प्याज की किस्म पूसा रिदी में गुणवता बीज उत्पादन का अनुकुलन

OPTIMIZATION OF QUALITY SEED PRODUCTION IN ONION (*Allium cepa* L.) cv. PUSA RIDDHI

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OPTIMIZATION OF QUALITY SEED PRODUCTION IN ONION (*Allium cepa* L.) cv. PUSA RIDDHI

A Thesis

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This is to certify that the thesis entitled "OPTIMIZATION OF QUALITY SEED PRODUCTION IN ONION (*Allium cepa* L.) Cv. PUSA RIDDHI" submitted to the Faculty of Post-Graduate School, ICAR-Indian Agricultural Research Institute, New Delhi, in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Seed Science and Technology, embodies the results of bonafide research work carried out by Mr. SANJAY KUMAR, Roll No. 10187 under my guidance and supervision and no part of the thesis has been submitted for any other degree or diploma.

All the assistance and help received during the course of investigation as well as source of information have been duly acknowledged.

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Dedicated to
"My
Parents,
Teachers
&
Farmers"

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

List of Abbreviations

%	:	Percentage
°C	:	Degree Celsius
μ	:	Micro
LSD	:	Least Significant Difference
cm	:	Centimeter
Cv.	:	Cultivar
DAP	:	Days After Planting
EC	:	Electrical Conductivity
g	:	Grams
ha	:	Hectare
HSD	:	Honest Significant Difference
IARI	:	Indian Agricultural Research Institute
m	:	Meter
mg	:	Milligram
RH	:	Relative Humidity
S.E(d)	:	Standard Error of Difference
nmol	:	Nano Mole

1. INTRODUCTION

Onion (*Allium cepa* L.), belonging to family Alliaceae, in considered to be originated from Asia Minor. It is the second important vegetable crop of the world (3.97mha) after tomato (4.5mha) (NHB, 2013-14) and one of the major vegetable crops cultivated in India. It is an indispensable item in every kitchen as vegetable and condiment, used to flavor many of the food stuffs. It is also used as salad and pickles. The powder and flakes prepared from dehydration of onion bulb is also becoming popular in urban areas and helping in employment generation.

Globally, India ranked first in area (1.2mha) and second in production (19.4mt) after China with an average productivity of 16.2t/ha (NHB, 2013-14). The productivity of onion in India is very low when compared to Ireland (68.7t/ha), USA (54.46t/ha), Spain (53.69t/ha) and China (21.75t/ha) (FAO, 2013). The higher productivity in European countries and USA is attributed to higher use of hybrid seed for its cultivation and long growing conditions, whereas; open pollinated varieties occupies maximum area in India. Moreover, quality seed of onion is not available in adequate quantity in the country; therefore, small and marginal farmers use their own produced seeds, having very low genetic potential, quality and poor yielding abilities to raise their commercial crop. The higher price of quality seed is another limiting factor for small and marginal farmers. Seed production of onion is largely concentrated in Maharashtra, Gujarat, Madhya Pradesh and Karnataka due to better suited growing conditions. Onion seed production under north Indian climatic condition is largely affected by biotic and abiotic factors leading to reduced seed yield and quality.

Quality seed production of onion depends on genotype, locality, season and method of seed production (Brewster, 1994). Despite many attempts in the recent past, to enhance the yield and quality of onion seed (Bhonde *et al.,* 1996) no definite and profitable technology has yet been developed which can be recommended to the farmers for growing onion seed at a commercial scale under north Indian conditions where climatic conditions are change suddenly during flowering and maturity of seed crop.

Onion is photo-thermo sensitive plant (Jones and Mann, 1963), therefore, any fluctuation in environmental conditions largely affect the yield and quality of seed. Planting time is one of the most important factors that greatly influence the plant growth and yield of onion (Mondal *et al.,* l986). Adjusting planting time for onion seed production is very important because shorter winter season in north Indian conditions affects the bolting of seed scape to a large extent. Anisuzzaman, *et al*., (2009) showed that planting dates significantly affect the plant growth and seed quality in onion. The variation in seed quality due to different planting time may be attributed to changing temperature during growing season that affects the time of bolting and seed stalk development. Perfect nicking of honey bee activities for pollination and anthesis of flowers is required for better seed setting, which is highly dependent on range of temperature prevailing in growing areas at the time of seed production (Teshome *et al*., 2014). High temperature during pollination leads to abortion of flowers and thus, reduced seed yield and quality. The high temperature at seed maturity, on other hand, results into shriveled seeds having poor seed quality. Maximum yield realization through early planting was due to the cumulative contribution of all the yield contributing characters influenced by comparatively high temperature and long day length (Mosleh, 2008).

Under field conditions, onion seed crop requires proper spacing to maintain optimum plant population per unit area to increase seed yield and quality. The optimum density provides congenial conditions by penetration of maximum light right from early growth to seed filling stage. Therefore, by changing the plant spacing, it is possible to achieve optimum vegetative and reproductive growth to boost up seed crop productivity per unit area. Optimum spaced plants produced more green leaf and extra food materials which promoted the better development of plant due to the less competition for nutrients, light, space, and moisture. Later on, these leaves accumulate more photosynthates and ultimately resulting into more number of flowers and yield (Asaduzzaman *et al.*, 2012).

Application of mineral nutrients is essential to fetch higher yields and quality because Indian soils are deficient in mineral nutrients. For better plant growth and development mineral nutrients are needed in small quantities but their deficiencies cause a great disturbance in the physiological and metabolic processes and ultimately reduced the seed yield and quality. The foliar application of mineral nutrients is a better option of supplying mineral nutrients to higher plants than soil application because it avoids antagonistic effects of nutrients during uptake from soil (Edral *et al*., 2004). It is widely accepted that foliar application of mineral nutrients at active growth stages improved the plant growth, yield and quality in various crops. Elements, especially B, Zn, Ca and Mg act either as metal components of various enzymes or functional or regulatory cofactors which are associated with carbohydrate metabolism, photosynthesis, and protein synthesis (Marschner, 1995). Zinc is an essential micronutrient for synthesis of auxins, cell division and maintenance of membrane structure & functions. Zinc deficiency reduces plant growth, pollen viability, flowering and number of fruits (Marschner, 1995). Boron plays an important role in differentiation of meristematic cells, translocation of carbohydrate from source to sink tissues and pollen viability. Magnesium on the other hand has an important role in photosynthesis because it forms the central atom of chlorophyll pigment. It is also necessary for activation of many critical enzymes, including Rubisco and phosphoenolpyruvate which are essential in carbon fixation. Calcium regulates transport of other nutrients into the plant and activation of certain plant enzymes which are required for different metabolic activities. Calcium plays important role in the formation of calcium pectate, which is main constituent of middle lamella of cell wall ultimately helpful in development of new plant cell. A notable feature of calcium-deficient plants is defective & stunting root system therefore, it is more important for shallow rooted crops like onion which fails to draw nutrients from deep soil profile. Mineral nutrients may help in obtaining uniform emergence of seed, rapid seedling growth, healthy plant stand, higher seed yield and better seed quality as reported by Sharma *et al.*, (2010). Sufficient amount of these nutrients in the plant is necessary for normal growth and to obtain satisfactory seed yields.

In onion, seed umbel is born on terminal part of seed scape and this seed scape length in most of the cultivars is very high. The high length of hollow seed scape and high wind velocity due to western disturbance during the flowering and maturation of crop increased the chance of seed scape lodging in north Indian conditions. Because of seed scape lodging it prevents the mechanical harvesting and also decreases the seed yield and quality. Plant growth retardants have been used to modify and control the growth and development of many vegetable crops (*Berova et al.,* 2002). Plant growth retardant like Paclobutrazol was used to reduce the onion seed scape height, but along with reducing scape height it also significantly reduced the seed yield parameters (Ashrafuzzaman *et al*., 2009). In onion, suitability of plant growth retardants for reducing the seed scape height as well as their optimum requirement to give better results in terms of quantity and quality of onion seed is yet to be worked out. Keeping in view the above facts the present investigation entitled “Optimization of quality seed production in onion (*Allium cepa* L.) cv. Pusa Riddhi” was undertaken with the following objectives:-

Objectives:-

1. To study the effect of planting time and crop geometry on growth, seed yield, and seed quality
2. To study the effect of foliar application of different mineral nutrients on growth, seed yield and seed quality
3. To study the effect of different plant growth retardants on onion seed scape height, seed yield and seed quality

2. REVIEW OF LITERATURE

Seed yield and quality is a complex trait and influenced by several factors and among them growing time, planting geometry, size of mother bulb and nutrient management particularly mineral nutrients play important role in attaining higher seed setting, seed yield and quality. The published information on various aspects of onion seed production has been collected and an attempt has been made to present a comprehensive review on quality seed production in onion.

2.1 Experiment 1: To study the effect of planting time and crop geometry on growth, seed yield, and seed quality

The planting time in onion seed production plays significant role on yield and quality due to coincidence of temperature and relative humidity during different vegetative and reproductive growth stages which highly affect the seed stalk development, pollination and maturation of seed. Similarly, planting density is also important which influence the availability of light, moisture; nutrients and disease development during crop period. Brewster (1994) reported that optimum plant density plays important role for better plant growth, seed yield and quality in allium crops. Plant to plant and row to row spacing are considered as important to have optimum plant population which will reflect into better yield and quality as reported by many workers.

2.1.1 Effect of planting time on growth, seed yield and quality

Mohamedali and Nouri (1988) showed that the optimum planting dates for onion seed production were from 15th October to 15th November. They revealed that significant higher seed yield was obtained under early planting and it was decreased in late sowing which was due to more flower abortion under higher temperature along with reduction in umbel size and total flowers/umbel. They concluded that plants of late sowings faced the adverse high temperature during March to May months which is unfavorable for seed setting and development.

Ibrahim *et al.,* (1996) reported that number of leaves/plants and number of scapes/plant were not significantly changed by planting dates in onion but the higher diameter of umbel, seed stalk height, seed yield/plant and seed quality were obtained when bulbs were planted on 25th November than late sowings.

El-Aweel and Ghobashi (1999) reported that seed yield was significantly increased in early planting of bulbs (10th November) and concluded that the higher seed yield/plant in early planting was mainly due to increase in number of umbels/plant and 1000 weight of seed. The similar results were also reported by Khodadadi (2009).

Mosleh (2008) reported that planting of onion for seed production at different times significantly influenced the seed yielding attributes. He recorded that planting at (30th October) produced the longest plants (62.29 cm) and higher number of leaves/plant (16.72) compared to late plantings (15th Nov. and 30th Nov.). The higher number of flowers/umbel (226.6), fruit setting (71.16%) and seed yield (383.2 kg/ha) were also found in early planting (30th October) which was due to the cumulative contribution of all the yield contributing characters influenced by comparatively high temperature and long day length. Similar results were reported by Lisabao *et al.* (1985), Singh *et al.* (1991) and Khokhar *et al.* (1970).

Anisuzzaman *et al.*, (2009) observed that planting of onion on 21th Nov. produced maximum number of tillers/plant (4.0), scape length (64.55 cm), number of flowers/umbel (239.0), and number of umbels/plant (4.21) than 30th Oct. planting. Consequently seed setting % (77.38 %), 1000 seed weight (3.48 g) and Germination percentage (85.41%) were also higher in 21st Nov. planting date while bulbs planted on 30th Oct. captured the longest time (54.04 days) for 50% flowering compared to 21st Nov (50.34 days).

Khodadadi and Hassanpanah (2012) noted that autumn planting (6th Nov.) of onion bulbs for seed production, produced higher plant height, umbel diameter, florets/umbel, 1000 seed weight and seed yield compared to winter (5th March) planting which was due to the fulfillment of optimum climatic requirement for bolting and seed setting.

Helaly and Karam (2012) studied the influence of different planting dates on onion seed production and reported that number of scapes/plant (5.06), scape diameter (2.73cm), main scape length (106.18cm), umbel diameter (7.30mm), seed yield/plant (24.01g), 1000-seeds weight (4.72g) and germination percentages (93%) were higher when bulbs were planted on 15th November, and delaying in planting time reduced the yield and quality.

Sanju *et al.,* (2012) reported that highest test weight of chilli seed was obtained from September sown crop (5.09 g) than February (4.85 g) and crop sown in September have longest shelf-life of fruit (6.57 days) than (4.16 days) in 15th February sown plants. The higher germination % was recorded in early sown crop than late sowing in chilli seed production.

Maria and Barbara (2013) reported that planting of shallot onion under different time had significant effect on growth and yield. They observed that planting of seedlings in 3rd week of July gives best results for development of seed stalks and delay in planting by 2-4 weeks significant reduced the percentage of plants producing seed stalks and their numbers/plant.

Teshome *et al*., (2014) observed that the maximum seed yield (1155.73kg/ha) was obtained onion bulbs were planted on 25th October than 15th November (75.15kg/ha). In terms of germination index, the highest (6.03) was obtained from 25th October planting compared to 15th November (3.37). Malik *et al.,* (1999) also revealed that early planting of onion had produced significant maximum plant height, number of umbels/plant, number of seeds/umbel and seed yield than late planting.

Mehri *et al.,* (2015) studied that number of leaves/plant, plant height, number of flowering stalks/plant, number of capsules/umbel, number of seeds/capsule and number of umbels/plant were significantly affected by changing in planting dates in onion under Iran conditions. The highest seed yield (1405kg/ha) was obtained when bulbs were planted on 21st October than 6th October (1204.7kg/ha) and 5th November (1187 kg/ha).

2.1.2 Effect of crop geometry on growth, seed yield and quality

Singh *et al*., (1990) studied six plant spacings (30×30, 30×45, 30×60, 45×45, 45×60 and 60×60 cm) in onion seed production and observed that the highest planting density (30×30 cm) gave a significantly higher seed yield compared to wider spacings but seed yield/umbel, seed yield per plant and 1000 seed weight were found low.

Verma *et al.,* (1994) reported that maximum seed yield/plant was obtained when largest bulbs were planted with wider spacing compared to closer spacing in onion seed production.

Tiwari *et al*., (2002) evaluated the effect of bulb spacing on seed yield of onion cv. Pusa Red and found that 60×45 cm spacing showed higher number of yield contributing traits than closer spacing.

Atif (2004) reported that planting density significantly influenced the seed yield of onion and revealed that 45×60 cm spacing had given higher seed yield/plant (16.27g), 1000 seed weight (3.43) than 30×60 cm (13.19g, 3.13g) and 15×6 cm spacing (10.16g & 3.42g) respectively.

Balraj *et al*., (2005) studied the effect of bulb spacing on plant growth and seed yield attributes in onion cultivar RO-1 and found that bulb size and bulb spacing had significant effect on plant growth and yield. They recorded maximum seed yield/umbel under wider spacing (60×30cm) than closer but seed yield per hectare was significantly higher in 45×30cm.

Narendra and Ahmed (2005) revealed that closer planting (30 x 10 cm) of onion bulbs, produced higher plant height (98.68 cm) than wider spacing (30 x 20 cm) (80.78 cm) which might be due to large plant population causes more competition for light, food and nutrients among the plants. The maximum number of sprouts/hill (5.53), number of umbellate (195.71), number of seeds/umbel (751.31), seed yield/ha (11.20) and germination % (74.8) were recorded in wider spacing under Leh (ladakh) region in onion cv. Sindhu Sweta and similar findings have also been reported by Lal *et al*., (1987).

Mirshekari *et al*., (2008) reported that wider intra row spacing (30cm) gave higher seed yield and higher stem lodging % compared to narrow intra row spacing (20cm) in onion in Tabriz region of Iran.

Asaduzzaman *et al.,* (2012) studied the influence of plant spacing on seed quality attributes in onion cv. Taherpuri. They revealed that among the four different spacings viz. 20×15, 25×10, 25×15, and 25×20cm, higher number of green leaves/plant (12.089), umbel diameter (5.437), number of flowers/umbel (229.497) seed yield/plant (3.263g) and germination (92.64%) were observed under wider spacing 25×20 cm than closer spacing. The higher growth and yield contributing traits under wider spacing might be due to the less competition among plants for space, moisture, nutrients and light. The similar results were recorded by Singh and Sachan (1999), Pandey *et al.,* (1992) and Begum *et al.,* (1998) in onion.

Asaduzzaman *et al.,* (2012a) conducted an experiment to determine the suitable spacing for onion seed production and observed that significant higher number of seed stalks (3.43), stalk length (83.25), number of umbels/plant (3.42), seeded fruits/umbel (227.17) and 1000-seed weight (3.56g), were obtained from 30×20 cm spacing. They concluded that these results might be due to more food materials supplied to the growing seeds under wider spacing compared to the closer and their results are in agreement with Ali *et al*., (1988).

Ayoub and Hala (2013) conducted an experiment to know the effect of row to row spacing in onion seed production and observed that 12.5cm spacing between the rows had given higher germination percentage (98.5) and emergence (98.2 %) than closer spacings viz., 2.5cm, 5cm, 10cm and 12.5 cm.

Mondal *et al.,* (2013) evaluated the effect of spacing on yield attributing traits in rice and found that wider spacing (20×20cm) plants showed better performance in morphological characters and resulted into higher grain yield (8.53t/ha) than closer spaced plants viz., 20×15 cm (7.53t/ha), 20×10 cm (6.47t/ha).

2.2 Experiment II: To study the effect of foliar application of different mineral nutrients on growth, seed yield and seed quality.

Vaganov and Sorokina (1970) reported that foliar application of 1.0% $ZnSO_4$ and 1.0% $CuSO_4$ increased the cucumber seed yield and germination percentage. The similar results were also obtained by Sharkawy *et al*., (1987) in summer squash and Khalate *et al.,* (1992) in onion.

Velu (1988) reported that maximum turmeric rhizome yield (21.4t/ha) was obtained when soil application of $FeSO_4$ (50kg/ha) and $ZnSO_4$ (50kg/ha) were combined with foliar spray of 1.0% $FeSO_4$ and 0.5% $ZnSO_4$ at three different stages of crop growth as compared to control (12.4t/ha).

Patil and Malewar (1994) reported that foliar application of 0.2% boron with combination of Fe and Zn significantly influenced the chlorophyll a &b content in cotton.

Ravichandran *et al.,* (1995) observed that the heaviest fruits (52.2 g/fruit) in brinjal cv. Annamalai were obtained when $ZnSO_4$ (25 kg/ha) was applied in soil. But highest fruit yield (27.1t/ha) and number of fruits/plant (20) were recorded when $ZnSO_4$ (25 kg/ha) was applied in soil followed by foliar spray of $ZnSo_4$ (0.5%) at 30 DAT.

Sharma (1995) concluded that higher dose of boron (20kg/ha) application had given maximum number of branches/plant (9.2), plant height (189.2 cm), 1000 seed weight (3.94 g) and germination (96.5%) as compared to 10 kg boron/ha in tomato.

Rathinavel *et al.*, (1999) reported that foliar application of zinc sulphate (0.5%) at 90 and 110 DAS in cotton significantly increased 100-seed weight, germination percentage, speed of germination, root length, shoot length and vigour index compared to control.

Sharma *et al.*, (1999) revealed that soil application of $ZnSO_4$ (10kg/ha) and foliar application of boric acid (0.1%) increased the number of seeds/pod, seed yield/plant, 1000 seed weight and germination % over the control in radish. They also observed that combination of boron and $ZnSO_4$ had given significant higher seed yield and quality than other treatments.

Dongre *et al.*, (2000) recorded maximum fruit yield/plant (395.33 g) and fruit yield per ha (109.8 q) when foliar spray of boron (H_3BO_3) at 0.25 % was given in chilli as compared to control (324.33 g/plant and 90.08 q/ha) respectively. They found that highest fruit length (11.12 cm) and fruit diameter (1.175 cm) were obtained when plants were sprayed with 0.1 % H_3BO_3 whereas, higher number of seeds/fruit (55.66) and weight of 500 seeds (2.549 g) were obtained under foliar spray of H_3BO_3 at 0.50 %.

Raj *et al.*, (2001) revealed that combined application of Zn and Fe in brinjal cv. Bhagyamathi significantly influenced seed yield and Zn/Fe contents in fruits. Among the treatments, soil application of $ZnSO_4$ (12.5 kg/ha) along with three foliar sprays of 0.2 % $ZnSO_4$ and 0.5% $FeSO_4$ had given highest fruit yield (37.7 t/ha) which was 23.6% increment over the control.

Ali *et al.*, (2003) reported that the significant higher paddy seed yield was obtained when recommended dose of NPK was applied along with combined application of Zn^{+2}+Cu^{+2}+ Fe^{+2}+Mn^{+2} (60.87q/ha) than control (40.73 q/ha).

Muhammad Hussain *et al.*, (2002) observed that, foliar application of $MgSO_4$ (300ml/m^3) on lentil had given higher number of pods/plant, seeds/pod, 1000 seed weight and seed yield than control. Similar results were also reported by Paikray, *et al.*, (2001) in Niger.

Karuppaiah (2005) reported that the foliar application of borax (0.5%) at 35, 50 and 65 DAT in brinjal cv. Annamalai had showed significant higher number of flowers/plant, number of productive flowers/plant, number of fruits/plant, individual fruit weight and yield (32.15 t/ha) than copper sulphate (0.5%) and zinc sulphate (0.5%) at 35, 50 and 65 DAT.

Yallapa *et al.*, (2006) studied the effect of foliar application of micro nutrients on seed yield and quality of cotton hybrid DHH-11 and observed that the maximum seed yield (795.49 kg/ha), germination percentage, root length, shoot length and vigour index were recorded when $MgSO_4$ (1% at 60DAS) was applied in combination with Boron (0.1% at 75 DAS) compared to control.

Christos (2006) reported that foliar application of B (400 mg/l) in alfalfa increased the pod formation up to 52% as compared to control and increased the seed germination and vigour up to 27% and 19% respectively**.**

Reddy *et al*., (2007) reported that application of sodium molybdate (3kg/ha) significantly increased the yield (2.3t/ha) as compared to other treatments and concluded that increment in yield was due to the result of improvement in morpho-physiological characters and enhanced dry matter production. The plant height and 100-seed weight were not influenced significantly by mineral nutrients when applied either through seed treatment or soil application. Similar results have been also observed by Velayutham *et al*. (2003) in black gram.

Khan *et al*., (2007) studied the response of onion for growth and yield by different levels of zinc (0, 5, 10 and 15 kg per hectare) and revealed that maximum leaf length (41.81 cm), plant height (56.33 cm) and bulb weight (136.5g) were obtained with application of Zn at 10kg/ha.

Wen *et al.*, (2009) conducted a study to evaluate the effect of foliar application of ammonium molybdate (0.05%), boric acid (0.38%), iron sulfate (0.76%), zinc sulfate (0.5%), manganese sulfate (0.76%) and copper sulfate (0.5%) in alfalfa. They found that molybdenum significantly increased the seed yield by 27-47%, number of racemes per shoot by 38–55%, the number of seeds per pod by 48–61% and 1000-seed weight by 24% whereas, boron increased the seed yield by 22–35%, number of seeds per pod by 41–52% and 1000-seed weight by 16% than control.

Yang *et al.,* (2009) conducted an experiment to study the effects of boron (B), molybdenum (Mo), zinc (Zn) and their interactions on seed yield in rapeseed and found that application of B fertilizer in sandy soil increased the seed yield by 46.1% as compared to control. The seed yield of the B+Mo+Zn treatment was the highest in all treatments, which was 68.1% above the control.

Muzzammil *et al.,* (2009) reported that application of micro nutrients significantly enhanced the plant growth parameters in sunflower. The plant height, stem girth, head diameter, number of seeds/head, seed weight/head and seed yield (17.38q/ha) were recorded higher under application of 15-1.5 Zn-B kg/ha treatment. They also reported that beyond this level of macro and micro nutrients responses were not significant. The application of adequate micro nutrient increased the crop yields, improved nutrient concentrations in plant tissue and enhanced soil macro and micro nutrient status as reported by (Adediran *et al.*, 2004) in maize and can give up to 67% higher yield over control (Taiwo *et al.*, 2001) in maize.

Soomro *et al.,* (2009) found that soil application of boron (2kg/ha) and zinc (5kg/ha) significantly increased the cotton seed yield 19%, 30% and 34% over control in boron, zinc and combined treatments respectively. Boron and zinc application also increased the boll weight and seed index in cotton.

Habib (2009) showed that foliar application of Zn and Fe increased seed yield and its quality in wheat as compared to control treatment. He observed that combine application of (Fe + Zn) significantly increased the seed yield and quality. Maralian (2009) also showed that foliar application of Zn+Fe significantly increased the seed yield and quality attributes in wheat as compared to control.

Sharma *et al.,* (2010) conducted a study to know the effect of mineral nutrients on pigeon pea and revealed that higher seed yield (13.73q/ha) was obtained than control (7.76q/ha) when $ZnSO_4$ was applied @15kg/ha. They also observed that yield contributing characters viz; number of pods/plant, number of seeds/pod and 100 seed weight were significantly higher in micronutrient treated plants than others.

Vahid *et al.,* (2010) noted that iron, manganese and zinc had significant effect on biological yield of soybean and observed that application of zinc (40kg/ha) and manganese (40kg/ha) helped to get higher seed yield (33.97 and 33.67q/ha), respectively.

The higher seed yield/plant and number of pods/plant also recorded in zinc and manganese treatment than others.

Alam *et al*., (2010) conducted an experiment to determine the effect of micro nutrients on growth and yield of onion. They revealed that the number of leaves per plant (14.63), plant height (61.30 cm), diameter of bulb (14.97 mm), fresh weight of leaves (31.42 g), fresh weight of bulb (9.21g), diameter of bulb (4.36 cm) and bulb yield (13.38 t/ha) were higher in Zn+B treatment. The combination of Zn+B increased the maximum bulb yield by 49.66% over control whereas Zn and B alone increased the bulb yield by 28.64% and 27.74% over control respectively.

Samad *et al.*, (2011) investigated the effect of foliar spray of mineral nutrients viz., Fe, Zn and Mn (2ml/l) (at 30 days interval after transplanting) in onion and observed that mineral nutrients had significant effect on plant growth, yield, quality and mineral contents of onion plants ($FeSO_4$ 8.5%, $ZnSO_4$ 8.5% and MnO_4 7%) than control.

Rafique *et al.*, 2011 reported that zinc application significantly increased the seed yield of onion cultivars and different cultivars were showed different response to Zn application. Among the different rate of Zn application viz., 0, 2, 4, 8, and 16 kg/ha the maximum seed yield (464kg/ha) was obtained when 8 kg/ha Zinc was applied in all the cultivars.

Zayed *et al.*, (2011) noted that the application of the Zn^{+2}, Fe^{+2} and Mn^{+2} mineral nutrients as single or in combination significantly improved the rice growth parameters viz., dry matter production, leaf area index, chlorophyll content, plant height and panicle length as compared to the control. The micronutrient application also showed improvement in panicle weight, filled grain/panicle and 1000 grains weight.

Gurmani, *et al.*, (2012) reported that application of Zn significantly increased the dry biomass, fruit yield, fruit fresh weight and number of fruits/plant in tomato. The highest improvement was noted when 10mg Zn was applied in one kg soil than 15mg/kg and 5mg/kg soil. The increase in growth and yield attributes could be due to influence of Zn to enhance metabolism, biosynthesis of auxins and better nutrient uptake (Cakmak, 1999).

Masoud *et al*., (2012) observed that micronutrient application significantly influenced the plant height, number of spikes/plant, number of grains/spike, 1000-grain weight, grain yield, biological yield and harvest index. Application of Mn+Fe had given highest positive effect on yield components and grain yield than other combinations. They concluded that micro nutrient application had positive effect on wheat growth and yield.

Pandey and Gupta (2012) reported that foliar spray of B (at 0.05%, 0.1% and 0.2% borax) in black gram significantly increased the pollen size, pollen tube growth, pollen viability, stigmatic receptivity and yield parameters (number of pods, pod size and number of seeds/plant). They also revealed that boron application increased the seed storage proteins (viz., albumin, globulin, glutenin and prolamin) and carbohydrates content in black gram.

Pandey and Gupta (2012a) revealed that foliar spray of Zn (at 0.01 and 0.5% $ZnSO_4$) improved pollen producing capacity, pollen viability, stigma-receptivity pollen-stigma interaction and yield parameters viz., number, size, weight of pods and seeds. They concluded that zinc deficiency changed the pollen grain structure, activity of esterase and poor stigmatic exudation leading to improper pollen stigma interaction, which seem to be the main cause of poor fertility and decreased seed yield. Many studies have revealed that stigma from Zn deficient plants showed lack of stigmatic exudation which is required for pollen tube hydration through style, leading to improper pollen-stigma interaction and finally reduced seed set (Pandey *et al.*, 2006, 2009). The positive effect of Zn sprays on nutritional status, seed setting, and yield were supported by other workers (Thalooth *et al*., 2006; Mousavi *et al*., 2007).

Yaseen *et al.,* (2013) recorded significant improvement in seed-cotton yield due to foliar application of Zn, B, Mn, Cu, and Fe. They observed that foliar application of micronutrient improved the nutrient status of plant leaves and resulting into increase in the number of flowers, number of bolls and seed-cotton yield up to 20-30% than control.

2.3 Experiment III: To study the effect of different plant growth retardants on onion seed scape height, seed yield and seed quality.

Levy *et al.,* (1972) reported that foliar application of ethephon (480ppm) at 75% visible seedstalk significantly reduced the seedstalk height which prevent the lodging of seedstalk and increased the efficiency of mechanical harvest in onion seed production.

However, this treatment has never been adopted by seed producers as a standard procedure, possibly due to the potential of plant tissue damage by ethylene.

Corgan, J.N. (1975) applied different dose of ethephon (2500, 5000 and 10,000 ppm) in onion at 5% seedstalk emergence stage and observed that seed stalk height was reduced from 94cm in control to 68, 62, and 54cm respectively. The lodging of seed stalk was reduced up to 53%. They also reported that 2500 and 5000ppm treatment had no effect on seed yield but the 10,000 ppm ethephon treatment significantly reduced the seed yield over the control.

Globerson *et al.,* (1989) reported that spraying of paclobutrazol (PP333) at 100 ppm in onion at 3-5% seed stalks visible stage significantly reduced the length of the seed stalk by 20-30%. They concluded that soaking of bulbs in a 500ppm PP333solution inhibited the growth of leaves & reduced the length of seed stalks but it caused many plants to dry up soon after foliage development.

Haim *et al*., (1991) observed a dwarf scape mutant in onion and tried to modify this dwarf scape mutant with external application of ethephon and GA_3. They reported that foliar spray of ethephon (500ppm) and GA_3 (50 ppm) had no effect on dwarf mutant scape elongation and a single recessive gene (dw_1) controls the scape dwarfness whose expression is slightly modified by minor genes.

Ozmen *et al.,* (2003) observed that paclabutrazol (40 mg) treated barley seedlings showed reduced shoot length and higher root/shoot ratio than control. The leaf chlorophyll, carotenoid and SOD were also recorded higher in PBZ treated seeds.

Ozturk *et al.,* (2003) studied the effects of ethephon on peroxidase (POD), polyphenol oxidase (PPO), catalase (CAT) activities and proline content in spinach leaves and revealed that ethephon significantly increased the enzyme activities in treated plants than control.

Kokare *et al*., (2006) studied the effect of plant growth regulators on growth, yield and quality of okra cv. Parbhani Kranthi. They revealed that maximum plant height was observed in the plots sprayed with GA_3 (200 ppm) while spraying the plants with NAA (200 ppm) resulted into higher number of leaves, leaf area, plant dry weight, number of fruits, fruit girth, fruit yield per plant, fruit yield (t/ha) and ascorbic acid content over the control. The growth retardant CCC (400ppm) enhanced total chlorophyll content and decreased days to 50 % flowering.

Ashrafuzzaman *et al*., (2009) studied the effect of different dose of paclobutrazol (0ppm, 20ppm, 40ppm and 80ppm) in onion and observed that PBZ (80ppm) reduced the plant height (36.72cm), number of leaves/plant (15.53), number of tillers/bulb (3.12), seed stalk height (61.38cm) diameter of scape (1.30cm), umbel diameter (4.79cm), flower/umbel (149.78), fruit set % (48.21), 1000 seeds weight (1.84g) and seed yield kg/ha (240.31) than control.

Nair *et al.,* (2009) revealed that paclobutrazol (PBZ) treatment increased the non-enzymatic antioxidants in root, shoot and leaves of *Ocimum sanctum*. They observed that enzymatic antioxidants like ascorbate peroxidase, catalase and superoxide dismutase were also significantly enhanced in PBZ treatment than control. Their results were in harmony with Jaleel *et al.,* (2006b); Sankhla *et al.,* (1992) in onion and Kraus & Fletcher (1994) in wheat. Berova *et al*., (2002) found that paclobutrazol enhanced the free radical scavenging capacity in wheat seedlings.

Ouzounidou *et al*., (2011) studied foliar spray of GA_3, Prohexadione-Calcium, and Ethephon on yield, biomass production, lipid peroxidation and quality characteristics in onion. They reported that prohex-ca (200mg/l) and ethephon (100mg/l) significantly reduced the biomass and chlorophyll content in the plant but they increased the peroxidase and MDA activity in the bulb compared to control and $GA_{3.}$

Sureyya (2011) studied the effects of chlormequat chloride (2000mg/l) and different rates of prohexadione-calcium (100mg/l, 200mg/l, 300mg/l) on seedling growth, flowering, fruit development and yield characteristics in tomato. He observed that 100 mg/l of pro-Ca was sufficient to reduce seedling height and to improve yield and quality of tomato.

Kavina *et al.,* (2012) found that triazole compounds like difenoconozole (DIZ) and propiconazole (PPZ) enhanced the enzymatic antioxidants like peroxidase (POX), polyphenol oxidase (PPO), Catalase (CAT), superoxide dismutase (SOD), ascorbate peroxidase (APX) activities in *Gloriosasuperba* stem and leaf.

Jungklang *et al.,* (2012) investigated the effects of paclobutrazol on physiological and biochemical changes in Patumma cv. Chiang Mai Pink and reduction trend of plant height, proline and MDA content were observed than control during water stress condition.

Davood *et al.,* (2012) revealed that foliar application of cycocel (CCC) and daminozide (B9) significantly affects the growth and flowering attributes of *Calendula officinalis* L. They observed that lowest plant height (30.67 cm), and maximum number of flowers/plant (3.33), were noted under treatment of 500 mg/L CCC + 4500 mg/L B9.

Tuna (2014) studied the effect of different triazole compounds viz; triadimenol (30 mg L^{-1}), tebuconazole (250 mg L^{-1}), bitertanol (250 mg L^{-1}), triadimefon (40 mg L^{-1}), and paclobutrazol (40 mg L^{-1}) on tomato seedlings. He revealed that application of triazole, compound helps to overcome the adverse effect of NaCl stress and enhanced the fresh and dry weight of plant. He also reported that triazole increased the total chlorophyll, carotenoid, antioxidants and relative water contents to a greater extent compared to salt-stressed plants.

3. MATERIALS AND METHODS

The research experiment entitled **"Optimization of quality seed production in onion (*Allium cepa* L.) cv. Pusa Riddhi"** was carried out during *rabi* season of 2013-14 and 2014-15 at Seed Production Unit, Division of Seed Science and Technology, Indian Agricultural Research Institute (IARI), New Delhi. During the investigation the materials and methodologies used along with observations recorded in the experiments have been presented below.

3.1 Experimental site

The field experiment was conducted at Seed Production Unit, Indian Agricultural Research Institute, New Delhi, which is situated at $28^0$35'N latitude & $77^0$12'E longitude and at an altitude of 228.6 m above mean sea level. It has a semi-arid and sub-tropical climate characterized with extreme hot summer and cool winter. The soil of experimental site is sandy loam in texture with slight salinity. The weather data from the crop growth to maturity (October to May) in 2013-14 and 2014-15 recorded at the Meteorological Observatory, Division of Agricultural Physics, IARI, New Delhi are presented in Appendix I & II.

3.2 Characteristics of soil

The soil samples were drawn from all three experimental sites after final preparation of the field. The soil sample was analyzed at Central Soil Testing Laboratory, Division of Soil Science and Agricultural Chemistry, IARI, New Delhi. The soil testing report of experimental plot (Mid B-e) is presented in Appendix III.

3.3 Materials

3.3.1 Source of seed

The seed of onion cv. Pusa Riddhi was procured from Division of Vegetable Science, IARI during 2013-14 & 2014-15 and bulb crop was raised at Seed Production Unit, Indian Agricultural Research Institute, New Delhi.

3.3.2 Description of Pusa Riddhi

Onion cv. Pusa Riddhi was developed at Division of Vegetable Science, IARI, New Delhi and released for commercial cultivation for Delhi and NCR region. It is suitable for both *kharif* and *rabi* season having compact, flat globe, and dark red colour bulbs. Average equatorial and polar diameters of bulbs range from 4.5-6.0 cm and 4.8-6.3

cm, respectively. The average bulb weight ranges from 70-100g and it is pungent and rich in antioxidant (quercetin 107.42 mg/100 g). The variety is also suitable for storage and export and has an average yield of 31.66 t/ha.

3.4 Agronomic practices

Onion seed production is biennial and it takes two seasons to complete each cycle. In first year, mother bulbs are produced and stored and then, in second year the selected medium size bulbs planted for seed production. Accordingly, the bulbs were produced during *rabi* 2012-13 & 2013-14.

3.4.1 Nursery preparation

To raise the nursery for mother bulb production 10 feet × 2 feet × 15 cm raised beds were prepared in well ploughed soil and 30 cm distance between two beds was maintained. Soil of bed was well mixed with decomposed fine farmyard manure and seeds were treated with thiram @2g/kg of seed to avoid damping off during nursery. Sowing of seeds was done in lines at spacing of 3.5-4 cm row to row and after sowing seeds covered with fine compost and then whole nursery bed was mulched with paddy straw followed by light watering. Watering was done through paddy straw till the emergence of seedlings. Immediately after emergence the paddy straw was removed and can watering was done. The required watering and hoeing was done to attained good growth of seedlings.

The seedlings were transplanted in the main field for bulb production after 45 days of sowing with spacing of 15×10cm. During the bulb production all recommended package of practices was used and bulbs were lifted at 75% neck fall stage. The bulbs were subjected to curing under shade for one week.

3.4.2 Storage of mother bulbs

The harvested mother bulbs in both seasons were cured and stored in plastic trays under naturally ventilated condition until the planting of bulbs. The bulbs were sorted out time to time to remove rotten and smutted bulbs and finally the medium size (60-80gm) bulbs were retained for seed production experiment.

3.4.3 Seed crop management

The mother bulbs which were stored at field lab under ambient storage condition, were planted with the spacing of 60 × 30 cm in two experiments i.e. foliar spray of macro and mineral nutrients and growth retardant. However, in time of planting and density experiment the spacing was maintained as per the treatments.

After the sprouting of bulbs first irrigation was provided and subsequent irrigations were given with the view to maintain the proper soil moisture throughout the crop growth period through check basin irrigation system. The crop was kept weed free through hand weeding which were carried out time to time during the crop growth. Nutrient management was practiced by application of 100:50:50 kg/ha (N: P: K) in two split doses, firstly was before bulb planting time and second was 30 DAP. The plant protection measures were adopted for the control of pest and disease. Imidacloprid (30.5%) @0.5ml/liter of water, regent (Fipronil) @10kg/acre and jump (Fipronil) @40gm/ha were applied to control thrips and other insects. Two spary of nativo (Tebuconazole 50% + Trifloxystrobin 25% WG) @ 100g/acre was applied at 25 DAP at bolting stage to avoid the fungal disease (stemphylium blight and purple blotch). Earthing up was practiced in seed crop field at 75 DAP to avoid lodging of seed stalk at later stage of crop growth.

3.5 Experiment 1: To study the effect of planting time and crop geometry on growth, seed yield, and seed quality

The experimental treatments contained three time of planting and three spacing. The detail of the treatments and their combinations are given below.

- **Planting time:**
  - **T_1-** Planting of bulbs on 15^{th} October
  - **T_2-** Planting of bulbs on 25^{th} October
  - **T_3-** Planting of bulbs on 5^{th} November
- **Spacing:**
  - **S_1-** Spacing of bulbs at 60 × 10 cm
  - **S_2-** Spacing of bulbs at 60 × 20 cm
  - **S_3-** Spacing of bulbs at 60 × 30 cm
- **Plot size:** 3m × 3m
- **Number of replication and experimental design:** 3, with split plot design

- **Treatment combinations:**

T_1: $T_1 \times S_1$	T_2: $T_1 \times S_2$	T_3: $T_1 \times S_3$
T_4: $T_2 \times S_1$	T_5: $T_2 \times S_2$	T_6: $T_2 \times S_3$
T_7: $T_3 \times S_1$	T_8: $T_3 \times S_2$	T_9: $T_3 \times S_3$

- **Field layout**

R_1	T_3	T_2	T_1	T_6	T_5	T_4	T_9	T_8	T_7
R_2	T_5	T_4	T_6	T_8	T_9	T_7	T_2	T_3	T_1
R_3	T_7	T_8	T_9	T_2	T_1	T_3	T_4	T_6	T_5

3m

3m

3.5.1 Material

The mother bulbs which were produced at SPU, IARI in 2012-13 & 2013-14 were used for seed production experiment in 2013-14 & 2014-15 respectively**.**

3.5.2 Methodology

3.5.2.1 Growth parameters

3.5.2.1.1 Number of leaves per plant

Numbers of leaves were counted from ten randomly tagged plants in three replications for each treatment at the time of seed scape initiation (maximum vegetative growth stage) and average was worked out.

3.5.2.1.2 Days to seed scape emergence

Days to seed head emergence was recorded as number of days from bulb planting to 50% seed scape emergence in plants/plot.

3.5.2.1.3 Number of seed scapes per plant

The number of seed scapes/plant were counted from ten randomly selected plants at peak flowering and average was worked out.

3.5.2.1.4 Height of seed scape (cm)

Height of seed scape was measured (main seed scape of plant) from ten randomly tagged plants and average was worked out.

3.5.2.1.5 Seed scape diameter (cm)

The seed scape diameter (main seed scape of plant) of ten tagged plants was recorded at maximum vegetative stage by vernier caliper with a precision of 1mm and average was worked out.

3.5.2.1.6 Days to initiation of flowering (anthesis of flowers)

Days to initiation of flowering was recorded as number of days from planting of bulb to initiation of flowering in 50% of plants per plot.

3.5.2.1.7 Umbel diameter (cm)

Umbel diameter of ten tagged plants was recorded at flowering stage by vernier caliper with a precision of 1 mm and average was worked out.

3.5.2.1.8 Number of umbellates per umbel

The numbers of umbellates/umbel (from main umbel of plant) were counted from ten tagged plants at the complete flowering stage and average was worked out.

3.5.2.1.9 Number of productive seed scapes per plant

The numbers of productive seed scapes per plant were counted from ten random plants at maturity and average was worked out.

3.5.2.1.10 Number of productive umbellates per umbel

The numbers of productive umbellates per umbel (from main umbel of plant) were counted from ten tagged plants at maturity and average was worked out.

3.5.2.1.11 Seed scape lodging percent

The lodging percent of seed scape per plant was calculated with total number of seed scape per plant and number of lodged seed scape per plant and percent was worked out.

3.5.2.1.12 Seed setting percent

The percent of seed setting was calculated with number of umbellates per umbel and number of productive umbellates per plant.

3.5.2.1.13 Number of disease infected plants

The numbers of disease infected plants per plot were counted before the maturity stage.

