# PRECISION FARMING TECHNIQUES FOR QUALITY SEED PRODUCTION IN OKRA (*Abelmoschus esculentus* (L.) Moench)


**By**

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**(2017-11-091)**

**DEPARTMENT OF SEED SCIENCE AND TECHNOLOGY**

**COLLEGE OF HORTICULTURE**

**VELLANIKKARA, THRISSUR – 680656**

**KERALA, INDIA**



**2019**

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**THESIS**

***Submitted in partial fulfillment of the***

***requirement for the degree of***

**Master of Science in Agriculture**

**Faculty of Agriculture**

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**DEPARTMENT OF SEED SCIENCE AND TECHNOLOGY**

**COLLEGE OF HORTICULTURE**

**VELLANIKKARA, THRISSUR- 680656**

**KERALA, INDIA**

**2019**

# DECLARATION

I, hereby declare that this thesis entitled **"Precision farming techniques for quality seed production in okra (*Abelmoschus esculentus* (L.) Moench)"** 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.

**Vellanikkara** **Rosna s**

**Date: 18-10-2019** **2017-11-091**

# CERTIFICATE

Certified that this thesis entitled **"Precision farming techniques for quality seed production in okra (*Abelmoschus esculentus* (L.) Moench)"** is a bonafide record of research work done independently by **Ms. Rosna S (2017-11-091)** 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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# CERTIFICATE

We, the undersigned members of the advisory committee of **Ms. Rosna S (2017-11-091)**, a candidate for the degree of **Master of Science in Agriculture** with major field in Seed Science and Technology, agree that this thesis entitled **"Precision farming techniques for quality seed production in okra (*Abelmoschus esculentus* (L.) Moench)"** may be submitted by **Ms. Rosna S** in partial fulfillment of the requirement for the degree.

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**EXTERNAL EXAMINER**

***Acknowledgement***

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**Rosna S**

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# Introduction

# INTRODUCTION

Vegetables are important part of human diet due to higher nutrition content, higher yield, shorter duration and economic feasibility. Okra, *Abelmoschus esculentus* (L.) Moench also known as lady's finger or bhendi belonging to family Malvaceae, is a native to Africa and grown in tropical and subtropical parts of the world. India is one the largest okra producer in the world with the productivity of 11.9 t/ha (National Horticulture Board, 2017). Although okra is an important warm season vegetable, its adaptability to a wide range of soil and climatic conditions has made possible its cultivation year round. The crop is grown extensively round the year for its immature fruits. Okra has been called "a perfect villager's vegetable" because of its robust nature, dietary fibre and distinct seed protein balance of both lysine and tryptophan amino acids. Okra seeds contain 20 to 40% oil rich in linoleic acid (47.4%) and polyunsaturated fatty acids essential for human nutrition.

The concept of agriculture is shifting from maximum yield to avoid wastage of water and increasing water use efficiency in agriculture. Today's trend is maximizing the production per unit drop of water. Hence for present day context, lot of importance is given to increase the vegetable production by improving the irrigation practices followed to sustain the level of production. Micro irrigation system proved its superiority over other conventional irrigation methods. Micro-irrigation helps to save water as well as to improve water use efficiency. Drip irrigation method reduces the water consumption by 30 to 70 per cent and increase the productivity by 20 to 80 per cent. Fertigation is the technique of supplying dissolved fertilizer to crops through an irrigation system. This method saves labour, reduces soil compaction in the field, thereby enhancing productivity. Fertigation allows nutrient placement directly into the plant root zone during critical periods in the required dose. By introducing drip fertigation, yield potential of vegetable crops can be increased by three fold with the same quantity of water. Drip irrigation becomes more efficient when combined with plastic mulching which in addition helps in water conservation and weed control. All these emphasize the need for precision farming techniques which ensure water conservation, improvement in productivity and resource use efficiency.

Okra is in great demand throughout the year in Kerala. The practice of cultivating the crop employing open precision farming technique is now gaining momentum among farmers in the state. This has also led to a quantum increase in area under the crop accompanied with a proportional increase in seed demand. The seed production centers under public sector in Kerala which usually raise the seed crop in open fields are unable to meet high demand for quality seeds. Okra responds positively to irrigation and fertilizer application. The impact of precision farming techniques on seed yield in okra needs to be explored. Standardization of fertigation level *i.e.,* quantity of fertilizers to be applied through fertigation and fertigation interval, in open field precision farming in okra will be useful for vegetable seed producers to enhance the seed yield of the crop.

An increased seed yield alone would not benefit seed growers. Retaining its viability for a long time period is also very important. A seed should be physically and genetically pure, physiologically sound and pathologically clean. The rapid loss of seed vigour as well as viability in storage leads to poor crop establishment in field. Hence, maintaining the quality of seed even after harvest to next sowing season is an important segment of seed industry.

The seed has to be stored safely to maintain its quality which mainly includes its viability and vigour. Protection to seeds from various fungal pathogen and metabolic changes occurring in seed during storage can be overcome by polymer treatment along with plant protection chemicals. Polymer coating is easy to apply, non-toxic as well as easily diffusible. It helps in uniform and proper germination of seeds and also maintains good plant population in field. Biodegradable polymer coating in seed will ensure dust free handling, maintains viability and vigour as well as eco-friendly. A polymer film acts as a physical barrier, which reduces the leaching of inhibitors from the seed coverings and the diffusion of oxygen into embryo (Vanagamudi *et al.,* 2003).

Present study was therefore planned with the following objectives:

- To standardize the levels of irrigation and fertigation for okra under precision farming
- To assess the impact of precision farming techniques on growth and seed yield of okra
- To study the impact of  synthetic polymer coating on longevity of okra seed

# Review of literature

# 2. REVIEW OF LITERATURE

Precision farming techniques are one of the major approaches for realizing maximum yield potential in crops. It provides a new solution to solve today's environmental issues and to increase the productivity. Various precision farming practices are available for the proper management of water, nutrients and weeds. Among these, drip irrigation, fertigation and mulching has a key role for maximizing productivity in vegetables. But role of these factors in quality seed production needs further refinement

Considering the above, the present study 'Precision farming techniques for quality seed production in okra' was formulated. Impact of different precision farming practices are reviewed here with more emphasis on levels of irrigation and fertigation.

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**2.1. Precision farming techniques**

'Precision farming' or 'Precision Agriculture (PA)' is a long term, site specific farming system which is designed to improve production efficiency, profitability and productivity with less impact on environment (US House of Representatives, 1997). Major tools used in PF agriculture are Global Positioning System (GPS), Geographical Information System (GIS), Variable Rate Technologies (VRT) etc. (Tran and Nguyen, 2006).

Precision farming is also known as Site Specific Crop Management system (SSCM). According to NRC (2007), SSCM promotes variable management practices with in a field according to soil conditions. PA aims at increasing productivity and decreasing production cost and environmental impacts (Maheshwari *et al.,* 2008).

**2.2. Drip irrigation and irrigation levels**

Increasing the crop yield by 25 to 30 per cent and reducing the water loss by 50 to 60 per cent can be achieved by drip irrigation when compared to other conventional irrigation methods (Yadav *et al.,*2016).

Sharma *et al.,* (2017) reported that drip irrigation is superior over conventional flood irrigation in chilli. They also reported that by adopting drip irrigation, 90-95 per cent irrigation efficiency can be achieved.

### 2.2.1. Effect of drip irrigation and irrigation levels on growth and yield of okra

A study was conducted by Bahadur *et al.,* (2009) with 4 levels of furrow irrigation (irrigation scheduled at 4, 7, 10 and 12 days intervals), and 2 levels of mulch (pea straw mulch at 12.5 tonnes/ha and no mulch). The irrigation treatments were kept in main plots and mulch and no mulch in subplots. Results on physiological parameters indicated that furrow irrigation at 4-day interval had maximum leaf water potential (–0.91 MPa), relative water content (83 per cent), photosynthetic rate (14.1 µmole $CO_2/m^2/s$), stomatal conductance (351.9 mmole $H_2O/m^2/s$) and lower T leaf (39.2°C) than the other irrigation treatment. of Okra. An improvement in leaf water potential (–1.58 MPa), soil water content (13 per cent), relative water content (78.7 per cent), photosynthetic rate (11.57 µmole $CO_2/m^2/s$) and stomatal conductance (279.5 mmole/$m^2$/s), and a significant reduction in CCI were recorded under pea-straw mulch. Pea-straw mulch significantly improves vegetative as well as fruit characters over non-mulched condition. Pea straw mulch also improved plant physiological parameters as well as soil water content. Higher water-use efficiency of 455.72 kg/ha/cm can be achieved under irrigation at 10-days interval along with pea-straw mulch.

Jayapiratha *et al.,* (2010) evaluated the yield parameters of okra which is under drip irrigation in red yellow latisol soil. Drip irrigation was given daily for 15 and 30 minutes and basin irrigation was given at three days interval which served as control. The results revealed that vegetative, flowering as well as fruit characters were significantly higher in drip irrigation when compared to plants under basin irrigation. The crop had a maximum water use efficiency of 705.2 kg/ha/cm at 15 minutes drip irrigation. Drip irrigation system saves water up to 60 per cent when compared to basin irrigation. The experiment revealed that drip irrigation with duration of 15 minutes daily with a discharge rate of 3.25 L/ha could be recommended for achieving significant yield and to increase water use efficiency in okra. The percentage of yield improvement in cotton by 40 per cent was reported under drip irrigation by Patil and Sivanappan in 2004.

Effect of different irrigation method along with different mulches on yield parameters of okra was studied by Birbal *et al.,* (2013) and reported that drip irrigation along with black plastic mulch produces highest yield of 83.92 q/ha. Effect of different irrigation method on yield attributes of okra was experimentally studied by Thirumalaikumar *et al.,* (2014). The results concluded that average fruit yield under drip irrigation (22.40 t/ha) was significantly superior sprinkler, surface as well as sub-surface irrigation methods.

Danso *et al.,* (2015) studied the effect of drip irrigation on yield attributes of okra. The experiment includes three irrigation treatments, $T_1$: 15 minutes irrigation, $T_2$: 30 minutes irrigation and $T_3$: basin irrigation twice in a week. The results indicated that the percentage of yield increase was 28.12 per cent under $T_1$ and 26 per cent under $T_2$ when compared to $T_3$. Narayanankutty *et al.,* (2016) evaluated the effect of mulching and fertigation in okra and recommended that if water is a limiting factor, irrigation at 0.60 ET along with mulching with 75 per cent of recommended dose of fertilizer was sufficient to achieve a yield of 23.87 tonnes/ha. A higher level of irrigation at 0.80 ET along with mulching and 125% of recommended dose of fertilizer was recommended for achieving a significantly higher yield of 32.44 tonnes/ha, at a condition of sufficient water availability. Sharma and Kaushal (2016) reported that drip fertigation in okra saved 20-60 per cent of water, 15-30 percent fertilizer and increased yield by 13-76 per cent and improved water use efficiency by 35.5-50.8 per cent when compared to basin irrigation. The percentage of yield improvement by 40 per cent was reported under drip irrigation by Patil and Tiwari in 2018.

### 2.2.2. Effect of drip irrigation and irrigation levels on growth and yield of other vegetables

Veeranna *et al.,* (2001) evaluated the effects of broadcast applications and fertigation of normal and water soluble fertilizers in chilli at three different rates through drip and furrow irrigation. Fertilizer use efficiency was highest for drip fertigation with 80 per cent water soluble fertilizer (WSF) which resulted in highest yield increase of 31 per cent with 20 per cent of saving in fertilizers. Antony and Singandhupe (2007) evaluated the effect of different levels of irrigation on vegetative and fruit characters of *Capsicum annum* L. var. California Wonder and found that all the vegetative as well as fruit characters were significantly superior in drip irrigation treatments when compared to basin irrigation.

Simsek *et al.,* (2005) conducted a study to evaluate the effects of drip irrigation on yield characters of *Cucumbis sativus* L. and found that maximum fruit yield of 76.65 & 68.13 t/ha was achieved at 100 per cent irrigation level. Kuscu *et al.,* (2009) reported that the highest yields of tomato (87.5 t/ha), pepper (59.2 t/ha), greenbean (7.6 t/ha) and eggplant (46.5t/ha) was obtained under drip irrigation at 100 and 80 per cent EP. Gupta *et al.,* (2009) evaluated the effect of different levels of drip irrigation and fertigation on Capsicum var. Nishat-1 and observed that combination of drip irrigation at 80 per cent ET and fertigation with 80 per cent recommended NPK achieved maximum fruit yield (366.48 q/ha).

Dunage *et al.,* (2010) conducted an experiment in tomato under protected cultivation to study the different levels of irrigation *i.e.,* 60, 80, 100 and 120. Irrigation was given daily based on pan evaporation data. The water use efficiency was high for irrigation at 60 per cent EP (11.90 t ha/cm) and low for irrigation under 120 per cent EP (7.45 t ha/cm). The study revealed that 60 per cent EP drip irrigation could be recommended in water scarce areas achieve an increased net return.

Popale *et al.,* (2012) evaluated the percentage of water saving in cabbage at different levels of drip irrigation and reported that highest water saving of 75.54 per cent at 0.4 CPE drip irrigation when compared to 0.6 and 0.8 CPE. Alaoui *et al.,* (2015) evaluated the effects of different levels of irrigation on yield parameters of tomatoes (*Lycopersicon esculentum* ) and concluded that irrigation has a major role in improving fruit yield as well as size.

### 2.3. Fertigation and fertigation levels

Fertigation refers to the practice of supplying the crops with fertilizers along with irrigation water. The amount of fertilizer saving through fertigation was 25 per cent (Vaishnava *et al.,* 1995). It improves the nutrient use efficiency of the crop as well as resource use efficiency (Jat *et al.,* 2011).

#### 2.3.1. Effect of fertigation and fertigation levels on growth and yield of okra

Patel and Rajput (2005) reported that fertigation with 60 per cent of recommended dose of fertilizers reduces 40 per cent fertilizer use and 16 per cent yield increase when compared broadcasting method of fertilizer application when 100 per cent recommended dose of fertilizers was applied. Rajput and Patel (2006) reported drip irrigation in onion has an important role in improving the fruit yield when compared furrow irrigation. The study revealed that application of 60 per cent RDN through drip fertigation recorded highest pod yield when compared to 80 and 100 per cent RDN, which indicates a nitrogen saving of 40 per cent. Rekha and Mahavishnan (2008) reported the water and fertilizer saving by 40-70 and 30-50 per cent, respectively through drip fertigation in okra

Similarly, fertigation of 75 per cent RDN through subsurface biwall drip system recorded higher pods per plant, pod weight and pod yield in okra over 100 per cent RDN applied by band placement + furrow irrigation, indicates saving 25 per cent nitrogen (Chaudhari *et al.,* 1997). Satpute *et al.,* (2017) reported that drip fertigation with 100 per cent nitrogen in onion recorded higher number of pods per plant (21), pod yield per plant (129.3 g) and yield (17.3 t/ha) over furrow irrigation + band placement of 100 per cent N.

### 2.3.2. Effect of fertilizer application on seed yield of okra

Significant increase in seed yield and seed germination can be achieved in okra by increasing the nitrogen dose from 150 to 450 kg/ha. But increasing N rates did not have any positive impact on pod size, number of seeds per pod and seed size ( Mohammadi *et al.,* 2016).

Response of okra to N application varies considerably not only according to genotype, but also in relation to soil and climatic conditions (Majanbu *et al.,*1985; Lenka *et al.,* 1989; and Naik and Srinivas, 2016).

### 2.3.3. Effect of fertigation and fertigation levels on growth and yield of other vegetables

Goyal *et al.,* (1988) conducted an experiment to evaluate the effect of different fertigation rates (13.8, 8.3 and 4.1 g of N per plant in 10 weekly applications), fertilizer application (6.9 g of N per plant on day 6 and 56) and silver coated plastic mulch on root distribution of sweet pepper. The results revealed that in all fertigation treatments under mulching, the root values were significantly higher for 0-11 cm soil depth than values for other soil depths. More than 80 per cent of the roots were within 0-22 cm soil depth in all plots where this depth corresponded to wetting zone under a dripper. Kaniszewski *et al.,* (1999) studied the effect of drip fertigation on yield parameters of celeriac and reported that yield, leaf area, dry matter production and nitrate-N and total N contents was highest for the drip irrigation when compared to basin irrigation.

The effect of NPK dosage (0, 50 and 100 per cent ) applied through fertigation with irrigation waters with EC 0.7 and 2.6 dS/m was studied on the soil-plant system of a pepper crop and the result indicated that crop showed a positive response to an increase of NPK concentration solution (Contreras *et al.,* 2004).

Murthy *et al.,* (2009) conducted experiment with capsicum *cv*. California Wonder and observed that N fertigation increased fruit yield, plant height, number of branches and fruit size. The highest fruit yield (111.3q per hectare) was obtained at 150 kg N per hectare. Khan *et al.,* (2010) evaluated the biometric, flower and fruit characters of capsicum under different rates of nitrogen and phosphorous fertigation and found that 100 kg N + 60 kg P/ha recorded maximum plant height and highest yield. Roy *et al.,* conducted a study to evaluate the different doses of nitrogen and phosphorous on fruit and yield attributes of capsicum and concluded that the maximum significant yield was found in the treatment combination of 150 kg N and 30 kg P /ha.

