IMPACT OF FOLIAR APPLICATION OF NUTRIENTS AND GROWTH PROMOTERS ON SEED YIELD AND QUALITY OF OKRA

By

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THESIS

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DECLARATION

I, hereby declare that this thesis entitled **'Impact of foliar application of nutrients and plant growth promoters on seed yield and quality of okra,'** is a bonafide record of the research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

28/11/18

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Certified that this thesis entitled **'Impact of foliar application of nutrients and plant growth promoters on seed yield and quality of okra,'** is a bonafide record of the research work done independently by **Ms. Nishidha C.T.** 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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Nishidha C.T.

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LIST OF ABBREVIATIONS

%	- Per cent
μSm^{-1}	- micro Siemens per metre
^oC	- degree Celsius
AI	- Allometric index
ANOVA	- Analysis of varience
B	- Boron
C	- Control
C.D	- Critical difference
Ca	- Calcium
cm	- centimetre
CRD	- Completely Randomized Design
Cu	- Copper
cv	- Cultivar
DAS	- Days after sowing
EC	- Electrical conductivity
et al.	- Co-workers
Fe	- Iron
Fig.	- Figure
G	- Gauge
g	- gram
gcm^{-3}	- gram per cubic centimeter
H_3BO_3	- Borax
$HgCl_2$	- Mercuric chloride
ISTA	- International Seed Testing Association
KAU	- Kerala Agricultural University
KCl	- Potassium chloride
kg	- kilogram
KVK	- Krishi Vigyan Kendra

MAS	- Months after storage
Mg	- Magnesium
mg	- milligram
MgO	- Magnesium oxide
mm	- millimetre
MSCS	- Minimum Seed Certification Standards
MT	- Metric Tones
NS	- Non significant
O.D	- Optical Density
Pf	- *Pseudomonas fluorescens*
RBD	- Randomized Block Design
RH	- Relative humidity
S	- Sulphur
SA	- Salicylic acid
S_1	- Refrigeration storage
S_2	- Ambient storage
S_3	-Unshelled pods
SE (m)	- Mean sum of squares of error
Sp. and spp.	- Species (Singular and Plural)
SVM	- Sampoorna KAU vegetable multimix
T	- Treatments
t/ha	- Tonnes per hectare
US-EPA	- United States - Environmental Protection Agency
Var	- Variety
VI-I	- Vigour index I
VI-II	- Vigour index II
W	- Weight
WASP	- Web agricultural statistical package
Zn	- Zinc

ZnO	- Zinc oxide
$ZnSO_4$	- Zinc sulphate

Introduction

INTRODUCTION

Okra, *Abelmoschus esculentus* (L.) Moench or bhendi, a native of Ethiopia, is an economically important vegetable of tropics and subtropics. It is mainly valued for its immature, edible, green, non-fibrous fruits. Unripe fruits of okra contain high fiber (3.2g), vitamins (Vit. C-38%, Vit. A-14%), minerals (magnesium-11.5%, potassium-7.3%, calcium-5%) and protein (1.93g) and is low in carbohydrate (7.45g), energy (33kcal) and fat (0.1g) (USDA, 2013).

India produced over 63.3 lakhs metric tonnes of okra during 2017 from an area of 5.31 lakh hectares which is valued at Rs. 4.93 lakh at current market rates. It is cultivated in all the states of the Indian subcontinent, with West Bengal leading in area and production followed by Gujarat, Odisha and Bihar (NHB, 2017). In Kerala, okra is cultivated on approximately 1415 ha with an average production of 22.50 tonnes (Farm Guide, 2018). Of the numerous varieties available, Arka Anamika is one of the most preferred variety in Kerala due to its tender-long fruits, high yield (20t/ha), good keeping and cooking quality and high tolerance to yellow vein mosaic disease.

Intensive cropping with introduction of high yielding varieties, greater use of chemical fertilizers, loss of micronutrients by leaching and decreased use of farm yard manure have made micronutrient application a necessity to realize good crop growth and yield (Berger, 1962). The fruit bearing in okra starts usually around 30- 35days after sowing and may continue for two to three months (up to 90-115 DAS). According to Abbasi *et al.* (2010), owing to the indeterminate growth pattern of okra characterized by simultaneous vegetative and reproductive growth, a continuous supply of macro and micronutrients are warranted. This is all the more relevant in Kerala as the soils are acidic, rich in iron and manganese, gravelly with low CEC, low water holding capacity, high phosphate fixing capacity and low in micronutrient content.

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Adoption of an optimum nutrient management strategy involving organic sources, bio-fertilizers, micronutrients and plant growth promoters to achieve increased crop productivity in okra has been advocated by several workers. Although there is a standard recommendation for primary macronutrient application in okra by Kerala Agricultural University, recommendations on secondary nutrients, micronutrient and plant growth promoters, their modes of application and information on their impact on seed yield and viability are wanting.

Foliar fertilization has been widely adopted in modern crop management to ensure optimal crop performance when nutrient supply from the soil is inadequate or uncertain. The superiority of foliar application of nutrients and growth promoters in annuals over broadcast and banded applications has been proved (Naga *et al.,* 2013). The main advantage being smaller quantity of nutrients required, reduced loss through leaching and cost effectiveness. It also offers specific advantage over soil fertilizers when plant demand for nutrients exceeds the capacity for root nutrient uptake; when elemental mobility within the plant limits delivery to tissues; and when environmental conditions limit the effectiveness or prevent the application of nutrients to the soil (Martens and Wastermann, 1991).

An increased seed yield alone would not benefit the seed growers. Retaining seed viability over a longer period is also a necessity. The retention of qualities such as germination, moisture content and seed health along with physical and genetic purity of seed stock till the next season is as important as producing good seeds. Seed storage being a problem in Kerala owing to the high temperature and relative humidity experienced for most part of the year, storage environments play a crucial role in determining seed longevity (Anitha, 1997).

Both the storage condition and type of storage containers are found to have profound influence on longevity of seed. Farmers in Kerala, usually store dried unshelled pods of bhindi and prefer to extract the seeds just before sowing, a method

which is difficult to emulate by a seed grower. Unlike farmers, seed growers store shelled seeds either under ambient storage or cold storage, all of which greatly impacts seed quality and longevity. Considering the above, the present study was formulated:

To study the impact of foliar application of secondary nutrients, micronutrients and growth promoters on growth, fruit and seed yield of okra.

To elucidate the influence of storage environment on quality and longevity of the seed thus produced.

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Review of Literature

2. REVIEW OF LITERATURE

Adoption of an optimum nutrient management strategy involving organic sources, bio-fertilizers, micronutrients and plant growth promoters to achieve increased crop productivity in okra has been advocated by several workers. Although there is a standard recommendation for primary macro-nutrients application in okra by Kerala Agricultural University, recommendations on secondary nutrients, micronutrients and plant growth promoters along with its impact on seed yield and viability are wanting.

Considering the above, the present study 'Impact of foliar application of nutrients and growth promoters on seed yield and quality of okra' was formulated. Literatures related to the various aspects of the study are reviewed henceforth under the following headings:

2.1 Impact of application of nutrients and plant growth promoters on crop growth, seed yield and quality

2.1.1 Application of nutrients individually or in combination

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2.1 Impact of application of nutrients and plant growth promoters on crop growth, seed yield and quality

According to Berger (1962), intensive cropping with introduction of high yielding varieties, greater use of chemical fertilizers, loss of micronutrients by leaching and decreased use of farm yard manure have made micronutrient application a necessity to realize good crop growth and yield.

The increased yield due to application of secondary and micronutrients may be attributed to enhanced photosynthetic activity, resulting in increased production and accumulation of carbohydrate. This favours vegetative growth and retention of flower and fruits leading to increased number of fruits per plant besides improvement in the fruit size (Pandita *et al.,* 1976).

Foliar fertilization has been recommended as a treatment in the integrated plant production system since it is environmentally safe and also increases the crop yield and quality (Tumbare *et al.*, 1999; Fageria *et al.*, 2009; El-Aal *et al.*, 2010; Abbasi *et al.,* 2010; Kashif *et al.*, 2014; Liu *et al.*, 2017).

Under the situations of low soil nutrients bioavailability, hard top soil, and decreased root activity during the reproductive growth stage of plants, foliar fertilization is most effective (Naruka *et al.*, 2000; Chattopadhyay, 2003; Fageria *et al.*, 2009; Zodape *et al.*, 2011).

Improved growth and yield traits of okra in relation to foliar fertilization were reported (Alkaff and Hassan, 2003). It became evident that integrated use of foliar and recommended soil applied chemical fertilizers improved the growth traits of okra plants and enhanced the okra yield.

Foliar fertilization not only improved plant growth traits, crop yields and nutrient uptake by crops (Maitlo *et al.*, 2006) but also enhances nutrient use efficiency

of crops (Fageria *et al.*, 2009; El-Aal *et al.*, 2010; Narimani *et al.*, 2010; Zodape *et al.*, 2011).

The superiority of foliar application of nutrients and growth promoters in annuals over broadcast and banded applications has been proved (Naga *et al.*, 2013). The main advantage being smaller quantity of nutrients required, reduced loss through leaching and cost effectiveness.

Haytova (2013) observed that the foliar nutrition is useful to meet the demands of plant nutrients at specific vegetative and fruiting stage of growth.

Foliar application of nutrients involves supply of nanoparticles to plants through foliage to increase plant growth, yield and profit by requiring less input and generating less wastage than the conventional methods of nutrient application (Servin *et al.*, 2015).

According to Tansey *et al.* (2017), impact of foliar application of nutrients on plants is highly influenced by their phloem and symplastic mobility. Like micronutrients, macronutrient requirement like potassium and nitrogen can also be met by foliar application due to their high mobility and rapid distribution throughout the plant.

2.1.1 Application of nutrients individually or in combination

Nutrients are essential in all cellular and metabolic functions. Plants differ in their need for micronutrients; boron (B), iron (Fe), zinc (Zn), copper (Cu), chloride (Cl), manganese (Mn), molybdenum (Mo) and nickel (Ni). These elements are active and they essentially function as catalytically active cofactors of enzymes, others have enzyme-activating functions, and yet others fulfill a structural role in stabilizing proteins. Improvement in growth characters due to micronutrient application might basically be due to enhanced photosynthetic and other metabolic activities related to cell division and elongation (Hatwar *et al.*, 2003).

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2.1.1.1 Zinc (Zn)

The foliar fertilization with organic and inorganic forms of zinc has a potential to increase its concentration in wheat grain (Rengel *et al.*, 1999)

Zinc may be required for chlorophyll production, pollen function and fertilization in tomato (Kaya and Higgs, 2002).

In tomato, maximum growth rate (85.7 %) was observed with the foliar application of zinc, followed by application of micronutrient mixture (78.2 %) and boron (77.5 %) (Hatwar *et al.*, 2003).

Increased yield in response to foliar application of micronutrients (B, Zn and mixture) have been reported by Davis *et al.* (2003) and Patil *et al.* (2010) in different vegetable crops.

Furthermore, it is the main composition of ribosome and is essential for their development. Amino acids accumulated in plant tissues and protein synthesis decline by zinc deficit. Zinc is known to have an important role either as a metal component of enzymes or as a functional, structural or regulatory cofactor of a large number of enzymes (Grotz and Guerinot, 2006). Zinc also plays an important role in the production of biomass (Cakmak, 2008).

According to Pandey *et al.* (2006), zinc is critically required for pollen function and fertilization in lentil. The role of Zn in reproduction of lentil (*Lens culinaris)* and the extent to which the Zn requirement for reproduction can be met through supplementation of Zn at the time of initiation of the reproductive phase have been investigated. Zinc deficiency decreased pollen viability in maize (*Zea mays* L. cv. G2) grown in sand culture.

In chilli plants treated with various micronutrients like $ZnSO_4$ (25 kg/ha), $ZnSO_4$ (0.1%), borax (10 kg/ha), borax (0.1 %), $MgSO_4$ (10 kg/ha), $MgSO_4$ (0.1%),

sulphur (10 kg/ha), mycorrhiza (2.5 kg/ha), vermicompost (2.5 tonnes/ha), FYM (10 tonnes/ha) and control, the foliar spray of $ZnSO_4$ (0.1%) recorded the maximum plant height (82.8 cm) and number of branches compared to control (Natesh *et al.*, 2010).

Foliar application of 0.5% $ZnSO_4$ (25 DAS and 45 DAS) recorded the highest seed yield of 1052 kg/ha in rainfed cowpea *(Vigna unguiculata* L. Walp) instead of 802 kg/ha from control plot by increasing the number of pods per plant, number of branches per plant and 100-seed weight (Patel *et al.*, 2011).

Maradana (2012) observed that among different micronutrients and growth promoters, the highest fruit weight (23.8 g) and number of seeds per fruit (54.3) was recorded with foliar application of 50 ppm GA_3 followed by 0.4% $ZnSO_4$ (22.8 g and 48.3 respectively).

The application of Zn and Fe either alone or in combination significantly influenced plant height, dry weight and number of leaves per plant in cucumber (Kazemi, 2013).

Lentil plants treated with 0.08% $ZnSO_4$ produced maximum seed yield of 1238kg/ha, whereas the untreated control plants produced a seed yield of 1063 kg/h (Singh and Batt, 2013)

Boonchuay *et al.* (2013) reported that even though a significant effect of foliar application of zinc was noticed on Zn concentration of paddy grain, there was no positive impact on grain yield and yield attributes of paddy.

There was a significant increase in zinc content of paddy grain (67.3mg/100g) when it was exposed to a foliar spray of 0.5% of $ZnSO_4$ after flowering (Yuan *et al.*, 2014).

According to Kalroo *et al.* (2014), a lower Zn concentration of 2 ml^{-1} water or 1 ml^{-1} water induced early flowering in chilli variety Talhari. But, with the increasing

Zn level, the growth and yield contributing traits of chilli were gradually improved. Zinc @ 4 ml^{-1}water was an optimum level for obtaining economical fruit yield whereas, maximum number of branches (13/ plant) were produced when the chilli plants were subjected to a foliar spray of Zn @ 5mll^{-1}.

According to Kumar (2015), among different micronutrients solutions sprayed on brinjal (*Solanum melongena* L. variety Pusa Purple Round) *viz.*, $ZnSO_4$, Fe_2SO_4 and Borax, 0.2% $ZnSO_4$ was found to be superior over other treatments in yield and quality parameters.

According to Esfandiari *et al.* (2016), the foliar application of zinc sulphate at booting and milking stages of wheat could enhance the quantity and quality of the wheat grain.

Compared to soil application, foliar application of Zn has been found to be more effective in zinc bio-fortification of wheat and rice grains (Liu *et al.*, 2017).

Sharma (2017) reported that in okra, the foliar application of zinc @ 7.5 kg/ha increased the fruit length, fruit diameter, number of fruits per plant, fruit yield per plant, protein and crude fiber content of fruits.

2.1.1.2 Boron (B)

The main functions of boron relate to cell wall strength and development, cell division, fruit and seed development, sugar transport and production of viable pollen and hormone development.

According to Westernmann (1993), the crop yield and quality responses to boron fertilization may not be consistent because of soil and other environmental interactions affecting B availability and plant growth.

Ninety per cent of foliar-applied boron can be absorbed within 24 hours of application by soybean plants. It can be used immediately at the site of maximum demand especially during the critical times of seed production (Freeborn *et al.*, 2001).

David *et al.* (2005) reported that there was a significant increase in plant height, dry matter production, pod yield, seed yield and test weight, when the pulse crops were sprayed with 1% boron 30 DAS and 45 DAS.

According to Haque (2007), the boron application @ 2.5ppm concentration improves growth, yield and nutrient content of tomato.

Numbers of primary branches per plant were more in mixture of micronutrients closely followed by treatments with boron and manganese (Patil *et al.*, 2008).

Significant increase in number of branches per plant has been reported by application of micronutrient mixture (Hatwar *et al.*, 2003), boron (Patil *et al.*, 2010) and zinc (Kiran *et al.*, 2010).

By stimulating the physiological processes during reproductive phase of growth, boron application increased the seed yield in lucerne (Sreedhara, 2011).

According to Roosta and Hamidpour (2011), foliar application of K, Mg, Fe, Mn, and B increased both vegetative and reproductive growth of tomato compared to other methods of nutrient applications.

In Gerbera, foliar application of B (50mg/l) increased the plant height, diameter of the stem and total dry weight of the plant (Khosa *et al.*, 2011)

Rab and Haq (2012) reported that in tomato, foliar application of borax alone could significantly enhance the number of branches per plant, number of flowers per cluster, fruits per cluster, fruits per plant, fruit weight, fruit firmness, and total soluble solid content of the fruits.

Foliar spray of 0.5% boron twice (flowering stage and seed filling stage) increased the concentration of boron (73%), protein (11%), oleic acid (27%) and sugar (40%) contents of soybean seeds (Bellaloui *et al.*, 2013).

According to Kaur and Nelson (2014), boron is needed by corn plants throughout their growing period. The foliar application of borax at earlier growth stages (4–6 leaves with visible collars and tasseling) was more beneficial for high yields.

Five different micronutrients *viz.* zinc, boron, molybdenum, manganese and cobalt were applied in different concentrations, singly and in combination. Pollen viability was found to be the maximum when the plants were treated with 0.5ppm boron (Beegum *et al.*, 2014).

According to Ar and Bhamburdekar (2015), foliar application of boron (1ppm) in spinach resulted in significant increase in plant height, fresh and dry weight of plant, number of branches and leaves and main stem thickness.

In corn, foliar application of 1ppm boron had a positive effect on grain yield and quality (protein and fatty acid content) (Koca, 2016).

Four different levels of boron (0, 0.1, 0.2 and 0.5%) were applied in onion through foliar spraying. Foliar spray of 0.5% boron significantly increased the growth (plant height, 63.93cm and number of leaves per plant, 7.25), yield (30.74 t ha^{-1}) and quality (total soluble solid) (Manna and Maity, 2016).

According to Kumar *et al.* (2017), among different micronutrient solutions sprayed on guava *viz.*, 0.01% B, 0.01% Zn and 0.01% Ca, 0.01% B was found to be superior over other treatments in fruit yield (27.27kg/tree) and seed index (0.76g).

2.1.1.3 Magnesium

Magnesium is the structural element of chlorophyll. Thus, it plays an indispensible role in photosynthesis. Magnesium acts as cofactor of large number of enzymes involved in energy transport system of plant body (Mayland, 1983).

Alcaraz-Lopez *et al.* (2004) explained that, in addition to the role of light absorption in chlorophyll tetra-pyrrolering, magnesium also performs the assimilation of CO_2 in the chloroplast of plant leaves. The deficiency of Mg^{2+} in chloroplast may also results in reduced photophosphorylation.

According to Hao *et al.* (2004), in tomato, the total fruit yield and dry matter was increased linearly with the increased Mg^{2+} concentration.

Plants require Mg^{2+} for the normal structural development of their chloroplasts as well as mitochondrion. Moreover, magnesium is also important for the biosynthesis of phospholipids and, therefore, in the formation of functional cell membranes (Cakmak and Kirkby, 2008).

Hansch and Mendel (2009) reported that Mg^{2+} plays an important role both in structural stability and the proper functioning of ribosomal particles. Thus, the production of protein and amino acids are partially controlled by these ions.

According to Gerendas and Fuhrs (2013), in Mg deficient soil, the supply of 0.5ppm Mg^{2+} through foliage tends to increase the quality of grains, fruits and vegetables. Fruit yield of mandarin orange was significantly influenced by the application of Mg^{2+} per plant along with the normal recommendation of primary nutrients. The highest production of fruits was achieved by the application of 60g of Mg^{2+} per plant (Nasreen *et al.*, 2013).

In wheat, foliar spray of 20ppm Mg^{2+} increased the activities of beneficial enzyme *viz.*, acid phosphatase, dehydrogenase, esterase, and nitrate reductase and it

also resulted in fast uptake and mobilization of nutrients by plants. Moreover, there was a significant improvement in yield and quality of wheat grains (Rathore and Tarafdar, 2015).

Fageria (2016) reported that Mg^{2+} is absolutely required for the synthesis of ATP acting as a bridging constituent between ATP and the enzyme.

A positive impact of magnesium on crop growth and grain yield of field grown cereals *viz.,* rice, wheat and maize was noticed (Farzadfar *et al.,* 2017).

2.1.1.4 Sulphur

Apart from the direct involvement of sulphur powder in plant growth and yield, it also activates the uptake of primary elements, N, P and K by plant roots (Beaton, 1966).

Sulphur is an essential component of various key enzymes and vitamins in plants and is necessary for the formation of chlorophyll also (Coleman, 1979).

According to Grill *et al.* (1979), an inadequate supply of sulphur will not only reduce yield and crop quality, but it will decrease nitrogen use efficiency by enhancing the risk of N loss to the environment.

Ravanel *et al.* (1998) found that sulphur is a component of three important amino acids methionine, cysteine and cystine, which are the essential building blocks of proteins.

Reproductive growth of wheat appeared to be more sensitive to S deficiency than vegetative growth. Application of sulphur resulted in increased wheat grain size thereby higher yield per unit area along with good processing quality (Zhao *et al.*, 1999).

Sulphur is one of the secondary essential elements that plays an important role in flowering and seed set in canola (Morandin and Winston, 2005).

According to Li *et al.* (2007), combined application of sulphur and nitrogen has a positive effect on total glucosinolate content of turnip, which gives the pungency to the crop.

Norton *et al.* (2013) reported that the adequate supply of sulphur improves plant protein quality, where it plays a major factor in the structure and function of enzymes and proteins in leafy tissues and seeds.

In soybean, the foliar spray of 1% sulphur improves number of pods per plant, number of grains per pod, test weight, grain yield, oil and protein content. (Dey *et al.*, 2014).

Moss *et al.* (2016) reported that the sunflower seeds having less sulphur content are relatively harder and less in oil content. An optimum supply of sulphur during the growth stage is much essential for high seed quality.

2.1.2 Application of micronutrient mixtures

In several crops, especially in flowering plants and vegetable crops, application of micronutrients mixtures rather than their individual application, is found to significantly impact plant growth, flowering and fruiting.

The maximum number of branches in okra plants was observed in response to foliar fertilization as compared to the soil application of $ZnSO_4$ and $MnSO_4$ fertilizers (Singh *et al.*, 2013)

In two varieties of tomato (Kumari and Raja), the maximum plant height was recorded with the spray of micronutrients mixtures (Naga *et al.*, 2013) as compared to individual micronutrient sprays.

According to Hatwar *et al.* (2003), the foliar spray of micronutrient mixture enhanced plant height, number of primary branches and compound leaves in most of the plants.

Foliar spray of micronutrients at flowering stage increased the growth and yield of chilli (*Capsicum annuum* L.). Highest yield and quality parameters were observed with foliar spray of $ZnSO_4$ (0.1%) followed by foliar micronutrition with borax and $MgSO_4$ (@ 0.1% each (Natesh *et al.*, 2010).

In tomato, the combined application of micronutrients produced the maximum fruit yield followed by application of boron and zinc. Increased yield in response to micronutrients (B, Zn and mixture) have been reported in different vegetable crops (Davis *et al.*, 2003; Basavarajeswari *et al.*, 2008).

According to Baloch *et al.* (2008), the consecutive improvement in growth and yield of chilies was evident with increase in micronutrient mix (Hi-Grow) concentration. But, the application beyond 7 mll^{-1} water was not effective and thus 7 mll^{-1} water was considered to be an optimum Hi-Grow concentration for commercial production of chillies (Baloch *et al.*, 2008). They also reported that in chilli, the commercial foliar fertilizer Hi-Grow, a combination of various macro and micronutrients was found to be more effective for better vegetative and reproductive growth than the individual nutrient application.

According to Naga *et al.* (2013), it was apparent that the foliar application of micronutrients either alone or in combination, enhanced most of the plant growth characteristics *viz.*, plant height, number of primary branches and compound leaves.

In tomato varieties, the maximum number of leaves (107 and 105) was observed in plants applied with boron. The application of mixture of micronutrients enhanced the fruit weight while other micro-nutrients did not show any positive effect on growth and yield of tomato (Sivaiah *et al.*, 2013).

Foliar application of micronutrients (Zn, Cu, Fe, Mn and B) alone and in combination were the most effective treatments in increasing chemical and physical parameters of peach fruit (Ali *et al.*, 2014).

Chandra and Singh (2015) stated that combined foliar application of Zinc sulphate, Magnesium sulphate and Copper sulphate (0.5% each) was found the best for higher fruit yield, production and better fruit quality of aonla.

Krishnamoorthy and Hanif (2015) reported that the foliar application of 0.5 per cent 'mango special'- micronutrient formulation-containing Zn, B, Mn, and Fe resulted in higher growth, yield (20.99% higher yield per ha than control) and total soluble solid (TSS) content of mango.

The foliar application of micronutrient mixture 'vegetable plus' at flowering time was having a positive impact on the boldness of both bitter gourd and cowpea seeds (KVK, 2016).

According to Gurung *et al.* (2016), the foliar application of 15ppm GA_3 along with 0.5% zinc and 0.1% boron improved growth morphology, fruit yield and fruit quality of Darjeeling mandarin.

In onion, compared to the combined soil application of 0.5% $CuSO_4$ and 0.5% $ZnSO_4$, 1.08 per cent more bolting was observed on combined foliar spray of these micronutrients (Aske *et al.*, 2017).

2.1.3 Application of Sampoorna KAU vegetable multimix

Regional Agricultural Research Station (RARS), Pattambi, Kerala Agricultural University (KAU) has developed an innovative plant nutrient formulation 'Sampoorna KAU multimix' to improve rice, banana and vegetable crop productivity. It is found suitable for foliar application owing to its soluble nature. The nutrient components of Sampoorna KAU vegetable multimix are as detailed below (Table 1).

Table 1. Nutrient composition of Sampoorna KAU vegetable multimix

Sl. no:	Nutrients	Concentration (%)
1.	Zinc (Zn)	4.5 - 5.5
2.	Boron (B)	2.5 - 3.5
3.	Copper (Cu)	< 0.5
4.	Iron (Fe)	< 0.2
5.	Manganese (Mn)	< 0.2
6.	Molybdenum (Mo)	< 0.02
7.	Potassium (K)	8.0 - 10.0
8.	Magnesium (Mg)	2.0 - 3.0
9.	Sulphur (S)	7.0 - 9.0

Several multi-location evaluation trials conducted to study the effect of Sampoorna KAU multimix indicated that Sampoorna KAU multimix (Rice) could improve crop yield by one tonnes/ha, and Sampoorna KAU Multimix (Banana) could improve bunch yield by 1.5 kg/ plant (Thulasi *et al.*, 2015).

However, the impact of Sampoorna KAU vegetable multimix on growth, yield and quality of seed in vegetables are yet to be deduced.

2.1.4 Application of plant growth promoters

Plant Growth Promoter (PGP) is the substance which improve the overall growth, development and health of plants. These substances which may be either produced synthetically or derived biologically are also effective in improving the quality and productivity of crops.

2.1.4.1 Salicylic acid

According to Moharekar *et al.* (2003), the chlorophyll content decreased significantly with the increased concentration of foliar spray of salicylic acid (SA) in both wheat and moong seedlings whereas, the total carotenoid content was increased significantly with an increase in SA concentration in both plant species.

Khan *et al.* (2003) found that the foliar applied salicylic acid improved stomatal conductance, transpiration, photosynthetic rate and plant growth of soybean (C_3 plant) and maize (C_4 plant) under greenhouse conditions.

According to Nandi *et al.* (2003), the foliar spray of salicylic acid induced resistance against *Meloidogyne incognita* (root knot nematode) in okra (*Abelmoschus esculentus* cv. Purbani Kranti) and cowpea (*Vigna unguiculata* cv. Pusa Ruby).

Rajjou *et al.* (2006) noticed that the application of SA improved protein translation, seed metabolism and antioxidant enzyme synthesis in seeds which in turn results in higher seed germination and vigour in Alfalfa (*Medicago sativa* L.). The foliar application of salicylic acid in spring wheat helped to alleviate the negative effect of salinity on vegetative and reproductive growth (Afzal *et al.*, 2006).

Yildirim *et al.* (2008) revealed that the foliar applications of salicylic acid resulted in increased shoot fresh weight, shoot dry weight, root fresh weight, root dry weight, shoot diameter and leaf number per plant in cucumber. Moreover, the seeds harvested from plants treated with foliar salicylic acid had lower values of electrolyte leakage than non-treated ones.

According to Farooq *et al.* (2009), the foliar application of salicylic acid improves the drought tolerance in rice. It also helps the plant tissue to enhance the potency of antioxidant system, to maintain water potential and cellular membrane integrity and to sustain photosynthesis and general metabolism of rice.

In okra, the foliar spray of salicylic acid (SA) increased proline production subsequently helping in mitigating the damage due to drought stress and also prevented root and leaf damage (Amin *et al.*, 2009).

Seedling growth, development and nitrogen use efficiency in cucumber (*Cucumis sativus* L.) improved when sprayed with salicylic acid (0.2%). It also increased chlorophyll content, total non-structural carbohydrate as well as nitrate assimilation through the induction of nitrate reductase activity. The seeds of SA sprayed cucumber plant had comparatively high per cent of germination and growth characteristics (Singh *et al.*, 2010).

Aftab *et al.* (2010) reported that, compared to soil application and seed treatment with salicylic acid, foliar application was found to be the best method to increase net photosynthetic rate, nitrate reductase activity, carboxylation efficiency and the seed yield in *Brassica juncea.*

Foliar spray with different levels (0.0, 0.5 and 1.0 %) of salicylic acid (SA) was practiced on broad bean (*Vicia faba* L.). The maximum activity of antioxidant enzyme, soluble sugars and protein contents was observed in bean plants which are subjected to 0.5% salicylic acid (Azooz *et al.*, 2011).

Foliar application of salicylic acid (0.2%) was the best concentration to induce the drought tolerance in vegetables by activating the protein interaction network and by stimulating antioxidants present in plant cells (Hao *et al.*, 2012).

Salicylic acid (SA) spray on plant foliage could activate plant immune system and impart systemic resistance against various plant pathogens (Fu e*t al.*, 2012).

The growth and flowering characteristics of Ixora plant increased by foliar spray of 200ppm salicylic acid (Abdul-Hafeez *et al.*, 2016)

2.1.4.2 *Pseudomonas fluorescens (Pf)*

Seed treatment with *Pseudomonas fluorescens* increased the yield in radish by 44.7 per cent and significantly reduced the disease incidence by 42.6 per cent (Leeman *et al.*, 1995).

According to Ganeshan and Kumar (2005), *Pseudomonas fluorescens* belongs to Plant Growth Promoting Rhizobacteria (PGPR), the group of bacteria that play an important role in promoting the plant growth, inducing systemic resistance and biological control of pathogens.

Pseudomonas fluorescens improves seed germination, seedling vigour, and nutrient uptake of roots, dry weight of the plants, seed weight and flowering in paddy (Kaymak, 2010).

Das (2014) proved that the rhizome treatment with *Pseudomonas fluorescens* exhibited a positive effect on controlling the root-knot nematode (*Meloidogyne incognita)* and quick wilt causing by *Ralstonia solanacearum* of ginger.

Shrivasthava and Kumar (2015) proved that *Pseudomonas fluorescens* play a significant role in increasing crop growth and yield by their unique properties to impart tolerance to saline conditions, synthesize compatible solutes, modify the soil conditions and to produce plant growth promoting hormones by interacting with crop plants.

The seed treatment with dust formulation of *Pseudomonas fluorescens* in cereals (rice, wheat, maize, oats), vegetables (chilli, mung bean, cucumber) and oil seeds (sunflower, soybean, sesame, mustard) resulted in higher root and shoot lengths, plant height, dry weight and number of productive tillers, grains per panicle and grain test weight when compared with control (Ramirez and Maiti, 2016).

According to Rodriguez (2017), the foliar spray of 1% *Pseudomonas fluorescens* resulted in increased plant growth, flowering, fruit and seed yield and quality of brinjal.

2.2 Impact of storage period on seed quality and longevity

Due to external and internal factors, seed loses its viability during storage (Roberts, 1961). Koostra and Harrigton (1969) reported that the different activities taking place during seed storage that causes seed deterioration are, reduction in protein synthesis, damage of free radicals, structural damage of cells and organelles, failure in metabolic reactions, accumulation of toxic metabolites, auto-oxidation of lipids and genetic degradation.

Christensen and Kaufmann (1969) proved that the storage fungus can withstand comparatively higher temperature and lesser moisture content than the field fungi. The infection of such storage fungi will cause faster deterioration of the seed lot by reducing their vigour and viability.

According to Abdul-Baki and Anderson (1972), even though there are many physiological changes happening in deteriorated seeds like discoloration of seed, less tolerance to sub-optimal environmental conditions, reduced seedling growth and increased abnormality in seedling, the decreased germinability is the most widely accepted criterion of seed deterioration. They pointed out that electrical conductivity is the measure of solute exudation from soaked seeds and it is inversely proportional to the seed quality.

The most important ultra-structural change found in the cell organelles of deteriorated seed was the loss of membrane integrity (Villers, 1980). Deterioration of the stored seeds was due to loss of organic molecules through ionic solute leakage that in turn results in reduced germination and vigour of seedling (Coolbear *et al.*, 1984). Urbaniak (1984) observed negative correlation between germination and speed of germination with electrical conductivity.

Any damage on the cell membrane leads to higher leaching of electrolytes to the imbibing media and there is a significant increase in electrolyte exudation with the ageing period (Pandey, 1992). With increased EC of seed leachate, there is a significant decrease in germination of solanaceous vegetable seeds like tomato (Kumar, 2000), brinjal (Kumar, 2005) and chilli (Divya, 2013; Shruthi, 2014).

The concept of taking EC value of seed leachate as an indication of seed storage potential is that the deteriorated seeds discharges more solutes to water and they shows higher electrical conductivity (Bewley and Black, 1994). By soaking the seeds in water, the seeds release the metabolites including sugars, amino acids, fatty acids, enzymes and ions in varying quantities based on their cell membrane integrity (Bewley and Black, 1994; Vijayakumari *et al.*, 2007).

Kalpana and Madhava (1995) noticed that the major symptoms associated with the ageing of seeds are reduced respiratory activity; incline in solute leakage, reduced imbibition and significant loss in seed vigour and viability.

Shanmugavel *et al.* (1995) reported that during ageing of soybean seeds, a decrease in per cent seed germination and seedling vigour were accompanied by an increase in seed leachate concentration.

Bailly *et al.* (1996) reported that the reduced seed viability is associated with less cell membrane integrity, high solute leakage and decreased activity of enzymes *viz.*, superoxide dismutase, catalase and glutathione reductase.

Krishnamurthy and Raveesha (1996) reported that *Aspergillus, Pencillium* and *Rhizopus* are commonly seen seed fungi associated with stored soybean seeds. The attack of these pathogens in turn reduced the seed quantity and longevity.

According to Copeland (1998), the deteriorative changes taking place in a seed during storage which leads to the death of seed are due to failure of beneficial enzymes involved in anabolism, increased activity of catalytic enzymes like catalase and

peroxidase, accumulation of toxic metabolites, lipid oxidation, reduction in cell membrane integrity and the decreased activity of repair mechanism.

Cellular membrane integrity of seeds decreased with their storage period (Dey and Mukherjee, 1998; Deshpande, 1998).

During storage, the sunflower seeds infected with the seed borne pathogen registered lower germination compared to the uninfected seeds (Basavaraju *et al.*, 2004).

Seed ageing is directly proportional to EC and deterioration and it is inversely proportional to seed qualities like seed vigour and viability soybean seeds (Saha and Sultana, 2008).

In soybean seeds, with increase in storage period, an increase in EC of seed leachate and decrease in germination was observed. The electrolyte concentration of the seed leachate is an indicator of seed quality especially longevity and viability (Mohammad, 2011).

Narayanan *et al.* (2011) reported that along with the damages to cells, free radicals also attacked the fatty acid molecules of the seed thus making it lose viability at a faster rate.

Surki *et al.* (2012) reported that the seed moisture content had adverse effect on storability of seeds. The electrical conductivity of seed increases with ageing of seeds which is owing to the high rate of lipid peroxidation and membrane disintegration. Vinodkumar (2012) also confirmed that the deterioration of the stored seeds was associated with higher production of free radicals during their storage.

As a result of seed deterioration, the vigour index I and II of different seed lots like corn, watermelon, sorghum and onion decreased with increase in storage period (Delouche and Baskin, 2016).

According to Navya (2016), seed quality parameters like seed germination per cent, seedling length and vigour indices I and II of chilli seeds of varieties Ujwala and Anugraha were found to be declined with the advancement of storage period.

