Evaluation of varieties and standardization of planting time in onion (*Allium cepa* L.)

By

ARUNA S.

(2016-12-002)

THESIS

Submitted in partial fulfilment of the

Requirement for the degree of

Master of Science in Horticulture

(VEGETABLE SCIENCE)

Faculty of Agriculture

Kerala Agricultural University, Thrissur

Department of Vegetable Science
COLLEGE OF HORTICULTURE
VELLANIKKARA, THRISSUR - 680 656
KERALA, INDIA

2018

DECLARATION

I hereby declare that the thesis entitled **"Evaluation of varieties and standardization of planting time in onion (*Allium cepa* L.)"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

Vellanikkara

Date:

ARUNA S.

(2016-12-002)

CERTIFICATE

Certified that the thesis entitled **"Evaluation of varieties and standardization of planting time in onion (*Allium cepa* L.)"** is a record of research work done independently by **Ms. Aruna S.** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

Vellanikkara
Date: 03/08/2018

Dr. P. Indira 3/08/18
(Major Advisor)
Professor & Head
Dept. of Vegetable Science
College of Horticulture, Vellanikkara

CERTIFICATE

We, the undersigned members of the advisory committee of **Ms. Aruna S. (2016-12-002)**, a candidate for the degree of **Master of Science in Horticulture**, with major field in **Vegetable Science**, agree that the thesis entitled **"Evaluation of varieties and standardization of planting time in onion (*Allium cepa* L.)"** may be submitted by **Ms. Aruna S.** in partial fulfilment of the requirement for the degree.

Dr. P. Indira 3/8/18
(Major Advisor)
Professor and Head
Dept. of Vegetable Science
CoH, Vellanikkara, KAU Thrissur

Dr. S. Nirmala Devi 3/8/18
Professor & AICVIP
Dept. of Vegetable Science
CoH, Vellanikkara, KAU Thrissur

Dr. Jalaja S. Menon
Assistant Professor
Dept. of Plantation crops and Spices
CoH, Vellanikkara, KAU, Thrissur

Dr. S. Krishnan 3/8/18
Professor and Head
Dept. of Agricultural Statistics
CoH, Vellanikkara, KAU Thrissur

3/8/18
EXTERNAL EXAMINER
V. RAJASHREE

ACKNOWLEDGEMENT

My eternal cheerleader, ***Sasidharan****: I would think of our interesting and long-lasting chats whenever I feel stressed during my post-graduation life. My forever interested, encouraging and always enthusiastic mother,* ***Sudha****: she was always keen to know what I was doing and how I was proceeding, although it is likely that she has never grasped what it was all about! I always enjoyed your screams of joy whenever a significant momentous was reached and also just your general impudence. I am also grateful to my chechi, chettan and kannan for they alone complete me with love and affection which they have showed all throughout my life.*

My words cannot express the immeasurable gratitude and indebtedness to ***Dr. P. Indira****, Professor & Head, Department of Vegetable Science, College of Horticulture, who is also my chairman for her expert advice, constructive criticisms, constant encouragements and immense patience, understandings and wholehearted cooperation rendered throughout the course of my study.*

I cannot go on without thanking ***Dr. Jalaja. S. Menon*** *Assistant Professor, Department of plantation crops and Spices, College of Horticulture, also a member of my advisory committee without whom I wouldn't have finished my thesis work in time. I thank her for the support, enthusiasm and relevant suggestions she gave throughout my course time.*

I consider it as my privilege to express my gratitude to ***Dr. S. Nirmala Devi****, Professor& AICVIP, Department of Vegetable Science and a member of my advisory committee for the advice, support and encouragement she has given at all moments of uncertainty and sadness.*

I am extremely thankful to ***Dr. S. Krishnan****, Professor and Head, Department of Agricultural Statistics and also a member of my advisory committee who helped me master statistics without whom I would still be battling with numbers.*

I express my sincere gratitude to my teachers, ***Dr. T. Pradeepkumar, Dr. P. Anitha, Dr. Sarah T. George, Dr. K.V. Suresh Babu*** *and* ***Dr. Salikutty Joseph,*** *for*

the warm study environment they made for us. It was fantastic to have the opportunity to work majority of my research in your facilities.

I bow my head before the ***Almighty God*** *who enabled me to successfully complete the thesis work in time.*

I also take this opportunity to extend my profound gratitude to ***Dr. A. T. Francies****, Librarian, College of Horticulture and to all other library staff for the facilities offered.*

I am also grateful to my seniors ***Malavika, Akhila, Shilpa****,* ***Archana*** *and* ***Reshamika*** *and teaching assistants,* ***Aiswarya****,* ***Nimisha*** *and* ***Bipin*** *for their unfailing support and assistance.*

I also show my gratitude to my batch mates ***Remzeena*** *and* ***Shilpasree****. Thank you for accepting, encouraging and loving me for the last two years. I will miss the fun times we had. I also extend my love and gratitude to* ***Minnu, Anita*** *and* ***Sadanad*** *for the time and help they have given throughout my course of study.*

With a special mention to ***Greeshma*** *(Research Assistant),* ***Sunitha chechi, Bahu chettan , Ansa and Deepak*** *(non-teaching staff),* ***Jhansi chechi*** *and all other field workers in the department of vegetable science, the role you played in my life at COH, Vellanikkara which though may look small really has made a huge impact in my life here. Thank you for making this place a heaven.*

I am grateful to my friends ***Jeen, Juby, Fazi*** *and* ***Sijo*** *for their sincere help, support and encouragement; and* ***Anjaly, Reynold*** *and* ***Sachin*** *who have provided me through moral and emotional support in my life.*

I am also thankful to ***Kerala Agricultural University*** *for providing a cozy student friendly atmosphere and for funding my research work.*

And finally, last but by no means least, also to everyone in the ***Department of Vegetable Science*** *... it was great sharing my work place with all of you during last two years. Thanks for all your encouragement!*

Aruna S.

To my life-coaches, my father Sasidharan and mother Sudha:
because I owe it all to you.

Many Thanks!

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

Appendix No.	Particulars
I	Weather data during September-March, 2017-18

INTRODUCTION

1. INTRODUCTION

Vegetables being rich in vitamins, minerals and dietary fibres play a vital role in providing nutritional security. India ranks second both in area and production of vegetables in the world next to China. The production of vegetables has increased from 101.246 mt in 2014-05 to 176.177 mt in the year 2016-17 (NHB, 2016). Similarly the productivity has also increased from 15.013 t/ha to 17.113 t/ha.

India is endowed with diverse ecological conditions and vegetable production is distributed across the country with 47.3 per cent area in the states like West Bengal, Uttar Pradesh, Maharashtra, Orissa and Bihar. About 40 different vegetables are grown commercially in different parts of the country. Vegetables contributing to major shares in total vegetable production are potato (25.5%), onion (11.9%) and tomato (11.5%). Onion contributes major share in vegetable export.

Onion (*Allium cepa* L.) belonging to the family Alliaceae is one of the oldest vegetables in the world and has been cultivated for more than 5000 years. It is native to Central Asia and the secondary centre of origin is in the near East (McCollum, 1976). Adaptation of onion in India occurred from very ancient times before Christian era. Originally being a native of temperate region of Central Asia with perennial / biennial habit and long day bulbing nature, it has established well in India under tropical and short day (11-11.5h) photoperiodic conditions (Seshadri and Chatterjee, 1996).

India ranks second both in area and production of onion in world after China and is the third exporter after Netherlands and Spain. During 2015-16, total area under onion cultivation in India was 13.20 lakh hectares with a total production of 209.31 lakh tons and productivity 15.86 t/ha (NHRDF, 2017). According to the reports of DGCIS (2017), export of onion during 2016-17 was 30.68 lakh tons worth Rs. 4195 crore.

Onion, which is an important and indispensable item of every kitchen, as a vegetable, spice and condiment, commands an extensive internal market. It is a commodity of masses and is used as salad and cooked in various ways. Besides

fresh consumption, onion provides a good raw material for processing industry as it can be processed in the form of dehydrated powder, rings, shreds and to make vinegar and brine. On account of its special characteristics of pungency due to the presence of allyl propyl disulphide it is valued much.

Onion bulb contains moisture 86.8 g, carbohydrates 11.0 g, protein 1.2 g, fiber 0.6 g, mineral 0.4 g, thiamine 0.08 mg, vitamin-C 11 mg, calcium 180 mg, phosphorus 50 mg, iron 0.7 mg, nicotinic acid 0.4 mg and riboflavin 0.01 mg per 100 g of edible portion. The important principles like allicin, ajoene, allixin thiosulfinates, sulphites etc. present in onion makes it a potential medicinal herb. They are good for eyes, helpful in the prevention of cardio vascular diseases and cancer insurgences, and has antioxidant, antibiotic, antirheumatic, hypoglycemic and hypolipidemic effects (Mahajan and Gopal, 2012).

In India, onion is grown under three crop seasons i.e. *kharif,* late *kharif* and *rabi*. Main crop is in *rabi* (60%) and 20% each is in *kharif* and late *kharif* (Lawande and Murkute, 2011). Generally, all states grow onion except North Eastern States and Kerala. Maharashtra alone contributes 26% of area, 29% of production and 90% of export of onion in our country.

The highly outcrossing behaviour of onion promoted its suitability to diverse environment during the course of adaptation and diversification. The establishment of onion cultivation in South India, i.e., in Bellary region of North Karnataka and Tamil Nadu are the recent results of tropicalization. However its cultivation is not yet commercialised in Kerala. The typical tropical humid agro climatic conditions prevailing in Kerala limits the cultivation of onion.

Successful onion production depends on the selection of varieties that are adapted to different conditions imposed by specific environment and best planting time. As a part of tropicalization of cool season vegetables, cultivation of cool season vegetables during winter season is gradually picking up in Kerala. Development of varieties suited to tropical climate triggers the tropicalization process.

Onion is a cool season crop adopted to a temperature range of 13-24°C and the day length requirement varies with varieties. Varieties such as Arka Kalyan, Arka Pragati, Agrifound Dark Red etc. are short day varieties which were developed for cultivation in tropical regions. Onion can be grown in almost all types of soils, but for higher yield and bulb quality, cool, deep and friable soil having high fertility is recommended. In general, sandy loam to clay loam soil with an optimum pH range between 5.8 and 6.5 is recommended. Highly alkaline and saline soils are not suitable for onion cultivation. Good drainage is essential for the crop. Onion is highly sensitive to high water table and this character limits its cultivation in Kerala, which receives around 2400 mm of rainfall annually. Preliminary studies have shown that the climatic conditions during winter season are congenial for the cultivation of tropical onion varieties. So there is a possibility for commercial cultivation of onion in Kerala also.

Menon *et al.* (2016) evaluated 20 onion varieties by raising seedlings under protected condition and found that all the varieties except Bhima Raj, Agrifound Rose and NHRDF Red 1 are suitable for cultivation in the plains of Kerala. The findings of this study indicated the need for more research on the standardization of crop management practices.

In this background, the present study was undertaken with the following objectives:

- To evaluate the onion varieties suitable for cultivation in the plains of Kerala
- To select the suitable planting time for the successful cultivation of onion in the plains of Kerala
- To study the effect of varieties, planting time and their interaction on the qualitative and quantitative traits of onion

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Onion (*Allium cepa* L.) is one of the important bulb crops. It is a rich source of vitamin C, potassium, calcium, protein, dietary fibres etc. This crop is cultivated in three seasons in India, *rabi, kharif* and late *kharif.* It is an important ingredient in the daily diet of people across the world. In India, almost all states except few are cultivating onion. Kerala is also a leading consumer of onion, but its cultivation is not yet commercialised here. Recent studies indicated the scope for cultivation of onion in Kerala also. The available literature pertaining to this study is reviewed under the following heads.

2.1. Influence of climatic conditions on the cultivation of onion

2.1.1. Effect of temperature

2.1.2. Effect of day length

2.2. Influence of soil conditions on the cultivation of onion

2.2.1. Effect of moisture

2.3. Effect of cultivars and planting time on growth, yield and quality

2.4. Incidence of pest and diseases

2.1. Influence of climatic conditions on the cultivation of onion

Growth and development of plants are controlled by the interaction between external and internal growth factors in the plants (Chory et al., 1996).

Onion is a temperate crop but can be grown under a wide range of climatic conditions such as temperate, tropical and subtropical climate. The best performance can be obtained in a mild weather without the extremes of cold and heat and excessive rainfall. However, onion plant is hardy and in the young stage can withstand freezing temperature also. In India, short-day onion is grown in the plains and requires 10-12 hours day length. The long-day onion is grown in hills requiring 13-14 hours day length. For vegetative growth, lower temperature combined with short photoperiod is required whereas relatively higher temperature along with longer photoperiod is required for bulb development and maturity. The

optimum temperature for vegetative phase and bulb development is 13-24˚C and 16-25˚C, respectively. It requires about 70% relative humidity for good growth. It can grow well in places where the average annual rainfall is 650-750 mm with good distribution during the monsoon period. Areas with low (< 650 mm) or heavy rainfall (>750 mm) are not particularly suitable for rain-fed crop (DOGR, 2017).

2.1.1. Effect of temperature

Thompson and Smith (1938) studied the seed stalk and bulb development in onion and they observed that under 15 hour day condition, bulbing did not take place at 50 to 60°F, but it did take place at 70 to 80°F. Bulbing began earlier by at least a month at 70 to 80°F than at 60 to 70°F.Seeding in onion takes place at relatively lower temperatures and long days, but higher temperatures are necessary for bulb formation (Milthorpe and Horowitz, 1943).

Heath and Holdsworth (1948) during their studies in the physiology of onion plant stated that bulbing is accelerated by higher night temperatures rather than higher day temperatures. Inflorescences were quickly initiated in sufficiently large plants when temperature was below 15°C, but temperatures above 17°C suppressed inflorescence initiation (Holdsworth and Heath, 1950).

Results of the physiological studies on bulb formation in onion conducted by Kato (1964) revealed that the higher the temperatures, the earlier the bulb developed during long-day period. The optimum temperature for leaf growth ranged between 17 and 25°C and the minimum temperature favouring leaf growth was reported to be 10°C.

Steer (1980) studied the role of night temperature in the bulbing of onion. He observed a decrease in the number of days from sowing to start of bulbing with increasing night temperature. He also reported that the rate of bulbing after bulb initiation increased with increase in night temperature. He also studied the bulbing response in onion to day length and temperature and reported that rapid bulbing takes place at higher temperature (34/26°C) and long days length (17hr).

The dry weight percentage of onion bulbs decreased as growth temperature increased from 22/16 to 33/28°C (day/night). Glucose content was reported to be high at higher temperatures, but total carbohydrate content did not change with growth temperature (Steer, 1982).

Ruiter (1986) studied the effect of temperature and photoperiod on onion bulb growth and development and reported that the bulbing in early maturing varieties depends more on temperature than photoperiod, but the reverse was true for the late maturing ones.