**2.4. Polythene mulch**

The word mulch derived from the German word "molsch" means soft to decay (Jacks *et al.,* 1955). Mulching reduces the rate of water loss from soil surface and facilitates moisture distribution, hence influencing irrigation schedule, earlier production (Call and Courter, 1989), improved yield (Jensen, 1990) and reduced insect and disease problems (Greenough, 1990). Use of different types of mulches maintain moisture, soil temperature, control weeds and finally increase the yield. Polyethylene film mulch is superior over other mulching materials for production of vegetables and it increase the productivity from 25-70 per cent (Lal Bhardwaj*,* 2013).

**2.4.1.Effect of polythene mulch on growth and yield of okra**

Tiwari *et al.,* (1998) compared the effect of drip irrigation with furrow irrigation either alone or in conjunction with black plastic mulch for growth and yield characters in okra and found that highest yield of (14.51 t/ha) was obtained in drip irrigation along with black plastic mulch.

### 2.4.2. Effect of polythene mulch on growth and yield of other vegetables

Hassan *et al.,* (1994) and Yamaguchi *et al.,* (1996) revealed that mulching and shading treatments improved vegetative characters of chilli seedlings. Lourduraj *et al.,* (1996) compared the tomato plants grown in black mulch, organic mulch and no mulch and he obtained highest plant height (81.5 cm) and number of laterals (8.6 per plant with the application of black LLDPE mulch when compared to others. Pandey *et al.,* 2005 reported that mulched plants exibit uniform growth and maturity when compared to non-mulched plants.

### 2.5. Effect of polymer coating on storability and quality of okra seeds

The process of coating the seeds with different colours of polymers along with plant protectants and nutrients which improve the aesthetic value of the seed is referred as polymer coating (TNAU agritech portal). Polymer film coating helps to further improve the seed storage potential. It prolongs the shelf life of seed and retains the germination health during storage (Vanagamudi *et al.,* 2010).

Hydroprimed okra seeds were subjected to polymer coating along with a combination of imidachloprid and stored for 12 months. The interaction effects due to the treatment hydropriming + polymer + imidachloprid recorded higher germination per cent at twelfth month of storage (Thakur, 2016). Polykote(10ml) + carbendazim-mancozeb (2g) + bifenthrin (0.1%) were found to be superior treatment with respect to germination (%), seedling shoot and root length, vigour indices and dehydrogenase activity (Reshma , 2018).

### 2.6. Effect of polymer coating on storability and quality of other crops

Anahosur and Bidari (1973) reported that soybean seeds treated with vitavax (3 g/kg) and thiram (2 g/kg ) prevents rotting of seeds in storage. Mote *et al.,* (1995) observed that seeds of sorghum treated with imidacloprid @ 2 per cent showed higher germination percentage (84.00), root length (15.0cm) and shoot length (6.73cm) as compared to control (78.00 per cent, 12 cm and 5.08 cm, respectively). Joshi *et al.,* (1998) studied that seeds of sorghum treated with captan (3g/kg) and vitavax (3g/kg) showed higher germination percentage even after six months of storage. Sorghum seeds treated with hitron @ 5 g/ kg showed minimum fungal infestation (19 per cent) after eight months of storage (Malarkodi and Dharamalingam, 1999).

Vanangamudi *et al.,* (2003) reported that maize seeds treated with polykote (synthetic polymer) along with fungicides and insecticides mainted higher germination of 98 per cent and higher vigour index (82.91). Similarly, Wilson and Geneve in 2004 reported that maize seeds treated with polykote along with fungicides and insecticides maintained higher germination of 98.50 per cent, less abnormal seedlings (1.50 per cent ) and low EC of seed leachate values (41.60 µmhos/g). Larissa *et al.,* (2004) reported that soybean seeds treated with polykote @ 3.00g/ kg of seed + fungicide + insecticide showed higher germination of 89.00 per cent when compared to control which was only 73.00 even after two months of storage. Seeds slurry coating with polykote @ 3 g, carbendazim @ 2g, imidacloprid @ 1 ml and nutrients such as DAP @ 30g and micronutrient mixture @ 19.7g/ kg were able to increase early emergence, establishment of seedlings with higher vigour, growth and yield of maize (John *et al.,* 2005). Polymer along with seed protectants treatments in soybean showed superiority in all seed quality attributes during storage (Baig, 2005). Rajeswari and Meena Kumarai (2009) reported that significant increase in germination (91 per cent), seed vigour (2630) with nil fungal colonies in thiram + carbendazim seed treatment followed by *T. viride* (91 per cent, 2601 and 5 per cent) over untreated seeds (77 per cent, 2470 and 20 per cent), respectively in soybean cv. JS -335.

Kunkur *et al.,* (2010) reported that seeds treated with polymer @ 5 g/kg along with fungicide and insecticide improved all seed quality attributes in cotton. Reddy (2012) reported that egg plant seeds treated with delsan (1.00 ml per kg), thiram (2.50 g per kg) and captan (2.50 g per kg) maintained higher germination percentage up to

21 months of storage. Studies by Braccini *et al.,* (2012) revealed that storage under laboratory natural conditions caused reduction in protein, lipid and polyunsaturated fatty acids content and promoted haxanal production in soybean. Similarly, soybean seeds treated with fungicides and/or insecticides reduced seed deterioration during the storage period of six months than untreated seeds (Adibisi *et al.,* 2013). Rathinavel (2015) observed that cotton seeds treated with polymer @ 5 g/kg along with thiram @ 1.50 g/kg of seed and imidacloprid @ 7.50 g/kg recorded higher germination percentage up to nine months of storage. Seed coating with polykote @ 3 ml/kg + vitavax 200 @ 2ml/kg of seed with storage in polythene bag (400 gauge) was better to maintain seed viability and longevity during cotton seed storage up to ten months.

# Materials and Methods

# 3. MATERIALS AND METHODS

An investigation entitled 'Precision farming techniques for quality seed production in okra (*Abelmoschus esculentus* L.)' was conducted to standardize the irrigation and fertigation levels and to assess the impact of precision farming techniques on the growth and seed yield of okra. The research programme was conducted in two experiments *viz.,* i) Standardization of precision farming techniques and ii) Seed quality and storage studies. The materials used and methods adopted for first experiment is briefly described below:

## 3.1. MATERIALS

### 3.1.1. Experimental site

The field investigation was carried out at the Centre for High-tech Horticulture and Precision Farming, Vellanikkara. The site is situated at 76°26' E longitude and 10°54'N latitude at an altitude of 22.5 m above MSL and the storage experiment was conducted in Department of Seed Science and Technology, College of Horticulture, Vellanikkara.

### 3.1.2. Season

The field experiment was conducted during January to April 2019 and the storage experiment was conducted during May 2018 to May 2019.

### 3.1.3. Weather condition

The experiment area is bestowed with tropical humid climate. The detailed weather data during the cropping period are depicted in table 1.

**Plate 1: Land preparation**


**Plate 2: Laying of polythene mulch**

### 3.1.4. Soil

Soil of the experimental site was sandy loam. Soil is strongly acidic, medium in organic carbon per cent and available potassium and high in available phosphorous. Physical and chemical properties of the soil are described in table 2.

**Table 1. Mean maximum and mean minimum temperature ($^0$C), relative humidity (%) and rainfall (mm) during the experiment period (January – April, 2019)**

| | MONTHLY DATA | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Max (°C)** | **Min (°C)** | **Mean RH (%)** | **Rainfall (mm)** | **Rainy days** | **Mean evp (mm)** | **Sunshine hours** | **Mean SS hrs** | **Wind speed (kmph)** |
| Jan | 32.9 | 20.4 | 55 | 0.0 | 0 | 4.7 | 261.4 | 8.4 | 6.5 |
| Feb | 35.3 | 23.4 | 59 | 0.0 | 0 | 5.1 | 244.4 | 8.7 | 5.1 |
| March | 36.7 | 24.8 | 65 | 0.0 | 0 | 4.8 | 265.9 | 8.6 | 2.9 |
| April | 34.6 | 25.5 | 70 | 76.4 | 3 | 4.7 | 240.7 | 8.0 | 2.3 |

**Table 2: Physical and chemical properties of soil at experimental site**

| **Parameters** | **Sample** | |
|---|---|---|
| | **Quantity** | **Status** |
| Ph | 4.9 | Very strongly acidic |
| Electrical conductivity (dS/m) | 0.08 | Normal |
| Organic carbon (%) | 1.13 | Medium |
| Available Phosphorous (Kg/ha) | 46.87 | High |
| Available Potassium (Kg/ha) | 210.22 | Medium |

### 3.1.5. Source of seed material

Seeds of okra variety Arka Anamika obtained from the Centre for High-tech Horticulture and Precision Farming, Vellanikkara, were used to initiate the field experiment intended to assess the impact of precision farming techniques on crop growth and seed yield of okra.

### 3.2. Experimental details

The study comprised of a field experiment and seed storage experiment as detailed below:

#### 3.2.1. Experiment 1: Precision farming techniques

An experiment was laid out in Factorial Randomized Block Design with six treatments and a control in the field facility of Centre for High-tech Horticulture and Precision Farming, Vellanikkara. A spacing of 1.0m between rows and 0.5m between plants was ensured in each sub-plot of size 3m x 3m to accommodate 36 plants. The seeds were soaked in water overnight and sown in the ridges in the last week of January, 2019.

##### 3.2.1.1. Treatment details

The treatments consisted of combination of different irrigation levels and fertigation

1. Irrigation (drip irrigation was given daily based on PAN evaporation data )

- $I_1$- Drip irrigation at 75% EP
- $I_2$- Drip irrigation at 100% EP

2. Fertigation

   Fertigation was given daily twice in a week. Fertilizer doses were calculated according to soil test data and also based on the POP recommended dose of fertilizer (RDF) *i.e.* 110:35:70 kg NPK/ ha.

3. $F_1$: 75% RDF
4. $F_2$:100% RDF

- $F_3$:125% RDF

Control – POP + basin irrigation

**Treatment combinations**: 6+1=7

$I_1F_1$, $I_1F_2$, $I_1F_3$, $I_2F_1$, $I_2F_2$, $I_2F_3$ + Control

### 3.2.3. Field preparation and planting

Field was cleaned and deep ploughing was done with disc plough. Since soil pH was in acidic range, lime was applied at rate of 500 kg/ha. Farm yard manure was applied @ 20 tonnes/ha. Raised beds of 18m length and 0.5m width were taken at spacing of 0.5 m. All the beds except the control were mulched with 30 micron silver black polythene sheet. In mulched beds holes were punched at a spacing of 0.5m for sowing okra seeds. Except for the control, each bed was provided with inline drippers (2 Lph), water for which was supplied from tanks kept on a raised platform. The actual discharge/hour was recorded. Irrigation was given daily based on EP data for the day. Fertigation was started at two-leaf stage and was given at three days interval. For control plot, flood irrigation was given twice in a week.

### 3.2.4. Fertilizers

Fertilizers were given based on already tested soil data. Physical and chemical properties of soil are given in table 2. Even though the status of P in soil was high, 25 per cent of RDF was applied basal as single super phosphate. The other major nutrients N and K were supplied as potassium nitrate and urea through fertigation. The actual fertilizer quantity for the three fertigation levels *viz.,* $F_1$, $F_2$ and $F_3$ was calculated and the total quantity for each level were divided into 30 doses which covered the total duration of the crop. The NPK doses for each fertilizer level is given in table 3. For control plot, 100 per cent RDF based on the soil test data was applied and this was applied as per POP, KAU.

**Plate 3: Fertigation tanks**

**Table 3: Schedule of nutrient applied through fertigation**

| Levels of nutrients | N:P:K doses (Kg/ha) | Quantity of fertilizer applied/ bed ($9m^2$) | | Application interval/ schedule |
|---|---|---|---|---|
| | | Urea (g) | KNO3 (g) | 3 days |
| **F1 (75% RDF)** | 69.3:0:37.27 | 115.00 | 80.00 | |
| **F2 (100% RDF)** | 92.4:0:49.7 | 152.00 | 100.00 | 20 per cent – Establishment (6 doses)<br>40 per cent – Vegetative stage (12 doses)<br>40 per cent – Flowering stage (12 doses)<br>Total – 30 doses |
| **F3 (125% RDF)** | 115.5:0:62.12 | 191.00 | 124.00 | |

### 3.2.5. Harvesting

Harvest of mature fruits for seed extraction was commenced on75 DAS and was repeated on alternate days until the mature fruits in all plots were harvested. Stage of seed harvesting was decided by the drying and cracking of fruits along the ridges.

## 3.3. Observations recorded

### 3.3.1. Biometric observations

Five plants per treatment per replication were tagged and the following observations were recorded:

#### 3.3.1.1. Plant height (cm)

Height of the plant was measured from the base to the terminal bud in all the observation plants at monthly intervals and the average was worked out and expressed in cm.

#### 3.3.1.2. Height of first bearing node (cm)

The height of node at which the first fruit was formed was measured from the ground level in all observational plants and the average was worked out and expressed in cm.

#### 3.3.1.3. Leaf area index (LAI)

Area of third leaf produced by plant was recorded using LI leaf area meter and total number of leaves in a plant was observed. LAI was worked out with the formula suggested by Watson (1952)

**LAI= Leaf area / Land area* Total number of leaves**

LAI was calculated 30 and 60 DAS. As the crop was left to full maturity of fruits, all the leaves were shed by the $90^{th}$ day after sowing making it impossible to compute LAI.

#### 3.3.1.4. Days to 50 percent flowering

In each plot, plants were observed for first flower formation and the date on which half the population of plants flowered was taken as the date to 50 per cent flowering.

#### 3.3.1.5. Fruit set (%)

From the total number of flowers bloomed and the number of fruits formed, and fruit set percentage was calculated for the observational plants and the average worked out.

**Plate 4: Growth of okra at 45 DAS**

### 3.3.2. Yield observations

#### 3.3.2.1. Length of the fruit (cm)

Length of five fruits from the tagged plants was measured. Fruit length was measured as the distance between the proximal end (stalk end) and distal end and the average fruit length expressed in centimeter.

#### 3.3.2.2. Girth of the fruit (cm)

The same fruits used for measuring the length were used for finding the girth. Measurement was effected by winding a thread around individual fruits. The average values were worked out and expressed in cm.

#### 3.3.2.3. Weight of mature fruit (g)

The weight of mature fruits obtained from the observational plants was recorded at each harvest. The total weight of the mature fruits per plant was worked out and the average calculated.

#### 3.3.2.4. Mature fruit yield per plant (g)

The weight of mature fruits obtained from the observational plants were recorded at each harvest and the total weight of fruits from the harvests was calculated and expressed as mature fruit yield plant.

#### 3.3.2.5. Total number of mature fruits harvested per plant

The total number of mature fruits harvested from the observation plants was calculated at the end of the cropping season and the average recorded.

### 3.3.3. Seed characters

#### 3.3.3.1 Number of seeds per fruit

Fifteen fruits were taken from the observational plants at random, the number of seeds were counted and the average worked out.

#### 3.3.3.2. Weight of seeds per fruit (g)

The fruits used to record the number of seeds per fruit were used for recording the weight of seeds per fruit.

#### 3.3.3.3. 100 seed weight (g)

Hundred seeds from each replication from each treatment were counted and weight recorded in gram

#### 3.3.3.4. Germination (%)

The germination test was conducted by adopting the sand method (Plate 8) prescribed by ISTA (1999). Three replicates of fifty seeds each were drawn from each replication of treatments (T1 to T7) and sown in trays containing sterilized sand. The test was conducted at 25±2°C temperature and 90±3 % relative humidity. The average number of normal seedlings produced on the 7th day of sowing to the total number of seeds sown was expressed as per cent.

#### 3.3.3.5. Hard seed (%)

Hard seeds were separated out from the seeds extracted from each pod based on their appearance (brown to black coloured seeds), counted and expressed in per cent hard seeds per pod.

### 3.3.6. Seedling shoot length (cm)

At the end of the germination test, ten normal seedlings from each replication of a treatment were randomly selected. Shoot length was measured from collar region of the seedling to the primary leaf base. The mean seedling shoot length was expressed in centimeter.

### 3.3.3.7. Seedling root length (cm)

Ten seedlings used for measuring the shoot length were used to measure the root length. The root length of each seedling was measured from collar region of the seedling to the tip of primary root. The mean root length was expressed in centimeter.

### 3.3.3.8. Vigour index I

The seedling vigour index was recorded by adopting the formula suggested by Abdul Baki and Anderson (1973) and expressed as whole number.

$$\text{Vigour index I} = \text{Germination (\%)} \times \text{Seedling length (cm)}$$

### 3.3.3.9. Seed moisture content (%)

The seed moisture content was determined through the low constant temperature method advocated by ISTA (1993). Two replicates of five grams of seeds (W2) from each replication of the treatment were taken and ground to a coarse powder using the grinding mill. A weighed airtight aluminum cup with a lid (W1) was used to hold the powdered material in hot air oven. The lid of aluminum cup was removed and the seed material was maintained at a temperature of 103±2°C. After a drying period of 17±1 hour, the samples were taken out of the oven and cooled the contents in desiccators for 30 minutes after replacing the lid over it. Each sample was weighed separately using an electronic weighing balance (W3). The moisture content present in the seed samples were computed as the following and average expressed as per cent.

$$\textbf{Moisture content (\%)} = W2 - W3 / W2 - W1 \times 100$$

Where, **W1**= Weight of the aluminum cup with lid

**W2**= Weight of the aluminum cup with lid + Weight of sample before drying

**W3**= Weight of the aluminum cup with lid + Weight of sample after drying

**3.3.3.10. 100 seed volume (ml)**

Seed volume was found out by immersing the seeds in water and noting the rise in water level from the initial level. 100 seeds from each treatment were used for the observation and the value expressed in ml.