3.5.2.1.14 Disease severity

Disease severity on seed scape of onion was scored in 2014-15 based on 0-4 scales as follows (Behera *et al*., 2013): 0= No disease symptoms, 1=1-25% seed scape area infected, 2=25-50% seed scape area infected, 3=50-75% seed scape area infected, 4=57-100% seed scape area infected and percent disease index was calculated by the following formula given by Wheeler (1969).

$$\text{PDI} = \frac{\text{Total sum of numerical ratings}}{\text{Number of observations}} \times \frac{100}{\text{Maximum disease rating}}$$

3.5.2.1.15 Days to maturity

Days to maturity of seed scape was visually recorded from plot.

3.5.2.2 Seed yield and quality attributes

3.5.2.2.1 Seed yield per umbel (g)

Seed yield per umbel was measured from five randomly tagged plants and average was worked out.

3.5.2.2.2 Seed yield per plant (g)

After harvesting seed yield per plant was measured from seed yield/umbel and number of productive seed scape per plant

3.5.2.2.3 Seed yield per plot (g)

Seed yield/plot was recorded after harvesting and expressed as gm/plot.

3.5.2.2.4 Seed yield per hectare (q)

Seed yield per hectare was calculated by multiplication of seed yield per plot with a common factor in each treatment combinations after consideration of 10 % area of one hectare into bunds and channels.

3.5.2.2.5 1000 Seed weight (g)

1000 seed weight (g) was determined by counting manually one hundred seeds of eight replicates from each treatment and weighed up to four significant figures by electronic balance. Variance, standard deviation and coefficient of variation were calculated using the formulae given below. The mean was multiplied by 10 to get the final 1000-seed weight and expressed in grams.

$$\text{Variance} = \frac{n(\Sigma X^2) - (\Sigma X)^2}{n\,(n-1)}$$

Where,

X= Weight of each replicates in grams

n= Number of replicates

Standard Deviation (SD) = $\sqrt{Variance}$

Coefficient of variation = S.D. x 100/ X (X = mean weight of 100 seeds)

3.5.2.2.6 Seed germination %

The laboratory germination test was conducted as per ISTA (2012) procedure by adopting petri plate (PP) method. Freshly harvested 100 seeds in four replications were taken at random from the seed lot of each treatment and placed uniformly on petri plate. These petri plates were kept in germinator, where the temperature was maintained at 20 ± 0.5^0C and the relative humidity at 95 ± 1 per cent. The final count was made on 12^{th} day on normal seedlings, abnormal seedlings and dead seeds and expressed in percent.

3.5.2.2.7 Seedling length (cm)

Ten normal seedlings were selected at random from germination test. The length between the collar region and the tip of the primary shoot was measured as shoot length (cm). The length between the collar region and the tip of primary root was measured as root length (cm). The seedling length was computed by using the following formula and mean value was expressed in centimeter

Seedling length (cm) = Shoot length (cm) + Root length (cm)

3.5.2.2.8 Seedling dry weight (mg seedling^{-1})

The ten normal seedlings selected randomly from the germination test, were dried in butter paper packets in hot air oven at 80^0C ± 1^0C for 16 hours. Thereafter, the seedlings were removed and cooled in desiccator for one hour before weighing on an electronic balance. The weight of the dried seedlings was recorded and dry weight per seedling was calculated and expressed in mg per seedling.

3.5.2.2.9 Seed Vigour index

Vigour indices were calculated using the procedure suggested by Abdul-Baki and Anderson (1973) and expressed in whole number.

Vigour index-I = Germination (%) X Seedling length (cm)

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

3.5.2.2.10 Electrical conductivity of seed leachates (μmhos/cm/g)

Two weighed replicates of 50 seeds were soaked in 25 ml of deionized water at 25 ± 0.5^0C for 16 hr. Seed leachate was collected and conductivity was recorded using digital conductivity meter along with deionized water as control and expressed as μ mhos $cm^{-1}g^{-1}$ of seeds (Dadlani & Agrawal, 1987).

The conductivity per gram of seed weight for each replicate was calculated after accounting the back ground conductivity of the original water and the average of the two replicates were calculated by using the following formula.

$$\text{Conductivity } (\mu \text{ mhos cm}^{-1}\text{g}^{-1}) = \frac{\text{Conductivity reading — background reading}}{\text{Weight of sample (g)}}$$

3.5.2.2.11 Chlorophyll content

Chlorophyll ‘a’ and ‘b’ estimation was done by method suggested by Hiscox and Israelstam (1979) by using dimethyl sulfoxide (DMSO). Fresh leaf samples (0.5gm) from different treatments were incubated in10 ml fresh DMSO in a capped vial and kept it in an oven at 65°C for overnight. Subsequently, the tubes were shaken to allow the pigment to distribute uniformly and the absorbance was taken at 645 and 663nm in a Spectrophotometer. Using the following formula, the amount of chlorophyll a and b in mg/g of leaf materials was calculated.

$$\text{Chlorophyll 'a' content} = \frac{[(12.7 \times A_{663}) - (2.69 \times A_{645})]}{W \times 1000} \times V$$

$$\text{Chlorophyll 'b' content} = \frac{[(22.9 \times A_{645}) - (4.68 \times A_{663})]}{W \times 1000} \times V$$

$$\text{Total chlorophyll content} = \text{Chl a} + \text{Chl b}$$

Where,

A_{645} = Absorbance at 645 nm

A_{663} = Absorbance at 663 nm

V = Volume of DMSO

W = Weight of plant sample

3.5.2.2 Statistical analysis

The data generated from field and laboratory experiments were subjected to suitable statistical analysis by adopting split plot design. The data recorded as percent were transformed to the respective angular (arcsine value) before adjusting them to statistical analysis. The computer software used in the present study was SAS version 9.3.

3.6 Experiment 2: To study the effect of foliar application of different mineral nutrients on growth, seed yield and seed quality

3.6.1 Materials:-

Medium size (60-80gm) bulbs of Pusa Riddhi raised during *rabi* season 2012-13 and 2013-14 were used as planting materials in the experiment during *rabi* 2013-14 & 2014-15 respectively. The four mineral nutrients viz., Boron, Zinc, Calcium and Magnesium were selected for foliar spray and purchased from Tata chemicals.

3.6.2 Treatments combinations – The recommended dose of mineral nutrients for bulb crops viz., Borax (B-11.3%), Zn-EDTA (Zn-12%), Ca-EDTA (Ca-10%) and Mg-EDTA (Mg-6%) were used in different combinations for foliar spray in onion seed crop.

T_1: Recommended dose of Boron at 60DAP (250g/acre)

T_2: 75% Recommended dose of Boron at 60DAP (187.5g/acre)

T_3: 125% Recommended dose of Boron at 60DAP (312.5g/acre)

T_4: Recommended dose of Zinc at 30DAP (200g/acre)

T_5: 75% Recommended dose of Zinc at 30DAP (150g/acre)

T_6: 125% Recommended dose of Zinc at 30DAP (250g/acre)

T_7: Recommended dose of Calcium at 30DAP (200g/acre)

T_8: 75% Recommended dose of Calcium at 30DAP (150g/acre)

T_9: 125% Recommended dose of Calcium at 30DAP (250g/acre)

T_{10}: Recommended dose of Mg at 30 DAP (200g/acre)

$T_{11:}$ 75% Recommended dose of Mg at 30DAP (150g/acre)

T_{12}: 125% Recommended dose of Mg at 30DAP (250g/acre)

T_{13}: Recommended dose of Boron + Zinc at 30 & 60 DAP

T_{14}: Recommended dose of Boron + Zinc + Calcium at 30 & 60 DAP

T_{15}: Recommended dose of Boron + Zinc + Calcium + Magnesium at 30 & 60 DAP

T_{16}: Control (Water spray)

3.6.3 Experimental design- Randomized block design two replication.

- Plot size- 3m × 3m
- Spacing -60 × 30
- Number of bulbs/plot- 50

Field layout

R_1	T_1	T_4	T_7	T_8	T_3	T_{11}	T_9	T_{13}
	T_{15}	T_2	T_{10}	T_5	T_{14}	T_6	T_{12}	T_{16}
R_2	T_8	T_3	T_{12}	T_5	T_9	T_{15}	T_{11}	T_1
	T_6	T_2	T_{14}	T_7	T_{13}	T_{16}	T_{10}	T_4

3m

3m

3.6.4 Methodology:-

Good quality medium size 50 bulbs/plot was planted on 30th October at the spacing of 60×30cm. The foliar spray of mineral nutrients were given as per the treatments combination at 60 DAP for boron and 30 DAP for Zn, Ca, Mg treatments. The borax (at 250g/acre) at 60 DAP, Zn-EDTA (at 200g/acre), Ca-EDTA (at 200g/acre) and Mg-EDTA (at 200g/acre) at 30 DAP is recommended for bulb crops which contains 11.3% B, 12% Zn, 10% Ca and 6% Mg respectively (Plate 1).

3.6.5 Methodology

3.6.5.1 Growth parameters

3.6.5.1.1 Number of leaves per plant: Same as expt.1

3.6.5.1.2 Days to seed scape emergence: Same as expt.1

3.6.5.1.3 Number of seed scapes per plant: Same as expt. 1

3.6.5.1.4 Height of seed scape (cm): Same as expt. 1

3.6.5.1.5 Seed scape diameter (cm): Same as expt.1

3.6.5.1.6 Days to initiation of flowering (anthesis of flowers): Same as expt.1

3.6.5.1.7 Umbel diameter (cm): Same as expt. 1

3.6.5.1.8 Number of umbellates per umbel: Same as expt. 1

3.6.5.1.9 Number of productive seed scapes per plant: Same as expt. 1

3.6.5.1.10 Number of productive umbellates per umbel: Same as expt. 1

3.6.5.1.11 Seed scape lodging percent: Same as expt. 1

3.6.5.1.12 Seed setting percent: Same as expt. 1

3.6.5.1.13 Number of disease infected plants: Same as expt. 1

3.6.5.1.14 Disease severity: Same as expt. 1

3.6.5.1.15 Days to maturity: Same as expt. 1

Plate: 1 Mineral nutrients used in the experiment

3.6.5.2 Seed yield and quality attributes

3.6.5.2.1 Seed yield per umbel (g): Same as expt.1

3.6.5.2.2 Seed yield per plant (g): Same as expt.1

3.6.5.2.3 Seed yield per plot (g): Same as expt.1

3.6.5.2.4 Seed yield per hectare (q): Same as expt.1

3.6.5.2.5 1000 Seed weight (g): Same as expt.1

3.6.5.2.6 Seed germination %: Same as expt.1

3.6.5.2.7 Seedling length (cm): Same as expt.1

3.6.5.2.8 Seedling dry weight (mg seedling^{-1}): Same as expt.1

3.6.5.2.9 Seed vigour index-I&II: Same as expt.1

3.6.5.2.10 Electrical conductivity of seed leachate: Same as expt.1

3.6.5.2.11 Chlorophyll content: Same as expt. 1

3.6.5.3 Statistical analysis

The data generated from field and laboratory experiments were subjected to suitable statistical analysis by adopting randomized block design. The data recorded as percent were transformed to the respective angular (arcsine value) before adjusting them to statistical analysis. The computer software used in the present study was SAS version 9.3.

3.7 Experiment 3: To study the effect of different plant growth retardants on onion seed scape height, seed yield and quality.

3.7.1 Materials

I. Medium size (60-80gm) bulbs of Pusa Riddhi raised during Rabi season 2012-13 and 2013-14 were used as planting materials in the experiment during Rabi 2013-14 and 2014-15 respectively.

II. The paclobutrazol was purchased from Excel Crop Care Limited Company as brand name of Celstar which contained 23% paclobutrazol, while ethephon was purchased from Bayer Crop Science as brand name of ethrel, which contains 52 % ethephon. The triadimefon a trizole compound which act as both growth retardant and fungicide was also purchased from Bayer Crop Science as bayleton brand name which contains 25% triadimefon compound (Plate 2).

3.7.2 Methodology:

Growth retardant chemicals were dissolved in water as per the treatments concentration and bulbs were soaked in solution for overnight. The next day these treated bulbs were dried in shade and then planted in 3m×3m plots with 60×30 cm spacing. The foliar spray of growth retardants were given according to treatment concentration at the time of seed scape emergence stage. All the recommended package of practices were uniformly followed in all treatments.

3.7.3 Treatment combinations

T_1- Soaking of bulbs in 80 ppm paclobutrazol solution

T_2- Foliar spray of paclobutrazol @ 80 ppm

T_3- Soaking of bulbs in 80 ppm paclobutrazol + foliar spray of paclobutrazol@80 ppm

T_4- Soaking of bulbs in 100 ppm paclobutrazol solution

T_5-Foliar spray of paclobutrazol @ 100 ppm

T_6- Soaking of bulbs in 100 ppm paclobutrazol + foliar spray of paclobutrazol@100 ppm

T_7- Soaking of bulbs in 400 ppm ethephon solution

T_8- Foliar spray of ethephon @ 400 ppm

T_9- Soaking of bulbs in 500 ppm ethephon solution

T_{10}- Foliar spray of ethephon @ 500 ppm

T_{11}- Soaking of bulbs in 200 ppm triadimefon solution

T_{12}- Foliar spray of triadimefon @ 200 ppm

T_{13}- Soaking of bulbs in 400 ppm triadimefon solution

T_{14}- Foliar spray of triadimefon @ 400 ppm

T_{15}-Control (Water spray)

- Experimental design- Randomized block design
- No of replication-Two
- Plot size- 3m×3m and spacing- 60×30 cm
- Number of bulbs per plot- 50

Paclobutrazol (Celstar)

Ethephon

Plate: 2 Growth retardants used in the experiment

Field layout

R_1	T_1	T_8	T_7	T_5	T_{12}	T_{14}	T_{10}	T_3
		T_{11}	T_9	T_{13}	T_4	T_6	T_2	T_{15}
R_2	T_5	T_{14}	T_8	T_3	T_{10}	T_{15}	T_{12}	T_1
		T_4	T_6	T_9	T_{13}	T_{11}	T_2	T_7

3m (plot height) × 3m (plot width)

3.7.4 Methodology

3.7.4.1 Growth parameters

3.7.4.1.1 Number of leaves per plant: Same as expt.1

3.7.4.1.2 Days to seed scape emergence: Same as expt. 1

3.7.4.1.3 Number of seed scapes per plant: Same as expt. 1

3.7.4.1.4 Height of seed scape (cm): Same as expt. 1

3.7.4.1.5 Seed scape diameter (cm): Same as expt. 1

3.7.4.1.6 Days to initiation of flowering: Same as expt. 1

3.7.4.1.7 Umbel diameter (cm): Same as expt. 1

3.7.4.1.8 Number of umbellates per umbel: Same as expt. 1

3.7.4.1.9 Number of productive seed scapes per plant: Same as expt. 1

3.7.4.1.10 Number of productive umbellates per umbel: Same as expt. 1

3.7.4.1.11 Seed scape lodging percent: Same as expt. 1

3.7.4.1.12 Seed setting percent: Same as expt. 1

3.7.4.1.13 Number of disease infected plants: Same as expt. 1

3.7.4.1.14 Disease severity: Same as expt. 1

3.7.4.1.15 Days to maturity: Same as expt. 1

3.7.4.2 Seed yield and quality attributes

3.7.4.2.1 Seed yield per umbel (g): Same as expt. 1

3.7.4.2.2 Seed yield per plant (g): Same as expt. 1

3.7.4.2.3 Seed yield per plot (g): Same as expt. 1

3.7.4.2.4 Seed yield per hectare (q): Same as expt.

3.7.4.2.5 1000 Seed weight (g): Same as expt. 1

3.7.4.2.6 Seed germination %: Same as expt. 1

3.7.4.2.7 Seedling length (cm): Same as expt. 1

3.7.4.2.8 Seedling dry weight (mg seedling^{-1}): Same as expt. 1

3.7.4.2.9 Seed vigour index-I&II: Same as expt. 1

3.7.4.2.10 Electrical conductivity of seed leachate: Same as expt. 1

3.7.4.2.11 Chlorophyll content: Same as expt. 1

3.7.4.3 Biochemical characteristics of seed

3.7.4.3.1 Superoxide dismutase activity (SOD):

SOD activity was measured by the procedure given by Dhindsa *et al.,* (1981). Superoxide dismutase activity was estimated by recording the decrease in optical density of formazone made by superoxide radical and nitro-blue tetrazolium dye by the enzyme. The absorbance was recorded at 560nm in a Spectrophotometer and one unit of enzyme activity was calculated as that amount of enzyme that reduced the absorbance reading by 50% in comparison with tubes lacking enzyme. The specific activity of all the enzymes was expressed as units/S/mg^{-1} protein.

3.7.4.3.2 Catalase activity (CAT):

CAT activity was measured by the procedure given by Aebi (1984) through measuring the disappearance of H_2O_2 (ε=39.4 mM^{-1} cm^{-1}). The 3ml reaction mixture containing sodium phosphate buffer (50 mM, pH 7.0) & 10mM H_2O_2 and absorbance was measured at 240 nm in a Spectrophotometer. The specific activity was expressed as nmol H_2O_2 reduced nmol min^{-1}mg^{-1} protein.

3.7.4.3.3 Peroxidase activity (POX):

Peroxidase activity (POX) was measured by the procedure given by Rao *et al.,* (1996), monitoring the formation of tetraguaiacol (ε=26.6 mM-1 cm-1) from guaiacol. The POX reaction mixture (3 ml) containing 0.5mM phosphate buffer (pH 6.1), 16 Mm guaiacol, 2 mM H2O2 and 20µl of enzyme extract was prepared and changes in absorbance of the reaction mixture at 470nm were observed after every 30sec. The specific activity of enzyme was expressed as µmol/min/mg protein tetraguaiacol formed.

3.7.4.3.4 Glutathione reductase activity:

Glutathione reductase assay was estimated based on the formation of red coloured complex by reduced glutathione with 5, 5-dithiobis-2-nitrobenzoic acid (DTNB) (Smith *et al,* 1988). The reaction mixture contains 10 mM potassium phosphate buffer, 0.33 mM EDTA, 0.5 mM DTNB, 2.0 mM NADPH, 20 mM GSSG (Oxidized Glutathione) , 0.1 ml of enzyme extract and double distilled water to make up the final volume to 3.0 ml. Reaction was started by adding 0.1 ml of 20 mM GSSG (oxidized glutathione). Increase in absorbance at 412 nm was recorded in UV-Visible spectrophotometer.

3.7.4.4 Statistical analysis

The data generated from field and laboratory experiments were subjected to suitable statistical analysis by adopting randomized block design. The data recorded as percent were transformed to the respective angular (arcsine value) before adjusting them to statistical analysis. The computer software used in the present study was SAS version 9.3.

4. RESULTS

4.1 To study the effect of planting time and crop geometry on growth, seed yield, and seed quality

The observations recorded on vegetative, flowering, seed yield and quality characters of onion cv. Pusa Riddhi were analyzed as per procedure of split plot design using PROC GLM of SAS 9.3 and results obtained have been discussed below.

4.1.1 Number of leaves per plant

The results presented in Table 1 showed that the planting density had significant effect on leaves number/plant. The numerically higher number of leaves/plant was observed in 15th October (38.61) followed by 25th October (37.21) and 5th November (36.25). The higher number of leaves/plant was recorded in wider spacing (S_3) (40.89) whereas, S2 and S1 had given lower number of leaves (37.05 & 34.12) respectively.

4.1.2 Days to seed scape emergence

The planting time had significant effect on seed scape emergence (Table 2). An early planting of bulbs (T1) had taken more days (66.44) as compared to 25th October (60.33) and 5th November planting (55.72). Planting density and interaction between time of planting and plant density could not influence the seed scape emergence.

4.1.3 Days to initiation of flowering

Planting time had significant effect on days to initiation of flowering; 15th October (126.0) had taken higher number of days followed by 25th October (122.65) and 5th November (120.50) (Table 3). The planting density had non-significant effect on initiation of flowering and similar result was recorded for interaction between T×S.

4.1.4 Seed scape height (cm)

It is evident from the Table 4 that planting time and plant density had effects on seed scape height. Significantly higher seed scape height was recorded in T_1 (101.74 cm) whereas lower in T_3 (100.61cm). The highest seed scape height was observed under wider spacing (60 × 30 cm) (102.26 cm) followed by 60 × 20 (101.17cm) and 60 × 10 cm (99.36). While, non-significant interaction was found between planting time and density.

4.1.5 Seed scape diameter (cm)

The results presented in Table 5 showed that planting time had non-significant effect on seed scape diameter but numerically higher seed scape diameter was recorded in T_1 (1.87 cm) followed by T_2 (1.83 cm) and T_3 (1.80cm). However, planting density had significant effect on seed scape diameter and higher diameter was observed under S_3 (1.88cm) followed by S_2 (1.83 cm) and S_1 (1.80 cm).

4.1.6 Umbel diameter (cm)

It is evident from the Table 6 that the planting time and plant density had significant effect on umbel diameter whereas interaction between T × S was recorded non-significant for umbel diameter. The umbel diameter was higher in 15th October planting (6.54) followed by 25th October (6.27) and 5th November (6.13) respectively. Among the treatments of planting density, 60×30cm spacing had registered significantly higher value of umbel diameter (6.58) than 60×20cm (6.31) and 60×10cm (6.05) (Plate 3).

4.1.7 Disease infected plants per plot (%)

The results of pooled data on disease infected plants per plot presented in Table 7 showed that 5th November planting had more incidence of disease (41.96) than 25th October (38.76) and 15th October (38.06) but found nonsignificant. However, planting density had significant effect on disease incidence %; closer spacing (S_1) had more disease incidence than (58.61) than S_2 (38.52) and S_3 (27.65) (Fig 1). The interaction between T×S was non-significant.

4.1.8 Percent disease index (PDI)

The results presented in Table 8 showed that 5th November planting had higher PDI (7.01) than 15th October (6.74) and 25th October (6.66), but differences was found non-significant. However, planting density had significant effect on PDI; 60×10cm spacing had highest PDI (8.38) followed by 60×20cm (6.22) and 60×30cm (5.81). The interaction between T×S was non-significant for PDI.

4.1.9 Number of seed scape per plant

The time of planting had no effect on numbers of seed scape/plant but numerically higher number of seed scape were recorded in 5th November planting (10.44) followed by 15th October (10.35) and 25th October (10.22) planting time. The planting density had significant effect on seed scape number/plant and maximum number of seed scape/plant

Table 1. Effect of planting time and density on number of leaves per plant (Pooled data over two years)

DOP	2013-14				2014-15				Pooled			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
T_1	35.77	37.63	42.33	**38.58**	35.07	38.63	42.23	**38.64**	35.41	38.13	42.28	**38.61**
T_2	33.90	37.37	41.40	**37.56**	33.83	36.60	40.17	**36.87**	33.86	36.98	40.78	**37.21**
T_3	34.37	36.90	40.10	**37.12**	31.83	35.17	39.13	**35.38**	33.10	36.03	39.61	**36.25**
Mean	**34.68^c**	**37.3^b**	**41.28^a**		**33.58^c**	**36.8^b**	**40.51^a**		**34.12^c**	**37.05^b**	**40.89^a**	
	SE(d)		**LSD (5%)**		**SE(d)**		**LSD (5%)**		**Significance (5%)**			
T	0.54		NS		1.26		NS		NS			
S	0.38		1.16		0.59		1.29		S*			
T × S	0.66		NS		1.02		NS		NS			

DOP- Date of planting T_1- 15[th] October, T_2- 25[th] October, T_3- 5[th] November, LSD- Fisher's Least Significance Difference
S_1- Spacing 60cm × 10cm, S_2- 60cm × 20cm, S_3- 60cm × 30cm, NS- Non significant, S- significant *Significant effects are shown with group letters

Table 2. Effect of planting time and density on seed scape emergence (in days) (Pooled data over two years)

DOP	2013-14				2014-15				Pooled			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
T_1	65.00	64.00	65.67	**64.89^a**	67.00	68.33	68.67	**68.00^a**	66.0	66.16	67.16	**66.44^a**
T_2	65.00	57.33	58.33	**58.44^b**	61.67	63.00	62.00	**62.22^b**	60.6	60.16	60.16	**60.33^b**
T_3	54.00	55.00	54.67	**54.56^c**	56.67	57.00	57.00	**56.89^c**	55.3	56.0	55.83	**55.72^c**
Mean	**59.56**	**58.78**	**59.56**		**61.78**	**62.78**	**62.56**		**60.6**	**60.7**	**61.05**	
	SE(d)		**LSD (5%)**		**SE(d)**		**LSD (5%)**		**Significance (5%)**			
T	0.52		1.44		1.07		2.97		**S***			
S	0.75		NS		0.80		NS		NS			
T × S	1.29		NS		1.38		NS		NS			

DOP- Date of planting T_1- 15[th] October, T_2- 25[th] October, T_3- 5[th] November, LSD- Fisher's Least Significance Difference
S_1- Spacing 60cm × 10cm, S_2- 60cm × 20cm, S_3- 60cm × 30cm, NS- Non significant, S- significant *Significant effects are shown with group letters

Table 3. Effect of planting time and density on initiation of flowering (in days) (Pooled data over two years)

DOP	2013-14				2014-15				Pooled			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
T_1	126.33	126.00	126.00	**126.11[a]**	126.00	125.66	126.00	**125.88 [a]**	126.16	126.83	126.00	**126.00[a]**
T_2	122.33	123.00	121.00	**122.11[b]**	122.33	122.66	121.66	**122.22 [b]**	122.33	122.83	121.33	**122.65[b]**
T_3	119.67	121.00	120.33	**120.33[c]**	119.33	121.66	121.00	**120.66 [c]**	119.50	121.16	120.66	**120.50[c]**
Mean	**122.78**	**123.33**	**122.44**		**122.55**	**123.33**	**122.88**		**122.65**	**123.60**	**122.66**	
	SE(d)		**LSD (5%)**		**SE(d)**		**LSD (5%)**		**Significance (5%)**			
T	0.57		1.59		0.51		1.61		S*			
S	0.46		NS		0.43		NS		NS			
T × S	0.80		NS		0.82		NS		NS			

DOP- Date of planting T_1- 15th October, T_2- 25th October, T_3- 5th November, LSD- Fisher's Least Significance Difference

S_1- Spacing 60cm × 10cm, S_2- 60cm × 20cm, S_3- 60cm × 30cm, NS- Non significant, S- significant *Significant effects are shown with group letters

Table 4. Effect of planting time and density on seed scape height (cm) (Pooled data over two years)

DOP	2013-14				2014-15				Pooled			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
T_1	100.83	102.33	103.03	**102.07**	98.80	101.87	103.57	**101.41**	99.81	102.10	103.30	**101.74[a]**
T_2	99.60	100.57	101.90	**100.69**	98.37	100.93	102.30	**100.53**	98.98	100.75	102.10	**100.61[b]**
T_3	99.83	100.23	101.20	**100.42**	98.77	101.07	101.53	**100.46**	99.30	100.65	101.37	**100.44[c]**
Mean	**100.09[c]**	**101.04[b]**	**102.04[a]**		**98.64[b]**	**101.29[a]**	**102.47[a]**		**99.36[c]**	**101.17[b]**	**102.26[a]**	
	SE(d)		**LSD (5%)**		**SE(d)**		**LSD (5%)**		**Significance (5%)**			
T	0.76		NS		0.44		NS		S*			
S	0.32		0.69		0.63		1.37		S*			
T × S	0.55		NS		1.09		NS		NS			

DOP- Date of planting T_1- 15th October, T_2- 25th October, T_3- 5th November, LSD- Fisher's Least Significance Difference

S_1- Spacing 60cm × 10cm, S_2- 60cm × 20cm, S_3- 60cm × 30cm, NS- Non significant, S- significant *Significant effects are shown with group letters

Fig. 1 Effect of planting time and density on disease infection % and seed scape lodging %
(On pooled data over two year's basis)

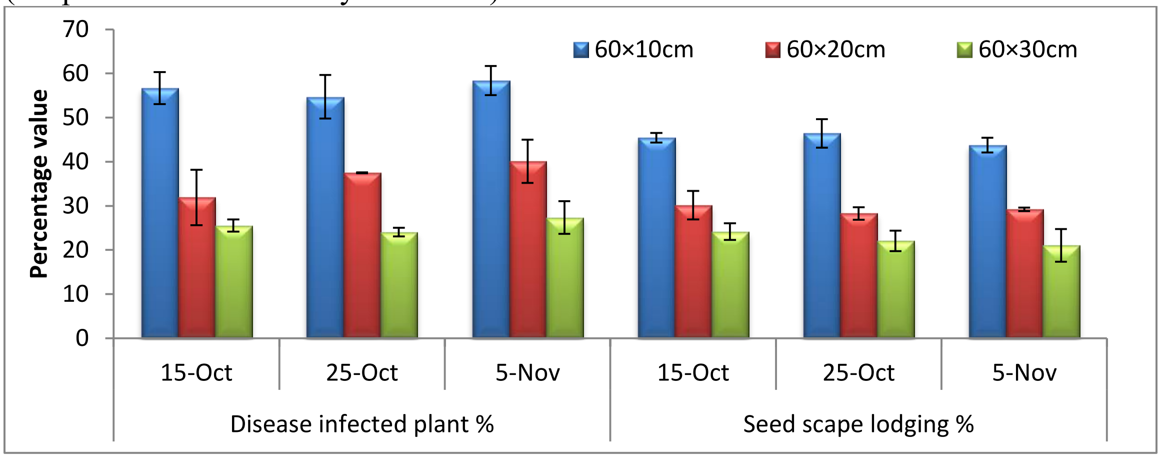


Fig. 2 Effect of planting time and density on umbellates/umbel and productive umbellates/umbel (On pooled data over two year's basis)

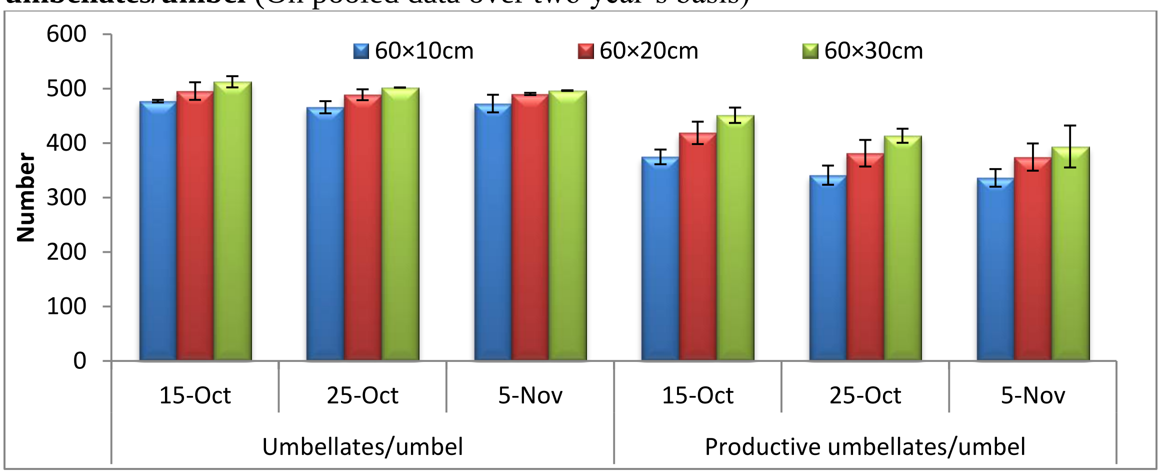
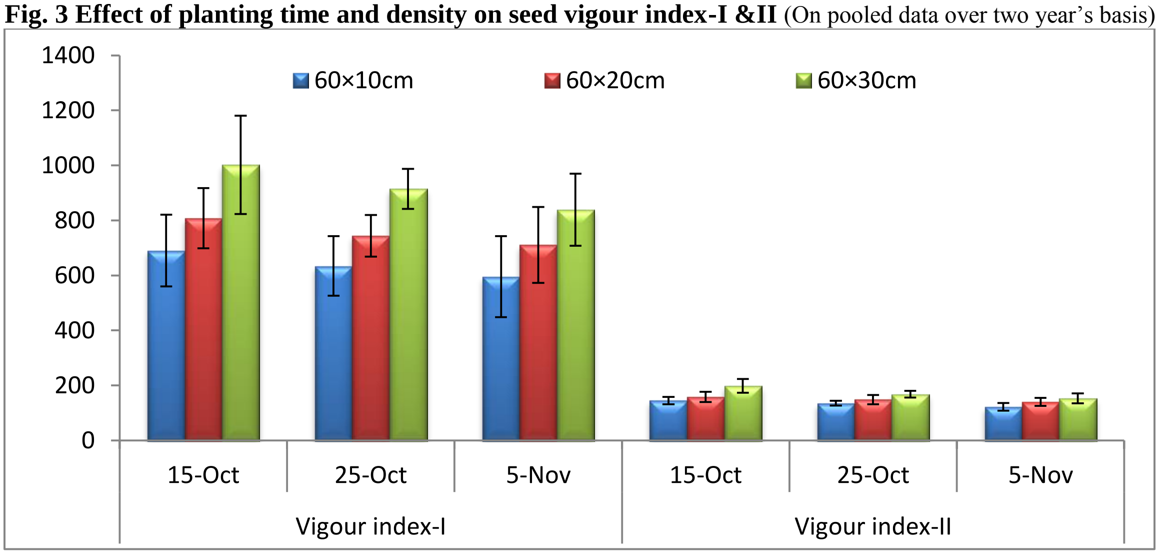


Fig. 3 Effect of planting time and density on seed vigour index-I &II (On pooled data over two year's basis)



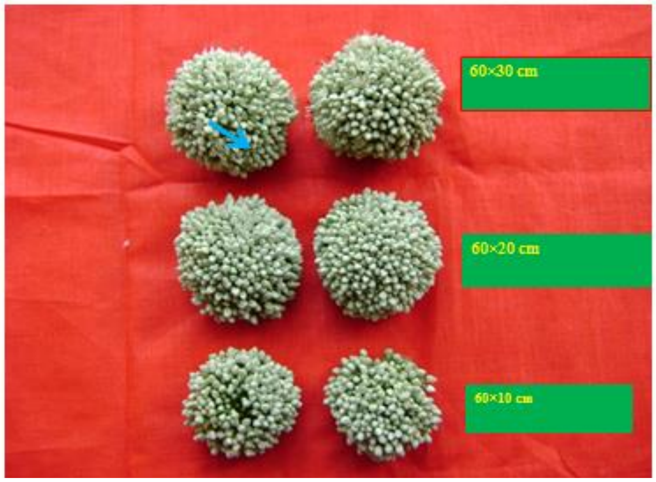


Plate: 3 Effect of planting time and density on umbel size

Plate: 4 Effect of planting time and density on seed scape was recorded in S3 (11.72) followed by S2 (10.06) and S1 (9.23). The interaction effect between T×S was non-significant.

4.1.10 Number of productive seed scape per plant

The planting time showed non-significant effect on productive seed scape per plant (Table 10) but numerically higher number of seed stalk was recorded in 15th October planting (6.78) than 25th October and 5th November planting (6.77 & 6.63) respectively. The planting density had significant effect on productive seed scape; 60×30cm had recorded higher value (8.35) than 60×20cm (6.82) and 60×10cm (5.01). The interaction among T×S was non-significant.

4.1.11 Seed scape lodging (%)

The non-significant difference was observed on seed scape lodging (%) for planting time and its interaction with planting density. However, higher seed scape lodging % was recorded in 15th October (33.26) followed by 25th October (32.27) and 5th November (31.34). Significant differences due to planting density were noticed for seed scape lodging %. It was significantly higher in S_1 (45.21) than S_2 (29.23) and S_3 (22.43) (Table 11) (Fig.1) (Plate 4).

4.1.12 Number of umbellates/umbel

The plant spacing had significant effect on umbellates/umbel; 60×30cm spacing had given higher number of umbellates/umbel (503.52) than 60×20 cm (491.4) and 60×10 cm spacing (471.68) (Fig. 2). The non-significant effect of planting time on number of umbellates/umbel was noted (Table 12) and number of umbellates/umbel were higher under 15th October planting (494.9) while 25th October planting and 5th November planting had less number of umbellates/umbel (486.37 & 485.33) respectively. The interaction between planting time and density was statistically non-significant.

4.1.13 Number of productive umbellates per umbel

Planting time had significant influence on number of productive umbellates per umbel; higher number of productive umbellates/umbel was recorded under 15th October (414.73) planting as compared to 25th October (378.67) and 5th November (367.97) planting. Among the different spacing, the S3 (60×30cm) had given significantly higher number of productive umbellates per plant (419.73) than 60×20cm (391.48) and 60×10cm (350.49) spacing (Fig 2).

The interaction effect due to planting time and density had also significant influence on the productive umbellates per umbel. The higher number of productive umbellates was recorded in T_1S_3 (450.97) followed by T_1S_2 (418.73) and T_2S_3 (413.50). The lower number of umbellates was recorded in T_3S_1 (335.97) (Table 13).

4.1.14 Seed setting (%)

The results of pooled analysis on seed setting % presented in Table 14 revealed marked differences with respect to planting time, density and their interaction effect. Significantly higher and lower seed setting % was noticed in T_1 (83.69) and T_3 (75.61) respectively, among the planting time. Significantly higher seed setting % was recorded in S_3 (83.24), followed by S_2 (79.62) and lowest in S_1 (74.35) among the planting density. Significant differences were also observed for T × S interaction effect and higher seed setting % was noticed in T_3S_3 (88.01), followed by T_1S_2 (84.52) and lowest in T_3S_1 (71.23).

4.1.15 Maturity (days)

The results presented in Table 15 had indicated significant effect of planting time and spacing on maturity. An early planting i.e. 15th October (190.54) had taken more number of days to maturity of crop than 25th October (186.41) and 5th November (181.83) planting. The 60×30cm spacing has taken more number of days to maturity (187.25) followed by 60×10cm (186.04) and 60×20cm (185.50). However, the interaction between planting time and density was non-significant.

4.1.16 Seed yield per umbel (g)

The non-significant, but numerically higher seed yield per umbel was recorded under T1 (3.50g) followed by T2 (3.25g) and T3 (3.18g) (Table 16). However, planting density had significant effect on seed yield per umbel and maximum seed yield/umbel was recorded in S_3 (3.48g) followed by S_2 (3.31g) and S_1 (3.14g). The interaction among T×S was non-significant.

4.1.17 Seed yield per plant (g)

The results presented in Table 17 showed difference for seed yield per plant with respect to planting time and density. The maximum seed yield per plant was recorded in

Table 5. Effect of planting time and density on seed scape diameter (cm) (Pooled data over two years)

DOP	2013-14				2014-15				Pooled			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
T_1	1.82	1.86	1.99	**1.89**	1.84	1.85	1.88	**1.86^a**	1.8300	1.8567	1.9350	**1.87**
T_2	1.78	1.87	1.91	**1.85**	1.81	1.85	1.82	**1.83^b**	1.7950	1.8583	1.8583	**1.83**
T_3	1.80	1.80	1.87	**1.82**	1.78	1.76	1.82	**1.79^c**	1.7933	1.7933	1.8433	**1.80**
Mean	**1.8^b**	**1.84^{ab}**	**1.92^a**		**1.81**	**1.82**	**1.84**		**1.80^b**	**1.83^b**	**1.88^a**	
	SE(d)		**LSD (5%)**		**SE(d)**		**LSD (5%)**		**Significance (5%)**			
T	0.04		NS		0.01		0.02		NS			
S	0.03		0.08		0.01		NS		S*			
T × S	0.05		NS		0.02		NS		NS			

DOP- Date of planting T_1- 15th October, T_2- 25th October, T_3- 5th November, LSD- Fisher's Least Significance Difference
S_1- Spacing 60cm × 10cm, S_2- 60cm × 20cm, S_3- 60cm × 30cm, NS- Non significant, S- significant *Significant effects are shown with group letters

Table 6. Effect of planting time and density on umbel diameter (cm) (Pooled data over two years)

DOP	2013-14				2014-15				Pooled			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
T_1	6.21	6.34	6.78	**6.44**	6.35	6.53	7.06	**6.65^a**	6.28	6.43	6.92	**6.54^a**
T_2	5.63	6.31	6.61	**6.18**	6.13	6.33	6.62	**6.36^b**	5.88	6.31	6.61	**6.27^b**
T_3	5.97	6.11	6.23	**6.11**	6.03	6.25	6.24	**6.17^b**	6.00	6.18	6.23	**6.13^b**
Mean	**5.94^c**	**6.25^b**	**6.54^a**		**6.17^c**	**6.37^b**	**6.64^a**		**6.05^c**	**6.31^b**	**6.58^a**	
	SE(d)		**LSD (5%)**		**SE(d)**		**LSD (5%)**		**Significance (5%)**			
T	0.17		NS		0.09		0.25		S*			
S	0.12		0.26		0.07		0.15		S*			
T × S	0.21		NS		0.12		NS		NS			

DOP- Date of planting T_1- 15th October, T_2- 25th October, T_3- 5th November, LSD- Fisher's Least Significance Difference
S_1- Spacing 60cm × 10cm, S_2- 60cm × 20cm, S_3- 60cm × 30cm, NS- Non significant, S- significant *Significant effects are shown with group letters

Table 7. Effect of planting time and density on disease infected plants per plot (%) (Pooled data over two years)

DOP	2013-14				2014-15				Pooled			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
T_1	55.1 (47.92)	31.1 (33.86)	24.83 (29.86)	**37.01 (37.22)**	58.33 (49.79)	32.8 (34.89)	26.3 (30.80)	**39.14 (38.49)**	56.71 (48.85)	31.92 (34.38)	25.54 (30.34)	**38.06 (37.85)**
T_2	53.83 (47.18)	37.13 (37.48)	23.63 (29.05)	**38.2 (37.90)**	55.63 (48.23)	37.96 (37.93)	24.5 (29.65)	**39.67 (38.60)**	54.72 (47.70)	37.51 (37.73)	24.05 (29.35)	**38.76 (38.26)**
T_3	58.47 (51.13)	43.63 (42.55)	29.5 (33.93)	**43.86 (42.54)**	58.36 (51.05)	36.7 (38.46)	25.26 (31.12)	**40.11 (40.21)**	58.40 (51.08)	40.13 (40.53)	27.36 (32.56)	**41.96 (41.39)**
Mean	**57.8 (50.74)[a]**	**39.28 (39.97)[b]**	**27.98 (32.95)[c]**		**59.44 (51.69)[a]**	**37.82 (39.09)[b]**	**27.35 (32.52)[c]**		**58.61 (51.21)[a]**	**38.52 (39.55)[b]**	**27.65 (32.75)[c]**	
	SE(d)		**LSD (5%)**		**SE(d)**		**LSD (5%)**		**Significance (5%)**			
T	0.83		NS		1.41		NS		NS			
S	1.10		2.40		1.02		2.21		S*			
T × S	1.91		NS		1.76		NS		NS			

DOP- Date of planting T_1- 15th October, T_2- 25th October, T_3- 5th November, LSD- Fisher's Least Significance Difference
S_1- Spacing 60cm × 10cm, S_2- 60cm × 20cm, S_3- 60cm × 30cm, NS- Non significant, S- significant *Significant effects are shown with group letters
**Arcsine values are given in parenthesis

Table 8. Effect of planting time and density on percent disease index (PDI) during 2014-15

DOP	Percent disease index (PDI)			
	S_1	S_2	S_3	Mean
T_1	(23.89) 8.41	(22.11) 6.33	(20.96) 5.25	**(22.32) 6.66**
T_2	(23.97) 8.00	(22.16) 6.00	(19.44) 6.22	**(21.86) 6.74**
T_3	(23.10) 8.75	(21.43) 6.33	(20.12) 5.97	**(21.55) 7.01**
Mean	**(23.65) 8.38 [a]**	**(21.9) 6.22 [b]**	**(20.17) 5.81 [c]**	

	SE(d)	LSD (5%)
T	0.57	NS
S	0.49	1.06
T × S	0.84	NS

DOP- Date of planting T_1- 15th October, T_2- 25th October, T_3- 5th November, LSD- Fisher's Least Significance Difference
S_1- Spacing 60cm × 10cm, S_2- 60cm × 20cm, S_3- 60cm × 30cm, NS- Non significant, S- significant *Significant effects are shown with group letters
**Arcsine values are given in parenthesis

Table 9. Effect of planting time and density on number of seed scapes per plant (Pooled data over two years)

DOP	2013-14				2014-15				Pooled			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
T_1	8.77	9.03	10.60	**9.47**	9.80	11.00	12.93	**11.24**	9.28	10.01	11.76	**10.35**
T_2	9.00	9.30	10.87	**9.72**	9.27	10.67	12.27	**10.73**	9.13	9.98	11.56	**10.22**
T_3	8.60	8.93	10.20	**9.24**	10.00	11.47	13.47	**11.64**	9.30	10.20	11.83	**10.44**
Mean	**8.79 [b]**	**9.09 [b]**	**10.56 [a]**		**9.69 [c]**	**11.04 [b]**	**12.89 [a]**		**9.23 [c]**	**10.06 [b]**	**11.72 [a]**	

	2013-14 SE(d)	2013-14 LSD (5%)	2014-15 SE(d)	2014-15 LSD (5%)	Pooled Significance (5%)
T	0.31	NS	0.26	NS	NS
S	0.20	0.43	0.28	0.62	S*
T × S	0.34	NS	0.49	NS	NS

DOP- Date of planting T_1- 15th October, T_2- 25th October, T_3- 5th November, LSD- Fisher's Least Significance Difference
S_1- Spacing 60cm × 10cm, S_2- 60cm × 20cm, S_3- 60cm × 30cm, NS- Non significant, S- significant *Significant effects are shown with group letters

Table 10. Effect of planting time and density on number of productive seed scape per plant (Pooled data over two years)

DOP	2013-14				2014-15				Pooled			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
T_1	5.03	6.97	8.23	**6.74**	5.17	6.60	8.73	**6.83**	5.1	6.78	8.48	**6.78**
T_2	4.80	6.63	8.17	**6.53**	4.97	7.37	8.70	**7.01**	4.88	7.0	8.43	**6.77**
T_3	4.73	6.33	7.97	**6.34**	5.40	7.07	8.33	**6.93**	5.07	6.7	8.15	**6.63**
Mean	**4.86^c**	**6.64^b**	**8.12^a**		**5.18^c**	**7.01^b**	**8.59^a**		**5.01^c**	**6.82^b**	**8.35^a**	
	SE(d)		LSD (5%)		SE(d)		LSD (5%)		Significance (5%)			
T	0.27		NS		0.26		NS		NS			
S	0.20		0.44		0.26		0.57		S*			
T × S	0.35		NS		0.45		NS		NS			

DOP- Date of planting T_1- 15th October, T_2- 25th October, T_3- 5th November, LSD- Fisher's Least Significance Difference
S_1- Spacing 60cm × 10cm, S_2- 60cm × 20cm, S_3- 60cm × 30cm, NS- Non significant, S- significant *Significant effects are shown with group letters

Table 11. Effect of planting time and density on seed scape lodging (%) (Pooled data over two years)

DOP	2013-14				2014-15				Pooled			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
T_1	45.99 (42.68)	29.66 (32.88)	24.84 (29.87)	**33.49 (35.14)**	44.93 (42.08)	30.67 (33.57)	23.50 (28.75)	**33.03 (34.80)**	45.46 (42.38)	30.16 (33.29)	24.16 (29.40)	**33.26 (35.02)**
T_2	46.59 (43.02)	28.47 (32.15)	24.47 (29.75)	**33.27 (34.97)**	46.27 (42.84)	28.11 (31.74)	19.39 (26.11)	**31.26 (33.56)**	46.43 (42.93)	28.29 (32.03)	22.08 (27.99)	**32.27 (34.32)**
T_3	41.70 (40.08)	22.06 (27.98)	19.25 (25.94)	**27.61 (31.33)**	45.96 (42.66)	36.39 (37.02)	22.87 (28.44)	**35.07 (36.04)**	43.75 (41.36)	29.22 (32.68)	21.06 (27.21)	**31.34 (33.75)**
Mean	**44.70 $(41.93^a$**	**26.73 $(31.0)^b$**	**22.95 $(28.52)^b$**		**45.72 $(42.52)^a$**	**31.72 $(34.11)^b$**	**21.92 $(27.77)^c$**		**45.21 $(42.22)^a$**	**29.23 $(32.67)^b$**	**22.43 $(28.20)^c$**	
	SE(d)		LSD (5%)		SE(d)		LSD (5%)		Significance (5%)			
T	2.24		NS		2.17		NS		NS			
S	1.49		3.26		1.88		4.10		S*			
T × S	2.59		NS		3.26		NS		NS			

DOP- Date of planting T_1- 15th October, T_2- 25th October, T_3- 5th November, LSD- Fisher's Least Significance Difference
S_1- Spacing 60cm × 10cm, S_2- 60cm × 20cm, S_3- 60cm × 30cm, NS- Non significant, S- significant *Significant effects are shown with group letters
**Arcsine values are given in parenthesis

15^{th} October planting (8.71g) and minimum was recorded in 5^{th} November planting (8.21g). The plant spacing (S3) was recorded higher seed yield/plant (12.43g) while it was lower in S2 and S1. The interaction between T×S was non-significant.

