	16.00
10	30st Day after planting	19:19:19	2.20	44.00
		13:0:45	8.00	160.00
		Urea	1.40	28.00
		12:61:0	0.70	16.00

APPENDIX IV Continued

11	33rd Day after planting	19:19:19	2.20	44.00
		13:0:45	8.00	160.00
		Urea	1.40	28.00
		12:61:0	0.70	16.00
12	36th Day after planting	19:19:19	2.20	44.00
		13:0:45	8.00	160.00
		Urea	1.40	28.00
		12:61:0	0.70	16.00
13	39th Day after planting	19:19:19	2.20	44.00
		13:0:45	8.00	160.00
		Urea	1.40	28.00
		12:61:0	0.70	16.00
14	42nd Day after planting	19:19:19	2.20	44.00
		13:0:45	8.00	160.00
		Urea	1.40	28.00
		12:61:0	0.70	16.00
15	45th Day after planting	19:19:19	2.20	44.00
		13:0:45	8.00	160.00
		Urea	1.40	28.00
		12:61:0	0.70	16.00
16	48th Day after planting	19:19:19	2.20	44.00
		13:0:45	8.00	160.00
		Urea	1.40	28.00
		12:61:0	0.70	16.00
17	51st Day after planting	19:19:19	2.20	44.00
		13:0:45	8.00	160.00
		Urea	1.40	28.00
		12:61:0	0.70	16.00
18	54th Day after planting	19:19:19	2.20	44.00
		13:0:45	8.00	160.00
		Urea	1.40	28.00
		12:61:0	0.70	16.00
19	57th Day after planting	19:19:19	2.20	44.00
		13:0:45	8.00	160.00
		Urea	1.40	28.00
		12:61:0	0.70	16.00
20	60th Day after planting	19:19:19	2.20	44.00
		13:0:45	8.00	160.00
		Urea	1.40	28.00
		12:61:0	0.70	16.00
21	63th Day after planting	19:19:19	2.20	44.00
		13:0:45	8.00	160.00
		Urea	1.40	28.00
		12:61:0	0.70	16.00
22	66st Day after planting	19:19:19	2.20	44.00
		13:0:45	8.00	160.00

		Urea	1.40	28.00
		12:61:0	0.70	16.00
23	69th Day after planting	19:19:19	2.20	44.00
		13:0:45	8.00	160.00
		Urea	1.40	28.00
		12:61:0	0.70	16.00
24	72th Day after planting	19:19:19	2.20	44.00
		13:0:45	8.00	160.00
		Urea	1.40	28.00
		12:61:0	0.70	16.00
25	75th Day after planting	19:19:19	2.20	44.00
		13:0:45	8.00	160.00
		Urea	1.40	28.00
		12:61:0	0.70	16.00
26	78th Day after planting	19:19:19	2.20	44.00
		13:0:45	8.00	160.00
		Urea	1.40	28.00
		12:61:0	0.70	16.00
27	81st Day after planting	19:19:19	2.20	44.00
		13:0:45	8.00	160.00
		Urea	1.40	28.00
		12:61:0	0.70	16.00
28	84th Day after planting	19:19:19	2.20	44.00
		13:0:45	8.00	160.00
		Urea	1.40	28.00
		12:61:0	0.70	16.00
29	87th Day after planting	19:19:19	2.20	44.00
		13:0:45	8.00	160.00
		Urea	1.40	28.00
		12:61:0	0.70	16.00
30	90th Day after planting	19:19:19	2.20	44.00
		13:0:45	8.00	160.00
		Urea	1.40	28.00
		12:61:0	0.70	16.00

* 40 per cent of recommended dose of fertigation for cucumber