**3.2.2. Experiment 2: Seed storage studies**

The study on 'Seed quality enhancement in okra with film coat', was undertaken at the Department of Seed Science and Technology, College of Horticulture, Vellanikkara, Kerala Agricultural University, Thrissur during the year 2018-2019 (May- April). The details of materials used and techniques utilized during the course of study are described below:

**3.2.2.1. Experimental materials**

Freshly harvested two month old seeds of okra variety Arka Anamika was procured from the Centre for High-tech Horticulture and Precision Farming at Vellanikkara, where the seeds were produced through precision farming techniques as per the recommended dose of fertilizer. Seeds were kept at a temperature of 18-20 $^{o}$C .The initial seed quality parameters were assessed before the start of study.

**3.2.2.2. Experimental details**

Seeds were treated separately with polykote (synthetic polymer) along with seed protectants at varying concentrations and packed.

#### 3.2.2.3. Treatment details

The experiment was conducted as a completely randomized design with three replications as per following treatments.

**Table 4: Seed storage treatments**

| | |
|---|---|
| **$T_1$** | Polykote (10ml) + carbendazim-mancozeb (2g) + bifenthrin (0.1%) per kg of seed |
| **$T_2$** | Polykote (10ml)+ *Trichoderma viridae* (4 g per kg of seed) |
| **$T_3$** | Polykote (5ml) + carbendazim-mancozeb (2g) + bifenthrin (0.1% ) per kg of seed |
| **$T_4$** | Polykote (5ml) + *Trichoderma viridae* (4 g per kg of seed ) |
| **$T_5$** | Untreated control |

Polykote – synthetic polymer; carbendazim-mancozeb - saaf

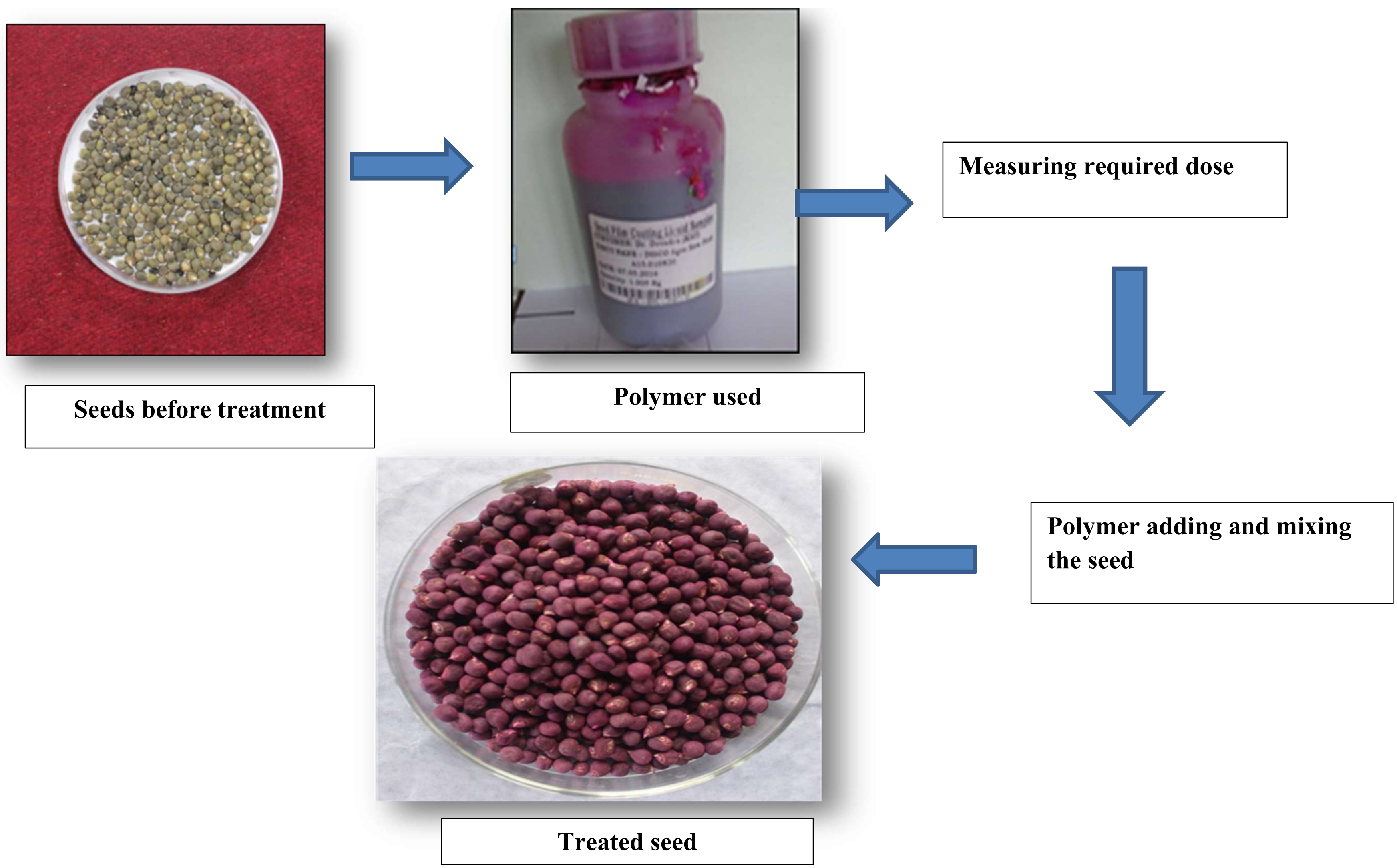
#### 3.2.2.4. Seed treatment procedure

The freshly harvested seeds of okra (12g/replication/treatment) were taken in polythene bag and treated with the plant protection chemicals as per the treatment combinations mentioned in table 4 and polymer was added according to the dosage (5ml/kg of seeds). The polythene bag was closed tightly and shaken until the seeds were uniformly coated with polykote. The treated seeds were shade dried back to less than or equal to original moisture content. They were then packed into separate lots (12 lots/replication/treatment) in 700 gauge polythene bags and stored under ambient and cold (6-10°C) storage conditions for twelve months. Untreated seeds were also kept in similar storage conditions which served as control.

#### 3.2.2.5. Observations

The required quantity of seed (150 seeds for germination test and 50 seeds for EC) was drawn randomly from each replication of each treatment at bimonthly intervals for taking observations on seed quality parameters. Observations on seed

**Plate 5: Seed treatment procedure**



microflora and seed moisture were recorded at the start and end of storage period. Seed quality parameters enumerated below were recorded in all the experiments.

#### 3.2.2.5.1. Germination (%)

Germination test was conducted as per ISTA standards using sand medium. Three replicates of fifty seeds each were drawn from each replication of treatments (T1 to T5) and sown in trays containing sterilized sand. The test was conducted at 25±2°C temperature and 90±3 % relative humidity. The average number of normal seedlings produced on the 7th day of sowing to the total number of seeds sown was expressed as per cent.

#### 3.2.2.5.2. Seedling shoot length (cm)

At the end of the germination test, ten normal seedlings from each replication of a treatment were randomly selected. Shoot length was measured from collar region of the seedling to the primary leaf base. The mean seedling shoot length was expressed in centimeter.

#### 3.2.2.5.3. Seedling root length (cm)

The ten seedlings used for measuring the shoot length were used to record the root length. The root length of each seedling was measured from collar region to the tip of primary root. The mean root length was expressed in centimeter.

#### 3.2.2.5.4. Seedling dry weight (g)

Ten seedlings used for measuring shoot and root length, were dried in a hot air oven maintained at 85 ± 1°C for 24 hours as per ISTA (2007). The seedlings were then removed and allowed to cool in desiccators for 30 minutes and weighed using a digital balance and expressed in gram.

**Plate 6: Germination test – Sand method**

### 3.2.2.5.5. Electrical conductivity of seed leachate (µS/m)

The electrical conductivity of seed leachate (EC) was recorded using 50 seeds from each replication per treatment. The seeds were soaked in 50ml distilled water. After 24 hour of incubation, leachate was collected in a beaker. The EC of the seed leachate was recorded with EUTECHCON-510 digital conductivity meter with a cell constant of 0.1 and expressed in micro Siemons per meter (µS/m).

### 3.2.2.5.6. Seed microflora (%)

### 3.2.2.5.6.1. Blotter method

Blotter method is the standard method prescribed by ISTA (1999) for the detection of storage fungi in seeds. Three layers of blotters moistened with distilled water are placed in sterilized petriplates. Three replications were kept for each treatment and ten seeds were taken in each replication. Incubate the plates at 20-22°C for seven days in alternating cycles of twelve hour of darkness and twelve hour of light. After seven days of incubation, the plates were examined under stereo microscope. The slides were prepared using the fungal growth on seeds and observed under light microscope for identification. The number of infected seeds were counted and expressed in per cent.

### 3.2.2.5.6.2. Agar plate method

Three replications of ten seeds each per treatment was used in the agar plate method. Seeds were surface sterilized using 0.1 per cent mercuric chloride and placed in a potato dextrose agar media equidistantly under the laminar air flow chamber. The petriplates were packed in a polyethylene cover and kept under the bell jar for incubation. The fungal growth was examined under the stereo binocular microscope.

#### 3.2.2.6.7. Statistical analysis

##### 3.2.2.6.7.1. Analysis of data from Experiment I

The statistical analysis of the data recorded in Experiment I was performed using Web Agri. Stat Package (WASP) for Randomized Block Design (RBD) and the significant test by Duncan's Multiple Range Test (DMRT). The data obtained were subjected to the analysis of variance (ANOVA) as shown in Table 5.

**Table 5. ANOVA for Randomized Block Design (RBD)**

| **Source of variation** | **Degrees of freedom** | **Sum of squares** | **Mean sum of squares** | **F-calculated** |
|---|---|---|---|---|
| **Replications** | t-1 | RSS | MSR | MSR/MSE |
| **Treatments** | r-1 | TrSS | MSTr | MSTr/MSE |
| **Error** | (t-1) (r-1) | ESS | MSE | |
| **Total** | N-1 | TSS | | |

##### 3.2.2.6.7.2. Analysis of data from Experiment II

Statistical analysis of the data on various seed quality parameters was performed using Web Agri Stat Package (WASP) developed by Indian Council of Agricultural Research for completely randomized design and significance test by Duncan's Multiple Range Test (DMRT). The treatment efficacy criteria expressed as per cent and the numbers having low counts and zero values were transformed to square root of (x + 0.5) before analysis of variance (ANOVA). Data obtained were subjected to analysis of variance (ANOVA).

**Table 6: ANOVA for completely randomized design**

| Source of variation | Degree of freedom (df) | Sum of squares (SS) | Mean square MS= SS/df | Computed f |
|---|---|---|---|---|
| Treatment | t-1 | SST | MST | MST/MSE |
| Error | n-t | SSE | MSE | |
| Total | n-1 | $SST_0$ | | |

# Results and Discussion

# 4. RESULTS AND DISCUSSION

Field experiment was conducted at Centre for High-tech Horticulture and Precision Farming in Vellanikkara, January to April 2019 to standardize the fertigation schedule for okra and to access the effect of precision farming techniques on growth and seed yield and quality of okra and the storage experiment was conducted at Department of Seed Science and Technology, College of Horticulture, Vellanikkara. The data on growth attributes, yield and yield attributes, seed quality, germination and moisture studies were statistically analyzed and the results are presented in this chapter.

## 4.1. Experiment I: Precision farming techniques

### 4.1.1. Biometric observations

#### 4.1.1.1. Plant height

The plant height recorded at 30, 60 and 90 DAS for various treatments is presented in Table 8. There existed significant difference in plant height among the treatments and control at 30, 60 and 90 DAS. Among the treatments, plant height was the significantly high in $I_1F_1$ at 30 (26.43 cm), 60 (66.55 cm) and 90 (84.40 cm) DAS. The least height was recorded in control at 30 (10.66 cm), 60 (39.00 cm) and 90 DAS (50.70 cm). In all the treatments, plant height ranged from 16.83 cm to 26.43 cm at 30 DAS, 53.30 cm to 66.55 cm at 60 DAS and 68.70 cm to 84.40 cm at 90 DAS. Significantly higher plant height in $I_1F_1$ might be attributed to the optimum microclimate in the root zone of the plant due to higher oxygen concentration facilitated by the excellent soil-water atmosphere. Haris *et al.,* (2014*)* reported that drip fertigation will keep the nutrients at optimum concentration in the crop root zone within the top 0 – 30 cm soil depth in okra and the similar results were reported by Raina *et al.,* (1999) in tomato.

**Table 7: Effect of different levels of irrigation and fertigation on plant height**

| Treatments | Plant height (cm) | | |
|---|---|---|---|
| | 30 DAS | 60DAS | 90DAS |
| **Levels of irrigation (I)** | | | |
| **$I_1$- Drip irrigation at 75% EP** | 20.47 | 61.86 | 79.23 |
| **$I_2$- Drip irrigation at 100% EP** | 21.74 | 54.43 | 70.76 |
| **CD** | NS | 3.36 | 4.94 |
| **SEm** | 1.16 | 4.97 | 4.97 |
| **Fertigation (F)** | | | |
| **$F_1$-75% RDF** | 23.31 | 60.47 | 78.80 |
| **$F_2$-100% RDF** | 21.05 | 57.07 | 73.95 |
| **$F_3$-125% RDF** | 18.96 | 56.90 | 72.25 |
| **CD** | 3.18* | NS | NS |
| **SEm** | 1.42 | 6.09 | 6.09 |

**Table 8: Interaction effect of different levels of irrigation and fertigation on plant height**

| Interaction (I X F) | Plant height (cm) | | |
|---|---|---|---|
| | 30 DAS | 60DAS | 90DAS |
| **$I_1F_1$** | 26.43 | 66.55 | 84.40 |
| **$I_1F_2$** | 18.16 | 58.55 | 77.50 |
| **$I_1F_3$** | 16.83 | 60.50 | 75.80 |
| **$I_2F_1$** | 20.20 | 54.40 | 73.20 |
| **$I_2F_2$** | 23.93 | 55.60 | 70.40 |
| **$I_2F_3$** | 21.10 | 53.30 | 68.70 |
| **CD (I xF) (0.05)** | 4.50 | NS | NS |
| **SEm** | 2.02 | 8.61 | 8.62 |

| | | | |
|---|---|---|---|
| **Control (C)** | 10.66 | 39.00 | 50.70 |
| **Control v/s Treatments (CD)** | 5.74** | 5.26* | 7.99* |

*–Significant at 5% level, **-Significant at 1% level, NS- Non significant

A perusal of the data also revealed that different levels of irrigation irrespective of fertigation had significant influence on plant height at 60 and 90 DAS (Table 7). $I_1$ (Drip irrigation at 75% EP) recorded significantly higher plant height at 60 DAS (61.86 cm) and 90 DAS (79.23 cm) when compared to $I_2$. But at 30 DAS, fertigation had significant effect on plant height irrespective of the levels of irrigation. Fertigation at 75% RDF recorded highest plant height at 30 DAS (23.31 cm). The interaction effect of different levels of irrigation and fertigation also showed significant increase in plant height at 30 DAS only whereas at 60 and 90 DAS, the interaction was not significant. Plant height at 30 DAS was maximum for $I_1F_1$ (26.43 cm) which was on par with $I_2F_2$ (23.93 cm) followed by $I_2F_3$ (21.10 cm).

**4.1.1.2. Height of the first bearing node**

Height of the first bearing node differed significantly among the treatments and control (Table 10). The average height of the first bearing node in treatments was 14.01 cm whereas in control it was 11.90 cm. However, different levels of irrigation and fertigation had significant influence on height of the first bearing node (Table 9). $I_1$ ( Drip irrigation at 75% EP) recorded significantly higher height of the first bearing node (14.40 cm) when compared to $I_2$. Similarly, $F_1$ (75% RDF) recorded significantly higher height of the first bearing node (15.20 cm) followed by $F_3$ (13.90 cm). Even then there was significant effect on interaction of different levels of irrigation and fertigation with respect to height of the first bearing node. The first bearing node was significantly higher in $I_1F_1$ (17.55 cm) when compared to all other treatments.