Datt (2018) reported that the seed germination remained above 90 per cent during the initial four months of storage and decreased gradually to 82.6 per cent after five months.

2.3 Impact of storage conditions on seed quality and longevity

Singh and Tripathi (1968) reported that the duration of seed storage can be extended by reducing the relative humidity of the seed storage area.

The longevity of stored seed is highly influenced by the type of packing material and storage condition. The selection of storage condition is based on the type of seed, kind and quantity of seed, duration of storage, temperature and relative humidity of the area and the material used for packing (Chin and Standifer, 1969).

Teng (1981) reported that the maize seeds stored either in cloth bag or polythene bag shows fluctuation in seed moisture content. They also show reduced germination per cent throughout the period of seed storage.

According to Dange and Patil (1984), increased relative humidity (RH) of storage place causes a higher deterioration of seed than when seeds are stored in areas having relatively less RH. The seeds of groundnut genotypes stored at relative humidity of 62, 72, 85 and 93 per cent respectively differed significantly in their quality and those stored at 62 per cent RH was found to be viable for a comparatively longer time.

Polythene bags were superior to cloth and paper bags in maintaining shelf life of corn seeds with good germination and vigour (Baskin *et al.*, 1987). Vanangamudi and Ramaswamy (1989) in bajra, Baskin *et al.* (1987) in wheat, Ashwathaiah and Sadasivamurthy (1986) in sorghum reported that moisture impervious containers like

polythene bags are better for maintaining seed viability than moisture pervious containers like cloth or jute bags.

According to Dwivedi and Shukla (1990), the storage of chickpea seeds in polythene bags rather than in cloth bags reduced the seed deterioration and fungal infection over twelve months of storage period.

Gao *et al.* (1996) found that the soybean seeds stored at room temperature showed faster decline in viability and vigour as compared to the seeds stored at lower temperature.

According to Kannath (1996), storing the ash gourd seeds in 700 gauge polythene bags are superior to both brown paper bag and cloth bag in maintaining high germination (61.42 per cent) and vigour (1217). It was concluded that, when the aged seeds were soaked in water, the extent of leakage of cytoplasmic components to the water was directly proportional to the loss of cell membrane integrity.

Maize seeds were stored in different storage structures *viz.,* traditional silo (inqolobane), metal tank, roofed building and sacks. Majority of maize farmers used the popular inqolobane for seed storage. The incidence of seed loss was minimum for the maize seeds stored in metal tanks whereas, it was maximum in seed lot kept open under roofed structure followed by sack storage (Thamaga *et al.*, 2004).

Malaker *et al.* (2008) observed that the germination was highest for wheat seeds stored under refrigerator followed by polyethylene bag and tin containers. The seed moisture content was found to be directly proportional to storage period whereas, the seed germination was inversely proportional to it.

Seeds of different vegetable crops were stored under a wide range of temperature (5, 15, 25 and 35°C). The highest and lowest germination per cent was observed when the seeds were stored at 5°C and 35°C respectively (Alhamdan *et al.,* 2011).

According to Raikar *et al.* (2011), the seed stored in polythene bags had less electrical conductivity and longer storage life than seeds stored in cloth bags. Minute pores present on cloth bags are the reason for entry of moisture into the seed and hence, comparatively higher deterioration and less storability.

The polythene bags of 700 gauge or double gunny bags are better for storing paddy seeds. Polythene bags of 400 gauge density is also equally preferred for storing paddy seeds having a moisture content of 10 per cent or less (KAU, 2011).

Kumar (2011) reported that the jute seeds stored in polythene bags recorded higher germination and seedling vigour parameters up to twelve months of storage compared to cloth bag which maintained upto ten months.

Seeds of papaya cultivar 'Sekaki' were dried to six, eight and ten per cent moisture content and stored at 0°C, 4°C and 28°C respectively for three months. The seeds containing lesser moisture content (6%) and stored at lower temperature (0°C) registered higher germination, lower dormancy and lower seed death compared to the seeds in other storage conditions at varying seed moisture levels (Zulhishyam *et al.*, 2013).

Narayanan and Prakash (2014) observed a rapid increase in the moisture content of groundnut seeds stored in cloth bags whereas, the seeds stored in polythene bags of 700 gauge densities shown a very low increase in moisture content.

The highest germination of 89.57 per cent after 12 months of storage was noticed in onion seeds dried to about 5 per cent moisture and stored in aluminum laminated bags with vacuum packing. After 27 months of storage the germination per cent gradually decreased to 61.7 per cent (Tripathi and Lawande, 2014).

Suganya (2015) reported that in rice, seed qualities declined progressively over the period of storage. The germination per cent of seeds stored in jute bags ranged from 97.25 per cent to 39.81 per cent whereas that of the seeds stored in 400 G polythene

bags varied between 97.75 per cent and 65.61 per cent over 15 months of storage. Other seed qualities like seedling length, seedling dry weight, vigour index I and II were also found to be maximum for the seeds stored in 400 G polythene bag than the jute bag. The electrical conductivity of seed leachate and incidence of seed pathogen was observed to be lower in seeds stored in polythene bags compared to jute bags.

According to Aswathy (2015), both the storage containers and storage conditions play an important role in retaining the quality and viability of cowpea seeds. Lower microflora infection was observed in cowpea seed lot which was stored under cold conditions than those stored under ambient condition. The seeds of cowpea stored under ambient condition were highly infected by the species of *Aspergillus* and *Rhizopus*.

Bulk storage of threshed or unthreshed seeds is practiced traditionally by vegetable farmers to reduce the cost of seed storage. Even though it is the cheapest method of seed storage, it leads to heating and deterioration of seed lot due to moisture migration throughout the seed mass (Delouche and Baskin, 2016).

The transmission of oxygen and vapor varies with the storage containers. Woven Polypropylene (WP) bags have higher transmission rate as compared to metalized polyethylene terepthalate (MPET), polyamide (PA) and polyethylene (PE) bags. The storability of seeds in PE bags persisted longer whereas, WP bags cannot be recommended for long term storage of seeds (Meena *et al.*, 2017).

Hendges *et al.* (2017) reported that storage temperature of 10° C provided better seed conservation whereas temperature of 30° C promoted higher deterioration and reduced vigour.

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.

Materials & Methods

3. MATERIALS AND METHODS

Production of quality seeds through appropriate crop management and facilitation of proper storage to extend seed longevity, are the two most essential activities in an efficient seed production programme. Foliar nutrition and application of growth regulators have been advocated to improve the crop growth and yield. An investigation was undertaken to study the differential impact of foliar applications of various nutrients and growth regulators on growth, fruit and seed yield, and seed quality of okra. The study also intended to evaluate the performance of seeds stored under various storage conditions. The details of the materials and techniques used for the experiment are described below.

3.1 Location and climate

The experiment was conducted in the Department of Seed Science and Technology, College of Horticulture, Kerala Agricultural University, (KAU), Vellanikkara, Thrissur, between August 2017 and July 2018, located 40 m above MSL at 10°54' North latitude and 76°28' East longitude. The location received a total rainfall of 3211.20 mm during the experimental period, with the highest receipt (793.20 mm) during July, 2018. The average relative humidity during the study was 72.66 per cent, humidity being highest (89.00%) during June, 2018 (Table 2). During the experimental period, the mean minimum temperature varied between 20.90°C in January, 2018 and 24.80°C in April, 2018 while the mean maximum temperature ranged from 29.80°C in June, 2018 to 36.70°C in March, 2018.

3.2 Experimental material

Processed seeds of okra variety Arka Anamika obtained from the Vegetable and Fruit Promotion Council, Kerala (VFPCK), Alathur, Palakkad, were used to initiate the field experiment intended to assess the impact of foliar application of nutrients and growth promoters on crop growth and seed yield of okra. The seeds harvested from the field experiment were subsequently used for the storage study.

Table 2. Mean maximum and mean minimum temperature (^{0}C), relative humidity (%) and rainfall (mm) during the experiment period (August 2017- July 2018).

Months	Temperature (°C)		Relative humidity (%)	Rainfall (mm)
	Maximum	Minimum		
Aug-17	30.10	23.30	87.00	470.00
Sep-17	31.50	22.90	84.00	413.90
Oct-17	31.70	22.30	81.00	183.40
Nov-17	33.00	21.80	73.00	58.30
Dec-17	32.40	21.10	63.00	11.50
Jan-18	33.50	20.90	53.00	0.00
Feb-18	35.70	22.50	47.00	5.20
Mar-18	36.70	24.00	59.00	33.20
Apr-18	36.10	24.80	69.00	28.90
May-18	33.20	22.60	79.00	483.60
June-18	29.80	23.20	89.00	730.00
July-18	29.60	22.5	88.00	793.20

3.3 Experiment details

The study comprised of a field experiment followed by the seed storage experiment as detailed below:

3.3.1 Experiment 1: Impact of foliar application of nutrients and growth promoters on seed yield in okra

An experiment was laid out in a Randomized Block Design (RBD) with 18 treatments (foliar application of nutrients/ growth promoters) and three replications in the field facility of Department of Seed Science and Technology, College of Horticulture. Ridges and furrows of 30 cm width were aligned along the plot area (Plates 1). The field was divided into 54 sub-plots for the randomized application of three replications of the 18 treatments. A spacing of 60cm between

Plate 1. Land preparation

rows and 45cm between plants was ensured in each sub-plot of size 3m x 3m to accommodate 24 plants. The seeds (Variety: Arka Anamika) were soaked in water overnight and sown in the ridges in the first week of September, 2017.

3.3.1.1 Fixing the foliar nutrient treatments

The dosage of micronutrients and secondary nutrients to be applied as foliar nutrition in the experimental plot were fixed based on the soil test data.

A representative soil sample of 500g was randomly collected from the experimental field following standard procedure for soil sampling (US-EPA, 2012) (United States- Environmental Protection Agency) and analyzed for various macro and micro nutrients at the Radio Tracer Laboratory, College of Horticulture, Vellanikkara, Thrissur. The soil test data is detailed in Table 3.

Table 3. Soil nutrient status of experimental plot

Sl No.	Nutrients	Values obtained (ppm)	Values required (ppm)
1.	Zinc (Zn)	0.62	1.00
2.	Iron (Fe)	20.10	5.00
3.	Manganese (Mn)	1.98	1.00
4.	Copper (Cu)	4.40	1.00
5.	Boron (B)	0.14	0.50
6.	Sulphur (S)	4.18	5.00
7.	Magnesium (Mg)	104.00	120.00

The soil of the experiment area was found to be deficient in secondary nutrients *viz.*, magnesium and sulphur. It was also deficient in micronutrients; zinc and boron. Hence, the treatments were designed to augment the required secondary and nutrients through foliar application. The foliar application was done either once (25 days after sowing: 25 DAS) or twice (at 25 DAS and 45 DAS) during the cropping period.

3.3.1.2 Treatment details

The nutrients and growth promoters applied and the schedule of their application are detailed in Table 4.

Table 4. Details of treatments

No.	Treatments	Concentration	Spray schedule	Abbreviations used
T_1.	ZnO	0.75%	25 DAS	T_1: 0.75% ZnO-I
T_2.	ZnO	0.75%	25 DAS & 45 DAS	T_2: 0.75% ZnO-II
T_3.	MgO	1.00%	25 DAS	T_3: 1% MgO-I
T_4.	MgO	1.00%	25 DAS & 45 DAS	T_4: 1% MgO-II
T_5.	*Pseudomonas fluorescens*	0.20%	25 DAS	T_5: 0.2% *Pf*-I
T_6.	*Pseudomonas fluorescens*	0.20%	25 DAS & 45 DAS	T_6: 0.2% *Pf*-II
T_7.	Salicylic acid	0.20%	25 DAS	T_7: 0.2% SA-I
T_8.	Salicylic acid	0.20%	25 DAS & 45 DAS	T_8: 0.2% SA-II
T_9.	Sampoorna-KAU vegetable multimix	0.50%	25 DAS	T_9: 0.5% SVM-I
T_{10}.	Sampoorna-KAU Vegetable multimix	0.50%	25 DAS & 45 DAS	T_{10}: 0.5% SVM-II
T_{11}.	H_3BO_3	0.10%	25 DAS	T_{11}: 0.1% H_3BO_3-I
T_{12}.	H_3BO_3	0.10%	25 DAS & 45 DAS	T_{12}: 0.1% H_3BO_3-II
T_{13}.	Sulphur powder	0.50%	25 DAS	T_{13}: 0.5% S-I
T_{14}.	Sulphur powder	0.50%	25 DAS & 45 DAS	T_{14}: 0.5% S-II
T_{15}.	$ZnSO_4$	0.75%	25 DAS	T_{15}: 0.75% $ZnSO_4$-I
T_{16}.	$ZnSO_4$	0.75%	25 DAS & 45 DAS	T_{16}: 0.75% $ZnSO_4$-II
T_{17}.	Water spray	-	25 DAS	T_{17}: C-I
T_{18}.	Water spray	-	25 DAS & 45 DAS	T_{18}: C-II

Plate 2. Experimental field

3.3.1.3 Treatment procedure

The per cent solution of each nutrient and growth promoter as specified in Table 4 was prepared by mixing the required quantity of the respective chemicals in water. The spray fluid required for the experimental area was calculated, prepared and applied over foliage using rocker spray early in the morning (between 7.00am and 9.00am) as per schedule.

3.3.1.4 Observations recorded

Observations at appropriate growth stages were recorded on five randomly selected plants in each replication of a treatment. The observations recorded (Plate 2) are detailed below.

3.3.1.4.1 Plant height (cm)

Height of the five tagged plants was recorded on 30 DAS, 45 DAS, 60 DAS and 75 DAS (Plate 3) using a metre scale and the average at each growth stage expressed in centimeter seperately.

3.3.1.4.2 Chlorophyll content (mg/g)

Chlorophyll a and chlorophyll b of the bhendi leaf were analyzed following the acetone method as specified by Hiscox and Israelstam (1979). The upper, middle and lower leaves from the five tagged plants were collected separately. For the estimation of chlorophyll, the collected leaves were cut devoid of the veins and mixed. Three leaf samples of 100mg each were taken from each replication of the 18 treatments. The leaf samples were ground using a pestle and mortar by adding 80 per cent acetone. The solution was centrifuged at 5000ppm for 10 minutes at room temperature and the clear supernatant was collected. It was then made up to 10ml and the optical density (OD) measured using the spectrophotometer (Make: HACH Model: S-340) at 663nm and 645nm separately (Holden, 1965). The content of Chlorophyll a and b was calculated using the equation detailed below.

$$\text{Chlorophyll a} = \frac{12.3 \times \text{OD at } 663\text{nm} - 0.86 \times \text{OD at } 645\text{nm}}{2 \times 1000 \times \text{weight of the sample taken}}$$

$$\text{Chlorophyll b} = \frac{19.3\text{xOD at } 645\text{nm} - 3.6\text{x OD at } 663\text{nm}}{2\text{x}1000\text{x weight of the sample taken}}$$

Total chlorophyll= Chlorophyll a+ Chlorophyll b

3.3.1.4.3 Branches per plant

The total number of branches of all the tagged plants was counted on 90 DAS and average value expressed in numbers.

3.3.1.4.4 Days to flowering

The days taken from sowing to anthesis of the first flower in all the tagged plants were recorded and averaged.

3.3.1.4.5 Pollen viability (%)

Pollens from three flowers selected randomly from each tagged plants were collected in the morning hours on the day of anthesis. Collected pollen grains were stained with acetocarmine dye. Pollen viability was scored according to staining level, as 'viable' if bright red colour and 'non-viable' if colourless, when viewed through the photonic microscope (Make: Olympus, Model:CX-31)at 10X. The total number of pollen and the number of viable pollen per three microscopic fields were recorded per replication and averaged. The per cent of viable pollen was determined as follows and averaged.

$$\text{Pollen viability (\%)} = \frac{\text{Number of viable pollen grains}}{\text{Total number of pollen grains observed}}$$

3.3.1.4.6 Flower shedding (%)

The flower drop from each tagged plants was counted on daily basis from the first day of commencement of flowering and per cent of flower shedding was calculated as follows.

$$\text{Flower shedding (\%)} = \frac{\text{Number of shedded flowers}}{\text{Total number of flowers opened per plant}}$$

Plate 3. Field view at different crop growth stages

30 Days after sowing

45 Days after sowing

60 Days after sowing

75 Days after sowing

3.3.1.4.7 Fruits per plant

The total number of fruits harvested from each tagged plants were counted and averaged.

3.3.1.4.8 Fruit length (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.

3.3.1.4.9 Fruit weight (g)

Five pods from each tagged plants were randomly selected and harvested separately at physiological maturity and recorded the average fruit weight in grams.

3.3.1.4.10 Seeds per pod

The seeds from the harvested pods were extracted and the total number of seeds per pod was counted.

3.3.1.4.11 Shriveled seeds per pod (%)

From the extracted seeds, based on the physical appearance, shriveled seeds were identified and sorted out. The ratio of shriveled seeds to total number of seeds per pod was computed and expressed in per cent.

3.3.1.4.12 Hard seeds per pod (%)

Hard seeds (Plate 4) 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.

Plate 4. Hard seed *vs* saleable seeds in okra

Hard seeds

Saleable seeds

3.3.1.4.13 Saleable seed per pod (%)

Number of saleable seeds per pod was arrived at by subtracting the sum of shrivelled and hard seeds per pod from the total number of seeds per pod.

$$\text{Saleable seeds per pod} = \text{Total number of seeds} - (\text{Shrivelled seeds} + \text{Hard seeds})$$

The per cent saleable seeds was calculated as follows.

$$\text{Saleable seed (\%)} = \frac{\text{Total number of seeds -(Shrivelled seeds+ Hard seeds)}}{\text{Total number of seeds per pod}}$$

3.3.1.4.14 Test weight (g)

Thousand seeds from each treatment were counted and weight recorded in gram.

3.3.1.4.15 Seed density (gcm^{-3})

Water (25 ml) was taken in a glass beaker. From each treatment, 25 seeds were selected randomly, weighed and put it in the beaker. Recorded the volume rise in water and calculated the seed density as follows.

$$\text{Seed density} = (\text{Weight of seed taken})/(\text{Final volume} - \text{initial volume})$$

3.3.1.4.16 Elemental composition of seeds

Random samples of seed drawn from each replication of the treatment was analyzed for elemental composition *viz.*, boron, zinc, sulphur, magnesium, iron, manganese, copper and calcium using Perkin- Elmer AAS (Piper 1966) at Radio Tracer Laboratory, KAU and expressed in mgg^{-1} of seed.

3.3.2 Experiment 2: Seed quality and seed storage study

The experiment was laid out following a two factorial Completely Randomized Design (CRD) with eighteen treatments (T_1 to T_{18}) under three storage conditions and three replications (R_1 to R_3). The study was done using the seeds extracted from the pods harvested at physiological

maturity from each of the 18 treatments in Experiment I. Seeds were stored under three storage conditions *viz.*, shelled seeds under refrigerated storage (S_1), shelled seeds under ambient storage (S_2) and unshelled pods under ambient storage (S_3).

3.3.2.1 Storage details

One-third of pods harvested at physiological maturity from each treatment (18 Nos.) in Experiment I were retained unshelled and divided to constitute three replicates. From the remaining two-third of pods, seeds were extracted and dried to a moisture content of $\leq$ eight per cent. In each treatment, six replicates of 400 grams seeds were then packed in polyethylene bags of 700 G and heat sealed.

Three replicates each of the packed seeds, were stored under refrigerated storage (S_1) and ambient conditions (S_2) respectively and their quality assessed for a period of eight months extending between January 2017 and July 2018, along with the seeds from unshelled pods which was kept under ambient storage (S_3).

3.3.2.1 Observations recorded

3.3.2.1.1 Germination (%)

The germination test was conducted at monthly intervals adopting the sand method (Plate 5) prescribed by ISTA (1999). Four replicates of hundred seeds each were drawn from each replication of treatments (T_1 to T_{18}) from each of the three storage conditions (S_1 to S_3) and sown in trays containing sterilized sand. The test was conducted at 25±2°C temperature and 90±3 % relative humidity. The mean number of normal seedlings produced on the 7^{th} day of sowing to the total number of seeds sown was expressed as per cent.

3.3.2.1.2 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 to the primary leaf base. The mean seedling shoot length was expressed in centimeter.

Plate 5. Conduct of germination test in okra

3 days after sowing

7 days after sowing

3.3.2.1.3 Seedling root length (cm)

Ten seedlings used for measuring the shoot length were used to measure 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.

3.3.2.1.4 Allometric index

Allometric index is the ratio between seedling root length (cm) and seedling shoot length (cm).

$$\text{Allometric Index (AI)} = \frac{\text{Seedling root length (cm)}}{\text{Seedling shoot length (cm)}}$$

3.3.2.1.5 Seedling dry weight (mg)

The ten seedlings used to assess the root length and shoot length were used for recording the seedling dry weight as prescribed by ISTA (2007). The seedlings were placed in butter paper cover and placed in the hot air oven at 85±1°C temperature. After 24 hours of drying, seedlings were removed and allowed to cool for 30 minutes. The weight of dried seedlings was measured in milligrams and averaged.

3.3.2.1.6 Vigour index-1

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

Vigour index I = Germination (%) x Seedling length (cm)

3.3.2.1.7 Vigour index-1I

The seedling vigour index II was computed by adopting the formula suggested by Abdul – Baki and Anderson (1973).

Vigour index II = Germination (%) x Seedling dry weight (mg)

3.3.2.1.8 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 follows and average expressed as per cent.

$$\text{Moisture content (\%)} = \frac{W2-W3}{W2-W1} \text{x}100$$

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

3.3.2.1.9 Electrical conductivity of seed leachate (μSm^{-1})

Five grams of stored seeds were taken from each replication of all treatments for testing for the Electrical Conductivity (EC) of seed leachate. The seeds were soaked in 0.1% KCl solution for 30 seconds. Seed were taken out and thoroughly washed in distilled water for two to three times. Then the seeds were again soaked in 25 ml of distilled water taken in glass beakers and the beakers were incubated at 25°±1°C temperature for 24 hours. After incubation, seed leachate was collected and EC of seed leachate estimated using EUTECH CON-510 digital conductivity meter, maintained at 0.1 cell constant and expressed in desiSiemens per meter (μSm^{-1}) (Presley, 1958).

3.3.2.1.10 Seed microflora (%)

The seed microflora was detected by using standard moist blotter paper method as recommended by ISTA (1996) and Neergaard (1973) respectively.

Standard blotter paper method

In moist blotter paper method, a pair of white blotter papers was jointly soaked in sterile distilled water and placed in pre-sterilized glass petriplates. Ten seeds from each treatment and control were placed at equal distance aseptically on the moist blotter paper. For detecting internal seed microflora, ten seeds from each treatment and control were taken and seeds were treated with 0.1% $HgCl_2$ solution for 5 minutes and then washed thoroughly with sterile distilled water. Then the seeds were taken and placed at equal distance on the moistened blotter paper in pre-sterilized petriplates. Three replicates were used per treatment and they were incubated at 25±2^{0}C under diurnal condition for 7 days. On the eighth day, the seeds were examined under microscope for the determination of seed microflora.

3.4 Statistical analysis

3.4.1 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) developed by Indian Council of Agricultural Research (ICAR) 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		

Where,

t = no. of treatments

r = no. of replications

N = no. of total observations

RSS = replication sum of squares

TrSS = treatment sum of squares

ESS = error sum of squares

TSS = total sum of squares

MSR= Mean sum of squares due to replication

MSTr = Mean sum of squares due to treatment

MSE = Mean sum of squares due to error

3.4.2 Analysis of data from Experiment II

The statistical analysis of data recorded on various seed quality parameters under Experiment II pertaining to each month of storage was performed using statistical software MSTAT-C developed by Michigan State University for Completely Randomized Design (CRD). Factorial ANOVA using Fisher's variance analysis method (Gomez and Gomez, 1976) was employed to estimate the effect of Factor A (foliar treatments) and Factor B (storage conditions) on dependent variables (seed quality parameters). It allows to determine the interactions between the independent variables or factors considered if any. Transformation of data was performed for those recorded in percent wherever applicable. The ANOVA for two factorial CRD is given in Table 6.

Table 6. ANOVA for two factorial CRD

Source	**Degrees of freedom**	**Sum of squares**	**Mean sum of squares**	**Computed F**
Main effect A	a-1	SS_A	MS_A	MS_A/MS_E
Main effect B	b-1	SS_B	MS_B	MS_B/MS_E
Interaction AB	(a-1) (b-1)	SS_{AB}	MS_{AB}	MS_{AB}/MS_E
Error	abc (r-1)	SS_E	MS_E	

Where,

SS_A-Sum of squares due to factor AMS_A - mean sum of squares due to A

SS_B -Sum of squares due to factor BMS_B - mean Sum of squares due to B

SS_{AB} -Sum of squares due to interaction ABMS_{AB} - mean sum of squares due to AB

SS_E -Sum of squires due to error MS_E - mean sum of squares due to error

65

3.4.3 Pair-wise comparison using DMRT test

DMRT is used for the experiments that require the evaluation of all possible pairs of treatment means, especially when the total number of treatments is large. Computation of numerical boundaries that allow for the classification of difference between any two treatments or means as significant or non-significant is done. However, unlike the LSD test in which only a single value is required for any pair comparison at a prescribed level of significance, the DMRT requires computation of a series of values, each corresponding to a specific series of pair comparisons. The following steps were used for ranking the data (Gomez and Gomez, 1976).

Step 1: All the treatment means were ranked in decreasing or increasing order. It is customary to rank the treatment means according to the order of preference.

Step 2: Computed the S_d value following the appropriate procedure.

$$S_d = \sqrt{\frac{2S^2}{r}}$$

Step 3: The (t-1) values of the shortest significant ranges was computed as:

$$R_p = \frac{r_p s_d}{\sqrt{2}}$$

Where,

t - Total number of treatments

s – Standard error of mean difference computed

r – Tabular values of the significant ranges

p – Distance in rank between the pairs of treatment means to be compared

Step 4: All treatment means that do not differ significantly from each other were identified and grouped together.

Step 5: Alphabet notation was used according to the ranking to present the test results.

Results & Discussion

4. RESULTS AND DISCUSSION

Increasing seed productivity through management practices and prolonging seed longevity under storage are vital for the success of a seed production programme. Considering the above, the present study was formulated and conducted in the Department of Seed Science and Technology, Kerala Agricultural University (KAU) during 2015- 2017 to elucidate the impact of foliar application of nutrients and growth promoters on seed yield and quality in okra. The results obtained are enumerated and discussed below.

4.1 Experiment I: Impact of foliar application of nutrients and growth promoters on growth, fruit and seed yield in okra

4.1.1 Analysis of variance

The analysis of variance revealed the existence of significant differences in most vegetative and reproductive traits in okra, following foliar application of various nutrients and growth promoters. However, no significant difference was observed with respect to plant height at 30 days after sowing (DAS) and 60 DAS, days to flowering, pollen viability (%), seeds per pod, shriveled seeds per pod (%) and seed yield per pod (g).

4.1.2 Impact on growth, fruit and seed yield in okra

The result pertaining to effect of foliar application of nutrients and growth promoters on seed yield in okra is presented in Tables 7, 8 and 9 and detailed below.

4.1.2.1 Plant height (30, 45, 60 and 75 DAS)

The treatments had no significant impact on plant height at 30 DAS and 60 DAS.

At 45 DAS, plant height ranged from 18.60cm (T_{15}: 0.75% $ZnSO_4$-I) to 22.70cm (T_{16}: 0.75% $ZnSO_4$-II). T_{16} was found to be on par with T_{10} (0.5% SVM-II; 22.37cm) and T_9 (0.5% SVM-I; 22.27cm). Apart from T_{15}, short plant stature was also observed in T_{18} (C-II; 19.33cm), T_5 (0.2% *Pf*-I; 19.40cm), T_3 (1% MgO-I; 19.60cm) and T_1 (0.75% ZnO-I; 19.63cm) at 45 DAS and they were on par with T_{15}.

Table 7. Impact of foliar treatments on plant height (cm), chlorophyll content (mg/g), branches per plant and days to

Treatments	Plant height (cm)				Chlorophyll content (mgg^{-1})	Branches per plant	Days to flowering
	30 DAS	45 DAS	60 DAS	75 DAS			
T_1: 0.75% ZnO-I	12.45	19.63^{fghi}	30.90	54.00^{ab}	1.86^{d}	2.20^{a}	43.00
T_2: 0.75% ZnO-II	11.70	19.87^{efgh}	31.63	45.57^{cde}	1.94^{cd}	1.73^{bcd}	44.07
T_3: 1% MgO-I	11.77	19.60^{fghi}	31.49	48.93^{abcde}	2.76^{a}	2.07^{ab}	43.87
T_4: 1% MgO-II	10.40	20.37^{cdefgh}	32.65	46.30^{bcde}	2.88^{a}	1.73^{bcd}	43.93
T_5: 0.2% *Pf*-I	10.98	19.40^{ghi}	34.16	50.57^{abcd}	2.03^{cd}	1.73^{bcd}	44.47
T_6: 0.2% *Pf*-II	11.97	20.43^{cdefg}	32.73	52.93^{abc}	2.14^{bc}	1.53^{cd}	44.27
T_7: 0.2% SA-I	11.40	19.75^{fgh}	32.71	56.67^{a}	1.89^{d}	1.33^{d}	44.40
T_8: 0.2% SA-II	10.60	21.10^{cd}	34.52	54.03^{ab}	1.90^{d}	1.53^{cd}	44.47
T_9: 0.5% SVM-I	11.13	22.27^{ab}	33.73	41.90^{e}	2.72^{a}	1.73^{bcd}	45.40
T_{10}: 0.5% SVM-II	10.37	22.37^{ab}	32.46	50.07^{abcde}	2.82^{a}	1.93^{abc}	44.40
T_{11}: 0.1% H_3BO_3-I	11.20	20.17^{defgh}	31.55	43.40^{de}	1.89^{d}	1.67^{bcd}	44.53
T_{12}: 0.1% H_3BO_3-II	11.80	20.90^{cde}	34.95	43.57^{de}	1.91^{d}	1.80^{abc}	44.47
T_{13}: 0.5% S-I	11.30	20.60^{cdef}	33.08	51.03^{abcd}	1.84^{d}	1.53^{cd}	44.60
T_{14}: 0.5% S-II	11.37	21.43^{bc}	32.81	43.43^{de}	1.91^{d}	2.00^{ab}	44.07
T_{15}: 0.75% $ZnSO_4$-I	11.57	18.60^{i}	32.77	44.80^{cde}	2.02^{cd}	1.53^{cd}	43.47
T_{16}: 0.75% $ZnSO_4$-II	11.87	22.70^{a}	34.68	47.07^{bcde}	2.25^{b}	1.53^{cd}	44.00
T_{17}: C-I	11.17	20.03^{defgh}	30.70	46.80^{bcde}	1.90^{d}	1.67^{bcd}	44.40
T_{18}: C-II	12.07	19.33^{hi}	32.06	47.96^{bcde}	1.88^{d}	1.67^{bcd}	44.73
C.D (0.05)	NS	1.067	NS	8.242	0.214	0.409	NS
SE(m)	0.740	0.413	8.369	24.680	0.017	0.061	1.047

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

At 75 DAS, plant height varied from 41.90cm (T_9: 0.5% SVM-I) to 56.67cm (T_7: 0.2% SA-I). Plant height in T_8: 0.2% SA-II (54.03cm), T_1: 0.75% ZnO-I (54.00cm), T_6: 0.2% *Pf*-II (52.93), T_{13}: 0.5% S-I (51.03cm), T_5: 0.2% *Pf*-I (50.57cm), T_{10}: 0.5% SVM-II (50.07cm) and T_3: 1% MgO-I (48.93cm) was found to be on par with that recorded in T_7 (0.2% SA-I) but differed significantly from T_9.

It was evident that spraying of $ZnSO_4$ (twice) and salicylic acid (once) resulted in increased plant stature at 45 DAS and 75 DAS respectively. However, in both instances plant height was found to be on par with that in application of two-time application of micronutrient mixture (Sampoorna KAU vegetable multimix). Positive effect of Sampoorna KAU vegetable multimix on plant height has been reported (Thulasi *et al.*, 2015).

In later stages of growth spraying of 0.2% salycilic acid or 1% MgO or 0.2% *Pf* either once or twice was also beneficial to improve plant stature. Spraying salycilic acid (Khan *et al.*, 2003; Afzal *et al.*, 2006; Farooq *et al.*, 2009; Aftab *et al.*, 2010) or MgO (Hao *et al.*, 2004; Fageria 2016) or *Pf* (Kaymak, 2010; Shrivasthava and Kumar, 2015) have been advocated earlier for improved plant growth.

4.1.2.2 Total chlorophyll (mgg^{-1})

Total chlorophyll (mgg^{-1}) in leaves was found to vary between 1.84mgg^{-1} in T_{13} (0.5% S-I) and 2.88mgg^{-1} in T_4 (1% MgO-II). Chlorophyll content in T_{10} (0.5% SVM-II; 2.82mgg^{-1}), T_3 (1% MgO-I; 2.76mgg^{-1}) and T_9 (0.5% SVM-I; 2.72mgg^{-1}) was also found to be on par with T_4 but significantly different from T_{13}.

Chlorophyll content in T_1 (0.75% ZnO-I; 1.86mgg^{-1}), T_{18} (C-II; 1.88mgg^{-1}), T_{11} (0.1% H_3BO_3-I) and T_7 (0.2% SA-I) (1.89mgg^{-1} each), T_{17} (C-I) and T_8 (0.2% SA-II) (1.90mgg^{-1} each), T_{14} (0.5% S-II) and T_{12} (0.1% H_3BO_3-II) (1.91mgg^{-1} each) and T_2 (0.75% ZnO-II; 1.94mgg^{-1}), T_{15} (0.75% $ZnSO_4$-I; 2.02mgg^{-1}) and T_5 (0.2% *Pf*-I; 2.03mgg^{-1}) were however, on par with T_{13} that registered the least value.

Higher chlorophyll content in T_3, T_4, T_9 and T_{10} involving application of magnesium nutrient is expected as it is an integral structural element of chlorophyll. Sampoorna KAU vegetable multimix contains less than 0.2 per cent of magnesium. This element is essential for the

normal structural development of chloroplasts as well as mitochondrion (Cakmak and Kirkby, 2008). Fageria (2016) also reported that Mg^{2+} is absolutely required for the synthesis of ATP acting as a bridging constituent between ATP and the enzyme.

Mg^{2+} acts also as cofactor of large number of enzymes involved in energy transport system of plant body (Mayland, 1983) and the total fruit yield and dry matter of tomato was reported to have increased linearly with the increased Mg^{2+} concentration (Hao *et al.,* 2004).

4.1.2.3 Branches per plant

Results revealed that the number of branches per plant ranged from 1.33 (T_7: 0.2% SA-I) to 2.20 (T_1: 0.75% ZnO-I). Significantly more number of branches was observed in T_3: 1% MgO-I (2.07), T_{14}: 0.5% S-II (2.00), T_{10}: 0.5% SVM-II (1.93) and T_{12}: 0.1% H_3BO_3-II (1.80). These were found to be on par with each other and T_1 and but significantly different from all other treatments including T_7 with the least number of branches.

Similar to the findings of the study, the advantage of foliar spray of $ZnSO_4$ was reported by Natesh *et al.* (2010) in chilli. They had recorded maximum plant height (82.8 cm) and number of branches compared to control through application of $ZnSO_4$ (0.1%). The application of either magnesium or sulphur or boric acid or micronutrient mixture have been reported to increase branching and plant growth (Ravanel *et al.*, 1998; Haque, 2007; Patil *et al.*, 2008; Kiran *et al.*, 2010).

Hither though, application of 1% MgO (once) and 0.5% Sampoorna KAU vegetable multimix (twice) had consistently exhibited higher vegetative growth (plant height at 75 DAS, chlorophyll content and branches per plant).

As in the present study, application of micronutrients alone or micronutrient mixture was found to be advantageous in enhancing plant growth (Naga *et al.*, 2013; Gurung *et al.,* 2016)

4.1.2.5 Days to flowering

The applied treatments did not exercise significant impact on days taken to flowering.

4.1.2.6 Flower shedding (%)

Flower shedding was found to vary between 11.22 per cent (T_{10}: 0.5% SVM-II) and 19.42 per cent (T_{13}: 0.5% S-I). T_{10} was also found to be on par with all other treatments except treatments with single spray of sulphur (T_{13}) or *Pf* (T_5: 0.2% *Pf*-I; 17.81%) or borax (T_{11}: 0.1% H_3BO_3-I; 16.22%) or MgO (T_3: 1% MgO-I; 15.64%) that had registered high per cent of flower shedding.