Sing *et al.* (1992) evaluated nine cultivars of onion at Hisar and found out that varieties such as Pusa White Round, Pusa White Flat and Hisar – 2 had the highest bulb yield. They also observed a higher TSS in Hisar-2 and Arka Kalyan.

Daymond *et al.* (1997) studied the growth, development and yield of onion in response to temperature and CO_2 and reported a decline in bulb yield at harvest maturity with progressively warmer temperature in onion. They used two onion cultivars for the experiment and noted that for each cultivar there was a positive linear function between temperature and the rate of progress from transplanting to bulb maturity.

Wurr *et al.* (1998) investigated the possible impacts of global rises in atmospheric CO_2 and temperature on different crops and observed that bulbing was accelerated by higher temperature and was delayed at lower temperature. He also reported the development of undesirable, thick necked onions which tended to remain green with erect leaves as a result of delay in bulbing at temperatures below 15°C.

Wickramasinghe *et al.* (2000) studied the bulbing response of two cultivars of red tropical onions (Red Creole and Agrifound Dark Red) to temperature under controlled growth conditions. They compared four temperature regimes in a growth room experiment. The results revealed that plants treated with 29-34°C bulbed within two weeks and matured within six weeks. Bulb initiation was delayed in

those plant receiving the 25-30°C. They also reported the production of bigger bulbs with thick necks at the lowest temperature (17-22°C).

Coolong and Randle (2006) conducted an experiment to understand the influence of root zone temperature on growth and flavour precursors in onion. They reported the highest bulb fresh weight at root zone temperature of 21°c. Total pyruvic acid (pungency) level and soluble solids contents showed an increasing trend between 12°C and 21°C, and were lowest in the 34°C treatment. The concentration of sulphur components were also lowest at 34°C.

Lee and Suh (2009) studied the effect of temperature on the growth, pyruvic acid and sugar contents in onion bulbs. They observed a decrease in leaf number with increasing temperatures while plant height did not change with temperature. As temperature increased, bulb diameter, bulb weight and bulb index (bulb/neck diameter) were also increased and they were better at 25°C. They also reported that temperatures ranging from 25 to 30° C were better for the subterranean growth while aerial growth was better at temperatures ranging from 20 to 25°C. Beyond 30°C there was a significant decrease in bulb weight. Pyruvic acid content was highest at 20°C while sugar content was maximum at 25°C. At 20°C, pyruvic acid and sugar content per unit weight of bulb were maximum.

In a study conducted by Tesfay *et al.* (2011) to determine the growth response of tropical onion cultivars to temperature based growing degree days concluded that temperature induces variations in leaf number, plant height, leaf area, and bulbing.

According to Lawande and Mahajan (2011), night temperature of 10-15˚C and day temperature of 20-25˚C favour bulb initiation in onion. For bulb development, night temperature of 18-20˚C and day temperature of 25-30˚C are found to be suitable, but for bulb maturity, 35-38˚C of day temperature is required.

Performance studies on promising onion lines were conducted by Singh *et al.* (2011) at NHRDF, Nasik. They evaluated promising lines of 9 red and 10 white

21

onion. They recorded the highest bulb yield in the variety Agrifound Light Red (378.46 q/ha) which was on par with that of the line 382 (357.67 q/ha).

Rayyan *et al.* (2012) conducted a study to understand the influence of temperature and light on onion seed germination. They reported that temperature ranging from 7.5 to 30°C assured a higher germination percentage and a high percentage of normal seedlings. They also observed that the most rapid germination occurred at 25°C in the dark. Normal germination was only about 10% at 5, 35, and 40°C.

Mahajan and Gupta (2016) reported that temperatures below 10°C during bulb development causes bolting and higher temperatures above 42°C at the time of bulb maturity causes the formation of undersized bulbs in Indian short day onions.

The ideal temperature for vegetative growth is 15-21.0^{0}C. For bulb development it requires higher temperature i.e.20-25^{0}C.Warm temperature favours good development of bulbs (NHRDF, 2017).

2.1.2. Effect of Day length

Thompson and Smith (1938) stated that for a given day length, bulb formation is accelerated by higher temperature, while longer days are needed for the same at lower temperature.

Day length is one of the major factor influencing bulbing in onion (Heath, 1945), but when it comes to tropical conditions where only small changes in day length occur, effect of day length on bulbing is not that significant (Abdalla, 1967). Terabun (1971) reported that exposure to a strongly inductive photoperiod induces bulb formation regardless of the size of the plant.

Steer (1980) studied the bulbing response of Australian onion cultivars to temperature and day length and reported that bulbing takes place rapidly in a combination of long day length and high temperatures.

Wickramasinghe *et al.* (2000) studied the bulbing response of two red tropical onion varieties, Red Creole and Agrifound Dark Red. They observed that both the cultivars required at least 12 hr photoperiod for bulb development and the number of true scales were increased when the photoperiod was increased to 13 hr.

According to Rabinowitch and Currah (2002) tropical onion varieties are generally short day onions because they form bulbs in less than 12 hr photoperiods and so are suited to warmer climates. Onion is predominantly a *rabi* season crop and most of the cultivars are sensitive to photoperiod and therefore their range of cultivation is limited (Pandey and Bhonde, 2002).

Okporie and Ekpe (2008) conducted a study to investigate the effect of photoperiod on the growth and bulbing of tropical onion. They exposed two tropical onion varieties to varying day lengths during 2000 and 2002. They observed that bulbing was suppressed drastically when photoperiod was below 11hr and leaf length, leaf number, plant height and bulbing were directly proportional to the increase in day length.

Mettananda and Fordham (2015) studied the effect of 12 hr and 16 hr day length on the onset of bulbing in 21 onion varieties and they concluded that varieties differed in their response to varying photoperiods and identification of accessions capable of bulbing under short day conditions determined the success of onion cultivation in the tropics. According to their findings Agrifound Light Red is such a variety that is suitable to tropics.

2.2. Influence of soil conditions on the cultivation of onion

Onion can be grown in all types of soils such as sandy loam, clay loam, silt loam and heavy soils. However, the best soil for successful onion cultivation is deep, friable loam and alluvial soils with good drainage, moisture holding capacity and sufficient organic matter. In heavy soils, the bulbs produced may be deformed. Onion crop can be grown successfully on heavy soil with application of organic manure prior to planting and preparation of the field for onion cultivation should be very good. The optimum pH range, regardless of soil type, is 6.0 - 7.5, but onion

can also be grown in mild alkaline soils. Onion crop is more sensitive to highly acidic, alkali and saline soils and water logging condition. Onions do not thrive in soils having pH below 6.0 because of trace element deficiencies, or occasionally, Al or Mn toxicity. The threshold electrical conductivity of a saturation extract for onion crop is 4.0 dS/m. When the EC level exceeds this, crop yield starts declining (DOGR, 2017).

2.2.1. Effect of soil moisture

Finch-savage (1986) suggested that high levels of seedling emergence with high uniformity can be achieved by irrigating the seed bed prior to sowing and maintaining the soil moisture during the first 3 days following sowing.

Being a shallow rooted crop, onion is very sensitive to water stress. So to avoid water deficiency and to recharge the plant root zone adequately it requires light and frequent irrigation (Koriem *et al.,* 1994).

Shock *et al.* (1998) conducted a trial with yellow onion variety 'Great Scott' and different irrigation thresholds in three successive years. They reported an increase in total yield, marketable yield and bulb size with increasing irrigation threshold and any soil moisture stressed even below field capacity lead to yield reduction. They also suggested that an irrigation threshold more than -12.5 kPa during years with dry, warm conditions could increase the onion yield and profit.

Sorensen and Grevsen (2001) reported a reduction in yields by water stress during the last 3 weeks of the growing season. Kanton *et al.* (2003) studied the influence of irrigation schedule on growth, yield and development of onion. They tried different irrigation regimes such as irrigating in morning and evening daily, morning daily, evening daily, morning and evening alternate days, morning or evening alternate days. Irrigation regime had significant influence on bulb yield, plant height, and foliage weight but, it didn't influence bulb sugar content. Bulb yield and yield components were negatively correlated with irrigation regime.

Pelter *et al.* (2004) studied the effect of water stress at specific growth stages on onion bulb yield and quality and reported that with holding irrigation at three and seven leaf stages resulted in an yield reduction by 26 %. Even though they observed a reduction in total yield as a result of water stress at any stages of growth, the greatest reduction was noted at 5 leaf, 7 leaf and 3leaf stages.

Response of bulb onion to water stress was studied by Bhatt *et al.* (2006). They imposed a water stress for a period of 15 days at 30 days after transplanting. They observed that bulb yield was reduced drastically in the stressed plants as a long term consequence of water stress.

Results of the study conducted by Kumar *et al.* (2007) to find out the effect of differential soil moisture and nutrient regimes on post-harvest attributes of onion revealed a significant increase in mean bulb size, mean bulb weight and yield with increasing levels of irrigation.

Water stress during certain stages of growth in onion may lead to drastic yield differences (Enciso *et al.*, 2009). For example, the results of the study conducted by Martin de Santa Olalla *et al.* (2004) revealed that water stress during bulbification and ripening stages lead to difference in bulb yield.

Most of the crop water requirement in onion is met from the top 300 mm depth of soil. So it requires frequent irrigations to keep the upper soil areas moist, which is necessary to stimulate root growth and provide adequate water (Anisuzzaman *et al.*, 2009).

In a study conducted by Biswas *et al.* (2010) to investigate the effect of different levels of irrigation on yield and purple blotch incidence in onion, four different levels of irrigations (irrigation at 10, 15, 20 and 30 days intervals) was tried along with non-irrigated treatment as control. They observed that bulb yield was positively correlated with higher levels of irrigation. Bulb size was highest in the first treatment. They also observed that the increase in bulb yield was continued only up to four irrigations and they could conclude that there was a decreasing trend in the rate of yield increase with increasing irrigation.

Leskovar and Agehara (2012) reported that deficit irrigation in onion resulted in a reduction in number of bulbs, bulb size and total yield and they concluded that the installation of deficit irrigation systems in semi-arid regions reduces the high value bulb grades and results in modest losses in yield.

2.2. Effect of varieties and planting time on growth and yield

In a two year trial conducted by Arora (1967), to study the effect of different dates of transplanting (various dates between late December and late February), poor bulb development and bulb yield was recorded in later planting.

The results of the investigation by Izquierdo *et al.* (1981) on the effects of sowing and transplanting dates on yields of valenciana type onion revealed that longest growth cycle and highest yield are obtained by early planting, i.e., on 16th November.

In a study conducted by Mondal *et al.* (1986) on the bulb development in onion, stated that although there are many agronomic factors that influence the cultivation of onion, the important factor influencing the growth and yield of onion is its planting time.

Results of the experiment conducted to determine the effect of time of transplanting on bulb yield revealed that yield was higher in early January transplantation than in February transplantation (Singh and Yadav, 1987).

Mohanty *et al.* (1990) studied the effect of planting time on yield by transplanting on various dates such as 20 Nov., 5 Dec., 20 Dec., 4 Jan. and 19 Jan. They obtained highest average yield (291.14-304.60 q/ha), bulb diameter (6.60-6.66 cm) and bulb weight (117.77-126.54 g) for the 20 Nov. and 5 Dec. planting.

Pandey *et al.* (1990) tried the transplantation on five different dates between 15 Dec. and 15Feb. in a trial over 3 years. They could obtain a higher yield of marketable bulbs and highest net return by transplanting on 1st January.

In the performance evaluation of 11 varieties of onion, highest bulb yields were obtained for Agrifound Light Red and Pusa White Flat (42.8 and 42.3 t/ha, respectively) (Jadhav *et al.*, 1990). Results of the field experiments conducted at IARI, Katrain by Verma *et al.* (1993) revealed that for quality bulb production in onion during *rabi* season, the most suitable planting time was 10th December.

Mohanty *et al.* (2000) assessed different onion varieties for various horticultural traits during Kharif season. Varieties such as Pusa Madhavi, Agrifound Dark Red, Arka Kalyan, Arka Niketan, Agrifound Light Red were having comparatively thinner neck thickness. Agrifound Dark Red recorded highest bulb yield of 315.2 q/ha.

Onion is a transplanted crop generally sown in nursery beds. The best time for sowing seeds for *kharif* crop is April-May and for *rabi* crop is September-October in South India. (Thamburaj and Singh, 2000).

Mohanty (2001) studied the effect of planting time on the performance of onion varieties. It was reported that Agrifound Light Red and Arka Niketan performed well among the varieties evaluated and 16th November planting produced taller plants with more number of leaves and yield compared to other planting dates. Results of the interaction effect showed that maximum yield was obtained from Agrifound Light Red planted on 16th November which was on par with Arka Niketan on 1st November and Arka Kalyan on 16th November planting.

In the study on varietal performance of onion in rainy season by Mohanty and Prusti (2002), with 12 varieties of onion noticed that *rabi* varieties when planted in kharif season performed well and the varieties such as N-53 (239.33q/ha), Arka Kalyan (238.20q/ha), Agrifound Dark Red (234.00q/ha) and Arka Niketan (214.37q/ha) recorded significantly higher yields.

Jain and Sarkar (2002) evaluated five onion varieties such as Agrifound Dark Red, Agrifound Light Red, Nasik Red, N-53 and Arka Niketan at Ranchi, Bihar during *kharif* season. They obtained a highest bulb yield in Agrifound Dark

Red (174.39 q/ha), which was followed by Arka Niketan (156.40 q/ha). They also reported that the lowest bulb yield was recorded for Agrifound Light Red (81.11 q/ha). The total soluble solid content was highest (11.4 °B) in Arka Niketan.

Devi *et al.* (2003) studied the effect of planting time on bulb growth and yield of onion cultivars in Bapatla. They observed that all the bulb characteristics were good in plants transplanted on 15th October. They also noted that earliness in bulb initiation was positively correlated with a progressive delay in planting. Earliness in bulb initiation and bulb maturity was highest in the variety Agrifound Dark Red.

In a study conducted to evaluate varieties and their plantig time of onion for off season production by Gautam *et al.* (2006), varieties differed significantly for the fresh bulb production only. However they observed a significant difference in plant height, plant stand at maturity and marketable bulb yield with different planting dates.

Mosleh ud-deen (2008) observed a significant influence of planting date on growth and bulb yield and higher bulb yields were favoured by early planting. Khokhar (2008) studied the effect of set size and planting time on bulbing and bolting in onion. Bulb yield was enhanced by late planting until 5 March, but time taken for bulb maturity was delayed.

Haldar *et al.* (2009) conducted a study to identify suitable varieties under West Bengal condition. They stated that varieties such as Baswant 780, Agrifound Dark Red, Arka Pragati and Phule Safed can be grown by planting the seedlings in the first week of October.