**Table 9: Effect of different levels of irrigation and fertigation on height of first bearing node**

| Treatments | Height of the first bearing node (cm) |
|---|---|
| **Levels of irrigation (I)** | |
| **$I_1$- Drip irrigation at 75% EP** | 14.40 |
| **$I_2$- Drip irrigation at 100% EP** | 13.63 |
| **CD (0.05)** | 0.25 |
| **SEm** | 0.62 |
| **Fertigation (F)** | |
| **$F_1$-75% RDF** | 15.20 |
| **$F_2$-100% RDF** | 12.95 |
| **$F_3$-125% RDF** | 13.90 |
| **CD (0.05)** | 0.31 |
| **SEm** | 0.76 |

**Table 10: Interaction effect of different levels of irrigation and fertigation on height of first bearing node**

| Interaction (I X F) | Height of the first bearing node (cm) |
|---|---|
| **$I_1F_1$** | 17.55 |
| **$I_1F_2$** | 12.90 |
| **$I_1F_3$** | 12.75 |
| **$I_2F_1$** | 12.86 |
| **$I_2F_2$** | 13.00 |
| **$I_2F_3$** | 15.05 |
| **CD (0.05) (I xF)** | 0.44 |
| **SEm** | 1.08 |

| | |
|---|---|
| **Control (C)** | 11.90 |
| **Control v/s Treatments (CD)** | 0.80 |

Significant at 5% level, NS- Non-significant

#### 4.1.1.3. Leaf Area Index (LAI) at 30 and 60 DAS

There exists significant difference in LAI among the treatments and control at 30 and 60 DAS, which includes different levels of irrigation and fertigation. In all the treatments, LAI ranged from 0.33 to 0.53 at 30 DAS and 1.19 to 0.67 at 60 DAS. Significantly highest LAI at 60 DAS was observed in $I_1F_1$ (1.19), which was on par with $I_1F_2$ (1.08) and $I_2F_3$ (0.93). The lowest LAI was observed in control (0.34).

The data on LAI revealed that different levels of irrigation, irrespective of fertigation levels had significant effect on LAI at 60 DAS. $I_1$ showed significantly greater LAI (1.01) when compared to $I_2$ (0.84). LAI which reflects the leafiness of the crop, is an important parameter influencing crop growth and thereby its photosynthetic capability. In the present study, the plant height was maximum in $I_1$ (Drip irrigation at 75% EP). In okra, increased plant height corresponds to more number of leaves and this might have contributed to the increased LAI in $I_1$ (Drip irrigation at 75% EP). Lakshmikanth *et al.,* (2018) have also observed higher LAI (3.20) in okra at lowest level of irrigation *i.e.,* 60 per cent ET with white on black plastic colour mulch.

When comparing the different fertigation levels irrespective of irrigation levels, it was observed that significant difference in LAI among the fertigation level was observed only at 30 DAS whereas at 60 DAS, there was no significant difference in LAI among the fertigation levels.

Interaction effect of levels of irrigation and fertigation had no significant effect on LAI at 30 DAS. But interaction effect had significant effect on 60 DAS. At 60 DAS, LAI ranged from 1.19 to 0.67 among the treatments. $I_1F_1$ recorded higher LAI (1.19) which was on par with $I_1F_2$ (1.08) and $I_2F_3$ (0.93).

**Table 11: Effect of different levels of irrigation and fertigation on LAI**

| Treatments | LAI (30 DAS) | LAI (60 DAS) |
|---|---|---|
| **Levels of irrigation (I)** | | |
| **$I_1$- Drip irrigation at 75% EP** | 0.41 | 1.01 |
| **$I_2$- Drip irrigation at 100% EP** | 0.57 | 0.84 |
| **CD (0.05)** | 0.08 | 0.16 |
| **SEm** | 0.15 | 0.20 |
| **Fertigation (F)** | | |
| **$F_1$-75% RDF** | 0.59 | 1.05 |
| **$F_2$-100% RDF** | 0.45 | 0.89 |
| **$F_3$-125% RDF** | 0.43 | 0.84 |
| **CD (0.05)** | 0.09 | NS |
| **SEm** | 0.45 | 1.18 |

**Table 12: Interaction effect of different levels of irrigation and fertigation on LAI**

| Interaction (I X F) | LAI (30 DAS) | LAI (60 DAS) |
|---|---|---|
| **$I_1F_1$** | 0.52 | 1.19 |
| **$I_1F_2$** | 0.39 | 1.08 |
| **$I_1F_3$** | 0.33 | 0.75 |
| **$I_2F_1$** | 0.66 | 0.90 |
| **$I_2F_2$** | 0.52 | 0.67 |
| **$I_2F_3$** | 0.53 | 0.93 |
| **CD (0.05) (I X F)** | NS | 0.28 |
| **SEm** | 1.12 | 1.39 |

| | | |
|---|---|---|
| **Control (C)** | 0.34 | 0.52 |
| **Control v/s Treatments (CD)** | 0.18** | 0.36** |

**- Significant at 1% level, *-Significant at 5% level, NS- Non significant

### 4.1.1.4. Days to 50 per cent flowering

Different levels of irrigation and fertigation did not have significant effect on days to 50 per cent flowering when compared to control. All the treatments took 47.33 to 56.33 days to attain 50 per cent flowering while control took 62 days to attain 50 per cent flowering. Earlier flowering under treatments might be attributed to less water stress in plant canopy. Similar results have been reported by Jayapiratha *et al.,* (2010) in okra. Among the treatments, $I_1F_1$ and $I_2F_3$ took the minimum number of days for 50 per cent flowering with values *viz.* 47.33 days and 49 days respectively. Irrespective of the levels of fertigation, earlier flowering was observed in $I_1$ (48.88 days) when compared to 53.33 days in $I_2$. But different fertigation levels alone had no significant effect of flowering. However, the interaction effect also did not exercise any significant effect on 50 per cent flowering.

### 4.1.1.5. Fruit set (%)

Different levels of irrigation and fertigation showed great influence on fruit set. Significantly higher fruit set ranging from 60.66 to 73.00 per cent was observed in the treatments while there was only 50. 66 per cent fruit set in control.

Irrespective of the levels of fertigation, different levels of irrigation had profound influence on the fruit set in okra. Drip irrigation at 75 per cent EP ($I_1$) showed a higher fruit set of 70.33 per cent while the fruit set was only 63.55 per cent in $I_2$ which is drip irrigation at 100 per cent EP. But there was no significant difference in fruit set observed at different levels of fertigation alone. Interaction effects of levels of irrigation and fertigation showed significant impact on fruit set per cent. Among treatments, $I_1F_1$ recorded greatest fruit set per cent (73.00 per cent) which was on par with $I_1F_2$ (70.33 per cent) followed by $I_1F_3$ and $I_2F_3$ (67.66). Control recorded lowest fruit set per cent (50.66).

**Table 13: Effect of different levels of irrigation and fertigation on days to 50 per cent flowering and fruit set**

| Treatments | Days to 50% flowering | Fruit set (%) |
|---|---|---|
| **Levels of irrigation (I)** | | |
| **$I_1$- Drip irrigation at 75% EP** | 48.88 | 70.33 |
| **$I_2$- Drip irrigation at 100% EP** | 53.33 | 63.55 |
| **CD (0.05)** | 3.78* | 2.64* |
| **SEm** | 1.69 | 1.18 |
| **Fertigation (F)** | | |
| **$F_1$-75% RDF** | 51.83 | 66.83 |
| **$F_2$-100% RDF** | 53.16 | 66.33 |
| **$F_3$-125% RDF** | 48.33 | 67.66 |
| **CD (0.05)** | NS | NS |
| **SEm** | 2.07 | 1.45 |

**Table 14: Interaction effect of different levels of irrigation and fertigation on days to 50 per cent flowering and fruit set**

| Interaction (I X F) | Days to 50% flowering | Fruit set (%) |
|---|---|---|
| **$I_1F_1$** | 47.33 | 73.00 |
| **$I_1F_2$** | 51.66 | 70.33 |
| **$I_1F_3$** | 47.66 | 67.66 |
| **$I_2F_1$** | 56.33 | 60.66 |
| **$I_2F_2$** | 54.66 | 62.33 |
| **$I_2F_3$** | 49.00 | 67.66 |
| **CD (0.05) (I xF)** | NS | 4.57* |
| **SEm** | 2.93 | 2.05 |

| | | |
|---|---|---|
| **Control (C)** | 62.00 | 50.66 |
| **C Vs. Treatments (CD)** | 9.16** | 5.89** |

** - Significant at 1% level, *-Significant at 5% level, NS –Non significant

Drip irrigation and fertigation had significant effect on growth attributes *viz.* plant height, height of the first bearing node, Leaf Area Index (LAI), early flowering and fruit set when compared to control. Highest values of all these parameters were recorded at 75 % EP. The increased growth attributes under drip irrigation might have resulted due to better utilization of water (Sharma *et al.,* 2010), higher uptake of nutrients (Kader *et al.,* 2010) and excellent soil-water-air relationship with higher oxygen concentration in the root zone (Jayapiratha *et al.,* 2010) and also due to less weed competition, better conserved soil moisture and reduced evaporation losses. Similar results have been reported by Bogle *et al.,* (1989) in tomato, Tiwari *et al.,* (1998) in okra and Lourduraj *et al.,* (1996) in tomato.

### 4.1.2. Fruit characters

#### 4.1.2.1. Fruit Length (cm)

When compared to control, all the treatments which were on par among them, produced significantly longer fruits. Average fruit length in treatment was 17.96 cm whereas in control the fruit length was only 7.56 cm. However, different levels of irrigation and fertigation alone and the interaction of these factors did not show any significant variations in length of fruit.

#### 4.1.2.2. Fruit Girth (cm)

Like that of fruit length, girth of fruit was also significantly higher in all the treatments (2.63 cm) when compared to control (1.90cm). However, different levels of irrigation and fertigation and their interaction did not show any variation in fruit girth.

#### 4.1.2.3. Mature fruit weight (g)

The data on mature fruit weight (Table 16) revealed that all the treatments recorded significantly greater mature fruit weight (9.10 cm) when compared to control (6.52 cm). Different levels of irrigation and fertigation as well as their interaction also influenced mature fruit weight. Between the irrigation levels, $I_1$ (75%EP) recorded highest mature fruit weight (8.09 cm) compared to $I_2$ (100% EP) with 7.34g.

Among the three fertigation tested, $F_1$ (75%RDF) recorded significantly highest mature fruit weight (8.20 g) which were on par with $F_2$ (8.09 g).

Comparing the interaction effect of different levels of irrigation and fertigation, $I_1F_1$ recorded the highest mature fruit weight (9.10 g) which was on par with $I_1F_2$ (8.59 g).

**4.1.2.4. Mature fruit yield (g)**

A perusal of the data (Table 16) revealed when compared to control, all the treatments recorded significantly high mature fruit yield per plant. The average mature fruit yield in treatments was 97.98 g where it was only 61.71 g in control. It is also evident from the table that different levels of irrigation and fertigation as well as their interaction influenced mature fruit yield/plant. Between the irrigation levels, $I_1$ recorded a mature fruit yield of 116.49 g while in $I_2$ it was 79.48 g. Among the different fertigation levels, mature fruit yield was significantly highest for $F_1$ (117.54 g) whereas it was on par in $F_2$ (100% RDF) and $F_3$ (125% RDF) with a fruit yield of 91.77 g and 84.64 respectively.

Comparing the interaction effect of different levels of irrigation and fertigation, $I_1F_1$ recorded the highest mature fruit yield of 154.85g/plant which was significantly higher than other treatments. It was followed by $I_1F_2$ (98.67 g) which was statistically on par with $I_1F_3$ (95.95 g) and the lowest yield was registered in $I_2F_3$ (73.33 g).

#### 4.1.2.5. Number of mature fruits/ plant

The data on number of mature fruits/ plant (Table 16) revealed that all the treatments recorded significantly higher number of fruits (22.00) when compared to control (14.55). Different levels of irrigation and fertigation as well as their interaction also influenced number of mature fruits/plant. Between the irrigation levels, $I_1$ (75% EP) recorded higher number of fruits (25.67) compared to $I_2$ (100% EP) with 18.34 fruits.

Among the three fertigation tested, $F_1$ (75% RDF) recorded significantly higher number of fruits (24.18). This was followed by $F_2$ and $F_3$ which were on par with regard to this parameter.

With respect to the interaction effect, $I_1F_1$ recorded the highest number of fruits (30.91) which was significantly higher than all other treatments and it was followed by $I_1F_2$ (24.64) which was statistically on par with $I_1F_3$ (21.46) and the lowest number was registered in $I_2F_3$ (16.26).

**Plate 7: Okra fruits under different treatments**


**$I_1F_1$ – Drip irrigation at 75% EP and fertigation at 75% RDF**

**$I_1F_2$ - Drip irrigation at 75% EP and fertigation at 100% RDF**

**$I_1F_3$ - Drip irrigation at 75% EP and fertigation at 125% RDF**

**$I_2F_1$ - Drip irrigation at 100% EP and fertigation at 75% RDF**

**$I_2F_2$ - Drip irrigation at 100% EP and fertigation at 100% RDF**

**$I_2F_3$ - Drip irrigation at 100% EP and fertigation at 125% RDF**

**Table 15: Effect of different levels of irrigation and fertigation on fruit characters**

| Treatments | Fruit characters | | | | |
|---|---|---|---|---|---|
| | Length (cm) | Girth (cm) | Mature fruit weight (g) | Mature fruit yield per plant (g) | Number of mature fruits per plant |
| **Levels of irrigation (I)** | | | | | |
| **$I_1$- Drip irrigation at 75% EP** | 17.98 | 2.73 | 8.09 | 116.49 | 25.67 |
| **$I_2$- Drip irrigation at 100% EP** | 17.20 | 2.55 | 7.34 | 79.48 | 18.34 |
| **CD(0.05)** | NS | NS | 0.72 | 6.75 | 1.76 |
| **SEm** | 0.41 | 0.073 | 0.41 | 3.02 | 0.79 |
| **Fertigation (F)** | | | | | |
| **$F_1$-75% RDF** | 17.10 | 2.74 | 8.20 | 117.54 | 24.18 |
| **$F_2$-100% RDF** | 18.00 | 4.64 | 8.09 | 91.77 | 22.97 |
| **$F_3$-125% RDF** | 17.68 | 2.48 | 6.85 | 84.64 | 18.86 |
| **CD(0.05)** | NS | NS | 0.88 | 8.27 | 2.16 |
| **SEm** | 0.50 | 0.10 | 0.51 | 3.71 | 0.96 |

**Table 16: Interaction effect of different levels of irrigation and fertigation on fruit characters**

| Interaction (I X F) | Fruit characters | | | | |
|---|---|---|---|---|---|
| | Length (cm) | Girth (cm) | Mature fruit weight (g) | Mature fruit yield per plant (g) | Number of mature fruits per plant |
| **$I_1F_1$** | 17.68 | 2.77 | 9.10 | 154.85 | 30.91 |
| **$I_1F_2$** | 18.05 | 2.83 | 8.59 | 98.67 | 24.64 |
| **$I_1F_3$** | 18.23 | 2.59 | 6.58 | 95.95 | 21.46 |
| **$I_2F_1$** | 16.52 | 2.71 | 7.30 | 80.24 | 17.46 |
| **$I_2F_2$** | 17.96 | 2.56 | 7.59 | 84.86 | 21.31 |
| **$I_2F_3$** | 17.13 | 2.37 | 7.12 | 73.33 | 16.26 |
| **CD (0.05)** | NS | NS | 1.25 | 11.69 | 3.05 |
| **SEm** | 0.72 | 0.14 | 0.72 | 5.24 | 1.37 |

| | | | | | |
|---|---|---|---|---|---|
| **Control (C)** | 7.56 | 1.90 | 6.52 | 61.71 | 14.55 |
| **C Vs. Treatments (CD)** | 2.34** | 0.414** | 1.67** | 14.67** | 4.34** |