Significant decrease in flower shedding have been reported through application of one or two sprays of Zn^{2+} (Hatwar *et al.*, 2003; Patel *et al.*, 2011) or salycilic acid (Yildirim *et al.*, 2008) or micronutrient mixtures by earlier workers (Davis *et al.*, 2003; Basavarajeswari *et al.*, 2008).

4.1.2.7 Pollen viability (%)

The per cent viability of pollen grains however did not differ significantly between treatments.

4.1.2.8 Fruits per plant

The number of fruits per plant varied from 10.93g in T_1 (0.75% ZnO-I) to 13.80g in T_{10} (0.5% SVM-II). Significantly high number of fruits were also recorded in T_9 (0.5% SVM-I; 13.60), T_8 (0.2% SA-II; 13.40), T_{14} (0.5% S-II; 13.00), T_{16} (0.75% $ZnSO_4$-II; 12.87), T_{12} (0.1% H_3BO_3-II; 12.67) and T_3 (1% MgO-I; 12.47). These treatments were found to be on par with T_{10} but significantly differed from T_1 (0.75% ZnO-I) which had recorded the least number of fruits per plant.

As in the present study, production of higher number of fruit on application of micronutrient mixture has been reported by Natesh *et al.* (2010) in chilli, Davis *et al.* (2003) and Basavarajeswari *et al.* (2008) in tomato, Chandra and Singh (2015) in aonla. Krishnamoorthy and Hanif (2015) in mango and Gurung *et al.* (2016) in mandarin. In addition, it was also evident that spraying of micronutrient twice (either salycilic acid or borax or sulphur or $ZnSO_4$) was beneficial in increasing the fruit yield per plant.

Table 8: Impact of foliar treatments on reproductive traits of okra

Treatments	Flower shedding (%)	Pollen viability (%)	Fruits per plant	Fruit length (cm)	Fruit weight (g)	Seeds per pod
T_1: 0.75% ZnO-I	14.39^{bcde}	78.67	10.93^{g}	12.78^{bcde}	19.69^{d}	51.20
T_2: 0.75% ZnO-II	13.81^{bcde}	80.53	12.33^{bcdef}	12.66^{bcde}	17.88^{f}	53.60
T_3: 1% MgO-I	15.64^{abcd}	78.07	12.47^{abcde}	12.52^{de}	19.94^{d}	48.07
T_4: 1% MgO-II	15.57^{abcde}	83.93	11.93^{cdefg}	13.53^{ab}	20.69^{bc}	51.93
T_5: 0.2% *Pf*-I	17.81^{ab}	83.47	11.60^{defg}	12.55^{cde}	18.85^{e}	54.73
T_6: 0.2% *Pf*-II	14.34^{bcde}	84.87	12.33^{bcdef}	13.99^{a}	18.81^{e}	52.80
T_7: 0.2% SA-I	15.50^{abcde}	81.60	11.62^{defg}	13.00^{bcde}	19.56^{d}	48.93
T_8: 0.2% SA-II	13.80^{bcde}	85.93	13.40^{ab}	13.49^{abcd}	19.73^{d}	54.07
T_9: 0.5% SVM-I	11.67^{de}	87.60	13.60^{ab}	13.31^{abcde}	21.22^{ab}	48.87
T_{10}: 0.5% SVM-II	11.22^{e}	87.27	13.80^{a}	13.48^{abcd}	21.18^{ab}	49.60
T_{11}: 0.1% H_3BO_3-I	16.22^{abc}	87.53	11.07^{fg}	13.17^{abcde}	18.57^{e}	49.73
T_{12}: 0.1% H_3BO_3-II	12.85^{cde}	88.47	12.67^{abcd}	13.55^{ab}	21.56^{a}	49.27
T_{13}: 0.5% S-I	19.42^{a}	79.47	11.60^{defg}	12.91^{bcde}	17.69^{f}	45.27
T_{14}: 0.5% S-II	14.49^{bcde}	82.87	13.00^{abc}	13.51^{abc}	21.29^{a}	48.60
T_{15}: 0.75% $ZnSO_4$-I	14.83^{bcde}	83.27	11.13^{efg}	12.49^{e}	18.67^{e}	50.53
T_{16}: 0.75% $ZnSO_4$-II	11.48^{de}	82.53	12.87^{abcd}	13.98^{a}	20.50^{c}	52.00
T_{17}: C-I	11.48^{de}	79.47	12.40^{bcdef}	13.41^{abcde}	16.34^{g}	52.33
T_{18}: C-II	14.51^{bcde}	81.73	11.27^{efg}	13.04^{abcde}	16.17^{g}	53.00
C.D (0.05)	4.385	NS	1.363	0.968	0.535	NS
SEm	6.985	30.188	0.675	0.340	0.104	16.496

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

4.1.2.9 Fruit length (cm)

Average fruit length ranged from 12.49cm (T_{15}: 0.75% $ZnSO_4$-I) to 13.99cm (T_6: 0.2% *Pf*-II). Length of fruit in T_6 was on par with that observed in all treatments except for those in T_{15}, T_3 (1% MgO-I: 12.52cm), T_5 (0.2% *Pf*-I; 12.55cm), T_2 (0.75% ZnO-II; 12.66 cm), T_1 (0.75% ZnO-I: 12.78cm), T_{13} (0.5% S-I: 12.91cm) and T_7 (0.2% SA-I; 13.00cm).

Beneficial effects of foliar spray of *Pseudomonas fluorescens* (*Pf*) on growth and yield parameters of vegetables was also reported by Kaymak (2010) and Shrivasthava and Kumar (2015). Similar to foliar application of *Pf,* it was observed that two-time application of either borax or micronutrient mixture or MgO, sulphur or $ZnSO_4$ was advantageous in increasing the fruit length. However, one-time application of boric acid or micronutrient mixture was sufficient to produce the same effect. Such increase in fruit length following application of secondary nutrients and micronutrients have been reported by earlier workers (Hatwar *et al.*, 2003 in chilli, Rab and Haq, 2012 in tomato).

4.1.2.10 Fruit weight (g)

Fruit weight varied from 16.17g in T_{18} (C-II) to 21.56g in T_{12} (0.1% H_3BO_3-II). T_{12} was found to be on par with T_{14} (0.5% S-II; 21.29g), T_9 (0.5% SVM-I; 21.22g) and T_{10} (0.5% SVM-II; 21.18g).T_{18} was on par with T_{17} (C-II; 16.34) but significantly differed from all other treatments.

Significant increase in fruit weight through the application of boron or sulphur at flowering and fruit formation stage of vegetable crops have been reported by several workers. The results of the present study are in agreement with the findings of David *et al.* (2005) in pulse; Krishna (2014) in soybean and Manna and Maity (2016) in onion.

4.1.2.11 Seeds per pod

The treatments did not exhibit significant impact on total number of seeds per pod.

4.1.2.12 Shrivelled seeds per pod (%)

The treatments did not register significant differences with respect to per cent shriveled seeds.

4.1.2.13 Hard seeds per pod (%)

Per cent hard seeds per pod varied from 6.67 per cent in T_6 (0.2% *Pf*-II) to 11.79 per cent in T_{15} (0.75% $ZnSO_4$-I). Similar to T_6, lower per cent of hard seeds was also observed in treatments T_{12} (0.1% H_3BO_3-II; 7.38%), T_9 (0.5% SVM-I; 7.40%) and T_{16} (0.75% $ZnSO_4$-II: 8.28%). These treatments were on par with each other but differed significantly from T_{15} (0.75% $ZnSO_4$-I; 11.79%), T_2 (0.75% ZnO-II; 11.67%) and T_{18} (C-II; 11.59%).

Similar to the study, reduction in hard seeds in okra was reported through the foliar application of boron (Olambe, 2012; Begum, 2014) or $ZnSO_4$ (Udoh *et al.*, 2016) or micronutrient application (Fang *et al.*, 2008).

4.1.2.14 Saleable seed per pod (%)

Per cent saleable seeds ranged from 73.74 per cent in T_3 (1% MgO-I) to 83.53 in T_{16} (0.75% $ZnSO_4$-II). Similar to T_{16}, higher per cent of saleable seeds was also observed in T_9 (0.5% SVM-I; 82.30%), T_6 (0.2% *Pf*-II; 81.04%), T_{10} (0.5% SVM-II; 80.99%) and T_{12} (0.1% H_3BO_3-II: 80.87%). These treatments were on par with each other but differed significantly from all other treatments including control.

As in the case of hard seeds (%), it was evident that two-time application of *Pf* or micronutrient mixture or borax or $ZnSO_4$ resulted in higher per cent of saleable seed. One-time application of the micronutrient mixture was also found to be sufficient to increase the saleable seed per cent. The impact of foliar application of $ZnSO_4$ on seed yield and good seed per cent of okra observed was similar to the results of Patel *et al.* (2011) in cowpea *(Vigna unguiculata* L. Walp), Singh and Batt (2013) in lentil and Esfandiari *et al.* (2016) in wheat. Similarly, application of micronutrient mixture was found to increase the seed yield in safflower (Ravi *et al.*, 2010).

4.1.2.15 Test weight (g)

Test weight was found to vary between 56.23g (T_3: 1% MgO-I) and 61.70g (T_{14}: 0.5% S-II). Significantly high test weight was also observed in T_{12} (0.1% H_3BO_3-II; 61.60g) and T_{17} (C-I; 60.67g). These treatments differed significantly from all other treatments.

As adequate supply of sulphur improves plant protein quality, it plays a major role in the structure and function of enzymes and proteins in leafy tissues and seeds. The impact of foliar

spray of sulphur on test weight and seed density of okra seeds are in agreement with the findings of Norton *et al.* (2013) and Gerendas and Fuhrs (2013).

4.1.2.16 Seed density (gcm^{-3})

Seed density ranged from 0.683 gcm^{-3} (T_{14}: 0.5% S-I) to 0.850 gcm^{-3} (T_3:1% MgO-I). T_3 exhibited the maximum seed density and was found to be on par with all treatments except T_{13}, T_8 (0.2% SA-II; 0.727 gcm^{-3}), T_{18} (C-II; 0.727 gcm^{-3}), T_{16}: (0.75% $ZnSO_4$-II; 0.733 gcm^{-3}), T_7 (0.2% SA-I; 0.747 gcm^{-3}) and T_9 (0.5% SVM-I; 0.747 gcm^{-3}).

Results indicated that two-time application of borax (T_{12}) had not only increased seed density but also registered high saleable seed per pod (%) and test weight. It registered low hard seed per cent per pod. The results of Bellaloui *et al.* (2013) was similar to the findings of the present study.

Application of salicylic acid or sulphur either once or twice and one-time application of micronutrient mixture had registered low seed density.

Considering the impact of various nutrients and growth regulators, it may be concluded that foliar application of micronutrient mixture (0.5% Sampoorna KAU vegetable multimix) or 0.75% $ZnSO_4$ or 0.1% H_3BO_3 twice during the crop growth was advantageous. Foliar application of micronutrient mixture (0.5% Sampoorna KAU vegetable multimix) twice exerted high positive influence on the vegetative growth and reproductive traits in okra seed crop except for per cent of hard seeds and test weight. The treatment had registered the highest fruits per plant and the least per cent of flower shedding. Two-time foliar application of 0.5% Sampoorna KAU vegetable multimix was more advantageous than its one-time application. Although high in saleable seed (%) as well as test weight and low in hard seed per cent, the plant stature at both 45 DAS and 75 DAS, chlorophyll content in leaves, number of branches and fruits per plant, fruit length and seed density were comparatively low in one-time application of 0.5% Sampoorna KAU vegetable multimix. The flower shedding was also comparatively high in one-time application of vegetable multimix. In several flowering plants and vegetable crops, application of micronutrients mixtures rather than their individual application, was found to significantly impact plant growth, flowering and fruiting.

Table 9. Impact of foliar treatments on seed and seed attributes of okra

Treatments	Shrivelled seed per pod (%)	Hard seeds per pod (%)	Saleable seed per pod (%)	Test weight (g)	Seed density (g/cm^3)
T_1: 0.75% ZnO-I	13.41	10.38^{abc}	76.30^{de}	57.03^{ef}	0.793^{abcd}
T_2: 0.75% ZnO-II	12.82	11.67^{a}	75.60^{de}	59.00^{cd}	0.823^{ab}
T_3: 1% MgO-I	15.39	10.87^{ab}	73.74^{e}	56.23^{f}	0.850^{a}
T_4: 1% MgO-II	13.87	10.21^{abc}	76.31^{de}	60.37^{b}	0.830^{ab}
T_5: 0.2% *Pf*-I	13.30	9.85^{abc}	76.99^{cde}	58.70^{d}	0.807^{abcd}
T_6: 0.2% *Pf*-II	12.29	6.67^{e}	81.04^{abc}	59.97^{bc}	0.793^{abcd}
T_7: 0.2% SA-I	11.73	10.78^{ab}	77.84^{cde}	56.50^{f}	0.747^{bcde}
T_8: 0.2% SA-II	13.55	9.69^{abcd}	76.75^{cde}	60.40^{b}	0.727^{de}
T_9: 0.5% SVM-I	10.28	7.40^{de}	82.30^{ab}	58.50^{d}	0.747^{bcde}
T_{10}: 0.5% SVM-II	8.49	10.65^{abc}	80.99^{abc}	58.00^{de}	0.797^{abcd}
T_{11}: 0.1% H_3BO_3-I	12.00	10.92^{ab}	77.08^{cde}	58.20^{d}	0.790^{abcd}
T_{12}: 0.1% H_3BO_3-II	11.78	7.38^{de}	80.87^{abc}	61.60^{a}	0.820^{abc}
T_{13}: 0.5% S-I	15.15	9.77^{abcd}	75.10^{de}	57.97^{de}	0.727^{de}
T_{14}: 0.5% S-II	12.44	9.08^{bcd}	78.47^{bcd}	61.70^{a}	0.683^{e}
T_{15}: 0.75% $ZnSO_4$-I	14.12	11.79^{a}	74.09^{e}	58.43^{d}	0.827^{ab}
T_{16}: 0.75% $ZnSO_4$-II	8.35	8.28^{cde}	83.53^{a}	59.00^{cd}	0.733^{cde}
T_{17}: C-I	14.73	10.53^{abc}	74.99^{de}	60.67^{ab}	0.813^{abcd}
T_{18}: C-II	14.49	11.59^{a}	73.92^{e}	58.53^{d}	0.727^{de}
C.D (0.05)	NS	2.406	4.360	1.089	0.087
SE(m)	7.735	2.104	6.904	0.431	0.003

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

The superior impact of foliar application of micronutrient mixture over individual micronutrient spray have been reported by several workers (Hatwar *et al.*, 2003; Davis *et al.*, 2003; Basavarajeswari *et al.*, 2008; Baloch *et al.*, 2008 Naga *et al.*, 2013; Sivaiah *et al.*, 2013; Aske *et al.,* 2017). Several multi-location trials revealed that Sampoorna KAU Multi-mix (Rice) could improve crop yield by one tonnes/ha, and Sampoorna KAU Multimix (Banana) could improve bunch yield by 1.5 kg/ plant (Thulasi *et al.*, 2015).

One-time application of 0.5% Sampoorna KAU vegetable multimix (T_9) was found next best to two-time application of 0.5% Sampoorna KAU vegetable multimix (T_{10}) or 0.75% $ZnSO_4$ (T_{16}) or 0.1% H_3BO_3 (T_{12}). Application of 0.75% $ZnSO_4$ twice (T_{16}) exhibited a highly beneficial effect on reproductive traits of seed crop. The highest saleable seed per cent was registered in this treatment. Low per cent of flower shedding and hard seeds as well as high number of fruits per plant and fruit length were observed in this treatment.

In spite of the low plant stature at both 45 and 75 DAS and chlorophyll content, all the reproductive traits *viz.,* number of fruits per plant, fruit length, saleable seed per pod (%), test weight and seed density in treatment 0.1% H_3BO_3 twice (T_{12}) was of high magnitude. In addition, the treatment had registered lower per cent of flower shedding and hard seed. Application of boron has been reported to aid significant increase in plant height, dry matter production, yield, seed yield, test weight in pulses, tomato and spinach (David, 2005; Haque 2007; Bhamburdekar, 2015).

Foliar application of 0.75% $ZnSO_4$ twice (T_{16}) and 0.1% H_3BO_3 twice (T_{12}) were comparable to each other. The treatments were on par with respect to plant height at 75 DAS, chlorophyll content in the leaf, flower shedding (%), number of fruits per plant, fruit length, per cent hard seeds and saleable seeds, test weight of seed and seed density.

Administering plant growth promoting rhizobacterium *Pseudomonas fluorescens* twice via foliar sprays can also be recommended to reduce per cent of hard seeds and obtain high saleable seed per pod (%). However, it did not improve the plant stature at early stages (45 DAS) and number of branches, chlorophyll content in leaves and seed test weight or lower

the occurrence of hard seeds per pod (%). *Pseudomonas fluorescens* improves seed germination, seedling vigour and nutrient uptake of roots, dry weight of the plants, seed weight and flowering (Kaymak, 2010). Shrivasthava and Kumar (2015) proved that *Pseudomonas fluorescens* play a significant role in increasing crop growth and yield by their unique properties to impart tolerance to saline conditions, synthesize compatible solutes, modify the soil conditions and to produce plant growth promoting hormones by interacting with crop plants.

The benefit-cost ratio (Appendix I, II, III and IV) of the promising treatments *i.e.,* two-time application of 0.5% Sampoorna KAU vegetable multimix, 0.75% zinc sulphate, 0.1% borax and the untreated control was 1.95, 1.81, 1.70 and 1.38 respectively. Hence, it was evident that the foliar spray of micronutrients and secondary nutrients not only extended the longevity of seed, but also enhanced the profitability of seed production.

4.2 Experiment II: Seed quality and seed storage studies

The seed storage experiment was conducted to elucidate the impact of foliar application of nutrients and growth promoters and the storage conditions on seed quality and longevity of okra. Pods from the twelve treatments under Experiment 1 were harvested separately. The seeds were dried to ≤ 8 per cent moisture content and packed in polyethylene bags (700 G). Three replicates of seeds were stored under, refrigeration (S_1) as well as under ambient storage (S_2). These seeds were evaluated along with those from unshelled pods stored under ambient condition (S_3). The storability and quality of the seeds thus stored was evaluated at monthly intervals following standard procedures. The result obtained over the storage period is enumerated below.

4.2.1 Seed quality before storage

The seed quality parameters before storage are presented in Table 10.

Table 10. Impact of foliar treatments on seed quality parameters before storage

Parameters	Germination (%)	Allometric index	Vigour index I	Vigour index II	EC (μSm^{-1})	Seed infection (%)
T_1: 0.75% ZnO-I	35.56^{e}	0.401	628.00^{e}	1.09^{c}	109.67	10.00
T_2: 0.75% ZnO-II	41.11^{de}	0.382	757.00^{de}	1.27^{bc}	104.33	3.30
T_3: 1% MgO-I	53.33^{abcd}	0.382	961.00^{abcd}	1.67^{ab}	120.00	10.00
T_4: 1% MgO-II	55.56^{abc}	0.399	969.00^{abcd}	1.78^{a}	115.67	6.60
T_5: 0.2% *Pf*-I	54.44^{abc}	0.379	1023.00^{abc}	1.69^{ab}	129.67	10.00
T_6: 0.2% *Pf*-II	60.00^{ab}	0.384	1094.00^{abc}	1.89^{a}	126.62	0.00
T_7: 0.2% SA-I	62.22^{a}	0.367	1174.00^{a}	1.85^{a}	114.67	6.60
T_8: 0.2% SA-II	56.67^{abc}	0.380	1009.00^{abc}	1.81^{a}	109.00	3.30
T_9: 0.5% SVM-I	53.33^{abcd}	0.413	924.00^{bcd}	1.63^{ab}	126.33	6.60
T_{10}: 0.5% SVM-II	57.78^{abc}	0.373	1050.00^{bc}	1.83^{a}	121.33	0.00
T_{11}: 0.1% H_3BO_3-I	56.67^{abc}	0.386	1034.00^{abc}	1.76^{a}	133.33	6.60
T_{12}: 0.1% H_3BO_3-II	55.56^{abc}	0.390	920.00^{bcd}	1.85^{a}	126.95	3.30
T_{13}: 0.5% S-I	46.67^{cde}	0.374	862.00^{cde}	1.54^{ab}	123.67	3.30
T_{14}: 0.5% S-II	48.89^{bcd}	0.429	859.00^{cde}	1.46^{abc}	101.00	0.00
T_{15}: 0.75% $ZnSO_4$-I	51.11^{abcd}	0.432	959.00^{abcd}	1.63^{ab}	125.67	3.30
T_{16}: 0.75% $ZnSO_4$-II	55.56^{abc}	0.432	1028.00^{abc}	1.79^{a}	110.33	3.30
T_{17}: C-I	58.89^{abc}	0.428	1058.00^{abc}	1.85^{a}	124.00	13.30
T_{18}: C-II	57.78^{abc}	0.411	1111.00^{ab}	1.90^{a}	121.33	6.60
SE(m)	56.207	0.001	21612.02	0.074	177.33	53.15
CD (0.05)	12.439	NS	243.908	0.450	NS	NS

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

4.2.1.1 Analysis of variance

The analysis of variance revealed that, seed quality parameters and elemental composition of seed before storage except allometric index, electrical conductivity of seed leachate and seed microflora, sulphur and iron content on seed, were significantly influenced by the foliar application of nutrients and growth promoters.

4.2.1.2 Germination (%)

Germination per cent varied from 35.56 (T_1: 0.75% ZnO-I) to 62.22 (T_7: 0.2% SA-I). Maximum germination per cent was recorded in T_7: 0.2% SA-I (62.22%). It was found to be on par with T_6: 0.2% *Pf*-II (60.00%), T_{17}: C-I (58.89%), T_{18}: C-II and T_{10}: 0.5% SVM-II (57.78% each), T_8: 0.2% SA-II and T_{11}: 0.1% H_3BO_3-I (56.67% each), T_4: 1% MgO-II, T_{12}: 0.1% H_3BO_3-II and T_{16}: 0.75% $ZnSO_4$-II (55.56% each), T_5: 0.2% *Pf*-I (54.44), T_3: 1% MgO-I and T_9: 0.5% SVM-I (53.33% each) and T_{15}:0.75% $ZnSO_4$-I (51.11%). These were significantly superior to T_1, T_2 (41.11%) and T_{13} (46.67%), which were on par with each other.

The advantage of foliar spray of salicylic acid during crop growth on subsequent germination of harvested seeds as observed in the study was in consonance with that of Rajjou *et al.* (2006) in alfalfa and Singh *et al.* (2010) in cucumber.

4.2.1.3 Allometric Index

The foliar application of nutrients and growth promoters had no significant impact on allometric index of harvested seeds before storage.

4.2.1.4 Vigour index I

Vigour index I was found to vary between 628.00 (T_1: 0.75% ZnO-I) and 1174.00 (T_7: 0.2% SA-I). T_7 was found to be on par with all other treatments except T_1, T_2 (0.75% ZnO-II; 757.00), T_{14} (0.5% S-II; 859.00) T_{13} (0.5% S-I; 862.00) and T_9 (0.5% SVM-I; 924.00).

4.2.1.5 Vigour index II

The vigour index II ranged from 1.09 (T_1: 0.75% ZnO-I) to 1.90 (T_{18}: C-II). T_{18} was on par with all other treatments except T_1 and T_2 (0.5% S-II: 1.27).

Similar to the study, the advantage of foliar application of nutrients and growth promoters in increasing seedling vigour (vigour index I and vigour index II) have been reported by several workers (Khan *et al.*, 2003 in soybean; Afzal *et al.,* 2006 in wheat; Hao *et al.*, 2012 in cucumber).

4.2.1.6 Electrical conductivity (μSm^{-1})

Before storage, there was no significant impact of the applied foliar nutrients and growth promoters on electrical conductivity of seedleachate.

The deteriorated seeds discharges more solutes to water and they shows higher electrical conductivity (Bewley and Black, 1994). The electrolyte concentration of the seed leachate thus, is an indicator of seed quality especially longevity and viability (Mohammad, 2011; Surki *et al.*, 2012). Hence, it can be inferred that foliar application did not cause seed deterioration.

4.2.1.7 Seed microflora infection (%)

There was no significant impact on seed microflora infection immediately after fruit harvest and seed extraction due to foliar treatments.

4.2.1.8 Elemental composition of seed (mg/100g)

Results (Table 11) revealed that significant differences existed among the treatments with respect to elemental composition of okra seeds *viz.*, boron, zinc, manganese, copper, calcium and magnesium. But they did not vary in iron and sulphur content.

a. Boron

Boron content of seed varied from 25.90 mg/100g (T_{18}: C-II) to 145.50 mg/100g (T_{12}: 0.1% H_3BO_3-II). Boron content in T_{12} was significantly higher than in other treatments including control. T_{11} (0.1% H_3BO_3-I; 112.40mg/100g) was the next best treatment and significantly superior to others. T_{10} (0.5% SVM-II; 68.80mg/100g), T_8 (0.2% SA-II; 51.30 mg/100g) and T_9 (0.5% SVM-I; 45.40mg/100g) were found next best to T_{11} in boron content.

Bellaloui (2013) also reported that the foliar spray of 0.5 per cent borax twice (flowering stage and seed filling stage) increased the concentration of boron (73%), protein (11%), oleic acid (27%) and sugar (40%) contents of soybean seeds. As observed in the study, Ghazijahani *et al.* (2014) had reported an increased uptake pattern of nutrients, especially boron and sulfur on application of salicylic acid.

b. Zinc

Zinc content of the seed was found to vary between 14.80 mg/100g (T_{17}: C-I.) to 84.50mg/100g (T_{16}: 0.75% $ZnSO_4$-II). T_{16} with the maximum zinc content was significantly superior to all other treatments. Similarly, application of zinc through 0.75% ZnO-II (T_2; 79.20mg/100g), 0.75% $ZnSO_4$-I (T_{15}; 77.70mg/100g) and 0.75% ZnO-I (T_1; 64.50mg/100g) were also found to increase Zinc content in seeds. The least zinc content was observed in T_{17} followed by T_{18} (C-II; 16.00mg/100g). The potential of foliar fertilization with organic and inorganic forms of zinc in increasing their elemental concentration in wheat grain has been reported by (Rengel *et al.* (1999). Similar findings were also reported in paddy grain (Boonchuay *et al.*, 2013).

c. Iron

There was no significant difference in iron content of seed among the various treatments.

Table 11. Impact of foliar treatments on elemental composition of okra seeds

Treatments	Nutrients (mg/100g)							
	Boron (B)	Zinc (Zn)	Iron (Fe)	Manganese (Mn)	Copper (Cu)	Calcium (Ca)	Magnesium (Mg)	Sulphur (S)
T_1: 0.75% ZnO-I	34.40^{j}	64.50^{d}	33.00	16.80^{q}	8.00^{g}	79.10^{j}	61.50^{l}	34.80
T_2: 0.75% ZnO-II	32.50^{k}	79.20^{b}	26.50	19.40^{l}	6.50^{k}	68.00^{m}	66.00^{i}	36.00
T_3: 1% MgO-I	24.60^{q}	27.40^{h}	28.80	27.30^{g}	11.00^{d}	94.00^{e}	246.60^{b}	31.00
T_4: 1% MgO-II	27.40^{n}	31.00^{g}	37.00	25.00^{h}	10.00^{e}	81.30^{i}	278.20^{a}	34.50
T_5: 0.2% *Pf*-I	28.70^{m}	23.00^{k}	26.60	31.00^{d}	6.50^{k}	78.10^{k}	64.50^{j}	35.00
T_6: 0.2% *Pf*-II	30.10^{l}	22.50^{m}	27.50	30.40^{e}	7.30^{h}	91.30^{f}	71.90^{g}	37.10
T_7: 0.2% SA-I	40.20^{f}	22.70^{l}	21.00	33.50^{c}	7.20^{i}	117.30^{d}	67.00^{h}	34.00
T_8: 0.2% SA-II	51.30^{d}	26.50^{i}	23.50	36.30^{b}	6.40^{l}	123.00^{c}	76.40^{f}	34.60
T_9: 0.5% SVM-I	45.40^{e}	38.40^{f}	27.10	29.90^{f}	13.10^{b}	145.40^{b}	160.50^{d}	36.90
T_{10}: 0.5% SVM-II	68.80^{c}	51.30^{e}	36.60	37.40^{a}	17.60^{a}	177.30^{a}	173.50^{c}	37.00
T_{11}: 0.1% H_3BO_3-I	112.40^{b}	23.00^{k}	28.00	19.20^{m}	11.60^{c}	89.90^{h}	55.40^{n}	34.10
T_{12}: 0.1% H_3BO_3-II	145.50^{a}	25.20^{j}	24.50	17.20^{p}	10.00^{e}	91.20^{g}	63.30^{k}	31.40
T_{13}: 0.5% S-I	39.40^{h}	19.70^{n}	30.00	21.30^{j}	8.40^{f}	64.00^{n}	49.00^{q}	31.40
T_{14}: 0.5% S-II	40.20^{f}	18.80^{o}	29.50	24.40^{i}	8.40^{f}	68.30^{l}	51.00^{o}	47.50
T_{15}: 0.75% $ZnSO_4$-I	40.10^{g}	77.70^{c}	26.50	19.90^{k}	6.50^{k}	44.30^{r}	61.00^{m}	42.50
T_{16}: 0.75% $ZnSO_4$-II	38.90^{i}	84.50^{a}	24.80	18.50^{n}	7.30^{h}	52.40^{q}	82.40^{e}	49.70
T_{17}: C-I	27.30^{o}	14.80^{q}	22.30	16.80^{q}	6.80^{j}	57.10^{p}	49.00^{q}	39.80
T_{18}: C-II	25.90^{p}	16.00^{p}	18.80	18.00^{o}	7.30^{ef}	61.20^{o}	50.30^{p}	33.30
SE(m)	0.46	0.59	17.2	0.65	0.78	1.11	1.22	1.03
C.D (0.05)	0.014	0.21	NS	0.182	0.082	0.078	0.46	NS

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

d. Manganese

Manganese content of seed was found to vary between 16.80 mg/100g (T_{17}: C-I and T_1: 0.75% ZnO-I) and 37.40 mg/100g (T_{10}: 0.5% SVM-II). T_{10} was significantly superior to other treatments with respect to manganese content. T_7 (0.2% SA-I; 33.50mg/100g) and T_8 (0.2% SA-II; 36.30mg/100g) were found next best to T_{10} in manganese content.

Application of 0.75% $ZnSO_4$ twice (T_{16}) exhibited a highly beneficial effect on reproductive traits of seed crop as observed vide one-time application of 0.5% Sampoorna KAU vegetab le multimix. The multimix contains 0.2 per cent manganese (Thulasi *et al.*, 2011). According to Soltangheisi *et al.* (2014), Mn and Zn concentrations in roots and shoots increased with increasing Mn and Zn concentration in nutrient solution. Mn concentration in shoots did not show any correlation with Zn concentration in nutrient solution, but Mn concentration in roots decreased with increasing levels of Zn. In terms of chemical behavior, manganese shows the same properties of the soil alkaline cations such as Ca and Mg and heavy metals such as Zn and Fe; thus these ions affect the uptake and transport of manganese in plants. Thalooth *et al.* (2006), had reported the advantage of foliar spray of 50 ppm $MgSO_4$ on manganese content of seeds (51.30g/100g) over control (21.5mg/100g).

f. Copper

Copper content in seed varied among treatments from 6.40mg/100g (T_8: 0.2% SA-II) to17.60mg/100g (T_{10}: 0.5% SVM-II). Next to T_{10}, T_9 (0.5% SVM-I; 13.10mg/100g) registered high content of copper. T_{11} (0.1% H_3BO_3-I; 11.60mg/100g) and T_3 (1% MgO-I; 11.00mg/100g) were found next best to T_9 in copper content. Next to T_8, low content of copper (6.50mg/100g each) was observed in T_5 (0.2% *Pf*-I) and T_{15} (0.75% $ZnSO_4$-I). These were significantly inferior to all other treatments.

Sampoorna KAU vegetable multimix contains nearly 0.5% of copper. The foliar application of Sampoorna KAU vegetable multimix either once (T_9) or twice (T_{10}) recorded

the maximum copper content in seeds. Increase in copper concentration with application of copper containing fertilizer as found in the study is in consonance with that of White and Broadley (2008).

g. Calcium

Calcium content of seed was ranged from 44.30mg/100g (T_{15}: 0.75% $ZnSO_4$-I) to 177.30mg/100g (T_{10}: 0.5% SVM-II). T_{10} was found to be superior over all other treatments. T_9 (0.5% SVM-I; 145.40mg/100g) proved to be next best to T_{10} in calcium content. T_7 (0.2% SA-I; 117.30mg/100g) and T_8 (0.2% SA-II; 123.00mg/100g) were found next best to T_{10} in calcium content. T_{16} (0.75% $ZnSO_4$-II; 52.40 mg/100g) registered the least calcium content next to T_{15}, both being significantly different from each other.

Fageria (2001) reported thatcalcium uptake by plants is significantly increased with the supply of multiple micronutrients *viz.*, copper (Cu), manganese (Mn), iron (Fe) and boron (B) whereas, it is negatively influenced by higher zinc (Zn) uptake.

h. Magnesium

Magnesium content of seed was found to vary between 49.00 mg/100g (T_{17}: C-I and T_{13}:0.5% S-I) and 278.20 mg/100g (T_4: 1% MgO-II). T_4 had also recorded significantly high magnesium content than other treatments. The next best treatment with high magnesium was T_3 (1% MgO-I; 246.60 mg/100g) followed by T_9 (0.5% SVM-I; 160.50mg/100g) and T_{10} (0.5% SVM-II; 173.50mg/100g). Next to T_{13} and T_{17}, the untreated control T_{18} (C-II; 50.30) had registered low magnesium content.

It was evident that the elemental composition of magnesium in seeds of okra has been influenced by foliar spray of magnesium. The findings of study are in consonance with that of Seadh *et al.* (2009), Gerendas and Fuhrs (2013) and Ali *et al.* (2014).

i. Sulphur

There was no significant in content of sulphur in seeds between treatments.

From the above, it is evident that foliar application of nutrients and growth promoters in okra significantly influenced the elemental composition of seeds except for iron and sulphur content. As observed in the study, the foliar application of boron, zinc, and magnesium was found to increase the content of respective elements in the seed of rice (Jin *et al.*, 2008) and maize (Aref, 2011). Sampoorna KAU vegetable multimix (0.5%) was beneficial in increasing the boron, manganese, copper calcium and magnesium content of seed. Several earlier workers have reported enhanced elemental composition in grains and seeds through foliar spray of micronutrient mixtures (Seadh *et al.,* 2009; Ali *et al.*, 2014). Next to the micronutrient mixture, it was also evident that the content of boron, manganese, magnesium and calcium content of seed was also enhanced through spray of salicylic acid. Similar to the study, Khan *et al.* (2010) had also reported an increase in content of boron, magnesium and calcium content of seed through spray of salicylic acid.

4.2.2 Seed quality during storage

4.2.2.1 Analysis of variance

The analysis of variance revealed that, there existed significant differences in the impact on seed qualities like germination per cent, allometric index, seedling vigour index I and II, electrical conductivity of seed leachate and seed infection per cent among the various storage conditions, foliar treatments and their interaction during storage.

4.2.2.2 Germination (%)

The impact of storage condition, foliar treatments and their interaction on germination during storage period are presented in Tables 12 and 13 and detailed below.

4.2.2.2.1 Due to storage condition (S)

As shown in Fig. 1, germination of seeds stored under refrigeration was significantly superior to those stored under ambient (S_2) condition and unshelled pods (S_3).