Sarada *et al.* (2009) evaluated eight onion varieties (Agrifound Dark Red, Agrifound Light Red, Arka Niketan, Arka Kalyan, Arka Pragati, Pusa Red, N 53 and Nasik Red) in the black soils of Andhra Pradesh and observed that varieties exhibited a significant variation in growth and other yield parameters studied. Number of leaves per plant, bulb diameter and yield were recorded maximum for

Arka Niketan and Arka Kalyan and greatest bulb weight was recorded for Arka Niketan, Arka Kalyan and Arka Pragati

Sharma (2009) evaluated onion varieties in *Kharif* season under low hills of Himachal Pradesh. Highest mean bulb production was reported for Baswant-780 (230.50 q/ha). Agrifound Dark Red showed an yield potential of 199.40 q/ha.

Bhat and Bhushan (2009) evaluated 10 genotypes namely Agrifound dark red, L-28, Agrifound light red, N-53, Arka Niketan, Yellow globe, Brown Spanish, Arka Kalyan, Patna Red and Local. They obtained a maximum yield for the variety Agrifound light red (35.2 q/ha) which was followed by Arka Nikatan (33.9 q/ha). However, four other cultivars such as, Arka Kalyan (32.2 q/ha), Patna Red (30.8 q/ha), N-53 (30.0 q/ha) and Brown Spanish (29.3 q/ha) also performed better than Local cultivar (24.3 q/ha) while the remaining genotypes performed poorly in terms of yield and other yield-contributing parameters..

Results of the evaluation studies conducted by Giri *et al.* (2009) in the plains of West Bengal revealed that varieties such as Agrifound Dark Red, Baswant-780, Agrifound Light Red and N-53 performed well as a *kharif* crop. Agrifound Dark Red recorded the highest bulb yield.

Mahanthesh *et al.* (2009) evaluated 13 varieties/hybrids for dry matter production and yield in Kharif season in Karnataka and they reported that Baswant-780, Arka Kalyan and Agrifound Light Red gave higher dry matter and bulb yield.

Dev (2009) conducted performance evaluation of kharif onion varieties in lower hills of Himachal Pradesh and reported that varieties Baswant-780 and Agrifound Dark Red excelled the existing recommended kharif onion variety N-53.

Hiremath and Nagaraju (2009) conducted frontline demonstration in the villages of Karnataka with improved (Arka Kalyan and Bellary red) and local cultivars of onion. They reported a higher yield in both Arka Kalyan and Bellary red compared to their respective local controls. There was around 28.96% yield increase in Arka Kalyan over the local control used in demonstration.

Results of the studies of onion varieties conducted by Yadav *et al.* (2010) in Firozabad revealed that Arka Niketan recorded the maximum plant height and number of leaves per plant. Agrifound Dark Red produced maximum bulb yield while the minimum was noted in Agrifound Light Red.

According to Dev (2011), 1st December is the best transplanting date for onion. He stated that early planting did not affect growth and yield, but was associated with low quality and high bolting percentage. Unlike early planting late planting resulted in poor grwth and yield reduction.

According to Chandrika and Reddy (2011) Arka Pragati was superior in yield paramaters compared to other genotypes such as Agrifound light red, Arka Niketan and Arka Kalyan.

Dwivedi *et al.* (2012) evaluated eight improved onion varieties viz; VL-1, VL-3, Arka Niketan, Arka Kalyan, Pusa Red, Pusa White flat, Pusa Hybrid 107 and Pusa Hybrid 102 to study their performance in Jabalpur. Significantly higher yield was obtained in the variety Pusa hybrid 102 and Arka Kalyan recorded the lowest yield. They also noticed the highest plant height, number of leaves, leaf width and bulb weight in Pusa hybrid 102.

Patil *et al.* (2012) showed that transplanting date has a significant effect on growth and other yield parameters of onion crop. He reported that early transplanting of seedlings. i.e., on 15th November yielded the maximum in all the varieties under study. Highest average bulb weight (83.9g) was recorded in the plants that were transplanted on 1st December while TSS was maximum (19%) in the bulbs from 1st January transplanted plants. They noticed a negative correlation between yield and TSS, i.e. even though the yield was maximum in the 15th November planting, TSS was the minimum.

Naik *et al.* (2012) evaluated 6 onion varieties under central Telengana conditions of Andrapradesh. They observed that Arka Pragati produced bulbs with highest weight and diameter and tallest plants were produced by Arka Kalyan.

Earlier planted onions have enough time to complete their growth and development stages and acquire more assimilates that can lead to increase in bulb weight (Hamma, 2013). Kandil *et al.* (2013) investigated the influence of different planting dates on growth and bulb yields and he observed that total yield, marketable yield, average bulb weight and total soluble solids were highest in 15th December transplanted crop.

In a study conducted to investigate the effect of planting time and varieties on the growth and yield of *Kharif* onion, the results revealed that a delay in planting from August to September increased growth and bulb size. Highest yield was obtained from the variety Agrifound Dark Red by planting on 30th September (Mohanta and Mandal, 2014). Caruso *et al.* (2014) reported a decrease in mean bulb fresh weight from earliest planting to the latest one.

Misra *et al.* (2014) reported 25th November as the best planting time for onion in Manipur as planting on this date resulted in maximum number of leaves (8.26), leaf length (50.50 cm), leaf area (87.93 cm2), yield (267.20 q/ha), polar diameter (4.92 cm), equatorial diameter (53.68 mm), average single bulb weight (68.48 g), bulb dry matter (13.68%) and harvest Index (72.92).

According to Boyhan *et al.* (2014) transplanting onion from the beginning of November until the end of December will give reasonable yield and quality, but the tendency of some varieties to form double bulbs can be reduced by late planting. They also added that there were no significant varietal effect on total bulb yield

The results of the experiment conducted by Bijarniya *et al.* (2015) revealed that, plant height and number of leaves per plant were higher in plants transplanted on 30th November, but the marketable bulb yield was maximum in plants transplanted on 15th December.

Devulkar *et al.* (2015) studied the influence of spacing and planting time in onion and reported a significant effect of different planting dates on different characters such as plant height, polar diameter, equatorial diameter, number of

leaves per plant etc. They tried five different planting dates (15th November, 25th November, 5th December, 15th December, and 25th December) and the highest vegetative growth (80.90 cm), marketable yield (29.87 t/ha) and total yield (30.58 t/ha) were recorded in early planting on 15th November.

Hirave *et al.* (2015) evaluated eight red onion varieties and reported a significant variation for plant and bulb characteristics. They also observed that the maximum TSS content was recorded in the variety Agrifound Dark Red (11.47°B).

Results of the study conducted by Sarkar *et al.* (2015) indicated that different varieties showed significant variations among each other for growth and other yield parameters. The variety Local Red produced the most dwarf plants followed by Agrifound Light Red (34.70 cm).

Tarai *et al.* (2015) studied the varietal performance of different onion varieties in Odisha. The results of the study revealed that N-2-4-1 recorded the lowest neck thickness which was followed by Arka Niketan and Agrifound Light Red. Bhima Sakti, Arka Kalyan and Agrifound Light Red exhibited superior performance with respect to bulb weight (77.5, 75.8 and 72.5), yield per plot and yield per ha (24.8t/ha, 24.3 t/ha & 23.2 t/ha).

In an investigation conducted to assess the growth, yield and quality parameters of different varieties, Agrifound White was found to have the highest TSS (14.26) followed by Arka Kalyan (13.46) and the lowest was recorded in Agrifound Light Red (11.24) (Umamaheswarappa *et al.*, 2015).

Plant growth, bulb development and bolting or flowering of onion are influenced by photoperiod (day length) and temperature. In India the onion varieties grown in the plains are short day types requiring 10-11.5 h day length while long day types, 13-14 h day length are cultivated in the hills (Vishnu Swarup, 2016). Ali *et al.* (2016) reported that all the yield parameters were best in plants that were transplanted on 15th December.

Bindu and Podikunju (2016) evaluated three onion varieties (Agrifound Dark Red, N-53 and Arka Kalyan) at KVK, Kollam. They transplanted the seedlings during the first week of November and obtained a higher bulb yield from the variety Agrifound Dark Red followed by Arka Kalyan. Shahnaz *et al.* (2016) reported that the intensity of leaf blight incidence was lowest and yield was maximum when planting was done on 1st November.

Menon *et al.* (2016) conducted a study on performance evaluation of onion varieties in the tropical plains of Thrissur district, Kerala. They screened 20 varieties of big onion and reported that onion varieties such as Bhima Sakthi, Agrifound Light Red, Agrifound White, Arka Kalyan, Bhima Super, and Agrifound Dark Red performed well in the plains of Thrissur district.

In a study conducted by Sharma and Dogra (2017), they reported that bulb diameter, bulb weight and yield were significantly influenced by varieties, transplanting dates and their interaction. Agrifound Dark red yielded maximum and 15th August was found to be the best planting time.

In an experiment conducted by Sharma and Jarial (2017) in the lower Shivalik hills of Himachal Pradesh, the results suggested Agrifoud Dark Red as the best performing variety and for getting maximum yield in *kharif* the planting time should be 25th July.

Higher productivity was reported in *rabi* onion when transplanted on 1st December rather than late transplanting on 30th December (Prasad *et al.*, 2017). Results of the experiment conducted by Vaghela *et al.* (2017) revealed that among the white onion varieties, Agrifound White gaves better growth, highest yield and superior quality when planted on 17th December.

Ganiger *et al.* (2017) evaluated six onion varieties for growth, bulb yield and quality parameters for Northern dry zone of Karnataka. Growth parameters such as plant height and leaf length was highest in Arka Niketan whereas more

number of leaves was recorded in Arka Bindu. Number of rings was maximum in Arka Bindu and was lowest in Arka Kalyan.

Kumbhkar *et al.* (2017) studied the dates of transplanting on the growth, yield and quality of onion and reported that good growth, maximum bulb yield and marketable bulb yield and minimum days required for maturity were recorded for plants transplanted on 30th September. Plant height and number of leaves per plant were higher for 15th September transplants whereas neck thickness, number of doubled bulbs, total yield per plot, unmarketable yield per plot, and TSS were recorded maximum for the 1st September transplanted plants.

Behera *et al.* (2017) assessed 24 red short day onion varieties for growth, yield and quality parameters. They observed a significant variation in almost all the characters such as plant height, leaf length, leaf diameter, number of leaves, neck diameter, and number of scales, TSS, average bulb weight and bulb yield among the genotypes evaluated.

Misu *et al.* (2018) conducted a study to determine the effect of planting date on planting with three varieties. Among the three planting dates (16th September, 18th October and 17th November), maximum yield was recorded from 16th Sep. planting while 17th Nov. planting recorded the lowest. The study also revealed that the combined effect of planting dates and varieties on growth and yield were statistically significant.

2.3. Incidence of pest and diseases

Bailey (1938) reported that as a result of feeding of the thrips on onion leaves, cellular content is removed causing the formation of silvery leaf spot that turn into white blotches along the leaves. According to Lewis (1973) young onion plants are more susceptible to the attack of thrips and are prone to be killed by high infestations.

Gupta *et al.* (1994) reported that around 10-15% yield losses occur annually due to diseases and insect pests. They conducted surveys during rainy and winter /

summer season and observed that *Colletotrichum* was severe in rainy periods whereas *Stemphilium* was severe during summer. Purple blotch was reported to be severe in both seasons while thrips were severe during summer season. Only *Stemphilium* blight, purple blotch and onion thrips are of national importance in India.

Srinivas and Lawande (2004) investigated the impact of planting dates on thrips infestation and yield loss in onion and stated that thrips infestation and yield loss was maximum in *rabi* season planting; especially on 15th November followed by 1st December planting. They also reported around 46.87% yield loss due to trips attack in onion during *rabi* season. The survey reports of Gupta *et al.* (1994) also concluded that thrips attack is more in onion during winter period.

The increase in the population of *Thrips tabaci* was favoured by hot and dry weather conditions (Rueda *et al.,* 2008). Ibrahim and Adesiyun (2009) studied the effect of different dates of planting on the control of thrips and yield of onion in Nigeria and they noticed that thrips population was very low in November transplanted crops.

Onion thrips has become a global pest of commercial onion cultivation. Blotches on leaves, premature senescence and distorted, undersized bulbs are the symptoms of their feeding. They can even cause a huge yield loss of more than 50% by acting as the vectors of some viral diseases (Montano *et al.*, 2011).

Basal rot caused by *Fusarium oxysporum* f.sp *cepae* is an important disease in onion which is prevalent in most of the onion growing tracts of the world. The characteristic symptoms are seen on the leaves and bulbs. Initially there will be yellowing of leaf blades at the tip. Then it spread down to the entire leaf. Rootsytem will be retarded and the plants can be pulled out easily (Patil., 2012).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present experiment entitled "Standardisation of planting time and evaluation of varieties in onion (*Allium cepa* L.)" was conducted at the Department of Vegetable Science, College of Horticulture, Vellanikkara, during the period from November to March of 2017-18.

3.1. Site selection

The location of the site was at the Department of Vegetable Science which is located at about 10°32'N latitude, 76 °13'E longitude with an average altitude of 22.25 m above MSL. The area experiences typical warm humid tropical climate and receives an average rainfall of 2663 mm per year. The soil of the experiment site is lateritic in origin grouped under the textural class of sandy clay loam and acidic in reaction. The climatic conditions during the period of the experimentation are shown in Appendix I. The objectives of the study were to evaluate the performance of onion varieties and to standardise the planting time.

3.2. Experimental materials

Experimental material consists of five varieties of onion (*Allium cepa* L.). The details of the varieties used are given in Table 1.

Table 1. Details of onion varieties used for the experiment

Sl. No.	Variety	Source	Colour	Duration (days after sowing)
1	Arka Kalyan	IIHR, Banglore	Deep pink	140-145
2	Arka Pragati	IIHR, Banglore	Attractive pink	140-145
3	Agrifound Dark Red	NHRDF, Coimbatore	Dark red	150-160
4	Agrifound Light Red	NHRDF, Coimbatore	Light red	160-165
5	Agrifound White	NHRDF, Coimbatore	White	160-165

D_3R_4		D_2R_4		D_4R_4		D_1R_4
D_2R_3		D_4R_3		D_1R_3		D_3R_3
D_3R_2		D_1R_2		D_2R_2		D_4R_2
D_1R_1		D_3R_1		D_4R_1		D_2R_1

Figure 1. Layout of the experimental plot

3.3. Design and layout of the experiment

The experiment was laid out in split plot design with four replications (Fig.1). The main plot treatments were planting dates and subplots were varieties. The details of the experiment are given below.

a) Varieties : 5 (Arka Kalyan, Arka Pragati, Agrifound Dark Red, Agrifound Light Red and Agrifound White)
b) Planting time : 4 (Nov.10th, Nov.25th, Dec.10th and Dec.25th)
c) Design: Split plot (Main plot- planting time and Sub-plot- varieties)
d) Plot size: 1 m^2
e) Spacing: 20 cm x 10 cm
f) Replications: 4

3.4. Season

The crop was raised during November to March, 2017-18. Seedlings were raised during September-October and transplanting was carried out during Nov-Dec after the cessation of North-East monsoon.