4.1.18 Seed yield per plot (g) The seed yield per plot significantly influenced by planting time and maximum seed yield/plot was recorded in T1 (685.61g) followed by T2 (660.28g). The significant higher seed yield per plot was noted in closer spacing (S1) (716.72g) than wider spacing (S3) (621.67g) (Table 18).

4.1.19 Seed yield per hectare (q/ha)

The data presented in Table 19 showed that planting time and density had effect on seed yield. The significantly higher seed yield/ha was recorded under T_1 (6.86q) while lowest was noted in T_3 (6.40q). The seed yield was higher S1 (7.17q) followed by S2 (6.48q) and S1 (6.22q). The interaction effect between T×S was non-significant.

4.1.20 1000 seed weight (g)

The planting density had significant effect on 1000 seed weight; maximum 1000 seed weight was recorded under S3 (3.01g) followed by S2 (2.91g) and lower in S1 (2.76g) (Table 20). The higher 1000 seed weight was recorded under T1 (2.97g) followed by T2 and T3 however, the difference was non-significant. The interaction among T×S was non-significant.

4.1.21 Germination %

The results of the effect of planting time and planting density and their interaction on germination % are presented in Table 21. The pooled data indicated that planting time had significant influence on germination % and seed obtained from T_1 showed significantly higher germination (88.33%) followed by T_2 (86.83%) and lower germination was recorded in T_3 (85.63%) (Plate 5).

Among different planting density, wider spacing (S_3) recorded higher germination (89.76%) followed by S_2 (86.38%), while the lower value was observed in S_1 (84.64%) and interaction effect was non-significant for germination percent.

4.1.22 Seedling length (cm)

The data given in table 22 revealed that time of planting and density had significant effect on seedling length. Significant higher seedling length was noted under T_1 (9.48cm) and minimum was found in T_3 (8.51cm). The planting density S_3 had given maximum seedling length (10.37cm) than S_2 (8.87cm) and S_1 (7.78cm) (Table 21). The interaction between T×S was non-significant for seedling length.

4.1.23 Seedling dry weight (mg seedling^{-1})

Seedling dry weight significantly changed with time of planting and spacing (Table 23). The maximum seedling dry weight was recorded under T_1 (1.90 mg) and S_3 (1.95mg) while minimum was recorded in T_3 (1.67mg) & S_1 (1.63mg) and results of T_2 (1.76mg) & T_3 (1.67mg) were at par with each other. The interaction between T×S was non-significant for seedling dry weight.

4.1.24 Seed vigour index- I & II

The data presented in Table 24 and 25 on seed vigour index-I and II respectively revealed that there was a significant difference between the treatments for planting time & spacing and their interaction. The higher seed vigour index-I (833.32) & seed vigour index-II (167.08) were recorded under T_1 whereas, lower value was recorded in T_3 (714.82 & 138.31) for seed vigour index-I and seed vigour index-II respectively (Fig 3).

The significant higher value was recorded under 60×30cm spacing (918.56 & 172.96) for seed vigour index-I and seed vigour index-II respectively. The lower value of seed vigour index-I and seed vigour index-II (639.92 & 134.08) were noted under 60×10cm spacing.

The interaction between planting time and spacing had significant influence on seed vigour index-I & seed vigour index-II. The maximum SV-I (1002.10) & SV-II (198.08) were found under T_1S_3 interaction while, minimum was recorded under T_3S_1 (595.02 & 122.26) interaction for seed vigour index-I and seed vigour index-II respectively.

4.1.25 Electrical conductivity of seed leachate (µ mhos/cm/g)

The pooled results presented in Table 26 showed that planting density had significant effect on EC of seed leachates and lower EC was measured in S3 (21.95) followed by S2 (23.93) and S1 (25.35). The effect of planting time and interaction between T×S were non-significant.

4.1.26 Economics of seed production

The economic analysis on acre basis showed higher B:C ratio under S_3 (1:1.47) than S_2 (1:1.42) and S_1(1:1.21).

Table 12. Effect of planting time and density on number of umbellates per umbel (Pooled data over two years)

DOP	2013-14				2014-15				Pooled			
	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**
T_1	478.13	487.27	507.33	**490.91**	475.60	503.40	517.67	**498.89**	476.87	495.33	512.50	**494.90**
T_2	471.20	483.67	501.80	**485.56**	460.13	493.67	501.53	**485.11**	465.67	488.67	501.67	**486.37**
T_3	480.60	491.20	496.13	**489.31**	464.40	489.20	496.67	**483.42**	472.50	490.20	496.40	**485.33**
Mean	**476.64^c**	**487.38^b**	**501.76^a**		**466.71^b**	**495.42^a**	**505.29^a**		**471.68^c**	**491.40^b**	**503.52^a**	
	SE(d)		**LSD (5%)**		**SE(d)**		**LSD (5%)**		**Significance (5%)**			
T	2.60		NS		6.42		NS		NS			
S	4.86		10.60		4.88		10.62		S*			
T × S	8.42		NS		8.44		NS		NS			

DOP- Date of planting T_1- 15th October, T_2- 25th October, T_3- 5th November, LSD- Fisher's Least Significance Difference
S_1- Spacing 60cm × 10cm, S_2- 60cm × 20cm, S_3- 60cm × 30cm, NS- Non significant, S- significant *Significant effects are shown with group letters
**Arcsine values are given in parenthesis

Table 13. Effect of planting time and density on number of productive umbellates per umbel (Pooled data over two years)

DOP	2013-14				2014-15				Pooled			
	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**
T_1	381.20	408.47	444.00	**411.22^a**	367.80	429.00	457.93	**418.24^a**	374.50	418.73	450.97	**414.73^a**
T_2	332.13	369.33	407.07	**369.51^b**	349.87	393.67	419.93	**387.82^b**	341.00	381.50	413.50	**378.67^b**
T_3	328.00	361.73	374.53	**354.76^b**	343.93	386.67	412.93	**381.18^b**	335.97	374.20	393.73	**367.97^b**
Mean	**347.11^c**	**379.84^b**	**408.53^a**		**353.87^c**	**403.11^b**	**430.27^a**		**350.49^c**	**391.48^b**	**419.4^a**	
	SE(d)		**LSD (5%)**		**SE(d)**		**LSD (5%)**		**Significance (5%)**			
T	10.71		29.72		4.97		13.80		S*			
S	4.38		9.55		4.40		9.58		S*			
T × S	7.59		NS		7.61		NS		S*			

DOP- Date of planting T_1- 15th October, T_2- 25th October, T_3- 5th November, LSD- Fisher's Least Significance Difference
S_1- Spacing 60cm × 10cm, S_2- 60cm × 20cm, S_3- 60cm × 30cm, NS- Non significant, S- significant *Significant effects are shown with group letters

Table 14. Effect of planting time and density on seed setting (%) (Pooled data over two years)

DOP	2013-14				2014-15				Pooled			
	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**
T_1	79.79 (63.43)	83.79 (66.39)	87.54 (69.36)	**83.70 (66.39)[a]**	77.31 (61.59)	85.26 (67.49)	88.47 (70.15)	**83.68 (66.41)[a]**	78.55 (62.49)	84.52 (66.90)	88.01 (69.75)	**83.69 (66.38)[a]**
T_2	70.48 (57.12)	76.35 (60.88)	81.14 (64.27)	**79.99 (60.76)[b]**	76.1 (60.76)	79.71 (63.23)	83.72 (66.19)	**79.84 (63.39)[b]**	73.29 (58.91)	78.03 (62.03)	82.43 (65.20)	**77.61 (62.05)[b]**
T_3	68.33 (55.83)	73.6 (59.08)	75.45 (60.31)	**72.46 (58.41)[b]**	74.13 (59.48)	79.33 (62.77)	83.13 (65.73)	**78.76 (62.66)[b]**	71.23 (57.61)	76.31 (60.88)	79.29 (62.92)	**75.61 (60.47)[b]**
Mean	**72.86 (58.79)[c]**	**77.91 (62.12)[b]**	**81.37 (64.65)[a]**		**75.84 (60.61)[c]**	**81.33 (64.49)[b]**	**85.11 (67.35)[a]**		**74.35 (59.67)[c]**	**79.62 (63.27)[b]**	**83.24 (65.96)[a]**	
	SE(d)		**LSD (5%)**		**SE(d)**		**LSD (5%)**		**Significance (5%)**			
T	1.49		4.13		0.90		2.49		S*			
S	1.02		2.23		0.88		1.91		S*			
T × S	1.77		NS		1.52		NS		S*			

DOP- Date of planting T_1- 15th October, T_2- 25th October, T_3- 5th November, LSD- Fisher's Least Significance Difference

S_1- Spacing 60cm × 10cm, S_2- 60cm × 20cm, S_3- 60cm × 30cm, NS- Non significant, S- significant *Significant effects are shown with group letters

**Arcsine values are given in parenthesis

Table 15. Effect of planting time and density on maturity (in days) (Pooled data over two years)

DOP	2013-14				2014-15				Pooled			
	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**
T_1	192.33	192.33	194.00	**192.89[a]**	188.33	186.67	188.00	**187.67[a]**	190.50	189.25	191.87	**190.54[a]**
T_2	189.67	191.33	190.33	**190.44[b]**	184.67	183.00	183.33	**183.67[b]**	186.87	186.37	186.00	**186.41[b]**
T_3	182.00	184.33	186.33	**184.22[c]**	**181.00**	**180.00**	**180.67**	**180.00[c]**	180.75	180.87	183.87	**181.83[c]**
Mean	**188[c]**	**189.3[b]**	**190.2[a]**		**184.67**	**183.22**	**184.00**		**186.04[b]**	**185.50[a]**	**187.25[c]**	
	SE(d)		**LSD (5%)**		**SE(d)**		**LSD (5%)**		**Significance (5%)**			
T	0.48		1.33		0.47		1.30		S*			
S	0.38		0.84		0.54		NS		S*			
T × S	0.67		1.77		0.94		NS		NS			

DOP- Date of planting T_1- 15th October, T_2- 25th October, T_3- 5th November, LSD- Fisher's Least Significance Difference

S_1- Spacing 60cm × 10cm, S_2- 60cm × 20cm, S_3- 60cm × 30cm, NS- Non significant, S- significant *Significant effects are shown with group letters

Table 16. Effect of planting time and density on seed yield per umbel (g) (Pooled data over two years)

DOP	2013-14				2014-15				Pooled			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
T_1	3.25	3.42	3.58	**3.42**	3.33	3.60	3.84	**3.59**	3.29	3.51	3.71	**3.50**
T_2	3.02	3.14	3.30	**3.15**	3.21	3.30	3.51	**3.34**	3.11	3.22	3.41	**3.25**
T_3	2.85	3.19	3.20	**3.08**	3.17	3.23	3.44	**3.28**	3.01	3.21	3.32	**3.18**
Mean	**3.04**^{c}	**3.25**^{b}	**3.36**^{a}		**3.24**^{c}	**3.37**^{b}	**3.6**^{a}		**3.14**^{c}	**3.31**^{b}	**3.48**^{a}	
	SE(d)		**LSD (5%)**		**SE(d)**		**LSD (5%)**		**Significance (5%)**			
T	0.10		NS		0.14		NS		NS			
S	0.05		0.10		0.05		0.10		S*			
T × S	0.08		NS		0.08		NS		NS			

DOP- Date of planting T_1- 15th October, T_2- 25th October, T_3- 5th November, LSD- Fisher's Least Significance Difference
S_1- Spacing 60cm × 10cm, S_2- 60cm × 20cm, S_3- 60cm × 30cm, NS- Non significant, S- significant *Significant effects are shown with group letters

Table 17. Effect of planting time and density on seed yield per plant (gm) (Pooled data over two years)

DOP	2013-14				2014-15				Pooled			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
T_1	5.19	7.84	12.37	**8.47**	5.98	7.88	13.03	**8.96**^{a}	5.58	7.86	12.70	**8.71**^{a}
T_2	5.38	7.57	12.37	**8.44**	5.21	7.61	12.47	**8.43**^{b}	5.30	7.59	12.42	**8.43**^{b}
T_3	5.03	7.31	11.90	**8.08**	5.07	7.51	12.47	**8.35**^{b}	5.05	7.41	12.18	**8.21**^{b}
Mean	**5.2**^{c}	**7.58**^{b}	**12.21**^{a}		**5.42**^{c}	**7.67**^{b}	**12.66**^{a}		**5.31**^{c}	**7.62**^{b}	**12.43**^{a}	
	SE(d)		**LSD (5%)**		**SE(d)**		**LSD (5%)**		**Significance (5%)**			
T	0.12		NS		0.12		0.32		S*			
S	0.13		0.29		0.20		0.43		S*			
T × S	0.23		NS		0.34		NS		NS			

DOP- Date of planting T_1- 15th October, T_2- 25th October, T_3- 5th November, LSD- Fisher's Least Significance Difference
S_1- Spacing 60cm × 10cm, S_2- 60cm × 20cm, S_3- 60cm × 30cm, NS- Non significant, S- significant *Significant effects are shown with group letters

Table 18. Effect of planting time and density on seed yield/plot (gm) (Pooled data over two years)

DOP	2013-14				2014-15				Pooled			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
T_1	700.33	666.67	618.33	**661.78**	806.67	670.00	651.67	**709.44^a**	753.50	668.33	635.00	**685.61^a**
T_2	726.67	643.33	618.33	**662.78**	703.33	646.67	623.33	**657.78^b**	715.00	645.00	620.83	**660.28^b**
T_3	678.33	621.67	595.00	**631.67**	685.00	638.33	623.33	**648.89^b**	681.67	630.00	609.17	**640.28^c**
Mean	**701.78^a**	**643.89^b**	**610.56^c**		**731.67^a**	**651.67^b**	**632.78^b**		**716.72^a**	**647.78^b**	**621.67^b**	
	SE(d)		**LSD (5%)**		**SE(d)**		**LSD (5%)**		**Significance (5%)**			
T	10.64		NS		6.35		17.63		S*			
S	11.27		24.55		18.20		39.65		S*			
T × S	19.51		NS		31.52		NS		NS			

DOP- Date of planting T_1- 15[th] October, T_2- 25[th] October, T_3- 5[th] November, LSD- Fisher's Least Significance Difference
S_1- Spacing 60cm × 10cm, S_2- 60cm × 20cm, S_3- 60cm × 30cm, NS- Non significant, S- significant *Significant effects are shown with group letters

Table 19. Effect of planting time and density on seed yield (q/ha) (Pooled data over two years)

DOP	2013-14				2014-15				Pooled			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
T_1	7.00	6.67	6.18	**6.62**	8.07	6.70	6.52	**7.09^a**	7.54	6.68	6.35	**6.86^a**
T_2	7.27	6.43	6.18	**6.63**	7.03	6.47	6.23	**6.58^b**	7.15	6.45	6.21	**6.60^b**
T_3	6.78	6.22	5.95	**6.32**	6.85	6.38	6.23	**6.49^b**	6.82	6.30	6.09	**6.40^c**
Mean	**7.02^a**	**6.44^b**	**6.11^c**		**7.32^a**	**6.52^b**	**6.33^b**		**7.17^a**	**6.48^b**	**6.22^b**	
	SE(d)		**LSD (5%)**		**SE(d)**		**LSD (5%)**		**Significance (5%)**			
T	0.11		NS		0.06		0.23		S*			
S	0.11		0.30		0.18		0.49		S*			
T × S	0.20		NS		0.32		NS		NS			

DOP- Date of planting T_1- 15[th] October, T_2- 25[th] October, T_3- 5[th] November, LSD- Fisher's Least Significance Difference
S_1- Spacing 60cm × 10cm, S_2- 60cm × 20cm, S_3- 60cm × 30cm, NS- Non significant, S- significant *Significant effects are shown with group letters

Table 20. Effect of planting time and density on 1000 seed weight (g) (Pooled data over two years)

DOP	2013-14				2014-15				Pooled			
	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**
T_1	2.63	2.83	3.03	**2.83**	2.96	3.14	3.23	**3.11**	2.80	2.99	3.13	**2.97**
T_2	2.73	2.71	2.97	**2.80**	2.85	3.07	2.96	**2.96**	2.79	2.89	2.97	**2.88**
T_3	2.64	2.75	2.92	**2.77**	2.78	2.94	2.96	**2.89**	2.71	2.85	2.94	**2.83**
Mean	**2.67^c**	**2.77^b**	**2.97^a**		**2.86^b**	**3.05^a**	**3.05^a**		**2.76^c**	**2.91^b**	**3.01^a**	
	SE(d)		**LSD (5%)**		**SE(d)**		**LSD (5%)**		**Significance (5%)**			
T	0.08		NS		0.06		NS		NS			
S	0.04		0.08		0.05		0.12		S*			
T × S	0.07		NS		0.10		NS		NS			

DOP- Date of planting T_1- 15th October, T_2- 25th October, T_3- 5th November, LSD- Fisher's Least Significance Difference
S_1- Spacing 60cm × 10cm, S_2- 60cm × 20cm, S_3- 60cm × 30cm, NS- Non significant, S- significant *Significant effects are shown with group letters

Table 21. Effect of planting time and density on germination percent (Pooled data over two years)

DOP	2013-14				2014-15				Pooled			
	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**
T_1	85.88 (67.92)	88.33 (70.14)	91.22 (72.83)	**88.48 $(70.3)^a$**	85.55 (67.64)	87.66 (69.43)	91.33 (72.88)	**88.18 (69.98)**	85.72 (67.78)	88.0 (69.79)	91.28 (72.28)	**88.33 (70.14)a**
T_2	84.44 (66.78)	86.11 (68.11)	89.33 (70.94)	**86.62 $(68.61)^{ab}$**	84.66 (66.93)	85.99 (68.02)	90.44 (72.01)	**87.03 (68.98)**	84.55 (66.85)	86.05 (68.06)	89.89 (71.47)	**86.83 (68.8)b**
T_3	83.33 (65.90)	84.00 (66.40)	87.44 (69.26)	**84.92 $(67.19)^b$**	83.99 (66.40)	86.22 (68.19)	88.78 (70.40)	**86.33 (68.33)**	83.66 (66.15)	85.11 (67.29)	88.11 (69.83)	**85.63 (67.76)c**
Mean	**84.55 $(66.86)^b$**	**86.14 $(68.22)^b$**	**89.33 $(71.01)^a$**		**84.79 $(66.99)^c$**	**86.62 $(68.55)^b$**	**90.18 $(71.76)^a$**		**84.64 (66.93)c**	**86.38 (68.38)b**	**89.76 (71.39)a**	
	SE(d)		**LSD (5%)**		**SE(d)**		**LSD (5%)**		**Significance (5%)**			
T	0.68		1.90		0.45		NS		S*			
S	0.64		1.40		0.27		0.58		S*			
T × S	1.11		NS		0.46		NS		NS			

DOP- Date of planting T_1- 15th October, T_2- 25th October, T_3- 5th November, LSD- Fisher's Least Significance Difference
S_1- Spacing 60cm × 10cm, S_2- 60cm × 20cm, S_3- 60cm × 30cm, NS- Non significant, S- significant *Significant effects are shown with group letters
**Arcsine values are given in parenthesis

Table 22. Effect of planting time and density on seedling length (cm) (Pooled data over two years)

DOP	2013-14				2014-15				Pooled			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
T_1	7.45	8.66	10.07	**8.72[a]**	8.89	9.83	11.99	**10.24[a]**	8.17	9.25	11.03	**9.48[a]**
T_2	7.15	8.41	9.83	**8.46[a]**	8.59	9.41	10.75	**9.58[b]**	7.87	8.91	10.29	**9.02[b]**
T_3	6.76	7.97	9.23	**7.99[b]**	7.83	8.95	10.34	**9.04[c]**	7.30	8.46	9.79	**8.51[c]**
Mean	**7.12[c]**	**8.35[b]**	**9.71[a]**		**8.44[c]**	**9.4[b]**	**11.03[a]**		**7.78[c]**	**8.87[b]**	**10.37[a]**	
	SE(d)		**LSD (5%)**		**SE(d)**		**LSD (5%)**		**Significance (5%)**			
T	0.11		0.32		0.12		0.34		S*			
S	0.13		0.27		0.20		0.44		S*			
T × S	0.22		NS		0.35		NS		NS			

DOP- Date of planting T_1- 15th October, T_2- 25th October, T_3- 5th November, LSD- Fisher's Least Significance Difference
S_1- Spacing 60cm × 10cm, S_2- 60cm × 20cm, S_3- 60cm × 30cm, NS- Non significant, S- significant *Significant effects are shown with group letters

Table 23. Effect of planting time and density on seedling dry weight (mg/seedling) (Pooled data over two years)

DOP	2013-14				2014-15				Pooled			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
T_1	1.65	1.71	2.05	**1.80**	1.78	1.91	2.31	**2.0[a]**	1.72	1.81	2.18	**1.90[a]**
T_2	1.61	1.67	1.81	**1.70**	1.67	1.83	1.97	**1.82[b]**	1.64	1.75	1.89	**1.76[b]**
T_3	1.49	1.65	1.71	**1.62**	1.59	1.74	1.85	**1.73[c]**	1.54	1.69	1.78	**1.67[b]**
Mean	**1.58[b]**	**1.68[b]**	**1.86[a]**		**1.68[c]**	**1.83[b]**	**2.04[a]**		**1.63[c]**	**1.75[b]**	**1.95[a]**	
	SE(d)		**LSD (5%)**		**SE(d)**		**LSD (5%)**		**Significance (5%)**			
T	0.05		NS		0.03		0.07		S*			
S	0.07		0.15		0.05		0.12		S*			
T × S	0.12		NS		0.09		NS		NS			

DOP- Date of planting T_1- 15th October, T_2- 25th October, T_3- 5th November, LSD- Fisher's Least Significance Difference
S_1- Spacing 60cm × 10cm, S_2- 60cm × 20cm, S_3- 60cm × 30cm, NS- Non significant, S- significant *Significant effects are shown with group letters
**Arcsine values are given in parenthesis

Table 24. Effect of planting time and density on seed vigour index-I in (Pooled data over two years)

DOP	2013-14				2014-15				Pooled			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
T_1	624.97	753.11	912.75	**763.61[a]**	755.21	862.43	1091.45	**903.03[a]**	690.09	807.77	1002.10	**833.32[a]**
T_2	580.60	706.57	878.48	**721.88[a]**	688.72	782.27	951.33	**807.44[b]**	634.66	744.42	914.90	**764.66[b]**
T_3	521.36	641.79	773.19	**645.45[b]**	668.67	779.78	904.15	**784.2[b]**	595.02	710.78	838.67	**714.82[c]**
Mean	**575.64[c]**	**700.49[b]**	**854.8[a]**		**704.2[c]**	**808.16[b]**	**982.31[a]**		**639.92[c]**	**754.32[b]**	**918.56[a]**	
	SE(d)		**LSD (5%)**		**SE(d)**		**LSD (5%)**		**Significance (5%)**			
T	15.63		43.39		20.90		58.03		S*			
S	14.10		30.72		20.43		44.52		S*			
T × S	24.42		NS		35.39		S		S*			

DOP- Date of planting T_1- 15th October, T_2- 25th October, T_3- 5th November, LSD- Fisher's Least Significance Difference

S_1- Spacing 60cm × 10cm, S_2- 60cm × 20cm, S_3- 60cm × 30cm, NS- Non significant, S- significant *Significant effects are shown with group letters

Table 25. Effect of planting time and density on seed vigour index-II (Pooled data over two years)

DOP	2013-14				2014-15				Pooled			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
T_1	138.22	148.94	185.65	**157.6[a]**	151.39	167.76	210.51	**176.56[a]**	144.81	158.35	198.08	**167.08[a]**
T_2	130.66	140.02	162.02	**144.23[ab]**	139.66	156.78	173.98	**156.81[b]**	135.16	148.40	168.00	**150.52[b]**
T_3	115.18	132.64	143.56	**130.46[b]**	129.34	147.11	162.03	**146.16[c]**	122.26	139.87	152.80	**138.31[b]**
Mean	**128.02[b]**	**140.53[b]**	**163.74[a]**		**140.13[c]**	**157.22[b]**	**182.17[a]**		**134.08[c]**	**148.88[b]**	**172.96[a]**	
	SE(d)		**LSD (5%)**		**SE(d)**		**LSD (5%)**		**Significance (5%)**			
T	6.21		17.25		3.45		9.58		S*			
S	6.51		14.18		4.87		10.62		S*			
T × S	11.28		NS		8.44		NS		S*			

DOP- Date of planting T_1- 15th October, T_2- 25th October, T_3- 5th November, LSD- Fisher's Least Significance Difference

S_1- Spacing 60cm × 10cm, S_2- 60cm × 20cm, S_3- 60cm × 30cm, NS- Non significant, S- significant *Significant effects are shown with group letters

Table 26. Effect of planting time and density on electrical conductivity (µmhos/cm/g) (Pooled data over two years)

DOP	2013-14				2014-15				Pooled			
	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**	S_1	S_2	S_3	**Mean**
T_1	2.62	2.57	2.24	**2.45**	2.38	2.21	2.09	**2.23**	2.50	2.35	2.16	**2.34**
T_2	2.71	2.50	2.43	**2.54**	2.31	2.14	2.01	**2.15**	2.51	2.36	2.22	**2.36**
T_3	2.83	2.73	2.44	**2.65**	2.39	2.21	1.94	**2.18**	2.60	2.46	2.19	**2.41**
Mean	**2.71^a**	**2.57^b**	**2.37^c**		**2.36^a**	**2.19^b**	**2.01^c**		**2.53^a**	**2.39^b**	**2.19^c**	
	SE(d)		**LSD (5%)**		**SE(d)**		**LSD (5%)**		**Significance (5%)**			
T	0.87		NS		0.57		NS		NS			
S	0.50		0.83		0.49		0.85		S*			
T × S	0.86		NS		0.84		NS		NS			

DOP- Date of planting T_1- 15th October, T_2- 25th October, T_3- 5th November, LSD- Fisher's Least Significance Difference
S_1- Spacing 60cm × 10cm, S_2- 60cm × 20cm, S_3- 60cm × 30cm, NS- Non significant, S- significant *Significant effects are shown with group letters

Table 27. Effect of spacing on economics of seed production

Factors	Spacing		
	60×10cm	**60×20cm**	**60×30cm**
Production cost(Rs)	1,47,515	1,13,815	1,05,515
Interest on variable cost (4% annum-1/2 of annum)	2950.30	2276.30	2110.30
Total cost (Rs)	**1,50,465.30**	**1,16,091.30**	**1,07,625.30**
Seed yield (Processed) (kg)	229.44	207.36	199.04
Final yield (Risk 15%) (kg)	183.55	165.88	159.23
Value of seed (Rs 1000/kg)	**1,83,550**	**1,65,880**	**1,59,230**
Benefit cost ratio	**1:1.21**	**1:1.42**	**1:1.47**

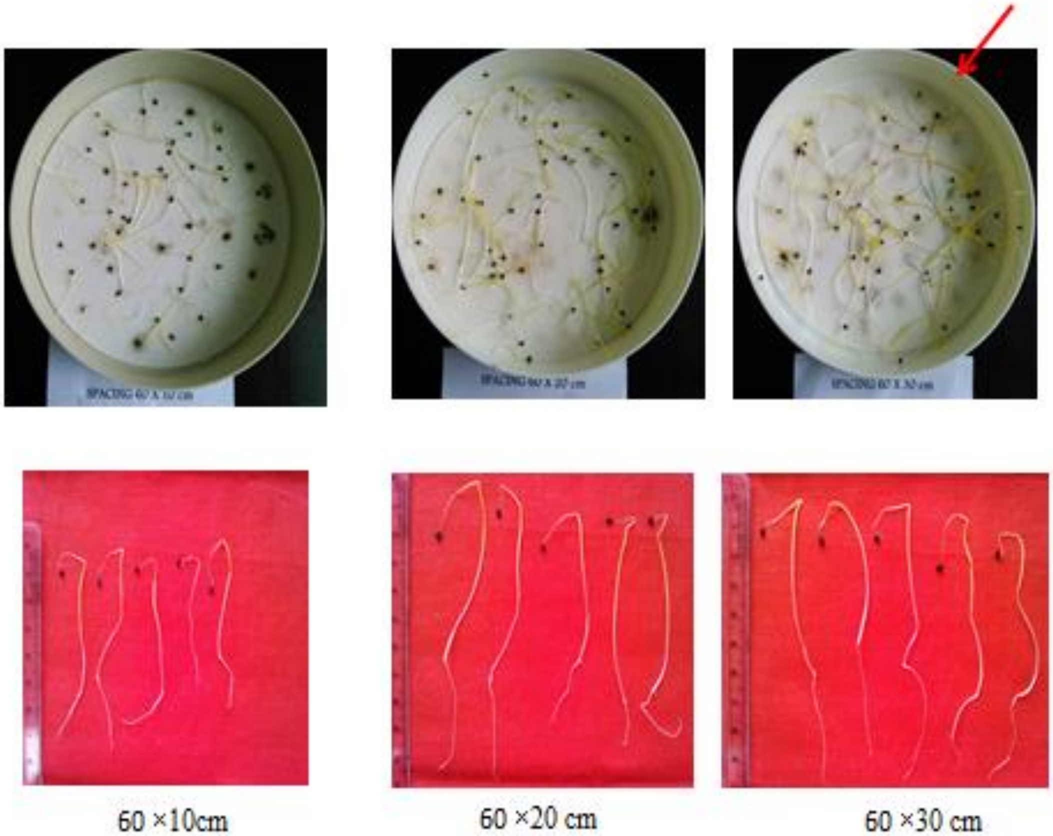


Plate: 5 Effect of planting time and density on seed germination and seedling length

4.1.27 Chlorophyll content (mg per g of tissue)

The chlorophyll content of leaves was higher under wider spacing planting than closer spacing (Fig. 4, 5 & 6) while, planting time did not influence the chlorophyll a, b and total chlorophyll content in leaves (Appendix IV).

4.2 To study the effect of foliar application of different mineral nutrients on growth, seed yield and seed quality

4.2.1 Number of leaves per plant

It is evident from the results presented in Table 28 that the foliar spray of mineral nutrients had no effect on leaves number/plant. However, numerically higher number leaves/plant was recorded in T_{14} (37.65) followed by T_5 (35.97) and T_3 (35.75), whereas, lowest number of leaves/plant was recorded in T_9 (32.20).

4.2.2 Days to seed scape emergence

The result of pooled data presented in Table 28 revealed that foliar spray of mineral nutrients had no significant effect on seed scape emergence. However, numerically higher number of days was taken by T_1, T_3, T_4 and T_{10} respectively, for seed scape emergence while, minimum was taken by T_{12} (53.25) for seed scape emergence.

4.2.3 Days to initiation of flowering and maturity

Foliar spray of mineral nutrients had non-significant effect on days to initiation of flowering. The higher days to initiation of flowering was taken by T_6 (122) followed by T_{11} (121.25) and T_{15} (120.5). The minimum days for initiation of flowering were recorded in T14 (118). The maturity period was also affected by foliar spray of nutrients significantly (Table 29). The higher days for maturity was taken by T_{11} (193.75) and the minimum days were taken by T_9 (190days). However, other treatments were statistically at par for harvestable maturity.

4.2.4 Seed scape height (cm)

The pooled data presented in Table30 revealed that foliar spray of mineral nutrients had significant effect on seed scape height. The significantly higher seed scape height was recorded in T_6 (105.35 cm) followed by T_{15} (104.08cm) and T_2 (103.08cm). However, the lower seed scape height was noted in control (T_{16}) (100.20cm). The seed scape height in treatments viz., T_1, T_4, T_5, T_8, T_9, T_{10}, T_{11}, T_{12}, T_{13} and T_{14} had higher height but results were at par with control treatment.

4.2.5 Seed scape diameter (cm)

It is evident from the perusal of the data presented in Table 30 that the foliar spray of mineral nutrients could not make any effect on seed scape diameter. The numerically maximum seed scape diameter was recorded in T_{14} (2.12cm) while, minimum seed scape diameter was recorded in T_1 (1.93cm).

4.2.6 Number of seed scape per plant

The number of seed scape per plant had not shown any significant effect for foliar spray of mineral nutrients (Table 31). However, higher seed scape per plant was recorded in T_{10} (11.2) followed by T_{14} (10.88), T_5 (10.58) and T_{16} (10.5). The minimum number of seed scape per plant was observed in T_9 (9.85).

4.2.7 Number of productive seed scape per plant

The pooled data presented in Table 31 revealed that foliar spray of mineral nutrients had significant effect on productive seed scape per plant. The higher number of productive seed scape was recorded in T_{14} (8.58). The treatments ranging from T_1 to T_{15} had registered significant difference over control (T_{16}) (6.88) but differences in treatments were statistically at par.

4.2.8 Seed scape lodging (%)

The seed scape lodging percent showed non-significant effect for foliar spray of mineral nutrients (Table 32). The lower seed scape lodging % was noted in T_{15} (16.74%) followed by T_9 (17.13%) and T_4 (17.54%). The control (T_{16}) showed higher seed scape lodging (29.56%) compared to other treatments.

4.2.9 Disease infected plants per plot (%)

The results presented in Table 33 showed that disease incidence significantly affected by foliar spray of mineral nutrients. The lower percent of disease incidence was recorded in T_6 (8.50) followed by T_4 (9.5), T_5, T_{13}, T_{14} (at par with each other i.e.10.0%) and T_{15} (10.5%). The other treatments viz., T_3 (17.5%), T_9 (18.5%), T_{10} (19%), T_{11} (18.5%) and T_{12} (16.5%) also showed significant lower disease incidence than control (T_{16}) (24%) and at par with each other.