Table 12. Impact of storage conditions and foliar treatments on seed germination (%) during storage

Storage condition/ Treatment	Period of storage (Months)					
	1 MAS	2 MAS	3 MAS	4 MAS	5 MAS	6 MAS
Storage condition (S)						
S_1 (Refrigeration)	69.57[a] (56.80)	76.42[a] (61.37)	81.72[a] (65.06)	86.91[a] (69.71)	78.52[a] (62.73)	76.11[a] (61.04)
S_2 (Ambient)	64.20[b] (53.35)	71.42[b] (58.13)	80.55[a] (64.52)	75.06[b] (60.42)	73.27[b] (59.04)	69.38[b] (56.47)
S_3 (Unshelled)	59.69[c] (50.69)	73.89[ab] (59.62)	65.43 (54.10)	50.56[c] (45.38)	48.46 (44.07)	46.04[c] (42.30)
SE(m)	0.701	0.903	0.702	1.086	0.788	0.63
CD (0.05)	1.968	2.536	1.971	3.048	2.212	1.768
Foliar treatment (T)						
T_1: 0.75% ZnO-I	53.70[e] (47.12)	67.78[c] (55.67)	74.81[bcd] (60.33)	75.93 (61.72)	72.59[a] (59.03)	70.37[a] (57.23)
T_2: 0.75% ZnO-II	58.52[de] (49.95)	71.48[abc] (57.89)	71.11[d] (57.81)	68.15 (56.05)	66.67[ab] (55.05)	61.48[bc] (51.87)
T_3: 1% MgO-I	64.08[bcd] (53.45)	75.18[abc] (60.91)	73.70[bcd] (59.34)	71.85 (58.46)	68.52[ab] (56.41)	66.30[ab] (54.82)
T_4: 1% MgO-II	63.33[bcd] (52.91)	75.92[abc] (60.99)	80.00[ab] (64.95)	73.71 (60.02)	69.63[ab] (56.87)	67.41[ab] (55.55)
T_5: 0.2% *Pf*-I	61.85cd[e] 51.89)	71.48[abc] (57.95)	75.92[bcd] (61.13)	70.74 (57.63)	69.26[ab] (56.67)	65.19[ab] (54.26)
T_6: 0.2% *Pf*-II	75.56[a] (60.66)	79.63[ab] (63.21)	75.18[bcd] (61.54)	72.59 (59.50)	69.26[ab] (56.88)	66.30[ab] (54.95)
T_7: 0.2% SA-I	68.89[abc] (56.20)	79.26[ab] (63.61)	79.63[abc] (63.79)	72.59 (59.35)	68.89[ab] (56.40)	66.67[ab] (55.07)

T_8: 0.2% SA-II	65.19^{bcd} (53.97)	74.82a^{bc} (60.73)	74.81^{bcd} (60.08)	71.11 (58.38)	68.15^{ab} (56.02)	65.93^{ab} (54.74)
T_9: 0.5% SVM-I	62.22^{cde} (52.24)	76.30^{abc} (61.08)	76.67^{bcd} (61.70)	69.63 (58.02)	62.22^{ab} (52.43)	61.48^{bc} (52.02)
T_{10}: 0.5% SVM-II	72.22^{ab} 58.50)	81.11^{a} (64.77)	83.70^{a} (67.68)	74.45 (62.19)	70.74^{ab} (58.21)	64.07^{abc} (53.80)
T_{11}: 0.1% H_3BO_3-I	63.70b^{cd} (52.98)	72.59^{abc} (58.62)	72.59^{cd} (58.75)	71.11 (58.93)	65.19^{ab} 54.74	61.48^{bc} (51.99)
T_{12}: 0.1% H_3BO_3-II	68.15^{abcd} (55.73)	75.56^{abc} (60.82)	74.82^{bcd} (60.09)	72.22 (60.68)	68.15^{ab} (56.06)	60.37^{bc} (51.20)
T_{13}: 0.5% S-I	62.22^{cde} (52.09)	67.78^{c} (55.54)	73.70^{bcd} (59.74)	67.78 (56.36)	64.07^{ab} (53.65)	62.96^{abc} (52.94)
T_{14}: 0.5% S-II	65.93^{bcd} (54.76)	77.41^{abc} (62.29)	79.26^{abcd} (63.53)	71.11 (59.70)	64.07^{ab} (53.70)	61.48^{bc} (51.97)
T_{15}: 0.75% $ZnSO_4$-I	67.04^{bcd} (55.20)	74.07^{abc} (59.68)	75.19^{bcd} (60.32)	65.93 (55.04)	61.11^{b} (51.70)	56.67^{c} (49.00)
T_{16}: 0.75% $ZnSO_4$-II	64.07^{bcd} (53.32)	72.22^{abc} (58.39)	73.33^{bcd} (59.17)	70.00 (58.26)	63.70^{ab} (53.38)	60.37^{bc} (51.23)
T_{17}: C-I	60.37^{cde} (51.00)	70.00^{bc} (56.99)	77.4^{bcd} (62.17)	70.74 (58.01)	65.56^{ab} (54.46)	63.70^{abc} (53.31)
T_{18}: C-II	63.70^{bcd} (53.03)	67.8^{c} (55.57)	74.44^{bcd} (59.88)	65.55 (54.71)	63.70^{ab} (53.33)	62.96^{abc} (52.89)
SE(m)	1.717	2.212	1.719	2.659	1.930	1.543
CD (0.05)	4.820	6.202	4.828	NS	5.410	4.325

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

**Values in parentheses are Arc sine transformed values

Germination in S_1 increased under storage up to 4 MAS (86.91%) and thereafter declined to 76.11 per cent at the end of storage (6 MAS). Germination in S_2 increased under storage up to 3 MAS (80.55%) and thereafter declined to 69.38 per cent at the end of storage while in unsehelled pods germination increased up to 2 MAS (73.89%) and thereafter declined to 46.04 per cent (6 MAS).

Germination of seeds in S_1, and S_2 was retained above MSCS of 65.00 per cent at the end of storage (6 MAS) compared to only three months in unshelled pods (S_3).

As in the present study, higher germination and seed longevity of seeds stored under refrigeration condition have been reported by several workers (Kannath, 1996 in ashgourd; Malaker *et al.,* 2008 in wheat; Alhamdan *et al.,* 2011 in tomato; Kumar, 2011 in jute; Suganya, 2015 in paddy).

It can be summarized that compared to unthreshed seeds and threshed seeds under ambient storage, cold storage of threshed seed is more beneficial in prolonging longevity and maintaining higher seed quality parameters during storage. Similar finding have been observed by Dhatt (2018) in pansy.

4.2.2.2.2 Due to foliar treatment

Per cent seed germination under storage increased initially and then decreased. At 1 MAS, germination ranged from 53.70 per cent in T_1 (0.75% ZnO-I) to 75.56 per cent in T_6 (0.2% *Pf*-II), whereas at the end of storage (6 MAS) it varied between 56.67 per cent (T_{15}: 0.75% $ZnSO_4$-I) to 70.37 per cent (T_1: 0.75% ZnO-I). Germination in all the treatments peaked at 3 MAS. At the end of storage period (6 MAS), the highest (70.37 %) seed germination was noticed in T_1 (0.75% ZnO-I). T_4 (1% MgO-II) with a germination of 67.41 per cent was the next best. T_{15} (0.75% $ZnSO_4$-I) recorded the least germination (56.67%) at the end of storage period.

Table 13. Interaction effect of storage conditions and foliar treatments on seed germination (%) during storage

Storage condition x Treatment	Period of storage (Months)					
	1 MAS	2 MAS	3 MAS	4 MAS	5 MAS	6 MAS
Interaction (S x T)						
S_1T_1 (Refrigeration + 0.75% ZnO-I)	46.67^{l}	71.11^{abcd}	$80.00^{bcdefghijk}$	$85.56^{abcdefg}$	88.89^{ab}	77.78^{abc}
S_1T_2 (Refrigeration + 0.75% ZnO-II)	$60.00^{efghijkl}$	76.67^{abcd}	$77.78^{defghijklmn}$	$78.89^{abcdefghijk}$	77.78^{abc}	73.33^{abc}
S_1T_3 (Refrigeration + 1% MgO-I)	74.45^{abcde}	76.66^{abcd}	$78.89^{bcdefghijklm}$	$82.22^{abcdefghi}$	76.67^{abc}	75.56^{abc}
S_1T_4 (Refrigeration + 1% MgO-II)	$70.00^{abcdefghi}$	80.00^{abc}	87.78^{abcde}	87.78^{abcdef}	78.89^{ab}	78.89^{abc}
S_1T_5 (Refrigeration + 0.2% *Pf*-I)	$66.67^{bcdefghijk}$	76.66^{abcd}	$82.22^{bcdefghi}$	$82.22^{abcdefghi}$	81.11^{ab}	80.00^{ab}
S_1T_6 (Refrigeration + 0.2% *Pf*-II)	77.78^{abc}	80.00^{abcd}	$84.44^{abcdefg}$	88.89^{abcde}	80.00^{ab}	78.89^{abc}
S_1T_7 (Refrigeration + 0.2% SA-I)	74.45^{abcde}	80.00^{abcd}	$80.00^{bcdefgh}$	87.78^{abcdef}	80.00^{ab}	77.78^{abc}
S_1T_8 (Refrigeration + 0.2% SA-II)	$72.22^{abcdefg}$	77.78^{abcd}	$78.89^{bcdefghijkl}$	$81.11^{abcdefghij}$	76.66^{abc}	75.55^{abc}
S_1T_9 (Refrigeration + 0.5% SVM-I)	$71.11^{abcdefgh}$	80.00^{abcd}	$84.44^{abcdefg}$	93.33^{abcd}	80.00^{ab}	78.89^{abc}
S_1T_{10} (Refrigeration + 0.5% SVM-II)	83.33^{a}	83.33^{abc}	87.78^{abcd}	94.45^{a}	86.67^{a}	83.33^{a}
S_1T_{11} (Refrigeration + 0.1% H_3BO_3-I)	$68.89^{abcdefghi}$	68.89^{abcd}	$77.78^{defghijklmn}$	90.00^{abcde}	76.67^{ab}	70.00^{abcd}
S_1T_{12} (Refrigeration + 0.1% H_3BO_3-II)	73.33^{abcdef}	82.22^{abc}	$82.22^{bcdefghij}$	92.22^{abc}	81.11^{ab}	70.00^{abcd}
S_1T_{13} (Refrigeration + 0.5% S-I)	$67.78^{bcdefghijk}$	71.11^{abcd}	$83.33^{abcdefg}$	87.78^{abcdef}	81.11^{ab}	80.00^{ab}
S_1T_{14} (Refrigeration + 0.5% S-II)	76.67^{abcd}	77.78^{abcd}	86.67^{abcdef}	93.33^{ab}	76.67^{abc}	76.67^{abc}
S_1T_{15} (Refrigeration + 0.75% $ZnSO_4$-I)	$67.78^{abcdefghij}$	70.00^{abcd}	$74.44^{efghijklmno}$	$83.33^{abcdefgh}$	68.89^{bcdefg}	66.67^{bcde}
S_1T_{16} (Refrigeration + 0.75% $ZnSO_4$-II)	$68.89^{abcdefghi}$	75.55^{abcd}	$77.78^{cdefghijklmn}$	90.00^{abcde}	74.45^{abcd}	70.00^{abcd}
S_1T_{17} (Refrigeration + C-I)	$61.11^{defghijkll}$	67.78^{abcd}	$82.22^{bcdefghij}$	$83.33^{abcdefgh}$	77.78^{abc}	77.78^{abc}
S_1T_{18} (Refrigeration + C-II)	$71.11^{abcdefghi}$	72.22^{abcd}	$81.11^{bcdefghij}$	$82.22^{abcdefghi}$	80.00^{ab}	78.89^{abc}
S_2T_1 (Ambient + 0.75% ZnO-I)	$63.33^{bcdefghijkl}$	68.89^{abcd}	$82.22^{bcdefghi}$	$81.11^{abcdefghi}$	78.89^{ab}	75.56^{abc}
S_2T_2 (Ambient + 0.75% ZnO-II)	$60.00^{efghijkl}$	72.22^{abcd}	$74.44^{defghijklmno}$	$74.45^{defghijklmno}$	72.22^{abcde}	65.55^{cdef}
S_2T_3 (Ambient +1% MgO-I)	$64.45^{bcdefghijkl}$	68.89^{abcd}	$77.78^{defghijklmn}$	$77.78^{bcdefghijkl}$	76.67^{abc}	73.33^{abc}
S_2T_4 (Ambient + 1% MgO-II)	$62.22^{cdefghijkl}$	71.11^{bcd}	90.00^{abc}	$75.56^{cdefghijklmn}$	74.45^{abcd}	70.00^{abcd}
S_2T_5 (Ambient + 0.2% *Pf*-I)	$60.00^{efghijkl}$	63.33^{cd}	$82.22^{bcdefghij}$	$73.33^{defghijklmnop}$	72.22^{abcde}	68.89^{bcd}
S_2T_6 (Ambient + 0.2% *Pf*-II)	$70.00^{abcdefghi}$	77.78^{abcd}	91.11^{ab}	$81.11^{abcdefghij}$	80.00^{ab}	75.56^{abc}
S_2T_7 (Ambient + 0.2% SA-I)	$67.78^{bcdefghijk}$	75.56^{a}	87.78^{abcde}	$71.11^{efghijklmnopq}$	70.00^{bcdef}	68.89^{bcd}

S_2T_8 (Ambient + 0.2% SA-II)	66.67^{bcdefghijk}	75.56^{abcd}	75.55^{defghijklmno}	77.78^{bcdefghijkl}	76.66^{abc}	71.11^{abcd}
S_2T_9 (Ambient + 0.5% SVM-I)	61.11^{defghijkl}	72.22^{abcd}	84.44^{abcdefg}	65.55^{fghijklmnopqr}	64.44^{bcdefgh}	64.44^{cdefg}
S_2T_{10} (Ambient + 0.5% SVM-II)	66.67^{bcdefghijk}	75.55^{abcd}	94.44^{a}	76.67^{bcdefghijklm}	75.56^{abc}	67.78^{bcde}
S_2T_{11} (Ambient + 0.1% H_3BO_3-I)	61.11^{defghijkl}	72.22^{abcd}	77.78^{defghijklm0n}	73.33^{defghijklmno}	71.11^{abcde}	71.11^{abcd}
S_2T_{12} (Ambient + 0.1% H_3BO_3-II)	70.00^{abcdefghi}	70.00^{abcd}	72.22^{fghijklmno}	71.11^{efghijklmnopq}	71.11^{abcde}	65.56^{cdef}
S_2T_{13} (Ambient + 0.5% S-I)	62.22^{cdefghijkl}	63.33^{cd}	74.45^{efghijklmno}	68.89^{efghijklmnopq}	68.89^{bcdefg}	66.67^{bcde}
S_2T_{14} (Ambient + 0.5% S-II)	71.11^{abcdefgh}	75.56^{abcd}	80.00^{bcdefghij}	80.00^{abcdefghijk}	75.56^{abc}	68.89^{bcd}
S_2T_{15} (Ambient + 0.75% $ZnSO_4$-I)	66.67^{bcdefghijk}	70.00^{abcd}	77.78^{defghijklmn}	76.67^{bcdefghijklm}	76.67^{abc}	66.67^{bcde}
S_2T_{16} (Ambient + 0.75% $ZnSO_4$-II)	60.00^{efghijkl}	70.00^{abcd}	72.22^{fghijklmno}	72.22^{efghijklmnopq}	70.00^{bcdef}	68.89^{bcd}
S_2T_{17} (Ambient + C-I)	60.00^{efghijkl}	73.33^{abcd}	83.33^{abcdefgh}	82.22^{abcdefghi}	73.34^{abcde}	70.00^{abcd}
S_2T_{18} (Ambient + C-II)	62.22^{cdefghijkl}	60.00^{d}	72.22^{fghijklmno}	72.22^{efghijklmnopq}	71.11^{abcde}	70.00^{abcd}
S_3T_1 (Unshelled + 0.75% ZnO-I)	51.11^{jkl}	63.33^{cd}	62.22^{nop}	61.11^{ghijklmnopqrs}	60.00^{cdefghi}	57.78^{defgh}
S_2T_2(Unshelled + 0.75% ZnO-II)	55.55^{ghijkl}	65.56^{bcd}	61.11^{op}	51.11^{mnopqrs}	50.00^{hij}	45.56^{hij}
S_3T_3 (Unshelled + 1% MgO-I)	53.33^{ijkl}	80.00^{abcd}	64.45^{klmnop}	55.56^{klmnopqrs}	52.22^{fghij}	50.00^{ghij}
S_3T_4 (Unshelled + 1% MgO-II)	57.78^{efghijkl}	74.44^{abcd}	62.22^{mnop}	57.78^{ijklmnopqrs}	55.55^{efghij}	53.33^{efghi}
S_3T_5 (Unshelled + 0.2% *Pf*-I)	58.89^{efghijkl}	74.45^{abcd}	63.33l^{mnop}	56.67^{jklmnopqrs}	54.45^{efghij}	46.67^{hij}
S_3T_6 (Unshelled + 0.2% *Pf*-II)	78.89^{ab}	81.11^{abcd}	50.00^{p}	47.78^{opqrs}	47.78^{hij}	44.45^{hij}
S_3T_7 (Unshelled + 0.2% SA-I)	64.44^{bcdefghijkl}	72.22^{abcd}	67.78^{ijklmno}	58.89^{hijklmnopqrs}	56.67^{defghij}	53.33^{efghi}
S_3T_8 (Unshelled + 0.2% SA-II)	56.67^{fghijkl}	71.11^{abcd}	70.00^{ghijklmno}	54.44^{jklmnopqrs}	51.11^{ghij}	51.11^{fghij}
S_3T_9 (Unshelled + 0.5% SVM-I)	54.44^{hijkl}	76.67^{abcd}	61.11^{op}	50.00^{nopqrs}	42.22^{ij}	41.11^{ij}
S_3T_{10} (Unshelled + 0.5% SVM-II)	66.67^{bcdefghijk}	84.44^{ab}	68.89^{hijklmno}	52.22^{lmnopqrs}	50.00^{hij}	41.11^{ij}
S_3T_{11} (Unshelled + 0.1% H_3BO_3-I)	61.11^{cdefghijkl}	71.11^{abcd}	62.22^{nop}	50.00^{nopqrs}	47.78^{hij}	43.33^{hij}
S_3T_{12} (Unshelled + 0.1% H_3BO_3-II)	61.11^{defghijkl}	74.44^{abcd}	70.00^{ghijklmno}	53.33^{klmnopqrs}	52.22^{fghij}	45.56^{hij}
S_3T_{13} (Unshelled + 0.5% S-I)	56.67^{fghijkl}	68.89^{abcd}	63.33^{lmnop}	46.67^{pqrs}	42.22^{ij}	42.22^{hij}
S_3T_{14} (Unshelled + 0.5% S-II)	50.00^{kl}	78.89^{abcd}	71.11^{ghijklmno}	40.00rs	40.00^{j}	38.89^{ij}
S_3T_{15} (Unshelled + 0.75% $ZnSO_4$-I)	66.67^{bcdefghijk}	82.22^{abc}	73.33^{fghijklmno}	37.78^{s}	37.7^{j}	36.67^{j}
S_3T_{16} (Unshelled + 0.75% $ZnSO_4$-II)	63.33^{bcdefghijkl}	71.11^{abcd}	70.00^{ghijklmno}	47.78^{opqrs}	46.67^{hij}	42.22^{hij}
S_3T_{17} (Unshelled + C-I)	60.00^{efghijkl}	68.89^{abcd}	66.67^{jklmnop}	46.67^{qrs}	45.56^{hij}	43.33^{hij}
S_3T_{18} (Unshelled + C-II)	57.78^{efghijkl}	71.11^{abcd}	70.00^{ghijklmno}	42.22^{s}	40.00^{j}	40.00^{ij}
SE(m)	2.973	3.832	2.978	4.606	3.342	2.672
CD (0.05)	8.337	10.74	8.362	12.91	9.31	7.492

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

Fig.1 Impact of storage conditions on seed germination (%) in okra

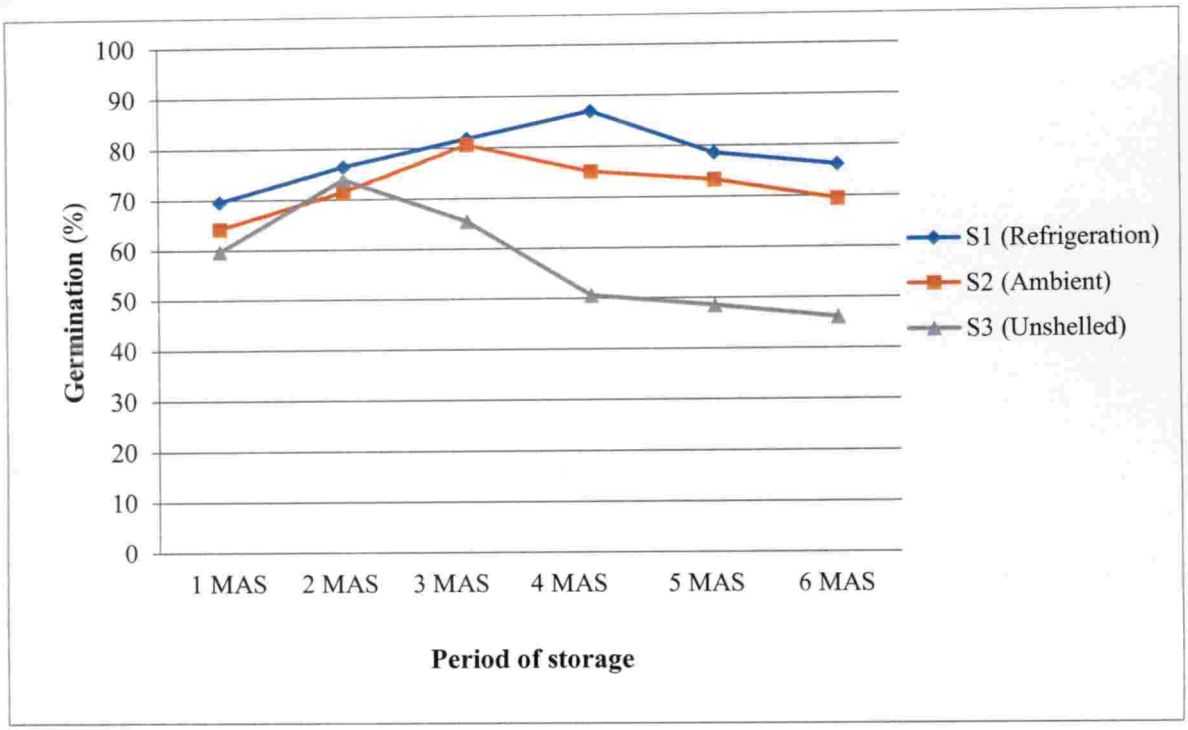
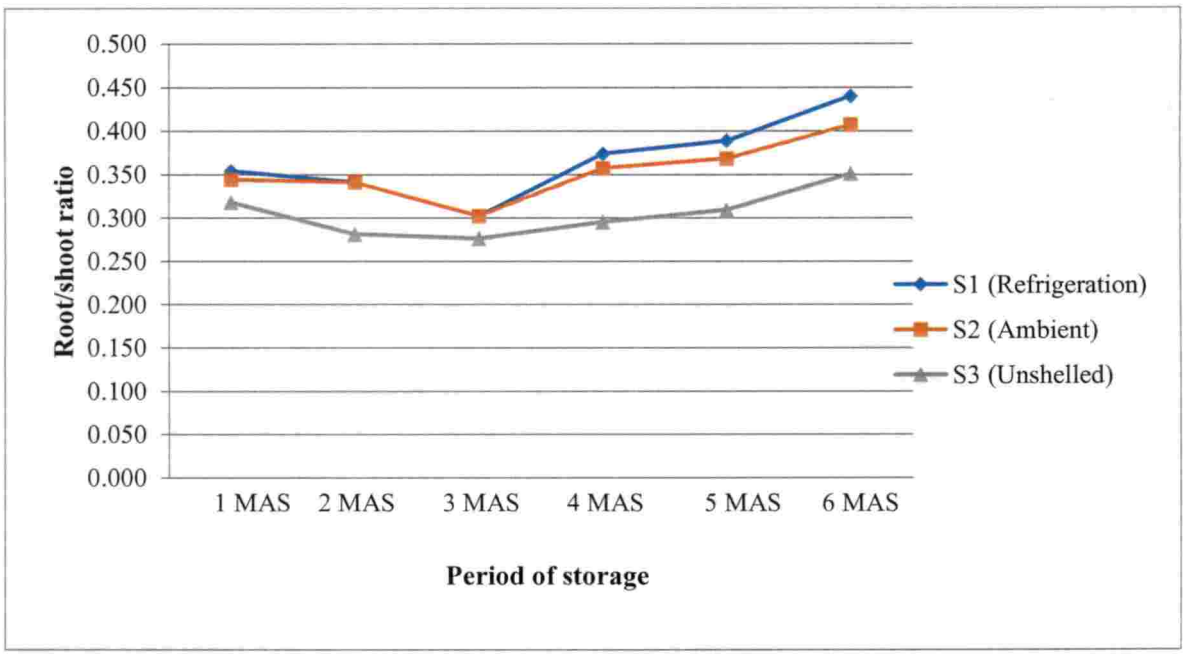


Fig. 2 Impact of storage conditions on allometric index (AI) in okra



The germination in T_{10} (0.5% SVM-II; 70.74%), T_{12} (0.1% H_3BO_3-II; 68.15%), T_{11} (0.1% H_3BO_3-I; 65.19%), and untreated control (T_{17}: C-I; 65.56%) was retained above the MSCS for five months compared to six months in T_1 (0.75% ZnO-I; 70.37%), T_4 (1% MgO-II; 67.41%), T_7 (0.2% SA-I; 66.67%), T_3 (1% MgO-I; 66.30%), T_6 (0.2% *Pf*-II; 66.30%) , T_8 (0.2% SA-II; 65.93%) and T_5 (0.2% *Pf*-I; 65.19%).

As observed in the study, the advantage of foliar treatment of micronutrients like Zn and Mg^{2+} on germination per cent of vegetables was reported by earlier workers (Bellaloui *et al.,* 2013 in soybean; Gerendas and Fuhrs, 2017 in groundnut). The positive impact of foliar spray of *Pseudomonas fluorescens* on yield and seed quality parameters (germination, seedling root length, seedling shoot length) of vegetable crops have been reported by Kaymak (2010). As in the present study, Yildirim *et al.* (2008) observed an increased germination, shoot fresh weight, shoot dry weight, root fresh weight, root dry weight, shoot diameter and leaf number per plant in cucumber plants sprayed with salicylic acid.

4.2.2.2.3 Due to interaction (S x T)

Germination was the highest (83.33%) in S_1T_{10} (refrigeration + T_{10}: 0.5% SVM-II) at both the start (1 MAS) and the end of storage (6 MAS). In addition, it registered the highest germination at 4 MAS (94.45%) and 5 MAS (86.67%). At 6 MAS it was found to be on par with all other treatments under refrigerated storage except S_1T_{15} (refrigeration + T_{15}: 0.75% $ZnSO_4$-I; 66.67%). It was also on par with S_2T_4 (ambient + T_4: 1% MgO-II; 70.00%), S_2T_8 (ambient + T_8: 0.2% SA-II; 71.11%), S_2T_{11} (ambient + T_{11}: 0.1% H_3BO_3-I; 71.11%), S_2T_3 (ambient + T_3: 1% MgO-I; 73.33%), S_2T_1 (ambient + T_1: 0.75% ZnO-I; 75.56%), S_2T_6 (ambient + T_6: 0.2% *Pf*-II; 75.56%) and untreated controls S_2T_{17} (ambient + T_{17}: C-I; 70.00%) and S_2T_{18} (ambient + T_{18}: C-II; 70.00%).

The viability of all the treatments including untreated seeds under refrigeration (S_1) was retained above MSCS up to the end of experiment (6 MAS). All treatments stored as unshelled pods (S_3) except S_3T_7 (unshelled + 0.2% SA-I; 67.78%), S_3T_{10} (unshelled + 0.5% SVM-II ; 68.89%), S_3T_8 (unshelled + 0.2% SA-II; 70.00%), S_3T_{12} (unshelled + 0.1% H_3BO_3-II;

70.00%), S_3T_{16} (unshelled + 0.75% $ZnSO_4$-II; 70.00%), S_3T_{14} (unshelled + 0.5% S-II; 71.11%), S_3T_{15} (unshelled + 0.75% $ZnSO_4$-I; 73.33%) and untreated controls S_3T_{17} (unshelled + C-I; 66.67%) and S_3T_{18} (unshelled + C-II; 70.00%), lost viability at 3 MAS. The germination in the above treatments fell below MSCS at 4 MAS.

As reported by earlier workers, Hendges *et al.* (2017) also found storing seeds (groundnut) under refrigeration beneficial to retain higher seed viability and other qualities compared to ambient storage of threshed or unthreshed seeds. As in the present study, application of micronutrient mixture in the seed crop was found to prolong the viability of vegetable seeds (Natesh *et al.,* 2010).

Although the traditional seed storage method (bulk storage of threshed or unthreshed seeds) practiced by vegetable farmers is the cheapest method of seed storage, it leads to heating and deterioration of seed lot due to moisture migration throughout the seed mass (Delouche and Baskin, 2016). However, owing to the short storage period (6 months), a conclusive evidence as to the best treatment that could prolong seed longevity cannot be drawn from the present study.

4.2.2.3 Allometric index (AI)

The results on root-shoot ratio (Allometric index) influenced by storage condition, foliar treatment and their interaction effects during the storage period are presented in Tables 14 and 15, and Plate 6.

4.2.2.3.1 Due to storage condition (S)

Allometric index decreased initially and then increased towards the end of storage in all the three storage conditions (Fig.2). AI in S_1 (refrigeration) at 1 MAS and 6 MAS was 0.354 and 0.440 respectively, whereas it was 0.344 and 0.407 respectively in S_2 (ambient storage). In S_3 (unshelled pods), AI was found to be 0.318 at 1 MAS and 0.351 at 6 MAS. Allometric index of seeds stored under both refrigeration (S_1) and ambient condition (S_2) were

Plate 6. Comparative study of seedlings under different treatments in okra at the start of storage

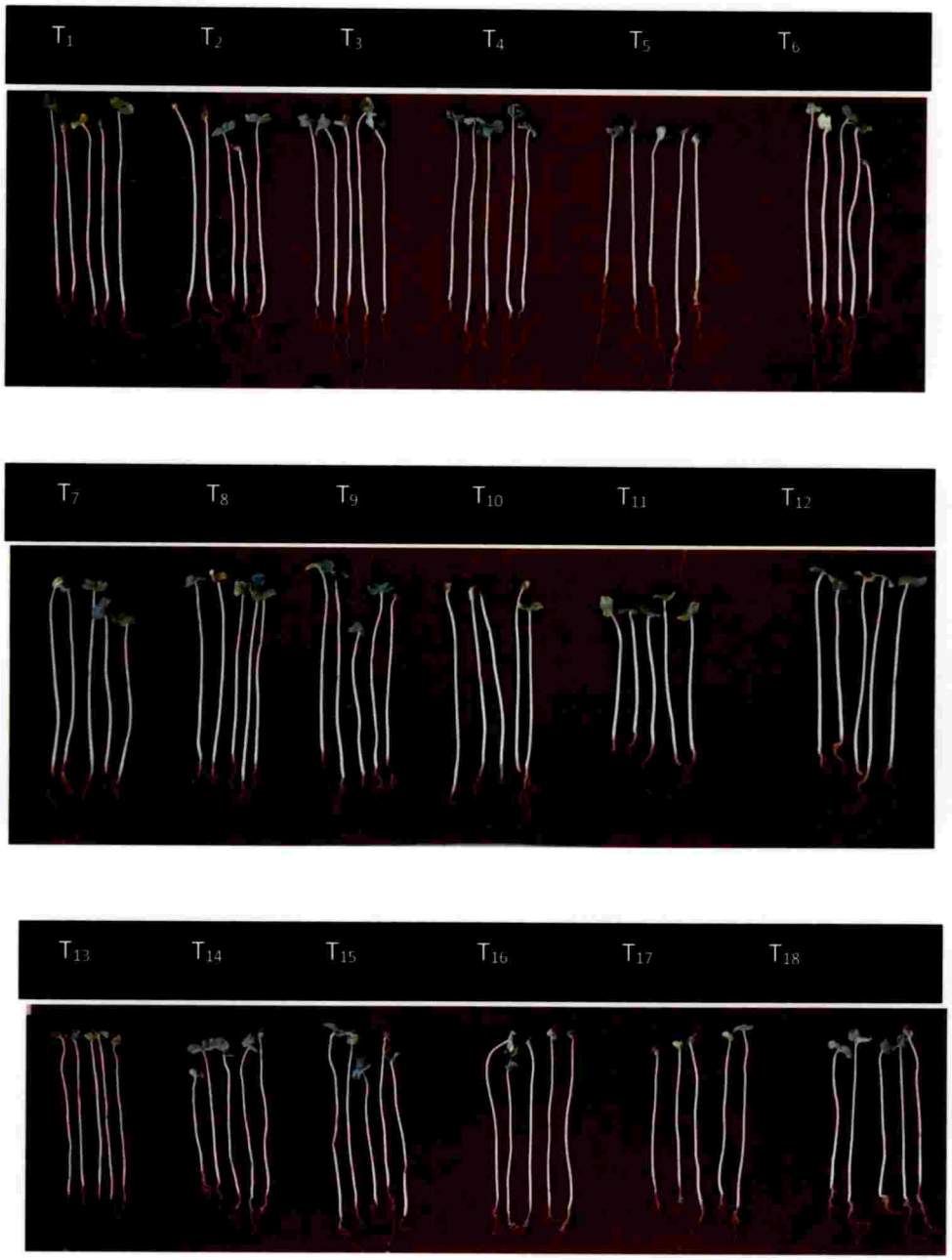


Table 14. Impact of storage conditions and foliar treatments on allometric index during seed storage

Storage condition/ Treatment	Period of storage (Months)					
	1 MAS	2 MAS	3 MAS	4 MAS	5 MAS	6 MAS
Storage condition (S)						
S_1 (Refrigeration)	0.354[a]	0.341[a]	0.302[a]	0.374[a]	0.389[a]	0.440[a]
S_2 (Ambient)	0.344[a]	0.341[a]	0.302[a]	0.357[a]	0.368[a]	0.407[a]
S_3 (Unshelled)	0.318[a]	0.281[b]	0.276[b]	0.295[b]	0.309[b]	0.351[b]
SE(m)	0.009	0.005	0.004	0.008	0.007	0.008
CD (0.05)	0.026	0.015	0.012	0.0518	0.021	0.023
Foliar treatment (T)						
T_1: 0.75% ZnO-I	0.324	0.306	0.299	0.360	0.379[ab]	0.400
T_2: 0.75% ZnO-II	0.344	0.307	0.280	0.370	0.396[a]	0.403
T_3: 1% MgO-I	0.334	0.323	0.281	0.366	0.389[ab]	0.402
T_4: 1% MgO-II	0.323	0.323	0.275	0.383	0.388[ab]	0.388
T_5: 0.2% *Pf*-I	0.333	0.331	0.305	0.383	0.358[ab]	0.373
T_6: 0.2% *Pf*-II	0.326	0.325	0.289	0.370	0.373[ab]	0.376
T_7: 0.2% SA-I	0.333	0.329	0.307	0.347	0.369[ab]	0.371
T_8: 0.2% SA-II	0.347	0.335	0.300	0.361	0.362[ab]	0.368
T_9: 0.5% SVM-I	0.346	0.324	0.306	0.363	0.356[ab]	0.375
T_{10}: 0.5% SVM-II	0.371	0.321	0.297	0.395	0.353[ab]	0.395
T_{11}: 0.1% H_3BO_3-I	0.354	0.319	0.284	0.365	0.376[ab]	0.378
T_{12}: 0.1% H_3BO_3-II	0.338	0.316	0.300	0.361	0.365[ab]	0.368
T_{13}: 0.5% S-I	0.325	0.328	0.303	0.346	0.339[ab]	0.354
T_{14}: 0.5% S-II	0.339	0.299	0.287	0.359	0.323[b]	0.347
T_{15}: 0.75% $ZnSO_4$-I	0.343	0.323	0.285	0.366	0.355[ab]	0.360
T_{16}: 0.75% $ZnSO_4$-II	0.339	0.323	0.295	0.353	0.342[ab]	0.363
T_{17}: C-I	0.332	0.324	0.296	0.362	0.350[ab]	0.352
T_{18}: C-II	0.341	0.326	0.292	0.343	0.340[ab]	0.341
SE(m)	0.022	0.013	0.011	0.019	0.020	0.018
CD (0.05)	NS	NS	NS	NS	0.0591	NS

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

found to be on par with each other throughout the storage period, but was significantly superior to those stored in unshelled pods (S_3).

Similar to the findings of the study, the impact of seed storage conditions on seedling root length and shoot length was reported by Suganya (2015) and Aswathy (2015). This study is also in agreement with the findings of Hendges *et al.* (2017). He reported that storage temperature of 10°C provided better seed conservation whereas temperature of 30° C promoted higher deterioration. Poor seedling establishment is a major deterrent in most vegetable crops. Allometric index is an indication of seedling field establishment.