3.5. CULTURAL PRACTICES

3.5.1. Nursery practices

Seedlings were raised on nursery beds (Plate 1 and 2). Nursery beds of 1m width and convenient length were taken inside a rain shelter to protect the seedlings from monsoon rains. Seeds were sown during the months of September and October. Sowing started by the last week of September and was repeated at an interval of 15 days. Weekly spraying of 19:19:19 was done at the rate of 4g/L in order to improve the growth of seedlings.

3.5.2. Preparation of main field

The field was prepared thoroughly by repeated ploughings to get a fine tilth. Lime was applied at the rate of 2kg per 40 m^2 and field was left as such for 15 days. During the final land preparation the entire experimental field was levelled and

Plate 1. Preparation of nursery bed

Plate 2. Germinated onion seedlings on the bed

divided into sub plots (Plate 3). Raised beds of $1m^2$ were prepared and vermicompost was incorporated before transplanting.

3.5.3. Transplanting

Forty five days old seedlings were used for transplanting in the main field (Plate 4). Transplanting was done at 15 days interval including four dates of transplanting, *i.e.* 10th November, 25th November, 10th December, and 25th December (Plate 5).

3.5.4. Weeding

Mulching was done after transplanting to limit the infestation of weeds. Weeding and hoeing was done at 10 days intervals up to 30-40 DAP.

3.5.6. Application of fertilizers

A fertilizer dose of 80:40:60 $N:P_2O_5:K_2O$ kg/ha was applied in two split doses, half N and K and full P basally and remaining N and K at one month after transplanting.

3.5.7. Irrigation

The crop was irrigated regularly. Irrigation was withheld gradually one week before harvesting.

3.5.8. Plant protection

To control damping off of seedlings, *Trichoderma* was incorporated in the beds before sowing. Major problem in nursery and main field was the burning of leaf tips. This was controlled by spraying of micronutrients and copper fungicides (Kocide-1.5g/L). Soil was drenched with SAAF (2g/L) to control soil borne diseases such as damping off and wilt. Frequent spraying of *Pseudomonas* was also done to control foliar diseases. Incidence of thrips was noticed and brought under control by the spray of Oberon (0.3 ml/L).

Plate 3. Main field layout

Plate 4. Transplanting seedlings in the main field

Plate 5. General view of the main field

3.5.9. Harvesting

Maturity is indicated by the yellowing and drying of the aerial part of the plants. Harvesting was done by just pulling out the plants and then bulbs were cured in the field with leaves intact.

3. 6. OBERVATIONS

Observations on morphological characters were recorded as per NBPGR descriptor. Five plants were selected randomly from each plot to record observations and the average was calculated for further statistical analysis

3. 6. 1 Seedling vigour

Seedling vigour was recorded by observing the nursery seedlings 25 days after sowing.

3. 6. 2 Bolting

Presence of bolting was observed on fully grown crop and recorded as present or absent.

3. 6. 3 Bulb location

Bulb location was recorded at maturity stage as underground or partially exposed or fully exposed based on NBPGR descriptor.

3. 6. 4 Bulb shape

Bulb shape was recorded on the mature bulb based on the classification given by NBPGR descriptor.

3. 6. 5 Bulb skin colour

Bulb skin colour was recorded at the time of harvest based on the NBPGR crop descriptor.

3. 6. 6 Bulb size

Bulb size was recorded at the harvesting time as small or medium or large based on NBPGR descriptor.

3. 6. 7 Bulb hearting

Bulb hearting was recorded at the harvest of crop as single or double or multiple based on NBPGR descriptor.

3. 6. 8 Bulb flesh colour

Bulb flesh colour was recorded from freshly harvested bulbs based on the colour classification given by NBPGR descriptor.

3. 6. 9 Pungency

Pungency of bulbs was classified into low, medium and high based on the evaluation by sensory method.

3. 6. 10 Plant height (cm)

Plant height was recorded using a meter scale. The measurement was taken from the ground to the tip of the plant at 90 days after transplanting.

3. 6. 11 Number of leaves per plant

Number of leaves per plant was recorded before the maturity of the crop (90 days after transplanting).

3. 6. 12 Leaf length (cm)

Leaf length was recorded using a meter scale. Length of five leaves were taken and average was calculated for each plant.

3. 6. 13 Leaf girth (cm)

Leaf girth was measured in the middle of leaf using a thread and meter scale. Girth of five leaves were taken and average was calculated for each plant.

3. 6. 14 Days to 75% maturity

Days to 75% maturity was recorded from the date of transplanting to the date when 75% of plants in a row matured.

3. 6. 15 Bolting percentage (%)

Bolting percentage was calculated as the ratio of bolted to the total number of plants.

3. 6. 16 Number of plants at harvest

Number of plants survived were recorded by counting at the time of harvest from each plot.

3. 6. 17 Neck thickness (cm)

Neck thickness was recorded from freshly harvested bulbs.

3. 6. 18 Bulbing percentage (%)

Bulbing percentage was calculated as the ratio of number of plants that formed bulbs to the total number of plants.

3. 6. 19 Bulb weight (g)

Bulb weight was recorded using a weighing balance and expressed in grams.

3. 6. 20 Number of scales per bulb

Number of scales per bulb was recorded as the average of five random mature bulbs.

3. 6. 21 Yield per plot (kg)

All the plants in a plot were harvested and bulb weight was recorded in kilograms.

3. 6. 22 Marketable yield per plot (kg)

Marketable yield per plot was recorded by weighing all the bulbs from a plot after removing unmarketable bulbs (diseased/malformed/undersized bulbs).

3. 6.23 Total soluble solids (° B)

Total soluble solids in bulbs were recorded by using a hand refractometer (Pal) at room temperature and the values were expressed in degree brix.

3. 6. 24 Pest and disease incidence

Throughout the cropping period pest and disease incidence on crop was monitored and corrective measures were taken.

3.6.25 Meteorological observations

Meteorological observations like temperature, rainfall, relative humidity, and sunshine hours were recorded from transplanting to harvesting.

3. 7 Statistical analysis

The mean of the values observed on five plants were recorded and tabulated and the data were analysed statistically. Analysis was carried out at the computer centre, Department of Statistics, Kerala Agricultural University.

RESULTS

4. RESULTS

The observations recorded on various growth and yield parameters of onion during the experiment were analysed statistically and the results are presented below.

4.1. Qualitative characters

4.2. Quantitative characters

4.3. Pest and disease incidence

4.1. QUALITATIVE CHARACTERS

4.1.1. **Seedling vigour**

The early seedling vigour (25 days after sowing) was influenced by the date of sowing. The performance of all the varieties were good on the first date of planting. Seedling vigour of all the varieties were very good during second, third and fourth dates of planting (Table 2) (Plate 6)

Table 2. Effect of varieties, sowing time and their interaction on seedling vigour

Dates of sowing	**Varieties**				
	Arka Kalyan	Arka Pragati	Agrifound Dark Red	Agrifound Light Red	Agrifound White
10th Nov.	Good	Poor	Good	Good	Poor
25th Nov.	Very good	Very good	Very good	Very good	Very good
10th Dec.	Very good	Very good	Very good	Very good	Very good
25th Dec.	Very good	Very good	Very good	Very good	Very good

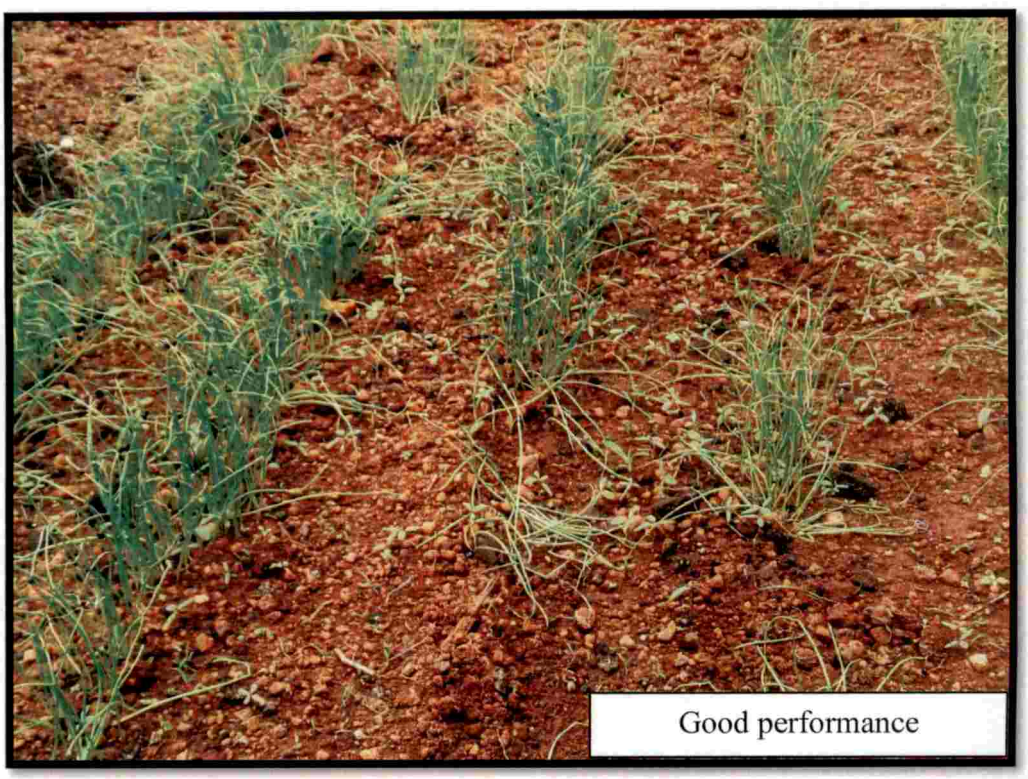


Plate 6. Variation in seedling vigour

4.1.2. Bolting

All the varieties except Agrifound White showed bolting behavior over different dates of planting. Bolting was observed in all the varieties except Agrifound White in the first date of planting (10th Nov.). None of the varieties bolted in the fourth date of planting, 25th Dec. (Table 3) (Plate 7).

Table 3. Effect of varieties, dates of planting and their interaction on bolting

Dates of sowing	**Varieties**				
	Arka Kalyan	Arka Pragati	Agrifound Dark Red	Agrifound Light Red	Agrifound White
10th Nov.	Present	Present	Present	Present	Absent
25th Nov.	Absent	Absent	Present	Absent	Absent
10th Dec.	Present	Present	Absent	Absent	Absent
25th Dec.	Absent	Absent	Absent	Absent	Absent

4.1.3. Bulb location

Bulb location was not influenced by dates of planting. Bulbs of all the varieties except that of Agrifound White was partially exposed. Agrifound White produced fully exposed bulbs (Table 4) (Plate 8).

Plate 7. Bolting in different varieties

Table 4. Effect of varieties, dates of planting and their interaction on bulb location

Dates of sowing	Varieties				
	Arka Kalyan	Arka Pragati	Agrifound Dark Red	Agrifound Light Red	Agrifound White
10th Nov.	Partially exposed	Partially exposed	Partially exposed	Partially exposed	Fully exposed
25th Nov.	Partially exposed	Partially exposed	Partially exposed	Partially exposed	Fully exposed
10th Dec.	Partially exposed	Partially exposed	Partially exposed	Partially exposed	Fully exposed
25th Dec.	Partially exposed	Partially exposed	Partially exposed	Partially exposed	Fully exposed

4.1.4. Bulb shape

Bulb shape varied among different varieties. Planting dates didn't influence the shape of bulbs. Arka Kalyan, Arka Pragati and Agrifound Dark Red produced bulbs with flat globe shape. Agrifound Light Red produced flat bulbs whereas Agrifound White produced globe shaped bulbs (Table 5) (Plate 9)

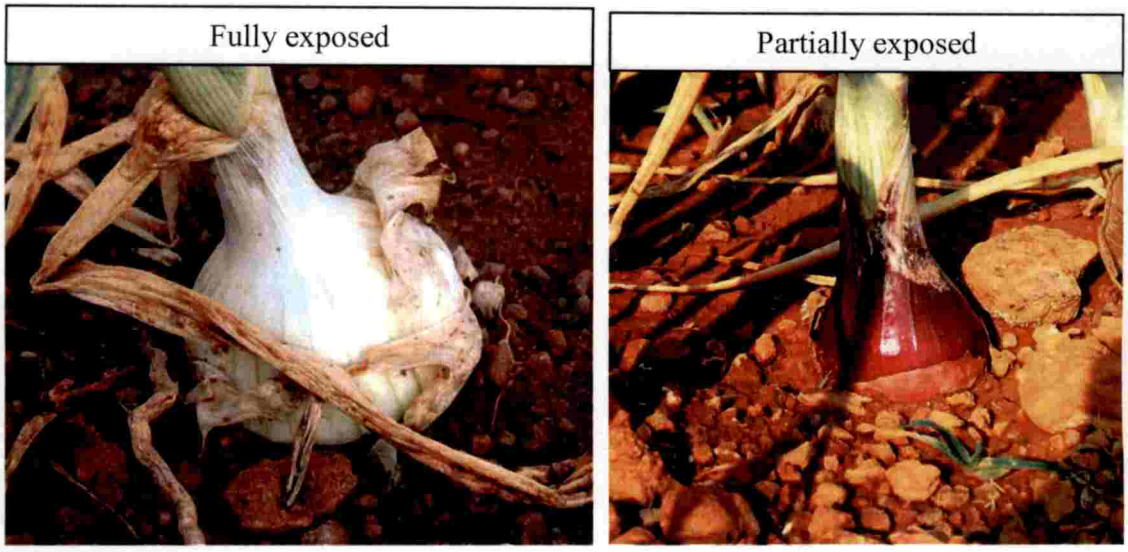


Plate 8. Variation in bulb location

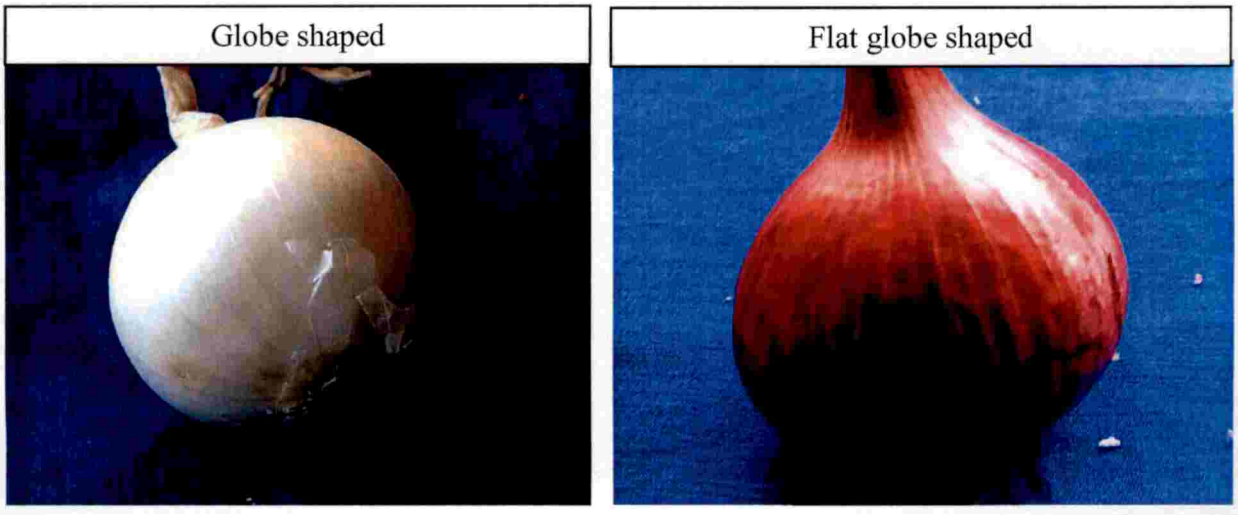


Plate 9. Variation in bulb shape

Table 5. Effect of varieties, dates of planting and their interaction on bulb shape

Dates of sowing	Varieties				
	Arka Kalyan	Arka Pragati	Agrifound Dark Red	Agrifound Light Red	Agrifound White
10th Nov.	Flat globe	Flat globe	Flat globe	Flat globe	Globe
25th Nov.	Flat globe	Flat globe	Flat globe	Flat globe	Globe
10th Dec.	Flat globe	Flat globe	Flat globe	Flat globe	Globe
25th Dec.	Flat globe	Flat globe	Flat globe	Flat globe	Globe

4.1.5. Bulb skin colour

There were no differences in skin colour with different planting dates. Arka Kalyan and Agrifound Dark Red produced dark red skinned bulbs and Arka Pragati produced pale red skinned bulbs in all the planting dates. Bulbs of Agrifound Light Red were having light brown coloured skin and the cultivar Agrifound White produced attractive silvery white skinned bulbs (Table 6) (Plate 10).