** - Significant at 1% level, *-Significant at 5% level, NS –Not significant

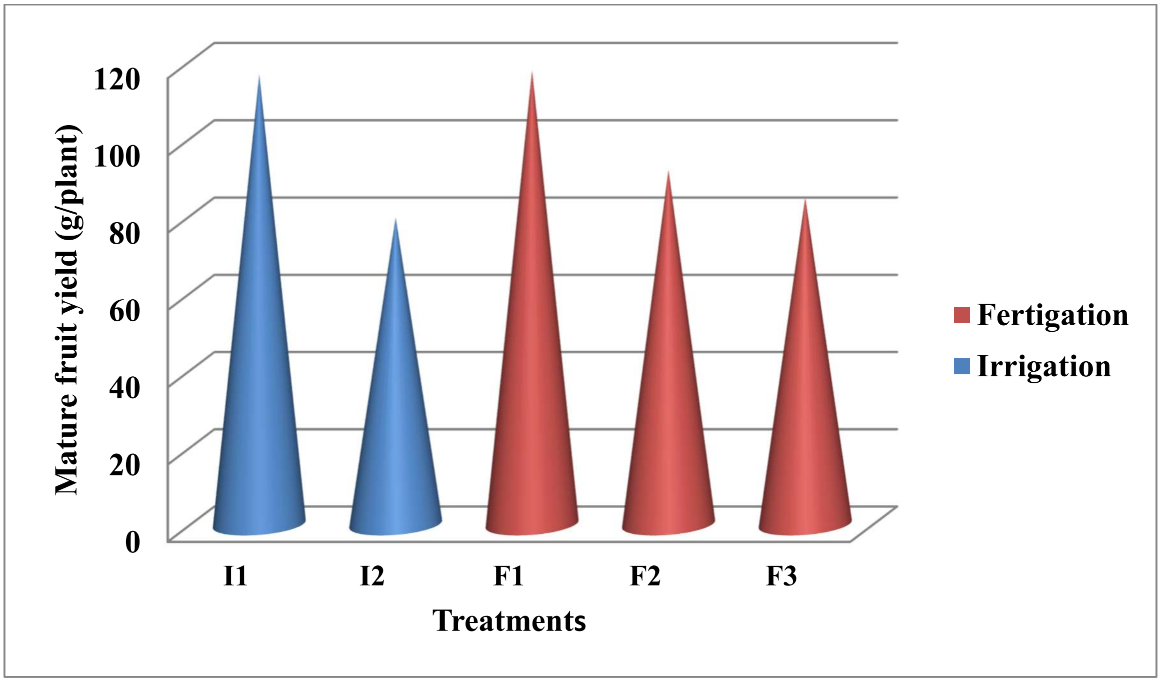



**Fig.1. Fruit yield as influenced by levels of irrigation (I) and fertigation(F)**

**$I_1$:** Drip irrigation at 75% EP

**$I_2$:** Drip irrigation at 100% EP

**$F_1$:** Fertigation at 75% RDF

**$F_2$:** Fertigation at 100% RDF

**$F_3$:** Fertigation at 125% RDF

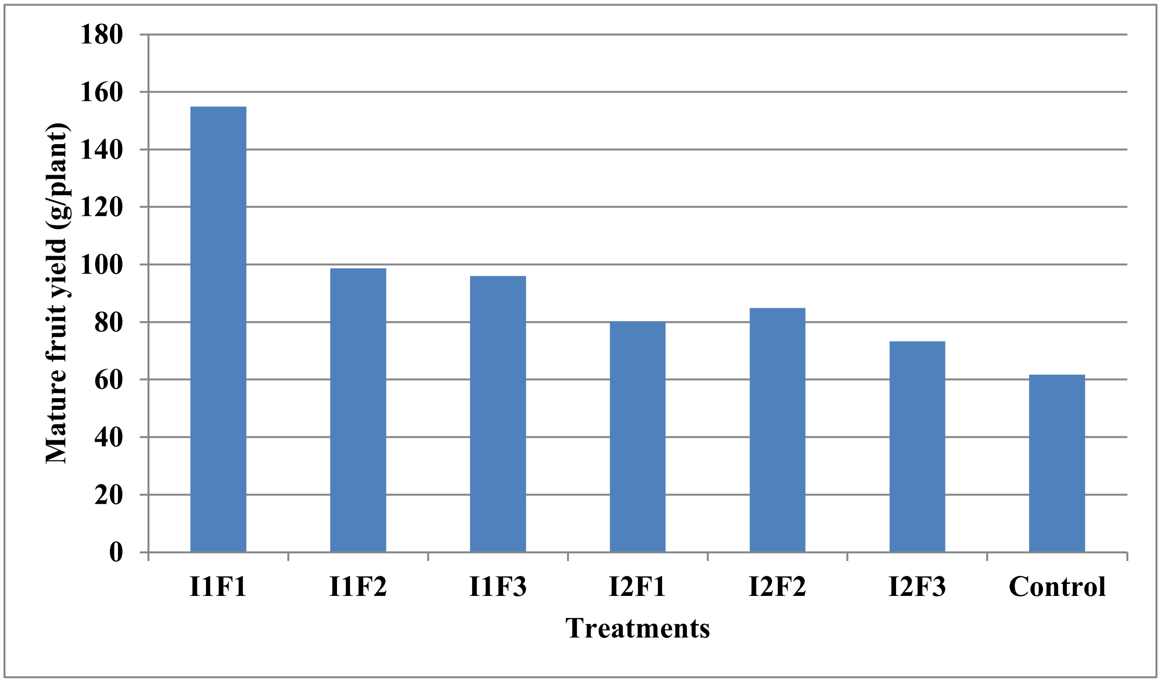



**Fig.2. Fruit yield as influenced by irrigation level – fertigation interaction**

**$I_1$:** Drip irrigation at 75% EP

**$I_2$:** Drip irrigation at 100% EP

**$F_1$:** Fertigation at 75% RDF

**$F_2$:** Fertigation at 100% RDF

**$F_3$:** Fertigation at 125% RDF

Drip irrigation at 0.80 ET along with mulch has been recorded with increased number of fruits in okra by Haris *et al.,* (2014), Narayanankutty *et al.,* (2016), and in brinjal by Singandupe *et al.,* (2007). Perhaps, $I_1$ (75%EP) is more close to drip irrigation at 0.80 ET in the studies quoted here and enhanced growth and yield under drip irrigation system might be due to excellent soil-water-air relationship with higher oxygen concentration in the root zone.

Different levels of irrigation and fertigation significantly influenced mature fruit yield/plant and number of fruits/plant. Highest value for all these parameters were recorded in drip irrigation at 75% EP and fertigation at 75% RDF. The results are in conformity as reported by Chaudhari *et al.,* (2012) and Narayanankutty *et al.,* (2016) in okra. In general, yield and yield attributes were the lowest for control compared to all the treatments. All the treatments were provided with 30 micron silver black polythene mulch. Better performance in drip irrigation and fertigation treatments might be attributed to better uptake of nutrients, reduced nutrient loss through leaching, less competition from weeds and reduced soil compaction. Enhanced growth and yield under mulched condition might also be due to improved plant microclimate especially in the root zone which in turn might have favoured enhanced photosynthesis and metabolic activities as reported by Bhatt *et al.,* (2011) in summer squash, Parmar *et al.,* (2013) in water melon, Danso *et al.,* (2015) and Thirumalaikumar *et al.,* (2014) in okra.

**4.1.3. Seed characters**

**4.1.3.1. Number of seeds per fruit**

When compared to control, treatments had significant influence on number of seeds per fruit (Table 18). On an average, treatments produced 41.22 number of seeds where as in control, it was 28.96. The data in table 17 also revealed that different levels of irrigation and fertigation had significant effect on number of seeds per fruit. $I_1$ (Drip irrigation at 75% EP) recorded significantly higher number of seeds (43.90) when compared to $I_2$ (38.54). Among the fertigation tested, $F_2$ (100 % RDF) recorded higher number of seeds which was on par with $F_3$ (41.45). With respect to interaction effect, $I_1F_3$ recorded greater number of seeds per fruit (46.00) which was on par with $I_2F_2$ (43.00), $I_1F_1$ (42.96) and $I_1F_2$ (42.75).

#### 4.1.3.2. Weight of seeds per fruit (g)

The applied treatments did not exercise significant impact on weight of seeds per fruit.

#### 4.1.3.3. Seed yield per plant (g)

Seed yield was significantly different between the treatments and control. Average seed yield in the treatments was 60.12 g whereas in control the seed yield was only 41.30 g. Different levels of irrigation had significant effect on seed yield per plant. $I_1$ (drip irrigation at 75% EP) recorded highest seed yield per plant (71.86 g) when compared to $I_2$ (drip irrigation at 100% EP) which recorded a seed yield of 48.40 g. But, different levels of fertigation alone and interaction effect of levels of irrigation and fertigation had no significant effect on seed yield per plant. Increased seed yield in cotton under drip irrigation has been reported by Jayakumar *et al.,* (2014).

#### 4.1.3.4. 100 seed weight (g)

When compared to control, treatments $I_1F_1$, $I_1F_3$ and $I_2F_3$ were significantly superior in terms of 100 seed weight. It was 5. 64 g in control whereas the 100 seed weight was 6.80 g in $I_1F_1$, 6.79 g in $I_2F_3$ and 6.46 g in $I_1F_3$. Different levels of irrigation did not have significant effect on 100 seed weight. But, fertigation and interaction effect of levels of irrigation and fertigation had significant effect on 100 seed weight. $F_3$ (125% RDF) recorded the highest 100 seed weight (6.70g) which was on par with $F_1$ (6.46 g). With respect to interaction effect, $I_1F_1$ and recorded greatest 100 seed weight (6.80 g) which was on par with $I_2F_3$ (6.79) and $I_1F_3$ (6.60).

#### 4.1.3.5. 100 seed volume (ml)

The applied treatments did not exercise significant impact on 100 seed volume

#### 4.1.3.6. Moisture content (%)

The applied treatments did not exercise significant impact on moisture content of the seed

#### 4.1.3.7. Germination (%)

When compared to control, treatments had significant influence on germination per cent. Average germination for the treatment was 84.77 per cent whereas in control it was 71.23 per cent. The data in table 17 revealed that seed germination was significantly influenced by different levels of fertigation irrespective of irrigation. $F_1$ (75% RDF) recorded the highest germination per cent of 93.33 when compared to $F_2$ and $F_3$. With respect to the interaction effect, $I_2F_1$ recorded highest germination (95 per cent) which was on par with $I_1F_3$ (92.50 per cent) and $I_1F_1$ (91.66 per cent).

#### 4.1.3.8. Hard seed (%)

The data in table 18 revealed that there is no significant difference exist between control and treatments in hard seed percentage. It was significantly influenced by different levels of fertigation irrespective of irrigation. $F_3$ (125 % RDF) recorded lowest hard seed percentage (8.48%) followed by $F_1$ (10.38%) which was on par with $F_2$ (10.64%). Interaction effect also did not excise significant effect on hard seed percentage.

#### 4.1.3.9. Seedling shoot length (cm)

The data on table 17 revealed that shoot length was significantly higher in control (23.90 cm) when compared to treatments (21.69 cm). Different levels of irrigation and interaction did not excise significant effect on seedling shoot length. But different levels of fertigation alone had significant impact on shoot length. $F_3$ (125% RDF) recorded highest shoot length (22.68 cm) followed by $F_2$ (100% RDF) which was 21.70cm.

#### 4.1.3.10. Seedling root length (cm)

Seedling root length was significantly higher in treatments when compared to control. The data in table 17 revealed that shoot length was significantly influenced by different levels of irrigation and fertigation. Between the irrigation levels, $I_2$ (Drip irrigation at 100% EP) recorded significantly higher seedling shoot length (10.60 cm) when compared to $I_1$ (Drip irrigation at 75% EP) which was 8.05 cm. Among the fertigation levels, $F_1$ (75% RDF) recorded the highest seedling root length (10.54 cm) whereas $F_2$ (100% RDF) and F3 (125% RDF) were on par with regard to seedling root length. With respect to interaction effect, $I_2F_1$ recorded highest seedling root length (10.70 cm) which was on par with $I_2F_3$ (10.60 cm), $I_1F_2$ (10.50 cm) and $I_1F_1$ (10.38 cm).

#### 4.1.3.11. Vigour index I

Seedling vigour index was significantly higher in treatments when compared to control. The data in table 17 revealed that seedling vigour index was significantly influenced by different levels of irrigation and fertigation. Between the irrigation levels, $I_2$ (Drip irrigation at 100% EP) recorded significantly higher seedling vigour index (2504) when compared to $I_1$ (Drip irrigation at 75% EP). Among the fertigation levels, $F_1$ (75% RDF) recorded the highest seedling vigour index (2914) when compared to $F_2$ and $F_3$. With respect to interaction effect, $I_2F1$ recorded significantly higher seedling vigour index (2947) when compared to other treatments.

Among the seed characters, number of seeds per fruit, seed yield per plant, 100 seed weight, seed germination, seedling root length and seedling vigour index were significantly improved in drip fertigation treatments when compared to control in which the conventional system of cultivation was followed. Drip irrigation coupled with fertigation might have enhanced nutrient availability and absorption by the crop. Consequently, this might have resulted in better formation and translocation of assimilates from source to sink which ultimately increased the seed yield. Application of fertilizer nutrients through irrigation systems (fertigation) has been found to increase seed yield, water use efficiency and nutrient uptake in cotton by Janat and Somi (2001), Janat (2005), Enciso-Medina *et al.,* (2007) and Thind *et al.,* (2008). Increased seed yield in seed spices *viz.* fenugreek, fennel and dill under the drip irrigation has been reported by Malhotra *et al.,* (2009). However, seed characters like weight of seed per fruit, 100 seed volume, seed moisture and hard seed per cent did not differ among the treatments and control.

**Table 17: Effect of different levels of irrigation and fertigation on seed characters of okra**

| Treatments | Seed characters | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | No:of seeds per fruit | Weight of seeds per fruit (g) | Seed yield per plant (g) | 100 seed weight (g) | 100 seed volume (ml) | Moisture content (%) | Germination (%) | Hard seed (%) | Seedling shoot length (cm) | Seedling root length (cm) | Vigour index I |
| **Levels of irrigation (I)** | | | | | | | | | | | |
| **$I_1$- Drip irrigation at 75% EP** | 43.90 | 3.33 | 71.86 | 6.19 | 9.80 | 7.23 | 80.97 | 9.86 | 21.54 | 8.05 | 2424 |
| **$I_2$- Drip irrigation at 100% EP** | 38.54 | 3.24 | 48.40 | 6.35 | 9.63 | 6.76 | 77.77 | 9.81 | 21.84 | 10.60 | 2504 |
| **CD** | 3.14** | NS | 6.95** | NS | NS | NS | NS | NS | NS | 1.23** | 1.22** |
| **Fertigation (F)** | | | | | | | | | | | |
| **$F_1$-75% RDF** | 39.35 | 3.30 | 63.28 | 6.46 | 10.01 | 6.88 | 93.33 | 10.38 | 20.70 | 10.54 | 2914 |
| **$F_2$-100% RDF** | 42.87 | 3.42 | 59.97 | 5.66 | 9.65 | 6.98 | 69.37 | 10.64 | 21.70 | 8.73 | 2131 |
| **$F_3$-125% RDF** | 41.45 | 3.13 | 57.13 | 6.70 | 9.48 | 7.12 | 75.41 | 8.48 | 22.68 | 8.70 | 2348 |
| **CD** | 2.70* | NS | NS | 0.49** | NS | NS | 7.75** | 1.44** | 1.24** | 1.51** | 1.50** |

**Table 18: Interaction effect of different levels of irrigation and fertigation on seed characters of okra**

| Interaction (I X F) | Seed characters | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | No:of seeds per fruit | Weight of seeds per fruit (g) | Seed yield per plant (g) | 100 seed weight (g) | 100 seed volume (ml) | Moisture content (%) | Germination (%) | Hard seed (%) | Seedling shoot length (cm) | Seedling root length (cm) | Seedling vigour |
| $I_1F_1$ | 42.96 | 3.18 | 76.43 | 6.80 | 10.00 | 7.36 | 91.66 | 10.53 | 21.05 | 10.38 | 2881 |
| $I_1F_2$ | 42.75 | 3.39 | 71.39 | 5.18 | 10.06 | 7.20 | 58.75 | 10.31 | 21.51 | 6.96 | 1671 |
| $I_1F_3$ | 46.00 | 3.42 | 67.76 | 6.60 | 9.33 | 7.13 | 92.50 | 8.74 | 22.06 | 7.36 | 2720 |
| $I_2F_1$ | 35.73 | 3.43 | 50.13 | 6.13 | 10.03 | 6.40 | 95.00 | 10.23 | 20.35 | 10.70 | 2947 |
| $I_2F_2$ | 43.00 | 3.44 | 48.56 | 6.14 | 9.23 | 6.76 | 80.00 | 10.96 | 21.88 | 10.50 | 2590 |
| $I_2F_3$ | 36.90 | 2.87 | 46.50 | 6.79 | 9.63 | 7.12 | 58.33 | 8.23 | 23.30 | 10.60 | 1975 |
| CD | 5.44** | NS | NS | 0.48 | NS | NS | 4.86 | NS | NS | 1.50 | 1.49 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Control (C) | 28.96 | 2.39 | 41.30 | 5.64 | 9.63 | 6.70 | 71.25 | 10.20 | 23.90 | 10.10 | 2420 |
| Control v/s Treatments (CD) | 7.73* | NS | 12.04** | 0.73** | NS | NS | 10.96** | NS | 1.16* | 2.14** | 1.89* |