Table 28: Effect of foliar spray of mineral nutrients on number of leaves per plant and seed scape emergence (days) in onion cv. Pusa Riddhi (Pooled data over two years)

Treatments	Number of leaves per plant			Seed scape emergence (days)		
	2013-14	**2014-15**	**Pooled**	**2013-14**	**2014-15**	**Pooled**
T_1	34.30	35.55	34.92	55.5	54^{ab}	54.75
T_2	32.10	38.35	35.22	55.5	53.5^{ab}	54.50
T_3	35.20	36.30	35.75	57.0	52.5^{ab}	54.75
T_4	34.45	37.00	35.72	54.0	55.5^{a}	54.75
T_5	36.05	35.90	35.97	54.5	54.0^{ab}	54.25
T_6	34.95	34.55	34.75	54.5	56.0^{a}	54.25
T_7	35.00	36.25	35.62	57.0	50.5^{b}	53.75
T_8	32.45	35.40	33.92	56.5	52.5^{ab}	54.50
T_9	32.40	32.00	32.20	55.5	53.5^{ab}	54.50
T_{10}	36.90	32.35	34.62	54.5	55.0^{ab}	54.75
T_{11}	35.10	33.55	34.32	54.0	54.5^{ab}	54.25
T_{12}	32.80	37.45	35.12	55.0	51.5^{ab}	53.25
T_{13}	33.40	34.70	34.05	54.5	53.5^{ab}	54.00
T_{14}	38.25	37.05	37.65	54.5	53.0^{ab}	53.75
T_{15}	33.00	37.95	35.47	54.0	53.0^{ab}	53.50
T_{16}	36.00	33.70	34.85	54.5	54.5^{ab}	54.50
Mean	**34.52**	**35.50**	**35.01**	**55.06**	**53.56**	**54.31**
SE(d)	**2.48**	**2.10**	**1.93**	**1.65**	**0.79**	**0.99**
HSD (5%)	**NS**	**NS**	**NS**	**NS**	**2.41**	**NS**

HSD (5%) - TUKEY's Honest Significant Difference, NS- Non-significant

RD- Recommended dose for bulb crop

SE(d)- Standard error of difference

T_1-RD of Boron at 60DAP

T_2-75% RD of Boron at 60DAP

T_3-125% RD of Boron at 60DAP

T_4-RD of Zinc at30DAP

T_5-75% RD of Zinc at 30DAP

T_6-125% RD of Zinc at 30DAP

T_7-RD of Calcium at 30DAP

T_8-75% RD of Calcium at 30DAP

T_9-125% RD of Calcium at 30DAP

T_{10}-RD of Mg at 30DAP

T_{11}-75% RD of Mg at 30DAP

T_{12}-125% RD of Mg at 30DAP

T_{13}-RD of Boron + Zinc at 30 & 60 DAP

T_{14}-RD of Boron + Zinc + Calcium at 30 & 60 DAP

T_{15}-RD of Boron + Zinc + Calcium + Magnesium at 30 & 60 DAP

T_{16}-Control (Water spray)

Table 29: Effect of foliar spray of mineral nutrients on initiation of flowering and maturity (days) in onion cv. Pusa Riddhi (Pooled data over two years)

	Initiation of flowering (days)			Maturity (day)		
Treatments	**2013-14**	**2014-15**	**Pooled**	**2013-14**	**2014-15**	**Pooled**
T_1	122.0	117.0	119.50	192.5	191.5	192.00^{ab}
T_2	121.5	118.5	120.00	192.5	190.0	191.25^{ab}
T_3	120.5	117.5	119.00	193.0	191.0	192.00^{ab}
T_4	121.0	116.0	118.50	189.5	191.5	190.50^{ab}
T_5	122.5	116.5	119.50	190.5	191.0	190.75^{ab}
T_6	122.5	121.5	122.00	194.5	191.5	193.00^{ab}
T_7	119.0	117.0	118.00	193.0	192.0	192.50^{ab}
T_8	122.0	116.5	119.25	189.0	192.5	190.75^{ab}
T_9	121.0	119.5	120.25	189.0	191.0	190.00^{b}
T_{10}	121.0	116.5	118.75	192.5	190.5	191.50^{ab}
T_{11}	122.5	120.0	121.25	194.5	193.0	193.75^{a}
T_{12}	122.0	118.5	120.25	192.5	193.0	192.75^{ab}
T_{13}	120.5	115.0	117.75	193.0	192.5	192.75^{ab}
T_{14}	119.5	116.5	118.00	191.5	193.5	192.50^{ab}
T_{15}	121.0	120.0	120.50	192.5	189.0	190.75^{ab}
T_{16}	121.5	118.0	119.75	191.5	192.0	191.75^{ab}
Mean	**121.25**	**117.78**	**119.52**	**191.97**	**191.59**	**191.78**
SE(d)	**1.71**	**2.0**	**1.31**	**1.56**	**1.26**	**1.00**
HSD (5%)	**NS**	**NS**	**NS**	**NS**	**NS**	**3.74**

HSD (5%) - TUKEY's Honest Significant Difference, NS- Non-significant

RD- Recommended dose for bulb crop

SE(d)- Standard error of difference

T_1-RD of Boron at 60DAP

T_2-75% RD of Boron at 60DAP

T_3-125% RD of Boron at 60DAP

T_4-RD of Zinc at30DAP

T_5-75% RD of Zinc at 30DAP

T_6-125% RD of Zinc at 30DAP

T_7-RD of Calcium at 30DAP

T_8-75% RD of Calcium at 30DAP

T_9-125% RD of Calcium at 30DAP

T_{10}-RD of Mg at 30DAP

T_{11}-75% RD of Mg at 30DAP

T_{12}-125% RD of Mg at 30DAP

T_{13}-RD of Boron + Zinc at 30 & 60 DAP

T_{14}-RD of Boron + Zinc + Calcium at 30 & 60 DAP

T_{15}-RD of Boron + Zinc + Calcium + Magnesium at 30 & 60 DAP

T_{16}-Control (Water spray)

Fig. 4 Effect of planting time and density on chlorophyll 'a 'content (On pooled data over two year's basis)

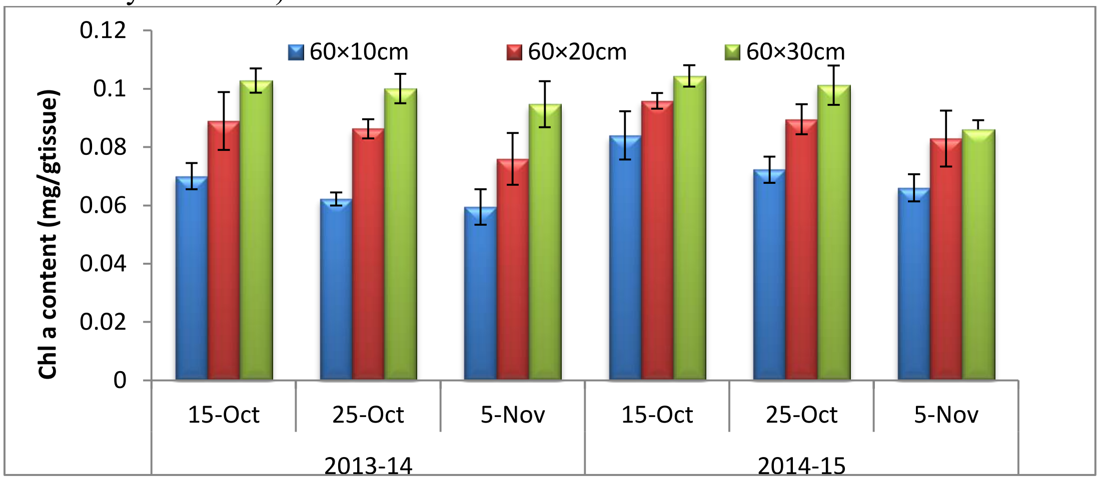


Fig. 5 Effect of planting time and density on chlorophyll 'b 'content (On pooled data over two year's basis)

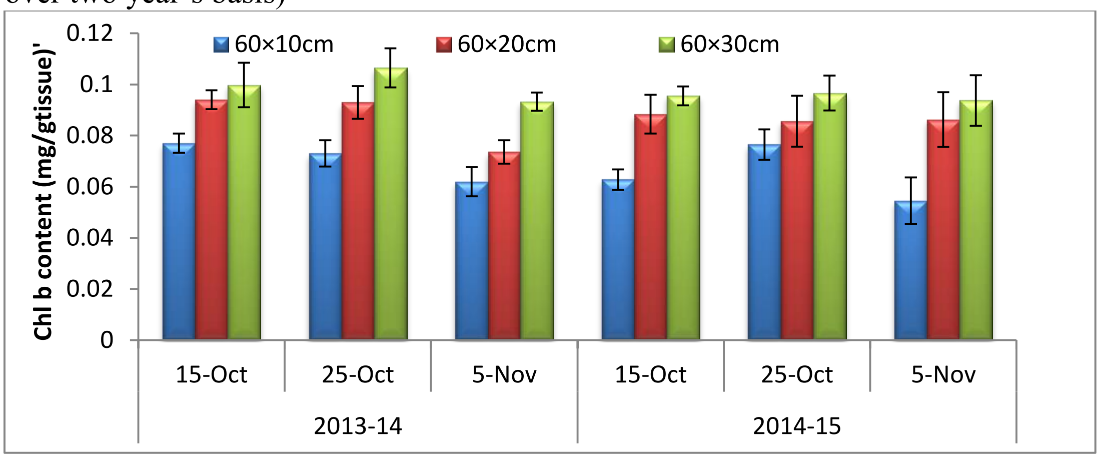
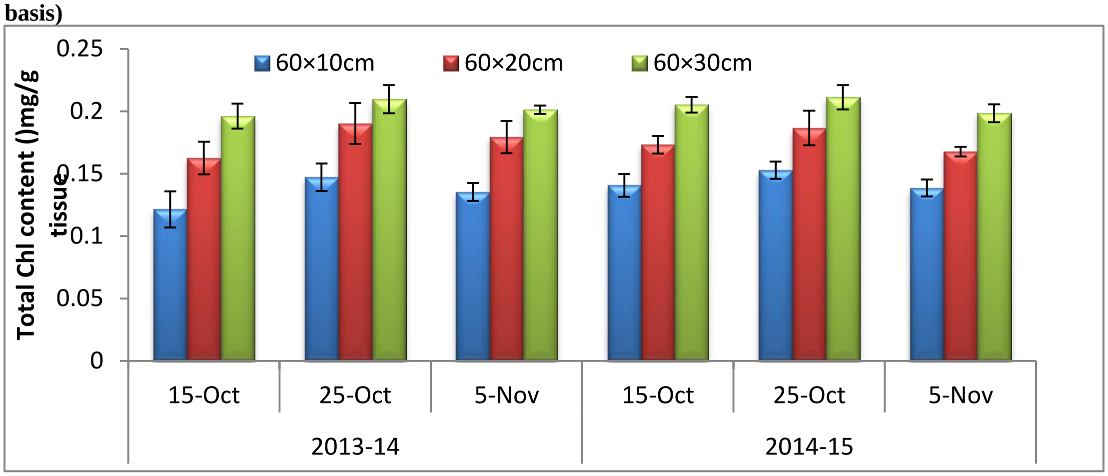


Fig. 6 Effect of planting time and density on total chlorophyll content (On pooled data over two year's basis)



4.2.10 Percent disease index (PDI)

The foliar application of mineral nutrients had significant effect on disease severity (Percent disease index) (Table 33). The minimum disease severity was noted in T_{12} (4.0%) but at par with other treatments except T_3, T_{13} and T_{16}. The treatments T_3, T_{13} & T_{16} had shown similar results and higher disease severity index was noted in control (T_{16}) (8.25%).

4.2.11 Number of umbellates/umbel

The foliar spray of mineral nutrients had significant influence on number of umbellates/umbel (Table 34). The highest umbellates/umbel was recorded in T_{15} (642.45) followed by T_{14} (610.60) and T_{13} (588.10) which had significant difference with each other (Fig 7). The treatments from T_1 to T_{12} also showed significant higher number of umbellates/umbel than control (T_{16}) (518.80) and results was at par among these treatments.

4.2.12 Number of productive umbellates per umbel

The results presented in Table 34 revealed that foliar spray of mineral nutrients had significant influence on number of productive umbellates per umbel. The higher number of productive umbellates/umbel was recorded under T_{15} (579.35), T_{14} (558.05), T_{13} (523.70), T_3 (502.10) and T_2 (494.70) which showed significant difference with other treatments and control (405.10) (Fig 7). The other treatments also showed significantly higher number of productive umbellates/umbel than control but difference between the treatments ranging from T_4 to T_{12} was recorded at par.

4.2.13 Seed setting (%)

The results of pooled data presented in Table 35 revealed marked difference with respect to foliar spray of macro & mineral nutrients. Significantly higher seed setting was recorded in T_{14} (91.37%) followed by T_{15} (90.18%) and T_{13} (89.05 %). The lower seed setting was recorded in control (T_{16}) (78.13%) which was at par with T_{10} (79.29%) and T_4 (79.69%). The treatments viz., T_1, T_2, T_3, T_5, T_6, T_7, T_8, T_9, T_{11} and T_{12} had also shown significantly higher number of productive umbellates/umbel than control and results were at par with them.

4.2.14 Umbel diameter (cm)

The data presented in Table 36 indicated that foliar spray of mineral nutrients had significant effect on umbel diameter. The maximum umbel diameter was recorded in T_{15} (7.38cm) followed by T_{14} (7.31cm), T_3 (7.10cm), T_{13} (7.08cm) and T_1 & T_2 (each 7.07cm) which had significant difference with other treatments. However, lower umbel diameter was recorded in control (6.25cm) and results were at par with $T_{5,}$ $T_{7,}$ T_8 $T_{10,}$ T_{11} and T_{12} (Plate 6 & 7).

4.2.15 1000 seed weight

The 1000 seed weight was significantly influenced by foliar spray of mineral nutrients (Table 36). Higher 1000 seed weight was noted in T_{15} (3.87g) followed by T_{14} (3.81g) and T_{13} (3.66g) which had significant difference with other treatments. The treatments ranging from T_1 to T_{12} also showed significant higher 1000 seed weight than control but difference between these treatments was at par with each other. The lowest 1000 seed weight was observed in control (T_{16}) (3.06g).

4.2.16 Seed yield/umbel (g)

The foliar spray of mineral nutrients had significant effect on seed yield/umbel (Table 37). The maximum seed yield/umbel was recorded in T_{15} (4.18g) followed by T_{14} (3.93g). Numerically treatments from T_1 to T_{13} also showed higher seed yield/umbel than control (T_{16}) (3.17g) but differences between the results of these treatments were found at par with each other.

4.217 Seed yield per plant (g)

The results presented in Table 38 showed that foliar spray of mineral nutrients had significant effect for seed yield per plant. The significantly highest seed yield per plant was recorded in T_{15} (16.70g) followed by T_{14} (15.78g) and T_{13} (14.95g). The lower seed yield/plant was recorded in control (T_{16}) (12.0g) and results were at par with other treatments viz., $T_{2,}$ $T_{3,}$ $T_{9,}$ T_{11} and T_{12}. The treatments $T_{1,}$ $T_{4,}$ $T_{5,}$ $T_{6,}$ $T_{7,}$ T_8 and T_{10} were also significantly higher in seed yield/plant than control.

4.2.18 Seed yield per plot (g)

The results presented in Table 38 showed that seed yield/plot was significantly influenced by foliar spray of mineral nutrients. The significantly highest seed yield/plot was recorded in T_{15} (835.0g) and results were at par with T_{14} (788.75g) and T_{13}

Table 30: Effect of foliar spray of mineral nutrients on seed scape height and seed scape diameter in onion cv. Pusa Riddhi (Pooled data over two years)

	Seed scape height (cm)			Seed scape diameter (cm)		
Treatments	**2013-14**	**2014-15**	**Pooled**	**2013-14**	**2014-15**	**Pooled**
T_1	100.90	104.35[abc]	102.63[abcd]	1.87	2.00	1.93
T_2	99.60	106.55[ab]	103.08[abc]	1.81	2.11	1.96
T_3	100.95	101.70[abc]	102.82[abc]	2.00	2.03	2.01
T_4	101.00	104.00[abc]	102.50[abcd]	1.89	2.04	1.96
T_5	101.65	102.85[abc]	102.25[abcd]	2.01	2.05	2.03
T_6	103.55	107.15[a]	105.35[a]	1.95	2.02	1.98
T_7	103.20	100.80[c]	100.80[bcd]	2.08	2.09	2.08
T_8	102.05	103.35[abc]	102.70[abcd]	1.99	2.07	2.03
T_9	102.25	102.45[abc]	102.35[abcd]	2.02	2.06	2.04
T_{10}	101.75	103.40[abc]	102.58[abcd]	2.00	2.02	2.01
T_{11}	100.25	100.95[bc]	100.60[bcd]	2.12	2.06	2.09
T_{12}	102.25	102.70[abc]	102.23[abcd]	2.05	2.05	2.05
T_{13}	101.00	100.40[c]	100.70[cd]	2.02	2.09	2.06
T_{14}	101.15	103.05[abc]	102.10[abcd]	2.18	2.05	2.12
T_{15}	102.80	105.35[abc]	104.08[ab]	2.13	1.93	2.09
T_{16}	100.10	100.55[c]	100.20[d]	2.02	2.11	1.98
Mean	**101.53**	**103.10**	**102.31**	**2.01**	**2.04**	**2.02**
SE(d)	**1.41**	**1.40**	**0.98**	**0.09**	**0.05**	**0.70**
HSD (5%)	**NS**	**5.66**	**3.68**	**NS**	**NS**	**NS**

HSD (5%) - TUKEY's Honest Significant Difference, NS- Non-significant

RD- Recommended dose for bulb crop
SE(d)- Standard error of difference
T_1-RD of Boron at 60DAP
T_2-75% RD of Boron at 60DAP
T_3-125% RD of Boron at 60DAP
T_4-RD of Zinc at30DAP
T_5-75% RD of Zinc at 30DAP
T_6-125% RD of Zinc at 30DAP
T_7-RD of Calcium at 30DAP
T_8-75% RD of Calcium at 30DAP
T_9-125% RD of Calcium at 30DAP
T_{10}-RD of Mg at 30DAP
T_{11}-75% RD of Mg at 30DAP
T_{12}-125% RD of Mg at 30DAP
T_{13}-RD of Boron + Zinc at 30 & 60 DAP
T_{14}-RD of Boron + Zinc + Calcium at 30 & 60 DAP
T_{15}-RD of Boron + Zinc + Calcium + Magnesium at 30 & 60 DAP
T_{16}-Control (Water spray)

Table 31: Effect of foliar spray of mineral nutrients on number of seed scape per plant and number of productive scape per plant in onion cv. Pusa Riddhi (Pooled data over two years)

Treatments	**Number of seed scapes/plant**			**Number of productive scapes/plant**		
	2013-14	**2014-15**	**Pooled**	**2013-14**	**2014-15**	**Pooled**
T_1	10.25	9.65	9.95	7.93^{ab}	8.30^{a}	8.11^{a}
T_2	10.40	10.15	10.28	8.14^{ab}	8.05^{ab}	8.10^{a}
T_3	9.75	10.50	10.13	7.79^{ab}	8.20^{a}	7.99^{a}
T_4	9.85	10.25	10.05	8.29^{a}	8.75^{a}	8.52^{a}
T_5	11.45	9.70	10.58	8.12^{ab}	8.40^{a}	8.26^{a}
T_6	10.10	10.50	10.30	8.25^{a}	8.10^{ab}	8.18^{a}
T_7	10.00	10.40	10.20	7.50^{ab}	8.30^{a}	7.90^{a}
T_8	10.45	10.10	10.28	7.64^{ab}	8.50^{a}	8.07^{a}
T_9	10.00	9.70	9.85	8.00^{ab}	8.30^{a}	8.15^{a}
T_{10}	11.25	11.15	11.20	7.93^{ab}	8.65^{a}	8.29^{a}
T_{11}	10.60	9.85	10.23	7.64^{ab}	8.15^{a}	7.90^{a}
T_{12}	10.40	9.90	10.15	8.07^{ab}	8.00^{ab}	8.04^{a}
T_{13}	10.35	10.70	10.53	8.50^{a}	8.40^{a}	8.45^{a}
T_{14}	11.15	10.60	10.88	8.50^{a}	8.65^{a}	8.58^{a}
T_{15}	10.25	10.05	10.15	8.65^{a}	8.25^{a}	8.45^{a}
T_{16}	10.40	10.60	10.50	8.86^{b}	6.90^{b}	6.88^{b}
Mean	**10.42**	**10.24**	**10.32**	**7.99**	**8.24**	**8.12**
SE(d)	**0.75**	**0.41**	**0.70**	**0.33**	**0.30**	**0.22**
HSD (5%)	**NS**	**NS**	**NS**	**1.33**	**1.22**	**0.83**

HSD (5%) - TUKEY's Honest Significant Difference, NS- Non-significant

RD- Recommended dose for bulb crop

SE(d)- Standard error of difference

T_1-RD of Boron at 60DAP

T_2-75% RD of Boron at 60DAP

T_3-125% RD of Boron at 60DAP

T_4-RD of Zinc at30DAP

T_5-75% RD of Zinc at 30DAP

T_6-125% RD of Zinc at 30DAP

T_7-RD of Calcium at 30DAP

T_8-75% RD of Calcium at 30DAP

T_9-125% RD of Calcium at 30DAP

T_{10}-RD of Mg at 30DAP

T_{11}-75% RD of Mg at 30DAP

T_{12}-125% RD of Mg at 30DAP

T_{13}-RD of Boron + Zinc at 30 & 60 DAP

T_{14}-RD of Boron + Zinc + Calcium at 30 & 60 DAP

T_{15}-RD of Boron + Zinc + Calcium + Magnesium at 30 & 60 DAP

T_{16}-Control (Water spray)

Table 32: Effect of foliar spray of mineral nutrients on seed scape lodging (%) in onion cv. Pusa Riddhi (Pooled data over two years)

Treatments	**Seed scape lodging (%)**		
	2013-14	**2014-15**	**Pooled**
T_1	22.47 (28.24)*	17.56 (24.76)	20.01 (26.50)
T_2	21.02 (26.77)	20.65 (26.97)	20.83 (26.87)
T_3	20.04 (26.46)	21.91 (27.90)	20.97 (27.18)
T_4	15.6 (22.99)	19.44 (26.00)	17.52 (24.49)
T_5	28.55 (32.12)	13.38 (21.40)	20.96 (26.76)
T_6	17.72 (24.37)	22.79 (28.48)	20.25 (26.42)
T_7	25.04 (30.01)	21.63 (27.71)	23.33 (28.85)
T_8	26.9 (31.22)	17.66 (24.59)	22.27 (27.90)
T_9	19.89 (26.37)	14.38 (22.18)	17.13 (24.27)
T_{10}	29.17 (32.60)	23.78 (29.17)	26.48 (30.89)
T_{11}	27.97 (31.89)	19.32 (25.86)	23.64 (28.88)
T_{12}	22.35 (28.20)	19.15 (25.83)	20.75 (27.02)
T_{13}	17.9 (25.01)	23.36 (28.89)	20.62 (26.95)
T_{14}	23.72 (29.13)	18.24 (25.01)	20.97 (27.07)
T_{15}	15.58 (23.23)	17.9 (24.99)	16.74 (24.11)
T_{16}	33.69 (35.42)	25.44 (30.27)	29.56 (32.85)
Mean	**22.98 (28.38)**	**19.79 (26.25)**	**21.38 (27.31)**
SE(d)	**4.37**	**3.05**	**2.66**
HSD (5%)	**NS**	**NS**	**NS**

HSD (5%) - TUKEY's Honest Significant Difference, NS- Non-significant
*Transformed arcsine values are given in parenthesis
RD- Recommended dose for bulb crop
SE(d)- Standard error of difference
T_1-RD of Boron at 60DAP
T_2-75% RD of Boron at 60DAP
T_3-125% RD of Boron at 60DAP
T_4-RD of Zinc at30DAP
T_5-75% RD of Zinc at 30DAP
T_6-125% RD of Zinc at 30DAP
T_7-RD of Calcium at 30DAP
T_8-75% RD of Calcium at 30DAP
T_9-125% RD of Calcium at 30DAP
T_{10}-RD of Mg at 30DAP
T_{11}-75% RD of Mg at 30DAP
T_{12}-125% RD of Mg at 30DAP
T_{13}-RD of Boron + Zinc at 30 & 60 DAP
T_{14}-RD of Boron + Zinc + Calcium at 30 & 60 DAP
T_{15}-RD of Boron + Zinc + Calcium + Magnesium at 30 & 60 DAP
T_{16}-Control (Water spray)

Table 33: Effect of foliar spray of mineral nutrients disease infected plants and PDI in onion cv. Pusa Riddhi (Pooled data over two years)

Treatments	**Disease infected plants (%)**			**PDI**
	2013-14	**2014-15**	**Pooled**	**2014-15**
T_1	15 *(22.68)^{abc}	16 (23.57)^{abc}	15.5 (23.12)^{bcd}	4.63^{b}
T_2	15 (22.77)^{abc}	15 (22.68)^{bc}	15.0 (22.72)^{bcd}	4.50^{b}
T_3	18 (25.06)^{abc}	17 (24.33)^{abc}	17.5 (24.70)^{ab}	5.04^{ab}
T_4	9 (17.43)^{c}	10 (18.43)^{c}	9.50 (17.93)^{de}	4.25^{b}
T_5	11 (19.34)^{abc}	9 (17.43)^{c}	10.0 (18.38)^{cde}	4.63^{b}
T_6	9 (17.43)^{c}	8 (16.42)^{c}	8.50 (16.92)^{e}	4.67^{b}
T_7	15 (22.77)^{abc}	10 (18.34)^{c}	12.50 (20.55)^{bcde}	4.58^{b}
T_8	15 (22.68)^{abc}	14 (21.91)^{bc}	14.50 (22.30)^{bcde}	4.96^{b}
T_9	21 (27.26)^{ab}	16 (23.57)^{abc}	18.50 (25.41)^{ab}	4.87^{b}
T_{10}	18 (25.09)^{abc}	20 (26.55)^{ab}	19.0 (25.82)^{ab}	4.33^{b}
T_{11}	20 (26.45)^{abc}	17 (24.26)^{abc}	18.50 (25.35)^{ab}	4.37^{b}
T_{12}	16 (23.53)^{abc}	17 (24.33)^{abc}	16.50 (23.93)^{abc}	4.00^{b}
T_{13}	10(18.34)^{bc}	10 (18.43)^{c}	10.0 (18.38)^{cde}	5.33^{ab}
T_{14}	10 (18.43)^{bc}	10 (18.34)^{c}	10.0 (18.38)^{cde}	4.00^{b}
T_{15}	10 (17.43)^{c}	11 (18.34)^{c}	10.50 (17.880^{de}	4.75^{b}
T_{16}	22 (27.87)^{a}	26 (30.63)^{a}	24.0 (29.25)^{a}	8.25^{a}
Mean	**14.63(22.16)**	**14.13 (21.72)**	**14.38 (21.94)**	**4.82**
SE(d)	**2.32**	**1.95**	**1.51**	**0.80**
HSD (5%)	**9.38**	**7.91**	**5.65**	**3.25**

HSD (5%) - TUKEY's Honest Significant Difference, NS- Non-significant
*Transformed arcsine values are given in parenthesis
RD- Recommended dose for bulb crop
SE(d)- Standard error of difference
T_1-RD of Boron at 60DAP
T_2-75% RD of Boron at 60DAP
T_3-125% RD of Boron at 60DAP
T_4-RD of Zinc at30DAP
T_5-75% RD of Zinc at 30DAP
T_6-125% RD of Zinc at 30DAP
T_7-RD of Calcium at 30DAP
T_8-75% RD of Calcium at 30DAP
T_9-125% RD of Calcium at 30DAP
T_{10}-RD of Mg at 30DAP
T_{11}-75% RD of Mg at 30DAP
T_{12}-125% RD of Mg at 30DAP
T_{13}-RD of Boron + Zinc at 30 & 60 DAP
T_{14}-RD of Boron + Zinc + Calcium at 30 & 60 DAP
T_{15}-RD of Boron + Zinc + Calcium + Magnesium at 30 & 60 DAP
T_{16}-Control (Water spray)

Table 34: Effect of foliar spray of mineral nutrients number of umbellates/umbel and productive umbellates/umbel in onion cv. Pusa Riddhi (Pooled data over two years)

Treatments	Number of umbellates/umbel			Productive umbellates/umbel		
	2013-14	**2014-15**	**Pooled**	**2013-14**	**2014-15**	**Pooled**
T_1	569.90^{bcd}	576.90^{cd}	573.40^{cd}	489.70^{bcde}	471.45^{cdef}	480.58^{cd}
T_2	566.70^{bcd}	579.50^{bcd}	573.10^{cd}	498.50^{bcd}	490.90^{cd}	494.70^{bc}
T_3	573.70^{bcd}	576.50^{cd}	575.10^{cd}	499.70^{bcd}	504.50^{bc}	502.10^{bc}
T_4	552.10^{cde}	552.50^{cde}	552.30^{de}	438.80^{efg}	441.10^{f}	439.95^{f}
T_5	543.70^{cde}	553.20^{cde}	548.45^{de}	447.80^{defg}	450.40^{ef}	449.10^{def}
T_6	551.40^{cde}	557.40^{cde}	554.40^{de}	454.10^{defg}	452.60^{ef}	453.35^{def}
T_7	547.50^{cde}	559.10^{cde}	553.30^{de}	450.30^{defg}	449.90^{ef}	450.10^{def}
T_8	538.00^{cde}	541.00^{de}	539.50^{ef}	435.90^{efg}	444.30^{ef}	440.10^{f}
T_9	532.10^{de}	538.70^{de}	535.40^{ef}	420.40^{fg}	451.70^{ef}	436.05^{fg}
T_{10}	561.80^{bcd}	556.70^{cde}	559.25^{cde}	430.80^{fg}	455.90^{ef}	443.35^{ef}
T_{11}	543.30^{cde}	548.50^{de}	545.90^{def}	449.00^{defg}	461.40^{def}	455.20^{def}
T_{12}	543.40^{cde}	562.40^{cde}	552.90^{de}	470.40^{cedf}	478.40^{cde}	474.40^{cde}
T_{13}	584.10^{abc}	592.10^{bc}	588.10^{bc}	519.70^{abc}	527.70^{b}	523.70^{b}
T_{14}	600.90^{ab}	620.30^{ab}	610.60^{b}	544.50^{ab}	571.60^{a}	558.05^{a}
T_{15}	627.90^{a}	657.00^{a}	642.45^{a}	562.70^{a}	596.00^{a}	579.35^{a}
T_{16}	512.80^{e}	524.80^{e}	518.80^{f}	411.60^{g}	398.60^{g}	405.10^{g}
Mean	**559.33**	**568.54**	**563.93**	**470.24**	**477.90**	**474.07**
SE(d)	**11.88**	**10.30**	**7.86**	**14.52**	**8.62**	**8.44**
HSD (5%)	**48.06**	**41.67**	**29.31**	**58.75**	**34.87**	**31.48**

HSD (5%) - TUKEY's Honest Significant Difference, NS- Non-significant

RD- Recommended dose for bulb crop
SE(d)- Standard error of difference

T_1-RD of Boron at 60DAP
T_2-75% RD of Boron at 60DAP
T_3-125% RD of Boron at 60DAP
T_4-RD of Zinc at30DAP
T_5-75% RD of Zinc at 30DAP
T_6-125% RD of Zinc at 30DAP
T_7-RD of Calcium at 30DAP
T_8-75% RD of Calcium at 30DAP
T_9-125% RD of Calcium at 30DAP
T_{10}-RD of Mg at 30DAP
T_{11}-75% RD of Mg at 30DAP
T_{12}-125% RD of Mg at 30DAP
T_{13}-RD of Boron + Zinc at 30 & 60 DAP
T_{14}-RD of Boron + Zinc + Calcium at 30 & 60 DAP
T_{15}-RD of Boron + Zinc + Calcium + Magnesium at 30 & 60 DAP
T_{16}-Control (Water spray)

Table 35: Effect of foliar spray of mineral nutrients on seed setting (%) in onion cv. Pusa Riddhi (Pooled data over two years)

Treatments	**Seed setting (%)**		
	2013-14	**2014-15**	**Pooled**
T_1	85.92 *(67.94)^{abcde}	81.17 (64.66)^{de}	83.82 (66.30)^{cde}
T_2	87.96 (69.66)^{abcde}	84.71 (66.95)^{bcd}	86.63 (68.52)^{bcd}
T_3	87.1 (68.92)^{abcd}	87.50 (69.26)^{abcd}	87.30 (69.09)^{abc}
T_4	79.88 (63.10)^{def}	79.88 (63.34)^{de}	79.69 (63.22)^{e}
T_5	81.45 (65.14)^{bcdef}	81.45 (64.48)^{de}	81.90 (64.81)^{de}
T_6	81.28 (65.16)^{bcdef}	81.28 (64.38)^{de}	81.82 (64.77)^{de}
T_7	80.47 (65.18)^{bcdef}	80.47 (63.75)^{de}	81.41 (64.47)^{de}
T_8	82.13 (64.16)^{cdef}	82.13 (64.97)^{cde}	81.57 (64.56)^{de}
T_9	83.85 (62.73)^{ef}	83.85 (66.28)^{bcde}	81.42 (64.51)^{de}
T_{10}	81.90 (61.10)^{f}	81.90 (64.82)^{cde}	79.29 (62.96)^{e}
T_{11}	84.12 (65.37)^{abcdef}	84.12 (66.50)^{bcde}	83.39 (65.94)^{cde}
T_{12}	85.06 (68.49)^{abcde}	85.06 (67.24)^{bcd}	85.82 (67.86)^{bcd}
T_{13}	89.12 (70.58)^{abc}	89.12 (70.72)^{abc}	89.05 (70.65)^{ab}
T_{14}	92.16 (72.17)^{a}	92.16 (73.73)^{a}	91.37 (72.95)^{a}
T_{15}	89.64 (71.21)^{ab}	90.72 (72.24)^{ab}	90.18 (71.73)^{ab}
T_{16}	80.28 (63.63)^{def}	75.98 (60.70)^{e}	78.13 (62.17)^{e}
Mean	**83.93 (66.54)**	**83.88 (66.5)**	**83.91 (66.52)**
SE(d)	**1.69**	**1.49**	**1.12**
HSD (5%)	**6.83**	**6.03**	**4.19**

HSD (5%) - TUKEY's Honest Significant Difference, NS- Non-significant
*Transformed arcsine values are given in parenthesis
RD- Recommended dose for bulb crop
SE(d)- Standard error of difference
T_1-RD of Boron at 60DAP
T_2-75% RD of Boron at 60DAP
T_3-125% RD of Boron at 60DAP
T_4-RD of Zinc at30DAP
T_5-75% RD of Zinc at 30DAP
T_6-125% RD of Zinc at 30DAP
T_7-RD of Calcium at 30DAP
T_8-75% RD of Calcium at 30DAP
T_9-125% RD of Calcium at 30DAP
T_{10}-RD of Mg at 30DAP
T_{11}-75% RD of Mg at 30DAP
T_{12}-125% RD of Mg at 30DAP
T_{13}-RD of Boron + Zinc at 30 & 60 DAP
T_{14}-RD of Boron + Zinc + Calcium at 30 & 60 DAP
T_{15}-RD of Boron + Zinc + Calcium + Magnesium at 30 & 60 DAP
T_{16}-Control (Water spray)

Table 36: Effect of foliar spray of mineral nutrients on umbel diameter in onion cv. Pusa Riddhi (Pooled data over two years)

Treatments	Umbel diameter (cm)			EC (µmhos/cm/g)		
	2013-14	**2014-15**	**Pooled**	**2013-14**	**2014-15**	**Pooled**
T_1	7.08^{abc}	7.07^{abc}	7.07^{abc}	1.81	1.90	1.85^{bc}
T_2	7.07^{abc}	7.08^{abc}	7.07^{abc}	1.76	1.71	1.73^{bc}
T_3	7.14^{ab}	7.06^{abc}	7.10^{ab}	1.93	1.66	1.80^{bc}
T_4	6.69^{bcd}	6.76^{bcde}	6.73^{cde}	2.05	2.13	2.09^{ab}
T_5	6.52^{cd}	6.67^{cde}	6.60^{def}	1.78	1.81	1.79^{bc}
T_6	6.63^{bcd}	6.95^{abcd}	6.79^{bcd}	1.70	1.60	1.65^{bc}
T_7	6.50^{d}	6.62^{cde}	6.56^{def}	1.97	1.67	1.82^{bc}
T_8	6.39^{d}	6.49^{de}	6.44^{def}	1.91	1.62	1.76^{bc}
T_9	6.24^{d}	6.32^{e}	6.28^{f}	1.80	1.89	1.85^{bc}
T_{10}	6.53^{cd}	6.38^{e}	6.46^{def}	1.72	1.77	1.75^{bc}
T_{11}	6.38^{d}	6.54^{cde}	6.46^{def}	1.76	1.87	1.81^{bc}
T_{12}	6.33^{dab}	6.49^{de}	6.41^{ef}	1.98	1.95	1.97^{ab}
T_{13}	7.15^{ab}	7.01^{abcd}	7.08^{abc}	1.82	1.54	1.68^{bc}
T_{14}	7.34^{a}	7.28^{ab}	7.31^{a}	1.59	1.41	1.50^{c}
T_{15}	7.29^{a}	7.47^{a}	7.38^{a}	1.82	1.48	1.65^{bc}
T_{16}	6.16^{d}	6.34^{e}	6.25^{f}	2.34	2.30	2.32^{a}
Mean	**6.71**	**6.78**	**6.75**	**1.86**	**1.77**	**1.81**
SE(d)	**0.14**	**0.13**	**0.09**	**0.15**	**0.19**	**0.12**
HSD (5%)	**0.57**	**0.55**	**0.36**	**0.60**	**0.77**	**0.45**

HSD (5%) - TUKEY's Honest Significant Difference, NS- Non-significant
*Transformed arcsine values are given in parenthesis

RD- Recommended dose for bulb crop
SE(d)- Standard error of difference
T_1-RD of Boron at 60DAP
T_2-75% RD of Boron at 60DAP
T_3-125% RD of Boron at 60DAP
T_4-RD of Zinc at30DAP
T_5-75% RD of Zinc at 30DAP
T_6-125% RD of Zinc at 30DAP
T_7-RD of Calcium at 30DAP
T_8-75% RD of Calcium at 30DAP
T_9-125% RD of Calcium at 30DAP
T_{10}-RD of Mg at 30DAP
T_{11}-75% RD of Mg at 30DAP
T_{12}-125% RD of Mg at 30DAP
T_{13}-RD of Boron + Zinc at 30 & 60 DAP
T_{14}-RD of Boron + Zinc + Calcium at 30 & 60 DAP
T_{15}-RD of Boron + Zinc + Calcium + Magnesium at 30 & 60 DAP
T_{16}-Control (Water spray)

Table 37: Effect of foliar spray of mineral nutrients on1000 seed weight and seed yield/umbel in onion cv. Pusa Riddhi (Pooled data over two years)

Treatments	**1000 seed weight (g)**			**Seed yield/umbel (g)**		
	2013-14	**2014-15**	**Pooled**	**2013-14**	**2014-15**	**Pooled**
T_1	3.41^{ab}	3.47^{cd}	3.44^{bc}	3.47^{ab}	3.39^{abc}	3.33^{c}
T_2	3.40^{ab}	3.28^{de}	3.34^{cd}	3.72^{ab}	3.61^{abc}	3.66^{abc}
T_3	3.33^{ab}	3.44^{cd}	3.39^{bc}	3.60^{ab}	3.44^{abc}	3.47^{bc}
T_4	3.34^{ab}	3.44^{cd}	3.39^{bc}	3.53^{ab}	3.70^{abc}	3.69^{abc}
T_5	3.50^{ab}	3.42^{cd}	3.46^{bc}	3.18^{b}	3.17^{bc}	3.18^{c}
T_6	3.32^{ab}	3.39^{cde}	3.35^{c}	3.38^{ab}	3.49^{abc}	3.44^{bc}
T_7	3.43^{ab}	3.44^{cd}	3.44^{bc}	3.37^{ab}	3.62^{abc}	3.74^{abc}
T_8	3.48^{ab}	3.32^{de}	3.40^{bc}	3.15^{b}	3.46^{abc}	3.30^{c}
T_9	3.43^{ab}	3.40^{cde}	3.41^{bc}	3.23^{b}	3.68^{abc}	3.58^{bc}
T_{10}	3.46^{ab}	3.33^{de}	3.39^{bc}	3.31^{ab}	3.63^{abc}	3.67^{abc}
T_{11}	3.42^{ab}	3.35^{cde}	3.39^{bc}	3.39^{ab}	3.50^{abc}	3.44^{bc}
T_{12}	3.44^{ab}	3.29^{de}	3.37^{c}	3.22^{a}	3.60^{abc}	3.71^{abc}
T_{13}	3.68^{a}	3.65^{bc}	3.66^{ab}	3.59^{ab}	3.70^{abc}	3.64^{abc}
T_{14}	3.73^{a}	3.89^{ab}	3.81^{a}	3.86^{ab}	3.91^{ab}	3.93^{ab}
T_{15}	3.75^{a}	3.99^{a}	3.87^{a}	3.98^{a}	4.12^{a}	4.18^{a}
T_{16}	3.05^{b}	3.08^{e}	3.06^{d}	3.40^{ab}	2.94^{c}	3.17^{c}
Mean	**3.45**	**3.45**	**3.45**	**3.46**	**3.56**	**3.57**
SE(d)	**0.12**	**0.08**	**0.07**	**0.18**	**0.2**	**0.15**
HSD (5%)	**0.51**	**0.31**	**0.27**	**0.74**	**0.80**	**0.58**

HSD (5%) - TUKEY's Honest Significant Difference, NS- Non-significant

RD- Recommended dose for bulb crop

SE(d)- Standard error of difference

T_1-RD of Boron at 60DAP

T_2-75% RD of Boron at 60DAP

T_3-125% RD of Boron at 60DAP

T_4-RD of Zinc at30DAP

T_5-75% RD of Zinc at 30DAP

T_6-125% RD of Zinc at 30DAP

T_7-RD of Calcium at 30DAP

T_8-75% RD of Calcium at 30DAP

T_9-125% RD of Calcium at 30DAP

T_{10}-RD of Mg at 30DAP

T_{11}-75% RD of Mg at 30DAP

T_{12}-125% RD of Mg at 30DAP

T_{13}-RD of Boron + Zinc at 30 & 60 DAP

T_{14}-RD of Boron + Zinc + Calcium at 30 & 60 DAP

T_{15}-RD of Boron + Zinc + Calcium + Magnesium at 30 & 60 DAP

T_{16}-Control (Water spray)

Fig. 7 Effect of foliar spray of mineral nutrients umbellates/umbel and productive umbellates/umbel (On pooled data over two year's basis)

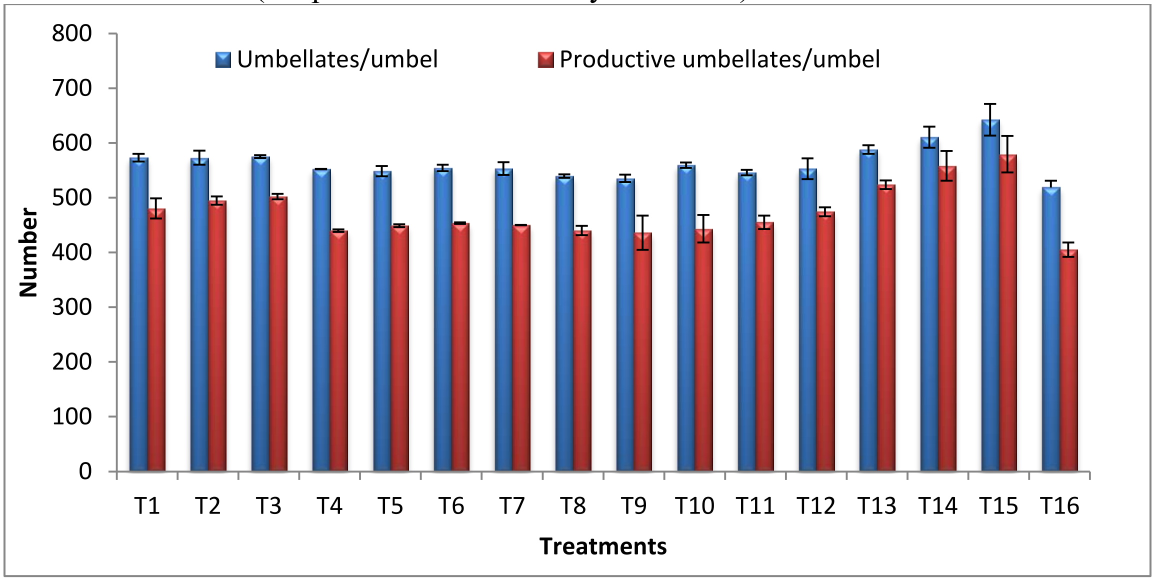


Fig. 8 Effect of foliar spray of mineral nutrients vigour index-I & II (On pooled data over two year's basis)

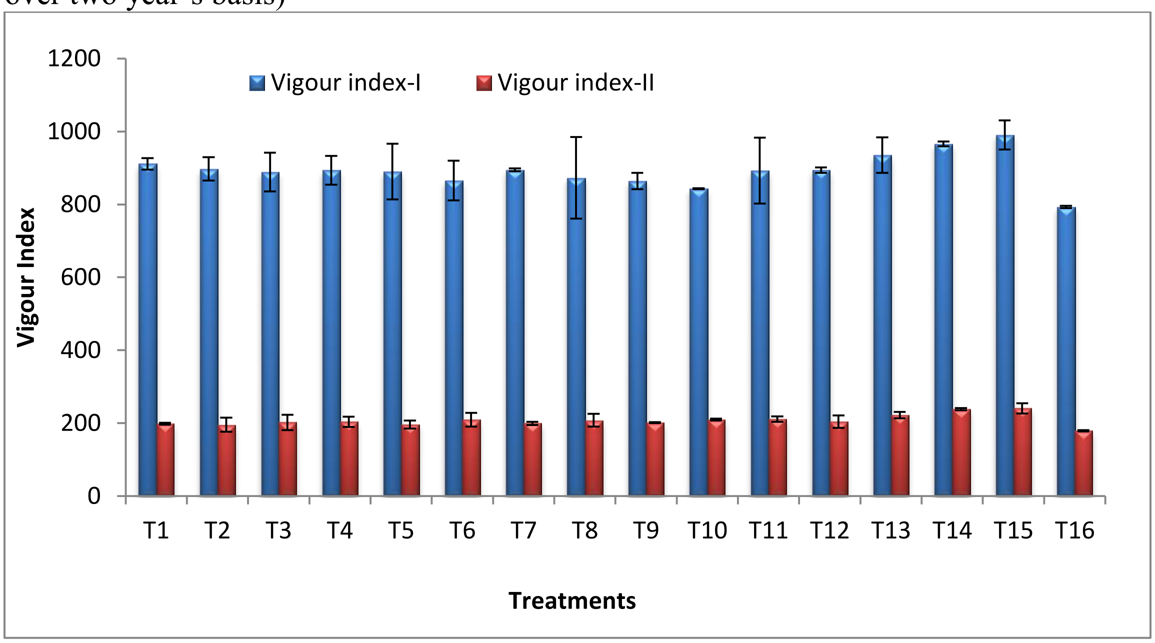


Plate: 6 Effect of mineral nutrients on growth performance of plants

Plate: 7 Effect of mineral nutrients on umbel size

(747.50g). The treatments viz., T_1 (702.5g), T_4 (713.75g), T_5 (717.50g), T_6 (716.25g), T_7 (725g), T_8 (731.25g) and T_{10} (725.0g) also showed significant superior seed yield/plot than control. The lower seed yield/plot was noted in control (T_{16}) (600g) which was at par with T_2, T_3, T_9, T_{11} and T_{12}.