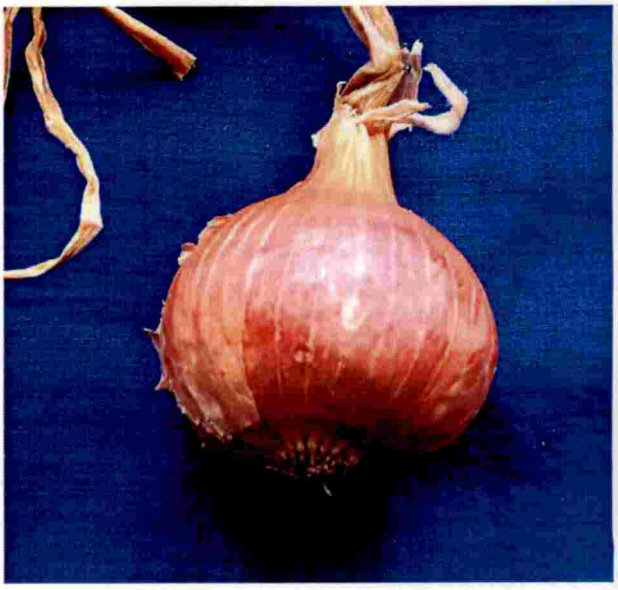
Table 6. Effect of varieties, dates of planting and their interaction on bulb skin colour

Dates of sowing	Varieties				
	Arka Kalyan	Arka Pragati	Agrifound Dark Red	Agrifound Light Red	Agrifound White
10th Nov.	Dark red	Pale red	Dark red	Light brown	Silvery White
25th Nov.	Dark red	Pale red	Dark red	Light brown	Silvery White
10th Dec.	Dark red	Pale red	Dark red	Light brown	Silvery White
25th Dec.	Dark red	Pale red	Dark red	Light brown	Silvery White

4.1.6. Bulb size

Bulb size was influenced by planting dates. All the varieties produced medium to large sized bulbs in 10th Nov., 25th Nov. and 10th Dec. plantings. All the five varieties produced only small sized bulbs in the last date of planting, 25th Dec. (Table 7).

Dark red



Pale red

Light brown

White

Plate 10. Variation in bulb skin colour

Table 7. Effect of varieties, dates of planting and their interaction on bulb size

Dates of sowing	Varieties				
	Arka Kalyan	Arka Pragati	Agrifound Dark Red	Agrifound Light Red	Agrifound White
10th Nov.	Medium	Medium	Medium	Large	Large
25th Nov.	Large	Medium	Medium	Medium	Medium
10th Dec.	Medium	Medium	Medium	Medium	Medium
25th Dec.	Small	Small	Small	Small	Small

4.1.7. Bulb hearting

All the varieties produced single hearted bulbs on all the four dates of planting (Table 8).

Table 8. Effect of varieties, dates of planting and their interaction on bulb hearting

Dates of sowing	Varieties				
	Arka Kalyan	Arka Pragati	Agrifound Dark Red	Agrifound Light Red	Agrifound White
10th Nov.	Single	Single	Single	Single	Single
25th Nov.	Single	Single	Single	Single	Single
10th Dec.	Single	Single	Single	Single	Single
25th Dec.	Single	Single	Single	Single	Single

4.1.8. Bulb flesh colour

Bulb flesh colour of different cultivars varied from white to reddish white. The varieties Agrifound Light Red and Agrifound White produced white fleshed bulbs. Arka Kalyan, Arka Pragati and Agrifound Dark Red produced pinkish white, yellowish white and reddish white fleshed bulbs respectively (Table 9) (Plate 11)

Table 9. Effect of varieties, dates of planting and their interaction on bulb flesh colour

Dates of sowing	**Varieties**				
	Arka Kalyan	Arka Pragati	Agrifound Dark Red	Agrifound Light Red	Agrifound White
10th Nov.	Pinkish white	Yellowish white	Reddish white	White	White
25th Nov.	Pinkish white	Yellowish white	Reddish white	White	White
10th Dec.	Pinkish white	Yellowish white	Reddish white	White	White
25th Dec.	Pinkish white	Yellowish white	Reddish white	White	White

4.1.9. Pungency

Pungency was classified in to low, medium and high after evaluating the samples by sensory method. All varieties except Agrifound White and Agrifound Light Red were having high pungency. Agrifound White was having a low pungency whereas Agrifound Light Red was having a medium pungency (Table 10).

Reddish white

Pinkish white

Yellowish white

White

Plate 11. Variation in bulb flesh colour

Table 10. Effect of varieties, dates of planting and their interaction on pungency

Dates of sowing	Varieties				
	Arka Kalyan	Arka Pragati	Agrifound Dark Red	Agrifound Light Red	Agrifound White
10th Nov.	High	High	High	Medium	Low
25th Nov.	High	High	High	Medium	Low
10th Dec.	High	High	High	Medium	Low
25th Dec.	High	High	High	Medium	Low

4.2. QUANTITATIVE CHARACTERS

4.2.1. Plant height

Plant height varied significantly over different dates of planting. The highest plant height was recorded in 10th Dec. followed by 25th Nov. and 10th Nov., with plant height of 51.05 cm, 50.70 cm, and 45.75 cm respectively. Plant height recorded from the second planting date, 25th Nov. was on par with that from 10th Dec. The lowest plant height among the four dates of planting was recorded from fourth date of planting, 25th Dec. (41.93 cm).

Significant differences in plant height were also noticed among different varieties. The highest plant height was recorded in Arka Kalyan with 50.47 cm. It was followed by Arka Pragati, Agrifound Light Red, and Agrifound Dark Red with a plant height of 47.97 cm, 47.86 cm and 46.56 cm respectively. The varieties such as Arka Pragati, Agrifound Dark Red and Agrifound Light Red were statistically on par with respect to plant height.

Interaction between planting dates and cultivars revealed that there is no significant variation with respect to plant height. (Table 11).

Table 11. Effect of varieties, dates of planting and their interaction on plant height (cm)

Dates of planting	Varieties					
	Arka Kalyan	Arka Pragati	Agrifound Dark Red	Agrifound Light Red	Agrifound White	**Mean (Dates of planting)**
10th Nov.	48.25	45.50	47.00	44.75	43.25	45.75
25th Nov.	53.25	52.00	50.25	52.50	45.50	50.70
10th Dec.	52.75	53.00	47.50	52.25	49.75	51.05
25th Dec.	47.63	41.38	41.50	42.00	37.13	41.93
Mean (Varieties)	50.47	47.97	46.56	47.88	43.91	

C.D (D)-3.87 CD (V)-2.34 CD (DxV)-N/A

4.2.2. Number of leaves per plant

Variation in leaf number was significant among different planting dates. It varied from 6.45 to 8.5 in 25th Dec. planting and 10th Dec. planting respectively. The planting date, 25th Nov. was on par with 10th Dec. with respect to leaf number (8.05).

The leaf number varied significantly among the varieties also. The highest leaf number was recorded in Agrifound Dark Red (8.313) and the lowest was recorded in Agrifound White (6.75). The varieties such as Arka Kalyan, Arka Pragati and Agrifound Light Red were statistically on par having 7.5, 7,813 and 7.375 number of leaves respectively.

There was no significant variation in leaf number among the varieties on different dates of planting. (Table 12).

Table 12. Effect of varieties, dates of planting and their interaction on number of leaves per plant

Dates of planting	Varieties					
	Arka Kalyan	Arka Pragati	Agrifound Dark Red	Agrifound Light Red	Agrifound White	**Mean (Dates of planting)**
10th Nov.	7.00	7.50	8.00	7.00	6.50	7.20
25th Nov.	8.25	8.25	9.00	8.25	6.50	8.05
10th Dec.	8.25	8.75	9.50	8.00	8.00	8.50
25th Dec.	6.50	6.75	6.75	6.25	6.00	6.45
Mean (Varieties)	7.50	7.81	8.31	7.38	6.75	

CD (D)-0.50 CD (V)-0.62 CD (DxV)-N/A

4.2.3. Leaf length (cm)

Analysis of data on leaf length showed significant difference among different dates of planting. Leaf length varied from 46.6 cm in 25th Nov. planting to 39.13 cm in 25th Dec. planting. Leaf length recorded from the third planting date (10th Dec.) was on par with the highest leaf length recorded from 25th Nov. planting.

There was a significant variation in leaf length among the varieties also. The highest leaf length was recorded from the cultivar Arka Kalyan (46.47 cm) which was followed by Agrifound Light Red (44.88 cm), Arka Pragati (43.88 cm) and Agrifound Dark Red (43.25 cm). Agrifound Light Red was on par with Arka Kalyan. The varieties such as Arka Pragati, Agrifound Dark Red and Agrifound Light Red were also statistically on par with each other. The lowest leaf length was recorded in Agrifound White (40.75 cm).

For getting the comparison between different dates of planting for each varieties, interaction between dates of planting and varieties were statistically

analysed. For Arka Kalyan and Agrifound Dark red all the three planting dates except 10th November was found to be statistically on par with respect to leaf length. For Arka Pragati, planting on 25th Nov. and 10th Dec. was found to be superior and on par with respect to leaf length. For the variety, Agrifound Light Red planting on 25th Nov. and 10th Dec. were found to be significantly superior and on par with respect to leaf length. For Agrifound White planting on 10th Nov. and 10th Dec. were on par with respect to leaf length (Table 13)

Table 13. Effect of varieties, dates of planting and their interaction on leaf length (cm)

Dates of planting	**Varieties**					
	Arka Kalyan	Arka Pragati	Agrifound Dark Red	Agrifound Light Red	Agrifound White	**Mean (Dates of planting)**
10th Nov.	44.25	43.50	43.25	41.00	43.50	43.10
25th Nov.	47.50	48.50	47.50	49.75	39.75	46.60
10th Dec.	49.25	45.75	43.50	49.25	45.00	46.55
25th Dec.	44.88	37.75	38.75	39.53	34.75	39.13
Mean (Varieties)	46.47	43.88	43.25	44.88	40.75	

CD (D)-3.21 CD (V)-2.03 CD (DxV at same level of V)-4.84

4.2.4. Leaf girth (cm)

Analysis of data on leaf girth showed significant difference among different dates of planting. The maximum leaf girth was recorded in 10th Nov. planting (3.49 cm) which was on par with 25th Nov. planting (3.36 cm). The planting dates, 25th Nov. and 10th Dec. were on par with respect to leaf girth. The minimum value for leaf girth was recorded from 25th Dec. planting (3 cm) which was on par with 10th Dec. planting.

Leaf girth varied significantly among the varieties and it ranged from 3.08 cm to 3.35 cm among different varieties. The maximum leaf girth was recorded in Agrifound Light Red (3.35 cm) which was on par with Arka Pragati (3.34 cm). The varieties Arka Kalyan (3.28 cm) and Agrifound Dark Red (3.26 cm) were on par with that of Arka Pragati. The minimum leaf girth was observed in Agrifound White (3.08 cm) which was on par with Agrifound Dark Red (Table 14).

.Table 14. Effect of varieties, dates of planting and their interaction on leaf girth (cm)

Dates of planting	**Varieties**					
	Arka Kalyan	Arka Pragati	Agrifound Dark Red	Agrifound Light Red	Agrifound White	**Mean (Dates of planting)**
10th Nov.	3.45	3.73	3.53	3.38	3.38	3.49
25th Nov.	3.55	3.43	3.25	3.63	2.93	3.36
10th Dec.	3.18	3.30	3.25	3.28	3.03	3.21
25th Dec.	2.95	2.93	3.00	3.13	3.00	3.00
Mean (Varieties)	3.28	3.34	3.26	3.35	3.08	

CD (D)-0.24 CD (V)-0.17 CD (DxV)-N/A

4.2.5. Days to 75% maturity

Days taken to reach 75% maturity varied significantly among the varieties and dates of planting. Interaction between varieties and dates of planting was also found significant with respect to days to 75% maturity. Number of days to 75% maturity was lowest in 10th Dec. (63.4) which was followed by 25th Nov. (64.8) and 25th Dec. (65.4).

Days to 75% maturity significantly varied among varieties also. The lowest number of days was noted in Agrifound Dark Red (64.25) followed by Agrifound White (66) and Agrifound Light Red (67.5).

Arka Kalyan and Agrifound Dark Red recorded minimum number of days to reach maturity when planted on 10th Dec. (62). Planting on 10th and 25th of Dec. favoured earliness in Arka Pragati (Table 15.). Agrifound Light Red and Agrifound White recorded a long duration to reach maturity when planting was done on 10th Nov.

Table 15. Effect of varieties, dates of planting and their interaction on days to 75% maturity

Dates of planting	**Varieties**					
	Arka Kalyan	Arka Pragati	Agrifound Dark Red	Agrifound Light Red	Agrifound White	**Mean (Dates of planting)**
10th Nov.	76	78	70	75	75	74.8
25th Nov.	65	70	62	65	62	64.8
10th Dec.	62	65	60	65	65	63.4
25th Dec.	70	65	65	65	62	65.4
Mean (Varieties)	68.25	69.5	64.25	67.5	66	

CD (D)-0.13 CD (V)-0.13 CD (DxV at same level of V)-0.27

4.2.6. Bolting percentage (%)

Bolting percentage varied significantly among dates of planting and varieties. Bolting percentage was highest in 10th Nov. planting (1.71%). 25th Nov., 10th Dec. and 25th Dec. plantings were statistically on par with each other with

respect to bolting percentage. Lowest bolting percentage was observed in 25th Dec. planting.