** - Significant at 1% level, * - Significant at 5% level, NS-Non significant

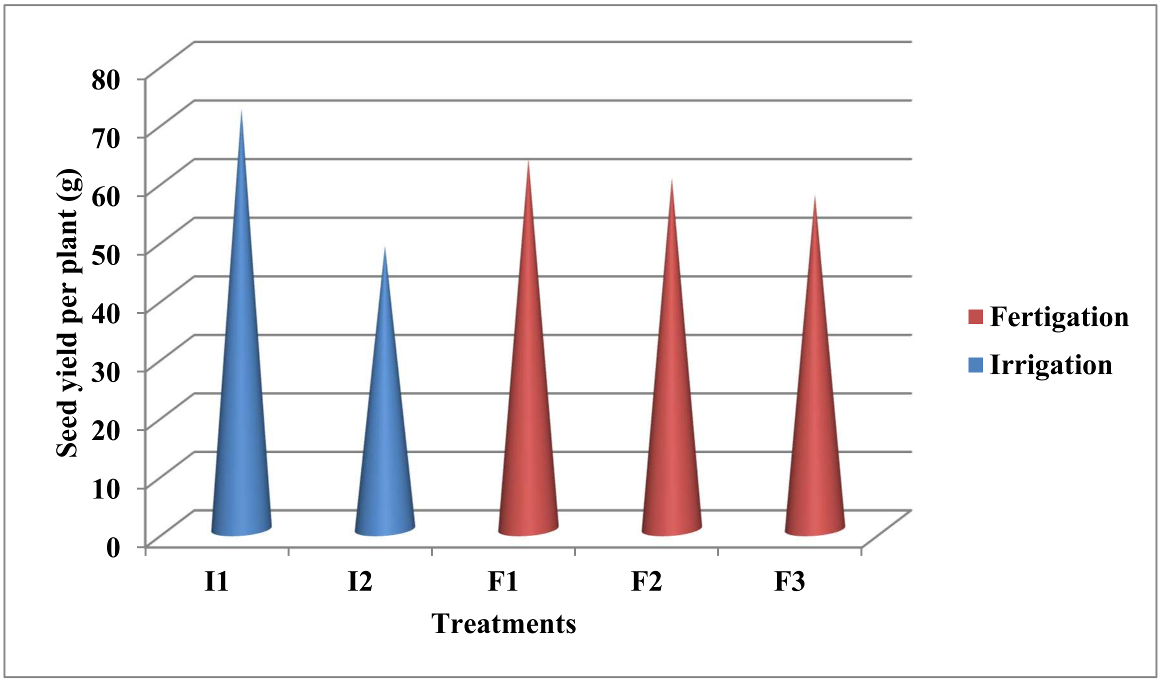



**Fig.3. Seed yield as influenced by levels of irrigation (I) and fertigation(F)**

**$I_1$:** Drip irrigation at 75% EP

**$I_2$:** Drip irrigation at 100% EP

**$F_1$:** Fertigation at 75% RDF

**$F_2$:** Fertigation at 100% RDF

**$F_3$:** Fertigation at 125% RDF

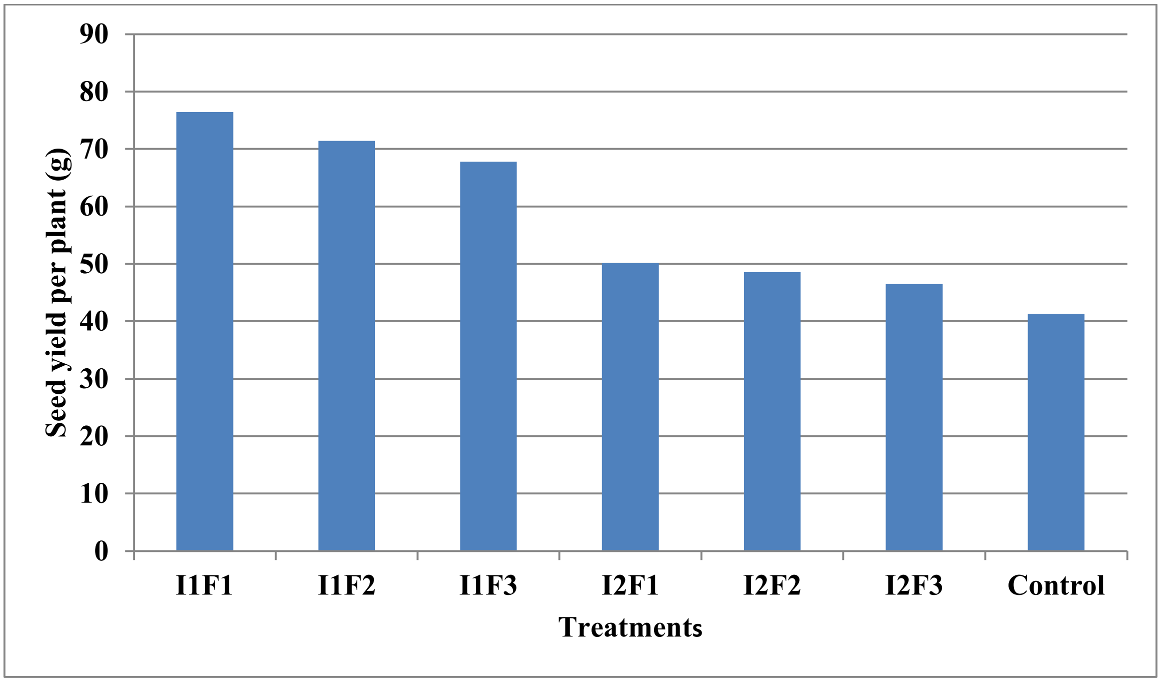



**Fig.4. Seed yield as influenced by irrigation level – fertigation interaction**

**$I_1$:** Drip irrigation at 75% EP

**$I_2$:** Drip irrigation at 100% EP

**$F_1$:** Fertigation at 75% RDF

**$F_2$:** Fertigation at 100% RDF

**$F_3$:** Fertigation at 125% RDF

## 2. Experiment II : Seed storage studies

The seed storage experiment was conducted to elucidate the impact of polykote (synthetic polymer) along with plant protection chemicals treatment on seed quality and longevity of okra. The results obtained for various seed quality parameters *viz.,* germination, shoot length, root length, seedling dry weight, electrical conductivity of seed leachate and seed microflora over the storage period is enumerated below.

### 4.2.1. Initial seed quality of okra

The initial seed quality parameters were ascertained at the start of the experiment and presented in Table 19. The seeds of okra had recorded an initial germination of 94 per cent. The seedling shoot length, root length and dry weight were 22.35 cm, 11.00 cm and 0.04g respectively. The electrical conductivity of seed leachate was 110 $\mu Sm^{-1}$ and the seeds were free from microflora infestation.

**Table 19: Initial seed quality parameters of okra**

| Parameter | Value |
|---|---|
| Germination (%) | 94.00 |
| Seedling shoot length (cm) | 22.35 cm |
| Seedling root length (cm) | 11.00 cm |
| Seedling dry weight (g) | 0.04 g |
| Electrical conductivity of seed leachate ($\mu Sm^{-1}$) | 110.00 |
| Seed infection (%) | 0.00 |

### 4.2.2. Seed germination

**Cold storage**

Seed germination were significantly differing among the treatments throughout the storage period and presented in Table 20. Irrespective of the treatments seed germination was found to be declining gradually with the advancement of storage period. All treatments maintained IMSCS (Indian Minimum Seed Certification Standards) of 65 per cent up to tenth months of storage. At the end of storage period *viz.,* on 12th month, $T_1$ (Polykote (10ml) + carbendazim- mancozeb (2g) + bifenthrin (0.1%) per kg of seed) recorded a higher germination percentage (75.33) followed by $T_3$ (71.00 %). Lowest germination per cent was recorded by $T_2$ (59.34 %) which was lower than that of control (60.33 %).

**Ambient storage**

Significant difference was observed among treatments from second month to 12 month of storage period. Germination per cent declined gradually with the advancement of storage period. All treatments maintained IMSCS (Indian Minimum Seed Certification Standards) of 65 per cent up to tenth months of storage. $T_4$ (Polykote (5ml) + *Trichoderma viridae* (4g per kg of seed) showed IMSCS germination per cent (64 per cent) during tenth month of storage. At the end of storage period *i.e.* on 12th month, $T_2$ (Polykote (10ml) + *Trichoderma viridae* (4 g per kg of seed) recorded highest germination per cent (72 per cent) which was on par with $T_1$ (71.33 %) and $T_3$ (67.00 %). Lowest germination per cent was recorded by $T_4$ (57.00 %) and control (56.33 %).

When comparing cold and ambient storage, there is no significant difference observed in seed germination up to eight months of storage. During tenth and twelfth months, seed germination was higher in cold storage. In cold storage, treatments showed germination per cent below IMSCS (Indian Minimum Seed Certification Standards) of 65 per cent only at twelfth month of storage but in ambient storage, $T_4$ (Polykote (5ml) + *Trichoderma viridae* (4 g per kg of seed) reached seed germination of 64 per cent at tenth month of storage. According to Dhatt (2018), after 12 months of seed storage, per cent germination of seeds in ornamental plant *Nemesia strumosa* was maximum for those stored under cold condition. Maximum seed viability (30.5%) was recorded in cold storage, followed by ambient storage (26.1%) for 18 months.

Higher percentage of germination was observed during the initial months of storage in both cold and ambient condition. In storage, germination per cent declined with increase in storage period irrespective of treatment and storage condition, as reported by several pioneer workers, Dhiman (2010) in okra and in field crops such as wheat (Tiwari *et al.,* 2015), maize (Kaushik *et al.,* 2014) and cotton (Rathinivel, 2000). The rate of reduction in germination percent from the initial to final months of storage was slower in polymer coated seeds compared to untreated seeds. Similar results were reported by Kumari *et al.,* (2014) in chilli (2015). Study conducted by Reshma (2018) revealed that seeds treated with polykote (10ml) + carbendazim-mancozeb (2g) + bifenthrin (0.1%) per kg of seed recorded highest germination per cent (60.67%) at the end of storage period *viz.,* 16 months. Polymer along with plant protection chemicals were effective in seed quality enhancement. According to Vanagamudi *et al., (*2010), polymer film coating helps to improve the seed storage potential and it prolongs the shelf life of seed and retains the seed health during storage and also he reported that increase in germination of polymer coated seeds is due to its hydrophilic nature which improves the imbibition rate which in turn leading to the increased enzyme activity of cells accelerating biochemical reaction which aiding germination.

**4.2.3.Seedling shoot length (cm)**

**Cold storage**

Gradual decline in seedling shoot length with the advancement of storage period was observed. Significant difference was observed among treatments up to 12 months of storage period. It is non-significant only at fourth month of storage. At the end of storage period, $T_1$ (Polykote (10ml) + carbendazim- mancozeb (2g) + bifenthrin (0.1%) per kg of seed) recorded highest seedling shoot length (12.66 cm) followed by $T_2$ (9.33 cm) and $T_3$ (9.33 cm). Lowest shoot length was recorded in control (7.33 cm).

**Ambient storage**

Gradual decline in seedling shoot length with the advancement of storage period was observed. At the end of storage period, $T_1$ (Polykote (10ml) + carbendazim- mancozeb (2g) + bifenthrin (0.1%) per kg of seed) recorded highest seedling shoot length (12.66 cm) followed by T2 (11.66 cm) which was on par with T4 (10.66 cm) and T3 (10.00 cm).

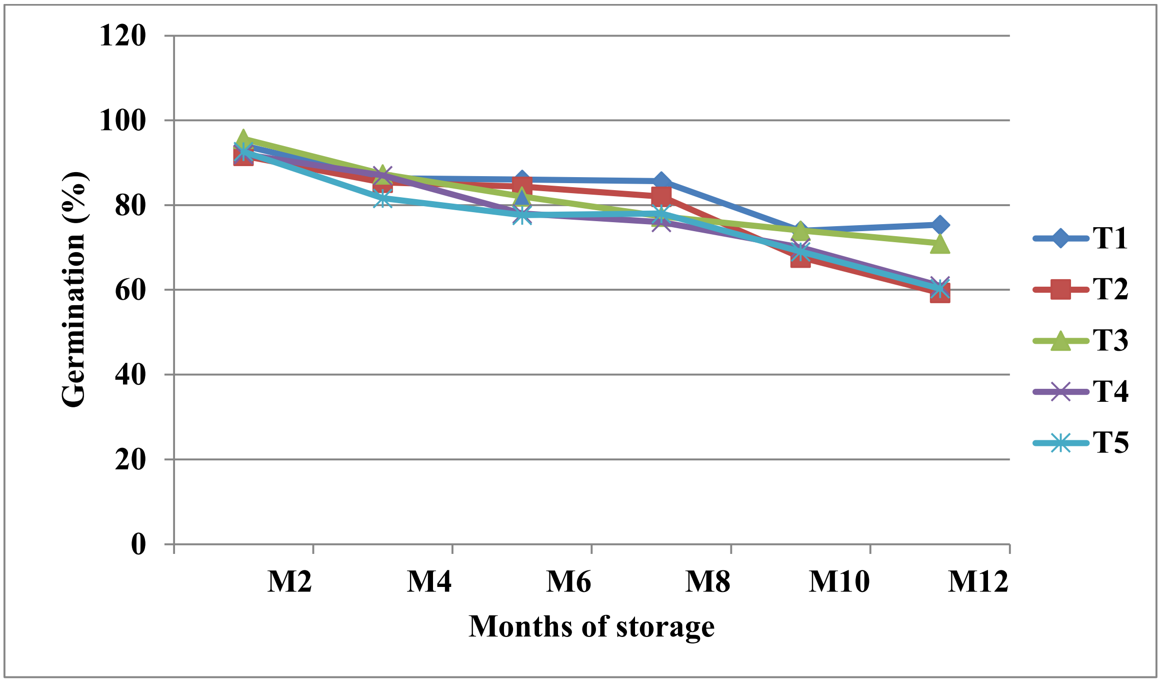
**Table 20: Effect of polymer coating on seed germination under cold storage**

| Treatments | | Germination (%) | | | | | |
|---|---|---|---|---|---|---|---|
| | | M2 | M4 | M6 | M8 | M10 | M12 |
| T1 | Polykote (10ml) + carbendazim- mancozeb (2g) + bifenthrin (0.1%) per kg of seed | $94.03^{ab}$ | $86.33^{a}$ | $86.00^{a}$ | $85.66^{a}$ | $74.00^{a}$ | $75.33^{a}$ |
| T2 | Polykote (10ml)+ *Trichoderma viridae* (4 g per kg of seed) | $91.66^{b}$ | $85.33^{a}$ | $84.33^{ab}$ | $82.00^{b}$ | $67.66^{b}$ | $59.34^{c}$ |
| T3 | Polykote (5ml) + carbendazim- mancozeb (2g) + bifenthrin (0.1%) per kg of seed | $95.66^{a}$ | $87.33^{a}$ | $82.00^{b}$ | $77.33^{c}$ | $74.00^{a}$ | $71.00^{b}$ |
| T4 | Polykote (5ml) + *Trichoderma viridae* (4 g per kg of seed ) | $92.00^{b}$ | $87.00^{a}$ | $78.00^{c}$ | $76.00^{c}$ | $70.00^{ab}$ | $61.00^{c}$ |
| T5 | Untreated control | $92.66^{b}$ | $81.66^{b}$ | $77.66^{c}$ | $78.00^{c}$ | $69.00^{b}$ | $60.33^{c}$ |
| | CD (0.05) | 2.48* | 2.97* | 2.39** | 2.25** | 4.48* | 2.58** |
| | SEm | 1.11 | 1.33 | 1.07 | 1.01 | 2.00 | 0.81 |

**Table 21: Effect of polymer coating on seedling shoot length under cold storage**

| Treatments | | Seedling shoot length (cm) | | | | | |
|---|---|---|---|---|---|---|---|
| | | M2 | M4 | M6 | M8 | M10 | M12 |
| T1 | Polykote (10ml) + carbendazim- mancozeb (2g) + bifenthrin (0.1%) per kg of seed | $21.05^{bc}$ | 19.73 | $16.56^{b}$ | $14.50^{a}$ | $11.66^{a}$ | $12.66^{a}$ |
| T2 | Polykote (10ml)+ *Trichoderma viridae* (4 g per kg of seed) | $21.51^{ab}$ | 19.00 | $16.16b^{c}$ | $13.00^{b}$ | $10.00^{b}$ | $9.33^{b}$ |
| T3 | Polykote (5ml) + carbendazim- mancozeb (2g) + bifenthrin (0.1%) per kg of seed | $22.06^{a}$ | 19.71 | $19.60^{a}$ | $15.30^{a}$ | $12.30^{a}$ | $9.33^{b}$ |
| T4 | Polykote (5ml) + *Trichoderma viridae* (4 g per kg of seed ) | $20.35^{c}$ | 18.80 | $15.73^{bc}$ | $12.30^{bc}$ | $9.66^{b}$ | $8.33^{c}$ |
| T5 | Untreated control | $21.8^{ab}$ | 19.36 | $15.33^{c}$ | $11.33^{c}$ | $9.33^{b}$ | $7.33^{c}$ |
| | CD (0.05) | 0.973 | NS | 1.47** | 1.73** | 2.11** | 2.21** |
| | SEm | 0.48 | 1.08 | 1.33 | 1.19 | 0.87 | 0.63 |