4.2.19 Seed yield per hectare (q)

The seed yield per hectare was significantly influenced by foliar spray of mineral nutrients (Table 38). The maximum seed yield/ha was recorded in T_{15} (8.35q) followed by T_{14} (7.89q) and T_{13} (7.48q). The minimum seed yield/ha was recorded in control (T_{16}) (6.0q) which showed at par results with T_2, T_3, T_9, T_{11} and T_{12}. Treatments viz., T_1 (7.03q), T_4 (7.14q), T_5 (7.18q), T_6 (7.17q), T_7 (7.25q), T_8 (7.31q) and T_{10} (7.25q) also showed significant higher seed yield than control.

4.2.20 Germination Percent

The results presented in Table 39 indicated that foliar spray of mineral nutrients had significant effects on germination. The higher germination was recorded with the foliar spray of B+Zn+Ca+Mg at 30 and 60 DAP (T_{15}) had resulted 91.84% germination followed by T_{14} (90.83%) and T_{13} (90.41%). The germination was low in control (T_{16}) (86.83%) which was statistically at par with treatments ranging from T_1 to T_{13}.

4.2.21 Seedling length (cm)

The foliar spray of mineral nutrients had significant effect on seedling length (Table 40) and higher but at par seedling length were recorded in T_{15} (10.79cm), T_{14} (10.64cm) and T_{13} (10.34cm). The minimum seedling length was noted in T_{16} (9.13cm) which showed at par results with other treatments ranging from T_1 to T_{12}

4.2.22 Seedling dry weight (mg/seedling)

The seedling dry weight was significantly influenced by foliar spray of mineral nutrients (Table 40). The higher seedling dry weight was observed in T_{15} (2.62mg) and T_{14} (2.62mg) which were at par. The lower seedling dry weight was noted in control (T_{16})(2.06mg) which was statistically at par with treatments ranging from T_1 to T_{13}.

4.2.23 Seed vigour index-I

The results presented in Table 41 showed that seed vigour had significant influence due to foliar spray of mineral nutrients. The higher seed vigour was recorded in T_{15} (990.34) followed by T_{14} (966.21) and T_{13} (935.22) (Fig 8). The lower seed vigour was recorded in

T_{16} (792.76) which was statistically at par with treatments ranging from T_1 to T_{12}. However, numerically the treatments from T_1 to T_{15} had higher seed vigour index-I than control treatment.

4.2.24 Seed vigour index-II

The foliar spray of micronutrient had significant effect on seed vigour (Table 41). The maximum seed vigour was recorded in T_{15} (240.73) followed by T_{14} (238.04) and T_{13} (221.81) (Fig 8). The lower seed vigour was noted in T_{16} (179.23) which was at par with other treatments ranging from T_1 to T_{12} but numerically the treatments from T_1 to T_{15} had higher seed vigour than control.

4.2.25 Electrical conductivity (µmhos/cm/g)

The foliar spray of mineral nutrients had significant effect on electrical conductivity of seed leachates (Table 36). The lowest EC was recorded in T_{14} (1.50µmhos/cm/g) followed by T_{15} (1.65) and T_6 (1.65) than control (2.32). However, all the treatments ranging from T_1 to T_{15} showed significant difference with control treatments except T_4 and T_{12}.

4.2.26 Economics of seed production

Table 42 revealed higher B: C ratio (2.08) under best treatment (T_{15}) than the control (T_{16}) (1.52).

4.2.27 Chlorophyll content (mg/g tissue)

The foliar application of mineral nutrients had significant effect on chlorophyll a, b and total chlorophyll content than control. The higher leaf chlorophyll content was recorded in T_{15} followed by T_{14} and T_{13}. Figure 9, 10 and 11 revealed that chlorophyll a, b and total chlorophyll was higher in foliar spray of mineral nutrients than control in both season of crop growth (Appendix-V).

4.3: To study the effect of different plant growth retardants on onion seed scape height, seed yield and quality

4.3.1 Number of leaves per plant

It is evident from the data presented in Table 43 that plant growth retardants had significant influence on the number of leaves per plant. The higher number of leaves per plant was noted in T_{15} (36.13) followed by T_8 (35.78) and T_7 (35.28). The bulb soaked in various concentration of paclobutrazol treatments viz., T_1, T_3, T_4 and T_6 had registered

Table 38: Effect of foliar spray of mineral nutrients on seed yield per plant, seed yield per plot and seed yield/ha in onion cv. Pusa Riddhi (Pooled data over two years)

Treatments	Seed yield per plant (g)			Seed yield per plot (g)			Seed yield/ha (q/ha)		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
T_{1}	13.75^{ab}	14.35^{abc}	14.05^{b}	687.5	717.50^{abc}	702.50^{b}	6.88	7.18^{abc}	7.03^{b}
T_{2}	13.65^{ab}	14.10^{bc}	13.88^{bc}	682.5	705.00^{bc}	693.75^{bc}	6.83	7.05^{bc}	6.94^{bc}
T_{3}	13.40^{ab}	14.25^{bc}	13.83^{bc}	670	712.50^{bc}	691.25^{bc}	6.70	7.13^{bc}	6.91^{bc}
T_{4}	13.55^{ab}	15.00^{abc}	14.28^{b}	677.5	750.00^{abc}	713.75^{b}	6.78	7.50^{abc}	7.14^{b}
T_{5}	14.00^{ab}	14.70^{abc}	14.35^{b}	700	735.00^{abc}	717.50^{b}	7.00	7.35^{abc}	7.18^{b}
T_{6}	13.55^{ab}	15.10^{ab}	14.33^{b}	677.5	755.00^{ab}	716.25^{b}	6.78	7.55^{ab}	7.16^{b}
T_{7}	13.90^{ab}	15.10^{ab}	14.50^{b}	695	755.00^{ab}	725.00^{b}	6.95	7.55^{ab}	7.25^{b}
T_{8}	14.25^{ab}	15.00^{abc}	14.63^{b}	712.5	750.00^{abc}	731.25^{b}	7.13	7.50^{abc}	7.31^{b}
T_{9}	13.95^{ab}	13.90^{bc}	13.93^{bc}	697.5	695.00^{bc}	696.25^{bc}	6.98	6.95^{bc}	6.96^{bc}
T_{10}	13.75^{ab}	15.25^{ab}	14.50^{b}	687.5	762.50^{ab}	725.00^{b}	6.88	7.63^{ab}	7.25^{b}
T_{11}	13.25^{ab}	14.40^{abc}	13.83^{bc}	662.5	720.00^{abc}	691.25^{bc}	6.63	7.20^{abc}	6.91^{bc}
T_{12}	13.50^{ab}	14.15^{bc}	13.83^{bc}	675	707.50^{bc}	691.25^{bc}	6.75	7.08^{bc}	6.91^{bc}
T_{13}	14.65^{ab}	15.25^{ab}	14.95^{ab}	732.5	762.50^{ab}	747.50^{ab}	7.33	7.63^{ab}	7.48^{ab}
T_{14}	15.45^{a}	16.10^{ab}	15.78^{ab}	772.5	805.00^{ab}	788.75^{ab}	7.73	8.05^{ab}	7.89^{ab}
T_{15}	15.85^{a}	17.55^{a}	16.70^{a}	792.5	877.50^{a}	835.00^{a}	7.93	8.78^{a}	8.35^{a}
T_{16}	12.25^{b}	11.75^{c}	12.00^{c}	612.5	587.50^{c}	600.00^{c}	6.13	5.88^{c}	6.00^{c}
Mean	**13.92**	**14.75**	**14.33**	**695.94**	**737.34**	**716.64**	**6.96**	**7.37**	**7.17**
SE(d)	**0.70**	**0.81**	**0.53**	**35.35**	**40.64**	**26.93**	**0.35**	**0.41**	**0.26**
HSD (5%)	**2.85**	**3.28**	**2.00**	**142.97**	**164.35**	**100.39**	**1.42**	**1.64**	**1.00**

HSD (5%) - TUKEY's Honest Significant Difference, NS- Non-significant

RD- Recommended dose for bulb crop

SE(d)- Standard error of difference

T_{1}-RD of Boron at 60DAP

T_{2}-75% RD of Boron at 60DAP

T_{3}-125% RD of Boron at 60DAP

T_{4}-RD of Zinc at30DAP

T_{5}-75% RD of Zinc at 30DAP

T_{6}-125% RD of Zinc at 30DAP

T_{7}-RD of Calcium at 30DAP

T_{8}-75% RD of Calcium at 30DAP

T_{9}-125% RD of Calcium at 30DAP

T_{10}-RD of Mg at 30DAP

T_{11}-75% RD of Mg at 30DAP

T_{12}-125% RD of Mg at 30DAP

T_{13}-RD of Boron + Zinc at 30 & 60 DAP

T_{14}-RD of Boron + Zinc + Calcium at 30 & 60 DAP

T_{15}-RD of Boron + Zinc + Calcium + Magnesium at 30 & 60 DAP

T_{16}-Control (Water spray)

Table 39: Effect of foliar spray of mineral nutrients on germination (%) in onion cv. Pusa Riddhi (Pooled data over two years)

Treatments	**Germination (%)**		
	2013-14	**2014-15**	**Pooled**
T_1	*(71.94) 90.33	(71.41) 89.84	(71.68) 90.08^{abc}
T_2	(70.3) 88.67	(69.85) 88.17	(70.08) 88.42^{abc}
T_3	(71.38) 89.83	(70.49) 88.83	(70.93) 89.33^{abc}
T_4	(70.03) 88.34	(72.04) 90.50	(71.03) 89.42^{abc}
T_5	(69.29) 87.50	(70.92) 89.33	(70.10) 88.42^{abc}
T_6	(69.58) 87.84	(71.7) 90.16	(70.64) 89.00^{abc}
T_7	(70.82) 89.17	(70.6) 88.83	(70.71) 89.00^{abc}
T_8	(69.27) 87.50	(71.54) 90.0	(70.41) 88.75^{abc}
T_9	(69.71) 88.00	(70.17) 88.50	(69.94) 88.25^{abc}
T_{10}	(70.21) 88.50	(70.15) 88.50	(70.18) 88.50^{abc}
T_{11}	(70.32) 88.67	(71.38) 89.83	(70.85) 89.25^{abc}
T_{12}	(69.72) 88.00	(69.9) 88.17	(69.81) 88.08^{bc}
T_{13}	(71.42) 89.83	(72.52) 91.0	(71.97) 90.41^{abc}
T_{14}	(73.06) 91.50	(71.72) 90.17	(72.39) 90.83^{ab}
T_{15}	(74.83) 93.17	(72.02) 90.50	(73.43) 91.84^{a}
T_{16}	(68.84)87.00	(68.58) 86.67	(68.71) 86.83^{c}
Mean	**(70.67) 88.99**	**(70.94) 89.31**	**89.15**
SE(d)	**1.36**	**1.57**	**1.03**
HSD (5%)	**5.50**	**6.34**	**3.87**

HSD (5%) - TUKEY's Honest Significant Difference, NS- Non-significant
*Transformed arcsine values are given in parenthesis
RD- Recommended dose for bulb crop
SE(d)- Standard error of difference
T_1-RD of Boron at 60DAP
T_2-75% RD of Boron at 60DAP
T_3-125% RD of Boron at 60DAP
T_4-RD of Zinc at30DAP
T_5-75% RD of Zinc at 30DAP
T_6-125% RD of Zinc at 30DAP
T_7-RD of Calcium at 30DAP
T_8-75% RD of Calcium at 30DAP
T_9-125% RD of Calcium at 30DAP
T_{10}-RD of Mg at 30DAP
T_{11}-75% RD of Mg at 30DAP
T_{12}-125% RD of Mg at 30DAP
T_{13}-RD of Boron + Zinc at 30 & 60 DAP
T_{14}-RD of Boron + Zinc + Calcium at 30 & 60 DAP
T_{15}-RD of Boron + Zinc + Calcium + Magnesium at 30 & 60 DAP
T_{16}-Control (Water spray)

Table 40: Effect of foliar spray of mineral nutrients on seedling length and seedling dry weight in onion cv. Pusa Riddhi (Pooled data over two years)

Treatments	**Seedling length (cm)**			**Seedling dry weight (mg/seedling)**		
	2013-14	**2014-15**	**Pooled**	**2013-14**	**2014-15**	**Pooled**
T_1	9.99	10.23	10.11[abc]	2.22	2.19	2.21[ab]
T_2	9.94	10.36	10.15[abc]	2.31	2.11	2.21[ab]
T_3	9.60	10.31	9.95[abc]	2.37	2.15	2.26[ab]
T_4	9.90	10.09	9.99[abc]	2.38	2.17	2.28[ab]
T_5	9.73	10.39	10.06[abc]	2.18	2.26	2.22[ab]
T_6	9.54	9.90	9.72[abc]	2.28	2.42	2.35[ab]
T_7	10.01	10.11	10.06[abc]	2.26	2.21	2.24[ab]
T_8	9.34	10.32	9.83[abc]	2.27	2.41	2.34[ab]
T_9	9.69	9.90	9.79[abc]	2.28	2.28	2.28[ab]
T_{10}	9.54	9.52	9.53[bc]	2.38	2.35	2.37[ab]
T_{11}	9.55	10.44	9.99[abc]	2.34	2.39	2.37[ab]
T_{12}	10.12	10.18	10.15[abc]	2.41	2.21	2.31[ab]
T_{13}	10.14	10.54	10.34[ab]	2.52	2.39	2.45[ab]
T_{14}	10.60	10.68	10.64[a]	2.58	2.66	2.62[a]
T_{15}	10.42	11.16	10.79[a]	2.66	2.58	2.62[a]
T_{16}	9.13	9.13	9.13[c]	2.05	2.08	2.06[b]
Mean	**9.83**	**10.2**	**10.02**	**2.34**	**2.3**	**2.32**
SE(d)	**0.40**	**0.43**	**0.29**	**0.17**	**0.14**	**0.11**
HSD (5%)	**NS**	**1.74**	**1.10**	**NS**	**NS**	**0.42**

HSD (5%) - TUKEY's Honest Significant Difference, NS- Non-significant

RD- Recommended dose for bulb crop

SE(d)- Standard error of difference

T_1-RD of Boron at 60DAP

T_2-75% RD of Boron at 60DAP

T_3-125% RD of Boron at 60DAP

T_4-RD of Zinc at30DAP

T_5-75% RD of Zinc at 30DAP

T_6-125% RD of Zinc at 30DAP

T_7-RD of Calcium at 30DAP

T_8-75% RD of Calcium at 30DAP

T_9-125% RD of Calcium at 30DAP

T_{10}-RD of Mg at 30DAP

T_{11}-75% RD of Mg at 30DAP

T_{12}-125% RD of Mg at 30DAP

T_{13}-RD of Boron + Zinc at 30 & 60 DAP

T_{14}-RD of Boron + Zinc + Calcium at 30 & 60 DAP

T_{15}-RD of Boron + Zinc + Calcium + Magnesium at 30 & 60 DAP

T_{16}-Control (Water spray)

Table 41: Effect of foliar spray of mineral nutrients on seed vigour index I and II in onion cv. Pusa Riddhi (Pooled data over two years)

Treatments	Seed vigour index-I			Seed vigour index-II		
	2013-14	**2014-15**	**Pooled**	**2013-14**	**2014-15**	**Pooled**
T_1	903.02[ab]	919.18[abc]	911.10[abc]	199.86[ab]	197.17	198.51[cd]
T_2	881.38[ab]	913.36[abc]	897.37[abcd]	205.16[ab]	185.71	195.44[cd]
T_3	862.34[ab]	915.57[abc]	888.96[abcd]	212.43[ab]	191.32	201.88[bcd]
T_4	873.71[ab]	913.47[abc]	893.59[abcd]	210.69[ab]	196.5	203.60[abcd]
T_5	851.74[ab]	928.25[abc]	889.99[abcd]	190.85[ab]	201.78	196.32[cd]
T_6	838.16[ab]	892.50[abc]	865.33[bcd]	199.88[ab]	218.67	209.27[abcd]
T_7	892.71[ab]	896.99[abc]	894.85[abcd]	201.34[ab]	196.97	199.16[cd]
T_8	817.26[ab]	929.24[abc]	873.25[bcd]	199.03[ab]	216.65	207.84[abcd]
T_9	852.77[ab]	875.50[abc]	864.13[bcd]	200.62[ab]	201.87	201.24[bcd]
T_{10}	843.89 [ab]	842.21[bc]	843.05[cd]	210.95[ab]	208.35	209.65[abcd]
T_{11}	847.31 [ab]	937.66[abc]	892.48[abcd]	207.53[ab]	214.88	211.21[abcd]
T_{12}	890.42 [ab]	897.67[abc]	894.04[abcd]	212.59[ab]	195.37	203.98[abcd]
T_{13}	910.91 [ab]	959.54[ab]	935.22[abc]	226.22[ab]	217.41	221.81[abc]
T_{14}	969.55[a]	962.88[ab]	966.21[ab]	236.50[ab]	239.57	238.04[ab]
T_{15}	970.45[a]	1010.22[a]	990.34[a]	247.71[a]	233.75	240.73[a]
T_{16}	794.34[b]	791.18[c]	792.76[d]	178.45[b]	180.01	179.23[d]
Mean	**875.00**	**911.59**	**893.29**	**208.74**	**206**	**207.37**
SE(d)	**42.66**	**36.78**	**28.16**	**14.89**	**14.38**	**10.35**
HCD(5%)	**172.56**	**148.76**	**104.99**	**60.23**	**58.17**	**38.59**

HSD (5%) - TUKEY's Honest Significant Difference, NS- Non-significant
RD- Recommended dose for bulb crop
SE(d)- Standard error of difference
T_1-RD of Boron at 60DAP
T_2-75% RD of Boron at 60DAP
T_3-125% RD of Boron at 60DAP
T_4-RD of Zinc at 30DAP
T_5-75% RD of Zinc at 30DAP
T_6-125% RD of Zinc at 30DAP
T_7-RD of Calcium at 30DAP
T_8-75% RD of Calcium at 30DAP
T_9-125% RD of Calcium at 30DAP
T_{10}-RD of Mg at 30DAP
T_{11}-75% RD of Mg at 30DAP
T_{12}-125% RD of Mg at 30DAP
T_{13}-RD of Boron + Zinc at 30 & 60 DAP
T_{14}-RD of Boron + Zinc + Calcium at 30 & 60 DAP
T_{15}-RD of Boron + Zinc + Calcium + Magnesium at 30 & 60 DAP
T_{16}-Control (Water spray)

Table 42: Effect of foliar spray of mineral nutrients on economics of seed production

Treatments	Control (T16)	Best treatment (T15)
Cost of production	1,06,729.38	1,06729.38
Cost of micronutrients	-	1000
Labour cost	-	800
Total cost	1,06,729.38	1,08,529.38
Seed yield (q/acre)	1.63	2.26
Value of seed (Rs)	1,63,000	2,26,000
Net profit (Rs)	56,270	1,18,200
B/C ratio	**1:52**	**2:08**

reduction in number of leaves per plant (26.28, 24.93, 25.65 and 24.58) respectively. However, soaking or foliar spray of ethaphone and triadimefon treatments were non-significant (Fig 12).

4.3.2 Days to seed scape emergence

The application of plant growth retardants particularly paclobutrazol had significantly delayed the emergence of seed scape (Table 43). The foliar spray of 100 ppm paclobutrazol + bulb soaking in 100 ppm solution T_6 had taken higher number of days (71.50) followed by (T_1) (70.25) and T_4 (69.0) for seed scape emergence. Whereas, the foliar spray and bulb soaking treatments of ethaphone and triadimefon at different concentration have taken less number of days for seed scape emergence than T_6, T_1, T_4 and T_3. The treatments T_7 to T_{15} were at par.

4.3.3 Days to initiation of flowering

The data presented in Table 44 showed that growth retardants had significantly delayed the initiation of flowering. The higher number of days for initiation of flowering was taken by T_6 (131.5) followed by T_4 (131) and T_1 (131). However, the treatments viz., T7 to T14 were statistically at par with T15 (120.5) but took significantly higher days than T6 (131.5).

4.3.4 Days to maturity

The growth retardant had significant influence on maturity (Table 44). The higher days to maturity was taken by T12 (181.5days) followed by T11 (181.2days) and T10 (181days). Whereas, the treatments in which bulb were soaked in paclobutrazol viz., T6 (160.2days), T4 (161 days), T1 (162.5days) and T3 (163 days) had taken less significantly days for maturity as compared to control (180 days).

4.3.5 Seed scape height (cm)

The growth retardant treatments particularly paclobutrazol either through foliar spray or soaking of bulb had significantly decreased the seed scape height (Table 45) (Fig 12). The significantly low seed scape height was recorded in T6 (69.9cm) followed by T3 (77.35cm), T4 (80.93cm) and T1 (81.33cm) than control (T15) (103.25cm). However, the ethaphone (from T7 to T10) and triadimefon (from T10 to T14) treatments had shown reduction in seed scape height but results were statistically at par with control (Plate 8).

4.3.6 Seed scape diameter (cm)

The data presented in Table 45 showed significant effect of growth retardants on seed scape diameter either through bulb soaking or foliar spray or combination (Table 43). The higher seed scape diameter was recorded in T4 (3.71cm) followed by T6 (3.68cm), T1 (3.68cm) and T3 (3.66cm) (Fig 13). The ethaphone and triadimefon based treatments also showed higher seed scape diameter than control (2.36cm) but the results were statistically at par.

4.3.7 Number of seed scapes per plant

The growth retardants application affected the number of seed scapes per plant (Table 46). The higher number of seed scapes per plant was observed in T_8 (11.58) followed by T_5 (10.95) and T_9 (10.70). However, paclobutrazol application significantly diminished the number of seed scapes per plant and lower number of seed scapes/plant; the lower number of seed scapes/plant was recorded in T4 (5.83) followed by T1 (6.70) and T6 (6.80).

4.3.8 Number of productive seed scapes per plant

The productive seed scape per plant was influenced by growth retardants (Table 46). The higher number of productive seed scapes/plant was observed in T15 (8.02) but statistically at par with treatments ranging from T_7 to T_{14}. Whereas, bulb soaked in paclobutrazol treatment had significantly reduced the number of productive seed scapes/plant and lower number was recorded in (T3) (3.25) followed by T4 (3.27) and (3.42) in each T1 & T6.

4.3.9 Seed scape lodging (%)

The pooled data presented in Table 47 revealed that growth retardants application had significant effect on the lodging percent of seed scape. The lower seed scape lodging was observed in T12 (23.34%) followed by T11 (24.60%) and T114 (25.89%). However, the higher seed scape lodging was recorded in T3 (54.99%) followed by T6 (50.07%) and T1 (49.08%).

4.3.10 Umbel diameter (cm)

The data presented in Table 47 indicated that growth retardants had effect on umbel diameter. The higher significantly umbel diameter was recorded in T6 (7.31cm) but at par with T1, T2, T3, T4 and T5 treatments. The ethaphone and triadimefon

Table 43. Effect of plant growth retardants on number of leaves per plant and days to seed scape emergence in onion cv. Pusa Riddhi (Pooled data over two years)

Treatments	Number of leaves per plant			Seed scape emergence (Days)		
	2013-14	**2014-15**	**Pooled**	**2013-14**	**2014-15**	**Pooled**
T_1	26.80[bc]	25.75[bc]	26.28[b]	68.0[ab]	72.5[a]	70.25[a]
T_2	33.45[ab]	33.20[ab]	33.33[a]	56.0[c]	53.5[b]	54.75[b]
T_3	26.25[bc]	23.60[c]	24.93[b]	65.5[ab]	71.5[a]	68.50[a]
T_4	26.25[bc]	25.05[c]	25.65[b]	68.5[a]	69.5[a]	69.00[a]
T_5	34.80[a]	34.30[a]	34.55[a]	55.5[c]	55.0[b]	55.25[b]
T_6	25.60[c]	23.55[c]	24.58[b]	69.5[a]	73.5[a]	71.50[a]
T_7	34.95[a]	35.60[a]	35.28[a]	55.0[c]	53.0[b]	54.00[b]
T_8	37.20[a]	34.35[a]	35.78[a]	53.0[c]	54.5[b]	53.75[b]
T_9	33.45[ab]	35.35[a]	34.40[a]	56.5[c]	52.0[b]	54.25[b]
T_{10}	32.15[abc]	35.20[a]	33.68[a]	59.5[bc]	52.0[b]	55.75[b]
T_{11}	33.95[ab]	34.95[a]	34.45[a]	54.0[c]	54.5[b]	54.25[b]
T_{12}	35.55[a]	34.25[a]	34.90[a]	55.5[c]	55.0[b]	55.25[b]
T_{13}	33.95[ab]	34.65[a]	34.30[a]	55.0[c]	52.0[b]	53.50[b]
T_{14}	33.80[ab]	33.45[a]	33.63[a]	55.0[c]	54.5[b]	54.75[b]
T_{15}	36.45[a]	35.80[a]	36.13[a]	55.5[c]	53.5[b]	53.50[b]
Mean	**32.31**	**31.94**	**32.12**	**55.0[c]**	**58.43**	**56.71**
SE(d)	**1.93**	**1.90**	**1.35**	**2.12**	**2.70**	**1.72**
HSD (5%)	**7.82**	**7.69**	**5.03**	**8.60**	**10.93**	**6.38**

HSD (5%) - TUKEY's Honest Significant Difference, NS- Non-significant

*Significant effects are shown with group letters

SE(d)- Standard error of difference,

T_1- Soaking of bulbs in 80 ppm paclobutrazol solution
T_2- Foliar spray of paclobutrazol @ 80 ppm
T_3- Soaking of bulbs in 80 ppm paclobutrazol + foliar spray of paclobutrazol@80 ppm
T_4- Soaking of bulbs in 100 ppm paclobutrazol solution
T_5- Foliar spray of paclobutrazol @ 100 ppm
T_6- Soaking of bulbs in 100 ppm paclobutrazol + foliar spray of paclobutrazol@100 ppm
T_7- Soaking of bulbs in 400 ppm ethaphone solution
T_8- Foliar spray of ethaphone @ 400 ppm
T_9- Soaking of bulbs in 500 ppm ethaphone solution
T_{10}- Foliar spray of ethaphone @ 500 ppm
T_{11}- Soaking of bulbs in 200 ppm triadimefon solution
T_{12}- Foliar spray of triadimefon @ 200 ppm
T_{13}- Soaking of bulbs in 400 ppm triadimefon solution
T_{14}- Foliar spray of triadimefon @ 400 ppm
T_{15}-Control (Water spray)

Table 44. Effect of plant growth retardants on days to initiation flowering and days to maturity in onion cv. Pusa Riddhi (Pooled data over two years)

Treatments	**Days to initiation of flowering**			**Days to maturity**		
	2013-14	**2014-15**	**Pooled**	**2013-14**	**2014-15**	**Pooled**
T_1	129.0^{abc}	133.0^{a}	131.0^{a}	161.5^{c}	163.5^{c}	162.5^{d}
T_2	118.5^{d}	117.0^{b}	117.7^{b}	174.5^{b}	173.0^{ab}	173.7^{c}
T_3	129.5^{ab}	132.0^{a}	130.7^{a}	160.5^{c}	165.5^{bc}	163.0^{d}
T_4	129.0^{abc}	133.0^{a}	131.0^{a}	160.5^{c}	161.5^{c}	161.0^{d}
T_5	118.5^{d}	116.5^{b}	117.5^{b}	176.0^{ab}	174.5^{ab}	175.2^{bc}
T_6	132.0^{a}	131.0^{a}	131.5^{a}	159.0^{c}	161.5^{c}	160.2^{d}
T_7	118.5^{d}	119.5^{b}	119.0^{b}	181.5^{ab}	179.0^{a}	180.2^{ab}
T_8	118.0^{d}	118.0^{b}	118.0^{b}	178.5^{ab}	179.5^{a}	179.0^{abc}
T_9	119.0^{d}	119.5^{b}	119.2^{b}	180.0^{ab}	179.5^{a}	179.7^{ab}
T_{10}	119.5^{cd}	120.0^{b}	119.7^{b}	183.5^{a}	178.5^{a}	181.0^{ab}
T_{11}	118.5^{d}	116.5^{b}	117.5^{b}	181.5^{ab}	181.0^{a}	181.2^{a}
T_{12}	119.5^{cd}	119.5^{b}	119.5^{b}	184.0^{a}	179.0^{a}	181.5^{a}
T_{13}	118.5^{d}	118.5^{b}	118.5^{b}	181.0^{ab}	179.5^{a}	180.2^{ab}
T_{14}	120.0^{bcd}	119.5^{b}	119.7^{b}	179.0^{ab}	180.0^{a}	179.5^{abc}
T_{15}	120.0^{bcd}	120.5^{b}	120.2^{b}	181.5^{ab}	178.5^{a}	180.0^{ab}
Mean	**121.87**	**122.27**	**122.07**	**174.83**	**174.27**	**174.55**
SE(d)	**2.41**	**2.09**	**1.59**	**2.18**	**2.24**	**1.56**
HSD (5%)	**9.74**	**8.46**	**5.92**	**8.82**	**9.06**	**5.80**

HSD (5%) - TUKEY's Honest Significant Difference, NS- Non-significant

*Significant effects are shown with group letters

SE(d)- Standard error of difference,

T_1- Soaking of bulbs in 80 ppm paclobutrazol solution
T_2- Foliar spray of paclobutrazol @ 80 ppm
T_3- Soaking of bulbs in 80 ppm paclobutrazol + foliar spray of paclobutrazol@80 ppm
T_4- Soaking of bulbs in 100 ppm paclobutrazol solution
T_5- Foliar spray of paclobutrazol @ 100 ppm
T_6- Soaking of bulbs in 100 ppm paclobutrazol + foliar spray of paclobutrazol@100 ppm
T_7- Soaking of bulbs in 400 ppm ethaphone solution
T_8- Foliar spray of ethaphone @ 400 ppm
T_9- Soaking of bulbs in 500 ppm ethaphone solution
T_{10}- Foliar spray of ethaphone @ 500 ppm
T_{11}- Soaking of bulbs in 200 ppm triadimefon solution
T_{12}- Foliar spray of triadimefon @ 200 ppm
T_{13}- Soaking of bulbs in 400 ppm triadimefon solution
T_{14}- Foliar spray of triadimefon @ 400 ppm
T_{15}-Control (Water spray)

Table 45. Effect of plant growth retardants on seed scape height and seed scape diameter in onion cv. Pusa Riddhi (Pooled data over two years)

Treatments	Seed scape height (cm)			Seed scape diameter (cm)		
	2013-14	**2014-15**	**Pooled**	**2013-14**	**2014-15**	**Pooled**
T_1	80.75^{cde}	81.9	81.33^{def}	3.63^{a}	3.73^{ab}	3.68^{a}
T_2	86.25^{bcd}	87.65	86.95^{bcde}	3.37^{a}	3.46^{abc}	3.41^{a}
T_3	79.80^{de}	74.9	77.35^{ef}	3.59^{a}	3.73^{ab}	3.66^{a}
T_4	80.30^{cde}	81.55	80.93^{def}	3.60^{a}	3.81^{a}	3.71^{a}
T_5	85.85^{bcd}	86.95	86.4^{bcde}	3.26^{ab}	3.41^{abcd}	3.33^{a}
T_6	71.20^{e}	68.6	69.9^{f}	3.61^{a}	3.75^{ab}	3.68^{a}
T_7	100.20^{a}	98.5	99.35^{ab}	2.41^{c}	2.57^{cde}	2.49^{b}
T_8	97.65^{ab}	97.8	97.73^{abc}	2.58^{bc}	2.80^{bcde}	2.69^{b}
T_9	100.25^{a}	99.75	100^{ab}	2.53^{c}	2.62^{cde}	2.57^{b}
T_{10}	100.30^{a}	92.8	96.55^{abc}	2.49^{c}	2.52^{cde}	2.50^{b}
T_{11}	93.65^{abc}	95.75	94.7^{abcd}	2.35^{c}	2.43^{e}	2.39^{b}
T_{12}	90.70^{abcd}	97.40	94.05^{abcd}	2.55^{c}	2.56^{cde}	2.55^{b}
T_{13}	94.65^{ab}	93.85	94.25^{abcd}	2.52^{c}	2.51^{de}	2.51^{b}
T_{14}	96.40^{ab}	96.75	96.58^{abc}	2.40^{c}	2.90^{cde}	2.65^{b}
T_{15}	102.10^{a}	104.4	103.25^{a}	2.2^{c}	2.42^{e}	2.36^{b}
Mean	**90.67**	**90.57**	**90.62**	**2.88**	**3.01**	**2.95**
SE(d)	**3.42**	**16.46**	**7.07**	**0.17**	**0.23**	**0.14**
HSD (5%)	**13.8**	**NS**	**2.62**	**0.17**	**0.9522**	**0.54**

HSD (5%) - TUKEY's Honest Significant Difference, NS- Non-significant

*Significant effects are shown with group letters

SE(d)- Standard error of difference,

T_1- Soaking of bulbs in 80 ppm paclobutrazol solution
T_2- Foliar spray of paclobutrazol @ 80 ppm
T_3- Soaking of bulbs in 80 ppm paclobutrazol + foliar spray of paclobutrazol@80 ppm
T_4- Soaking of bulbs in 100 ppm paclobutrazol solution
T_5- Foliar spray of paclobutrazol @ 100 ppm
T_6- Soaking of bulbs in 100 ppm paclobutrazol + foliar spray of paclobutrazol@100 ppm
T_7- Soaking of bulbs in 400 ppm ethaphone solution
T_8- Foliar spray of ethaphone @ 400 ppm
T_9- Soaking of bulbs in 500 ppm ethaphone solution
T_{10}- Foliar spray of ethaphone @ 500 ppm
T_{11}- Soaking of bulbs in 200 ppm triadimefon solution
T_{12}- Foliar spray of triadimefon @ 200 ppm
T_{13}- Soaking of bulbs in 400 ppm triadimefon solution
T_{14}- Foliar spray of triadimefon @ 400 ppm
T_{15}-Control (Water spray)

Table 46. Effect of plant growth retardants on number of seed scapes/plant and productive seed scapes/plant in onion cv. Pusa Riddhi (Pooled data over two years)

Treatments	Number of seed scapes per plant			Number of productive seed scapes per plant		
	2013-14	**2014-15**	**Pooled**	**2013-14**	**2014-15**	**Pooled**
T_1	6.95^{bc}	6.45^{de}	6.70^{c}	3.60^{b}	3.25^{b}	3.42^{b}
T_2	10.35^{ab}	10.0^{ab}	10.18^{a}	7.40^{a}	6.45^{a}	6.92^{a}
T_3	7.15^{bc}	7.45^{bcde}	7.30^{bc}	3.60^{b}	2.90^{b}	3.25^{b}
T_4	5.95^{c}	5.70^{e}	5.83^{c}	3.30^{b}	3.25^{b}	3.27^{b}
T_5	10.80^{ab}	11.10^{a}	10.95^{a}	6.80^{a}	6.95^{a}	6.88^{a}
T_6	6.90^{bc}	6.70^{cde}	6.80^{c}	3.80^{b}	3.05^{b}	3.42^{b}
T_7	10.55^{ab}	10.40^{a}	10.48^{a}	7.10^{a}	7.05^{a}	7.08^{a}
T_8	11.30^{a}	11.85^{a}	11.58^{a}	7.20^{a}	7.55^{a}	7.37^{a}
T_9	10.65^{ab}	10.75^{a}	10.70^{a}	7.10^{a}	7.30^{a}	7.20^{a}
T_{10}	9.45^{abc}	9.60^{abc}	9.53^{ab}	7.05^{a}	7.05^{a}	7.05^{a}
T_{11}	9.65^{abc}	9.25^{abcd}	9.45^{ab}	7.25^{a}	7.00^{a}	7.12^{a}
T_{12}	10.30^{ab}	10.80^{a}	10.55^{a}	7.40^{a}	7.15^{a}	7.27^{a}
T_{13}	10.45^{ab}	9.60^{abc}	10.03^{a}	7.40^{a}	7.20^{a}	7.30^{a}
T_{14}	10.30^{ab}	10.50^{a}	10.40^{a}	7.05^{a}	6.95^{a}	7.00^{a}
T_{15}	11.15^{a}	9.90^{ade}	10.53^{a}	7.80^{a}	8.25^{a}	8.02^{a}
Mean	**9.46**	**9.34**	**9.40**	**6.26**	**6.09**	**6.17**
SE(d)	**0.97**	**0.72**	**0.60**	**0.66**	**0.75**	**0.50**
HSD (5%)	**3.94**	**2.94**	**2.25**	**2.68**	**3.02**	**1.85**

HSD (5%) - TUKEY's Honest Significant Difference, NS- Non-significant

*Significant effects are shown with group letters

SE(d)- Standard error of difference,

T_1- Soaking of bulbs in 80 ppm paclobutrazol solution
T_2- Foliar spray of paclobutrazol @ 80 ppm
T_3- Soaking of bulbs in 80 ppm paclobutrazol + foliar spray of paclobutrazol@80 ppm
T_4- Soaking of bulbs in 100 ppm paclobutrazol solution
T_5- Foliar spray of paclobutrazol @ 100 ppm
T_6- Soaking of bulbs in 100 ppm paclobutrazol + foliar spray of paclobutrazol@100 ppm
T_7- Soaking of bulbs in 400 ppm ethaphone solution
T_8- Foliar spray of ethaphone @ 400 ppm
T_9- Soaking of bulbs in 500 ppm ethaphone solution
T_{10}- Foliar spray of ethaphone @ 500 ppm
T_{11}- Soaking of bulbs in 200 ppm triadimefon solution
T_{12}- Foliar spray of triadimefon @ 200 ppm
T_{13}- Soaking of bulbs in 400 ppm triadimefon solution
T_{14}- Foliar spray of triadimefon @ 400 ppm
T_{15}-Control (Water spray)

Fig. 9 Effect of foliar spray of mineral nutrients on chlorophyll 'a 'content (On pooled data over two year's basis)

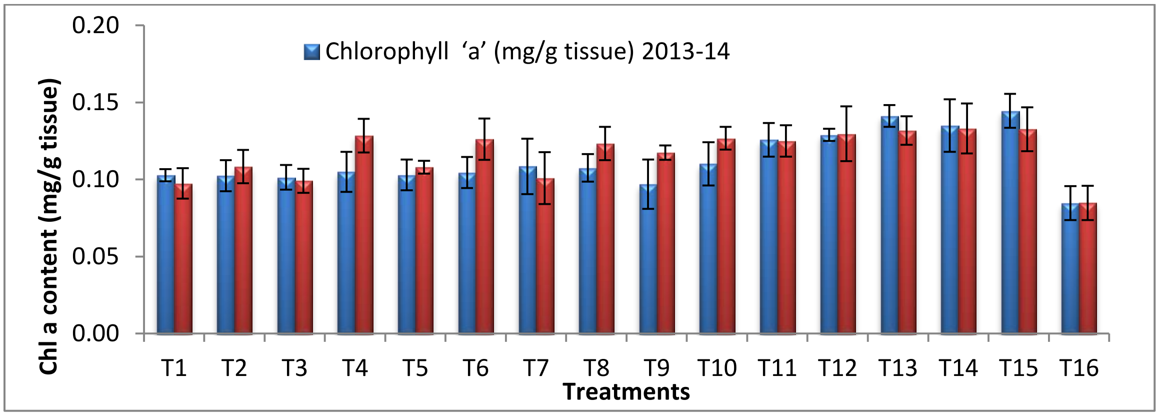


Fig. 10 Effect of foliar spray of mineral nutrients on chlorophyll 'b 'content (On pooled data over two year's basis)

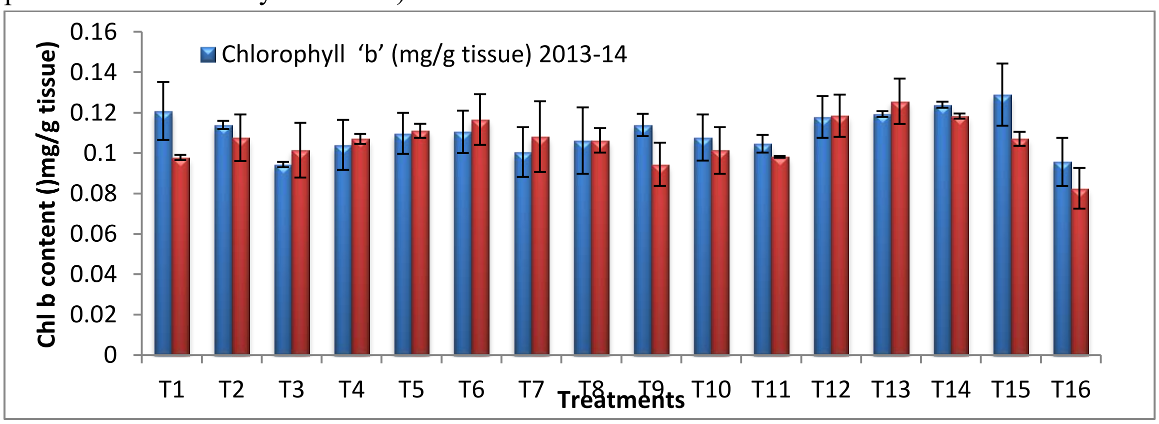


Fig. 11 Effect of foliar spray of mineral nutrients on total chlorophyll content(On pooled data over two year's basis)

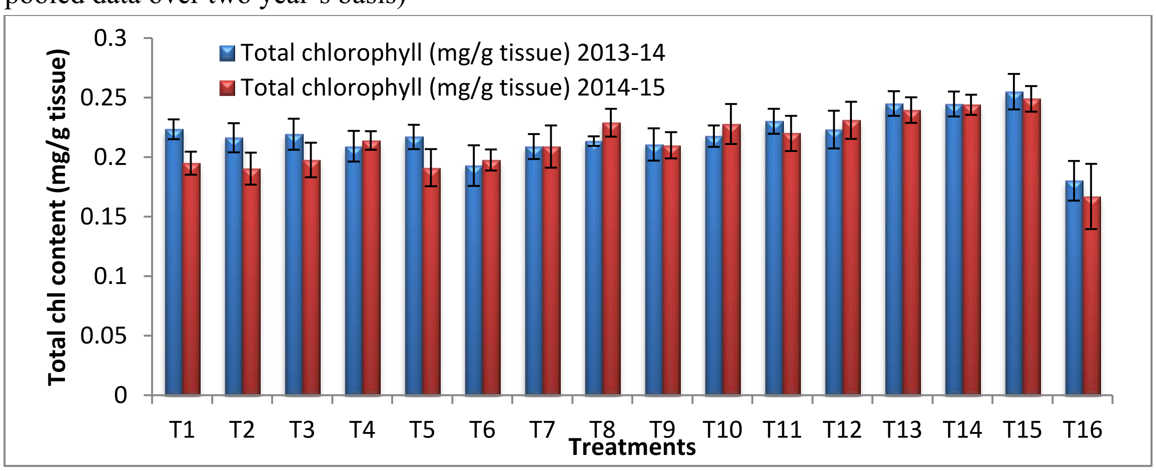


Fig. 12 Effect of growth retardants on number of leaves/plant and seed scape height(On pooled data over two year's basis)

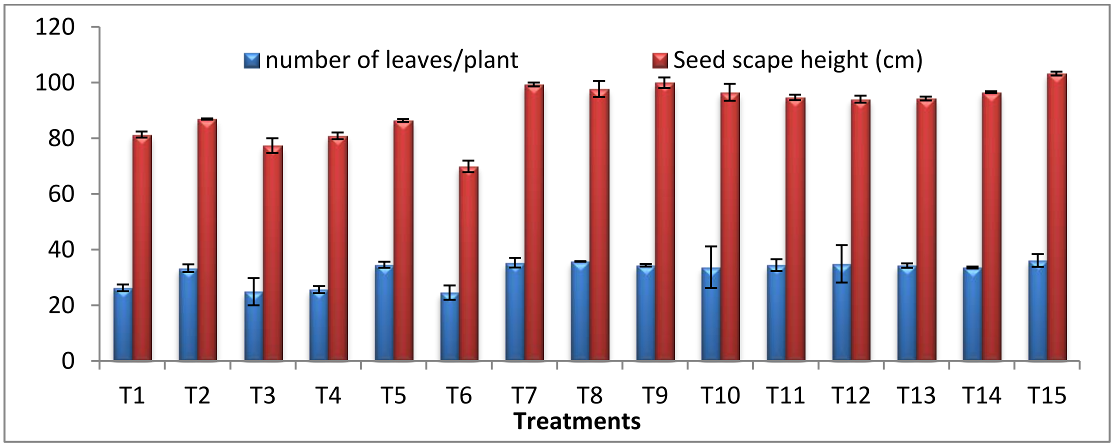


Fig. 13 Effect of growth retardants on seed scape diameter and umbel diameter (On pooled data over two year's basis)

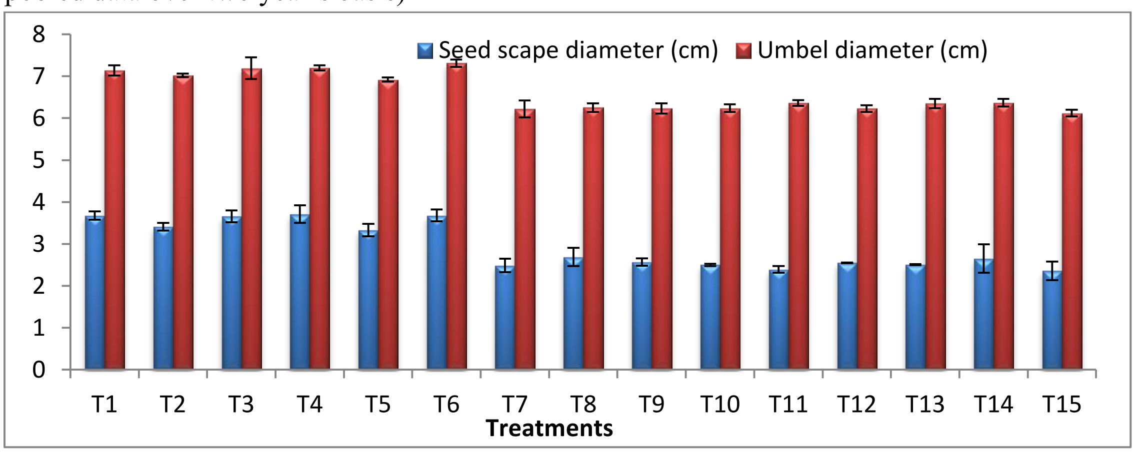


Fig. 14 Effect of growth retardants on umbellates/plant and productive umbellates/plant (On pooled data over two year's basis)

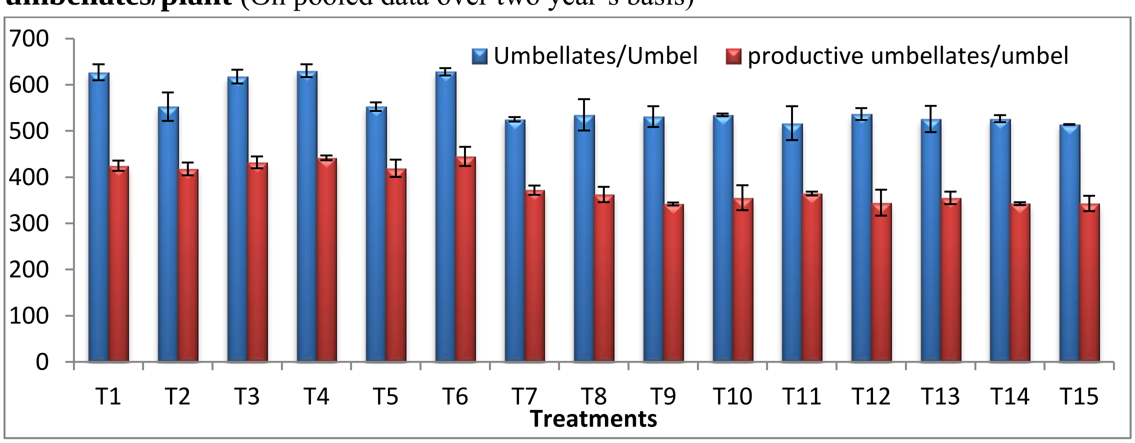


Plate: 8 Effect of growth retardants on seed scape height

Plate: 9 Effect of growth retardants on umbel size treatments (from T7 to T14) also showed higher umbel diameter (ranging from 6.22cm to 6.37cm) than control (6.12cm) (Fig 13) (Plate 9).