4.2.2.3.2 Due to foliar treatment (T)

Irrespective of foliar treatment, allometric index decreased initially owing to the increase in seedling shoot length and then increased towards the end of storage period. AI of treatments were significantly different only at 5 MAS. Although T_2 (0.75% ZnO-II: 0.396) registered the highest allometric index, it was found to be on par with all other treatments including untreated control, but was found to be significantly superior to T_{14} (0.5% S-II) at 5 MAS. The allometric index of T_{14} at 5 MAS was 0.323.

As in the present study, among different micronutrients solutions (Zn^{2+}, Fe^{2+} and Borax) sprayed on brinjal (*Solanum melongena* L. variety Pusa Purple Round), Zn^{2+} was found to be superior over other treatments in fruit yield, seed yield and field establishment of seedlings (Kumar, 2015). However, unlike the results of the present study, Yuncai *et al.* (2008) reported existence of a negative correlation between foliar application of nutrients and seedling shoot length, root length and dry weight of maize.

4.2.2.3.3. Due to interaction (S x T)

Due to interaction effect of both foliar treatments and storage conditions, allometric index in various treatments differed significantly throughout storage, the exception being at 1 MAS and 4 MAS. At the end of storage period, S_1T_3 (refrigeration + T_3: 1% MgO-I) exhibited the highest seedling allometric index (0.570). However, it was found to be on par with S_1T_2

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Table 15. Interaction effect of storage conditions and foliar treatments on allometric index during seed storage

Storage condition x Treatment	Period of storage (Months)					
	1 MAS	2 MAS	3 MAS	4 MAS	5 MAS	6 MAS
Interaction (S x T)						
S_1T_1 (Refrigeration + 0.75% ZnO-I)	0.329	$0.305^{bcdefghijklm}$	$0.303^{abcdefg}$	0.331	$0.381^{bcdefghijk}$	0.469^{abcd}
S_1T_2 (Refrigeration + 0.75% ZnO-II)	0.355	$0.317^{abcdefghijklm}$	$0.307^{abcdefg}$	0.362	$0.380^{bcdefghijk}$	0.531^{ab}
S_1T_3 (Refrigeration + 1% MgO-I)	0.353	0.361^{abc}	$0.313^{abcdefg}$	0.378	$0.404^{bcdefghi}$	0.570^{a}
S_1T_4 (Refrigeration + 1% MgO-II)	0.344	$0.327^{abcdefghijklm}$	$0.293^{abcdefg}$	0.384	$0.397^{bcdefghijk}$	0.481^{abc}
S_1T_5 (Refrigeration + 0.2% *Pf*-I)	0.370	0.371^{a}	0.329^{abc}	0.391	$0.406^{bcdefgh}$	$0.420^{bcdefghij}$
S_1T_6 (Refrigeration + 0.2% *Pf*-II)	0.336	$0.333^{abcdefghijkl}$	$0.289^{abcdefg}$	0.354	$0.367^{bcdefghijk}$	0.452^{bcde}
S_1T_7 (Refrigeration + 0.2% SA-I)	0.364	0.353^{abcde}	0.320^{abcde}	0.358	$0.372^{bcdefghijk}$	0.467^{abcde}
S_1T_8 (Refrigeration + 0.2% SA-II)	0.369	0.371^{a}	$0.292^{abcdefg}$	0.364	0.425^{abcd}	$0.426^{bcdefgh}$
S_1T_9 (Refrigeration + 0.5% SVM-I)	0.348	$0.331^{abcdefghijklm}$	$0.299^{abcdefg}$	0.374	$0.389^{bcdefghijk}$	$0.403^{cdefghijk}$
S_1T_{10} (Refrigeration + 0.5% SVM-II)	0.376	$0.335^{abcdefghijk}$	$0.298^{abcdefg}$	0.406	0.423^{abcde}	$0.424^{bcdefghi}$
S_1T_{11} (Refrigeration + 0.1% H_3BO_3-I)	0.372	$0.324^{abcdefghijklm}$	$0.292^{abcdefg}$	0.389	$0.398^{bcdefghijk}$	0.465^{abcde}
S_1T_{12} (Refrigeration + 0.1% H_3BO_3-II)	0.347	$0.330^{abcdefghijklm}$	$0.287^{abcdefg}$	0.387	$0.401^{bcdefghij}$	0.444^{bcdef}
S_1T_{13} (Refrigeration + 0.5% S-I)	0.346	0.346^{abcdef}	$0.303^{abcdefg}$	0.368	$0.373^{bcdefghijk}$	$0.398^{cdefghijk}$
S_1T_{14} (Refrigeration + 0.5% S-II)	0.346	$0.322^{abcdefghijklm}$	$0.285^{abcdefg}$	0.367	$0.369^{bcdefghijk}$	$0.373^{cdefghijk}$
S_1T_{15} (Refrigeration + 0.75% $ZnSO_4$-I)	0.374	0.352^{abcde}	$0.303^{abcdefg}$	0.416	0.417^{abcdef}	0.435^{bcdefg}
S_1T_{16} (Refrigeration + 0.75% $ZnSO_4$-II)	0.343	0.360^{abc}	0.339^{ab}	0.361	$0.362^{bcdefghijk}$	$0.383^{cdefghijk}$
S_1T_{17} (Refrigeration + C-I)	0.327	0.347^{abcdef}	$0.293^{abcdefg}$	0.377	$0.385^{bcdefghijk}$	$0.403^{cdefghijk}$
S_1T_{18} (Refrigeration + C-II)	0.374	0.355^{abcd}	$0.292^{abcdefg}$	0.361	$0.361^{bcdefghijk}$	$0.38^{cdefghijk}$
S_2T_1 (Ambient + 0.75% ZnO-I)	0.349	$0.322^{abcdefghijklm}$	$0.301^{abcdefg}$	0.387	0.515^{a}	$0.365^{cdefghijk}$
S_2T_2 (Ambient + 0.75% ZnO-II)	0.386	$0.320^{abcdefghijklm}$	0.250^{g}	0.391	0.423^{abcde}	$0.366^{cdefghijk}$
S_2T_3 (Ambient +1% MgO-I)	0.352	$0.333^{abcdefghijkl}$	0.253^{fg}	0.360	0.437^{abc}	$0.338^{efghijk}$
S_2T_4 (Ambient + 1% MgO-II)	0.349	0.364^{abc}	0.271^{cdefg}	0.405	0.451^{ab}	$0.374^{cdefghijk}$
S_2T_5 (Ambient + 0.2% *Pf*-I)	0.338	$0.340^{abcdefghi}$	$0.308^{abcdefg}$	0.395	$0.407^{bcdefgh}$	$0.352^{defghijk}$
S_2T_6 (Ambient + 0.2% *Pf*-II)	0.348	$0.339^{abcdefghi}$	$0.297^{abcdefg}$	0.406	$0.413^{abcdefg}$	$0.357^{cdefghijk}$
S_2T_7 (Ambient + 0.2% SA-I)	0.300	0.360^{abc}	0.332^{abc}	0.341	$0.397^{bcdefghijk}$	$0.362^{cdefghijk}$

S_2T_8 (Ambient + 0.2% SA-II)	0.347	0.353^{abcde}	0.330^{abc}	0.368	0.378^{bcdefghijk}	0.371^{cdefghijk}
S_2T_9 (Ambient + 0.5% SVM-I)	0.340	0.349^{abcde}	0.327^{abcde}	0.358	0.423^{abcde}	0.358^{cdefghijk}
S_2T_{10} (Ambient + 0.5% SVM-II)	0.376	0.351^{abcde}	0.317^{abcdef}	0.392	0.443^{ab}	0.357^{cdefghijk}
S_2T_{11} (Ambient + 0.1% H_3BO_3-I)	0.346	0.355^{abcd}	0.291^{abcdefg}	0.362	0.393^{bcdefghijk}	0.382^{cdefghijk}
S_2T_{12} (Ambient + 0.1% H_3BO_3-II)	0.333	0.341^{abcdefgh}	0.340^{ab}	0.382	0.387^{bcdefghijk}	0.361^{cdefghijk}
S_2T_{13} (Ambient + 0.5% S-I)	0.317	0.368^{ab}	0.346^{a}	0.350	0.355^{bcdefghijk}	0.384^{cdefghijk}
S_2T_{14} (Ambient + 0.5% S-II)	0.323	0.305^{bcdefghijklm}	0.305^{abcdefg}	0.329	0.369^{bcdefghijk}	0.323^{fghijk}
S_2T_{15} (Ambient + 0.75% $ZnSO_4$-I)	0.325	0.336^{abcdefghij}	0.275^{bcdefg}	0.328	0.370^{bcdefghijk}	0.340^{defghijk}
S_2T_{16} (Ambient + 0.75% $ZnSO_4$-II)	0.374	0.342^{abcdefg}	0.284^{abcdefg}	0.379	0.432^{abc}	0.349^{defghijk}
S_2T_{17} (Ambient + C-I)	0.346	0.336^{abcdefghij}	0.309^{abcdefg}	0.347	0.373^{bcdefghijk}	0.352^{defghijk}
S_2T_{18} (Ambient + C-II)	0.337	0.334^{abcdefghijk}	0.307^{abcdefg}	0.337	0.356^{bcdefghijk}	0.343^{defghijk}
S_3T_1 (Unshelled + 0.75% ZnO-I)	0.295	0.292^{defghijklm}	0.292^{abcdefg}	0.363	0.303^{ghijk}	0.302^{hijk}
S_2T_2(Unshelled + 0.75% ZnO-II)	0.291	0.284^{fghijklm}	0.284^{abcdefg}	0.356	0.327^{cdefghijk}	0.311^{ghijk}
S_3T_3 (Unshelled + 1% MgO-I)	0.297	0.276^{ijklm}	0.276^{bcdefg}	0.361	0.313^{defghijk}	0.299^{hijk}
S_3T_4 (Unshelled + 1% MgO-II)	0.274	0.277^{hijklm}	0.262^{defg}	0.362	0.318^{defghijk}	0.309^{ghijk}
S_3T_5 (Unshelled + 0.2% *Pf*-I)	0.290	0.281^{ghijklm}	0.278^{bcdefg}	0.363	0.307^{fghijk}	0.303^{hijk}
S_3T_6 (Unshelled + 0.2% *Pf*-II)	0.294	0.302^{cdefghijklm}	0.281^{bcdefg}	0.350	0.346^{bcdefghijk}	0.310^{ghijk}
S_3T_7 (Unshelled + 0.2% SA-I)	0.336	0.273^{jklm}	0.268^{cdefg}	0.344	0.287^{k}	0.284^{k}
S_3T_8 (Unshelled + 0.2% SA-II)	0.324	0.280^{ghijklm}	0.278^{bcdefg}	0.351	0.300^{hijk}	0.290^{k}
S_3T_9 (Unshelled + 0.5% SVM-I)	0.349	0.294^{defghijklm}	0.294^{abcdefg}	0.356	0.312^{efghijk}	0.307^{ghijk}
S_3T_{10} (Unshelled + 0.5% SVM-II)	0.362	0.277^{hijklm}	0.275^{bcdefg}	0.388	0.319^{defghijk}	0.278^{k}
S_3T_{11} (Unshelled + 0.1% H_3BO_3-I)	0.344	0.278^{ghijklm}	0.270^{cdefg}	0.346	0.344^{bcdefghijk}	0.282^{k}
S_3T_{12} (Unshelled + 0.1% H_3BO_3-II)	0.335	0.276^{ijklm}	0.273^{cdefg}	0.313	0.308^{fghijk}	0.300^{hijk}
S_3T_{13} (Unshelled + 0.5% S-I)	0.312	0.269^{lm}	0.260^{efg}	0.322	0.289^{jk}	0.280^{k}
S_3T_{14} (Unshelled + 0.5% S-II)	0.349	0.271^{klm}	0.270^{cdefg}	0.380	0.304^{ghijk}	0.273^{k}
S_3T_{15} (Unshelled + 0.75% $ZnSO_4$-I)	0.332	0.280^{ghijklm}	0.277^{bcdefg}	0.355	0.293^{ijk}	0.288^{k}
S_3T_{16} (Unshelled + 0.75% $ZnSO_4$-II)	0.300	0.267^{m}	0.261^{efg}	0.318	0.295^{hijk}	0.295^{ijk}
S_3T_{17} (Unshelled + C-I)	0.321	0.290^{efghijklm}	0.287^{abcdefg}	0.361	0.298^{hijk}	0.294^{ijk}
S_3T_{18} (Unshelled + C-II)	0.311	0.289^{efghijklm}	0.279^{bcdefg}	0.331	0.305^{fghijk}	0.297^{hijk}
SE(m)	0.039	0.022	0.018	0.032	0.031	0.035
CD (0.05)	NS	0.051	0.053	NS	0.088	0.102

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

(refrigeration + T_2: 0.75% ZnO-II; 0.531), S_1T_4 (refrigeration + T_4: 1% MgO-II; 0.481), S_1T_1 (refrigeration + T_1: 0.75% ZnO-I; 0.469) S_1T_7 (refrigeration + T_7: 0.2% SA-I; 0.467) and S_1T_{11} (refrigeration + T_{11}: 0.1% H_3BO_3-I; 0.465). At the end of storage, S_3T_{14} (refrigeration +0.5% S-II) recorded the least seedling allometric index (0.273) and was found to be on par with all the other treatments under S_2 and S_3 as well as treatment S_1T_{17}(refrigeration + T_{17}: C-I), S_1T_9 (refrigeration + T_9: 0.5% SVM-I), S_1T_{13} (refrigeration + T_{13}: 0.5% S-I), S_1T_{16} (refrigeration + T_{16}: 0.75% $ZnSO_4$-II), S_1T_{18} (refrigeration + T_{18}: C-II) and S_1T_{14} (refrigeration + T_{14}: 0.5% S-II) under refrigerated storage

The findings of this study with respect to root length and shoot length during seed storage are in consonance with that of Kumar (2011) and Gao *et al.* (1996). The result of the study regarding root length and shoot length under various storage conditions is also in agreement with the findings of Chin and Standifer (1969). They opined that the longevity of stored seed is highly influenced by the storage condition, type of packing material, initial quality of seed lot, kind and quantity of seed, duration of storage, temperature and relative humidity of the area.

4.2.2.4 Vigour index I (VI-I)

The results on seedling vigour index I as influenced by storage condition, foliar treatment and their interaction effects during the storage period are presented in Tables 16 and 17.

4.2.2.4.1 Due to storage condition (S)

Seedling vigour index I was observed to increase initially and decreased towards the end of storage. In S_1, VI-I increased upto 4 MAS, whereas in S_2 and S_3 the increase was upto 3 MAS (2299.00) and 2 MAS (2007.00) respectively (Fig 3). In S_1, the seedling vigour index I increased from 1500.00 (1 MAS) to 2530.00 (4 MAS) and was 1815.00 at 6 MAS while in S_2, it increased from 1389.00 (1 MAS) to 2299.00 (3 MAS) and reached 1646.00 at 6 MAS.

Table 16. Impact of storage conditions and foliar treatments on seedling vigour index 1 during seed storage

Storage condition/ Treatment	Period of storage (Months)					
	1 MAS	2 MAS	3 MAS	4 MAS	5 MAS	6 MAS
Storage condition (S)						
S_1 (Refrigeration)	1500.00^{a}	1956.00^{a}	2210.00^{b}	2530.00^{a}	1976.00^{a}	1815.00^{a}
S_2 (Ambient)	1389.00^{b}	1794.00^{b}	2299.00^{a}	1970.00^{b}	1827.00^{b}	1646.00^{b}
S_3 (Unshelled)	1445.00^{ab}	2007.00^{a}	1617.00^{c}	1215.00^{c}	1120.00^{c}	897.00^{c}
SE(m)	79.00	100.64	86.88	120.60	90.31	68.22
CD (0.05)	28.00	35.85	30.95	42.96	32.17	24.30
Foliar treatment (T)						
T_1: 0.75% ZnO-I	1176.00^{d}	1785.00^{ab}	2036.00^{ab}	2052.00	1743.00	1595.00^{a}
T_2: 0.75% ZnO-II	1304.00^{cd}	1869.00^{ab}	1949.00^{b}	1881.00	1640.00	1377.00^{bc}
T_3: 1% MgO-I	1439.00^{bc}	1992.00^{ab}	1997.00^{ab}	1950.00	1696.00	1520.00^{ab}
T_4: 1% MgO-II	1413.00^{bc}	1969.00^{ab}	2178.00^{ab}	1994.00	1732.00	1524.00^{ab}
T_5: 0.2% *Pf*-I	1331.00^{cd}	1876.00^{ab}	2071.00^{ab}	1864.00	1704.00	1496.00^{ab}
T_6: 0.2% *Pf*-II	1711.00^{a}	2064.00^{a}	2068.00^{ab}	1982.00	1699.00	1504.00^{ab}
T_7: 0.2% SA-I	1534.00^{abc}	2024.00^{ab}	2143.00^{ab}	2005.00	1687.00	1523.00^{ab}
T_8: 0.2% SA-II	1508.00^{abc}	1921.00^{ab}	1966.00^{b}	1981.00	1719.00	1528.00^{ab}
T_9: 0.5% SVM-I	1359.00^{cd}	2008.00^{ab}	2068.00^{ab}	1861.00	1517.00	1420.00^{abc}
T_{10}: 0.5% SVM-II	1627.00^{ab}	2067.00^{a}	2249.00^{a}	1984.00	1763.00	1504.00^{ab}
T_{11}: 0.1% H_3BO_3-I	1406.00^{bc}	1890.00^{ab}	1942.00^{b}	1885.00	1578.00	1382.00^{bc}
T_{12}: 0.1% H_3BO_3-II	1526.00^{abc}	1942.00^{ab}	2011.00^{ab}	1932.00	1660.00	1377.00^{bc}
T_{13}: 0.5% S-I	1394.00^{bcd}	1748.00^{b}	1988.00^{b}	1757.00	1549.00	1427.00^{abc}
T_{14}: 0.5% S-II	1451.00^{bc}	2042.00^{ab}	2114.00^{ab}	1870.00	1555.00	1425.00^{abc}
T_{15}: 0.75% $ZnSO_4$-I	1537.00^{abc}	1928.00^{ab}	2012.00^{ab}	1759.00	1517.00	1289.00^{c}
T_{16}: 0.75% $ZnSO_4$-II	1485.00^{bc}	1852.00^{ab}	1947.00^{b}	1905.00	1596.00	1382.00^{bc}
T_{17}: C-I	1342.00^{cd}	1811.00^{ab}	2062.00^{ab}	1875.00	1594.00	1435.00^{abc}
T_{18}: C-II	1461.00^{bc}	1756.93^{b}	1957.00^{b}	1753.00	1585.00	1440.00^{abc}
SE(m)	69.67	87.82	75.81	105.24	78.81	59.53
CD (0.05)	195.00	246.20	212.50	N/A	N/A	166.90

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

In S_3, VI-I increased from 1445.00 (1 MAS) to 2007.00 (2 MAS) and then decreased to 897.00 (6 MAS).

It was evident that seedling vigour index I of seeds stored under refrigeration (S_1) was significantly superior to that in other storage conditions (S_2: Ambient and S_3: Unshelled pods) as storage period increased (4 MAS onwards). Hence, it can be concluded that irrespective of the foliar treatment, storing seeds under refrigeration is more beneficial for not only prolonging the seed longevity but also to maintain higher seed quality parameters during storage. Seed storage studies in papaya by Zulhishyam *et al.* (2013) had also revealed that seeds containing lesser moisture content (6 %) and stored at lower temperature (0°C) recorded higher germination, lower dormancy and lower seed death compared to the seed in other storage conditions and seed moisture. Similar findings were also reported by Vishnurammethi (I996) in cowpea, Jasper (1998) in garden pea, Ananthi (2015) in greengram and Sudini *et al.* (2015) in groundnut.

4.2.2.4.2 Due to foliar treatment (T)

Irrespective of the foliar treatment, seedling vigour index I increased initially and later decreased towards the end of storage period. T_1 (0.75% ZnO-I) recorded the maximum seedling vigour index I (1595.00) at the end of storage. However, it was found to be on par with all other treatments including untreated controls. The exceptions being T_{15} (0.75% $ZnSO_4$-I; 1289.00), T_2 (0.75% ZnO-II; 1377.00), T_{12} (0.1% H_3BO_3-II; 1377.00), T_{11} (0.1% H_3BO_3-I; 1382.00) and T_{16} (0.75% $ZnSO_4$-II; 1382.00). The least seedling vigour index I was recorded in T_{15} (0.75% $ZnSO_4$-I; 1289.00). However, a conclusive evidence as to the best treatment cannot be drawn from the present study owing to the short storage period.

According to Movahhedy *et al.* (2009), the foliar application of zinc and manganese improves the rate of seed germination per cent, seedling dry weight and final seedling emergence of safflower over storage period of 4 months. As in the present study, Dordas (2006) also found that foliar application of micronutrients in alfalfa improved seed germination and seed vigor. Due to foliar spray of nutrients germination per cent increased

Fig.3. Impact of storage conditions on seedling vigour index I in okra

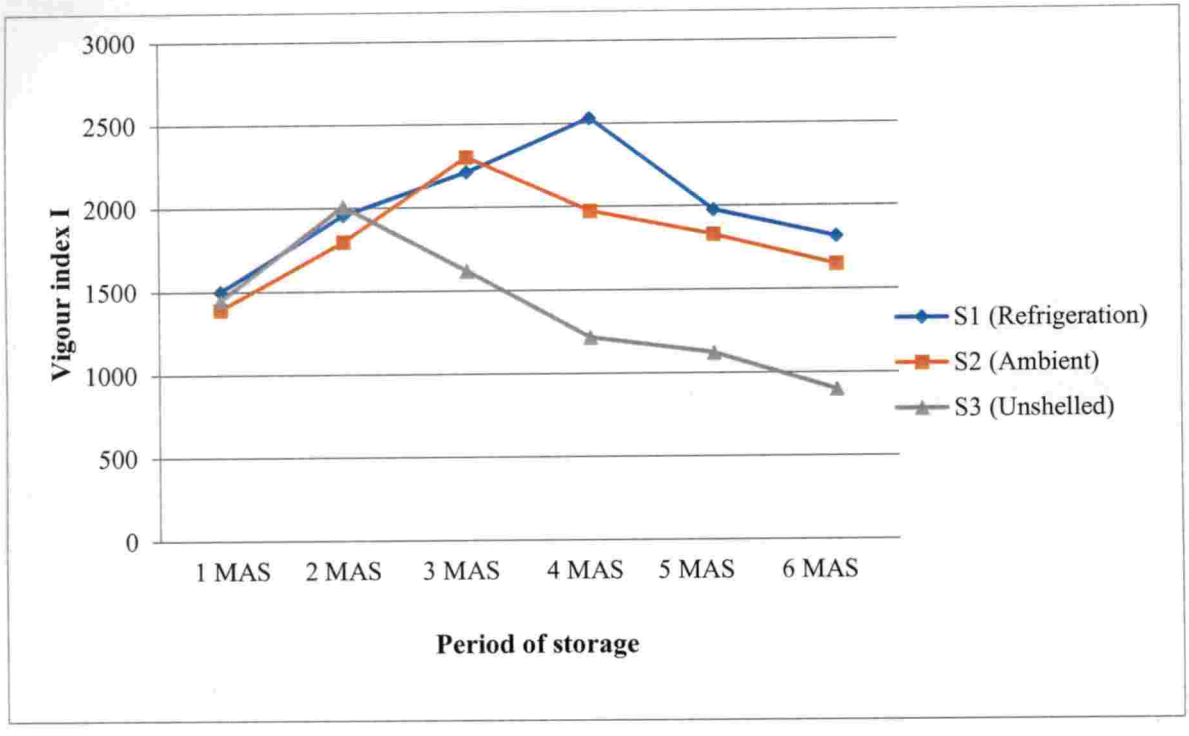
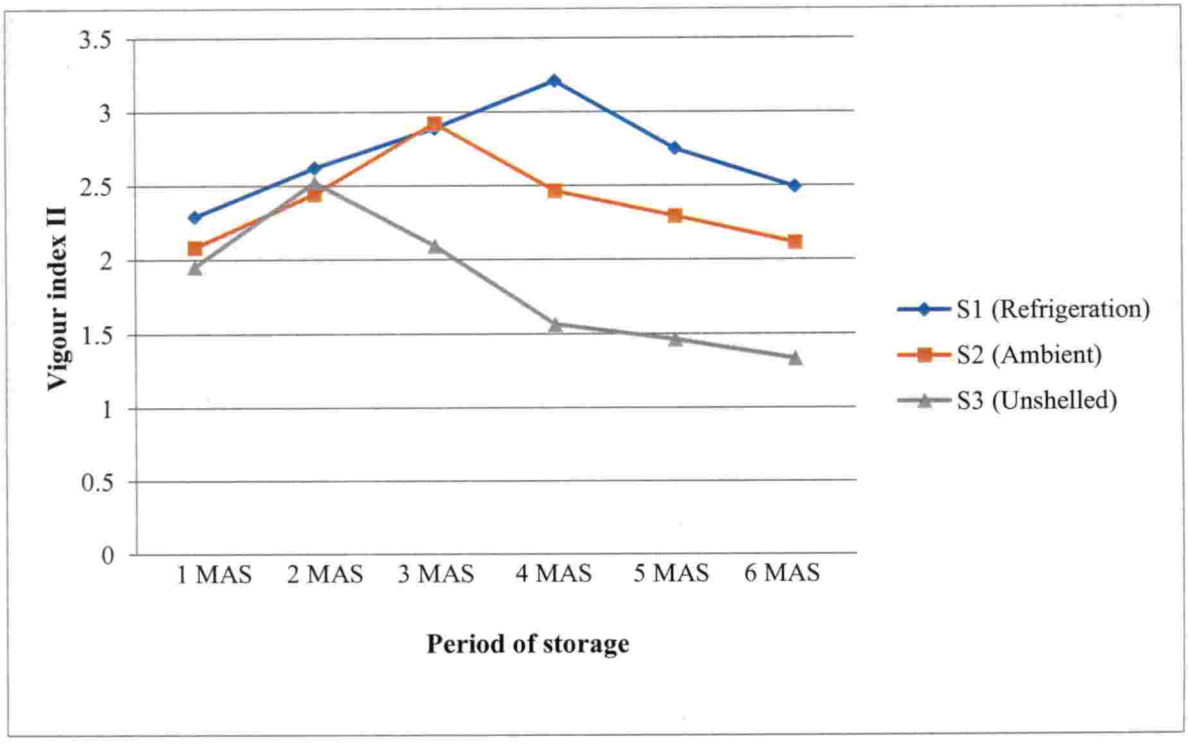


Fig.4. Impact of storage conditions on seedling vigour index II in okra



by 27 per cent immediately after harvest and up to 19 per cent after 10 months of storage compared with the untreated control. Throughout the storage period, higher per cent seed germination and seedling vigour indices I and II were observed in okra seed lot harvested from micronutrients treated fields over control fields (Mohammadi *et al.,* 2016).

4.2.2.4.3 Due to interaction (S x T)

Seedling vigour index I increased initially and later decreased towards the end of storage period. Seedling vigour index I at 1 MAS ranged between 1016.00 in S_1T_1 (refrigeration + T_1: 0.75% ZnO-I) and 1921.00 in S_3T_6 (unshelled pods + T_6: 0.2% *Pf*-II), whereas at 6 MAS it ranged between 719.00 in S_3T_{15} (unshelled pods + T_{15}: 0.75% $ZnSO_4$-I) and 2003.00 in S_1T_{10} (refrigeration + T_{10}: 0.5% SVM-II).

At the end of storage, seedling vigour in all treatments under S_3 was found to be inferior to seeds stored under both refrigeration and ambient storage. At the same instance, all treatments under refrigeration were on par with S_1T_{10}, which had registered the highest SV-I at 6 MAS. In addition, all treatments including controls (S_2T_{17} and S_2T_{18}) under ambient storage except S_2T_2 (ambient + 0.75% ZnO-II; 1520.00), S_2T_5 (ambient + 0.2% *Pf*-I; 1624.00), S_2T_9 (ambient + 0.5% SVM-I; 1560.00), S_2T_{11} (ambient + 0.1% H_3BO_3-I; 1641.00), S_2T_{12} (ambient + 0.1% H_3BO_3-II; 1578.00), S_2T_{13} (ambient + 0.5% S-I; 1567.00, S_2T_{14} (ambient + 0.5% S-II; 1632.00) and S_2T_{15} (ambient + 0.75% $ZnSO_4$-I; 1559.00) were found to be on par with S_1T_{10}.

According to Delouche and Baskin (2016), as a result of seed deterioration, the vigour indices I and II of different seed lots of corn, watermelon, sorghum and onion was found to decrease with increase in storage period. It was evident that storing unthreshed seeds leads to loss of seedling vigour over storage. Storing unthreshed seeds as such would lead to higher seed moisture fluctuation as they are not impervious. Such deviations from optimum seed moisture which in turn may lead to increased seed microflora would hasten the rate of seed deterioration.

Table 17. Interaction effect of storage conditions and foliar treatments on seedling vigour index I during seed storage

Storage condition x Treatment	Period of storage (Months)					
	1 MAS	2 MAS	3 MAS	4 MAS	5 MAS	6 MAS
Interaction (S x T)						
S_1T_1 (Refrigeration + 0.75% ZnO-I)	1016.00^{f}	1884.00^{abcde}	2165.00^{cdefgh}	2603.00^{abcde}	1918.00^{ab}	1844.00^{abcd}
S_1T_2 (Refrigeration + 0.75% ZnO-II)	1276.00^{def}	1982.00^{abcde}	2127.00^{defghi}	2424.00^{abcdefgh}	2017.00^{ab}	1766.00^{abcd}
S_1T_3 (Refrigeration + 1% MgO-I)	1630.00^{abcde}	2004.00^{abcd}	2202.00^{bcdefg}	2536.00^{abcdefg}	1975.00^{ab}	1843.00^{abcd}
S_1T_4 (Refrigeration + 1% MgO-II)	1474.00^{bcde}	2127.00^{abcd}	2411.00^{abcde}	2594.00^{abcdef}	1951.00^{ab}	1877.00^{abcd}
S_1T_5 (Refrigeration + 0.2% *Pf*-I)	1361.00^{bcdef}	2010.00^{abcd}	2243.00^{bcdef}	2333.00^{abcdefgh}	2064.00^{ab}	1931.00^{ab}
S_1T_6 (Refrigeration + 0.2% *Pf*-II)	1657.00^{abcd}	2084.00^{abcd}	2303.00^{abcde}	2649.00^{abc}	2015.00^{ab}	1852.00^{abcd}
S_1T_7 (Refrigeration + 0.2% SA-I)	1576.00^{abcde}	1980.00^{abcde}	2225.00^{bcdef}	2738.00^{a}	2027.00^{ab}	1874.00^{abcd}
S_1T_8 (Refrigeration + 0.2% SA-II)	1669.00^{abcd}	2016.00^{abcd}	2128.00^{defghi}	2540.00^{abcdefg}	2012.00^{ab}	1829.00^{abcd}
S_1T_9 (Refrigeration + 0.5% SVM-I)	1562.00^{abcde}	2130.00^{abcd}	2311.00^{abcde}	2691.00^{ab}	1960.00^{ab}	1843.00^{abcd}
S_1T_{10} (Refrigeration + 0.5% SVM-II)	1760.00^{ab}	2081.00^{abcde}	2336.00^{abcde}	2632.00^{abcd}	2159.00^{a}	2003.00^{a}
S_1T_{11} (Refrigeration + 0.1% H_3BO_3-I)	1417.00^{bcdef}	1876.00^{abcd}	2053.00^{efghijk}	2592.00^{abcdef}	1888.00^{ab}	1656.00^{abcd}
S_1T_{12} (Refrigeration + 0.1% H_3BO_3-II)	1605.00^{abcde}	2067.00^{abcde}	2234.00^{bcdef}	2617.00^{abcde}	2007.00^{ab}	1655.00^{abcd}
S_1T_{13} (Refrigeration + 0.5% S-I)	1514.00^{abcde}	1768.00^{abcde}	2262.00^{bcde}	2454.00^{abcdefgh}	2021.00^{ab}	1877.00^{abcd}
S_1T_{14} (Refrigeration + 0.5% S-II)	1617.00^{abcde}	1967.00^{abcde}	2367.00^{abcde}	2569.00^{abcdef}	1909.00^{ab}	1845.00^{abcd}
S_1T_{15} (Refrigeration + 0.75% $ZnSO_4$-I)	1486.00^{bcde}	1786.00^{bcde}	2012.00^{efghijklm}	2377.00^{abcdefgh}	1718.00^{abcde}	1590.00^{bcd}
S_1T_{16} (Refrigeration + 0.75% $ZnSO_4$-II)	1516.00^{abcde}	1875.00^{abcde}	2021.00^{efghijkl}	2551.00^{abcdefg}	1913.00^{ab}	1689.00^{abcd}
S_1T_{17} (Refrigeration + C-I)	1269.00^{def}	1710.00^{bcde}	2180.00^{bcdefgh}	2305.00^{abcdefghi}	1952.00^{ab}	1821.00^{abcd}
S_1T_{18} (Refrigeration + C-II)	1602.00^{abcde}	1864.00^{abcde}	2204.00^{bcdefg}	2350.00^{abcdefgh}	2061.00^{ab}	1887.00^{abc}
S_2T_1 (Ambient + 0.75% ZnO-I)	1308.00^{cdef}	1716.00^{abcde}	2400.00^{abcde}	2079.00^{bcdefghijk}	1918.00^{ab}	1796.00^{abcd}
S_2T_2 (Ambient + 0.75% ZnO-II)	1338.00^{bcdef}	1867.00^{abcde}	2173.00^{bcdefgh}	1958.00^{fghijklm}	1805.00^{abcd}	1520.00^{d}
S_2T_3 (Ambient +1% MgO-I)	1428.00^{bcdef}	1754.00^{abcde}	2173.00^{bcdefgh}	1987.00^{efghijkl}	1938.00^{ab}	1728.00^{abcd}
S_2T_4 (Ambient + 1% MgO-II)	1404.00^{bcdef}	1787.00^{abcde}	2602.00^{abc}	2040.00^{cdefghijk}	1894.00^{ab}	1641.00^{abcd}
S_2T_5 (Ambient + 0.2% *Pf*-I)	1278.00^{def}	1591.00^{de}	2362.00^{abcde}	1933.00^{ghijklmn}	1798.00^{abcd}	1624.00^{bcd}
S_2T_6 (Ambient + 0.2% *Pf*-II)	1555.00^{abcde}	1930.00^{abcde}	2629.00^{ab}	2122.00^{abcdefghij}	1960.00^{ab}	1779.00^{abcd}
S_2T_7 (Ambient + 0.2% SA-I)	1447.00^{bcde}	2127.00^{abcde}	2524.00^{abcd}	1867.00^{hijklmno}	1747.00^{abcd}	1652.00^{abcd}