Among the varieties, bolting percentage was lowest in Agrifound White (0 %) which was on par with Arka Pragati, Agrifound Light Red and Agrifound Dark Red having 0.32%, 0.61% and 0.83% respectively. Bolting was completely absent in the variety, Agrifound White.

Bolting percentage among the varieties over different dates of planting was not significant. (Table 16).

Table 16. Interaction effect of dates of planting and varieties on bolting percentage (%) of onion

Dates of planting	**Varieties**					
	Arka Kalyan	Arka Pragati	Agrifound Dark Red	Agrifound Light Red	Agrifound White	**Mean (Dates of planting)**
10th Nov.	4.17	0.64	1.32	2.42	0.00	1.71
25th Nov.	1.06	0.00	2.00	0.00	0.00	0.61
10th Dec.	1.08	0.63	0.00	0.00	0.00	0.34
25th Dec.	0.00	0.00	0.00	0.00	0.00	0.00
Mean (Varieties)	1.58	0.32	0.83	0.61	0.00	

CD (D)-1.0 3 CD (V)-1.06 CD (DxV)-N/A

4.2.7. Number of plants at harvest

Number of plants at harvest varied significantly among different varieties as well as planting dates. Maximum number of plants were recorded in 10th Dec. planting (40.3) which was on par with 25th Nov. (40.15) and 10th Nov. (35.35) plantings. Minimum plant stand was recorded in 25th Dec. planting (27.05).

Number of plants at harvest ranged from 30.06 to 39.63 among the varieties. Highest number of plants were recorded in Arka Kalyan (39.63) which was on par with Agrifound Dark Red (38.06) and Agrifound White (36.63). Lowest plant stand at harvest was noted in Agrifound Light Red (34.06) which was on par with Arka Pragati (34.19).

There were no significant differences in number of plants at harvest among different varieties over different planting dates. (Table 17).

Table 17. Effect of varieties, dates of planting and their interaction on number of plants at harvest

Dates of planting	**Varieties**					
	Arka Kalyan	Arka Pragati	Agrifound Dark Red	Agrifound Light Red	Agrifound White	**Mean (Dates of planting)**
10th Nov.	39.75	38.25	37.00	26.50	35.25	35.35
25th Nov.	44.75	34.75	42.25	38.50	40.50	40.15
10th Dec.	45.25	36.25	44.25	33.25	42.50	40.30
25th Dec.	28.75	27.50	28.75	22.00	28.25	27.05
Mean (Varieties)	39.63	34.19	38.06	30.06	36.63	

CD (D)-7.21 CD (V)-4.98 CD (DxV)-N/A

4.2.8. Neck thickness (cm)

Neck thickness showed significant difference among different planting dates. Lowest value was recorded in 25th Dec. planting (3.54 cm) followed by 10th Dec. (3.86 cm) The highest neck thickness was noted in 25th Nov. planting with

4.41 cm which was statistically on par with 10th Nov. planting having a neck thickness of 4.14 cm.

Neck thickness ranged from 3.66 cm to 4.16 cm among different varieties. Lowest neck thickness was noted in Agrifound White which was on par with Agrifound Dark Red. Highest neck thickness was noted in the variety Arka Kalyan (4.16 cm) which was statistically on par with Arka Pragati (4.13 cm), Agrifound Light Red (4.06 cm) and Agrifound Dark Red (3.9 cm).

There was no significant differences in neck thickness among varieties over different dates of planting (Table 18).

Table 18. Effect of varieties, dates of planting and their interaction on neck thickness (cm)

Dates of planting	**Varieties**					
	Arka Kalyan	Arka Pragati	Agrifound Dark Red	Agrifound Light Red	Agrifound White	**Mean (Dates of planting)**
10th Nov.	3.98	4.10	4.15	4.35	4.10	4.14
25th Nov.	4.78	4.53	4.40	4.46	3.88	4.41
10th Dec.	3.78	4.10	3.70	4.13	3.58	3.86
25th Dec.	4.13	3.80	3.35	3.30	3.10	3.54
Mean (Varieties)	4.16	4.13	3.90	4.06	3.66	

CD (D)-0.27 CD (V)-0.33 CD (DxV)-N/A

4.2.9. Bulbing percentage (%)

Bulbing percentage was significantly influenced by different dates of planting. It was recorded as highest in 25th Nov. (88.09%) which was followed by 10th Nov. (80.36%). Lowest bulbing percentage was noted in 25th Dec. planting (44.4%).

Bulbing percentage didn't vary significantly among the varieties. Highest bulbing percentage was recorded in Agrifound Light Red (76.43%) which was followed by Arka Pragati (71.95%).

Interaction effect of dates of planting and varieties on bulbing percentage was not significant (Table 19).

Table 19. Effect of varieties, dates of planting and their interaction on bulbing percentage (%)

Dates of planting	**Varieties**					
	Arka Kalyan	Arka Pragati	Agrifound Dark Red	Agrifound Light Red	Agrifound White	**Mean (Dates of planting)**
10th Nov.	78.71	86.31	85.60	78.31	72.89	80.36
25th Nov.	90.56	90.92	87.36	90.79	80.82	88.09
10th Dec.	77.38	74.23	58.67	72.01	78.65	72.19
25th Dec.	36.38	36.34	36.92	64.62	47.74	44.40
Mean V (Dates of planting)	70.76	71.95	67.14	76.43	70.02	

CD (D)-6.99 CD (V)-N/A CD (DxV)-N/A

4.2.10. Bulb weight (g)

Bulb weight differed significantly with different planting dates. The highest bulb weight was recorded in 25th Nov. planting (66.2 g) which was followed by 10th Dec. and 10th Nov. plantings with 52.2 g and 48.15 g respectively. The lowest bulb weight was recorded from fourth date of planting, 25th Dec. (20.45 g).

There was no significant difference in bulb weight among different varieties and interaction between planting dates and varieties. (Table 20).

Table 20. Effect of varieties, dates of planting and their interaction on bulb weight (g)

Dates of planting	**Varieties**					
	Arka Kalyan	Arka Pragati	Agrifound Dark Red	Agrifound Light Red	Agrifound White	**Mean (Dates of planting)**
10th Nov.	47.25	52.25	49.5	52	39.75	48.15
25th Nov.	57.25	71.75	73.5	63.5	65	66.2
10th Dec.	53	55	49.75	50.75	52.5	52.2
25th Dec.	24.25	20.5	20	19.5	18	20.45
Mean (Varieties)	45.44	49.88	48.19	46.44	43.81	

CD (D)-4.34 CD (V)-N/A CD (DxV)-N/A

4.2.11. Number of scales per bulb

There was no significant variation in the number of scales per bulb with respect to varieties as well as dates of planting. Interaction effect of dates of planting and varieties was found non-significant (Table 21).

Table 21. Effect of varieties, dates of planting and their interaction on number of scales per bulb

Dates of planting	Varieties					
	Arka Kalyan	Arka Pragati	Agrifound Dark Red	Agrifound Light Red	Agrifound White	**Mean (Dates of planting)**
10th Nov.	8	8	8.75	7.25	8.25	8.05
25th Nov.	7.5	7.5	7.75	8	8	7.75
10th Dec.	8.25	8.25	7.75	7.75	8.75	8.15
25th Dec.	7.5	7.75	6.5	7.25	7.5	7.3
Mean (Varieties)	7.81	7.88	7.69	7.56	8.13	

CD (D)-N/A CD (V)-N/A CD (DxV)-N/A

4.2.12. Yield per plot (kg)

Yield per plot varied significantly among different dates of planting and varieties. Effect of interaction between dates of planting and varieties was also found significant with respect to yield per plot.

The highest yield was recorded in 25th Nov. planting (1.30 kg) which was on par with 10th Dec. and 10th Nov. plantings with 1.26 kg and 1.02 kg respectively. Lowest yield was obtained in 25th Dec. planting with 0.57 kg (Plate 12).

Yield per plot varied significantly among different varieties also. Highest yield was recorded in Arka Kalyan (1.21 kg) which was statistically on par with Agrifound Dark Red (1.15 kg) and Arka Pragati (1.07 kg). Yield was lowest in Agrifound White (0.86 kg) which was on par with Agrifound Light Red (0.90 kg).

Arka Kalyan

Arka Pragati

Agrifound Dark Red

Agrifound Light Red

Agrifound White

Plate 12. Harvested bulbs of different varieties

Interaction effect of dates of planting and varieties on yield per plot was also significant. All the dates of planting except 25th Dec. were found to be statistically on par with respect to total bulb yield for the varieties, Arka Kalyan, Arka Pragati, Agrifound Dark Red and Agrifound Light Red but, yield was the lowest in 25th Dec. planting. Planting on 25th Nov. and 10th Dec. were found to be on par with respect to yield in Agrifound White (Table 22).

Table 22. Effect of varieties, dates of planting and their interaction on yield per plot (kg)

Dates of planting	**Varieties**					
	Arka Kalyan	Arka Pragati	Agrifound Dark Red	Agrifound Light Red	Agrifound White	**Mean (Dates of planting)**
10th Nov.	1.24	1.20	1.32	0.79	0.53	1.02
25th Nov.	1.41	1.11	1.59	1.17	1.23	1.30
10th Dec.	1.40	1.30	1.27	1.18	1.15	1.26
25th Dec.	0.78	0.68	0.40	0.46	0.54	0.57
Mean (Varieties)	1.21	1.07	1.15	0.90	0.86	

CD (D)-0.28 CD (V)-0.18 CD (DxV at same level of V)-0.43

4.2.13. Marketable yield per plot (kg)

Marketable yield per plot varied significantly among different dates of planting and interaction between dates of planting and varieties, but there was no significant difference in marketable yield among different varieties.

Marketable yield was maximum for second date of planting, 25th Nov. with 0.96 kg which was on par with that of 10th Dec. (0.93 kg) and 10th Nov. (0.76 kg) plantings. The lowest marketable yield was recorded in 25th Dec. planting with 0.26 kg.

Among the varieties Agrifound Dark Red had the highest marketable yield of 0.83 kg which was followed by Arka Kalyan, Arka Pragati, Agrifound White and Agrifound Light Red with 0.80 kg, 0.74 kg, 0.67 kg and 0.60 kg respectively.

Interaction effect of dates of planting and varieties on marketable yield per plot was also significant. All the dates of planting except 25th Dec. were found to be statistically on par with respect to marketable bulb yield for the varieties, Arka Kalyan, Arka Pragati, Agrifound Dark Red and Agrifound Light Red but, marketable yield was the lowest in 25th Dec. planting. Planting on 25th Nov. and 10th Dec. were found to be on par with respect to marketable yield in Agrifound White (Table 23) (Plate 13).

Table 23. Effect of varieties, dates of planting and their interaction on marketable yield per plot (kg)

Dates of planting	**Varieties**					
	Arka Kalyan	Arka Pragati	Agrifound Dark Red	Agrifound Light Red	Agrifound White	**Mean (Dates of planting)**
10th Nov.	0.97	0.85	0.96	0.62	0.40	0.76
25th Nov.	1.07	0.79	1.30	0.71	0.95	0.96
10th Dec.	0.86	1.01	0.95	0.80	1.04	0.93
25th Dec.	0.31	0.31	0.11	0.27	0.29	0.26
Mean (Varieties)	0.80	0.74	0.83	0.60	0.67	

CD (D)-0.28 CD (V)-N/A CD (DxV)-0.43

4.2.14. Total Soluble Sugars (° B)

Total Soluble Solids varied significantly with varieties, dates of planting and interaction between dates of planting and varieties.

Plate 13. Marketable bulbs of different varieties planted on 25th Nov.

TSS varied from 16.92° B to 14.74° B among different planting dates. The highest value was recorded in 10th Dec. planting (16.92° B) which was followed by 10th Nov., 25th Nov. and 25th Dec. plantings with 15.30°B, 15.04°B and 14.74° B respectively. The lowest value for TSS was recorded in 25th Dec. planting which was on par with 25th Nov. and 10th Nov. plantings.

TSS ranged between 16.37° B and 14.91° B among different varieties. The highest value was recorded in Agrifound Light Red (16.37° B) which was statistically on par with Arka Pragati and Arka Kalyan having 15.86° B and 15.70° B respectively. The lowest value was observed in Agrifound Dark Red (14.66° B) which was on par with Agrifound White (14.91° B) (Table 24).

Table 24. Effect of varieties, dates of planting and their interaction on TSS (° B)

Dates of planting	**Varieties**					
	Arka Kalyan	Arka Pragati	Agrifound Dark Red	Agrifound Light Red	Agrifound White	**Mean (Dates of planting)**
10th Nov.	15.76	15.18	14.01	16.67	14.87	15.30
25th Nov.	14.77	15.10	15.39	15.44	14.49	15.04
10th Dec.	17.73	16.03	15.42	18.32	17.11	16.92
25th Dec.	15.18	16.49	13.83	15.04	13.15	14.74
Mean (Varieties)	15.86	15.70	14.66	16.37	14.91	

CD (D)-0.93 CD (V)-0.79 CD (DxV at same level of V)-1.7

4.3. PEST AND DISEASE INCIDENCE

The major diseases found in the nursery was damping off and leaf tip burning. The incidence of damping off was more in the 25th September sown seedlings. There was no serious pest incidence in the nursery. Damping off was

controlled by periodical drenching of SAAF (2g/L) and *Pseudomonas* (20g/L). Burning of leaf tips was controlled by the spray of Kocide (1.5g/L).

The major diseases and pests encountered under field condition were, leaf tip burning, damping off, wilt, infestation of thrips and foliar feeders. Leaf tip burning was a problem in the seedlings immediately after transplanting. It was brought under control by foliar sprays of fungicide (Kocide) and micronutrient (Megamix). Leaf tip burning was noticed in all the plants as well as in all the dates of planting. The plants transplanted on 10th November were not infested by the leaf feeder, *Helicoverpa,* but in later plantings, a mild attack was noticed (Plate 14).

4.3.1 Incidence of thrips (%)

Almost all the plants in all the planting dates were attacked by thrips. As a result of thrips attack cellular chlorophyll content was removed and silvery spots were seen on the leaves. Later these spots turned into white blotches along the leaves. The severity of attack was reduced by spraying Oberon (0.3 mL/L).

Among the different dates of planting, percentage incidence of thrips was highest in the second date of planting, i.e., 25th Nov. which was followed by 10th Dec. planting. Among the varieties Agrifound White was comparatively resistant to thrips attack.