4.3.11 Disease infected plants (%)

The data presented in Table 48 showed that application of growth retardants did not affect the disease incidence. Numerically, low disease incidence was recorded in triadimefon treatments (T_{13}) (15.5%) followed by T_{12} (16.5%) and T_{14} (17%). Whereas, control showed higher disease incidence (22.5%) compared to other treatments.

4.3.12 Percent disease index (PDI)

The disease severity was significantly affected by growth retardants application (Table 48). The lower PDI was recorded in T13 (4.50%) followed by T14 (5.16%) and T4 (5.25%). The higher disease severity was observed in ethephon treatments viz., T7 (7.37%), T8 (6.79%) and in control (6.75%).

4.3.13 Number of umbellates per umbel

It was evident from data presented in Table 49 that umbellates/umbel was influenced by growth retardant application particularly bulb soaking treatments of paclobutrazol. The significantly higher number of umbellates/umbel was recorded in T_4 (630.35) followed by T_6 (628.05), T_1 (627) and T_3 (617.80) (Fig 14). The significantly low umbellates/umbel was observed in control (T_{15}) (514.25) but results were at par with ethephon and triadimefon treatments.

4.3.14 Number of productive umbellates per umbel

The significantly higher number of productive umbellates/umbel was noted in T6 (444.80) followed by T4 (441.60) and T3 (431.75) (Table 49) (Fig 14). However, the lower number of productive umbellates/umbel was recorded in control treatment (343.0) which is non-significant with other treatments.

4.3.15 Seed setting percent

Seed setting percent was influenced by growth retardant (Table 50). The foliar spray of paclobutrazol @ 100ppm (T5) showed significantly higher seed setting (75.81%) followed by foliar spray of 80ppm paclobutrazol (T2) (75.57%). The other bulb soaking treatments of paclobutrazol (T1, T3, T4 and T6), ethaphone and triadimefon treatments were statistically at par seed setting % whereas the lower seed setting observed in T12 (64.16%).

4.3.16 1000 seed weight (g)

1000 seed weight showed impact due to application of growth retardants (Table 50). The significantly higher 1000 seed weight was recorded in bulb soaking in 80 ppm paclobutrazol (T1) (3.32g) followed by T3 (3.18g) and T6 (3.11g). The lower 1000 seed weight was recorded in control (2.72g) which was at par with other treatments ranging from T8 to T14.

4.3.17 Seed yield per umbel (g)

Difference was observed for seed yield per umbel with growth retardants application (Table 51). The significantly higher seed yield per umbel was observed in T6 (3.48g) followed by T1 (3.43g) and T4 (3.39g). Whereas, lower seed yield per umbel was noted in T8 and T15 (each 2.79g) which showed at par results with other treatments except T6.

4.3.18 Seed yield per plant (g)

A significantly higher seed yield/plant was recorded in foliar spray of 400ppm triadimefon (T14) (12.67g) followed by T13 (12.40g) and T11 (12.05g) (Table 51). The lower seed yield per plant was observed in bulb soaking treatments of paclobutrazol viz., T6 (6.18g), T3 (6.63g), T1 (6.90g) and T4 (6.93g) which showed significant difference with all other treatments.

4.3.19 Seed yield per plot (g)

The pooled data presented in Table 52 revealed that growth retardant application had affected seed yield/plot. The significantly higher seed yield/plot was noted in foliar spray of 400ppm triadimefon (T14) (633.75g) followed by T13 (620g) and T11 (602.50g) than control (586.25g). However, lower seed yield per plot was recorded in paclobutrazol treatments viz., T6 (308.75g), T3 (331.25g) and T1 (345g) and results were at par with each other.

4.3.20 Seed yield per hectare (q)

The results presented in Table 52 showed that growth retardant application had effected seed yield/ha. The significantly higher seed yield/ha was recorded in foliar spray

Table 47. Effect of plant growth retardants on seed scape lodging % and umbel diameter in onion cv. Pusa Riddhi (Pooled data over two years)

Treat ments	Seed scape lodging %			Umbel diameter (cm)		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
T_1	**(44.18)48.61^{ab}	(44.72) 49.54	(44.45) 49.08^{ab}	7.20^{a}	7.08^{a}	7.14^{a}
T_2	(32.22) 28.45^{cd}	(36.48) 35.42	(34.35) 31.94^{defg}	7.04^{a}	7.00^{a}	7.02^{a}
T_3	(45.73) 49.80^{a}	(50.99) 60.19	(48.36) 54.99^{a}	7.06^{a}	7.32^{a}	7.19^{a}
T_4	(41.95) 44.73^{abc}	(40.3) 42.22	(41.13) 43.48^{abcd}	7.17^{a}	7.23^{a}	7.20^{a}
T_5	(37.38) 36.89^{abcd}	(37.66) 37.35	(37.52) 37.12^{bcde}	6.90^{ab}	6.95^{ab}	6.92^{a}
T_6	(42.11) 44.99^{abc}	(47.95) 55.15	(45.03) 50.07^{abc}	7.26^{a}	7.35^{a}	7.31^{a}
T_7	(34.80) 32.65^{bcd}	(34.36) 32.14	(34.58) 32.39^{de}	6.12^{c}	6.32^{c}	6.22^{b}
T_8	(37.01) 36.26^{abcd}	(36.58) 35.89	(36.79) 36.07^{bcde}	6.30^{bc}	6.20^{c}	6.25^{b}
T_9	(35.19) 33.25^{abcd}	(34.49) 32.09	(34.84)32.67^{cde}	6.29^{c}	6.17^{c}	6.23^{b}
T_{10}	(31.51) 31.46^{cd}	(35.53) 33.8	(33.52) 32.63^{de}	6.28^{c}	6.19^{c}	6.24^{b}
T_{11}	(29.84) 24.83^{d}	(29.57) 24.38	(29.7) 24.6^{e}	6.39^{bc}	6.32^{bc}	6.36^{b}
T_{12}	(33.18) 29.98^{cd}	(23.99) 16.7	(28.58) 23.34^{e}	6.19^{c}	6.27^{c}	6.23^{b}
T_{13}	(29.40) 29.01^{cd}	(29.57) 24.56	(29.48) 26.79^{e}	6.40^{bc}	6.29^{c}	6.35^{b}
T_{14}	(38.09) 25.52^{d}	(30.77) 26.26	(34.43) 25.89^{e}	6.42^{bc}	6.33^{bc}	6.37^{b}
T_{15}	(32.04) 28.17^{cd}	(35.26) 33.58	(33.65) 30.87^{de}	6.08^{c}	6.16^{c}	6.12^{b}
Mean	**(35.37) (34.97**	**(36.55) 35.95**	**(36.42) 35.46**	**6.61**	**6.61**	**6.61**
SE(d)	**4.22**	**9.69**	**0.70**	**0.14**	**0.16**	**0.10**
HSD (5%)	**17.05**	**39.13**	**2.62**	**0.60**	**0.62**	**0.39**

HSD (5%) - TUKEY's Honest Significant Difference, NS- Non-significant

*Significant effects are shown with group letters

** Values in parenthesis are arcsine transformed value

SE(d)- Standard error of difference,

T_1- Soaking of bulbs in 80 ppm paclobutrazol solution
T_2- Foliar spray of paclobutrazol @ 80 ppm
T_3- Soaking of bulbs in 80 ppm paclobutrazol + foliar spray of paclobutrazol@80 ppm
T_4- Soaking of bulbs in 100 ppm paclobutrazol solution
T_5- Foliar spray of paclobutrazol @ 100 ppm
T_6- Soaking of bulbs in 100 ppm paclobutrazol + foliar spray of paclobutrazol@100 ppm
T_7- Soaking of bulbs in 400 ppm ethaphone solution
T_8- Foliar spray of ethaphone @ 400 ppm
T_9- Soaking of bulbs in 500 ppm ethaphone solution
T_{10}- Foliar spray of ethaphone @ 500 ppm
T_{11}- Soaking of bulbs in 200 ppm triadimefon solution
T_{12}- Foliar spray of triadimefon @ 200 ppm
T_{13}- Soaking of bulbs in 400 ppm triadimefon solution
T_{14}- Foliar spray of triadimefon @ 400 ppm
T_{15}-Control (Water spray)

Table 48. Effect of plant growth retardants on disease infected plants/plot (%) and percentage disease index in onion cv. Pusa Riddhi (PDI) (Pooled data over two years)

Treatments	Disease infected plants (%)			PDI
	2013-14	**2014-15**	**Pooled**	**2014-15**
T_1	**(26.53) 20	(25.82) 19	(26.17) 19.5	5.62[b]
T_2	(25.06) 18	(24.26) 17	(24.66) 17.5	5.54[b]
T_3	(25.06) 18	(25.76) 19	(25.41) 18.5	5.50[b]
T_4	(23.41) 16	(26.53) 20	(24.97) 18.0	5.25[bc]
T_5	(25.76) 19	(24.26) 17	(25.01) 18.0	5.75[b]
T_6	(25.82) 19	(25.76) 19	(25.79) 19.0	5.75[b]
T_7	(26.53) 20	(25.76) 19	(26.15) 19.5	7.37[a]
T_8	(26.53) 20	(26.45) 20	(26.49) 20.0	6.79[a]
T_9	(27.21) 21	(25.06) 18	(26.13) 19.5	6.37[b]
T_{10}	(27.87) 22	(25.06) 18	(26.47) 20.0	6.58[a]
T_{11}	(24.33) 17	(25.06) 18	(24.70) 17.5	5.16[bc]
T_{12}	(23.53) 16	(24.26) 17	(23.89) 16.5	5.33[bc]
T_{13}	(23.57) 16	(22.68) 15	(23.12) 15.5	4.50[bc]
T_{14}	(23.41) 16	(25.06) 18	(24.23) 17.0	5.16[bc]
T_{15}	(29.24) 24	(27.21) 21	(28.23) 22.5	6.75[a]
Mean	**(25.59) 18.8**	**(25.27) 18.33**	**(25.43) 18.57**	**5.83**
SE(d)	**3.85**	**3.89**	**2.735**	**0.39**
HSD (5%)	**NS**	**NS**	**NS**	**0.85**

HSD (5%) - TUKEY's Honest Significant Difference, NS- Non-significant

*Significant effects are shown with group letters

** Values in parenthesis are arcsine transformed value

SE(d)- Standard error of difference,

T_1- Soaking of bulbs in 80 ppm paclobutrazol solution
T_2- Foliar spray of paclobutrazol @ 80 ppm
T_3- Soaking of bulbs in 80 ppm paclobutrazol + foliar spray of paclobutrazol@80 ppm
T_4- Soaking of bulbs in 100 ppm paclobutrazol solution
T_5- Foliar spray of paclobutrazol @ 100 ppm
T_6- Soaking of bulbs in 100 ppm paclobutrazol + foliar spray of paclobutrazol@100 ppm
T_7- Soaking of bulbs in 400 ppm ethaphone solution
T_8- Foliar spray of ethaphone @ 400 ppm
T_9- Soaking of bulbs in 500 ppm ethaphone solution
T_{10}- Foliar spray of ethaphone @ 500 ppm
T_{11}- Soaking of bulbs in 200 ppm triadimefon solution
T_{12}- Foliar spray of triadimefon @ 200 ppm
T_{13}- Soaking of bulbs in 400 ppm triadimefon solution
T_{14}- Foliar spray of triadimefon @ 400 ppm
T_{15}-Control (Water spray)

Table 49. Effect of plant growth retardants on number of umbellates/umbel and productive umbellates/umbel in onion cv. Pusa Riddhi (Pooled data over two years)

Treatments	Number of umbellates/umbel			Number of productive umbellates/umbel		
	2013-14	**2014-15**	**Pooled**	**2013-14**	**2014-15**	**Pooled**
T_1	618.50^{ab}	635.50^{a}	627.0^{a}	419.20^{abcde}	430.20^{ab}	424.70^{ab}
T_2	568.10^{bc}	537.20^{c}	552.65^{b}	424.60^{abcd}	410.70^{ab}	417.65^{abc}
T_3	625.30^{a}	610.30^{ab}	617.80^{a}	438.10^{ab}	425.40^{ab}	431.75^{a}
T_4	623.50^{a}	637.20^{a}	630.35^{a}	444.30^{a}	438.90^{ab}	441.60^{a}
T_5	547.90^{cd}	557.20^{bc}	552.55^{b}	428.30^{abcd}	409.50^{ab}	418.90^{abc}
T_6	624.20^{a}	631.90^{a}	628.05^{a}	434.40^{abc}	455.20^{a}	444.80^{a}
T_7	527.50^{cd}	522.70^{c}	525.10^{b}	366.70^{abcdef}	376.80^{ab}	371.75^{bcd}
T_8	551.60^{cd}	517.80^{c}	534.70^{b}	354.0^{cdef}	370.50^{ab}	362.25^{cd}
T_9	542.40^{cd}	520.0^{c}	531.20^{b}	340.30^{ef}	343.40^{b}	341.85^{d}
T_{10}	533.30^{cd}	536.0^{c}	534.65^{b}	341.90^{ef}	368.70^{ab}	355.30^{d}
T_{11}	535.10^{cd}	498.30^{c}	516.70^{b}	362.40^{bcdef}	366.60^{ab}	364.50^{cd}
T_{12}	530.20^{cd}	542.90^{bc}	536.55^{b}	330.40^{f}	358.40^{ab}	344.40^{d}
T_{13}	540.20^{cd}	511.60^{c}	525.90^{b}	348.30^{def}	362.0^{ab}	355.15^{d}
T_{14}	530.20^{cd}	522.60^{c}	526.40^{b}	341.0^{ef}	344.30^{b}	342.65^{d}
T_{15}	514.60^{d}	513.90^{c}	514.25^{b}	334.60^{f}	351.40^{b}	343.0^{d}
Mean	**560.84**	**553.01**	**556.92**	**380.57**	**387.47**	**384.02**
SE(d)	**12.63**	**17.68**	**10.86**	**19.93**	**24.958**	**15.97**
HSD (5%)	**51.05**	**71.44**	**40.28**	**80.56**	**100.84**	**59.20**

HSD (5%) - TUKEY's Honest Significant Difference, NS- Non-significant

*Significant effects are shown with group letters

SE(d)- Standard error of difference,

T_1- Soaking of bulbs in 80 ppm paclobutrazol solution
T_2- Foliar spray of paclobutrazol @ 80 ppm
T_3- Soaking of bulbs in 80 ppm paclobutrazol + foliar spray of paclobutrazol@80 ppm
T_4- Soaking of bulbs in 100 ppm paclobutrazol solution
T_5- Foliar spray of paclobutrazol @ 100 ppm
T_6- Soaking of bulbs in 100 ppm paclobutrazol + foliar spray of paclobutrazol@100 ppm
T_7- Soaking of bulbs in 400 ppm ethaphone solution
T_8- Foliar spray of ethaphone @ 400 ppm
T_9- Soaking of bulbs in 500 ppm ethaphone solution
T_{10}- Foliar spray of ethaphone @ 500 ppm
T_{11}- Soaking of bulbs in 200 ppm triadimefon solution
T_{12}- Foliar spray of triadimefon @ 200 ppm
T_{13}- Soaking of bulbs in 400 ppm triadimefon solution
T_{14}- Foliar spray of triadimefon @ 400 ppm
T_{15}-Control (Water spray)

Table 50. Effect of plant growth retardants on seed setting % and 1000 seed weight in onion cv. Pusa Riddhi (Pooled data over two years)

Treat ments	**Seed setting percentage**			**1000 seed weight (g)**		
	2013-14	**2014-15**	**Pooled**	**2013-14**	**2014-15**	**Pooled**
T_1	**(55.39) 67.78^{abc}	(55.34) 67.69	(55.37) 67.74^{abc}	3.12	3.09	3.11^{ab}
T_2	(59.80) 74.74^{ab}	(60.95) 76.45	(60.36) 75.57^{ab}	2.97	2.9	2.94^{ab}
T_3	(56.81) 70.06^{abc}	(56.58) 69.70	(56.69) 69.89^{abc}	3.15	3.21	3.18^{ab}
T_4	(57.56) 71.26^{abc}	(56.07) 68.88	(56.80) 70.06^{abc}	3.19	2.98	3.08^{ab}
T_5	(62.12) 78.17^{a}	(58.99) 73.49	(60.52) 75.81^{a}	2.96	2.92	2.94^{ab}
T_6	(56.51) 69.59^{abc}	(58.05) 72.04	(57.28) 70.82^{abc}	3.35	3.3	3.32^{a}
T_7	(56.49) 69.53^{abc}	(58.11) 72.06	(57.30) 70.8^{abc}	2.9	2.86	2.88^{ab}
T_8	(53.21) 64.17^{bc}	(57.79) 71.61	(55.50) 67.89^{abc}	2.61	2.94	2.78^{b}
T_9	(52.37) 62.73^{bc}	(54.88) 66.55	(53.63) 64.64^{c}	2.92	2.73	2.82^{ab}
T_{10}	(53.14) 64.04^{bc}	(55.99) 68.74	(54.57) 66.39^{bc}	3.07	2.98	3.02^{ab}
T_{11}	(52.26) 62.56^{bc}	(57.12) 70.53	(54.69) 66.55^{bc}	2.98	2.94	2.96^{ab}
T_{12}	(52.11) 62.29^{c}	(54.33) 66.02	(53.22) 64.16^{c}	2.79	2.89	2.84^{ab}
T_{13}	(53.40) 64.49^{abc}	(57.4) 70.83	(55.40) 67.66^{abc}	2.82	2.86	2.84^{ab}
T_{14}	(53.29) 64.31^{abc}	(54.23) 65.87	(53.76) 65.09^{c}	2.83	2.94	2.89^{ab}
T_{15}	(57.10)70.48^{abc}	(57.69) 71.37	(57.40) 70.92^{abc}	2.72	2.73	2.72^{b}
Mean	**(55.42) 67.73**	**(56.94) 70.16**	**(56.18) 68.94**	**2.96**	**2.95**	**2.96**
SE(d)	**3.03**	**5.45**	**0.70**	**0.17**	**0.24**	**0.14**
HSD (5%)	**12.25**	**NS**	**2.62**	**NS**	**NS**	**0.54**

HSD (5%) - TUKEY's Honest Significant Difference, NS- Non-significant

*Significant effects are shown with group letters

** Values in parenthesis are arcsine transformed value

SE(d)- Standard error of difference,

T_1- Soaking of bulbs in 80 ppm paclobutrazol solution
T_2- Foliar spray of paclobutrazol @ 80 ppm
T_3- Soaking of bulbs in 80 ppm paclobutrazol + foliar spray of paclobutrazol@80 ppm
T_4- Soaking of bulbs in 100 ppm paclobutrazol solution
T_5- Foliar spray of paclobutrazol @ 100 ppm
T_6- Soaking of bulbs in 100 ppm paclobutrazol + foliar spray of paclobutrazol@100 ppm
T_7- Soaking of bulbs in 400 ppm ethaphone solution
T_8- Foliar spray of ethaphone @ 400 ppm
T_9- Soaking of bulbs in 500 ppm ethaphone solution
T_{10}- Foliar spray of ethaphone @ 500 ppm
T_{11}- Soaking of bulbs in 200 ppm triadimefon solution
T_{12}- Foliar spray of triadimefon @ 200 ppm
T_{13}- Soaking of bulbs in 400 ppm triadimefon solution
T_{14}- Foliar spray of triadimefon @ 400 ppm
T_{15}-Control (Water spray)

Table 51. Effect of plant growth retardants on seed yield per umbel (g) and seed yield per plant (g) in onion cv. Pusa Riddhi (Pooled data over two years)

Treatments	Seed yield per umbel (g)			Seed yield per plant (g)		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
T_1	3.39	3.47	3.43^{ab}	7.45^{c}	2.00^{ab}	6.90^{d}
T_2	2.91	2.80	2.86^{ab}	10.35^{b}	2.11^{a}	10.50^{c}
T_3	3.41	3.32	3.37^{ab}	6.75^{c}	1.55^{ab}	6.63^{d}
T_4	3.38	3.4	3.39^{ab}	6.90^{c}	1.73^{ab}	6.93^{d}
T_5	3.18	2.89	3.03^{ab}	10.45^{b}	1.86^{ab}	10.63^{c}
T_6	3.52	3.45	3.48^{a}	6.55^{c}	1.38^{b}	6.18^{d}
T_7	2.91	2.84	2.87^{ab}	10.30^{b}	1.90^{ab}	10.93^{bc}
T_8	2.78	2.80	2.79^{b}	10.75^{ab}	2.11^{a}	10.68^{c}
T_9	3.06	2.97	3.01^{ab}	10.65^{ab}	2.01^{ab}	10.68^{c}
T_{10}	3.41	2.73	3.07^{ab}	10.85^{ab}	2.05^{a}	10.90^{bc}
T_{11}	3.00	2.84	2.92^{ab}	11.90^{ab}	1.97^{ab}	12.05^{abc}
T_{12}	2.74	3.00	2.87^{ab}	11.90^{ab}	2.07^{a}	11.75^{abc}
T_{13}	2.77	2.9	2.84^{ab}	12.30^{ab}	1.96^{ab}	12.40^{ab}
T_{14}	2.90	2.91	2.91^{ab}	12.90^{a}	2.06^{a}	12.67^{a}
T_{15}	2.87	2.72	2.79^{b}	11.30^{ab}	2.07^{a}	11.72^{abc}
Mean	**3.08**	**3.00**	**3.04**	**10.09**	**1.92**	**10.10**
SE(d)	**0.27**	**0.23**	**0.17**	**0.60**	**0.16**	**0.46**
HSD (5%)	**NS**	**NS**	**0.65**	**2.44**	**0.64**	**1.72**

HSD (5%) - TUKEY's Honest Significant Difference, NS- Non-significant

*Significant effects are shown with group letters

SE(d)- Standard error of difference

T_1- Soaking of bulbs in 80 ppm paclobutrazol solution
T_2- Foliar spray of paclobutrazol @ 80 ppm
T_3- Soaking of bulbs in 80 ppm paclobutrazol + foliar spray of paclobutrazol@80 ppm
T_4- Soaking of bulbs in 100 ppm paclobutrazol solution
T_5- Foliar spray of paclobutrazol @ 100 ppm
T_6- Soaking of bulbs in 100 ppm paclobutrazol + foliar spray of paclobutrazol@100 ppm
T_7- Soaking of bulbs in 400 ppm ethaphone solution
T_8- Foliar spray of ethaphone @ 400 ppm
T_9- Soaking of bulbs in 500 ppm ethaphone solution
T_{10}- Foliar spray of ethaphone @ 500 ppm
T_{11}- Soaking of bulbs in 200 ppm triadimefon solution
T_{12}- Foliar spray of triadimefon @ 200 ppm
T_{13}- Soaking of bulbs in 400 ppm triadimefon solution
T_{14}- Foliar spray of triadimefon @ 400 ppm
T_{15}-Control (Water spray)

Table 52. Effect of plant growth retardants on seed yield per plot and seed yield per hectare in onion cv. Pusa Riddhi (Pooled data over two years)

Treatments	Seed yield (g/plot)			Seed yield (q/ha)		
	2013-14	**2014-15**	**Pooled**	**2013-14**	**2014-15**	**Pooled**
T_1	372.50^{c}	317.50^{b}	345.0^{d}	3.73^{c}	3.18^{b}	3.45^{d}
T_2	517.50^{b}	532.50^{a}	525.0^{c}	5.18^{b}	5.33^{a}	5.25^{c}
T_3	337.50^{c}	325.0^{b}	331.25^{d}	3.38^{c}	3.25^{b}	3.31^{d}
T_4	345.0^{c}	347.50^{b}	346.25^{d}	3.45^{c}	3.48^{b}	3.46^{d}
T_5	522.50^{b}	540.0^{a}	531.25^{c}	5.23^{b}	5.40^{a}	5.31^{c}
T_6	327.50^{c}	290.0^{b}	308.75^{d}	3.28^{c}	2.90^{b}	3.09^{d}
T_7	515.0^{b}	577.50^{a}	546.25^{bc}	5.15^{b}	5.78^{a}	5.46^{bc}
T_8	537.50^{ab}	530.0^{a}	533.75^{c}	5.38^{ab}	5.30^{a}	5.34^{c}
T_9	532.50^{ab}	535.0^{a}	533.75^{c}	5.33^{ab}	5.35^{a}	5.34^{c}
T_{10}	542.50^{ab}	547.50^{a}	545.0^{bc}	5.43^{ab}	5.48^{a}	5.45^{bc}
T_{11}	595.0^{ab}	610.0^{a}	602.50^{abc}	5.95^{ab}	6.10^{a}	6.03^{abc}
T_{12}	595.0^{ab}	580.0^{a}	587.50^{abc}	5.95^{ab}	5.80^{a}	5.88^{abc}
T_{13}	615.0^{ab}	625.0^{a}	620.0^{ab}	6.15^{ab}	6.25^{a}	6.20^{ab}
T_{14}	645.0^{a}	622.50^{a}	633.75^{a}	6.45^{a}	6.23^{a}	6.34^{a}
T_{15}	565.0^{ab}	607.50^{a}	586.25^{abc}	5.65^{ab}	6.08^{a}	5.86^{abc}
Mean	**504.33**	**505.83**	**505.08**	**5.04**	**5.06**	**5.05**
SE(d)	**30.29**	**35.20**	**23.22**	**0.30**	**0.352**	**0.23**
HSD (5%)	**122.39**	**142.22**	**86.06**	**1.22**	**1.4222**	**0.86**

HSD (5%) - TUKEY's Honest Significant Difference, NS- Non-significant

*Significant effects are shown with group letters

SE(d)- Standard error of difference,

T_1- Soaking of bulbs in 80 ppm paclobutrazol solution
T_2- Foliar spray of paclobutrazol @ 80 ppm
T_3- Soaking of bulbs in 80 ppm paclobutrazol + foliar spray of paclobutrazol@80 ppm
T_4- Soaking of bulbs in 100 ppm paclobutrazol solution
T_5- Foliar spray of paclobutrazol @ 100 ppm
T_6- Soaking of bulbs in 100 ppm paclobutrazol + foliar spray of paclobutrazol@100 ppm
T_7- Soaking of bulbs in 400 ppm ethaphone solution
T_8- Foliar spray of ethaphone @ 400 ppm
T_9- Soaking of bulbs in 500 ppm ethaphone solution
T_{10}- Foliar spray of ethaphone @ 500 ppm
T_{11}- Soaking of bulbs in 200 ppm triadimefon solution
T_{12}- Foliar spray of triadimefon @ 200 ppm
T_{13}- Soaking of bulbs in 400 ppm triadimefon solution
T_{14}- Foliar spray of triadimefon @ 400 ppm
T_{15}-Control (Water spray)

of 400ppm triadimefon (T14) (6.34q) followed by T13 (6.20q) and T11 (6.03q) than control treatment (5.86q). The lower seed yield per hectare was recorded in paclobutrazol treatments viz., T6 (3.09q), T3 (3.31q) and T1 (3.45q) and results were statistically at par with each other.

4.3.21 Germination percent

The pooled analyzed data presented in Table 53 indicated that growth retardant had non-significant effect on germination percent. However, numerically higher germination was recorded in T8 (91.08%) followed by T3 (90.33%) and T1 (89.91%) with lower germination was recorded in control (T15) (87.99%).

4.3.22 Seedling length (cm)

The pooled data over two years presented in Table 53 showed non-significant effect of growth retardants on seedling length but numerically, higher seedling length was observed in control (T15) (10.82cm) followed by T14 (10.78cm) and T13 (10.67cm). The lower seedling length was noted in paclobutrazol treatment T6 (8.48cm) and T3 (9.28cm).

4.3.23 Seedling dry weight (mg/seedling)

Difference due to the application of plant growth retardants was observed among the treatments (Table 54). The significantly higher seedling dry weight was recorded in T1 and T2 (2.07mg) followed by control (2.03mg). The lower seedling dry weight was observed in T6 (1.44g) followed by T3 (1.56mg).

4.3.24 Electrical conductivity (µmhos/cm/g)

The pooled data presented in Table 54 revealed that electrical conductivity of seed leachates showed non-significant effect for growth retardant. However, numerically lower seed leachates conductivity was recorded in T7 (2.26) and higher in T4 (2.61).

4.3.25 Seed vigour index-I

Seed vigour index-I showed significant difference due to use of growth retardants (Table 55). The significant higher vigour index-I was recorded in T6 (959.73) followed by followed by T15 (952.14) and T14 (950.36). The 100 ppm paclobutrazol treatment both as bulb soaking and foliar spray (T6) showed significant lower vigour index-I (759.73) than other treatments.

4.3.26 Seed vigour index-II

The results presented in Table 55 indicated that growth retardants had effect on vigour index-II and significantly higher vigour index-II was recorded in T1 (186.13) followed by T2 (183.59) and in control treatment (178.67). The lower value for vigour index-II was recorded in T6 (129.12) and T3 (141.03) which was significant lower than rest of the treatments.

4.3.27 Chlorophyll content (mg/g of tissue)

The application of growth retardants had effect on leaf chlorophyll a, b and total chlorophyll content (Figs. 15, 16 &17). The significantly higher total chlorophyll content was observed in paclobutrazol treatments viz., T_1, T_2, T_3, T_4, T_5 and T_6 than control and other treatments (Appendix-VI).

4.3.28 Superoxide dismutase enzyme (SOD)

The growth retardants treatments of onion bulbs particularly paclobutrazol had effect on superoxide dismutase antioxidant in seed (Fig.18). The significantly higher SOD activity was recorded in T1 (0.347 unit/S/mg protein) followed by T2 and T4 than control treatment (0.235 unit/S/mg protein) (Appendix-VII).

4.3.29 Catalase enzyme

Catalase enzymes also affected by application of growth retardants than control. The significantly higher activity of catalase antioxidants was observed in T1 (15.13nmol/min/mg protein) followed by T2 (14.25nmol/min/mg protein) and T6. The lower activity of catalase was noted in T8 (6.34 nmol/min/mg protein) (Fig. 19) (Appendix-VII).

4.3.30 Guaiacol peroxidase

The antioxidant guaiacol peroxidase was not affected by growth retardants treatments (Fig 20). However, higher activity was recorded in T13 (57µlmol/min/mg protein) followed by T1 and T11 (Appendix-VII).

4.3.31 Glutathione reductase

The application of growth retardants influenced the activity of glutathione antioxidants in seed (Fig. 21). The higher activity of glutathione reductase was observed in T1 (4.99unit/s/mg) followed by T3 (4.83 unit/s/mg) and T4 (4.80unit/s/mg). However, the lower activity was noted in control (3.3unit/s/mg) (Appendix-VII).

Table 53 Effect of plant growth retardants on germination percentage and seedling length in onion cv. Pusa Riddhi (Pooled data over two years)

Treat ments	Germination percentage			Seedling length (cm)		
	2013-14	**2014-15**	**Pooled**	**2013-14**	**2014-15**	**Pooled**
T_1	90.00 (71.54)**	89.84 (71.39)	89.91 (71.46)	10.11[ab]	10.29[ab]	10.20
T_2	88.00 (69.75)	89.50 (71.25)	88.75 (70.50)	10.23[ab]	10.27[ab]	10.25
T_3	90.67 (72.21)	90.00 (71.43)	90.33 (71.81)	9.44[bc]	9.13[bc]	9.28
T_4	90.67 (72.31)	89.00 (70.61)	89.83 (71.46)	10.03[ab]	10.19[ab]	10.11
T_5	87.67 (69.42)	89.83 (71.42)	88.74 (70.41)	10.95[a]	10.31[ab]	10.63
T_6	90.17 (71.75)	89.34 (71.13)	89.75 (71.43)	8.75[c]	8.20[c]	8.48
T_7	90.33 (72.40)	88.33 (70.01)	89.33 (71.20)	10.31[ab]	10.36[ab]	10.33
T_8	88.50 (71.23)	93.67 (77.49)	91.08 (74.35)	10.49[a]	10.33[ab]	10.41
T_9	88.84 (73.39)	87.50 (69.32)	88.16 (71.35)	10.22[ab]	10.37[ab]	10.29
T_{10}	89.33 (70.98)	88.50 (70.15)	88.91 (70.56)	10.44[ab]	10.25[ab]	10.34
T_{11}	88.50 (70.65)	89.00 (70.60)	88.75 (70.62)	10.26[ab]	10.54[ab]	10.40
T_{12}	88.00 (70.61)	88.84 (70.45)	88.41 (70.53)	10.29[ab]	10.48[ab]	10.38
T_{13}	87.84 (69.61)	88.83 (70.45)	88.33 (70.03)	10.18[ab]	11.15[a]	10.67
T_{14}	88.00 (71.57)	88.34 (70.15)	88.16 (70.86)	10.63[a]	10.93[ab]	10.78
T_{15}	88.67 (74.26)	87.33 (69.23)	87.99 (71.74)	10.79[a]	10.85[ab]	10.82
Mean	**89.01 (71.45)**	**89.19 (71.01)**	**89.10 (71.23)**	**10.21**	**10.24**	**31.98**
SE(d)	**2.07**	**3.23**	**1.92**	**0.24**	**0.45**	**0.70**
HSD (5%)	**NS**	**NS**	**NS**	**0.99**	**1.82**	**NS**

HSD (5%) - TUKEY's Honest Significant Difference, NS- Non-significant

*Significant effects are shown with group letters

** Values in parenthesis are arcsine transformed value

SE(d)- Standard error of difference,

T_1- Soaking of bulbs in 80 ppm paclobutrazol solution
T_2- Foliar spray of paclobutrazol @ 80 ppm
T_3- Soaking of bulbs in 80 ppm paclobutrazol + foliar spray of paclobutrazol@80 ppm
T_4- Soaking of bulbs in 100 ppm paclobutrazol solution
T_5- Foliar spray of paclobutrazol @ 100 ppm
T_6- Soaking of bulbs in 100 ppm paclobutrazol + foliar spray of paclobutrazol@100 ppm
T_7- Soaking of bulbs in 400 ppm ethaphone solution
T_8- Foliar spray of ethaphone @ 400 ppm
T_9- Soaking of bulbs in 500 ppm ethaphone solution
T_{10}- Foliar spray of ethaphone @ 500 ppm
T_{11}- Soaking of bulbs in 200 ppm triadimefon solution
T_{12}- Foliar spray of triadimefon @ 200 ppm
T_{13}- Soaking of bulbs in 400 ppm triadimefon solution
T_{14}- Foliar spray of triadimefon @ 400 ppm
T_{15}-Control (Water spray)

Table 54 Effect of plant growth retardants on seedling dry weight and electrical conductivity in onion cv. Pusa Riddhi (Pooled data over two years)

Treatments	Seedling dry weight (mg)			Electrical conductivity (μmhos/cm/g)		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
T_1	2.0^{ab}	2.14^{a}	2.07^{a}	2.61	2.30	2.46
T_2	2.11^{a}	2.03^{ab}	2.07^{a}	2.31	2.37	2.34
T_3	1.55^{ab}	1.57^{bc}	1.56^{bc}	2.32	2.86	2.59
T_4	1.73^{ab}	1.89^{abc}	1.81^{ab}	2.62	2.61	2.61
T_5	1.86^{ab}	1.85^{abc}	1.85^{ab}	2.53	2.44	2.48
T_6	1.38^{b}	1.50^{c}	1.44^{c}	2.52	2.38	2.45
T_7	1.90^{ab}	1.90^{abc}	1.90^{ab}	2.29	2.23	2.26
T_8	2.11^{a}	1.82^{abc}	1.97^{a}	2.36	2.78	2.57
T_9	2.01^{ab}	1.88^{abc}	1.94^{a}	2.34	2.39	2.36
T_{10}	2.05^{a}	1.91^{abc}	1.98^{a}	2.64	2.49	2.57
T_{11}	1.97^{ab}	1.75^{abc}	1.86^{ab}	2.18	2.42	2.30
T_{12}	2.07^{a}	1.92^{abc}	2.0^{a}	2.53	2.50	2.51
T_{13}	1.96^{ab}	1.81^{abc}	1.88^{ab}	2.23	2.73	2.48
T_{14}	2.06^{a}	1.89^{abc}	1.98^{a}	2.22	2.39	2.30
T_{15}	2.07^{a}	2.0^{ab}	2.03^{a}	2.38	2.22	2.30
Mean	**1.92**	**1.86**	**1.89**	**2.40**	**2.47**	**2.44**
SE(d)	**0.16**	**0.11**	**0.09**	**0.27**	**0.22**	**0.16**
HSD (5%)	**0.64**	**0.47**	**0.36**	**NS**	**NS**	**NS**

HSD (5%) - TUKEY's Honest Significant Difference, NS- Non-significant

*Significant effects are shown with group letters

SE(d)- Standard error of difference,

T_1- Soaking of bulbs in 80 ppm paclobutrazol solution
T_2- Foliar spray of paclobutrazol @ 80 ppm
T_3- Soaking of bulbs in 80 ppm paclobutrazol + foliar spray of paclobutrazol@80 ppm
T_4- Soaking of bulbs in 100 ppm paclobutrazol solution
T_5- Foliar spray of paclobutrazol @ 100 ppm
T_6- Soaking of bulbs in 100 ppm paclobutrazol + foliar spray of paclobutrazol@100 ppm
T_7- Soaking of bulbs in 400 ppm ethaphone solution
T_8- Foliar spray of ethaphone @ 400 ppm
T_9- Soaking of bulbs in 500 ppm ethaphone solution
T_{10}- Foliar spray of ethaphone @ 500 ppm
T_{11}- Soaking of bulbs in 200 ppm triadimefon solution
T_{12}- Foliar spray of triadimefon @ 200 ppm
T_{13}- Soaking of bulbs in 400 ppm triadimefon solution
T_{14}- Foliar spray of triadimefon @ 400 ppm
T_{15}-Control (Water spray)

Table 55 Effect of plant growth retardants on seed vigour index-I & II in onion cv. Pusa Riddhi (Pooled data over two years)