S_2T_8 (Ambient + 0.2% SA-II)	1441.00^{bcdef}	1852.00^{abcde}	2066.00^{defghi}	2108.00^{abcdefghij}	1943.00^{ab}	1735.00^{abcd}
S_2T_9 (Ambient + 0.5% SVM-I)	1215.00^{ef}	1824.00^{abcde}	2387.00^{abcde}	1670.00^{jklmnop}	1600.00^{bcdefg}	1560.00^{cd}
S_2T_{10} (Ambient + 0.5% SVM-II)	1387.00^{bcdef}	1848.00^{abcde}	2731.00^{a}	2060.00^{bcdefghij}	1977.00^{ab}	1698.00^{abcd}
S_2T_{11} (Ambient + 0.1% H_3BO_3-I)	1324.00^{cdef}	1837.00^{cde}	2234.00^{bcdef}	1853.00^{hijklmno}	1738.00^{abcd}	1641.00^{abcd}
S_2T_{12} (Ambient + 0.1% H_3BO_3-II)	1494.00^{bcde}	1757.00^{abcde}	2069.00^{defghi}	1875.00^{hijklmno}	1742.00^{abcd}	1578.00^{bcd}
S_2T_{13} (Ambient + 0.5% S-I)	1349.00^{bcdef}	1637.00^{abcde}	2132.00^{defghi}	1694.00^{ijklmnop}	1672.00^{bcdef}	1567.00^{bcd}
S_2T_{14} (Ambient + 0.5% S-II)	1476.00^{bcde}	1934.00^{abcde}	2240.00^{bcdef}	2077.00^{bcdefghijk}	1827.00^{abc}	1632.00^{bcd}
S_2T_{15} (Ambient + 0.75% $ZnSO_4$-I)	1494.00^{bcde}	1745.00^{abcde}	2234.00^{bcdef}	2003.00^{defghijkl}	1972.00^{ab}	1559.00^{cd}
S_2T_{16} (Ambient + 0.75% $ZnSO_4$-II)	1355.00^{bcdef}	1804.00^{abcde}	2058.00^{efghij}	1999.00^{defghijkl}	1788.00^{abcd}	1614.00^{bcd}
S_2T_{17} (Ambient + C-I)	1338.00^{bcdef}	1846.00^{abcde}	2405.00^{abcde}	2219.00^{abcdefghij}	1786.00^{abcd}	1651.00^{abcd}
S_2T_{18} (Ambient + C-II)	1384.00^{bcdef}	1444.00^{e}	1974.00^{efghijklm}	1923.00^{ghijklmn}	1785.00^{abcd}	1659.00^{abcd}
S_3T_1 (Unshelled + 0.75% ZnO-I)	1203.00^{ef}	1755.00^{ab}	1545.00^{nop}	1477.00^{klmnopq}	1395.00^{cdefgh}	1147.00^{e}
S_2T_2(Unshelled + 0.75% ZnO-II)	1299.00^{def}	1758.00^{abcd}	1548.00^{nop}	1261.00^{opq}	1099.00^{hij}	846.00^{ef}
S_3T_3 (Unshelled + 1% MgO-I)	1261.00^{def}	2221.00^{abcd}	1617.00^{jklmnop}	13299.00^{nopq}	1176.00^{ghij}	991.00^{ef}
S_3T_4 (Unshelled + 1% MgO-II)	1362.00^{bcdef}	1993.00^{abc}	1524.00^{op}	1349.00^{mnopq}	1352.00^{defghi}	1055.00^{ef}
S_3T_5 (Unshelled + 0.2% *Pf*-I)	1354.00^{bcdef}	2027.00^{abcde}	1608.00^{klmnop}	1327.00^{nopq}	1253.00^{fghij}	934.00^{ef}
S_3T_6 (Unshelled + 0.2% *Pf*-II)	1921.00^{a}	2180.00^{abcde}	1275.00^{p}	1178.00^{pq}	1123.00^{hij}	884.00^{ef}
S_3T_7 (Unshelled + 0.2% SA-I)	1580.00^{abcde}	1966.00^{abcd}	1680.00^{ijklmnop}	1411.00^{lmnopq}	1288.00^{efghij}	1045.00^{ef}
S_3T_8 (Unshelled + 0.2% SA-II)	1416.00^{bcdef}	1897.00^{abcde}	1707.00^{ijklmnop}	1296.00^{opq}	1204.00^{ghij}	1022.00^{ef}
S_3T_9 (Unshelled + 0.5% SVM-I)	1302.00^{def}	2070.00^{abcde}	1506.00^{op}	1224.00^{pq}	991.00^{hij}	858.00^{ef}
S_3T_{10} (Unshelled + 0.5% SVM-II)	1736.00^{abc}	2273.00^{a}	1682.00^{ijklmnop}	1262.00^{opq}	1155.00^{ghij}	814.00^{ef}
S_3T_{11} (Unshelled + 0.1% H_3BO_3-I)	1479.00^{bcde}	1958.000^{abcde}	1542.00^{nop}	1213.00^{pq}	1109.00^{hij}	851.00^{ef}
S_3T_{12} (Unshelled + 0.1% H_3BO_3-II)	1480.00^{bcde}	2004.00^{ab}	1730.00^{hijklmno}	1306.00^{opq}	1232.6^{fghij}	901.00^{ef}
S_3T_{13} (Unshelled + 0.5% S-I)	1321.00^{cdef}	1842.00^{ab}	1569.00^{mno}	1123.00^{pq}	955.00^{hij}	840.00^{ef}
S_3T_{14} (Unshelled + 0.5% S-II)	1261.00^{def}	2226.00^{abcde}	1737.00^{hijklmno}	965.00^{q}	931.00^{hij}	799.00^{ef}
S_3T_{15} (Unshelled + 0.75% $ZnSO_4$-I)	1632.00^{abcde}	2254.00^{abcde}	1793.00^{fghijklmno}	899.00^{q}	861.00^{j}	719.00^{f}
S_3T_{16} (Unshelled + 0.75% $ZnSO_4$-II)	1586.00^{abcde}	1878.00^{abcde}	1762.00^{ghijklmno}	1168.00^{pq}	1086.00^{hij}	844.00^{e}
S_3T_{17} (Unshelled + C-I)	1421.00^{bcdef}	1878.00^{abcde}	1603.00^{lmnop}	1104.00^{pq}	1045.00^{hij}	835.00^{fef}
S_3T_{18} (Unshelled + C-II)	1398.00^{bcdef}	1963.00^{abcde}	1694.00^{ijklmnop}	988.00^{q}	910.000^{j}	775.00^{f}
SE(m)	120.50	152.10	131.31	182.28	136.49	103.11
CD (0.05)	337.80	426.40	368.10	511.00	382.6	289.00

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

According to Delouche *et al.* (1973), the storability of seed in a specific environment is largely determined by its inheritance and pre-storage history. Inherent differences in longevity among species and cultivars are biological facts over which one has no control. The pre-storage history of seed, however, is controllable. Timely harvesting and threshing, prompt and adequate drying, and careful handling minimize quality losses from field exposure, high moisture contents, and mechanical damage, and contribute to a seed history favourable for storage. Relative humidity and temperature of the storage environment are the most important factors affecting maintenance of seed quality during the storage period. Of these two factors, relative humidity is most important because of its direct relation to seed moisture content. Ambient temperature and relative humidity in the subtropics and tropics are usually sufficiently adverse for storage of seed that some conditioning of the environment is necessary for successful storage.

4.2.2.5 Vigour index II (VI-II)

The results on seedling vigour index II as influenced by storage condition, foliar treatment and their interaction effects during the storage period are presented in Tables 18 and 19.

4.2.2.5.1 Due to storage condition (S)

As in the case of seedling vigour index I, seedling vigour index II was also observed to increase in initial months of storage and decreased thereafter. As seen in Fig. 4, the seedling vigour index II of seeds stored in S_1 was found to be significantly superior to that in S_2 and S_3 throughout the storage period except at 3 MAS. At 3 MAS, the vigour index II in S_1 was 2.49 compared to 2.11 and 1.33 in S_2 and S_3 respectively.

Considering the above, it can be concluded that storing bhendi seeds under refrigeration is beneficial compared to storing seeds in ambient condition or as unshelled pods. The result is in consonance with the findings of Malaker *et al.* (2008).

Table 18. Impact of storage conditions and foliar treatments on seedling vigour index II during seed storage

Storage condition/ Treatment	Period of storage (Months)					
	1 MAS	2 MAS	3 MAS	4 MAS	5 MAS	6 MAS
Storage condition (S)						
S_1 (Refrigeration)	2.29^{a}	2.62^{a}	2.89^{a}	3.21^{a}	2.75^{a}	2.49^{a}
S_2 (Ambient)	2.08^{b}	2.44^{b}	2.92^{a}	2.46^{b}	2.29^{b}	2.11^{b}
S_3 (Unshelled)	1.95^{c}	$2.52a^{b}$	2.09^{b}	1.56^{c}	1.46^{c}	1.33^{c}
SE(m)	0.112	0.131	0.121	0.164	0.123	0.156
CD (0.05)	0.04	0.047	0.043	0.058	0.044	0.056
Foliar treatment (T)						
T_1: 0.75% ZnO-I	1.76^{d}	2.27^{d}	2.58^{b}	2.50	2.28	2.16
T_2: 0.75% ZnO-II	1.88^{cd}	2.38^{bcd}	2.46^{b}	2.35	2.22	1.89
T_3: 1% MgO-I	2.05^{bcd}	2.50^{abcd}	2.49^{b}	2.35	2.11	1.85
T_4: 1% MgO-II	2.08^{bcd}	2.62^{abcd}	2.69^{b}	2.43	2.12	2.02
T_5: 0.2% *Pf*-I	2.08^{bcd}	2.53^{abcd}	2.71^{b}	2.41	2.25	2.06
T_6: 0.2% *Pf*-II	2.49^{a}	2.78^{a}	2.66^{b}	2.55	2.27	2.15
T_7: 0.2% SA-I	2.21^{abc}	2.69^{abc}	2.76^{b}	2.48	2.23	2.05
T_8: 0.2% SA-II	2.11^{bc}	2.48^{abcd}	2.54^{b}	2.41	2.16	2.06
T_9: 0.5% SVM-I	2.06^{bcd}	2.57^{abcd}	2.69^{b}	2.40	2.08	1.77
T_{10}: 0.5% SVM-II	2.32^{ab}	2.78^{a}	3.13^{a}	2.59	2.40	2.04
T_{11}: 0.1% H_3BO_3-I	2.05^{bcd}	2.42^{abcd}	2.57^{b}	2.45	2.16	1.95
T_{12}: 0.1% H_3BO_3-II	2.34^{ab}	2.65^{abcd}	2.65^{b}	2.45	2.25	1.93
T_{13}: 0.5% S-I	2.10^{bc}	2.36^{bcd}	2.59^{b}	2.31	2.11	2.03
T_{14}: 0.5% S-II	2.11^{bc}	2.71^{ab}	2.65^{b}	2.44	2.11	1.99
T_{15}: 0.75% $ZnSO_4$-I	2.17^{bc}	2.49^{abcd}	2.63^{b}	2.27	2.04	1.83
T_{16}: 0.75% $ZnSO_4$-II	2.11^{bc}	2.61^{abcd}	2.46^{b}	2.43	2.11	1.86
T_{17}: C-I	1.94^{cd}	2.32^{cd}	2.64^{b}	2.35	2.12	1.98
T_{18}: C-II	2.06^{bcd}	2.30^{d}	2.54^{b}	2.21	2.03	1.94
SE(m)	0.098	0.114	0.106	0.143	0.108	0.136
CD (0.05)	0.275	0.321	0.297	N/A	N/A	N/A

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

4.2.2.5.2 Due to foliar treatment (T)

In all the treatments seedling vigour index II was found to increase upto 3 MAS and declined towards end of storage (6 MAS). Significant difference in VI-II was observed only in the initial months of storage (upto 3 MAS). At 3 MAS, T_{10} (0.5% SVM-II) registered the highest seedling vigour index II (3.13) and it was significantly superior to all other treatments. This pointed out the advantage of two-time foliar application of micronutrient mixture in producing robust and vigorous seedlings.

As in the present study, the foliar application of micronutrient mixture enhanced the seed quality parameters like germination and vigour indices of seeds on storage (Abdul-Baki and Anderson, 1973 in soybean; Sivaiah, *et al.*, 2013 in tomato).

4.2.2.5.3 Due to interaction (S x T)

As observed earlier, in all the treatments seedling vigour index II was found to increase initially and declined towards end of storage (6 MAS). There was significant difference in the interaction between storage environment and foliar treatments throughout the storage period.

At the end of storage, VI-II in all treatments under S_3 was found to be inferior to seeds stored under both refrigeration and ambient storage except S_1T_3 (refrigeration + T_3: 1% MgO-I: 1.94), S_2T_2 (ambient + T_2: 0.75% ZnO-II: 1.84) and S_2T_4 (ambient + T_4: 1% MgO-II: 1.96). All other treatments including the control T_{17} and T_{18} were on par with each other at 6 MAS, although S_1T_{10} (refrigeration + T_{10}: 0.5% SVM-II: 2.84) had registered the highest VI-II at 6 MAS. It was observed that this treatment had also registered the maximum vigour at 4 MAS (3.73) and 5 MAS (3.27). It is to be noted that S_1T_{10} had also registered the highest SV-I at 6 MAS.

Hence, the results clearly points out the advantage of foliar application of micronutrient mixture, *i.e.,* Sampoorna KAU vegetable mix in obtaining high germination as well as vigorous seedlings. Studies by Biradar (2001) and

Tammanagouda (2002) in green gram, Madinur (2007) in drumstick have all pointed that foliar application of micronutrient exerted significant positive impact on seed germination and seedling vigour.

4.2.2.6 Electrical conductivity of seed leachate (μSm^{-1}) (EC)

The results on electrical conductivity of seed leachate as influenced by storage condition, foliar treatment and their interaction effects during the storage period are presented in Tables 20 and 21.

4.2.2.6.1 Due to storage condition (S)

The electrical conductivity of seed leachate was observed to increase with increase in storage period. Throughout the storage period the electrical conductivity of seed leachate of seeds stored under refrigeration (S_1) was found to be the least and significantly lower to those under ambient storage (S_2) and as unshelled pods (S_3) (Fig. 5). The electrical conductivity of seed leachate increased from 121.84μSm^{-1} at 1 MAS to 141.21μSm^{-1} at 6 MAS in S_1 while the increase was from 136.28μSm^{-1} to 188.37μSm^{-1} in S_2 and 154.13μSm^{-1} to 582.11μSm^{-1} in S_3 respectively at the start and end of storage period. As observed in the study, an increase in electrical conductivity of seed leachate of okra with increase in storage period have been reported earlier (Kalpana and Madhava, 1995; Saha and Sultana, 2008).

Generally, seed quality is inversely related to seed leachate values; higher the EC, lower is the seed quality. The proportional increase in the extent of leakage of cytoplasmic components to external medium with ageing has been confirmed by Simon (1976) and Dahuja and Lodha (2014). It was observed that the electrical conductivity of leachate in seeds within unthreshed pods were inferior and least throughout storage period indicating the disadvantage of storing seeds without threshing. This may be because, the seeds in the pods harvested at physiological maturity may have imbibed moisture over the storage period owing to the presence of hair-line cracks.

Table 19. Interaction effect of storage conditions and foliar treatments on seedling vigour index II during seed storage

Storage condition x Treatment	Period of storage (Months)					
	1 MAS	2 MAS	3 MAS	4 MAS	5 MAS	6 MAS
Interaction (S x T)						
S_1T_1 (Refrigeration + 0.75% ZnO-I)	1.45^{j}	2.35^{abcd}	$2.73^{cdefghijklm}$	$3.03^{abcdefg}$	2.57^{bcdefg}	2.46^{abcde}
S_1T_2 (Refrigeration + 0.75% ZnO-II)	$2.01^{cdefghij}$	2.60^{abcd}	$2.70^{cdefghijklmn}$	$2.82^{bcdefgh}$	2.76^{abcdef}	2.49^{abcde}
S_1T_3 (Refrigeration + 1% MgO-I)	2.42^{abcde}	2.53^{abcd}	$2.52^{efghijklmnop}$	$2.80^{bcdefgh}$	$2.43^{bcdefgh}$	$1.94^{cdefghijklmnopq}$
S_1T_4 (Refrigeration + 1% MgO-II)	2.40^{abcdef}	2.84^{ab}	3.14^{bcde}	3.25^{abcd}	$2.71^{abcdefg}$	2.62^{abcd}
S_1T_5 (Refrigeration + 0.2% *Pf*-I)	$2.31^{abcdefg}$	2.67^{abcd}	3.01^{bcdefg}	3.06^{abcdef}	2.95^{ab}	2.80^{ab}
S_1T_6 (Refrigeration + 0.2% *Pf*-II)	2.61^{ab}	2.80^{abc}	3.07^{bcdef}	3.45^{abc}	2.81^{abcde}	2.76^{abc}
S_1T_7 (Refrigeration + 0.2% SA-I)	2.41^{abcdef}	2.81^{abc}	3.03^{bcdefg}	3.16^{abcdef}	$2.69^{abcdefg}$	2.47^{abcde}
S_1T_8 (Refrigeration + 0.2% SA-II)	2.37^{abcdef}	2.62^{abcd}	$2.76^{cdefghijkl}$	$2.82^{bcdefgh}$	2.52^{bcdefg}	2.47^{abcde}
S_1T_9 (Refrigeration + 0.5% SVM-I)	$2.29^{abcdefg}$	2.57^{abcd}	$2.81^{bcdefghijk}$	3.57^{ab}	2.88^{abc}	$2.15^{abcdefghij}$
S_1T_{10} (Refrigeration + 0.5% SVM-II)	2.67^{a}	2.80^{abc}	3.40^{ab}	3.73^{a}	3.27^{a}	2.84^{a}
S_1T_{11} (Refrigeration + 0.1% H_3BO_3-I)	$2.27^{abcdefg}$	2.48^{abcd}	$2.86^{bcdefghi}$	3.51^{ab}	2.83^{abcde}	2.42^{abcde}
S_1T_{12} (Refrigeration + 0.1% H_3BO_3-II)	2.62^{ab}	2.93^{a}	3.04^{bcdef}	3.42^{abc}	2.91^{ab}	2.38^{abcde}
S_1T_{13} (Refrigeration + 0.5% S-I)	$2.26^{abcdefgh}$	2.44^{abcd}	3.04^{bcdef}	3.23^{abcde}	2.85^{abcd}	2.70^{abc}
S_1T_{14} (Refrigeration + 0.5% S-II)	2.49^{abcd}	2.82^{abc}	$2.85^{bcdefghi}$	3.42^{abc}	2.74^{abcdef}	2.72^{abc}
S_1T_{15} (Refrigeration + 0.75% $ZnSO_4$-I)	$2.21^{abcdefgh}$	2.41^{abcd}	$2.68^{cdefghijklmn}$	3.15^{abcdef}	2.50^{bcdefg}	2.28^{abcdef}
S_1T_{16} (Refrigeration + 0.75% $ZnSO_4$-II)	$2.29^{abcdefg}$	2.76^{abc}	$2.59^{defghijklmnop}$	3.45^{abc}	$2.70^{abcdefg}$	2.26^{abcdef}
S_1T_{17} (Refrigeration + C-I)	$1.96^{cdefghij}$	2.28^{abcd}	2.90^{bcdefg}	$2.92^{abcdefgh}$	2.73^{abcdef}	2.54^{abcde}
S_1T_{18} (Refrigeration + C-II)	$2.25^{abcdefgh}$	2.44^{abcd}	2.93^{bcdefg}	$2.99^{abcdefg}$	$2.70^{abcdefg}$	2.50^{abcde}
S_2T_1 (Ambient + 0.75% ZnO-I)	$2.09^{abcdefghi}$	2.33^{abcd}	2.93^{bcdefg}	$2.53^{defghijk}$	2.47^{bcdefg}	2.29^{abcdef}
S_2T_2 (Ambient + 0.75% ZnO-II)	1.88^{efghij}	2.36^{abcd}	$2.71^{cdefghijklm}$	$2.62^{cdefghijk}$	$2.31^{bcdefghi}$	$1.84^{defghijklmnopq}$
S_2T_3 (Ambient +1% MgO-I)	$2.06^{bcdefghi}$	2.30^{abcd}	$2.83^{bcdefghij}$	$2.48^{defghijkl}$	$2.31^{bcdefghi}$	$2.20^{abcdefgh}$
S_2T_4 (Ambient + 1% MgO-II)	$1.99^{cdefghij}$	2.45^{abcd}	3.10^{bcdef}	$2.40^{defghjklm}$	$2.13^{fghijklm}$	$1.96^{cdefghijklmnopq}$
S_2T_5 (Ambient + 0.2% *Pf*-I)	$1.96^{cdefghij}$	2.27^{abcd}	3.04^{bcdef}	$2.38^{efghijklmno}$	$2.24^{cdefghij}$	$2.04^{abcdefghijklmno}$
S_2T_6 (Ambient + 0.2% *Pf*-II)	$2.32^{abcdefg}$	2.81^{abc}	3.31^{abc}	$2.73^{bcdefghi}$	2.59^{bcdefg}	2.39^{abcde}

S_2T_7 (Ambient + 0.2% SA-I)	$2.06^{bcdefghi}$	2.71^{abcd}	3.07^{bcdef}	$2.46^{defghijklm}$	$2.31^{bcdefghi}$	$2.17^{abcdefghi}$
S_2T_8 (Ambient + 0.2% SA-II)	$2.14^{abcdefghi}$	2.50^{abcd}	$2.67^{cdefghijklmn}$	$2.77^{bcdefghi}$	$2.42^{bcdefgh}$	$2.22^{abcdefg}$
S_2T_9 (Ambient + 0.5% SVM-I)	$2.06^{bcdefghi}$	2.59^{abcd}	3.23^{abcd}	$2.11^{hijklmnopqr}$	$2.07^{ghijklm}$	$2.00^{bcdefghijklmnop}$
S_2T_{10} (Ambient + 0.5% SVM-II)	$2.18^{abcdefghi}$	2.67^{abcd}	3.73^{a}	$2.44^{defghijklmn}$	$2.37^{bcdefgh}$	$2.11^{abcdefghijklm}$
S_2T_{11} (Ambient + 0.1% H_3BO_3-I)	$1.97^{cdefghij}$	2.41^{abcd}	$2.86^{bcdefghi}$	$2.31^{fghijklmnopq}$	$2.19^{efghijk}$	$2.13^{abcdefghijk}$
S_2T_{12} (Ambient + 0.1% H_3BO_3-II)	2.37^{abcdef}	2.50^{abcd}	$2.68^{cdefghijklmn}$	$2.31^{fghijklmnopq}$	$2.22^{defghij}$	$2.03^{abcdefghijklmno}$
S_2T_{13} (Ambient + 0.5% S-I)	$2.12^{abcdefghi}$	2.17^{bcd}	$2.71^{cdefghijklm}$	$2.18^{ghijklmnopq}$	$2.15^{fghijkl}$	$2.09^{abcdefghijklmn}$
S_2T_{14} (Ambient + 0.5% S-II)	$2.24^{abcdefgh}$	2.59^{abcd}	$2.88^{bcdefgh}$	$2.73^{bcdefghi}$	$2.39^{bcdefgh}$	$2.09^{abcdefghijklmn}$
S_2T_{15} (Ambient + 0.75% $ZnSO_4$-I)	$2.14^{abcdefghi}$	2.29^{abcd}	$2.82^{bcdefghij}$	$2.44^{defghijklmn}$	$2.43^{bcdefgh}$	$2.04^{abcdefghijklmno}$
S_2T_{16} (Ambient + 0.75% $ZnSO_4$-II)	1.88^{efghij}	2.49^{abcd}	$2.63^{defghijklmno}$	$2.35^{fghijklmnop}$	$2.21^{defghij}$	$2.09^{abcdefghijklmn}$
S_2T_{17} (Ambient + C-I)	$1.90^{defghij}$	2.39^{abcd}	2.91^{bcdefg}	$2.62^{cdefghij}$	$2.25^{cdefghi}$	$2.13^{abcdefghij}$
S_2T_{18} (Ambient + C-II)	$2.04^{bcdefghij}$	2.04^{d}	$2.47^{fghijklmnopq}$	$2.33^{fghijklmnop}$	$2.18^{efghijk}$	$2.12^{abcdefghijkl}$
S_3T_1 (Unshelled + 0.75% ZnO-I)	1.73^{ghij}	2.12^{cd}	2.07^{nopqr}	$1.93^{ijklmnopqrs}$	$1.80^{hijklmno}$	$1.73^{efghijklmnopq}$
S_2T_2(Unshelled + 0.75% ZnO-II)	1.76^{ghij}	2.18^{bcd}	1.96^{pqr}	1.60^{nopqrs}	1.58^{klmno}	$1.33^{jklmnopq}$
S_3T_3 (Unshelled + 1% MgO-I)	1.66^{hij}	2.68^{abcd}	$2.13^{lmnopqr}$	$1.76^{klmnopqrs}$	1.59^{klmno}	$1.42^{ghijklmnopq}$
S_3T_4 (Unshelled + 1% MgO-II)	1.84^{efghij}	2.57^{abcd}	1.85^{qr}	$1.64^{lmnopqrs}$	1.52^{mno}	$1.48^{fghijklmnopq}$
S_3T_5 (Unshelled + 0.2% *Pf*-I)	$1.97^{cdefghij}$	2.65^{abcd}	2.07^{nopqr}	$1.80^{jklmnopqrs}$	1.54^{lmno}	$1.35^{ijklmnop}$
S_3T_6 (Unshelled + 0.2% *Pf*-II)	2.55^{abc}	2.73^{abcd}	1.61^{r}	1.46^{qrs}	1.43^{o}	$1.31^{klmnopq}$
S_3T_7 (Unshelled + 0.2% SA-I)	$2.17^{abcdefghi}$	2.57^{abcd}	$2.18^{klmnopqr}$	$1.82^{jklmnopqrs}$	$1.68^{ijklmno}$	$1.51^{fghijklmnop}$
S_3T_8 (Unshelled + 0.2% SA-II)	1.81^{fghij}	2.31^{abcd}	$2.18^{klmnopqr}$	$1.63^{lmnopqrs}$	1.53^{lmno}	$1.50^{fghijklmnopq}$
S_3T_9 (Unshelled + 0.5% SVM-I)	1.85^{efghij}	2.56^{abcd}	2.02^{opqr}	1.53^{opqrs}	1.29^{o}	1.17^{q}
S_3T_{10} (Unshelled + 0.5% SVM-II)	$2.13^{abcdefghi}$	2.87^{ab}	$2.25^{hijklmnopq}$	1.59^{nopqrs}	1.56^{lmno}	1.18^{q}
S_3T_{11} (Unshelled + 0.1% H_3BO_3-I)	$1.91^{defghij}$	2.36^{abcd}	1.99^{pqr}	1.54^{opqrs}	1.45^{no}	1.30^{lmnopq}
S_3T_{12} (Unshelled + 0.1% H_3BO_3-II)	$2.04^{bcdefghij}$	2.51^{abcd}	$2.24^{ijklmnopq}$	$1.62^{mnopqrs}$	1.62^{jklmno}	$1.39^{hijklmnop}$
S_3T_{13} (Unshelled + 0.5% S-I)	$1.91^{defghij}$	2.47^{abcd}	2.03^{opqr}	1.53^{opqrs}	1.33^{o}	1.29^{mnopq}
S_3T_{14} (Unshelled + 0.5% S-II)	1.59^{ij}	2.71^{abcd}	$2.21^{jklmnopqr}$	1.17^{s}	1.21^{o}	1.18^{q}
S_3T_{15} (Unshelled + 0.75% $ZnSO_4$-I)	$2.17^{abcdefghi}$	2.79^{abc}	$2.39^{ghijklmnopq}$	1.23^{s}	1.19^{o}	1.16^{q}
S_3T_{16} (Unshelled + 0.75% $ZnSO_4$-II)	$2.16^{abcdefghi}$	2.58^{abcd}	$2.16^{lmnopqr}$	1.47^{qrs}	1.42^{o}	1.22^{opq}

S_3T_{17} (Unshelled + C-I)	$1.95^{cdefghij}$	2.30^{abcd}	2.11^{mnopqr}	1.51^{pqr}	1.38^{o}	1.27^{nopq}
S_3T_{18} (Unshelled + C-II)	1.88^{efghij}	2.43^{abcd}	$2.23^{ijklmnopqr}$	1.31^{s}	1.20^{o}	1.20^{pq}
SE(m)	0.170	0.198	0.183	0.247	0.186	0.236
CD (0.05)	0.4746	0.5536	0.5118	0.6942	0.5219	0.6634

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

According to Nagarajan and Karivaratharaju (1976), Krishnaveni and Ramaswamy (1985), Bharathi (1999), Hemashree and Kurdikeri (2011) and Suganya (2015), seeds stored in moisture impervious containers recorded significantly lower EC values especially during later stages of seed storage, indicating better seed quality with them as compared to moisture-pervious containers. This could be due to increased membrane permeability during seed ageing as opined by Malarkodi and Dharmalingam (1999) in bajra, Dharmalingam *et al.* (2000) in pulses and Raikar *et al.* (2011) in scented rice. Raikar *et al.* (2011) had also reported that the seeds stored under refrigeration exhibited low electrical conductivity and thus low deterioration.

4.2.2.6.2 Due to foliar treatment (T)

Electrical conductivity of seed leachate increased over storage irrespective of the foliar treatment. The foliar treatments influenced EC of seed leachate significantly throughout storage. However, none of the treatments exhibited a consistent trend with respect to this trait during storage. At 1 MAS the least EC was observed in T_{14} (0.5% S-II; 121.44μSm^{-1}) while it was least in T_7 (0.2% SA-I; 236.78μSm^{-1}). T_2 (0.75% ZnO-II; 245.11μSm^{-1}), T_2 (0.75% ZnO-II; 261.45μSm^{-1}), T_3 (1% MgO-I; 280.22μSm^{-1}) and T_3 (1% MgO-I; 294.05μSm^{-1}) respectively at 2 MAS, 3 MAS, 4 MAS, 5 MAS and 6 MAS.

At 6 MAS, T_3 was found to be on par with most of the treatments including control T_{18} (C-II; 304.44μSm^{-1}). However, it was significantly superior to T_6 (0.2% *Pf*-II; 311.62μSm^{-1}) and control T_{17} (C-I: 309.38μSm^{-1}).

Reports on significant influence of foliar nutrition on EC of seed leachate over storage are few. Wilcox and Shibles (2001) had also observed that foliar nutrition in seed crop exerted a significant impact on rate of seed deterioration.

Fig.5 Impact of storage conditions on electrical conductivity of seed leachate (μSm^{-1}) in okra

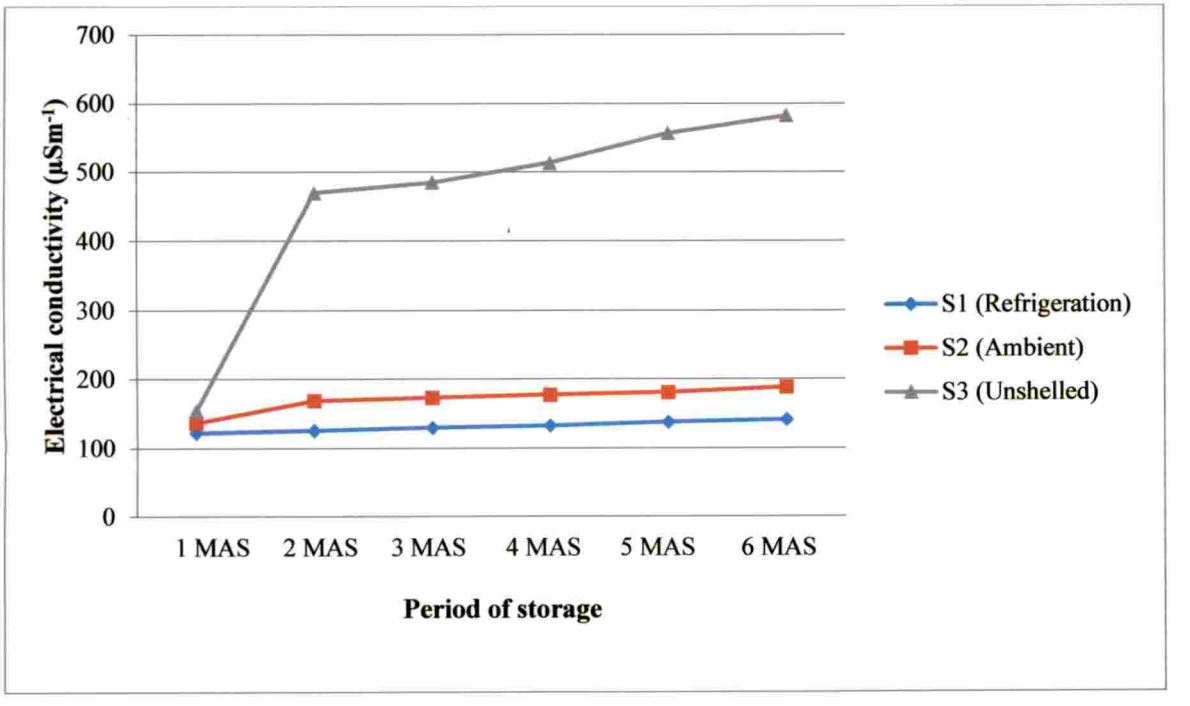


Fig.6 Impact of storage conditions on seed moisture content (%) in okra

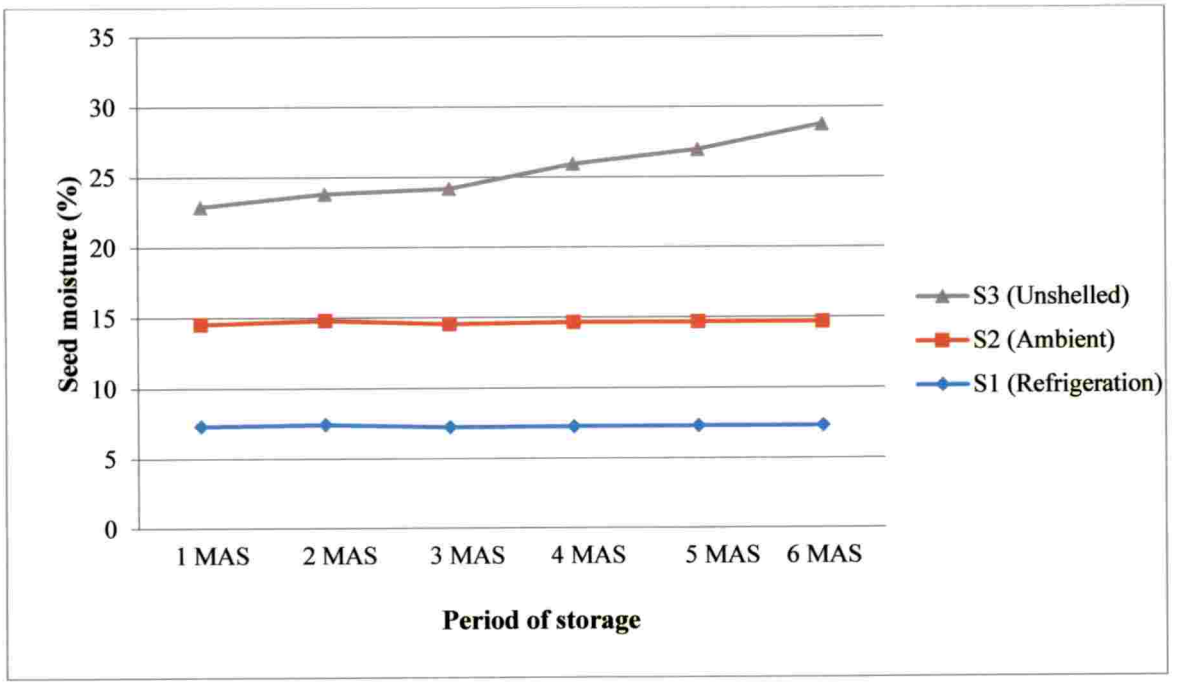


Table 20. Impact of storage conditions and foliar treatments on electrical conductivity (μSm^{-1}) of seed leachate during storage

Storage condition / Treatment	Period of storage (Months)					
	1 MAS	2 MAS	3 MAS	4 MAS	5 MAS	6 MAS
Storage condition (S)						
S_1 (Refrigeration)	121.84^{c}	125.38^{c}	129.40^{c}	132.32^{c}	137.47^{c}	141.21^{c}
S_2 (Ambient)	136.28^{b}	168.59^{b}	173.22^{b}	177.25^{b}	180.84^{b}	188.37^{b}
S_3 (Unshelled)	154.13^{a}	469.43^{a}	484.54^{a}	513.28^{a}	556.33^{a}	582.11^{a}
SE(m)	6.40	7.72	6.48	6.45	5.95	4.81
CD (0.05)	2.28	2.75	2.31	2.30	2.12	1.71
Foliar treatment (T)						
T_1: 0.75% ZnO-I	130.67^{cde}	238.22^{cd}	253.22^{ab}	286.33^{abc}	289.67^{ab}	301.71^{abc}
T_2: 0.75% ZnO-II	127.00^{cde}	240.11^{bcd}	245.11^{b}	261.45^{d}	281.67^{ab}	296.40^{bc}
T_3: 1% MgO-I	125.88^{cde}	252.11^{abcd}	255.89^{ab}	267.89^{cd}	280.22^{b}	294.05^{c}
T_4: 1% MgO-II	151.56^{ab}	262.45^{ab}	267.91^{a}	276.67^{abcd}	293.96^{ab}	307.82^{abc}
T_5: 0.2% *Pf*-I	156.78^{a}	254.40^{abcd}	260.00^{ab}	274.89^{abcd}	297.74^{ab}	306.80^{abc}
T_6: 0.2% *Pf*-II	151.33^{ab}	263.89^{a}	264.67^{a}	270.00^{bcd}	291.33^{ab}	311.62^{a}
T_7: 0.2% SA-I	135.00^{bcde}	236.78^{d}	259.33^{ab}	264.89^{d}	288.93^{ab}	301.89^{abc}
T_8: 0.2% SA-II	126.78^{cde}	249.11^{abcd}	258.67^{ab}	264.22^{d}	286.33^{ab}	301.70^{abc}
T_9: 0.5% SVM-I	141.00^{abcd}	260.45^{abc}	266.67^{a}	268.67^{cd}	287.44^{ab}	300.44^{abc}
T_{10}: 0.5% SVM-II	136.78^{bcde}	259.78^{abc}	262.89^{ab}	267.52^{cd}	287.67^{ab}	299.33^{abc}
T_{11}: 0.1% H_3BO_3-I	149.82^{ab}	261.41^{ab}	269.89^{a}	286.11^{abc}	295.22^{ab}	307.58^{abc}
T_{12}: 0.1% H_3BO_3-II	138.67^{abcde}	255.11^{abcd}	263.11^{ab}	270.22^{bcd}	293.89^{ab}	302.63^{abc}
T_{13}: 0.5% S-I	140.67^{abcd}	259.67^{abc}	268.39^{a}	288.78^{a}	297.96^{ab}	307.85^{abc}
T_{14}: 0.5% S-II	121.44^{e}	257.59^{abcd}	264.33^{a}	269.22^{cd}	288.18^{ab}	308.22^{abc}
T_{15}: 0.75% $ZnSO_4$-I	142.21^{abc}	259.45^{abc}	263.45^{ab}	265.33^{d}	295.89^{ab}	303.98^{abc}
T_{16}: 0.75% $ZnSO_4$-II	122.44^{de}	254.82^{abcd}	266.56^{a}	274.22^{abcd}	294.78^{ab}	304.31^{abc}
T_{17}: C-I	140.33^{abcd}	261.30^{ab}	265.78^{a}	288.33^{ab}	298.11^{a}	309.38^{ab}
T_{18}: C-II	135.11^{bcde}	253.77^{abcd}	267.11^{a}	292.33^{a}	298.89^{a}	304.44^{abc}
SE(m)	5.58	6.73	5.65	5.63	5.19	4.20
CD (0.05)	15.64	18.87	15.84	15.78	14.55	11.76