**Fig 5: Effect of polymer coating on seed germination in okra (Cold storage)**




**T1 :** Polykote (10ml) + Carbendazim-Mancozeb (2g) + Bifenthrin (0.1%) per kg of seed

**T2 :** Polykote (10ml)+ *Trichoderma viridae* (4 g per kg of seed)

**T3 :** Polykote (5ml) + Carbendazim-Mancozeb (2g) + Bifenthrin (0.1% ) per kg of seed

**T4 :** Polykote (5ml) + *Trichoderma viridae* (4 g per kg of seed )

**T5 :** Untreated control

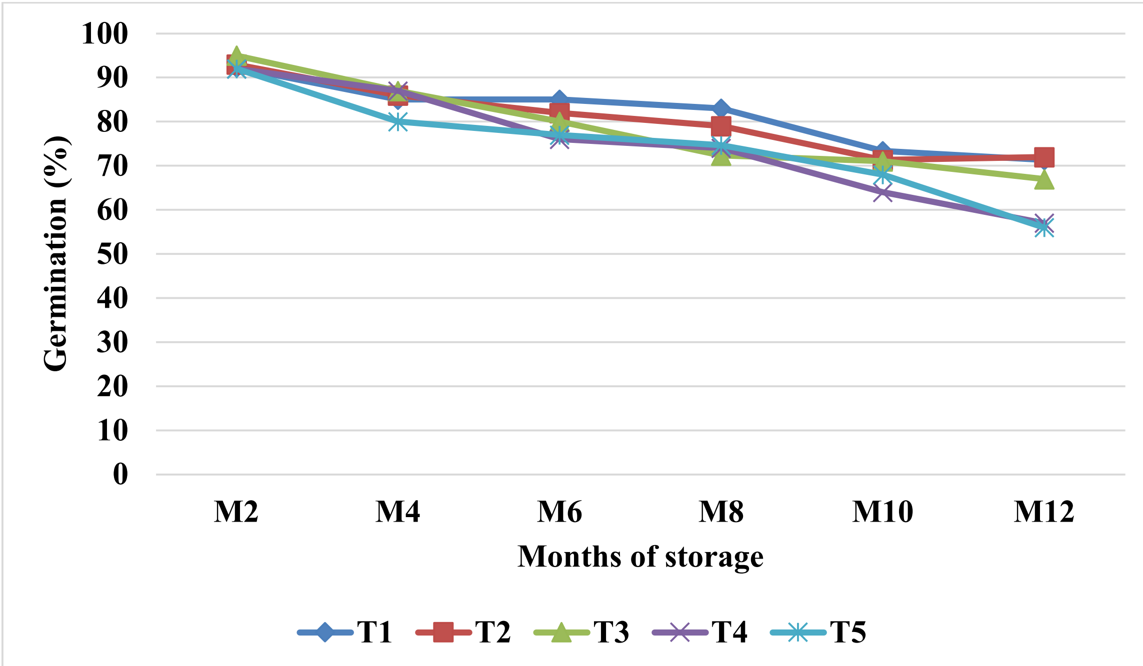
**Table 22: Effect of polymer coating on seed germination under ambient storage**

| Treatments | | Germination (%) | | | | | |
|---|---|---|---|---|---|---|---|
| | | M2 | M4 | M6 | M8 | M10 | M12 |
| $T_1$ | **Polykote (10ml) + carbendazim- mancozeb (2g) + bifenthrin (0.1%) per kg of seed** | $92.33^{bc}$ | $85.00^{d}$ | $85.00^{a}$ | $83.00^{a}$ | $73.33^{a}$ | $71.33^{a}$ |
| $T_2$ | **Polykote (10ml)+ *Trichoderma viridae* (4 g per kg of seed)** | $93.00^{b}$ | $86.00^{c}$ | $82.00^{b}$ | $79.00^{b}$ | $71.33^{b}$ | $72.00^{a}$ |
| $T_3$ | **Polykote (5ml) + carbendazim- mancozeb (2g) + bifenthrin (0.1% ) per kg of seed** | $95.00^{a}$ | $87.00^{b}$ | $80.33^{c}$ | $72.33^{e}$ | $71.00^{b}$ | $67.00^{a}$ |
| $T_4$ | **Polykote (5ml) + *Trichoderma viridae* (4 g per kg of seed )** | $91.00^{c}$ | $87.66^{a}$ | $76.33^{e}$ | $74.00^{d}$ | $64.00^{b}$ | $57.00^{b}$ |
| $T_5$ | **Untreated control** | $92.33^{bc}$ | $80.00^{e}$ | $77.00^{d}$ | $74.66^{c}$ | $68.67^{c}$ | $56.33^{b}$ |
| | **CD (0.05)** | 1.93 | 0.66** | 0.94** | 0.945** | 1.76** | 3.32** |
| | **SEm** | 0.86 | 0.66 | 0.29 | 0.29 | 0.55 | 4.20 |

**Table 23: Effect of polymer coating on seedling shoot length under ambient storage**

| Treatments | | Seedling shoot length (cm) | | | | | |
|---|---|---|---|---|---|---|---|
| | | M2 | M4 | M6 | M8 | M10 | M12 |
| $T_1$ | **Polykote (10ml) + carbendazim- mancozeb (2g) + bifenthrin (0.1%) per kg of seed** | $21.05^{bc}$ | 19.73 | $16.56^{b}$ | $14.50^{a}$ | $11.66^{a}$ | $12.66^{a}$ |
| $T_2$ | **Polykote (10ml)+ *Trichoderma viridae* (4 g per kg of seed)** | $21.51^{ab}$ | 19.00 | 16.16b$^{c}$ | $13.00^{b}$ | $10.00^{b}$ | $9.33^{b}$ |
| $T_3$ | **Polykote (5ml) + carbendazim- mancozeb (2g) + Bifenthrin (0.1%) per kg of seed** | $22.06^{a}$ | 19.71 | $19.60^{a}$ | $15.30^{a}$ | $12.30^{a}$ | $9.33^{b}$ |
| $T_4$ | **Polykote (5ml) + *Trichoderma viridae* (4 g per kg of seed )** | $20.35^{c}$ | 18.80 | $15.73^{bc}$ | $12.30^{bc}$ | $9.66^{b}$ | $8.33^{c}$ |
| $T_5$ | **Untreated control** | $21.8^{ab}$ | 19.36 | $15.33^{c}$ | $11.33^{c}$ | $9.33^{b}$ | $7.33^{c}$ |
| | **CD (0.05)** | 0.973 | NS | 1.47** | 1.73** | 2.11** | 2.21** |
| | **SEm** | 0.48 | 1.08 | 1.33 | 1.19 | 0.87 | 0.63 |

**Fig 6: Effect of polymer coating on seed germination in okra (Ambient storage)**




**$T_1$ :** Polykote (10ml) + Carbendazim-Mancozeb (2g) + Bifenthrin (0.1%) per kg of seed

**$T_2$ :** Polykote (10ml)+ *Trichoderma viridae* (4 g per kg of seed)

**$T_3$ :** Polykote (5ml) + Carbendazim-Mancozeb (2g) + Bifenthrin (0.1% ) per kg of seed

**$T_4$ :** Polykote (5ml) + *Trichoderma viridae* (4 g per kg of seed )

**$T_5$ :** Untreated control

### 4.2.4. Seedling root length (cm)

**Cold storage**

Gradual decline in seedling root length with the advancement of storage period was observed. Significant difference was observed among treatments only from eighth month onwards. At the end of storage period *viz.,* on 12th month, $T_1$ (Polykote (10ml) + carbendazim- mancozeb (2g) + bifenthrin (0.1%) per kg of seed) recorded highest seedling root length (6.30 cm) followed by $T_3$ (5.16 cm). The lowest seedling root length was recorded by control (3.66 cm).

**Ambient storage**

Significant difference was observed among treatments up to 12 month of storage period in seedling root length. Gradual decline in seedling root length with the advancement of storage period was observed irrespective of treatments. At the end of storage period, $T_1$ (Polykote (10ml) + carbendazim- mancozeb (2g) + bifenthrin (0.1%) per kg of seed) recorded the highest seedling root length (5.53 cm) and lowest was recorded by control (2.66 cm).

A gradual decline in seedling shoot and root length was observed with the advancement of storage period. This might be due to reduction in seed vigour and also due to increased number of abnormal seedlings over the storage period. Similar results were reported by Navya (2016) in chilli and Antony (2015) in cowpea. Reshma (2018) reported that polykote (10ml) recorded highest shoot length (14.45 cm) and polykote (10ml) + carbendazim- mancozeb (2g) + bifenthrin (0.1%) per kg of seed recorded highest root length (4.67) at 16 months of storage period.

There is no significant difference observed between cold and ambient storage condition among treatments in the case of seedling shoot and root length.

**Table 24: Effect of polymer coating on seedling root length under cold storage**

| Treatments | | Seedling root length (cm) | | | | | |
|---|---|---|---|---|---|---|---|
| | | M2 | M4 | M6 | M8 | M10 | M12 |
| $T_1$ | Polykote (10ml) + carbendazim- mancozeb (2g) + bifenthrin (0.1%) per kg of seed | 10.66 | 7.66 | 8.66 | $6.53^{a}$ | $6.66^{a}$ | $6.30^{a}$ |
| $T_2$ | Polykote (10ml)+ *Trichoderma viridae* (4 g per kg of seed) | 8.00 | 8.66 | 8.33 | $5.80^{ab}$ | $4.40^{b}$ | $4.26^{c}$ |
| $T_3$ | Polykote (5ml) + carbendazim- mancozeb (2g) + bifenthrin (0.1% ) per kg of seed | 10.66 | 11.33 | 6.33 | $6.46^{a}$ | $5.00^{b}$ | $5.16^{b}$ |
| $T_4$ | Polykote (5ml) + *Trichoderma viridae* (4 g per kg of seed ) | 12.00 | 6.33 | 7.00 | $5.46^{ab}$ | $4.73^{b}$ | $4.36^{c}$ |
| $T_5$ | Untreated control | 11.33 | 6.66 | 6.00 | $5.00^{b}$ | $4.33^{b}$ | $3.66^{c}$ |
| | CD (0.05) | NS | NS | NS | 1.09 | 1.25 | 1.03** |
| | SEm | 2.93 | 2.08 | 1.15 | 0.48 | 0.56 | 0.32 |

**Table 25: Effect of polymer coating on seedling dry weight under cold storage**

| Treatments | | Seedling dry weight (g) | | | | | |
|---|---|---|---|---|---|---|---|
| | | M2 | M4 | M6 | M8 | M10 | M12 |
| $T_1$ | Polykote (10ml) + carbendazim- mancozeb (2g) + bifenthrin (0.1%) per kg of seed | $0.038^{a}$ | 0.032 | $0.033^{a}$ | 0.028 | $0.032^{a}$ | $0.030^{a}$ |
| $T_2$ | Polykote (10ml)+ *Trichoderma viridae* (4 g per kg of seed) | $0.035^{ab}$ | 0.029 | $0.032^{a}$ | 0.027 | $0.027^{b}$ | $0.027^{a}$ |
| $T_3$ | Polykote (5ml) + carbendazim- mancozeb (2g) + bifenthrin (0.1% ) per kg of seed | $0.033^{bc}$ | 0.029 | $0.029^{b}$ | 0.025 | $0.028^{b}$ | $0.022^{b}$ |
| $T_4$ | Polykote (5ml) + *Trichoderma viridae* (4 g per kg of seed ) | $0.035^{ab}$ | 0.029 | $0.029^{b}$ | 0.028 | $0.022^{c}$ | $0.022^{b}$ |
| $T_5$ | Untreated control | $0.031^{c}$ | 0.029 | $0.028^{b}$ | 0.027 | $0.022^{c}$ | $0.021^{b}$ |
| | CD (0.05) | 0.004** | NS | 0.003 | 0.003 | 0.004 | 0.004 |
| | SEm | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

**Table 26: Effect of polymer coating on seedling root length under ambient storage**

| Treatments | | Seedling root length (cm) | | | | | |
|---|---|---|---|---|---|---|---|
| | | M2 | M4 | M6 | M8 | M10 | M12 |
| $T_1$ | Polykote (10ml) + carbendazim- mancozeb (2g) + bifenthrin (0.1%) per kg of seed | $13.66^{a}$ | $11.66^{a}$ | 9.66 | 6.33 | 5.83 | $5.53^{a}$ |
| $T_2$ | Polykote (10ml)+ *Trichoderma viridae* (4 g per kg of seed) | $6.33^{c}$ | $7.00^{b}$ | 6.33 | 5.66 | 4.16 | $3.80^{b}$ |
| $T_3$ | Polykote (5ml) + carbendazim- mancozeb (2g) + bifenthrin (0.1% ) per kg of seed | $8.66^{bc}$ | $7.66^{b}$ | 6.00 | 5.33 | 4.66 | $3.66^{b}$ |
| $T_4$ | Polykote (5ml) + *Trichoderma viridae* (4 g per kg of seed ) | $8.00^{bc}$ | $7.00^{b}$ | 5.66 | 4.66 | 4.33 | $3.00^{b}$ |
| $T_5$ | Untreated control | $10.66^{ab}$ | $7.00^{b}$ | 4.66 | 4.33 | 4.00 | $2.66^{b}$ |
| | CD (0.05) | 4.38** | 3.008 | 2.67** | NS | NS | 1.50 |
| | SEm | 1.38 | 1.34 | 0.84 | 0.69 | 0.66 | 0.67 |

**Table 27: Effect of polymer coating on seedling dry weight under ambient storage**

| Treatments | | Seedling dry weight (g) | | | | | |
|---|---|---|---|---|---|---|---|
| | | M2 | M4 | M6 | M8 | M10 | M12 |
| $T_1$ | Polykote (10ml) + carbendazim- mancozeb (2g) + bifenthrin (0.1%) per kg of seed | 0.032 | 0.032 | $0.032^{a}$ | $0.030^{a}$ | $0.027^{a}$ | 0.024 |
| $T_2$ | Polykote (10ml)+ *Trichoderma viridae* (4 g per kg of seed) | 0.029 | 0.029 | $0.027^{b}$ | $0.027^{a}$ | $0.022^{b}$ | 0.021 |
| $T_3$ | Polykote (5ml) + carbendazim- mancozeb (2g) + bifenthrin (0.1% ) per kg of seed | 0.029 | 0.029 | $0.028^{b}$ | $0.022^{b}$ | $0.022^{b}$ | 0.021 |
| $T_4$ | Polykote (5ml) + *Trichoderma viridae* (4 g per kg of seed ) | 0.029 | 0.032 | $0.022^{c}$ | $0.022^{b}$ | $0.021^{b}$ | 0.020 |
| $T_5$ | Untreated control | 0.029 | 0.027 | $0.022^{c}$ | $0.021^{b}$ | $0.020^{b}$ | 0.020 |
| | CD (0.05) | NS | NS | 0.004 | 0.004 | 0.004 | NS |
| | SEm | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

### 4.2.5. Seedling dry weight (g)

**Cold storage**

Gradual decline in seedling dry weight with the advancement of storage period was observed. At the end of storage period, $T_1$ (Polykote (10ml) + carbendazim- mancozeb (2g) + bifenthrin (0.1%) per kg of seed) recorded highest seedling dry weight (0.030 g) which was on par with $T_2$ (Polykote (10ml)+ *Trichoderma viridae* (4 g per kg of seed) which is 0.027g.

**Ambient storage**

Gradual decline in seedling dry weight with the advancement of storage period was observed. There is no significant difference observed among treatments at the end of storage period *viz.,* 12 month in seedling dry weight.

Seeds treated with polymer, fungicide and insecticide showed higher seedling dry weight which indicated that there is a positive effect of seed coating polymer on seedling dry weight. These results agree with the findings of Vijayalakshmi *et al.,* (2013) and Rajeshwari *et al.,* (2017) in rice. Reshma (2018) reported that polykote (10ml) + carbendazim- mancozeb (2g) + bifenthrin (0.1%) per kg of seed recorded highest seedling dry weight (0.016 g) at $16^{th}$ month of storage period.

There is no significant difference observed between cold and ambient storage condition among treatments in the case of seedling dry weight from fourth month to 12 month of storage.

### 4.2.6. Electrical conductivity

Irrespective of treatments the electrical conductivity of seed leachate was found to increase gradually with the advancement of storage period. From the table 28 and 29, it is evident that, treated seeds had lower values for electrical conductivity compared to control. Untreated seeds exhibited highest value.

**Cold storage**

At the end of storage period, T1 (Polykote (10ml) + carbendazim- mancozeb (2g) + bifenthrin (0.1%) per kg of seed) recorded lowest value (315.00 µS/m) and highest value was recorded by control (585 µS/m).

Reshma (2018) reported that untreated control and seeds treated with polykote (10ml) + *T. viridae* (4g) recorded highest value (398.33 and 426.00 µS/m) for EC of seed leachate at 16$^{th}$ month of storage where as polykote (10ml) + carbendazim- mancozeb (2g) + bifenthrin (0.1%) per kg of seed least value (324.97 µS/m) for this parameter.

**Ambient storage**

There is no significant difference observed among treatments at the end of storage period *viz.,* 12 month in EC of seed leachate.

There exist a significant difference between between cold and ambient storage condition among treatments in EC of seed leachate through out the storage period. Treatments in cold storage recorded least value for this parameter when compared to ambient storage condition. The seeds stored under cold storage condition recorded lower electrical conductivity (0.545 $dSm^{-1}$) compared to the seeds stored under ambient condition 0.558 $dSm^{-1}$) at the end of 12 months of storage in onion seeds (Nagaveni, 2005).

The electrical conductivity of seed leachate increased with the advancement in storage period. The untreated control observed the highest value for this parameter. This may be due to higher incidence of fungi which can destroy the membrane texture in seeds which is stored with out any prestorage chemical treatments. Similar result were reported by Basavaraj and Rai (2016) in chilli.

### 4.2.7. Seed microflora

Seed infection by microflora increased as the storage period advanced (Table 30 and 31). Presence of storage fungi on seeds was observed in all treatments.

In both methods the untreated control showed high percentage of infection compared to other treatment. While comparing cold and ambient storage, the percentage of infection was more in ambient storage

#### 4.2.7.1. Blotter method

In case of cold storage, $T_1$ (Polykote (10ml) + carbendazim- mancozeb (2g) + bifenthrin (0.1%) per kg of seed) shows less infection (14.77 per cent) where as in case of ambient storage $T_2$ shows less infection (16.32 per cent).

#### 4.2.7.2. Agar method

In case of cold storage as well as in ambient storage, $T_1$ (Polykote (10ml) + carbendazim- mancozeb (2g) + bifenthrin (0.1%) per kg of seed) shows less infection in both cold (16.32 per cent) and ambient storage (26.31 per cent).