Table 25. Incidence of thrips (%)

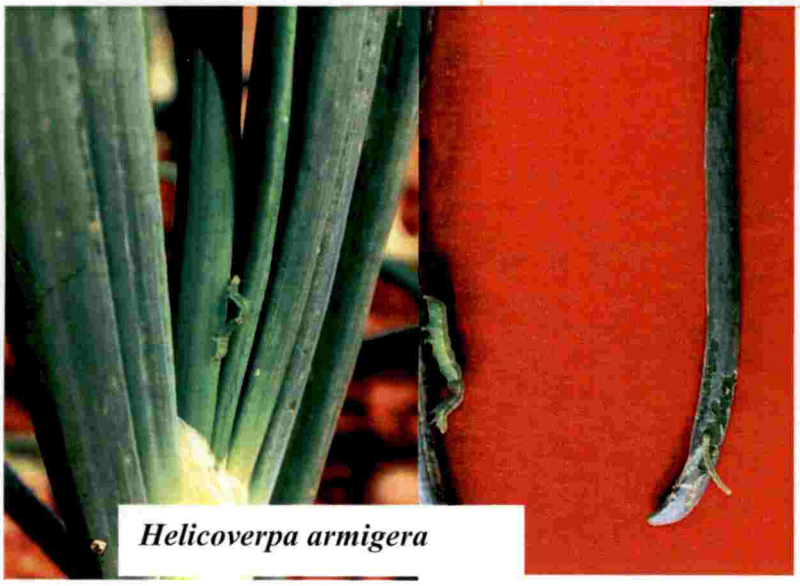
	Arka Kalyan	Arka Pragati	Agrifound Dark Red	Agrifound Light Red	Agrifound White
10th Nov.	64	60	56	62	10
25th Nov.	80	85	90	88	12
10th Dec.	75	78	80	80	8
25th Dec.	54	50	50	45	5

Damping off

Leaf tip burning

Symptoms of thrips attack

Thrips tabaci



Helicoverpa armigera

Plate 14. Pest and disease incidence

DISCUSSION

5. DISCUSSION

Results of the study are discussed under the following heads

5.1. Qualitative characters

5.2. Quantitative characters

5.3. Pest and disease incidence

5.1. Qualitative characters

The qualitative characters of onion varieties under different dates of planting are discussed below.

Seedling vigour was recorded visually 25 days after sowing. The performance of all the varieties were comparatively poor in seedlings sown on 25th September. This may be because of the high rainfall and humidity prevailed during the month of October (Appendix 1).

Bolting is the phenomenon of premature flowering seen in onion that are grown for bulbs and this behaviour is subjected to variation as the season changes (Brewster *et al.*, 1977). All the varieties except Agrifound White showed bolting behaviour over different dates of planting. Bolting was observed in all the varieties except Agrifound White in 10th November planting. Rajpurohit (2016) also noted a very low percentage of bolting in the variety Agrifound White. Wagh (1988) reported that the occurrence of bolters were high in onion planted early, i.e., during the months of September, October and November.

Bulbs of all the varieties except that of Agrifound White were partially exposed. Agrifound White produced fully exposed bulbs. Bulb shape varied among different varieties. Planting dates didn't influence the shape of bulbs. All the varieties except Agrifound White produced flat globular bulbs while Agrifound White produced globe shaped bulbs.

There were no differences in skin colour with different planting dates. Arka Kalyan and Agrifound Dark Red produced dark red skinned bulbs and Arka Pragati produced pale red skinned bulbs on all the planting dates. Bulbs of Agrifound Light Red were having light brown coloured skin and the cultivar Agrifound White produced attractive silvery white skinned bulbs on all dates of planting.

Bulb size was influenced by planting dates. All the varieties produced medium to large sized bulbs in 10th November, 25th November and 10th December. All the five varieties produced only small sized bulbs on the last date of planting, 25th December.

Bulb flesh colour of different cultivars varied from white to reddish white. The varieties Agrifound Light Red and Agrifound White produced white fleshed bulbs. Arka Kalyan, Arka Pragati and Agrifound Dark Red produced pinkish white, yellowish white and reddish white fleshed bulbs respectively. Bulb flesh colour didn't vary with respect to different dates of planting as it is under genetic control.

According to the morphological characterization done by Ahmed *et al.* (2013) Arka Kalyan, Arka Pragati, Agrifound Dark Red and Agrifound Light Red were having a flat globe shape which confirms with present study. In the case of bulb skin colour, they observed a pale red colour for the variety Agrifound Light Red, while it was light brown in the present study. They reported non-bolting behaviour in all the 5 varieties, but in the present study, all the varieties except Agrifound White exhibited bolting behaviour.

Varieties were classified as low, medium and highly pungent after tasting the sample. Agrifound White was having a low pungency.

5.2. Quantitative characters

5.2.1. Plant height

In the present investigation there was a significant variation in plant height with respect to varieties and planting dates. But the variation was insignificant in the interaction between varieties and planting dates. Goutam *et al.* (2006) and

Sharma and Jarial (2017) also reported a significant variation in plant height with respect to different dates of panting and a non-significant effect on plant height due to interaction between varieties and planting time.

The highest plant height (51.05 cm) was recorded in 10th December planting which was on par with that of 25th November and 10th November planting. Prasad *et al.* (2017) reported that among the four different planting dates (15th November, 1st, 15th, and 30th December) highest plant height of 62.20 cm was noted in 15th November planting. Devulkar (2013) also reported a highest plant height (50.24 cm) in 15th November planting. Mohanta and Mondal (2014) reported an increase in plant height with delayed planting dates, but in the present study this was observed only up to third date of planting. Lowest plant height was recorded in 25th December planting. Bijarniya *et al.* (2015) reported that highest plant height of 57.75 cm in 30th November planting.

Among the varieties, the highest plant height of 50.47 cm was noted in the variety, Arka Kalyan and the lowest (43.91 cm) was recorded in Agrifound White. This was supported by the findings of Menon *et al.* (2016). Khan *et al.* (2001) reported that variation in plant height among onion varieties may be due to their differential adaptability to a particular environmental condition. Dev (2011) reported a decrease in plant height as a result of delayed transplanting in onion.

5.2.2. Number of leaves per plant

Leaf number varied significantly among different dates of planting. Maximum number of leaves (8.5) was recorded in 10th December planting which was on par with that of 25th November planting (8.05). This was supported by the findings of Misra *et al.* (2014) who reported the highest number of leaves in 25th November and 10th December planted crops. Das (2008) also reported variation in number of leaves of onion varieties among different planting dates.

Effect of varieties on number of leaves was significant. Agrifound Dark Red recorded the highest number of leaves. Chandrika and Reddy (2011) also noted a significant varietal effect on number of leaves in onion plant.

Interaction effect of varieties and planting time on the number of leaves per plant was found to be non-significant. This was supported by the results revealed from the studies of Mohanta and Mondal (2014) and Nayee *et al.* (2010). However Mohanty (2001) reported a significant interaction effect on number of leaves.

5.2.3. Leaf length

Variation in leaf length was significant among different dates of planting. Highest leaf length (46.6 cm) was noted in 25th November planting which was on par with that of 10th December planting. Varieties also differed significantly for leaf length. Maximum leaf length was recorded in Arka Kalyan (46.47 cm) which was on par with that of Agrifound Light Red (44.88 cm). Interaction effect between dates of planting and varieties on leaf length was also significant. Highest leaf length was recorded in the variety Agrifound Light Red planted on 25th November (Figure 2)

The results on leaf length is in conformity with those obtained by Mohanta and Mondal (2014) and Khurana *et al.* (2003). Similar results were reported by Misra *et al.* (2014). They noticed a highest leaf length of 50.50 cm in 25th November planting which was followed by 10th December planting (47.85 cm).

5.2.4. Leaf girth

Variation in leaf girth was significant among different varieties and planting dates, but it was not influenced by the interaction between varieties and dates of planting. The highest leaf girth (3.49 cm) was recorded in 10th November planting which was on par with 25th November planting (3.36 cm). Among the varieties, Agrifound Light Red recorded the highest leaf girth (3.35 cm) which was on par with Arka Pragati (3.34 cm). Mohanta and Mondal (2014) also noticed a significant variation in leaf girth with respect to different planting dates and varieties. They evaluated 5 varieties (Agrifound Dark Red, Arka Kalyan, Arka Niketan, Indam Marshal and Red stone) and observed the highest leaf girth in the variety Indam Marshal which was followed by Agrifound Dark Red.

Dewangan (2011) evaluated different genotypes in onion and found out that leaf girth is significantly influenced by different genotypes.

5.2.5. Days to 75% maturity

The number of days taken from the date of transplanting to the date when at least 75% of plants in a row become mature is regarded as the days to 75% maturity, which is an indication of earliness in onion. It varied significantly among varieties and different dates of planting. The days taken to 75% maturity was lowest (63.4) in 10th December planting. Long sunshine hours and lower relative humidity may be the reason behind the reduced number of days to maturity in 10th December and 25th November (Appendix I). Among the varieties, minimum days to reach 75% maturity was recorded in the variety Agrifound Dark red which was followed by Agrifound Light Red. Days taken to 75% maturity also varied significantly among varieties over different dates of planting. Minimum number of days was taken by the variety Agrifound Dark Red planted on 10th December (Figure 3). The results were supported by the findings of Devi *et al.* (2003) who also reported that the bulb initiation was early in the variety Agrifound Dark Red.

Goutam *et al.* (2006) and Sharma and Jarial (2017) also reported significant variation in days taken to reach harvest among different dates of planting in onion, but they obtained an insignificant variation with respect to varieties and interaction between varieties and planting dates. According to them the number of days taken to maturity decreased with later transplanting. Similarly, in the present study also with later planting, number of days taken to maturity was decreased, but this trend was not followed in the last planting date, i.e. in 25th December planting. This might be because of the higher temperature prevailed during the bulbing period (Appendix I.)

Sharma and Dogra (2017) observed that Agrifound Light Red took the lowest time period to reach harvest when they evaluated 4 different onion varieties (Agrifound Dark Red, Agrifound Light Red, Nasik Red and N 53). Results are also in conformity with the results obtained by Bijarniya *et al.* (2015). They reported a

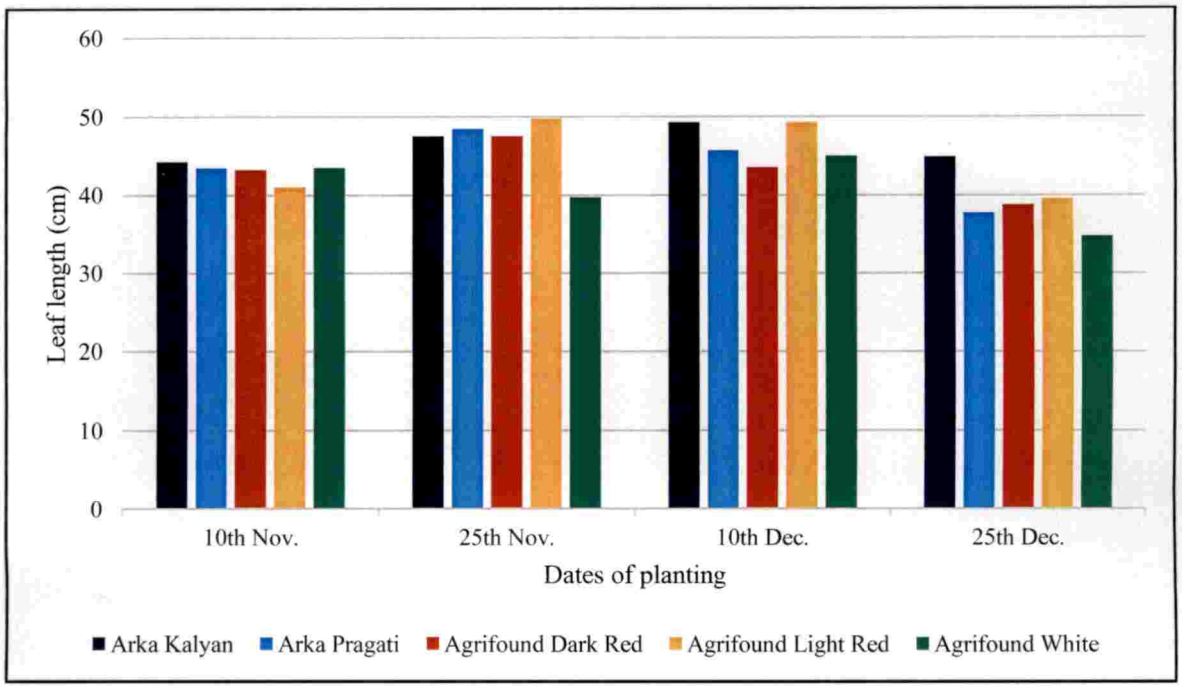


Figure 2. Effect of planting time on leaf length (cm) of onion varieties

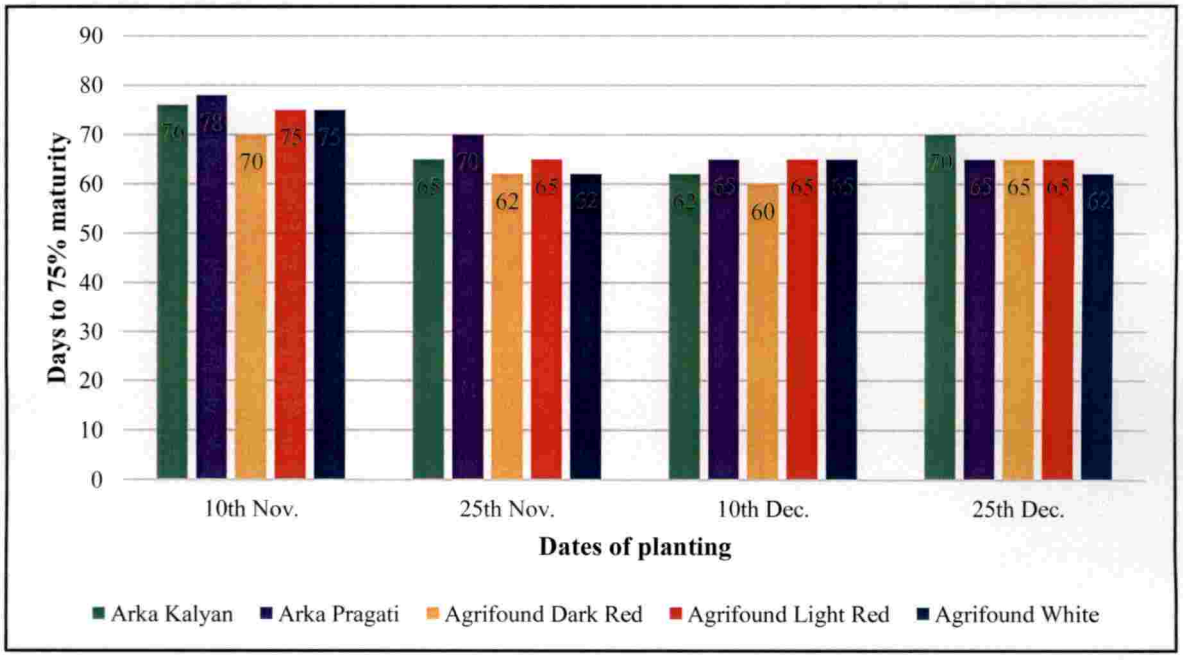


Figure 3. Effect of planting time on days to 75% maturity of onion varieties

reduced maturity period in onion planted on 15th December. Rajpurohit (2016) evaluated different onion varieties and noted that Agrifound White took more number of days for maturity.