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

Table 21. Interaction effect of storage conditions and foliar treatments on electrical conductivity (μSm^{-1}) of seed leachate during storage

Storage condition x Treatment	Period of storage (Months)					
	1 MAS	2 MAS	3 MAS	4 MAS	5 MAS	6 MAS
Interaction (S x T)						
S_1T_1 (Refrigeration + 0.75% ZnO-I)	119.00^{jkl}	120.33^{klm}	120.00^{i}	125.00^{lm}	126.33^{i}	131.33^{jk}
S_1T_2 (Refrigeration + 0.75% ZnO-II)	105.33^{l}	109.00^{m}	114.00^{i}	120.00^{m}	125.33^{i}	125.50^{k}
S_1T_3 (Refrigeration + 1% MgO-I)	120.97^{jkl}	122.00^{jklm}	126.67^{hi}	127.33^{lm}	128.33^{i}	134.67^{jk}
S_1T_4 (Refrigeration + 1% MgO-II)	122.00^{ijkl}	126.00^{hijklm}	130.73^{ghi}	134.33^{jklm}	145.67^{ghi}	154.67^{fghij}
S_1T_5 (Refrigeration + 0.2% *Pf*-I)	$132.00^{defghijkl}$	$134.54^{efghijklm}$	144.67^{efghi}	153.00^{hijklm}	156.33^{defghi}	159.67^{efghi}
S_1T_6 (Refrigeration + 0.2% *Pf*-II)	$129.00^{efghijkl}$	$129.33^{ghijklm}$	129.33^{ghi}	129.67^{klm}	154.33^{efghi}	161.00^{defgh}
S_1T_7 (Refrigeration + 0.2% SA-I)	123.33^{hijkl}	124.00^{ijklm}	125.67^{i}	127.67^{lm}	129.00^{i}	133.70^{jk}
S_1T_8 (Refrigeration + 0.2% SA-II)	109.33^{kl}	119.00^{lm}	122.67^{i}	126.00^{lm}	134.33^{hi}	135.50^{ijk}
S_1T_9 (Refrigeration + 0.5% SVM-I)	126.67^{ghijkl}	$127.33^{ghijklm}$	127.67^{hi}	129.33^{klm}	129.31^{i}	133.67^{jk}
S_1T_{10} (Refrigeration + 0.5% SVM-II)	$127.00f^{ghijkl}$	$127.00^{ghijklm}$	127.33^{hi}	130.33^{klm}	135.00^{hi}	135.43^{ijk}
S_1T_{11} (Refrigeration + 0.1% H_3BO_3-I)	$135.47^{cdefghijkl}$	$141.67^{defghijklm}$	142.00^{fghi}	142.67^{ijklm}	151.67^{fghi}	152.67^{ghij}
S_1T_{12} (Refrigeration + 0.1% H_3BO_3-II)	$127.67^{fghijkl}$	$128.00^{ghijklm}$	132.33^{ghi}	136.00^{iklm}	138.33^{ghi}	138.67^{hij}
S_1T_{13} (Refrigeration + 0.5% S-I)	124.00^{hijkl}	125.33^{ijklm}	129.52^{ghi}	136.6^{iklm}	141.33^{ghi}	142.00^{hij}
S_1T_{14} (Refrigeration + 0.5% S-II)	102.67^{l}	113.67^{m}	121.00^{i}	121.67^{m}	125.87^{i}	138.67^{hij}
S_1T_{15} (Refrigeration + 0.75% $ZnSO_4$-I)	$129.63^{efghijkl}$	$131.00^{fghijklm}$	132.00^{ghi}	134.67^{jklm}	140.00^{ghi}	142.00^{hij}
S_1T_{16} (Refrigeration + 0.75% $ZnSO_4$-II)	111.00^{kl}	115.67^{lm}	134.00^{ghi}	134.00^{iklm}	135.67^{hi}	135.96^{ijk}
S_1T_{17} (Refrigeration + C-I)	126.00^{ghijkl}	$134.00^{efghijklm}$	136.00^{ghi}	139.33^{jklm}	143.00^{ghi}	150.33^{ghij}
S_1T_{18} (Refrigeration + C-II)	122.00^{ijkl}	$128.98^{ghijklm}$	133.67^{ghi}	134.00^{iklm}	134.67^{hi}	136.33^{ijk}
S_2T_1 (Ambient + 0.75% ZnO-I)	$132.33^{defghijkl}$	$160.00^{defghijk}$	173.00^{def}	174.33^{ghi}	176.67^{bcdef}	187.00^{bc}
S_2T_2 (Ambient + 0.75% ZnO-II)	123.67^{hijkl}	$146.33^{defghijklm}$	147.00^{efghi}	156.00^{ghijkl}	161.67^{cdefgh}	176.67^{bcdef}
S_2T_3 (Ambient +1% MgO-I)	120.00^{jkl}	$160.67^{defghij}$	161.00^{defg}	162.00^{ghijk}	167.67^{bcdefg}	168.00^{cdefg}
S_2T_4 (Ambient + 1% MgO-II)	171.67^{ab}	171.67^{de}	172.00^{def}	174.00^{ghi}	176.56^{bcdef}	189.33^{bc}
S_2T_5 (Ambient + 0.2% *Pf*-I)	$159.67^{abcdefg}$	173.00^{de}	173.33^{def}	173.67^{ghi}	174.89^{bcdef}	179.33^{bcde}

S_2T_6 (Ambient + 0.2% *Pf*-II)	164.00^{abcd}	171.00^{de}	173.33^{def}	176.00^{gh}	176.67^{bcdef}	194.67^{b}
S_2T_7 (Ambient + 0.2% SA-I)	122.33^{ijkl}	160.33^{defghijk}	169.33^{def}	175.00^{gh}	182.78^{bcde}	184.00^{bcd}
S_2T_8 (Ambient + 0.2% SA-II)	112.00^{kl}	155.67^{defghijkl}	160.00^{defgh}	164.00^{ghij}	179.67^{bcdef}	189.67^{bc}
S_2T_9 (Ambient + 0.5% SVM-I)	127.33^{fghijkl}	172.00^{de}	174.67^{def}	175.33^{gh}	179.33^{bcdef}	182.00^{bcde}
S_2T_{10} (Ambient + 0.5% SVM-II)	127.33^{fghijkl}	166.00^{defgh}	172.67^{def}	177.56^{gh}	179.67^{bcdef}	184.67^{bc}
S_2T_{11} (Ambient + 0.1% H_3BO_3-I)	151.67^{abcdefghij}	176.89^{d}	177.00^{de}	189.00^{g}	180.67^{bcdef}	195.67^{b}
S_2T_{12} (Ambient + 0.1% H_3BO_3-II)	141.33^{bcdefghijk}	166.67^{defg}	181.33^{d}	181.00^{gh}	185.00^{bcd}	190.67^{bc}
S_2T_{13} (Ambient + 0.5% S-I)	142.00^{bcdefghijk}	180.00^{d}	182.33^{d}	187.33^{g}	188.89^{bc}	195.67^{b}
S_2T_{14} (Ambient + 0.5% S-II)	111.00^{kl}	181.44^{d}	184.33^{d}	185.67^{gh}	193.33^{b}	195.00^{b}
S_2T_{15} (Ambient + 0.75% $ZnSO_4$-I)	140.00^{bcdefghijk}	181.67^{d}	184.00^{d}	185.33^{gh}	185.67^{bcd}	186.67^{bc}
S_2T_{16} (Ambient + 0.75% $ZnSO_4$-II)	127.33^{fghijkl}	178.78^{d}	183.67^{d}	185.67^{gh}	186.00^{bcd}	195.00^{b}
S_2T_{17} (Ambient + C-I)	143.00^{bcdefghijk}	169.89^{def}	171.33^{def}	181.00^{gh}	185.00^{bcd}	195.67^{b}
S_2T_{18} (Ambient + C-II)	136.33^{cdefghijkl}	162.67^{defghi}	177.67^{de}	187.67^{g}	195.00^{b}	201.00b^{a}
S_3T_1 (Unshelled + 0.75% ZnO-I)	140.67^{bcdefghijk}	434.33^{bc}	466.67^{bc}	559.67^{a}	566.00^{a}	586.80^{a}
S_2T_2(Unshelled + 0.75% ZnO-II)	152.00^{abcdefghijj}	465.00^{ab}	474.33^{abc}	508.33^{def}	558.00^{a}	587.03^{a}
S_3T_3 (Unshelled + 1% MgO-I)	136.67^{cdefghijkl}	473.67^{a}	480.00^{abc}	514.33^{cde}	544.67^{a}	579.48^{a}
S_3T_4 (Unshelled + 1% MgO-II)	161.00^{abcdef}	489.67^{a}	501.00^{a}	521.67^{cde}	559.67^{a}	579.47^{a}
S_3T_5 (Unshelled + 0.2% *Pf*-I)	178.67^{a}	455.67^{abc}	462.00^{c}	498.00^{def}	562.00^{a}	581.41^{a}
S_3T_6 (Unshelled + 0.2% *Pf*-II)	161.00^{abcdef}	491.33^{a}	491.33^{abc}	504.33^{def}	543.00^{a}	579.20^{a}
S_3T_7 (Unshelled + 0.2% SA-I)	159.33^{abcdefg}	426.00^{c}	483.00^{abc}	492.00^{ef}	555.00^{a}	587.97^{a}
S_3T_8 (Unshelled + 0.2% SA-II)	159.00^{abcdefg}	472.67^{ab}	493.33^{abc}	502.67^{def}	545.00^{a}	579.93^{a}
S_3T_9 (Unshelled + 0.5% SVM-I)	169.00^{abc}	482.00^{a}	497.67^{ab}	501.33^{def}	553.67^{a}	585.66^{a}
S_3T_{10} (Unshelled + 0.5% SVM-II)	156.00^{abcdefghi}	486.33^{a}	488.67^{abc}	494.67^{def}	548.33^{a}	577.89^{a}
S_3T_{11} (Unshelled + 0.1% H_3BO_3-I)	162.33^{abcde}	465.67^{ab}	490.67^{abc}	526.67^{bcd}	553.33^{a}	574.40^{a}
S_3T_{12} (Unshelled + 0.1% H_3BO_3-II)	147.00^{abcdefghij}	470.67^{ab}	475.67^{abc}	493.67^{ef}	558.33^{a}	578.55^{a}
S_3T_{13} (Unshelled + 0.5% S-I)	156.00^{abcdefghi}	473.67^{a}	493.33^{abc}	542.33^{abc}	563.67^{a}	585.87^{a}
S_3T_{14} (Unshelled + 0.5% S-II)	150.67^{abcdefghij}	477.67^{a}	487.67^{abc}	500.33^{def}	545.33^{a}	590.98^{a}
S_3T_{15} (Unshelled + 0.75% $ZnSO_4$-I)	157.00^{abcdefg}	465.67^{ab}	474.33^{abc}	476.00^{f}	562.00^{a}	583.28^{a}

S_3T_{16} (Unshelled + 0.75% $ZnSO_4$-II)	$129.00^{efghijkl}$	470.00^{ab}	482.00^{abc}	503.00^{def}	562.67^{a}	581.96^{a}
S_3T_{17} (Unshelled + C-I)	$152.00^{abcdefghij}$	480.00^{a}	490.00^{abc}	544.67^{abc}	566.33^{a}	582.13^{a}
S_3T_{18} (Unshelled + C-II)	$147.00^{abcdefghij}$	469.67^{ab}	490.00^{abc}	555.33^{ab}	567.00^{a}	575.99^{a}
SE(m)	9.67	11.66	9.79	9.75	8.99	7.27
CD (0.05)	27.10	32.69	27.44	27.33	5.20	20.37

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

4.2.2.6.3 Due to interaction (S x T)

As observed earlier, EC over storage increased during storage irrespective of the storage environment and foliar nutrition. Significant influence of the interaction of these factors were evident throughout the storage period. As in most other seed quality parameters, EC of seed leachate at 6 MAS was high in the seeds from unshelled pods. Seeds in unshelled pods irrespective of the foliar treatment were significantly inferior to that of threshed seeds stored in refrigeration and ambient storage. As seed ages, the cell membrane and cell organelle become leaky on account of decrease in phospholipids content due to enzymatic or non-enzymatic lipid auto oxidation (Ching and Schoolcraft, 1968; Koostra and Harrington, 1969; Pammenter *et al.*, 1974). Hence, a high EC of seed leachate may be inferred as a reflection of high seed deterioration. Therefore, it may be inferred that storing unthreshed seed would lead to higher rate of deterioration. In addition, at 6 MAS it was observed that all the treatments under refrigerated storage except S_1T_4 (refrigeration + T_4: 1% MgO-II; 154.67μSm^{-1}), S_1T_5 (refrigeration + T_5: 0.2% *Pf*-I; 159.67μSm^{-1}), S_1T_6 (refrigeration + T_6: 0.2% *Pf*-II; 161.00μSm^{-1}), S_1T_{11} (refrigeration + T_{11}: 0.1% H_3BO_3-I; 152.67 units) and S_1T_{17} (refrigeration + T_{17}: C-I; 150.33μSm^{-1}) were superior to all other treatments under S_1 (ambient storage) as well as unthreshed pods (S_3). Thus, the advantage of storing seeds refrigeration to reduce deterioration was evident.

According to Sucheta *et al.* (2005) in soya bean, Alhamdan *et al.* (2011) in several vegetable crops, Zulhishyam *et al.* (2013) in papaya, Aswathy (2015) in cowpea and Dhatt (2018) in ornamental *Nemesia*, storing seeds under refrigerated condition was more advantageous in checking lipid peroxidation, to reduce the pest incidence and fungal infection and thus to reduce seed deterioration and thereby to improve seed quality and longevity.

Although on par with most treatments under refrigeration, EC of seed leachate was the least in S_1T_2 (refrigeration + T_2: 0.75% ZnO-II) throughout the storage period,

Table 22. Impact of storage conditions and foliar treatments on seed moisture (%) during storage

Storage condition / Treatment	Period of storage (Months)					
	1 MAS	2 MAS	3 MAS	4 MAS	5 MAS	6 MAS
Storage condition (S)						
S_1 (Refrigeration)	7.31^{b}	7.43^{b}	7.23^{b}	7.26^{b}	7.29^{b}	7.31^{b}
S_2 (Ambient)	7.23^{b}	7.37^{b}	7.31^{b}	7.39^{b}	7.38^{b}	7.37^{b}
S_3 (Unshelled)	8.34^{a}	9.00^{a}	9.63^{a}	11.29^{a}	12.29^{a}	14.09^{a}
SE(m)	0.068	0.075	0.077	0.075	0.048	0.064
CD (0.05)	0.191	0.211	0.215	0.212	0.134	0.179
Foliar treatment (T)						
T_1: 0.75% ZnO-I	7.02^{c}	8.28	7.95^{ab}	8.69^{ab}	9.00	9.67
T_2: 0.75% ZnO-II	7.79^{b}	7.93	8.09^{ab}	8.69^{ab}	8.93	9.53
T_3: 1% MgO-I	7.91^{b}	8.22	7.86^{ab}	8.80^{ab}	9.13	9.71
T_4: 1% MgO-II	7.65^{b}	8.24	8.05^{ab}	8.69^{ab}	8.91	9.60
T_5: 0.2% *Pf*-I	7.59^{b}	8.12	7.73^{abc}	8.53^{ab}	8.84	9.51
T_6: 0.2% *Pf*-II	8.62^{a}	8.07	7.73^{abc}	8.64^{ab}	8.93	9.60
T_7: 0.2% SA-I	7.67^{b}	8.22	7.94^{ab}	8.69^{ab}	9.00	9.62
T_8: 0.2% SA-II	8.02^{b}	8.30	7.74^{abc}	8.29^{b}	8.98	9.64
T_9: 0.5% SVM-I	7.72^{b}	8.33	7.79^{abc}	8.56^{ab}	8.78	9.67
T_{10}: 0.5% SVM-II	7.47^{bc}	8.14	8.27^{a}	8.53^{ab}	9.02	9.67
T_{11}: 0.1% H_3BO_3-I	7.62^{b}	8.07	7.92^{ab}	9.02^{a}	9.18	9.64
T_{12}: 0.1% H_3BO_3-II	7.69^{b}	7.95	7.23^{c}	8.49^{ab}	8.98	9.67
T_{13}: 0.5% S-I	7.06^{c}	8.15	7.55^{bc}	8.58^{ab}	8.96	9.49
T_{14}: 0.5% S-II	7.60^{b}	7.98	7.73^{abc}	8.56^{ab}	8.89	9.51
T_{15}: 0.75% $ZnSO_4$-I	7.63^{b}	8.41	7.84^{abc}	8.82^{ab}	9.00	9.47
T_{16}: 0.75% $ZnSO_4$-II	7.06^{c}	7.95	8.16^{ab}	8.84^{ab}	9.09	9.49
T_{17}: C-I	7.69^{b}	7.99	7.92^{ab}	8.67^{ab}	9.09	9.56
T_{18}: C-II	7.47^{bc}	8.20	7.73^{abc}	8.53^{ab}	9.07	9.53
SE(m)	0.167	0.184	0.188	0.185	0.117	0.156
CD (0.05)	0.468	NS	NS	NS	NS	NS

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

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pointing out the advantage of two-time foliar application of 0.75% ZnO in reducing the rate of seed deterioration. However, a conclusive statement to this cannot be drawn owing to the short storage period of the study. Prasad *et al.* (2012) reported that in comparison to untreated seeds, nano-scale ZnO (1000 ppm) treated peanut seeds recorded higher seed germination, seedling vigor, early field establishment and lower electrical conductivity of seed leachate.

4.2.2.7 Seed moisture content (%)

The results on moisture content (%) as influenced by storage condition, foliar treatment and their interaction effects during the storage period are presented in Tables 22 and 23.

4.2.2.7.1 Due to storage condition (S)

As shown in Fig. 6, throughout the storage period, the moisture content of seeds stored under refrigeration (S_1) and ambient (S_2) storage conditions were on par with each other but differed significantly from unshelled pods (S_3). Under S_1, the per cent seed moisture content ranged from 7.31 (1 MAS) to 7.31 (6 MAS), whereas in S_2, the seed moisture content was found to vary between 7.23 per cent (1 MAS) and 7.37 per cent (6 MAS). In S_3, the moisture content varied between 8.34 per cent (1 MAS) and 14.09 per cent (6 MAS).

Similar to the study, the advantage of storing seeds in moisture impervious polythene bags over cloth or jute bags for maintaining seed viability was also reported by several workers (Vanangamudi and Ramaswamy, 1989 in bajra, Baskin *et al.*, 1987 in wheat, Ashwathaiah and Sadasivamurthy, 1986 in sorghum). According to Teng (1981), maize seeds stored in moisture pervious containers exhibited fluctuation in seed moisture content leading to higher seed deterioration. Dange and Patil (1984) reported that increased relative humidity of storage place causes a higher deterioration of seeds. These could probably be the reason for the faster rate of deterioration of seeds stored

Table 23. Interaction effect of storage conditions and foliar treatments on seed moisture content (%) during seed storage

Storage condition x Treatment	Period of storage (Months)					
	1 MAS	2 MAS	3 MAS	4 MAS	5 MAS	6 MAS
Interaction (S x T)						
S_1T_1 (Refrigeration + 0.75% ZnO-I)	7.02^{d}	7.46	7.02	7.47	7.40	7.40
S_1T_2 (Refrigeration + 0.75% ZnO-II)	7.02^{d}	7.19	7.68	7.40	7.40	7.20
S_1T_3 (Refrigeration + 1% MgO-I)	6.90^{d}	7.70	7.10	7.80	7.80	7.40
S_1T_4 (Refrigeration + 1% MgO-II)	6.78^{d}	7.24	7.27	7.47	7.47	7.33
S_1T_5 (Refrigeration + 0.2% *Pf*-I)	8.47^{ab}	7.41	7.10	7.13	7.27	7.13
S_1T_6 (Refrigeration + 0.2% *Pf*-II)	8.47^{ab}	6.94	7.19	7.33	7.27	7.40
S_1T_7 (Refrigeration + 0.2% SA-I)	7.02^{d}	7.51	7.74	7.13	7.27	7.27
S_1T_8 (Refrigeration + 0.2% SA-II)	9.09^{ab}	7.47	7.06	7.20	7.20	7.60
S_1T_9 (Refrigeration + 0.5% SVM-I)	7.27^{d}	7.62	7.07	7.07	7.00	7.53
S_1T_{10} (Refrigeration + 0.5% SVM-II)	7.02^{d}	7.50	7.24	7.20	7.27	7.27
S_1T_{11} (Refrigeration + 0.1% H_3BO_3-I)	6.90^{d}	7.41	7.28	7.27	7.27	7.53
S_1T_{12} (Refrigeration + 0.1% H_3BO_3-II)	6.90^{d}	7.37	6.90	6.93	7.20	7.40
S_1T_{13} (Refrigeration + 0.5% S-I)	7.14^{d}	7.42	7.19	7.20	7.20	6.93
S_1T_{14} (Refrigeration + 0.5% S-II)	7.14^{d}	7.53	7.10	7.07	7.07	7.27
S_1T_{15} (Refrigeration + 0.75% $ZnSO_4$-I)	7.14^{d}	7.62	7.28	7.33	7.33	7.13
S_1T_{16} (Refrigeration + 0.75% $ZnSO_4$-II)	7.02^{d}	7.32	7.46	7.27	7.27	7.07
S_1T_{17} (Refrigeration + C-I)	7.41^{cd}	7.23	7.17	7.20	7.27	7.33
S_1T_{18} (Refrigeration + C-II)	6.90^{d}	7.80	7.28	7.27	7.33	7.33
S_2T_1 (Ambient + 0.75% ZnO-I)	6.90^{d}	7.41	7.19	7.20	7.20	7.27
S_2T_2 (Ambient + 0.75% ZnO-II)	7.27^{d}	7.46	7.02	7.40	7.40	7.33

S_2T_3 (Ambient +1% MgO-I)	7.41^{cd}	7.46	7.33	7.47	7.40	7.47
S_2T_4 (Ambient + 1% MgO-II)	7.55^{cd}	7.37	7.19	7.33	7.33	7.53
S_2T_5 (Ambient + 0.2% *Pf*-I)	7.02^{d}	7.55	6.94	6.93	7.07	7.47
S_2T_6 (Ambient + 0.2% *Pf*-II)	8.77^{ab}	7.32	7.11	7.13	7.13	7.33
S_2T_7 (Ambient + 0.2% SA-I)	6.90^{d}	7.46	7.15	7.27	7.27	7.27
S_2T_8 (Ambient + 0.2% SA-II)	7.55^{cd}	7.37	7.18	7.20	7.20	7.27
S_2T_9 (Ambient + 0.5% SVM-I)	7.41^{cd}	7.32	7.14	7.27	7.27	7.40
S_2T_{10} (Ambient + 0.5% SVM-II)	6.78^{d}	7.50	7.74	7.53	7.47	7.40
S_2T_{11} (Ambient + 0.1% H_3BO_3-I)	7.02^{d}	7.28	7.77	7.80	7.67	7.27
S_2T_{12} (Ambient + 0.1% H_3BO_3-II)	7.41^{cd}	7.38	7.29	7.33	7.53	7.33
S_2T_{13} (Ambient + 0.5% S-I)	7.02^{d}	7.15	7.15	7.33	7.40	7.40
S_2T_{14} (Ambient + 0.5% S-II)	6.90^{d}	7.28	7.12	7.20	7.33	7.40
S_2T_{15} (Ambient + 0.75% $ZnSO_4$-I)	7.14^{d}	7.33	7.24	7.80	7.80	7.20
S_2T_{16} (Ambient + 0.75% $ZnSO_4$-II)	6.90^{d}	7.32	7.86	7.80	7.53	7.60
S_2T_{17} (Ambient + C-I)	6.90^{d}	7.41	7.32	7.67	7.60	7.33
S_2T_{18} (Ambient + C-II)	7.27^{d}	7.24	7.82	7.27	7.27	7.33
S_3T_1 (Unshelled + 0.75% ZnO-I)	7.14^{d}	9.98	9.63	11.40	12.40	14.33
S_2T_2(Unshelled + 0.75% ZnO-II)	9.09^{ab}	9.15	9.58	11.27	12.00	14.07
S_3T_3 (Unshelled + 1% MgO-I)	9.43^{a}	9.52	9.15	11.13	12.20	14.27
S_3T_4 (Unshelled + 1% MgO-II)	8.62^{ab}	10.11	9.67	11.27	11.93	13.93
S_3T_5 (Unshelled + 0.2% *Pf*-I)	7.27^{d}	9.41	9.15	11.53	12.20	13.93
S_3T_6 (Unshelled + 0.2% *Pf*-II)	8.62^{ab}	9.95	8.89	11.47	12.40	14.07
S_3T_7 (Unshelled + 0.2% SA-I)	9.09^{ab}	9.69	8.93	11.67	12.47	14.33
S_3T_8 (Unshelled + 0.2% SA-II)	7.41^{cd}	10.05	8.99	10.47	12.53	14.07
S_3T_9 (Unshelled + 0.5% SVM-I)	8.47^{ab}	10.06	9.15	11.33	12.07	14.07
S_3T_{10} (Unshelled + 0.5% SVM-II)	8.62^{ab}	9.40	9.82	10.87	12.33	14.33
S_3T_{11} (Unshelled + 0.1% H_3BO_3-I)	8.93^{ab}	9.52	8.72	12.00	12.60	14.13
S_3T_{12} (Unshelled + 0.1% H_3BO_3-II)	8.77^{ab}	9.09	7.49	11.20	12.20	14.27

S_3T_{13} (Unshelled + 0.5% S-I)	7.02^{d}	9.88	8.30	11.20	12.27	14.13
S_3T_{14} (Unshelled + 0.5% S-II)	8.77^{ab}	9.15	8.98	11.40	12.27	13.87
S_3T_{15} (Unshelled + 0.75% $ZnSO_4$-I)	8.62^{ab}	10.29	8.99	11.33	11.87	14.07
S_3T_{16} (Unshelled + 0.75% $ZnSO_4$-II)	7.27^{d}	9.21	9.15	11.47	12.47	13.80
S_3T_{17} (Unshelled + C-I)	8.77^{ab}	9.32	9.26	11.13	12.40	14.00
S_3T_{18} (Unshelled + C-II)	8.25^{bc}	9.56	8.09	11.07	12.60	13.93
SE(m)	0.289	0.319	0.325	0.320	0.203	0.271
CD (0.05)	0.810	NS	NS	NS	NS	NS

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

in unshelled pods than those stored under refrigeration and ambient conditions. As observed by Gao *et al.* (1996), it was also evident that the seeds stored at room temperature showed faster decline in viability and vigour as compared to the seeds stored at lower temperature.

4.2.2.7.2 Due to foliar treatment (T)

Irrespective of the storage condition, the significant impact of foliar application of nutrients and growth promoters on moisture content of stored seeds was exhibited only at 1 MAS.

At 1 MAS, moisture content of stored seeds varied from 7.02% (T_1: 0.75% ZnO-I) to 8.62 (T_6: 0.2% *Pf*-II). T_1 was found to be on par with T_{16}: 0.75% $ZnSO_4$-II (7.06%), T_{13}: 0.5% S-I (7.06%), T_{18}: C-II (7.47%) and T_9: 0.5% SVM-I (7.72%) whereas T_6: 0.2% *Pf*-II recorded the highest moisture content and was found to be significantly different from all the other treatments.

4.2.2.7.3 Due to interaction (S x I)

The interaction between storage environment and foliar treatments exerted no significant influence on seed moisture content, except at the start of storage (1 MAS). The moisture content at 1 MAS ranged between 6.78 (S_1T_4 and S_2T_{10}) and 9.43 (S_3T_3).

4.2.2.8 Seed microflora (%)

The results on seed infection per cent as influenced by storage condition, foliar treatment and their interaction effects during the storage period are presented in Tables 24 and 25.

4.2.2.8.1 Due to storage condition (S)

The per cent seed microflora infection increased with increase in storage period (Fig. 7). The seed infection (%) varied from 14.44 to 33.52 per cent in S_1 (refrigeration),

Table 24. Impact of storage conditions and foliar treatments on seed microflora infection (%) during storage

Storage condition / Treatment	Period of storage (Months)					
	1 MAS	2 MAS	3 MAS	4 MAS	5 MAS	6 MAS
Storage condition (S)						
S_1 (Refrigeration)	14.44[b]	20.37[b]	20.37[b]	23.89[b]	31.11[b]	33.52[c]
S_2 (Ambient)	15.74[b]	21.67[b]	24.26[b]	27.41[b]	33.7[b]	38.15[b]
S_3 (Unshelled)	25.37[a]	30.93[a]	33.7[a]	35.74[a]	41.67[a]	48.33[a]
SE(m)	0.962	1.344	1.717	1.181	1.069	1.335
CD (0.05)	2.701	2.668	2.325	2.344	2.122	2.651
Foliar treatment (T)						
T_1: 0.75% ZnO-I	20.00	25.56	25.56	31.11	35.56	38.89
T_2: 0.75% ZnO-II	14.44	25.56	24.44	26.67	35.56	38.89
T_3: 1% MgO-I	15.56	22.22	26.67	27.78	35.56	41.11
T_4: 1% MgO-II	17.78	25.56	27.78	30.00	36.67	40.00
T_5: 0.2% *Pf*-I	18.89	25.56	25.56	27.78	34.44	40.00
T_6: 0.2% *Pf*-II	18.89	22.22	23.33	28.89	36.67	37.78
T_7: 0.2% SA-I	17.78	24.44	27.78	26.67	35.56	36.67
T_8: 0.2% SA-II	18.89	23.33	25.56	30.00	35.56	42.22
T_9: 0.5% SVM-I	16.67	25.56	26.67	28.89	36.67	38.89
T_{10}: 0.5% SVM-II	20.00	18.89	24.44	27.78	34.44	41.11
T_{11}: 0.1% H_3BO_3-I	17.78	24.44	24.44	28.89	32.22	38.89
T_{12}: 0.1% H_3BO_3-II	17.78	22.22	24.44	31.11	37.78	40.00
T_{13}: 0.5% S-I	18.89	25.56	28.89	28.89	35.56	40.00
T_{14}: 0.5% S-II	18.89	25.56	24.44	28.89	38.89	42.22
T_{15}: 0.75% $ZnSO_4$-I	18.89	26.67	28.89	30.00	36.67	42.22
T_{16}: 0.75% $ZnSO_4$-II	20.00	24.44	27.78	30.00	36.67	40.00
T_{17}: C-I	22.22	25.56	25.56	27.78	30.00	41.11
T_{18}: C-II	20.00	24.44	27.78	31.11	34.44	40.00
SE(m)	2.357	3.292	2.869	2.893	2.619	3.271
CD (0.05)	NS	NS	NS	NS	NS	NS

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

from 15.74 to 38.15 per cent in S_2 (ambient) and from 25.37 to 48.33 per cent in S_3 (unshelled) during the storage period. Throughout the storage period, the seed microflora infection per cent was minimum in S_1 followed by S_2. S_3 registered the highest infection throughout the storage period and was significantly inferior to S_1 and S_2 indicating the advantage of threshed seed storage over unthreshed seeds. The result of this study is also in agreement with the findings of Dwivedi and Shukla (1990). They observed that over twelve months of storage period, storage of chickpea seeds in polythene bags reduced the seed deterioration and fungal infection compared to those stored in moisture pervious containers like the cloth bags.

Zulhishyam *et al.* (2013), Aswathy (2015), observed that both the storage containers and storage conditions plays an important role in retaining the quality and viability of cowpea seeds. Lower microflora infection was observed in cowpea seed lot which was stored under cold conditions than those stored under ambient condition. According to Bhattacharya and Raha (2002), the highest per cent microflora infection was observed in maize seeds stored as unthreshed corn compared to the seeds stored under ambient condition. The least per cent microflora infection was recorded in maize seeds stored under refrigeration

4.2.2.8.2 Due to foliar treatment (T)

Irrespective of the foliar treatment, seed infection was found to increase over storage. However, no significant influence of foliar nutrition on seed microflora infection was evident.