Treatments	Seed vigour index-I			Seed vigour index-II		
	2013-14	**2014-15**	**Pooled**	**2013-14**	**2014-15**	**Pooled**
T_1	910.22^{a}	924.14^{ab}	917.18^{ab}	179.95	192.32^{a}	186.13^{a}
T_2	900.26^{a}	918.96^{ab}	909.61^{ab}	185.93	181.26^{a}	183.59^{a}
T_3	855.56^{ab}	821.42^{bc}	838.49^{bc}	140.75	141.31^{bc}	141.03^{bc}
T_4	909.61^{a}	906.99^{ab}	908.30^{ab}	156.43	168.54^{abc}	162.49^{ab}
T_5	959.70^{a}	926.01^{ab}	942.85^{a}	163.06	166.11^{abc}	164.58^{ab}
T_6	788.85^{b}	730.60^{c}	759.73^{c}	124.54	133.71^{c}	129.12^{c}
T_7	931.15^{a}	915.07^{ab}	923.11^{ab}	171.59	167.93^{abc}	169.76^{ab}
T_8	928.75^{a}	963.46^{ab}	946.10^{a}	186.77	170.03^{abc}	178.40^{a}
T_9	907.83^{a}	908.00^{ab}	907.92^{ab}	178.49	164.12^{abc}	171.31^{ab}
T_{10}	931.89^{a}	906.82^{ab}	919.36^{ab}	182.95	168.75^{abc}	175.85^{a}
T_{11}	907.62^{a}	938.17^{ab}	922.90^{ab}	174.61	155.90^{abc}	165.26^{ab}
T_{12}	905.08^{a}	930.49^{ab}	917.78^{ab}	182.2	170.69^{abc}	176.44^{a}
T_{13}	894.16^{ab}	990.72^{a}	942.44^{a}	171.69	160.86^{abc}	166.27^{ab}
T_{14}	935.42^{a}	965.29^{ab}	950.36^{a}	181.24	167.26^{abc}	174.25^{ab}
T_{15}	956.92^{a}	947.36^{ab}	952.14^{a}	182.98	174.37^{ab}	178.67^{a}
Mean	**908.2**	**912.9**	**910.55**	**170.88**	**165.54**	**168.21**
SE(d)	**27.06**	**38.53**	**23.54**	**15.08**	**9.81**	**8.99**
HSD (5%)	**109.33**	**155.68**	**87.26**	**60.93**	**39.64**	**33.34**

HSD (5%) - TUKEY's Honest Significant Difference, NS- Non-significant

*Significant effects are shown with group letters

SE(d)- Standard error of difference,

T_1- Soaking of bulbs in 80 ppm paclobutrazol solution
T_2- Foliar spray of paclobutrazol @ 80 ppm
T_3- Soaking of bulbs in 80 ppm paclobutrazol + foliar spray of paclobutrazol@80 ppm
T_4- Soaking of bulbs in 100 ppm paclobutrazol solution
T_5- Foliar spray of paclobutrazol @ 100 ppm
T_6- Soaking of bulbs in 100 ppm paclobutrazol + foliar spray of paclobutrazol@100 ppm
T_7- Soaking of bulbs in 400 ppm ethaphone solution
T_8- Foliar spray of ethaphone @ 400 ppm
T_9- Soaking of bulbs in 500 ppm ethaphone solution
T_{10}- Foliar spray of ethaphone @ 500 ppm
T_{11}- Soaking of bulbs in 200 ppm triadimefon solution
T_{12}- Foliar spray of triadimefon @ 200 ppm
T_{13}- Soaking of bulbs in 400 ppm triadimefon solution
T_{14}- Foliar spray of triadimefon @ 400 ppm
T_{15}-Control (Water spray)

Fig. 15 Effect of growth retardants on chlorophyll 'a 'content (On pooled data over two year's basis)

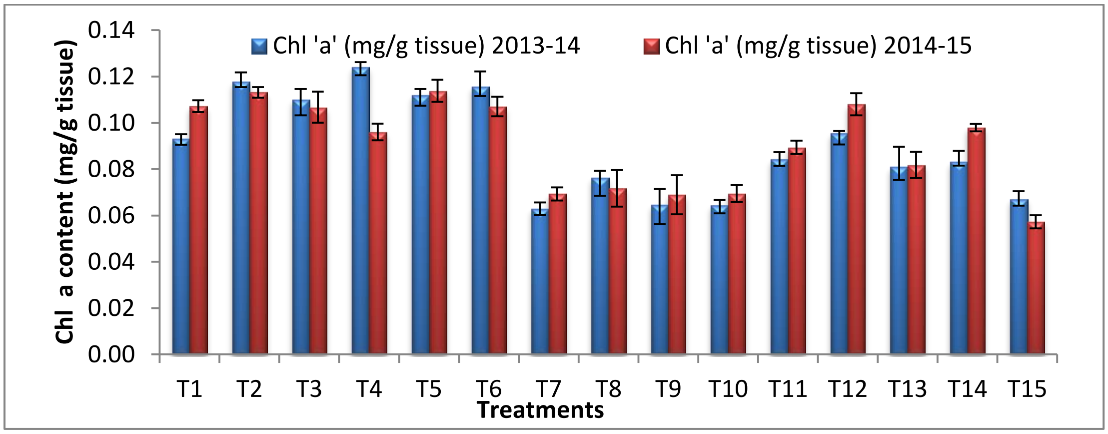


Fig. 16 Effect of growth retardants on chlorophyll 'b 'content (On pooled data over two year's basis)

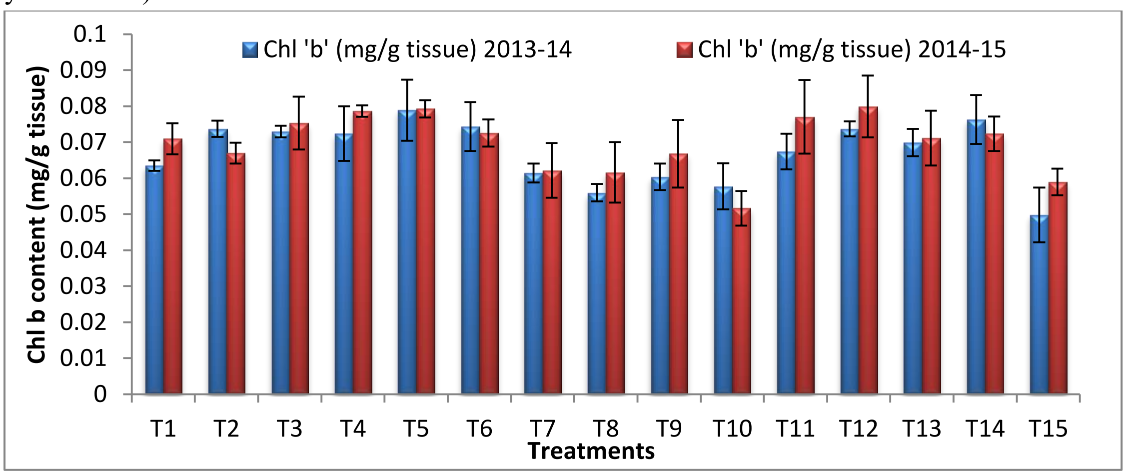
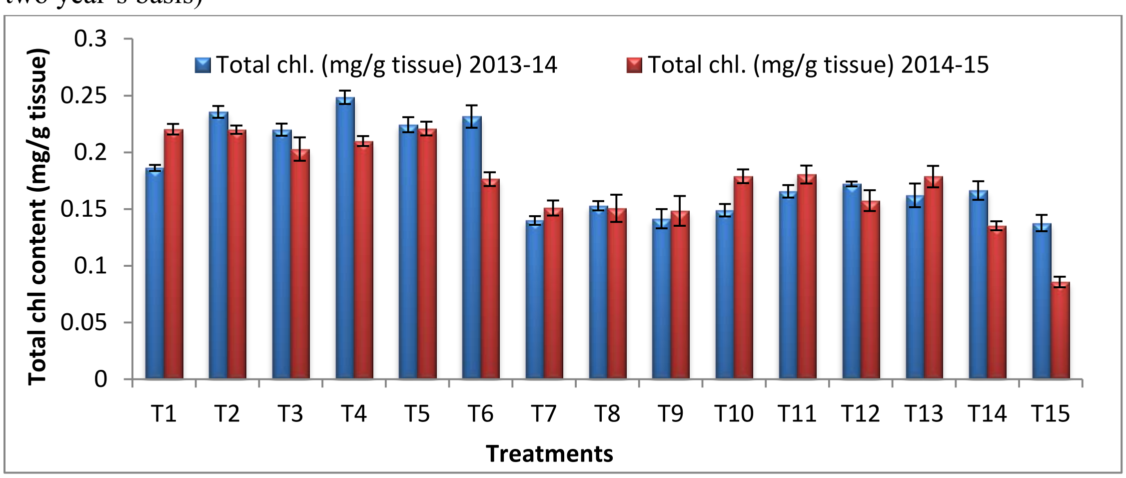


Fig. 17 Effect of growth retardants on total chlorophyll content (On pooled data over two year's basis)



5. Discussion

The present investigation entitled **"Optimization of quality seed production in onion (*Allium cepa* L.) Cv. Pusa Riddhi"** was carried out with the objectives to study

1. Effect of the planting time and crop geometry on growth, seed yield and quality
2. Effect of the foliar application of different mineral nutrients on growth, seed yield and quality
3. Effect of the plant growth retardants application on seed scape height, seed yield and quality attributes

The experiments were carried out at Seed Production Unit, farm Indian, Agricultural Research Institute during *rabi* season of 2013-14 and 2014-15, and laboratory observations were observed at Division of Seed Science and Technology and Division of Plant Physiology, IARI. The observations on various characters recorded in the experiments were subjected to pooled analysis and their results have been discussed here under.

5.1 Effect of planting time and crop geometry on growth, seed yield, and seed quality

5.1.1 Effect of planting time and crop geometry on growth attributes

The better vegetative growth of plant played an important role in attaining the higher seed yield and quality through higher production and supply of photosynthates. The number of leaves was significantly higher under wider spacing (S3) as compared to other treatments. The higher number of leaves/plants in wider spacing (S3) attributed to the better availability of nutrition and light which might favoured the production of more photosynthates ultimately resulting into more number of leaves/plant. The results are in agreement with Singh and Sachan (1999), Pandey *et al.* (1992) and Begum *et al*. (1998) in onion. The late planting of bulbs i.e. 5th November took less time for seed scape initiation (55.72 days) than early planting (66.44 days). The significantly less time taken by late planting may be due to the availability of low temperature during December and January which promotes an early initiation of seed scape in late planting. The similar results were reported by Asaduzzaman *et al.,* (2012) in onion seed production. The seed scape height and umbel diameter were also significantly higher in early planting (15th October) than later. It could be due to the fact that in early planting plants received longer

Fig. 18 Effect of growth retardants on SOD content in seed

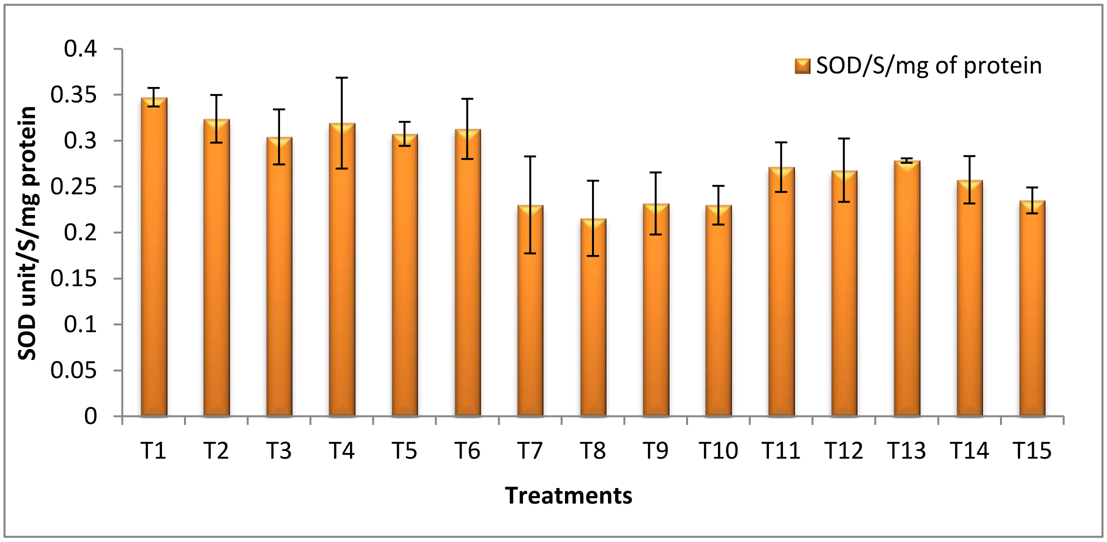


Fig. 19 Effect of growth retardants on catalase content in seed

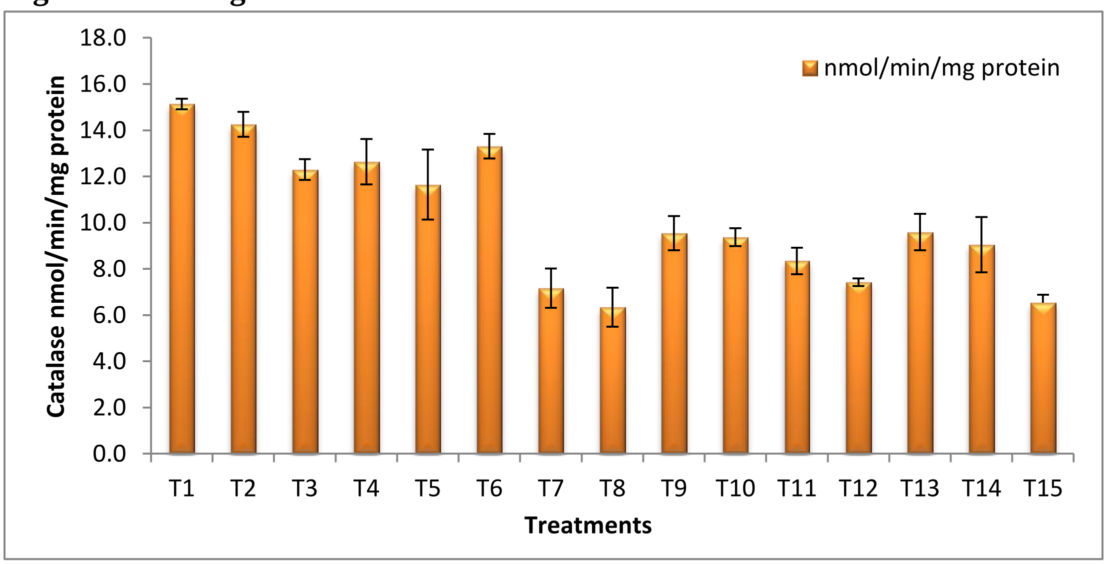


Fig. 20 Effect of growth retardants on peroxidase content in seed

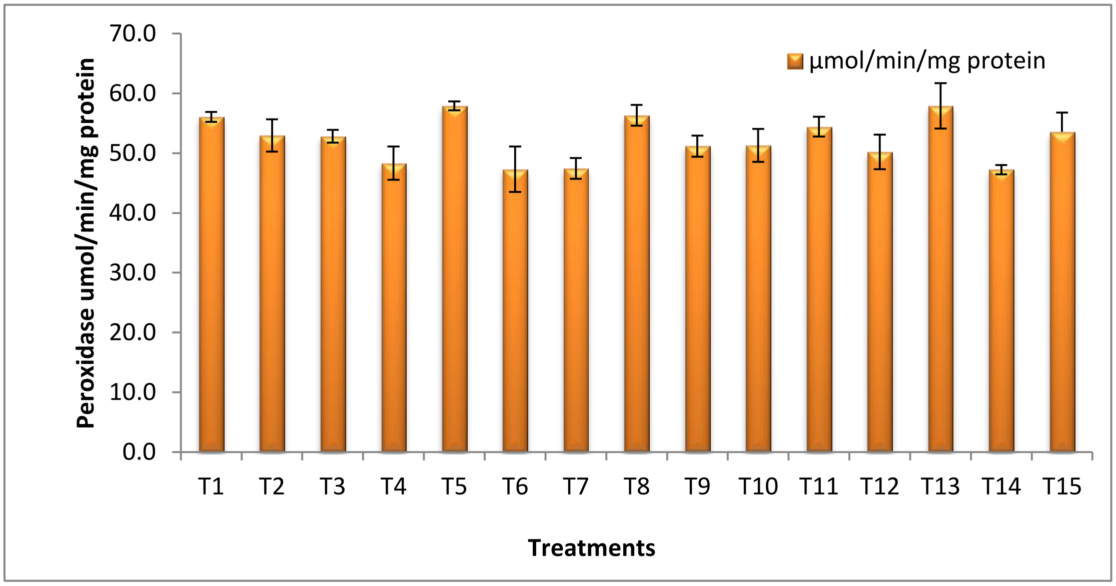
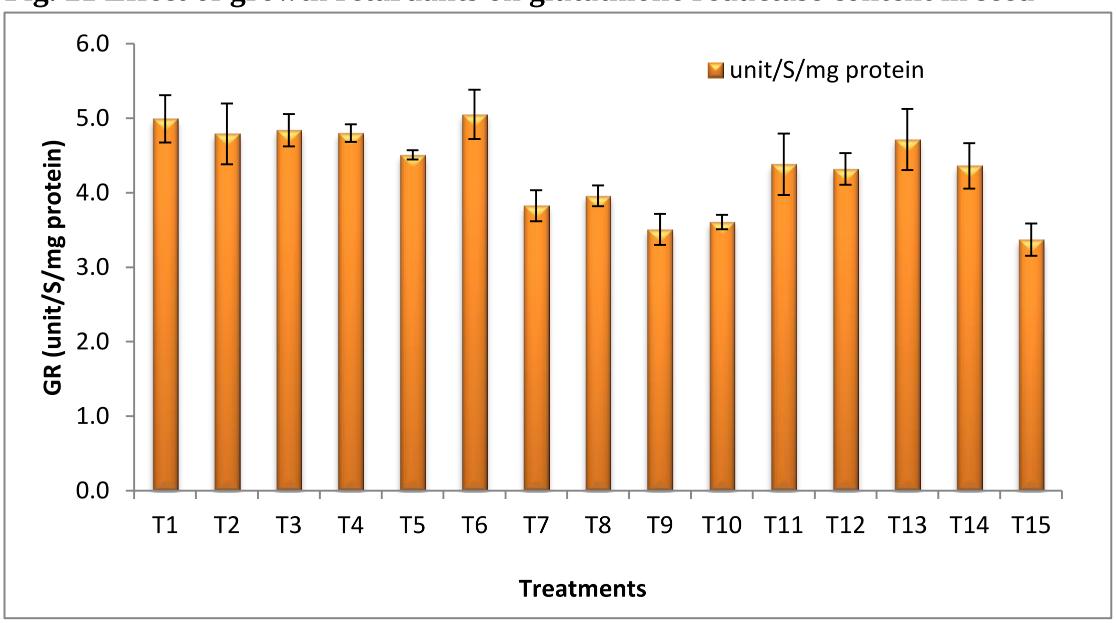


Fig. 21 Effect of growth retardants on glutathione reductase content in seed



period for growth and development and promoted better vegetative growth as evident in more number of leaves/plant in early planting. The higher number of leaves per plant in 15^{th} October had contributed more photosynthates, resulting into significant increase in seed scape height and umbel diameter in 15^{th} Oct planting (T_1).

Seed scape height, scape diameter, total number of seed scapes/plant, productive seed scapes/plant and umbel diameter were recorded significantly superior in wider spacing (60×30cm) than closer spacing and it could be due to the less competition for nutrition and light in wider spacing than the closer. The results are in agreement with Pandey *et al*., (1992) Ibrahim *et al.,* (1996) and Helaly and Karam (2012) in onion. The maturity of umbel had taken significant higher days in early planting with wider spacing and it may be attributed to the better vegetative growth that favoured the delay in maturity. The seed scape lodging percent was significant lower (22.43%) in wider spacing and showed significant increase in lodging with decreasing in spacing. The low seed scape lodging in wider spacing could be due to lower disease incidence and severity and also due to strong scape as evidenced in higher scape diameter.

5.1.2 Effect of planting time and crop geometry on flowering traits

The initiation of flowering was significantly delayed in early planting (15^{th} Oct.) (Table 3) and attributed to better vegetative growth and availability of nutrition which has prolonged the vegetative phase. Contrary to that, the rising temperature at the end of February might favour an early initiation in late plantings than 15^{th} October. The total umbellates/umbel was significantly higher in wider spacing (60×30cm) than closer spacing and it might be due to availability of more photosynthates and less competition for moisture and light in wider spacing. Secondly, production of more number of leaves/plant in wider spacing (S3) also helped in attain the higher number of umbellates/umbel (Fig. 2).

The productive umbellates/umbel and percent seed setting significantly higher in early planting and wider spacing and reduction was realized in late planting coupled with reduced spacing. The interaction was also significant for productive umbellates and seed setting which could be attributed to the higher number of umbellates/umbel in early planting and wider spacing. The reduction in productive umbellates and seed setting in delayed planting and closer spacing were due to the coincidence of high temperature conditions during flowering which resulted in poor pollination and fertilization due to decrease pollen viability and stigma receptivity. Inadequate pollinators activities might have also reduced the number of productive umbellates/umbel and seed setting. The similar results were reported by Balraj *et al.*, (2005) and Anisuzzaman *et al.*, (2009). Begum *et al.* (1998) also recorded the highest number of productive umbellates/umbel in wider spacing.

5.1.3 Effect of planting time and crop geometry on disease development and severity

The planting density had significant effect on disease incidence and disease severity (Table 7 & 8). The disease infection and severity showed increasing trend with reduction in spacing. The enhanced disease infection and severity (stemphylium blight and purple blotch) were due to less transmission of light and air under higher density which provide congenial environment for fungal growth and development at closer spacing than wider spacing. Whereas in wider spacing (60×30cm) the disease incidence and severity were significantly lower due to limited opportunity to inoculum for contamination.

5.1.4 Effect of planting time and crop geometry on seed yielding attributes

Seed yield is complex character and greatly influenced by number of characters viz., vegetative growth, number of productive umbel, higher seed setting, lower incidence of disease with less severity and 1000 seed weight.

The 1000 seed weight was superior in wider spacing and attributed to better availability of nutritions to developing seed due to higher number of leaves/plant and less competition for source resulting better translocation of photosynthates into seeds. However, 1000 seed weight had decreased with delaying in planting which was due to lesser time available for vegetative growth resulting into low accumulation of food reserve into seed and had immature seed.

The higher seed yield per umbel under wider spacing (S_3) with early planting (15^{th} October) was due to the more number of umbellates/umbel, productive umbellates/umbel, seed setting and 1000 seed weight. The results were in agreement with El-Aweel & Ghobashi (1999) and Helaly and Karam (2012). Seed yield per plant was recorded significant higher in T_1 and S_3 (Fig. 22) compared to delayed planting and high density which could be due to more number of leaves/plant, better seed scape traits, more productive seed scape, productive umbellates/umbel, and 1000 seed weight and also optimum temperature for the development of seed in early planting. Teshome, *et al.*, (2014) had reported similar results in onion.

The higher seed yield per plot and seed yield per hectare (Fig. 22) was recorded in early planting (15^{th} October) which could be due to the higher vegetative growth, more number of seed scape/plant, higher productive seed scape/plant, higher productive umbellates/umbel seed setting % and lower disease incidence and severity in early planting than late planting. The results are in confirmity with Mohamedali G H and Nourai A H (1988); Ibrahim *et al*., (1996); Mosleh (2008) and Mehri *et al.*, (2015).

The significantly higher seed yield/plot and seed yield/ha were recorded in closer spacing (60×10cm) than wider spacing which could be due to higher number of plants under closer spacing than wider spacing which resulted into higher seed yield. The results were in agreement with Balraj *et al.,* (2005) and contrary to Narendra and Ahmed (2005), and due to the variation in climatic condition and long day variety in their experiment.

5.1.5 Effect of planting time and crop geometry on seed quality attributes

Time of planting and density had significant effect on germination. Significant higher germination percent was recorded in early planting (15^{th} October) and low density (S_3) than other plantings and densities. The higher germination % in early planting and wider spacing was due to the sound development of seed which was evident from the higher 1000 seed weight in S_3 and T_1. However, decreasing trend was observed in late planting for germination which indicates the poor development of seed. Similar results were reported by Ayoub and Hala (2013).

The seedling length and seedling dry weight were recorded higher under early planting (15^{th} October) than late planting (5^{th} November) which could be due to higher 1000 seed weight. The wider spacing (60 × 30 cm) had produced significantly higher seedling length and dry weight than closer spacing and increase in both the traits attributed to higher availability of nutrition's and moisture for the developing seed. The results are in agreement with Verma *et al.*, (1994) and Singh & Sachan (1999).

The planting time had significant influence on seed vigour index-I & II and higher vigour index-I (833.32) & II (167.08) were observed under early planting which could be due to the higher germination percent, seedling length and seedling dry weight under early planting (15th October) than late planting and results were in agreement with Malik *et al*., (1999). The higher vigour index-I (918.56) and vigour index-II (172.96) were noted in wider spacing due to higher germination percent, seedling length and seedling dry weight.

The electrical conductivity of seed leachates was significantly in wider spacing which indicates the sound development of seed due to higher opportunity to get nutrition in wider spacing. The higher B:C ratio was obtained under wider spacing which could be mainly due to higher bulb cost under closer spacing which increased the cost of production and decreased the B:C ratio.

The wider spacing leads to development of higher leaf chlorophyll content in both the season than high density and reduction in leaf chlorophyll content under closer spacing was due to shading effect to lower canopy of plants, causing poor transmission of the photo-synthetically active radiation (Brahim *et al.,* 1998) resulting into less chlorophyll content under higher density of plant than wider spacing (Fig 4, 5 and 6).

5.2 Effect of foliar application of different mineral nutrients on growth, seed yield and seed quality

The level of mineral nutrients in soil is continuously depleting due to the intensive crop cultivation, use of high yielding varieties, high soil pH, use of poor quality irrigation water, loss of mineral nutrients by leaching, imbalance application of NPK fertilizers, loss of top soil by erosion, non-addition of organic manure and lack of awareness & limited use makes the soil becomes hungry for mineral nutrients (Fageria *et al.,* (2002); (Narimani *et al.,* 2010). The foliar application of mineral nutrients could be effectively utilized for remedying their short falls and enhancing crop yield and quality.

5.2.1 Effect of foliar spray of mineral nutrients on growth attributes and disease development

The foliar application of B, Zn^{+2}, Ca^{+2} and Mg^{+2} as a single or in different combinations significantly influenced the different growth parameters. However, the number of leaves per plant and days to seed scape emergence were not significantly affected by foliar spray of mineral nutrients. Significantly higher scape height was recorded in 125% RD of Zn (T_6) (105.35cm) compared to control (100.20cm) that may be attributed to the fact is that zinc play important role the synthesis of tryptophan, which

Fig. 22 Effect of planting time and density on seed yield/plant and seed yield/ha (On pooled data over two year's basis)

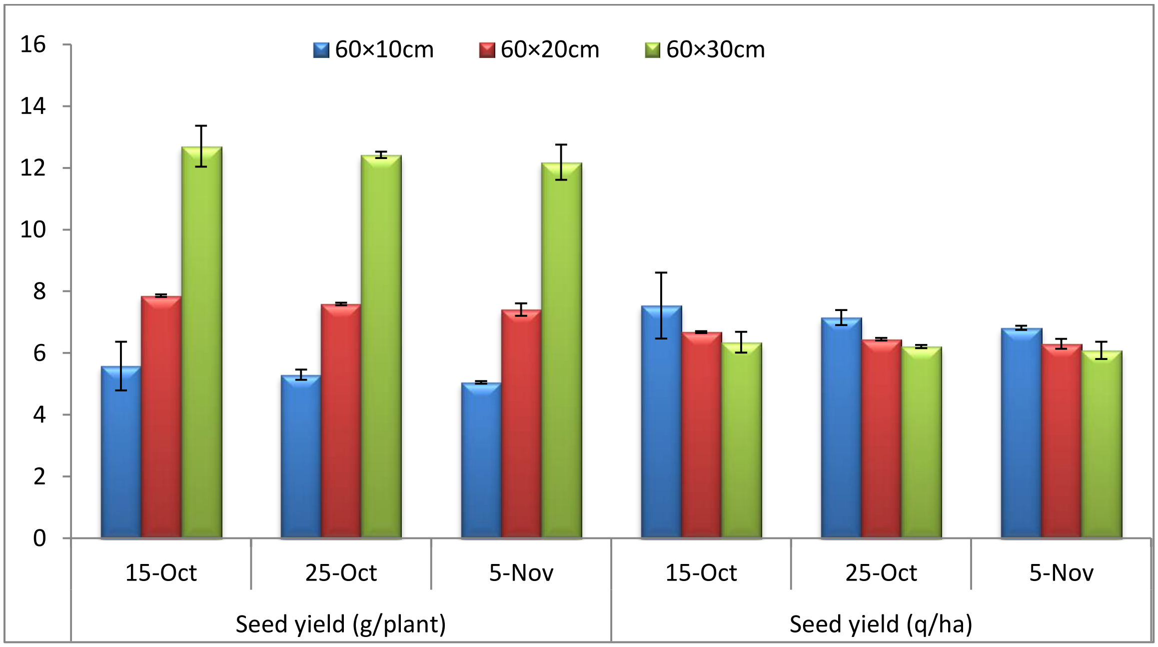
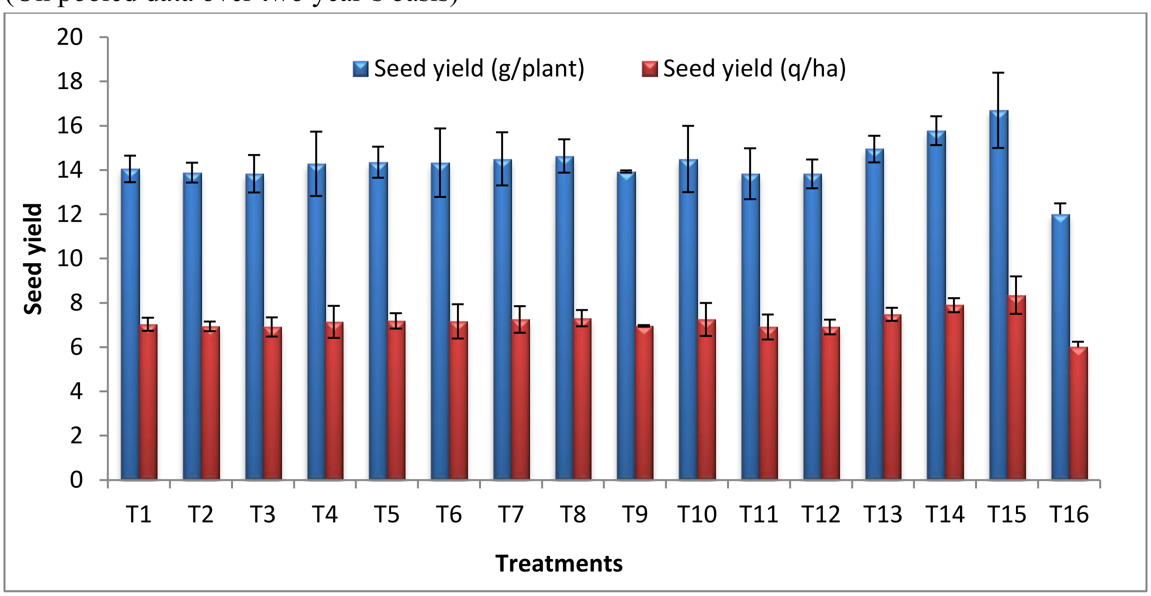


Fig. 23 Effect of foliar spray of mineral nutrients seed yield/plant and seed yield/ha (On pooled data over two year's basis)



is a precursor of growth promoting substance (Indol Acetic Acid). The numbers of seed scape per plant and seed scape diameter were influenced by foliar spray of mineral nutrients.

The foliar spray of mineral nutrients had significantly reduced the disease incidence and percent disease index (PDI) as compared to control. The significant reduction in disease severity index was noted in T_{14} (4.00%) and T_4 (4.25%). The reduction in disease incidence and severity as compared to control could be due to antifungal property of zinc and vital role of other minerals in development of disease resistance in plants. The results were corroborated with Trehan *et al*., (1995) who had reported the reduction in late blight of potato through zinc application and Usama *et al.*, (2013); Abd-El karem *et al.*, (2004) in the control of *Alternaria* blight. The seed scape lodging percent was remained unaffected with the spray of mineral nutrients but comparatively lower level of seed scape lodging was realized even after the strong wind and western disturbance during late flowering.

The number of productive scapes per plant was significant higher in all treatments of mineral nutrients compared to control. The higher number of productive scape/plant could be due to lower disease incidence and severity resulting into the reduced seed scape lodging. The mineral nutrients sprayed plants were taken higher number of days to maturity than control which is due to higher level of chlorophyll content (Fig.9, 10, 11).

5.2.2 Effect of foliar spray of mineral nutrients on flowering

The foliar spray of mineral nutrients had at par effect on initiation of flowering in both year of seed production. The numbers of umbellates/umbel and umbel diameter were significantly superior in combined foliar spray of B+Zn+Ca+Mg (T_{15}) followed by T_{14} and T_{13}. The higher number of umbellates/umbel and umbel diameter in T_{15} may be attributed to the involvement of boron in metabolic processes and reproductive development particularly on microsporogenesis. The enhanced photosynthetic activity due to higher chlorophyll content (Fig. 9, 10, 11) might promote the number of umbellates/umbel and umbel diameter. The similar results have been reported by many workers (Davis *et al*., 2003; Basavarajeswari *et al*., 2008 in tomato and Yaseen *et al.*, 2013 in cotton).

The significantly higher productive umbellates/umbel and seed setting % in T_{15} followed by T_{14}, T_{13}, T_3 and T_2 which might be due to the beneficial impact of boron in pollen tube growth, pollen viability, stigma receptivity and pollination (Huang and Dell, 2000) (Pandey and Gupta, 2012) and biosynthesis of endogenous hormones responsible for better development of reproductive organs (Battal, 2004; Hansch and Mendel, 2009). Percia *et al.,* (2001) and Asad *et al.,* (2003) studies also support the results and revealed that B deficiency highly affects the reproductive yield than biomass yield, even in the absence of any visible symptoms of deficiency.

5.2.3 Effect of foliar spray of mineral nutrients on seed yielding traits

The significantly superior 1000 seed weight in T_{15} and T_{14} than others indicated the beneficial role of B, Zn, Ca and Mg through increased vegetative growth and better translocation of carbohydrates from leaves to seed resulting into higher accumulation of food reserves (Barker and Pilbeam, 2007; Masoud *et al*., 2012).

The highest seed yield/umbel and seed yield/plant were obtained in combined application of nutrients in T_{15} and T_{14} (Fig. 23). The highest seed yield/umbel and seed yield/plant in T_{15} and T_{14} attributed to positive effects of these elements in activation of metabolic enzymes for photosynthates translocation, carbohydrate metabolism, synthesis of proteins and activation of oxidation process resulting into better vegetative growth and accumulation of higher food materials which finally converted into higher seed yield (Verma *et al*., 2004; Movahhedi-Dehnavi *et al.,* 2009). Rafique *et al*., (2011) and Yaseen *et al.,* (2013) also reported similar result for application of mineral nutrients on yield attributing traits.

Foliar spray of mineral nutrients had significant effect on seed yield per plot and seed yield per hectare (Fig. 23). The significantly higher seed yield per plot and seed yield per hectare were recorded in combined application of RD of B+Zn+Ca+Mg at 30 and 60 DAP in T_{15} followed by T_{14} and T_{13} which might be due to higher number of productive umbellates/umbel, higher seed setting percent, higher 1000 seed weight, seed yield per umbel and higher seed yield per plant. Vahid *et al.,* (2010) in soybean and Gurmani *et al.,* (2012) in tomato also observed similar result and revealed that combined application of different mineral nutrients gave higher yield per hectare.

5.2.4 Effect of foliar spray of mineral nutrients on seed quality attributes

The seed quality attributes viz., germination percent, seedling length, seedling dry weight, vigour index-I &II and electrical conductivity of seed leachates increased due to application of mineral nutrients.

The higher germination percent (91.84) in T_{15} with combined foliar spray of B+Zn+Ca+Mg at 30 and 60 DAP followed by T14 (90.83) with the spray of B+Zn+Ca at 30 and 60 DAP could be attributed to higher accumulation of photosynthates and increased the activation of enzymes through mineral nutrients viz., B, Zn and Ca which acts as a co-factors for many metabolic enzymes. The similar results were also reported by (Vaganov and Sorokina, 1970) in cucumber, (Sharkawy *et al*., 1987) in summer squash, (Sharma, 1995) in tomato and (Ranthnavel *et al.*, 1999 and Yallapa *et al*., 2006) in cotton.

Seedling length and seedling dry weight were also significantly high in T_{15} and at par with T_{14}. The higher seedling length and dry weight in T_{15} was due to higher 1000 seed weight and better seed maturation which was catalyzed by micronutrient through different metabolic activities. The results are in agreement with Yallapa *et al*., 2006 and Habib, 2009).

The seed vigour index-I and II were significantly higher in T_{15} (990.34 & 240.73) and T_{14} (966.21 & 238.04) than control (792.76 & 179.23). The higher vigour index-I and II in T_{15} and T_{14} could be due to higher germination percent, seedling length and seedling dry weight in combined application of mineral nutrients and results are corroborated with findings of Ranthnavel *et al.,* (1999) and Yallapa *et al*., (2006). The better seed quality under mineral nutrients treatments was evident by lower electrical conductivity in T_{14} (1.50 µmhos/cm/g) followed by T_{15} (1.65µmhos/cm/g) than control (2.32 µmhos/cm/g). The lower electrical conductivity in T_{14} and T_{15} was attributed to higher stability of membrane and cell wall which is highly affected by combination of different mineral nutrients particularly boron, zinc and calcium (Brown *et al.,* 2002).

5.2.5 Effect of foliar spray of mineral nutrients on leaf chlorophyll content

The chlorophyll a, b and total chlorophyll content were significantly affected by application of mineral nutrients. All the treatments showed higher leaf chlorophyll content than control whereas, maximum amount of chlorophyll a, b and total chlorophyll were recorded in combined application of boron, zinc, calcium and magnesium (Fig. 9, 10, 11) which could be due to these mineral nutrients which have important role in chlorophyll formation particularly magnesium and zinc through activation of protein synthesizing machinery which ultimately affects the chlorophyll synthesis and increase the vegetative growth of plant (Singh, 1969 and Verma *et al.,* 2004).

The higher B: C ratio in best treatment (T_{15}) (2.08) than T_{16} (1.52) revealed that higher benefit can be achieved through application of mineral nutrients

5.3 Effect of different plant growth retardants on seed scape height, seed yield and quality

Growth retardants are important substances which have potential to modify the plant growth and flowering behavior. Onion seed production in north Indian conditions is very risky because of strong winds due to western disturbance during flowering and maturation stage caused the lodging of seed scape and ultimately affects the seed yield and quality hence, farmers are reluctant to take the seed production. In order to make seed production feasible in north India, plant growth retardants can play an important role by reducing the seed scape height and increasing the scape thickness thus, can prevent the lodging of seed scape and result into higher seed yield and quality. Generally, plant growth retardants are known for affecting the plant height through inhibition of GA_3 biosynthesis. Paclobutrazol and triadimefon are trizole compounds and act as growth retardants, which reduce the plant height through blocking of GA_3 biosynthesis at the step between *ent*- kaurene and *ent*-keurenoic acid (Rademacher, 2000). Whereas, ethephon suppress the shoot growth *via* liberation of ethylene, which interferes in the growth process (Davies, 1995).

5.3.1 Effect of growth retardants on growth attributes and disease incidence

The number of leaves per plant was significantly reduced with paclobutrazol application (soaking of bulbs in 80 & 100 ppm+foliar spray). The reduction in number of leaves/plant in T6, T1, T3 and T4 might be due to the inhibition of GA synthesis pathway which leads to the reduction in number of sprouts from bulb. The findings are in agreement with the reports of Globerson *et al.,* (1989) and Ashrafuzzaman *et al*., (2009) in onion. The significant delay in the seed scape emergence with the application of paclobutrazol (soaking + foliar spray) could be due to the inhibitory action of the paclobutrazol compounds on biosynthesis of endogenous hormones resulted the delay in seed scape emergence.

The significant reduction in seed scape height with the use of paclobutrazol and comparative reduction with application of ethephon and triadimefon attributed to the fact that these retardants act on iso-propanoid pathway and block the production of GAs which is required for scape expansion. The similar results were also reported by Mansuroglu *et al*., (2009); Currey and Lopez, (2010).

The application of retardants had significantly changed the diameter of seed scape and under paclobutrazol treatment (T_4), and maximum scape diameter (3.68cm) was recorded. The blocking of GAs synthesis by trizoles, reduced the cell elongation but there was continuous cell division still occurs and resulting into increase in thickness of stem (Fleture *et al.,* 2000) due to an additional layer of palisade and spongy cells (Burrows *et al*., 1992; Jaleel *et al*., 2007_b). The reduction in number of seed scape per plant as well as number of productive scape in T_1, T_3, T_4 and T_6 may be due to the inhibitory action of paclobutrazol on production of sprouts and decreased the number of seed scapes per plant. However, significantly higher seed scape and productive scape in ethephon and triadimefon treatments may be due to their influence on the sprouting of seed scape per plant because of limited stimulatory substance i.e. GAs.

The disease severity was significantly affected by applications of growth retardants; lower disease index were recorded in triadimefon treatments (T_{11} to T_{14}) which could be due to the changes in ergosterol biosynthesis (Fleture, 2000) because these compounds inhibit one specific enzyme, C_{14}-demethylase, which is essential for sterol production. Sterols, particularly ergosterols are useful for membrane structure and development of fungus cell wall. Therefore, due to these trizoles there is abnormal growth and eventually death of fungus as reported by Fletcher *et al*., (1986), Tadao *et al*., (2003). The triadimefon treatments (T_{11} to T_{14}) showed significantly lower seed scape lodging % than other treatments which could be due lower disease incidence and associated with lower severity (PDI) among the treatments (T11 to T14) (Fig. 24).

The paclobutrazol based treatments took significantly less period for maturity which may be due to physiological stress induced by the paclobutrazol eventually leading to early completion of plant life cycle and change in sterol composition of cell membrane, which may change the membrane stability and acclimatization (Sridharan *et al*., 2009).

5.3.2 Effect of growth retardants on flowering traits

The growth retardants had significantly altered the flowering traits viz., umbel diameter, number of umbellates per umbel and number of productive umbellates per umbel. The paclobutrazol significantly delayed in initiation of flowering which was due to late emergence of seed scape. The umbel diameter and number of umbellates/umbel were also reported significantly higher in T_6 (soaking +spray of 100 ppm paclobutrazol) as compared to other treatments except (T_1 to T_5), and this may be attributed to higher production of cytokinin due to the application of trizole compounds (Fleture *et al.*, 2000); (Kamountsis *et al.,* 1999) which enhanced the reproductive growth of plants as reported by Isabel *et al.,* (2007) in Arabidopsis and Gomathinayagam *et al*., (2007) in cassava.

The significantly higher number of umbellates in T4 (630.35) and number of productive umbellates/umbel in T6 (444.80) which was at par with T3, T4 and T1 can be attributed to higher umbel diameter and delayed initiation of flowering which probably received higher photosynthates.

The treatments T_5 and T_2 were recorded for higher seed setting percent than other treatments. The higher seed setting percent in T_5 and T_2 is comparative performance between the number of umbellates per umbel and productive umbellates/umbel resulted into higher seed setting.

5.3.3 Effect of growth retardants on seed yield contributing traits

Seed yield is a complex trait which is greatly affected by seed yield/plant, seed yield/umbel, disease severity index, lodging of seed scape and duration of maturation etc. in onion.

1000 seed weight was significantly higher in T1 (3.32g) but at par with other treatments expect T8 and T15. The superiority of 1000 seed weight in T1 (soaking of bulbs in 80 ppm paclobutrazol) attributed to higher accumulation of food reserve due to lower number of seed scapes/plant and is conformity with Ashrafuzzaman *et al*., (2009).