Incidence of storage pathogen increases with advancement of storage period. Storage fungi invasion can cause loss of viability and discoloration of seed. In the present study, it was found that pathogen infection less in seeds treated with polymer along with insecticides and fungicides when compared to untreated control. This might be due to the treatment effect of polymer and fungicide which act as a barrier absorption of moisture as well as infection by various fungi.

**Table 28: Effect of polymer coating on EC of seed leachate under cold storage**

| Treatments | | Electrical conductivity of seed leachate ($\mu Sm^{-1}$) | | | | | |
|---|---|---|---|---|---|---|---|
| | | M2 | M4 | M6 | M8 | M10 | M12 |
| $T_1$ | **Polykote (10ml) + carbendazim- mancozeb (2g) + bifenthrin (0.1%) per kg of seed** | 113.50$^{bc}$ | 155.66 | 181.00 | 255.33 | 252.66 | 315.00$^{b}$ |
| $T_2$ | **Polykote (10ml)+ *Trichoderma viridae* (4 g per kg of seed)** | 111.86$^{c}$ | 136.66 | 208.33 | 310.66 | 379.00 | 518.33$^{a}$ |
| $T_3$ | **Polykote (5ml) + carbendazim- mancozeb (2g) + bifenthrin (0.1% ) per kg of seed** | 114.60$^{ab}$ | 140.33 | 156.33 | 303.33 | 400.66 | 460.00$^{ab}$ |
| $T_4$ | **Polykote (5ml) + *Trichoderma viridae* (4 g per kg of seed )** | 112.06$^{c}$ | 135.66 | 181.33 | 293.00 | 324.66 | 496.00$^{a}$ |
| $T_5$ | **Untreated control** | 116.50$^{a}$ | 156.66 | 254.33 | 336.66 | 430.33 | 585.00$^{a}$ |
| | **CD (0.05)** | 3.370** | NS | NS | NS | NS | 7.48 |
| | **SEm** | 1.06 | 84.15 | 84.15 | 8.24 | 30.30 | 70.60 |

**Table 29: Effect of polymer coating on EC of seed leachate under ambient storage**

| Treatments | | Electrical conductivity of seed leachate ($\mu Sm^{-1}$) | | | | | |
|---|---|---|---|---|---|---|---|
| | | M2 | M4 | M6 | M8 | M10 | M12 |
| $T_1$ | **Polykote (10ml) + carbendazim- mancozeb (2g) + bifenthrin (0.1%) per kg of seed** | 108.00$^{c}$ | 132.33 | 159.66$^{b}$ | 240.66$^{b}$ | 411.66$^{b}$ | 574.66 |
| $T_2$ | **Polykote (10ml)+ *Trichoderma viridae* (4 g per kg of seed)** | 125.00$^{bc}$ | 214.00 | 306.33$^{a}$ | 461.66$^{a}$ | 536.33$^{a}$ | 595.33 |
| $T_3$ | **Polykote (5ml) + carbendazim- mancozeb (2g) + bifenthrin (0.1% ) per kg of seed** | 143.66$^{ab}$ | 222.66 | 339.66$^{a}$ | 429.66$^{a}$ | 518.33$^{a}$ | 621.33 |
| $T_4$ | **Polykote (5ml) + *Trichoderma viridae* (4 g per kg of seed )** | 128.00$^{bc}$ | 226.00 | 321.33$^{a}$ | 433.33$^{a}$ | 415.66$^{b}$ | 581.33 |
| $T_5$ | **Untreated control** | 169.00$^{a}$ | 251.33 | 354.33$^{a}$ | 525.33$^{a}$ | 518.33$^{a}$ | 626.00 |
| | **CD (0.05)** | 36.061 | NS | 95.41 | 71.90 | 73.57 | NS |
| | **SEm** | 15.71 | 72.51 | 43.39 | 54.24 | 33.01 | 26.90 |

* - Significant at 5% level of significance ; ** - Significant at 1% level of significance.

**Table 30: Effect of polymer coating on seed microflora at the end of storage period under cold storage**

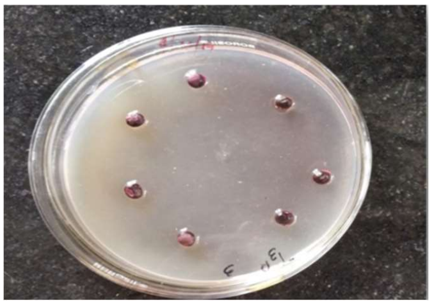
| Treatments | Seed infection (%) | |
|---|---|---|
| | Blotter method | Agar method |
| **Polykote (10ml) + carbendazim-mancozeb (2g) + bifenthrin (0.1%) per kg of seed** | 14.77 | 28.55 |
| **Polykote (10ml)+ *Trichoderma viridae* (4 g per kg of seed)** | 15.78 | 31.55 |
| **Polykote (5ml) + carbendazim-mancozeb (2g) + bifenthrin (0.1% ) per kg of seed** | 17.11 | 28.99 |
| **Polykote (5ml) + *Trichoderma viridae* (4 g per kg of seed )** | 17.29 | 34.21 |
| **Untreated control** | 32.11 | 46.22 |

**Table 31: Effect of polymer coating on seed microflora at the end of storage period under ambient storage**

| Treatments | Seed infection (%) | |
|---|---|---|
| | Blotter method | Agar method |
| **Polykote (10ml) + carbendazim-mancozeb (2g) + bifenthrin (0.1%) per kg of seed** | 16.32 | 26.31 |
| **Polykote (10ml)+ *Trichoderma viridae* (4 g per kg of seed)** | 15.93 | 31.22 |
| **Polykote (5ml) + carbendazim-mancozeb (2g) + bifenthrin (0.1% ) per kg of seed** | 21.11 | 32.11 |
| **Polykote (5ml) + *Trichoderma viridae* (4 g per kg of seed )** | 19.46 | 29.46 |
| **Untreated control** | 35.2 | 47.33 |

**Plate 8: Seed microflora**

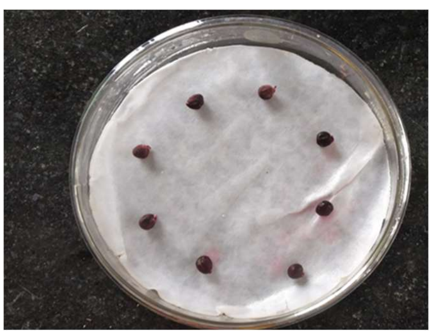
**Agar method**



Before incubation

After incubation

**Blotter method**



Before incubation

After incubation

# Summary

# 5. SUMMARY

An experiment entitled "Precision farming techniques for quality seed production in okra (*Abelmoschus esculentus* (L) Moench) was carried out at the Centre for High-tech Horticulture and Precision Farming, Vellanikkara during January to April, 2019 to standardize the fertigation schedule for okra and to access the effect of precision farming techniques on growth and seed yield and quality of okra. The salient findings of the study are summarized below:

**I. Precision farming techniques**

- Different levels of irrigation and fertigation significantly influenced most of the growth, fruit and seed yield characters in okra. The growth parameters, fruit and seed characters of the crop in all the drip fertigation treatments were significantly superior to control.
- Between the different levels of irrigation, $I_1$ (irrigation at 75% EP) showed significant increase in plant height (79.23 cm), height of the first bearing node (14.40 cm), LAI (1.01) and fruit set (70.33%) when compared to $I_2$ (100% EP). $I_1$ also registered earlier flowering (48.89 days) when compared to $I_2$ (53.33 days).
- No significant difference was exerted by different levels of fertigation on characters *viz.,* plant height, LAI, days to 50% flowering and fruit set. However, in the case of first bearing node, $F_1$ (Fertigation at 75% RDF) recorded higher value (15.21 cm) followed by $F_3$ (13.90 cm) was superior to $F_2$ (12.95 cm).
- Among the interaction effect of different levels of irrigation and fertigation, $I_1F_1$ (Irrigation at 75% EP and fertigation at 75% RDF) exhibited significant superiority over other treatments with respect to plant height (84.40 cm), height of the first bearing node (17.55 cm), LAI (0.80) and fruit set (73.00%).

Early flowering (47.33days for 50% flowering) was also observed in this treatment.

- Fruit characters like fruit length and girth were not influenced by different levels of irrigation and fertigation as well as their interaction effect. However, $I_1$ (Irrigation at 75% EP) showed significant increase in fruit weight (8.09 g), mature fruit yield (116.49 g) and number of fruits (25.67g) when compared to $I_2$ (Irrigation at 100% EP). Mature fruit weight (8.20 g & 8.09 g) and number of fruits (24.19 & 22.98) were on par in $F_1$ and $F_2$.
- Among the interaction effect of different levels of irrigation and fertigation, $I_1F_1$ (Irrigation at 75% EP and fertigation at 75% RDF) showed superior performance in mature fruit weight (9.10g), mature fruit yield/plant (154.85g) and number of fruits/plant (30.91).
- Among the seed characters, $I_1$ (Irrigation at 75% EP) significantly increased number of seeds/fruit (43.90), seed yield/plant (71.86) when compared to $I_2$ (Irrigation at 100% EP). But seedling vigour index was significantly higher in $I_2$ (2504) compared to $I_1$ (2424). However, characters like seed weight/fruit, 100 seed weight, 100 seed volume, germination, moisture content, hard seed content and seedling shoot length were not affected by irrigation levels.
- Among the fertigation levels, seed germination and seedling vigour index was highest in $F_1$ (93.33 % and 2914) while $F_2$ showed increased number of seeds/fruit (42.87) whereas $F_3$ showed increased 100 seed weight (6.70g), seedling shoot length (22.68 cm) and low hard seed content (8.48%). Seed weight and seed yield were not influenced by fertigation levels.
- Significant interaction effect of irrigation and fertigation levels were evident in number of seeds/fruit, 100 seed weight, seed germination and seedling root length. $I_1F_1$ was found to be significantly superior for most seed traits studied. But seedling vigour index was significantly higher in $I_2F_1$ (2947).

## II. Seed storage studies

- With the advancement of storage period, germination declined irrespective of the treatments in both the storage conditions. Throughout the storage period, performance of treated seeds was found to be superior over control. At the end of twelve months of storage, higher seed germination was recorded in seeds treated with polykote (10ml) +carbendazim- mancozeb (2g) + bifenthrin (0.1%) both under cold (75.33%) and ambient (71.33%) conditions. Lower seed germination was recorded in untreated control (60.33 per cent under cold storage and 56.33 under ambient storage).
- Both seedling shoot length and root length were significantly higher in treatment with polykote (10ml) +carbendazim- mancozeb (2g) + bifenthrin (0.1%) both under cold and ambient conditions. Seedling dry weight was also significantly higher in the same treatment in the cold storage while in the ambient condition, there was no significant difference among the treatments.
- The EC of seed leachate also showed the same trend with very low value for polykote (10ml) +carbendazim- mancozeb (2g) + bifenthrin (0.1%). Seed microflora was also very low (14.77 in blotter method and 26.31 in agar plate method) in polykote (10ml) +carbendazim- mancozeb (2g) + bifenthrin (0.1%) in both cold and ambient conditions.

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# PRECISION FARMING TECHNIQUES FOR QUALITY SEED PRODUCTION IN OKRA (*Abelmoschus esculentus* (L) Moench)


**By**

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## ABSTRACT OF THE THESIS

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## ABSTRACT

Quality seeds of okra, a popular vegetable crop in Kerala, are in great demand. An experiment was conducted during the period from January to April 2019 at the Centre for High-tech Horticulture and Precision Farming, Vellanikkara, to study the effect of precision farming techniques on growth, fruit and seed yield of okra. The field experiment was laid out in a Randomized Block Design (RBD) with 7 treatments which included two levels of irrigation *viz*., $I_1$- Drip irrigation at 75% evapo-transpiration (EP) and $I_2$- Drip irrigation at 100% EP and three levels of Fertigation *viz*., $F_1$: 75% RDF (recommended dose of fertilizer), $F_2$:100% RDF and $F_3$:125% RDF. Fertilizer doses as per POP recommendation for the crop *i.e.,* 110:35:70 kg NPK/ ha was adjusted based on soil test data. Drip irrigation was given daily based on PAN evaporation data while fertigation was administered twice a week. All the drip fertigation plots were mulched with 30 μ silver polythene film. A plot that was administered flood irrigation along with soil application of fertilizer as per POP fixed, vide soil test data, served as the control.

The growth parameters of the crop in all the drip fertigation treatments were significantly superior to control. $I_1F_1$ exhibited significant superiority over other treatments with respect to plant height (84.40 cm), height of the first bearing node (17.55 cm), LAI (1.19) and fruit set (73.00%). Early flowering (47.33days) was also observed in this treatment. Between the different levels of irrigation, $I_1$ (irrigation at 75% EP) showed significant increase in plant height (79.23 cm), height of the first bearing node (14.40 cm), LAI (1.01) and fruit set (70.33%) when compared to $I_2$ (100% EP). $I_1$ also registered earlier flowering (48.89 days) when compared to $I_2$ (53.33 days). However, LAI was not influenced by different levels of irrigation. No significant difference was exerted by different levels of fertigation on characters like plant height, LAI, days to 50% flowering and fruit set. However, in the case of first bearing node, $F_1$ (15.21 cm) followed by $F_3$ (13.90 cm) was superior to $F_2$ (12.95 cm).

Significant interaction effect of irrigation and fertigation levels was evident with respect to LAI and fruit set.

Fruit characters like length, girth, weight, mature fruit yield per plant and number of mature fruits per plant were significantly superior in drip fertigation treatments compared to control. Except $I_2F_3$, all other fertigation treatment produced significantly thicker fruits than the control (1.90 cm). Mature fruit weight was significantly high in treatments $1_1F_1$ (9.10 g) and $I_1F_2$ (8.59 g), followed by $I_2F_2$ (7.60g). However, mature fruit yield (154.85 g) and number of mature fruits (30.91) were significantly high in $I_1F_1$. Fruit characters like fruit length and girth were not influenced by different levels of irrigation and fertigation as well as their interaction effect. However, $I_1$ showed significant increase in fruit weight (8.09 g), mature fruit yield (116.49 g) and number of fruits (25.67g) when compared to $I_2$. Mature fruit weight (8.20 g & 8.09 g) and number of fruits (24.19 & 22.98) were on par in $F_1$ and $F_2$. Among the interactions, $I_1F_1$ showed superior performance in fruit weight, mature fruit yield/plant and number of fruits/plant.

With respect to seed characters like number of seeds per fruit, seed weight /fruit, seed yield per plant, 100 seed weight, seed germination and seedling vigour index, the drip fertigation treatments were significantly superior to control. Between the irrigation levels, $I_1$ significantly increased number of seeds/fruit, seed yield/plant and seedling root length when compared to $I_2$. But seedling vigour index was significantly higher in $I_2$ (2504) compared to $I_1$ (2424). However, characters like seed weight/fruit, 100 seed weight, 100 seed volume, germination, moisture content, hard seed content and seedling shoot length were not affected by irrigation levels. Among the fertigation levels, seed germination and seedling vigour index was highest in $F_1$ (93.33 % and 2914) while $F_2$ showed increased number of seeds/fruit (42.87) whereas $F_3$ showed increased 100 seed weight (6.70g), seedling shoot length (22.68 cm) and low hard seed content (8.48%). Seed weight and seed yield were not influence by fertigation levels. Significant interaction effect of irrigation and fertigation levels were evident in number of seeds/fruit, 100 seed weight, seed germination and seedling root length. $I_1F_1$ was found to be significantly superior for most seed traits studied. But seedling vigour index was significantly higher in $I_2F_1$ (2947).

Storage studies were conducted with seeds of okra variety, Arka Anamika procured from Centre for High-tech Horticulture and Precision Farming, Vellanikkara. The seeds were treated with polykote (synthetic polymer) @ 5 and 10 ml per kg of seed along with plant protection chemicals *viz.,* carbendazim-mancozeb (Saaf- 2g/kg of seed) and bifenthrin (0.1%) or biocontrol agent- *Trichoderma viridae* (4g/kg of seed). Untreated seeds served as control. The seeds were packed in 700 gauge polyethylene bags and stored under both cold (refrigerated) and ambient conditions and seed quality parameters assessed at bimonthly intervals.

With the advancement of storage period, germination declined irrespective of the treatments in both the storage conditions. Throughout the storage period, performance of treated seeds was found to be significantly superior over control. At the end of twelve months of storage, higher seed germination was recorded in seeds treated with polykote (10ml) + carbendazim- mancozeb (2g) + bifenthrin (0.1%) both under cold (75.33%) and ambient (71.33%) conditions. Lower values were recorded in untreated control (60.33 per cent under cold storage and 56.33 under ambient storage). Both seedling shoot length and root length were significantly higher in treatment with polykote (10ml) + carbendazim- mancozeb (2g) + bifenthrin (0.1%) both under cold and ambient conditions. Seedling dry weight was also significantly higher in the same treatment in the cold storage while in the ambient condition, there was no significant difference among the treatments. The EC of seed leachate and seed microflora also showed the same trend with very low value for polykote (10ml) +carbendazim- mancozeb (2g) + bifenthrin (0.1%) in both cold and ambient conditions.

From the study it can be concluded that drip irrigation at 75% EP and 75% of RDF along with mulch, is best for seed production in okra. Storage of seeds treated with polykote (10ml) + carbendazim- mancozeb (2g) + bifenthrin (0.1%) in cold is recommended to ensure minimum seed certification standards.