4.1.4.8.3 Due to interaction (S x T)

Results indicated the presence of significant interaction between storage environment and foliar nutrition on seed microflora occurrence during the storage. Seed microflora incidence was significantly high in most treatments stored in S_3 (unshelled pods) throughout the storage period. Although on par with other treatments

Table 25. Interaction effect of storage conditions and foliar treatments on seed microflora infection (%) during storage

Storage condition x Treatment	Period of storage (Months)					
	1 MAS	2 MAS	3 MAS	4 MAS	5 MAS	6 MAS
Interaction (SXT)						
S_1T_1 (Refrigeration + 0.75% ZnO-I)	20.00^{bcde}	20.00^{bcd}	20.00^{cde}	26.67^{bcde}	26.67^{d}	30.00^{d}
S_1T_2 (Refrigeration + 0.75% ZnO-II)	13.33^{de}	23.33^{abcd}	20.00^{cde}	23.33^{cde}	33.33^{bcd}	33.33^{cd}
S_1T_3 (Refrigeration + 1% MgO-I)	10.00^{e}	16.67^{cd}	26.67^{abcd}	26.67^{bcde}	33.33^{bcd}	36.67^{bcd}
S_1T_4 (Refrigeration + 1% MgO-II)	13.33^{de}	20.00^{bcd}	20.00^{cde}	23.33^{cde}	30.00^{cd}	30.00^{d}
S_1T_5 (Refrigeration + 0.2% *Pf*-I)	13.33^{de}	26.67^{abc}	20.00^{cde}	16.67^{e}	30.00^{cd}	33.33^{cd}
S_1T_6 (Refrigeration + 0.2% *Pf*-II)	13.33^{de}	16.67^{cd}	13.33^{e}	23.33^{cde}	33.33^{bcd}	30.00^{d}
S_1T_7 (Refrigeration + 0.2% SA-I)	10.00^{e}	20.00^{bcd}	20.00^{cde}	20.00^{de}	33.33^{bcd}	33.33^{cd}
S_1T_8 (Refrigeration + 0.2% SA-II)	10.00^{e}	20.00^{bcd}	16.67^{de}	23.33^{cde}	26.67^{d}	33.33^{cd}
S_1T_9 (Refrigeration + 0.5% SVM-I)	20.00^{bcde}	20.00^{bcd}	20.00^{cde}	23.33^{cde}	30.00^{cd}	33.33^{cd}
S_1T_{10} (Refrigeration + 0.5% SVM-II)	10.00^{e}	13.33^{d}	16.67^{de}	23.33^{cde}	30.00^{cd}	33.33^{cd}
S_1T_{11} (Refrigeration + 0.1% H_3BO_3-I)	13.33^{de}	26.67^{abc}	23.33^{bcde}	26.67^{bcde}	30.00^{cd}	30.00^{d}
S_1T_{12} (Refrigeration + 0.1% H_3BO_3-II)	16.67^{cde}	16.67^{cd}	20.00^{cde}	26.67^{bcde}	33.33^{bcd}	33.33^{cd}
S_1T_{13} (Refrigeration + 0.5% S-I)	16.67^{cde}	20.00^{bcd}	26.67^{abcd}	23.33^{cde}	30.00^{cd}	33.33^{cd}
S_1T_{14} (Refrigeration + 0.5% S-II)	16.67^{cde}	20.00^{bcd}	16.67^{de}	23.33^{cde}	36.67^{abcd}	40.00^{abcd}
S_1T_{15} (Refrigeration + 0.75% $ZnSO_4$-I)	13.33^{de}	23.33^{abcd}	26.67^{abcd}	26.67^{bcde}	33.33^{bcd}	33.33^{cd}
S_1T_{16} (Refrigeration + 0.75% $ZnSO_4$-II)	20.00^{bcde}	20.00^{bcd}	23.33^{bcde}	26.67^{bcde}	33.33^{bcd}	36.67^{bcd}
S_1T_{17} (Refrigeration + C-I)	13.33^{de}	26.67^{abc}	16.67^{de}	20.00^{de}	26.67^{d}	33.33^{cd}
S_1T_{18} (Refrigeration + C-II)	16.67^{cde}	16.67^{cd}	20.00^{cde}	$26.67b^{cde}$	30.00^{cd}	36.67^{bcd}
S_2T_1 (Ambient + 0.75% ZnO-I)	13.33^{de}	23.33^{abcd}	23.33^{bcde}	30.00^{abcd}	33.33^{bcd}	36.67^{bcd}
S_2T_2 (Ambient + 0.75% ZnO-II)	16.67^{cde}	20.00^{bcd}	20.00^{cde}	23.33^{cde}	36.67^{abcd}	36.67^{bcd}
S_2T_3 (Ambient +1% MgO-I)	16.67^{cde}	20.00^{bcd}	23.33^{bcde}	23.33^{cde}	33.33^{bcd}	43.33^{abcd}

S_2T_4 (Ambient + 1% MgO-II)	10.00^{e}	23.33^{abcd}	26.67^{abcd}	30.00^{abcd}	36.67^{abcd}	40.00^{abcd}
S_2T_5 (Ambient + 0.2% *Pf*-I)	16.67^{cde}	23.33^{abcd}	26.67^{abcd}	26.67^{bcde}	33.33^{bcd}	36.67^{bcd}
S_2T_6 (Ambient + 0.2% *Pf*-II)	13.33^{de}	20.00^{bcd}	23.33^{bcde}	26.67^{bcde}	33.33^{bcd}	36.67^{bcd}
S_2T_7 (Ambient + 0.2% SA-I)	16.67^{cde}	23.33^{abcd}	26.67^{abcd}	26.67^{bcde}	30.00^{cd}	33.33^{cd}
S_2T_8 (Ambient + 0.2% SA-II)	16.67^{cde}	20.00^{bcd}	23.33^{bcde}	26.67^{bcde}	33.33^{bcd}	43.33^{abcd}
S_2T_9 (Ambient + 0.5% SVM-I)	10.00^{e}	23.33^{abcd}	26.67^{abcd}	26.67^{bcde}	33.33^{bcd}	33.33^{cd}
S_2T_{10} (Ambient + 0.5% SVM-II)	16.67^{cde}	16.67^{cd}	23.33^{bcde}	26.67^{bcde}	30.00^{cd}	36.67^{bcd}
S_2T_{11} (Ambient + 0.1% H_3BO_3-I)	16.67^{cde}	16.67^{cd}	20.00^{cde}	26.67^{bcde}	33.33^{bcd}	40.00^{abcd}
S_2T_{12} (Ambient + 0.1% H_3BO_3-II)	20.00^{bcde}	20.00^{bcd}	20.00^{cde}	26.67^{bcde}	36.67^{abcd}	36.67^{bcd}
S_2T_{13} (Ambient + 0.5% S-I)	16.67^{cde}	23.33^{abcd}	26.67^{abcd}	30.00^{abcd}	33.33^{bcd}	40.00^{abcd}
S_2T_{14} (Ambient + 0.5% S-II)	16.67^{cde}	26.67^{abc}	26.67^{abcd}	30.00^{abcd}	33.33^{bcd}	36.67^{bcd}
S_2T_{15} (Ambient + 0.75% $ZnSO_4$-I)	13.33^{de}	23.33^{abcd}	26.67^{abcd}	26.67^{bcde}	33.33^{bcd}	43.33^{abcd}
S_2T_{16} (Ambient + 0.75% $ZnSO_4$-II)	20.00^{bcde}	23.33^{abcd}	23.33^{bcde}	30.00^{abcd}	36.67^{abcd}	36.67^{bcd}
S_2T_{17} (Ambient + C-I)	16.67^{cde}	20.00^{bcd}	23.33^{bcde}	26.67^{bcde}	30.00^{cd}	40.00^{abcd}
S_2T_{18} (Ambient + C-II)	16.67^{cde}	23.33^{abcd}	26.67^{abcd}	30.00^{abcd}	36.67^{abcd}	36.67^{bcd}
S_3T_1 (Unshelled + 0.75% ZnO-I)	26.67^{abcd}	33.33^{a}	33.33^{ab}	36.67^{ab}	46.67^{a}	50.00^{ab}
S_2T_2(Unshelled + 0.75% ZnO-II)	13.33^{de}	33.33^{a}	33.33^{ab}	33.33^{abc}	36.67^{abcd}	46.67^{abc}
S_3T_3 (Unshelled + 1% MgO-I)	20.00^{bcde}	30.00^{ab}	30.00^{abc}	33.33^{abc}	40.00^{abc}	43.33^{abcd}
S_3T_4 (Unshelled + 1% MgO-II)	30.00^{abc}	33.33^{a}	36.67^{a}	36.67^{ab}	43.33^{ab}	50.00^{ab}
S_3T_5 (Unshelled + 0.2% *Pf*-I)	26.67^{abcd}	26.67^{abc}	30.00^{abc}	40.00^{a}	40.00^{abc}	50.00^{ab}
S_3T_6 (Unshelled + 0.2% *Pf*-II)	30.00^{abc}	30.00^{ab}	33.33^{ab}	36.67^{ab}	43.33^{ab}	46.67^{abc}
S_3T_7 (Unshelled + 0.2% SA-I)	26.67^{abcd}	30.00^{ab}	36.67^{a}	33.33^{abc}	43.33^{ab}	43.33^{abcd}
S_3T_8 (Unshelled + 0.2% SA-II)	30.00^{abc}	30.00^{ab}	36.67^{a}	40.00^{a}	46.67^{a}	50.00^{ab}
S_3T_9 (Unshelled + 0.5% SVM-I)	20.00^{bcde}	33.33^{a}	33.33^{ab}	36.67^{ab}	46.67^{a}	50.00^{ab}
S_3T_{10} (Unshelled + 0.5% SVM-II)	33.33^{ab}	26.67^{abc}	33.33^{ab}	33.33^{abc}	43.33^{ab}	53.33^{a}
S_3T_{11} (Unshelled + 0.1% H_3BO_3-I)	23.33^{abcde}	30.00^{ab}	30.00^{abc}	33.33^{abc}	33.33^{bcd}	46.67^{abc}
S_3T_{12} (Unshelled + 0.1% H_3BO_3-II)	16.67^{cde}	30.00^{ab}	33.33^{ab}	40.00^{a}	43.33^{ab}	50.00^{ab}
S_3T_{13} (Unshelled + 0.5% S-I)	23.33^{abcde}	33.33^{a}	33.33^{ab}	33.33^{abc}	43.33^{ab}	46.67^{abc}

S_3T_{14} (Unshelled + 0.5% S-II)	23.33^{abcde}	30.00^{ab}	30.00^{abc}	33.33^{abc}	46.67^{a}	50.00^{ab}
S_3T_{15} (Unshelled + 0.75% $ZnSO_4$-I)	30.00^{abc}	33.33^{a}	33.33^{ab}	36.67^{ab}	43.33^{ab}	50.00^{ab}
S_3T_{16} (Unshelled + 0.75% $ZnSO_4$-II)	20.00^{bcde}	30.00^{ab}	36.67^{a}	33.33^{abc}	40.00^{abc}	46.67^{abc}
S_3T_{17} (Unshelled + C-I)	36.67^{a}	30.00^{ab}	36.67^{a}	36.67^{ab}	33.33^{bcd}	50.00^{ab}
S_3T_{18} (Unshelled + C-II)	26.67^{abcd}	33.33^{a}	36.67^{a}	36.67^{ab}	36.67^{abcd}	46.67^{abc}
SE(m)	4.082	5.702	4.969	5.010	4.536	5.666
CD (0.05)	11.44	9.849	9.831	9.931	8.991	11.23

*Means in each column with atleast one letter in common are not significantly different at 5% level of probability

Fig.7. Impact of storage conditions on seed microflora (%) in okra

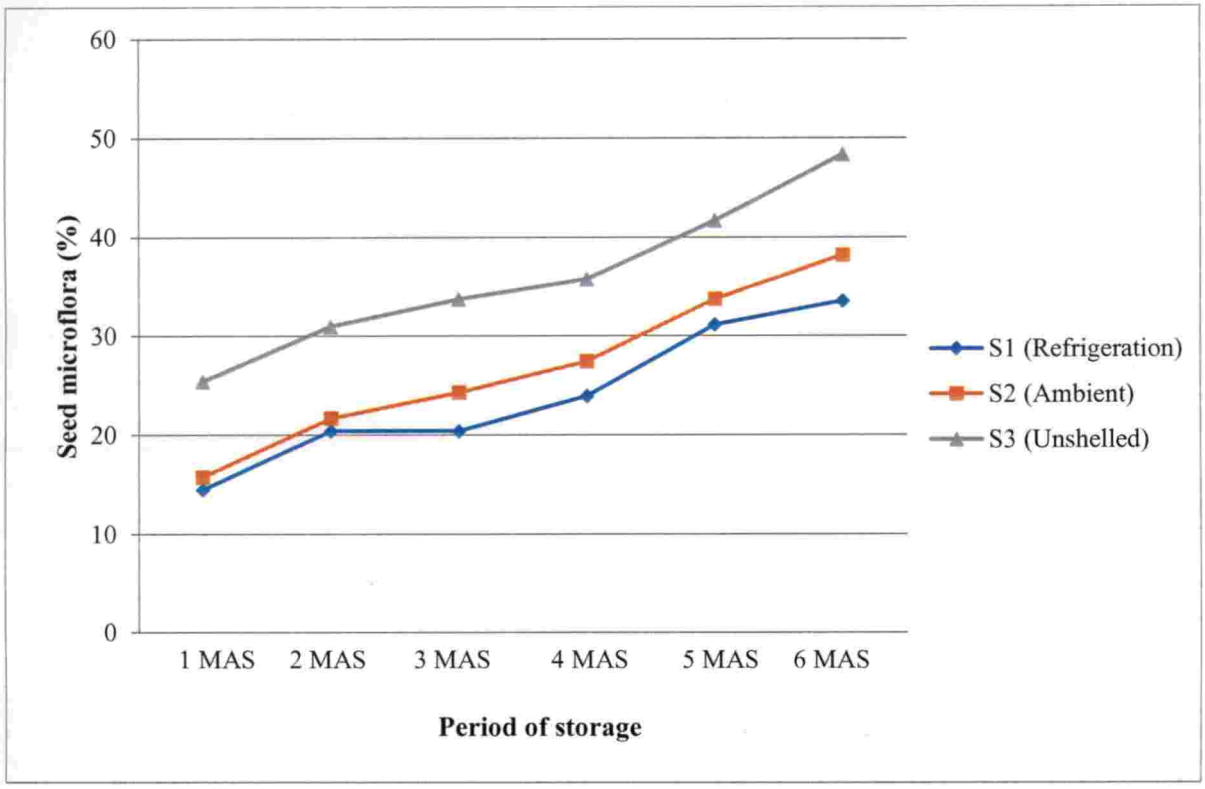
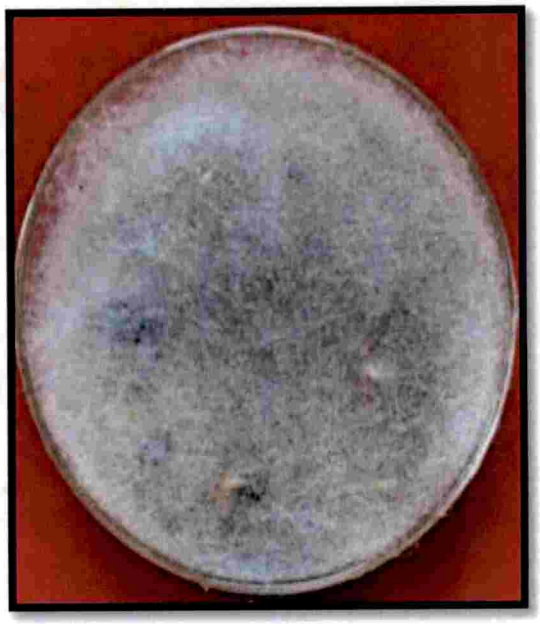
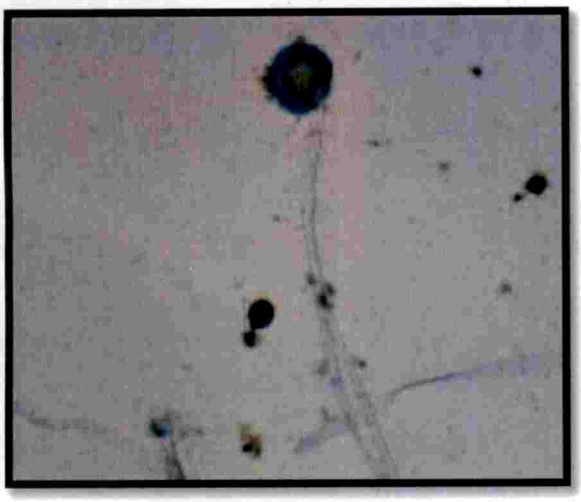


Plate 7. Pathogens observed during storage of okra seed

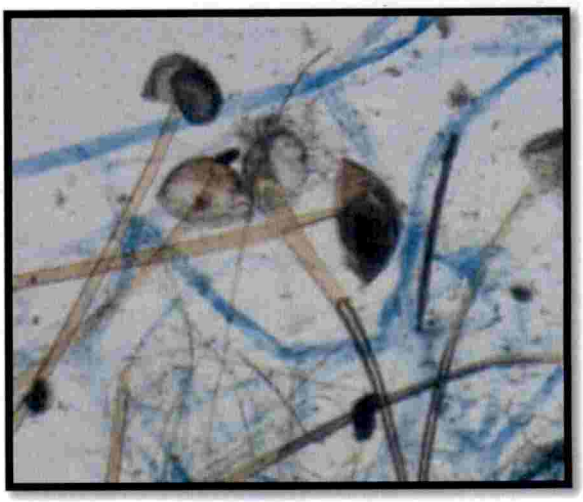
Aspergillus sp.



Rhizopus sp.



Aspergillus sp.



Rhizopus sp.

stored under refrigeration as well as ambient storage, the seed microflora at 6 MAS was the least in S_1T_1 (refrigeration + T_1: 0.75% ZnO-I) at 5 MAS (26.67%) and 6 MAS (30.00%). However, a conclusion on the advantage of foliar application of ZnO (T_1: 0.75%) in reducing seed microflora can be concluded owing to the short storage period of the study, but, there is a clear advantage in storing seeds under refrigeration to reduce seed microflora. Malaker *et al.* (2008) had earlier reported that maximum microflora infection was recorded in seeds stored in unshelled pods compared to the seeds stored under ambient condition.

During seed storage, the okra seeds were infected with different pathogens, namely *Aspergillus flavus*, *Aspergillus niger* and *Rhizopus sp.* (Plate 7.).

Seed deterioration has been found to be directly correlated to seed microflora incidence. Christensen and Kaufman (1969) reported that fungi not only cause qualitative and quantitative loss of seed, but also increased the moisture content of the seeds in storage, bringing biochemical changes leading to decreased membrane integrity of seeds.

From the results discussed above, it was evident that, as storage period increased the seed quality decreased irrespective of the storage environment. The rate of seed deterioration was found to be maximum when the seeds were stored in unshelled pods. Hence, it can be concluded that this traditional practice is highly unsuitable for seed storage under high humid conditions prevailing in Kerala. It can also be summarized that ambient storage and cold storage conditions are beneficial in prolonging longevity and maintaining higher seed quality parameters during storage. Although, the results point out that foliar application of micronutrient mixture (0.5% Sampoorna KAU vegetable multimix twice *i.e.*, at 25 DAS and 45 DAS; T_{10}) positively influenced seed quality during storage, a conclusive evidence as to the best foliar treatment that positively impacts seed quality parameters can be drawn only from the study of seed quality parameters over prolonged storage (>6 months). Further

evaluation of seed quality under ambient and refrigerated storage environment over a longer storage period is also essential to delineate the impact of these treatments as well as environment on seed longevity and quality during prolonged storage. The foliar spray of micronutrients and secondary nutrients not only extended the longevity of seed, but also enhanced the profitability of seed production.

Summary

5. SUMMARY

Experiment to elucidate the impact of foliar application of secondary nutrients, micronutrients and growth promoters on growth, fruit and seed yield of okra and also to evaluate the efficacy of foliar treatments on quality and longevity of the seeds stored under different storage conditions *viz.*, refrigeration (S_1), ambient (S_2) and unshelled pods (S_3), were carried out at the Department of Seed Science and Technology, College of Horticulture, Kerala Agricultural University, (KAU), Vellanikkara, Thrissur. The salient findings of the study are summarized below.

I. Impact of foliar application of nutrients and growth promoters on growth, fruit and seed yield in okra

1. Foliar application of nutrients and growth promoters significantly influenced the most of the growth, fruit and seed yield in okra. However, no significant difference was observed with respect to plant height at 30 days after sowing (DAS) and 60 DAS, days to flowering, pollen viability (%), seeds per pod, shriveled seeds per pod (%) and seed yield per pod (g).

2. Spraying of 0.75% $ZnSO_4$ (twice) and salicylic acid (once) resulted in increased plant stature at 45 DAS and 75 DAS respectively. In both instances, plant height was found to be on par with that in application of two-time application of micronutrient mixture (0.5% Sampoorna KAU vegetable multimix).

3. High chlorophyll content observed following spray of 1% MgO or 0.5% Sampoorna KAU vegetable multimix involving application of magnesium nutrient is expected as Mg^{2+} is an integral structural element of chlorophyll.

4. One time foliar spray of 0.75% ZnO (T_1), 1% MgO (T_3) and two-time application of 0.5% Sulphur (T_{14}), 0.5% Sampoorna KAU vegetable multimix (T_{10}) and 0.1% borax (T_{12}) increased branching in okra.

5. Significant decrease in flower shedding was found through the application of 0.75% $ZnSO_4$ (twice) or one or two sprays of Sampoorna KAU vegetable multimix.

6. Significantly high number of fruits were recorded following one or two sprays of 0.5% Sampoorna KAU vegetable multimix (T_{10} and T_9), or two-time application of 0.2% salicylic acid (T_8), 0.5% sulphur (T_{14}), 0.75% $ZnSO_4$ (T_{16}), 0.1% borax (T_{12}) and 1% MgO (T_3).

7. Fruit length was highest following application of 0.2% *Pf* twice. It was on par with most other treatment while, fruit weight was the highest following foliar application of 0.1% borax (T_{12}). Fruit weight in treatment T_{14} (0.5% Sulphur twice) or one or two application of 0.5% Sampoorna KAU vegetable multimix (T_9 and T_{10}) was found to be on par with T_{12}.

8. Per cent hard seeds per pod was the least following application of 0.2% *Pf* twice (T_6). Lower per cent of hard seeds was also observed in treatments T_{12} (0.1% H_3BO_3-II), T_9 (0.5% SVM-I) and T_{16} (0.75% $ZnSO_4$-II).

9. The saleable seeds per pod (%) was the highest in T_{16} (0.75% $ZnSO_4$-II). It was on par with treatments T_9 (0.5% SVM-I; 82.30%), T_6 (0.2% *Pf*-II; 81.04%), T_{10} (0.5% SVM-II; 80.99%) and T_{12} (0.1% H_3BO_3-II: 80.87%).

10. Significantly high test weight of seed was recorded after two-time application of 0.5% Sulphur (T_{14}), 0.1% H_3BO_3 (T_{12}) and untreated control (C-I: T_{17}). The

highest seed density was registered in one or two-time application of 1% MgO (T_3 orT_4) or two-time application of 0.75% $ZnSO_4$ (T_{15}) or 0.75% ZnO (T_2).

11. Considering the impact of various nutrients and growth regulators, it may be concluded that foliar application of micronutrient mixture (0.5% Sampoorna KAU vegetable multimix) or 0.75% ZnSO4 or 0.1% H_3BO_3 twice during the crop growth was advantageous.

12. Foliar application of micronutrient mixture (0.5% Sampoorna KAU vegetable multimix) twice exerted high positive influence on the vegetative growth and reproductive traits in okra seed crop except per cent of hard seeds and test weight. The treatment had registered the highest fruits per plant and the least per cent of flower shedding.
13. Application of 0.5% Sampoorna KAU vegetable multimix twice was more advantageous than its one-time application. Although high in chlorophyll content and saleable seed (%), the plant stature at 75 DAS, number of branches/ plant, fruit length and seed density were comparatively low in one-time application of 0.5% Sampoorna KAU vegetable multimix. The fruit shedding was also comparatively high in one-time application of vegetable multimix.
14. Foliar spray of 0.75% $ZnSO_4$ twice (T_{16}) exhibited a highly beneficial effect on reproductive traits of seed crop. The highest per cent saleable seed per pod was registered in this treatment. Low per cent of flower shedding and hard seeds as well as high number of fruits per plant and fruit length were observed in this treatment.
15. Reproductive traits like number of fruits per plant, fruit length, saleable seed per pod (%), test weight and seed density were found to be high following two-time application of 0.1% H_3BO_3 (T_{12}). In addition, the treatment had registered lower per cent of flower shedding and hard seed.

16. Foliar application of 0.75% $ZnSO_4$ twice (T_{16}) and 0.1% H_3BO_3 twice (T_{12}) were comparable to each other. The treatments were on par with respect to flower shedding (%), number of fruits per plant, fruit length, per cent hard seeds and saleable seeds, test weight of seed and seed density.
17. One-time application of 0.5% Sampoorna KAU vegetable multimix (T_9) was found next best to two-time application of 0.5% Sampoorna KAU vegetable multimix (T_{10}) or 0.75% $ZnSO_4$ (T_{16}) and 0.1% H_3BO_3 (T_{12}).
18. Administering plant growth promoting rhizobacterium *Pseudomonas fluorescens* twice via foliar spray may be recommended to reduce per cent of hard seeds and obtain high saleable seed per pod (%).

II. Seed quality and seed storage studies

1. Except sulphur and iron content, the elemental composition of seed were significantly influenced by the foliar application of nutrients and growth promoters.
2. The foliar application of boron, zinc, and magnesium was found to increase the content of respective elements in the seed
3. Sampoorna KAU vegetable multimix (0.5%) was beneficial in increasing the boron, manganese, copper calcium and magnesium content of seed. Next to the micronutrient mixture, it was also evident that the content of boron, manganese, magnesium and calcium content of seed was enhanced through spray of salicylic acid.
4. Seed quality and longevity during storage were found to be significantly influenced by storage condition. The exceptions being allometric index, electrical conductivity of seed leachate and seed microflora.
5. As the storage period increased the seed quality decreased irrespective of the storage environment. The rate of seed deterioration was found to be maximum when the seeds were stored in unshelled pods. Hence, compared to storing seeds within unshelled pods, ambient storage and cold storage conditions was found

beneficial in prolonging longevity and maintaining higher seed quality parameters during storage.

6. Irrespective of the foliar treatment, seeds stored under refrigeration recorded significantly high germination per cent, seedling shoot length, seedling dry weight and vigour index I and II.
7. Although, the results point out that two-time foliar application of micronutrient mixture (0.5% Sampoorna KAU vegetable multimix at 25 DAS and 45 DAS) positively influenced seed quality during storage, a conclusive evidence as to the best foliar treatment that positively impacts seed quality parameters can be drawn only from the study of seed quality parameters over prolonged storage (>6 months).
8. Further evaluation of seed quality under ambient and refrigerated storage environment over a longer storage period is also essential to delineate the impact of these treatments as well as environment on seed longevity and quality during prolonged storage.
9. The foliar spray of micronutrients and secondary nutrients not only extended the longevity of seed, but also enhanced the profitability of seed production.

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Appendices

Appendix I

Benefit-cost ratio of okra seed production with foliar application of 0. 5% Sampoorna KAU vegetable multimix

Total cost (acre)				Total return (acre)		
Parameters		**Quantity**	**Rate (Rs.)**	**Parameters**	**Quantity (Kg)**	**Rate (Rs.)**
Seed		3.5 kg@ 800	2800	Saleable seed	411.52	32,8,800
Sampoorna-KAU vegetable multi-mix (0.5%)		2 kg@ 220/kg-	440			
Manure		12 tonnes@5/kg	60,000			
Tractor		12 hrs@600/hr	7,200			
Fertilizer	Urea	100 kg@ 6/kg	600			
	Rock phosphate	100 kg@ 17/kg	1,700			
	MOP	50 kg@16/kg	800			
Field labour	Land preparation and sowing	26 men@ 600	15,600			
	Weeding and roguing	22 women@ 600	13,200			
	Micronutrient spray	8 men@ 600	4,800			
	Plant protection	10 men@ 600	6,000			
	Fertilizer application and earthing up	28 women@ 600	16,800			
Post-harvest operations	Harvest and seed extraction.	25 women	15,000			
	Cleaning and drying	14 woman	8,400			
	Seed packing	8 women	4,800			
Transportation			10,000			
Total			1,68,140			3,28,800
B:C ratio		3,28,800/1,68,140 =**1.95**				

Appendix II

Benefit-cost ratio of okra seed production with foliar application of 0.75 % Zinc sulphate

Parameters		Quantity	Rate (Rs.)	Parameters	Quantity (Kg)	Rate (Rs.)
Seed		3.5 kg@ 800	2800	Saleable Seed	382.14	3,05,712
Zinc sulphate (0.75%)		3 Kg@ 440/kg	1320			
Manure		12 tonnes@5/kg	60,000			
Tractor		12 hrs@600/hr	7,200			
Fertilizer	Urea	100 kg@ 6/kg	600			
	Rock phosphate	100 kg@ 17/kg	1,700			
	MOP	50 kg@16/kg	800			
Field labour	Land preparation and sowing	26 men@ 600	15, 600			
	Weeding and roguing	22 women@ 600	13,200			
	Micronutrient spray	8 men@ 600	4,800			
	Plant protection	10 men@ 600	6,000			
	Fertilizer application and earthing up	28 women@ 600	16,800			
Post-harvest operations	Harvest, seed extraction.	25 women	15,000			
	Cleaning and drying	14 woman	8,400			
	Seed packing	8 women	4,800			
Transportation			10,000			
Total			1,68,800			3,05,712
B:C ratio		3,05,712/1,68,800 =**1.81**				

Appendix III

Benefit-cost ratio of okra seed production with foliar application of 0.1% Borax

Total cost (acre)				Total return (acre)		
Parameters		**Quantity**	**Rate (Rs.)**	**Parameters**	**Quantity (Kg)**	**Rate (Rs.)**
Seed		3.5 kg@ 800	2800	Saleable seed	357.12	2,85,696
Borax (0.1%)		80 g@ 293/kg	24.00			
Manure		12 tonnes@5/kg	60,000			
Tractor		12 hrs@600/hr	7,200			
Fertilizer	Urea	100 kg@ 6/kg	600			
	Rock phosphate	100 kg@ 17/kg	1,700			
	MOP	50 kg@16/kg	800			
Field labour	Land preparation and sowing	26 men@ 600	15,600			
	Weeding and roguing	22 women@ 600	13,200			
	Micronutrient spray	8 men@ 600	4,800			
	Plant protection	10 men@ 600	6,000			
	Fertilizer application and earthing up	28 women@ 600	16,800			
Post-harvest operations	Harvest and seed extraction.	25 women	15,000			
	Cleaning and drying	14 woman	8,400			
	Seed packing	8 women	4,800			
Transportation			10,000			
Total			1,67,724			2,85,696
B:C ratio		2,85,696/1,67,724 =**1.70**				

Appendix IV

Benefit-cost ratio of okra seed production from untreated control

Total cost (acre)				Total return (acre)		
Parameters		**Quantity**	**Rate (Rs.)**	**Parameters**	**Quantity (Kg)**	**Rate (Rs.)**
Seed		3.5 kg@ 800	2800	Saleable seed	281.39	2,25,112
Manure		12 tonnes@5/kg	60,000			
Tractor		12 hrs@600/hr	7, 200			
Fertilizer	Urea	100 kg@ 6/kg	600			
	Rock phosphate	100 kg@ 17/kg	1,700			
	MOP	50 kg@16/kg	800			
Field labour	Land preparation and sowing	26 men@ 600	15, 600			
	Weeding and roguing	22 women@ 600	13,200			
	Plant protection	10 men@ 600	6,000			
	Fertilizer application and earthing up	28 women@ 600	16,800			
Post-harvest operations	Harvest, seed extraction.	25 women	15,000			
	Cleaning and drying	14 woman	8,400			
	Seed packing	8 women	4,800			
Transportation			10,000			
Total			1,62,900			2,25,112
B:C ratio		2,25,112/1,62,900 =**1.38**				

Abstract

IMPACT OF FOLIAR APPLICATION OF NUTRIENTS AND GROWTH PROMOTERS ON SEED YIELD AND QUALITY OF OKRA

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ABSTRACT OF THE THESIS

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ABSTRACT

Experiments to assess the impact of foliar application of secondary nutrients, micronutrients and growth promoters on growth, fruit and seed yield of okra variety Arka Anamika, and the influence of storage environment on quality and longevity of the seed thus produced were conducted at College of Horticulture, Vellanikkara, Thrissur, during 2016-2018. The field experiment was laid out in a Randomized Block Design (RBD) with 18 treatments. The dosage of micronutrients and secondary nutrients to be applied as foliar nutrition in the experimental plot were fixed based on the soil test data. As the soil of the experimental plot was found to be deficient in secondary nutrients *viz*., magnesium and sulphur as well as in micronutrients; zinc and boron, the treatments were designed to augment the required secondary and nutrients through foliar application. Foliar application of 0.75% ZnO, 1% MgO, 0.2% *Pseudomonas fluorescens* (*Pf*), 0.2% Salicylic acid (SA), 0.5% Sampoorna KAU vegetable multimix (SVM), 0.1% H_3BO_3, 0.5% Sulphur (S), 0.75% $ZnSO_4$ and water (Control: C), was done either once at 25 days after sowing (T_1: 0.75% ZnO-I, T_3: 1% MgO-I, T_5: 0.2% *Pf*-I, T_7: 0.2% SA-I,T_9: 0.5% SVM-I, T_{11}: 0.1% H_3BO_3-I, T_{13}: 0.5% S-I, T_{15}: 0.75% $ZnSO_4$-I and T_{17}: C-I) or twice at 25 DAS and 45 DAS (T_2: 0.75% ZnO-II, T_4: 1% MgO-II, T_6: 0.2% *Pf*-II, T_8: 0.2% SA-II, T_{10}: 0.5% SVM-II, T_{12}: 0.1% H_3BO_3-II, T_{14}: 0.5% S-II, T_{16}: 0.75% $ZnSO_4$-II and T_{18}: C-II), during the cropping period and observation on growth and yield parameters were recorded at appropriate stages.

Results revealed the existence of significant differences in most vegetative and reproductive traits in okra, following foliar application of various nutrients and growth promoters. However, no significant difference was observed with respect to plant height at 30 days after sowing (DAS) and 60 DAS, days to flowering, pollen viability (%), seeds per pod, shrivelled seeds per pod (%) and seed yield per pod (g).

Considering the impact of various nutrients and growth regulators, it may be concluded that foliar application of micronutrient mixture (0.5% Sampoorna KAU

vegetable multimix) or 0.75% ZnSO4 or 0.1% H_3BO_3 twice during the crop growth was advantageous. Foliar application of micronutrient mixture (0.5% Sampoorna KAU vegetable multimix) twice, exerted high positive influence on the vegetative growth and reproductive traits in okra seed crop except per cent of hard seeds and test weight. The treatment had registered the highest fruits per plant and the least per cent of flower shedding. Two-time foliar application of 0.5% Sampoorna KAU vegetable multimix was more advantageous than its one-time application. Although high in saleable seed (%) as well as test weight and low in hard seed per cent, the plant stature at both 45 DAS and 75 DAS, chlorophyll content in leaves, number of branches and fruits per plant, fruit length and seed density were comparatively low in one-time application of 0.5% Sampoorna KAU vegetable multimix. The flower shedding was also comparatively high in one-time application of vegetable multimix. One-time application of 0.5% Sampoorna KAU vegetable multimix was found next best to two-time application of 0.5% Sampoorna KAU vegetable multimix or 0.75% $ZnSO_4$ and 0.1% H_3BO_3.

Foliar application of 0.75% $ZnSO_4$ twice and 0.1% H_3BO_3 twice were comparable to each other. The treatments were on par with respect to plant height at 75 DAS, chlorophyll content in the leaf, flower shedding (%), number of fruits per plant, fruit length, per cent hard seeds and saleable seeds, test weight of seed and seed density. Application of 0.75% $ZnSO_4$ twice exhibited a highly beneficial effect on reproductive traits of seed crop. The highest saleable seed per cent was registered in this treatment. Low per cent of flower shedding and hard seeds as well as high number of fruits per plant and fruit length were observed in this treatment. In spite of the low plant stature at both 45 and 75 DAS and chlorophyll content, all the reproductive traits *viz.*, number of fruits per plant, fruit length, saleable seed per pod (%), test weight and seed density in treatment 0.1% H_3BO_3 twice *i.e.*, at 25 DAS and 45 DAS was of high magnitude. In addition, the treatment had registered lower per cent of flower shedding and hard seed. High test weight coupled with high seed density indicates good grain filling.

Administering plant growth promoting rhizobacterium *Pseudomonas fluorescens* twice via foliar sprays can also be recommended to reduce per cent of hard seeds and obtain high saleable seed per pod (%). However, it did not improve the plant stature at early stages (45 DAS) and number of branches, chlorophyll content in leaves and seed test weight or lower the occurrence of hard seeds per pod (%).

Seed storage experiments were laid out following a Completely Randomized Design (CRD) with eighteen treatments (T_1 to T_{18}) and three replications (R_1 to R_3) under three storage conditions. The study was done using the seeds extracted from the pods harvested at physiological maturity from each of the 18 treatments in Experiment I. Seeds were stored under three storage conditions *viz.*, shelled seeds under refrigerated storage (S_1), shelled seeds under ambient storage (S_2) and unshelled pods under ambient storage (S_3).

The foliar application of nutrients and growth promoters in okra significantly influenced the seed the elemental composition of seeds except for iron and sulphur content. It was observed that the foliar application of boron, zinc, and magnesium increased the content of respective elements in the seed. Sampoorna KAU vegetable multimix (0.5%) was beneficial in increasing the boron, manganese, copper calcium and magnesium content of seed. Next to the micronutrient mixture, it was also evident that the content of boron, manganese, magnesium and calcium content of seed was enhanced through spray of salicylic acid.

Before storage, the foliar application of nutrients and growth promoters was found to exert a significant influence on the seed quality indices (germination per cent, seedling vigour index I and seedling vigour index II). Results of storage studies indicated that, as storage period increased the seed quality decreased irrespective of the storage environment. The rate of seed deterioration was found to be maximum when the seeds were stored in unshelled pods. Hence, it can be summarized that compared to storing seeds within unshelled pods, ambient storage and cold storage conditions are beneficial in prolonging longevity and maintaining higher seed quality parameters during storage.

Although, the results point out that foliar application 0.5% Sampoorna KAU vegetable multimix twice positively influenced seed quality during storage, a conclusive evidence as to the best foliar treatment that positively impacts seed quality parameters can be drawn only from the study of seed quality parameters over prolonged storage (>6 months). Further evaluation of seed quality under ambient and refrigerated storage environment over a longer storage period would also help delineate the impact of these treatments as well as environment on seed longevity and quality during prolonged storage.