The seed yield per plant and seed yield per hectare were significantly influenced by application of growth retardants (Table 9 & 10). The higher seed yield per plant and seed yield per hectare was obtained in T_{14} (12.67g and 6.34q) (Fig. 25) followed by T_{13}

Fig. 24 Effect of growth retardants on disease infection and seed scape lodging % (On pooled data over two year's basis)

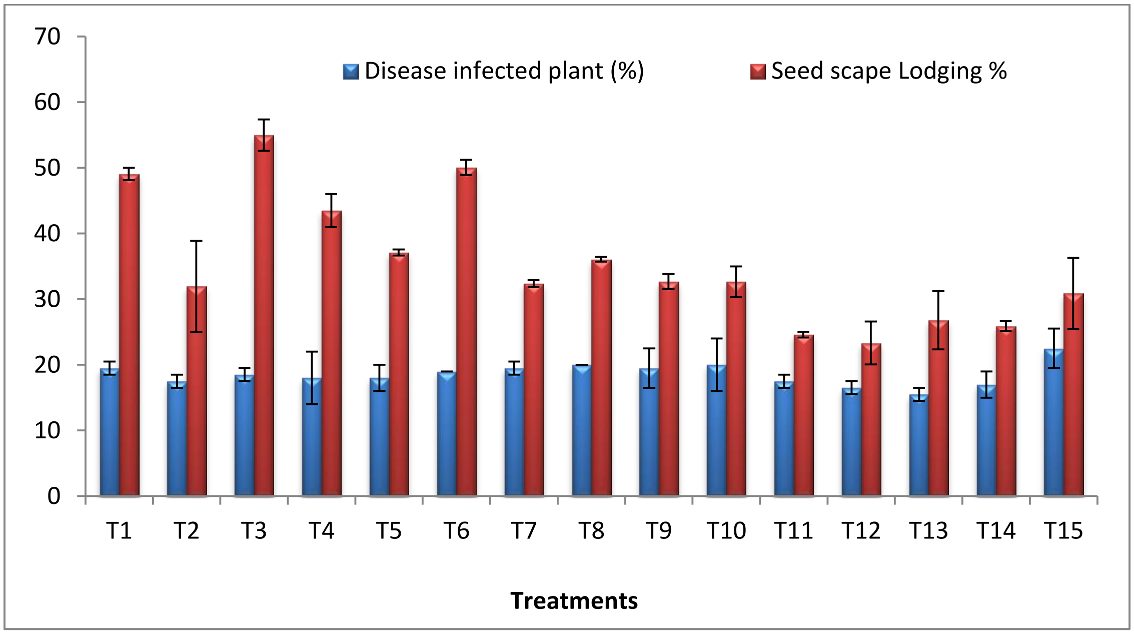
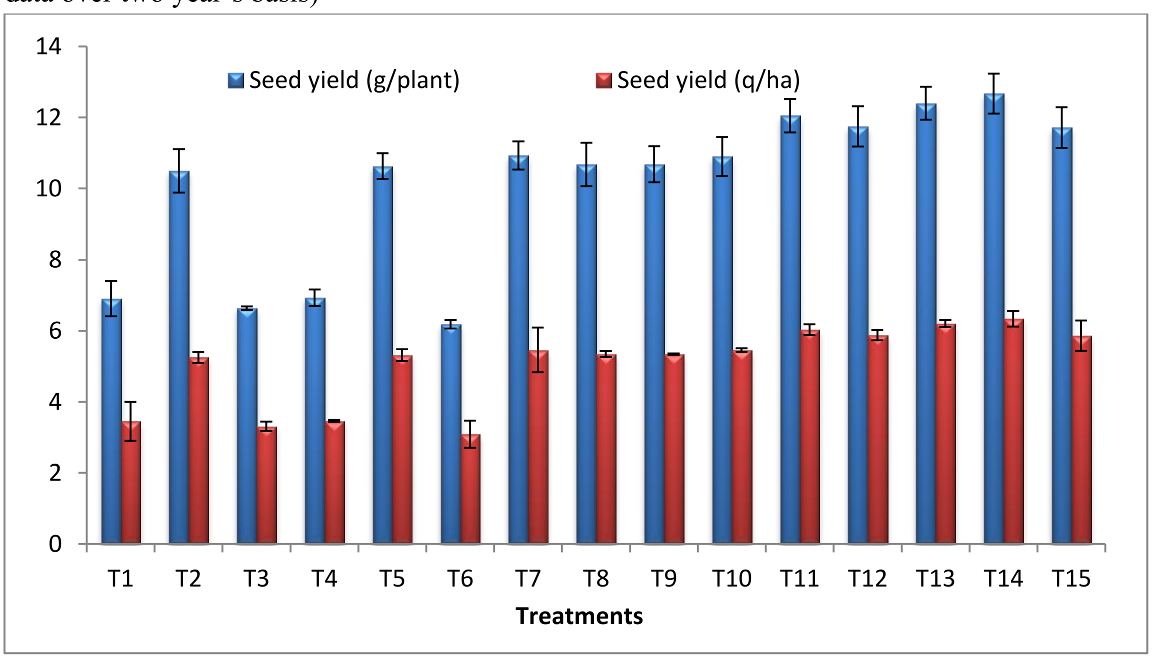


Fig. 25 Effect of growth retardants on seed yield/plant and seed yield/ha (On pooled data over two year's basis)



which could be due to less disease incidence & severity, higher productive seed scapes per plant and less seed scape lodging that had resulted into higher seed yield. Ashrafuzzaman *et al*., (2009) also reported similar findings.

5.3.4 Effect of growth retardants on seed quality attributes

Among the growth retardants none of them could make significant effect on germination percent and seedling length (Table 11). The seedling dry weight had significantly ameliorated by growth retardants application and higher seedling dry weight was recorded in paclobutrazol treatment (T1& T_2) (each 2.07mg) which was at par with other treatments except T6 (1.44mg). The superior seedling dry weight could be due to the better food reserve in seed. No difference in electrical conductivity of seed leachates could be due to the freshness of seed.

The vigour index-I was significantly higher under T15 but at par with T14, T13, T8 and T5 which could be due to higher seedling length under control treatment. The higher vigour index-II was noted in T_1 (186.13) which might be due to the better germination percent and more seedling dry weight.

5.3.5 Effect of growth retardants on chlorophyll and antioxidants enzymes in seed

The trizole compound treatments had significant effect on leaf chlorophyll content. The higher chlorophyll ‘a’ ‘b’ and total chlorophyll were recorded in paclobutrazol treatments which could be due to fact that trizole compounds induced the cytokinin which enhance the chloroplast size and chlorophyll content. The inhibition of GAs pathway which controls the cell size but continuous synthesis of chlorophyll which results in densely packing of chlorophyll hence makes the leaf greener than control. The results were corroborated with Pinhero and Fletcher (1994) in maize seedlings and Nouriyani *et al*. (2012) in wheat seedling.

The antioxidants viz., superoxide dismutase (SOD), catalase, and glutathione reductase activity were highly influenced by growth retardants particularly paclobutrazol application (Fig. 4, 5 and 6). The higher activity of antioxidants in growth retardants treatment could be due to stress condition induced by trizoles which promoted the activity of these enzymes. These triazole compounds may protect membrane components from oxidative damage and lipid peroxidation during abiotic stress conditions by increasing the defense mechanisms of the local tissues against free radicals (Fletcher and

Hofstra, 1990; Fleture *et al.*, 2000). The similar results were also reported by different workers (Nair *et al*., 2012; Sivakumar and Panneerselvam, 2011). Triazoles have been called as plant multiprotectants because of their ability to induce tolerance in plants to environmental stresses. Protection of plants from apparently unrelated stress by triazole is mediated by a reduction in free radical damage and increase in antioxidant potential.

6. SUMMARY AND CONCLUSION

The present investigation entitled **"Optimization of quality seed production in onion (*Allium cepa* L.) cv. Pusa Riddhi"** was conducted at Seed Production Unit, IARI during *rabi* seasons 2013-14 and 2014-15 with the following objectives

1. To study the effect of planting time and crop geometry on growth, seed yield and seed quality
2. To study effect of foliar application of different mineral nutrients on growth, seed yield and seed quality
3. To study effect of different plant growth retardants on onion seed scape height, seed yield and seed quality

The observations recorded on various characters in field experiment and laboratories were subjected to suitable statistical analysis and salient findings are summarized here under.

6.1. Effect of planting time and crop geometry on growth, seed yield and seed quality

- 15^{th} October planting (T_1) showed significantly higher mean values of growth attributes viz., number of leaves per plant (38.61), seed scape emergence (66.44days), seed scape height (101.74cm), seed scape diameter (1.87cm), productive seed scape per plant (6.78) and umbel diameter (6.54cm) over late plantings (T_2 and T_3).
- 15^{th} October planting (T_1) recorded significantly lower disease incidence (38.06%), percent disease index (PDI) (6.66 %) and higher seed scape lodging (33.26%) than later plantings viz., T_2 (32.27%) and T_3 (31.34%).
- Significant higher number of umbellates per umbel (494) and productive umbellates per umbel (414.73) were recorded in 15^{th} October planting than 25^{th} October and 5^{th} November.
- The planting of bulbs at 15^{th} October showed significantly higher seed setting (83.69%) than 25^{th} Oct (77.61%) and 5^{th} November (75.61%) respectively, seed yield per umbel (3.50g), seed yield per plant (8.71g), seed yield per plot (685.61g) and seed yield/ha (6.86q) than 25^{th} October and 5^{th} November planting.
- The seed obtained from 15^{th} October planting time (T_1) also showed superiority in

1000 seed weight (2.97g), seedling length (9.48cm), seedling dry weight (1.90mg/seedling), germination (88.33%), vigour index-I (833.32), vigour index-II (167.08) and lower EC (2.34 µmhos/cm/g) than T_2 and T_3.

- The significant effect of crop geometry was observed on growth attributes. Higher number of leaves per plant (40.89), seed scape height (102.26cm), seed scape diameter (1.88cm), number of seed scape per plant (11.72), productive seed scapes per plant (8.35 and umbel diameter (6.58cm) were recorded in wider spacing (S_3) than closer spacings (S_1& S_2).
- Wider spacing i.e. 60 × 30cm spacing showed significant lower disease infected plants (27.65%), disease severity (PDI) (5.81%) and seed scape lodging (22.43%) than 60 × 20cm and 60 × 10cm spacing.
- Wider spacing (S_3) had showed significant effect on number of umbellates/umbel (503.52) and productive umbellates per umbel (419.4) compared to closer spacings.
- Among the seed yield contributing traits viz., seed setting % (83.24%), seed yield per umbel (3.48g) and seed yield per plant (12.43g) were significantly higher in wider spacing (S_3) than S_2&S_1. However, seed yield per plot and seed yield per hectare were significantly higher in S_1 (716.72g & 7.17q) respectively than S_2 and S_3.
- The wider spacing (S_3) showed significantly higher 1000 seed weight (3.01g), seedling length (10.37cm), seedling dry weight (1.95 mg/seedling), germination percent (89.76%), vigour index-I (918.56) and vigour index-II (172.96) than S_1 and S_2. Whereas, lower EC of seed leachates was recorded in S_3.
- The interaction between planting time and spacing also showed significant effect and the interaction $T_1 \times S_3$ showed significantly higher number of productive umbellates per umbel (450.97), seed setting (88.01%), vigour index-I (1002.10) and vigour index-II (198.08) than other possible interactions.

6.2. Effect of foliar spray of nutrients (macro & micro) on growth, seed yield and quality

- The foliar spray of mineral nutrients either individually or in combinations had non-significant effect for number of leaves/plant days to seed scape emergence and days to initiation of flowering. Whereas, significant higher number of day to maturity (193.75days) was taken by T_{11}.

- Significantly higher seed scape height and seed scape diameter were observed in T_6 (106.35cm) and T_{14} (2.12) respectively.
- The higher number of seed scapes per plant (11.2), productive seed scapes per plant (8.45) and lower seed scape lodging percent (16.74%) were recorded in T_{10}, T_{14} and T_{15} respectively, but difference was observed non-significant.
- The foliar application of mineral nutrients significantly affects the disease incidence and severity. The lower number of disease infected plants was recorded in 125% RD of Zinc (T_6) (8%). Whereas, T_{12} (4.0%) and T_{14} (4.0%) showed lower disease severity than other treatments.
- The combined application of mineral nutrients (T_{15}) showed significantly higher number of umbellates per umbel (642.45), productive umbellates per umbel (579.35) and umbel diameter (7.38cm). Whereas, T_{14} had given significantly higher seed setting percent (91.37%) and results were at par with T_{15} (90.18%).
- The seed yield contributing traits were significantly influenced by foliar application of different mineral nutrients and combined application of B+Zn+Ca+Mg (T_{15}) showed significant higher 1000 seed weight (3.87g), seed yield per umbel (4.18g), seed yield per plant (16.70g), seed yield per plot (835g) and seed yield per hectare (8.35q) than other treatments.
- The significantly higher germination (91.84%), seedling length (10.79cm), seedling dry weight (2.62mg/seedling), vigour index-I (990.34), vigour index-II (240.73) were observed in T_{15} than other treatments. While, lower EC of seed leachates was recorded in T14 (1.50 µmhos/cm/g) followed by T_{15} (1.65 µmhos/cm/g).

6.3 Effect of different plant growth retardants on seed scape height, seed yield and seed quality

- The significant effect of growth retardants on plant growth was observed. Paclobutrazol treatment (T_6) showed lower number of leaves per plant (24.58) and had taken less days for maturity (160.2days). The significantly higher number of days for seed scape emergence (71.50days) and initiation of flowering (131.5days) was taken by T_6.

- The paclobutrazol had significant effect on seed scape height. Lower seed scape height was recorded in T_6 (69.9cm) whereas, T_4 had significant higher seed scape diameter (3.71cm) than other treatments.
- Significantly higher number of seed scapes per plant (10.95) and higher number of productive seed scapes per plant (8.02) were recorded in T_5 and T_{15} respectively. Whereas, lower seed scape lodging (24.6%) was recorded in T_{11}.
- Triadimefon treatment significantly reduced disease incidence. Lower disease infected plants (15.5%) and severity (4.50%) were recorded in T_{13}.
- Significantly higher umbel diameter (7.31cm), number of umbellates per umbel (630.35) and productive umbellates per umbel (444.80) were recorded in T_4 & T_6 respectively than other treatments. Whereas, seed setting % was significantly higher in T_5 (75.81%) followed by T_2 and T_6.
- Significantly higher 1000 seed weight (3.32g) and seed yield per umbel (3.48g) were noted in T_6. Whereas, foliar spray of triadimefon @400 ppm (T14) showed higher seed yield per plant (12.67g), seed yield per plot (633.75g) and seed yield per hectare (6.34q) than other treatments.
- Seed quality attributes viz., germination %, seedling length, and EC of seed leachates showed non-significant effect due to growth retardants. However, significant higher seedling dry weight (2.07g) in T1, vigour index-I (952.14) in T15 and vigour index-II (186.13) in T_1 was recorded.
- The paclobutrazol treatments (ranging from T1 to T6) showed higher chlorophyll content and higher antioxidant enzymes than other treatments.

6.4 Conclusion

- Based upon the results obtained from this study, it is recommended that under Delhi conditions onion cv. Pusa Riddhi medium sized bulbs should be planted on 15^{th} October at the spacing of 60×30cm and foliar spray of Borax (626g/ha) + Zn-EDTA (500g/ha) + Ca-EDTA (500g/ha) + Mg-EDTA (500g/ha) at 30 and 60 DAP along with the spray of triadimefon @ 400 ppm should be given to obtain higher seed yield and quality.

7. ABSTRACT

The present investigation entitled **"Optimization of quality seed production in onion (*Allium cepa* L.) cv. Pusa Riddhi"** was conducted at Seed Production Unit, Indian Agricultural Research Institute during *rabi* seasons 2013-14 and 2014-15 with the objectives to study the effect of planting time and crop geometry, effect of foliar application of different mineral nutrients and effect of different plant growth retardants on growth, disease intensity seed yield and seed quality characters.

Among the time of planting, 15^{th} October planting (T_1) showed significantly higher values for growth characters viz., seed scape height (101.74cm), umbel diameter (6.54cm) productive umbellates per umbel (414.73) seed yield attributes such as seed setting (83.69%), seed yield per plant (8.71g) and seed yield/ha (6.86q). Higher seed quality attributes viz., seedling length (9.48cm), seedling dry weight (1.90mg/seedling), germination (88.33%), vigour index-I (833.32), vigour index-II (167.08) and lower disease infection (38.06%) were observed in 15^{th} October planting. Among the treatments spacing 60×30cm had recorded significantly higher number of leaves/plant (40.89), seed scape height (102.26cm), productive seed scapes per plant (8.35), productive umbellates per umbel (419.4), seed setting % (83.24%), seed yield per plant (12.43g) and 1000 seed weight (3.01g). The seedling length (10.37cm), seedling dry weight (1.95 mg/seedling), germination percent (89.76%), vigour index-I (918.56) and vigour index-II (172.96) were significantly higher in S_3 (60×30cm). The lower disease incidence (27.65%), PDI (5.81%) and EC of seed leachates (2.19 μ mhos/cm/g) were also recorded in S_3. Whereas, seed yield/ha (7.17q) was maximum in 60×10cm spacing (S_1). The chlorophyll content was also recorded higher in 15^{th} October planting and 60×30cm spacing.

The foliar spray in combination of B+Zn+Ca+Mg (at 30 & 60 DAP) showed superiority in productive umbellates per umbel (579.35), umbel diameter (7.38cm), 1000 seed weight (3.87g), seed yield per umbel (4.18g), seed yield per plant (16.70g) and seed yield per hectare (8.35q). Among the quality attributes viz., germination (91.84%), seedling length (10.79cm), seedling dry weight (2.62mg/seedling), vigour index-I (990.34), vigour index-II (240.73) and chlorophyll content were significantly higher in

T_{15} than others. While, lower EC of seed leachates was recorded in T_{14} (1.50 µmhos/cm/g) followed by T_{15} (1.65 µmhos/cm/g).

The paclobutrazol treatment (T_6) showed significant lower number of leaves per plant (24.58) and lower seed scape height (69.9cm) than other treatments. The T_6 also showed higher umbel diameter (7.31cm), number of umbellates per umbel (628.05), 1000 seed weight (3.32g) and seed yield per umbel (3.48g). The triadimefon treatments T_{13} & T_{14} significantly reduced the disease incidence (16.5% & 17%) and severity (4.50% & 5.16%) resulting into higher seed yield per plant (12.67g) and seed yield per hectare (6.34q) than other treatments. Paclobutrazol treatments (T_1 to T_6) showed higher chlorophyll content and antioxidant enzymes viz., SOD, catalase and glutathione reductase than other treatments.

सारांश

यह अध्ययन जिसका भीर्शक '' प्याज की किस्म पूसा रिधी में गुणवत्ता बीज उत्पादन का अनुकुलन'' को बीज उत्पादन इकाई, भारतीय कृशि अनुसंधान पूसा, नई दिल्ली में वर्श 2013–14 एवं 2014–15 के दौरान रबी में आयोजित किया गया जिसका उद्दे य फसल रोपन और फसल ज्यामिती, विभिन्न सुक्ष्म पोशको का पत्तियो पर छिड़काव एवं पादप वृद्धि नियंत्रको का प्रयोग का रोग तीव्रता, बीज उपज और बीज गुणवत्ता कारको पर प्रभाव देखना था। विभिन्न रोपण समय मे से 15 अक्टूबर की रोपण समय से पादप वृद्धि कारको और बीज वृन्त लम्बाई (101.74 सेमी) , पुश्पक्रम व्यास (6.54 सेमी) उत्पादक पुश्पक्रमांग प्रति पुश्पक्रम (414.73ः) बीज उपज कारको जैसे बीज स्थापन (83.69ःद्ध बीज उपज प्रति पादप (8.71ग्राम) एवं बीज उपज प्रति हैक्टेयर (6.86 कुन्तल) सार्थक रूप मे अधिक पाए गऐ। बीज गुणवत्ता कारको जैसे नवोदभिद की लम्बाई (9.48 सेमी) नवोदभिद का भ्ाुश्क भार (1.90 मिली ग्राम/नवोदभिद) बीज नवोदभिदण (88.33ःद्ध बीज ओज सुचकांक–प् (883.32द्ध बीज ओज सुचकांक–प्प् (167. 08) और कम बीमारी प्रति ात (38. 06 ःद्ध भी 15 अक्टूबर रोपन मे देखा गया।विभिन्न पादप ज्यामिती के उपचार में 60ग30 सेमी की अवस्था मे ज्यादा पत्तियो की संख्या (40.89), बीज तने की लम्बाई (102.26 सेमी), उत्पादक बीज वृन्तों की संख्या/प्रति पादप (8.35), उत्पादक पुश्पक्रमांग प्रति पुश्पक्रम (419.4) बीज स्थापन ः (83.24 ःद्ध बीज उपज प्रति पादप (12.43 ग्राम) एवं 1000 बीजो का भार (3.01 ग्राम) भी सार्थक रूप से अधिक पाया गया। नवोदभिद की लम्बाई (10.37 सेमी), नवोदभिद का भ्ाुश्क भार (1.95 मिलीग्राम/नवोदभिद), जमाव प्रति ात (89. 76ःद्धए बीज ओज सुचकांक–प् (918.56) और बीज ओज सुचकांक–प्प् (172.96) भी सार्थक रूप सेएस3 (60ग30सेमी) में ज्यादा पाया गया। कम बीमारी का लगना (27.65 ः) पी.डी.आई (5.81ः) और बीज का विद्युतीय चालकता (2.19 माईका म्हो/सेमी/ग्राम) भी एस3 में कम पाया गया। जबकि बीज उपज प्रति हैक्टेयर (7.17 कुन्तल) 60ग10 सेमी (एस1) ज्यादा थी। क्लोरोफिल की मात्रा भी 15 अक्टुबर रोपन और 60ग30 सेमी मे ज्यादा पाई गई। र्ढ़दृब्ठ के सयोजन का 30 और 60 बीजाई उपरान्त पर छिड़काव से उत्पादक पुश्पक्रमांग/पुश्पक्रम (579.35), पुश्पक्रम प्यास (7.38 सेमी) 1000 बीजो का भार (3.87 ग्राम), बीज उपज प्रति/पुश्पक्रम (4.18) बीज उपज प्रति पादप (16.76) एवं बीज उपज प्रति हैक्टेयर भी श्रेश्ठ पाऐ गऐ । विभिन्न लक्षण कारको जैसे जमाव (91. 84ः), अंकूर की लम्बाई (10.79 सेमी) , नवोदभिद भ्ाुश्क भार (2.62 मिलीग्राम/नवोदभिद), बीज ओज सुचकांक–प् (990.34) , बीज ओज सुचकांक–प्प् (240.73) और क्लोरोफिल की मात्रा भी टी15 उपचार में ज्यादा मिली। जबकि कम बीजों की विद्युतीय चालकता (1.50 माईक्रो म्हो/सेमी/ग्राम) टी14 और उसके बाद में टी 15 (1.65 माईक्रो म्हो/सेमी/ग्राम) मे दर्ज की गई। पेक्लोबुटराजोल उपचार (टी 6) मे पत्तियो की संख्या/प्रति पादप (24. 58) और बीज वृन्त की लम्बाई (69.9 सेमी) भी सार्थक रूप से दूसरे उपचारो से कम पाई गई। टी 6 मे ज्यास पुश्पक्रम व्यास (7.31 सेमी) , पुश्पक्रमांग की संख्या प्रति पुश्पक्रम (628.05) , 1000 बीजो का भार (3. 32 ग्राम) और बीज उपज प्रति पुश्पक्रम (3.48) भी ज्यादा पाई गई। ट्राईडिमेफोन उपचार टी13 और टी14 सार्थक रूप से बीमारी का आक्रमण (16.5ः और 17ः) , और तीव्रता (4.5ः और 5.16ः) कम करता है। फलस्वरूप उपज/पादप (12.67 ग्राम) और बीज उपज/हैक्टेयर अन्य उपचारो के परिणाम से बेहतर पाई गई । पेक्लोब्युटराजोल उपचार(टी 1 से टी 6) में क्लोरोफिल की मात्रा और एंटी ऑक्सीडेन्ट एजाइमो जैसे एस.ओ.डी, कैटालेज, ग्लुटाथीयॉन रिडक्टेज भी अन्य उपचारो की तुलना में बढ़ाता है।

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Appendix-I: Meteorological data with respect to Temperature, Relative humidity & Rainfall during the crop growing season (October 2013 to May 2014)

Month/Week	Temperature (^{0}C)			Relative humidity (%)			Rainfall (mm)	AWS (Km/h)
	Max	Min	Mean	Morning	Evening	Mean		Max in week
October, 2013								
1st week	31.3	22.9	27.1	88.7	70.9	79.8	0.06	6.6
2nd week	31.8	22.1	26.9	95.1	66.9	81.0	15.5	3.6
3rd week	32.2	18.1	25.2	95.0	47.1	71.1	0.0	3.6
4th week	30.8	16.1	23.5	94.6	47.3	70.9	0.0	2.0
5th week	31.2	13.7	22.5	96.0	45.7	70.8	0.0	3.5
November,2013								
1st week	27.9	13.3	20.6	90.4	57.9	74.1	0.1	8.8
2nd week	25.5	10.0	17.7	92.4	54.1	73.3	0.0	4.4
3rd week	26.4	7.1	16.7	90.4	39.9	65.1	0.0	4.8
4th week	27.5	9.8	18.6	90.8	44.8	67.8	0.0	8.0
5th week	27.8	8.9	18.3	87.0	40.0	63.5	0.0	4.3
December,2013								
1st week	26.1	7.1	16.6	94.1	43.1	68.6	0.0	4.0
2nd week	24.6	7.6	16.1	92.6	40.4	66.5	0.0	11.7
3rd week	21.9	8.2	15.0	96.1	72.6	84.4	0.0	5.8
4th week	18.4	6.6	12.5	91.6	66.3	78.9	0.0	6.9
5th week	18.8	4.2	11.5	95.3	58.3	76.8	0.6	5.4
January, 2014								
1st week	17.74	4.77	11.26	96.14	55.29	75.71	0.00	6.8
2nd week	19.61	4.34	11.98	96.29	54.71	75.50	0.00	4.1
3rd week	17.20	8.20	12.70	97.17	78.50	87.83	0.97	4.3
4th week	18.11	9.07	13.59	96.57	76.00	86.29	1.83	6.8
5th week	21.47	8.37	14.92	97.33	63.67	80.50	0.00	4.7
February, 2014								
1st week	22.77	8.60	15.69	96.57	56.00	76.29	0.23	5.1
2nd week	20.36	5.56	12.96	96.00	68.71	82.36	5.40	5.7
3rd week	18.21	6.23	12.22	96.00	64.43	80.21	2.17	5.6
4th week	22.81	9.66	16.24	95.29	69.57	82.43	1.23	6.4
March, 2014								
1st week	22.79	9.26	16.02	96.71	59.86	78.29	5.57	4.6
2nd week	25.44	11.84	18.64	87.86	53.00	70.43	1.16	8.8
3rd week	27.50	12.66	20.08	90.86	40.71	65.79	0.51	7.3
4th week	29.79	15.91	22.85	89.71	45.14	67.43	1.06	6.7
5th week	31.33	15.63	23.48	78.33	33.00	55.67	1.80	8.6
April, 2014								
1st week	33.7	16.5	25.1	80.4	37.7	59.1	0.0	8.5
2nd week	33.6	17.6	25.6	71.0	43.7	57.4	0.0	11.3
3rd week	32.6	17.6	25.1	80.3	45.9	63.1	2.3	10.3
4th week	37.5	19.6	28.5	63.4	37.4	50.4	0.0	7.7
5th week	40.6	19.0	29.8	68.5	25.5	47.0	0.0	16.5
May, 2014								
1st week	39.46	23.2	31.3	67.0	37.6	52.3	2.6	7.8
2nd week	36.40	20.3	28.3	80.0	54.3	67.1	5.9	8.2
3rd week	37.07	23.0	30.1	75.1	48.9	62.0	0.0	10.0
4th week	39.90	22.7	31.3	76.6	36.6	56.6	2.5	12.2
5th week	43.27	25.0	34.1	65.0	30.3	47.7	0.7	7.3

Appendix-II: Meteorological data with respect to Temperature, Relative humidity, Rainfall during the crop growing season (October 2014 to 2nd week of May 2015)

Month/Week	Temperature (^{0}C)			Relative humidity (%)			Rainfall (mm)	AWS (Km/h)
	Max	Min	Mean	Morning	Evening	Mean		
October, 2014								
1st week	36.8	23.1	29.9	84.2	32.8	58.4	0.0	5.8
2nd week	34.6	20.4	27.5	78.7	36.3	57.5	0.0	6.3
3rd week	30.5	16.1	23.3	82.4	41.6	62.0	0.0	6.0
4th week	32.1	17.4	24.7	92.1	42.3	67.2	0.0	2.7
5th week	32.0	16.9	24.4	92.0	34.3	63.1	0.0	3.4
November, 2014								
1st week	30.0	15.3	22.7	82.9	36.1	59.6	0.0	8.5
2nd week	29.0	11.8	20.4	83.0	35.3	59.1	0.0	4.9
3rd week	27.3	7.7	17.5	85.4	44.1	64.8	0.0	4.3
4th week	26.6	7.5	17.1	84.7	35.6	60.1	0.0	4.4
5th week	28.6	11.4	20.0	89.0	35.0	62.0	0.0	2.3
December, 2014								
1st week	27.9	10.6	19.2	85.9	43.7	65.1	0.0	8.8
2nd week	23.8	7.0	15.4	92.4	51.7	72.1	0.0	9.6
3rd week	17.0	7.3	12.2	97.0	71.6	84.4	3.8	6.8
4th week	14.8	3.1	9.0	98.3	68.0	83.1	0.0	6.1
5th week	18.2	4.2	11.2	97.3	61.7	79.5	0.0	4.7
January, 2015								
1st week	17.89	8.67	13.28	96.57	79.86	88.21	2.66	10.6
2nd week	15.06	5.24	10.15	97.29	73.43	85.36	0.20	5.7
3rd week	18.53	5.27	11.90	96.29	61.14	78.71	0.06	5.6
4th week	16.06	9.07	12.56	96.00	73.43	84.71	2.20	7.6
5th week	17.53	4.50	6.87	91.33	40.00	65.67	0.00	7.5
February, 2015								
1st week	21.60	8.23	14.91	93.29	51.00	72.14	0.00	7.3
2nd week	23.49	7.21	15.35	92.71	40.86	66.79	0.00	4.4
3rd week	26.49	13.67	20.08	92.29	56.14	74.21	0.00	6.8
4th week	26.94	13.33	20.14	89.29	45.29	67.29	0.00	10.0
March, 2015								
1st week	22.97	10.13	16.55	95.71	61.43	78.57	19.34	11.3
2nd week	24.96	11.19	18.07	93.57	51.14	72.36	6.43	6.2
3rd week	25.71	13.19	19.45	91.57	51.00	71.29	0.06	10.3
4th week	32.96	15.80	24.38	85.57	37.57	61.57	0.00	7.4
5th week	32.13	18.43	25.28	83.33	57.67	70.50	7.00	10.2
April, 2015								
1st week	30.39	17.00	23.69	91.86	51.43	71.64	6.49	6.8
2nd week	31.47	17.36	24.41	78.43	44.57	61.50	0.91	6.5
3rd week	35.47	20.71	28.09	74.14	41.00	57.57	0.00	6.6
4th week	37.64	20.59	29.11	65.57	37.43	51.50	0.00	10.8
5th week	36.10	22.85	29.48	64.50	40.50	52.50	0.00	10.5
May, 2015								
1st week	39.59	20.97	30.28	65.14	31.43	48.29	0.00	9.5
2nd week	40.34	25.27	32.81	59.71	39.00	49.36	0.11	10.7

Appendix-III: **Physio-chemical parameters of soil in MID-B-e block of seed production unit, IARI**

S.No.	Chemical properties	Value
1.	P^H	7.84
2.	Electrical conductivity	0.383 ds/m
3.	Organic carbon content	0.482 %
4.	Nitrogen availability	160 kg/ha
5.	Phosphorus availability	25kg/ha
6.	Potassium availability	220kg/ha
6.	Boron availability	0.26 ppm
7.	Zn^{+2} availability	0.637 mg/kg
8.	Ca^{+2} availability	0.34meq/100g
9.	Mg^{+2} availability	0.48meq/100g

Appendix-IV: Effect of planting time and crop geometry on leaf chlorophyll (mg/g of tissue) (Pooled data over two years)

Treat ments	Chlorophyll 'a'		Chlorophyll 'b'		Total chlorophyll	
	2013-14	**2014-15**	**2013-14**	**2014-15**	**2013-14**	**2014-15**
T_1S_1	0.059±0.004	0.072±0.008	0.073±0.008	0.062±0.005	0.121±0.003	0.160±0.003
$T_1 S_2$	0.089±0.009	0.089±0.003	0.092±0.007	0.088±0.003	0.162±0.005	0.167±0.005
$T_1 S_3$	0.102±0.004	0.104±0.002	0.106±0.003	0.095±0.009	0.196±0.005	0.185±0.009
$T_2 S_1$	0.070±0.002	0.066±0.004	0.077±0.003	0.083±0.010	0.147±0.003	0.152±0.007
$T_2 S_2$	0.087±0.003	0.082±0.005	0.104±0.004	0.086±0.007	0.190±0.004	0.166±0.009
$T_2 S_3$	0.100±0.005	0.086±0.006	0.106±0.006	0.097±0.003	0.209±0.006	0.221±0.010
$T_3 S_1$	0.062±0.006	0.084±0.004	0.046±0.003	0.054±0.003	0.135±0.008	0.138±0.003
$T_3 S_2$	0.086±0.008	0.095±0.003	0.073±0.005	0.066±0.003	0.179±0.007	0.167±0.006
$T_3 S_3$	0.094±0.007	0.101±0.009	0.093±0.005	0.077±0.002	0.201±0.003	0.173±0.009

T_1- planting of bulbs on 15th October
T_2- planting of bulbs on 25th October
T_3- planting of bulbs on 5th November

S_1- Spacing- 60× 10 cm
S_2- Spacing- 60× 20 cm
S_3- Spacing- 60× 30 cm

Appendix-V: Effect of foliar spray of mineral nutrients on leaf chlorophyll content (mg/g of tissue) (Pooled data over two years)

Treatments	Chlorophyll 'a' (mg/g tissue)		Chlorophyll 'b' (mg/g tissue)		Total chlorophyll (mg/g tissue)	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
T_1	0.102±0.004	0.097±0.0098	0.120±0.0143	0.097±0.0014	0.223±0.0083	0.195±0.0097
T_2	0.102±0.010	0.108±0.0108	0.113±0.0020	0.107±0.0116	0.216±0.0123	0.190±0.0134
T_3	0.101±0.008	0.099±0.0078	0.094±0.0014	0.101±0.0136	0.219±0.0130	0.197±0.0145
T_4	0.104±0.013	0.128±0.0110	0.104±0.0124	0.107±0.0024	0.209±0.0129	0.214±0.0078
T_5	0.103±0.010	0.107±0.0042	0.109±0.0102	0.111±0.0035	0.217±0.0102	0.191±0.0156
T_6	0.104±0.010	0.126±0.0134	0.110±0.0105	0.116±0.0125	0.193±0.0170	0.197±0.0088
T_7	0.108±0.018	0.100±0.0169	0.100±0.0123	0.108±0.0176	0.209±0.0104	0.208±0.0177
T_8	0.107±0.009	0.123±0.0108	0.106±0.0164	0.106±0.0006	0.213±0.0040	0.229±0.0118
T_9	0.096±0.016	0.117±0.0046	0.113±0.0056	0.094±0.0107	0.210±0.0136	0.211±0.0110
T_{10}	0.110±0.014	0.126±0.0074	0.107±0.0114	0.1010.0115	0.217±0.0099	0.228±0.0168
T_{11}	0.125±0.011	0.124±0.0102	0.104±0.0044	0.098±0.0035	0.230±0.0104	0.223±0.0147
T_{12}	0.128±0.004	0.129±0.0178	0.117±0.0103	0.118±0.0105	0.223±0.0159	0.231±0.0157
T_{13}	0.141±0.007	0.131±0.0092	0.119±0.0014	0.125±0.0113	0.245±0.0103	0.239±0.0107
T_{14}	0.134±0.017	0.133±0.0162	0.123±0.0015	0.118±0.0013	0.244±0.0104	0.244±0.0085
T_{15}	0.144±0.011	0.132±0.0142	0.128±0.0154	0.1070.0035	0.255±0.0149	0.249±0.0108
T_{16}	0.084±0.011	0.084±0.0111	0.095±0.0120	0.082±0.0101	0.180±0.0166	0.167±0.0274

T_1-RD of Boron at 60DAP
T_2-75% RD of Boron at 60DAP
T_3-125% RD of Boron at 60DAP
T_4-RD of Zinc at30DAP
T_5-75% RD of Zinc at 30DAP
T_6-125% RD of Zinc at 30DAP
T_7-RD of Calcium at 30DAP
T_8-75% RD of Calcium at 30DAP
T_9-125% RD of Calcium at 30DAP
T_{10}-RD of Mg at 30DAP
T_{11}-75% RD of Mg at 30DAP
T_{12}-125% RD of Mg at 30DAP
T_{13}-RD of Boron + Zinc at 30 & 60 DAP
T_{14}-RD of Boron + Zinc + Calcium at 30 & 60 DAP
T_{15}-RD of Boron + Zinc + Calcium + Magnesium at 30 & 60 DAP
T_{16}-Control (Water spray)

Appendix-VI: Effect of growth retardants on leaf chlorophyll content (mg/g of tissue) (Pooled data over two years)

Treatments	Chlorophyll 'a' (mg/g tissue)		Chlorophyll 'b' (mg/g tissue)		Total chlorophyll (mg/g tissue)	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
T_1	0.093±0.0020	0.107±0.0026	0.064±0.0015	0.071±0.0043	0.186±0.0028	0.220±0.0048
T_2	0.118±0.0040	0.113±0.0023	0.074±0.0023	0.067±0.0029	0.236±0.0052	0.220±0.0038
T_3	0.110±0.0046	0.107±0.0067	0.073±0.0016	0.075±0.0073	0.220±0.0054	0.203±0.0104
T_4	0.124±0.0021	0.096±0.0036	0.072±0.0076	0.079±0.0016	0.248±0.0059	0.210±0.0044
T_5	0.112±0.0025	0.114±0.0048	0.079±0.0085	0.079±0.0024	0.224±0.0068	0.221±0.0060
T_6	0.116±0.0064	0.107±0.0042	0.074±0.0068	0.073±0.0038	0.231±0.0098	0.176±0.0061
T_7	0.063±0.0026	0.069±0.0028	0.061±0.0026	0.062±0.0076	0.140±0.0039	0.151±0.0066
T_8	0.076±0.0029	0.072±0.0079	0.056±0.0024	0.062±0.0084	0.153±0.0041	0.151±0.0121
T_9	0.065±0.0067	0.069±0.0084	0.060±0.0037	0.067±0.0094	0.142±0.0086	0.148±0.0131
T_{10}	0.064±0.0023	0.069±0.0036	0.058±0.0064	0.052±0.0048	0.149±0.0055	0.179±0.0060
T_{11}	0.084±0.0031	0.089±0.0029	0.067±0.0049	0.077±0.0102	0.166±0.0056	0.180±0.0080
T_{12}	0.096±0.0010	0.108±0.0048	0.074±0.0021	0.080±0.0086	0.172±0.0021	0.157±0.0091
T_{13}	0.081±0.0086	0.082±0.0057	0.070±0.0038	0.071±0.0076	0.162±0.0105	0.179±0.0095
T_{14}	0.083±0.0048	0.098±0.0016	0.076±0.0068	0.072±0.0048	0.166±0.0082	0.135±0.0040
T_{15}	0.067±0.0034	0.057±0.0028	0.050±0.0076	0.059±0.0037	0.138±0.0072	0.086±0.0047

T_1- Soaking of bulbs in 80 ppm paclobutrazol solution
T_2- Foliar spray of paclobutrazol @ 80 ppm
T_3- Soaking of bulbs in 80 ppm paclobutrazol + foliar spray of paclobutrazol@80 ppm
T_4- Soaking of bulbs in 100 ppm paclobutrazol solution
T_5- Foliar spray of paclobutrazol @ 100 ppm
T_6- Soaking of bulbs in 100 ppm paclobutrazol + foliar spray of paclobutrazol@100 ppm
T_7- Soaking of bulbs in 400 ppm ethaphone solution
T_8- Foliar spray of ethaphone @ 400 ppm
T_9- Soaking of bulbs in 500 ppm ethaphone solution
T_{10}- Foliar spray of ethaphone @ 500 ppm
T_{11}- Soaking of bulbs in 200 ppm triadimefon solution
T_{12}- Foliar spray of triadimefon @ 200 ppm
T_{13}- Soaking of bulbs in 400 ppm triadimefon solution
T_{14}- Foliar spray of triadimefon @ 400 ppm
T_{15}-Control (Water spray)

Appendix-VII: Effect of growth retardants on antioxidant enzymes content in onion seed

Treatments	**SOD** (Unit/s/mg of protein)	**Catalase** (nmol/min/mg protein)	**Guaiacol peroxidase** (µmol/min/mg protein)	**Glutathione reductase** (Unit/s/mg of protein)
T_1	0.3473±0.010	15.13±0.224	56.061±0.814	4.9921±0.318
T_2	0.3239±0.026	14.25±0.538	52.961±2.710	4.7899±0.410
T_3	0.3041±0.030	12.29±0.448	52.838±1.077	4.8394±0.216
T_4	0.3190±0.050	12.64±0.984	48.334±2.794	4.8003±0.118
T_5	0.3075±0.013	11.65±1.512	57.907±0.764	4.5069±0.062
T_6	0.3128±0.033	13.31±0.529	47.321±3.812	5.0508±0.331
T_7	0.2301±0.053	7.17±0.846	47.456±1.736	3.8249±0.207
T_8	0.2155±0.041	6.34±0.847	56.323±1.750	3.9590±0.140
T_9	0.2317±0.034	9.54±0.746	51.182±1.755	3.5077±0.209
T_{10}	0.2298±0.021	9.37±0.39	51.318±2.756	3.6056±0.096
T_{11}	0.2713±0.027	8.34±0.57	54.418±1.666	4.3815±0.412
T_{12}	0.2679±0.035	7.42±0.163	50.209±2.875	4.3194±0.211
T_{13}	0.2784±0.002	9.59±0.784	57.917±3.815	4.7144±0.411
T_{14}	0.2573±0.026	9.05±1.194	47.233±0.757	4.3600±0.306
T_{15}	0.2350±0.014	6.54±0.344	53.576±3.214	3.3690±0.217

T_1- Soaking of bulbs in 80 ppm paclobutrazol solution
T_2- Foliar spray of paclobutrazol @ 80 ppm
T_3- Soaking of bulbs in 80 ppm paclobutrazol + foliar spray of paclobutrazol@80 ppm
T_4- Soaking of bulbs in 100 ppm paclobutrazol solution
T_5- Foliar spray of paclobutrazol @ 100 ppm
T_6- Soaking of bulbs in 100 ppm paclobutrazol + foliar spray of paclobutrazol@100 ppm
T_7- Soaking of bulbs in 400 ppm ethaphone solution
T_8- Foliar spray of ethaphone @ 400 ppm
T_9- Soaking of bulbs in 500 ppm ethaphone solution
T_{10}- Foliar spray of ethaphone @ 500 ppm
T_{11}- Soaking of bulbs in 200 ppm triadimefon solution
T_{12}- Foliar spray of triadimefon @ 200 ppm
T_{13}- Soaking of bulbs in 400 ppm triadimefon solution
T_{14}- Foliar spray of triadimefon @ 400 ppm
T_{15}-Control (Water spray)