5.2.6. Bolting percentage

Bolting is the premature flowering behaviour in onion which is not a desirable trait in a bulb yielding crop.

Bolting percentage varied significantly among different dates of planting and varieties whereas, the variation was non-significant among the interaction between varieties and planting dates. Goutam *et al.* (2006) reported a non-significant variation in bolting percentage among varieties, planting time and interaction between the two. Devulkar (2013) reported a non-significant variation for bolting percentage among different dates of planting (15tt November, 25th November, 5th December, 15th December and 25th December).

The highest bolting percentage was noticed in 10th November planting (1.71%). These findings are in line with those of Singh *et al.* (1993), Cramer (2003) and Bijarniya *et al.* (2015). Similarly, higher bolting percentage in early plantings was also noticed by Dev (2011).

Among the varieties, bolting percentage was lowest/absent in Agrifound White (0%) which was on par with Arka Pragati, Agrifound Light Red and Agrifound Dark Red having 0.32%, 0.61% and 0.83% respectively.

Umamaheswarappa *et al.* (2015) also observed a significant variation in bolting percentage when they studied 21 onion varieties including the varieties undertaken in the present study. They observed a bolting percentage of 0.34% in Arka Kalyan, 0.31% in Arka Pragati, 0.29% in Agrifound Dark Red, 0.30% in Agrifound Light Red and 0.37% in Agrifound White.

5.2.7. Number of plants at harvest

Number of plants at harvest is a direct indication of the survival percentage of the crop. It varied significantly among different varieties as well as planting dates. Highest number of plants was recorded in 10th December planting (40.3) which was on par with 25th November planting (40.15) and 10th November planting (35.35). Lowest plant stand was recorded in 25th December planting (27.05). According to Kumbhkar *et al.* (2017) the effect of planting dates on the number of plants at harvest was non-significant.

Among the varieties, maximum number of plants was recorded in Arka Kalyan (39.63) which was on par with Agrifound Dark red (38.06) and Agrifound White (36.63). Lowest plant stand at harvest was noted in Agrifound Light Red (34.06) which was on par with Arka Pragati (34.19). There were no significant differences in number of plants at harvest among different varieties over different planting dates

5.2.8. Neck thickness

Neck thickness is an important parameter in onion as it determines the storability of onion. Onion having thin neck thickness store better than those having a higher neck thickness.

Neck thickness showed significant difference among different planting dates and varieties but, the variation was non-significant among the interactions. Lowest value for neck thickness was recorded in 25th December planting with 3.54 cm which was followed by that in 10th December planting.

Lowest neck thickness was noted in Agrifound White (3.66cm). Sharma and Jarial (2017) evaluated different onion varieties and reported a lowest neck thickness in the variety Agrifound Light Red.

Similar to the present reports, Mohanta and Mondal (2014) also reported significantly different variations in neck thickness with respect to varieties, planting

time and interaction between both. They noticed a highest neck thickness in the variety Agrifound Dark Red (2.08 cm).

5.2.9. Bulbing percentage

Bulbing percentage refers to the percentage of plants those produced marketable bulbs.

Bulbing percentage was significantly influenced by different dates of planting. It was recorded as highest in 25th November planting (88.09%) which was followed by 10th November planting (80.36%). Lowest bulbing percentage was noted in 25th December (44.4%). Bulbing percentage didn't vary with varieties as well as with interaction between varieties and planting dates.

5.2.10. Bulb weight

Bulb weight differed significantly with different planting dates. The highest bulb weight was recorded in 25th November planting (66.2 g) which was followed by 10th December planting and 10th November planting with 52.2 g and 48.15 g respectively. The lowest bulb weight was recorded from fourth date of planting, 25th December (20.45 g). Mohanta and Mondal (2014), Singh and Singh (2002), Mahadeen (2009) also reported a significant variation in average bulb weight with respect to planting dates.

The variation was non-significant among different varieties as well as among the interactions. However a significant variation in bulb weight was noted among varieties by Tripathy and Lawande (2008). Behera *et al.* (2017) reported a significant variation in average bulb weight among varieties and noticed a highest average bulb weight in the variety, Arka Pragati (82.5 g). Haldar *et al.* (2009) obtained a significantly higher bulb weight in the variety Agrifound Dark Red (71.25 g).

5.2.11. Number of scales per bulb

There was no significant variation in the number of scales per bulb with varieties, dates of planting and interaction between dates of planting and varieties. A significant variation in number of scales was reported by Behera et al. (2017). According to them, number of scales were maximum in the varieties, Arka Pragati and Agrifound Light Red (10).

5.2.12. Yield per plot

Yield per plot varied significantly among different dates of planting, varieties as well as interaction between dates of planting and varieties.

The highest yield was recorded in 25th November planted crop (1.30 kg/m^2) which was on par with 10th December and 10th November planted crops with 1.26 kg/m^2 and 1.02 kg/m^2 per plot respectively. This higher yield may be due to the long sun shine hours prevailed during the months of December and January. These findings are in agreement with the results obtained by Misra *et al.* (2014) and are also in line with the findings of Bijarniya *et al.* (2015) who reported a highest yield in the crop planted on 15th November. Similar results were also obtained by Kumar *et al* (1998) and Hiray *et al.* (2001). In the present study, lowest yield was obtained in 25th December planting with 0.57 kg/m^2. Dev (2011) obtained a maximum yield of 202.40 q/ha from the crop transplanted on 1st December.

Yield per plot varied significantly among different varieties also. Highest yield was recorded in Arka Kalyan (1.21 kg/m^2) which was statistically on par with Agrifound Dark Red (1.15 kg/m^2) and Arka Pragati (1.07 kg/m^2). Yield was lowest in Agrifound White (0.86 kg/m^2) which was on par with Agrifound Light Red (0.90 kg/m^2). The results of the present study is strongly supported by the findings of Mahanthesh *et al.* (2009) who reported that Arka Kalyan and Agrifound Light Red are the best suited varieties in Karnataka region. Agrifound Dark Red was identified as a promising variety with a bulb yield 5.83 kg/m^2 by Haldar *et al.* (2009). Bindu and Podikunju *et al.* (2016) also came up with the similar results. They evaluated three onion varieties such as Arka Kalyan, Agrifound Dark Red and N 53 and

obtained a higher yield from Agrifound Dark Red which was followed by Arka Kalyan. Bhonde *et al.* (1992) and Mohanty (2001) also noticed a significant variation among onion varieties with respect to bulb yield. Khar *et al.* (2000) and Yadav *et al.* (2010) also reported variation in bulb yield among different varieties under same cultural practices.

Menon *et al.* (2016) reported a highest total bulb yield in the variety Agrifound Light Red which was followed by Arka Kalyan, Agrifound White, Arka Pragati, and Agrifound Dark Red. Rajpurohit (2016) evaluated 10 kharif onion varieties including the varieties in the present study and observed that the bulb yield was significantly higher in the variety Agrifound Dark Red.

A significant variation in bulb yield among varieties and planting time was reported by Sharma and Jarial (2017). They recorded the highest bulb yield in the variety Agrifound Dark Red which confirms with the present study results. Bhagchandani *et al.* (1972) also reported a better performance of Agrifound Dark Red under *kharif* production system.

5.2.13. Marketable yield per plot (kg)

Marketable yield is the yield of good quality bulbs after removing all damaged, bruised, diseased, undersized, jointed and bolted bulbs.

Marketable yield per plot varied significantly among different dates of planting and interaction between dates of planting and varieties, but there was no significant difference in marketable yield among different varieties. Marketable yield was maximum for second date of planting, i.e. on 25th November with 0.96 kg/m^2 which was on par with that of 10th December (0.93 kg/m^2) and 10th November (0.76 kg/m^2). The lowest marketable yield was recorded in 25th December planting with 0.26 kg/m^2. These findings are on par with the reports of Patil *et al.* (2003) who reported a least percentage of unmarketable bulbs (0.6%) in 15th November planted onion. Devulkar (2013) reported a highest marketable yield (29.87 t/ha) in 15th November planting.

Among the varieties Agrifound Dark Red had the highest marketable yield with 0.83 kg/m^2 which was followed by Arka Kalyan, Arka Pragati, Agrifound White and Agrifound Light Red with 0.80 kg/m^2, 0.74 kg/m^2, 0.67 kg/m^2 and 0.60 kg/m^2 respectively. Singh *et al.* (2011) evaluated nine red varieties of onion and reported the highest marketable bulb yield in Agrifound Light Red (353.37 q/ha) (Figure 4).

Menon *et al.* (2016) reported a significant variation in bulb yield among 20 different varieties of onion under humid tropical conditions of Thrissur district. They found out that the marketable yield was highest in the variety Bhima Sakthi (1.62 kg/m^2) and was on par with almost all the varieties including Arka Kalyan (1.30 kg/m^2), Arka Pragati (1.44 kg/m^2), Agrifound Dark Red (1.12 kg/m^2), Agrifound Light Red (1.54 kg/m^2) and Agrifound White (1.4 kg/m^2).

5.2.14. Total Soluble Sugars (^{o} B)

The total soluble solids in onion is significantly influenced by the different dates of planting (Caruso *et al.*, 2014)

Total Soluble Solids varied significantly with varieties, dates of planting and interaction between dates of planting and varieties. . The highest value was recorded in 10th December planting (16.92°B) which was followed by 10th November planting, 25th November planting and 25th December with 15.30°B, 15.04°B and 14.74°B respectively. The lowest value for TSS was recorded in D_4 which was on par with 25th November and 10th November.

TSS ranged between 16.37°B and 14.91°B among different varieties. The values obtained in the present study were much higher than that of the reported values of each varieties.The highest value was recorded in Agrifound Light Red (16.37°B) which was statistically on par with Arka Pragati and Arka Kalyan having 15.86°B and 15.70°B respectively. The lowest value was observed in Agrifound Dark Red (14.66°B) which was on par with Agrifound White (14.91°B). Dwivedi *et al.* (2012) and Sarkar et al. (2015) also noticed a significant variation among different varieties of onion. Variation in TSS may also be attributed to external

parameters such as sunlight, humidity, temperature and supply of nutrients and other inputs (Vaghela *et al.*, 2017)

TSS showed significant variation in interaction between dates of planting and varieties also. The highest value was recorded in the interaction, D_3V_4 (Agrifound Light Red planted on 10th December) (18.32°B). Sharma and Dogra (2017) obtained a non-significant variation in TSS with respect to interaction between planting dates and varieties (Figure 5).

5.3. Pest and disease incidence

The major diseases found in the nursery was damping off and leaf tip burning. The incidence of damping off was more in the 25th September sown seedlings. There was no serious pest incidence in the nursery. The major diseases and pests encountered under field condition were, leaf tip burning, damping off, wilt, infestation of thrips and foliar feeders. Leaf tip burning was a problem in the seedlings immediately after transplanting. Leaf tip burning was noticed in all the plants as well as in all the dates of planting.

Almost all the plants in all the planting dates were attacked by thrips. As a result of thrips attack cellular chlorophyll content was removed and silvery spots were seen on the leaves. Later these spots were turned into white blotches along the leaves. Bailey (1938) also reported similar symptoms in onion due to thrips attack. Infestation was noticed from younger stages itself and was present until maturity. Lewis (1973) reported a severe incidence of thrips at younger stages in onion.

Among the different dates of planting, percentage incidence of thrips was highest in the second date of planting, i.e., 25th Nov. which was followed by 10th Dec. planting. Srinivas and Lawande (2004) investigated the impact of planting dates on thrips infestation and yield loss in onion and stated that thrips infestation and yield loss was maximum in *rabi* season planting; especially on 15th November followed by 1st December planting.

The plants transplanted on 10th November were not infested by the leaf feeder, *Helicoverpa,* but in later plantings, a mild attack was noticed. Suresh et al. (2015) also reported that the incidence of defoliators were very low in the early transplanted crop of onion.

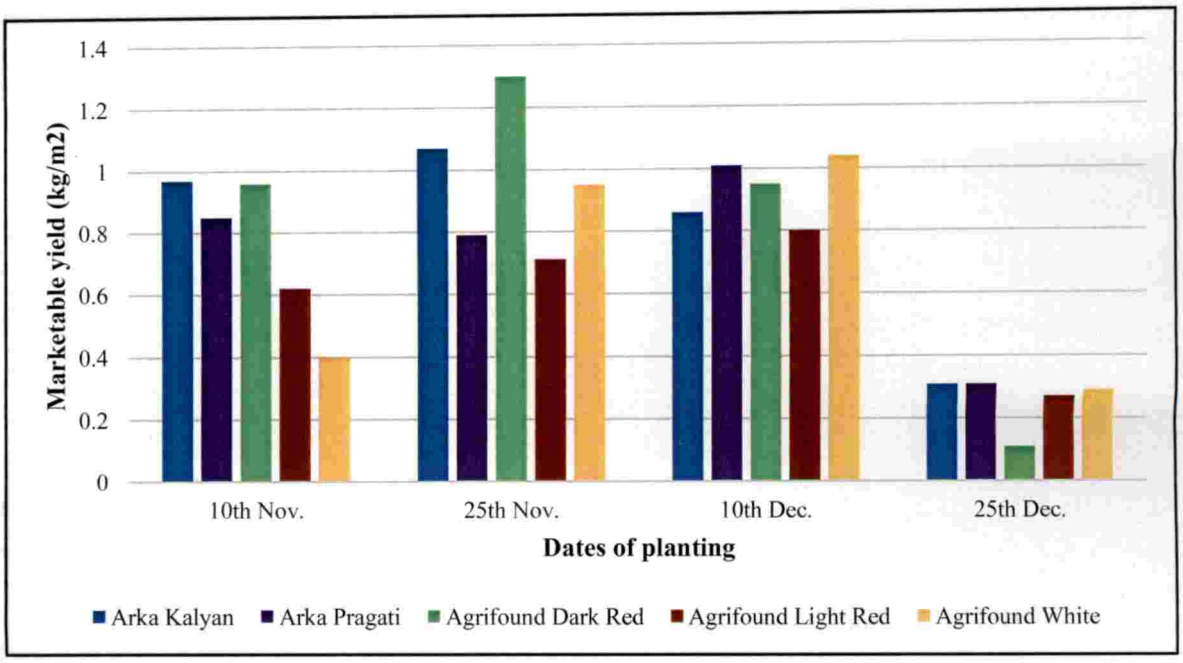


Figure 4. Effect of planting time on marketable yield (kg/m^2) of onion varieties

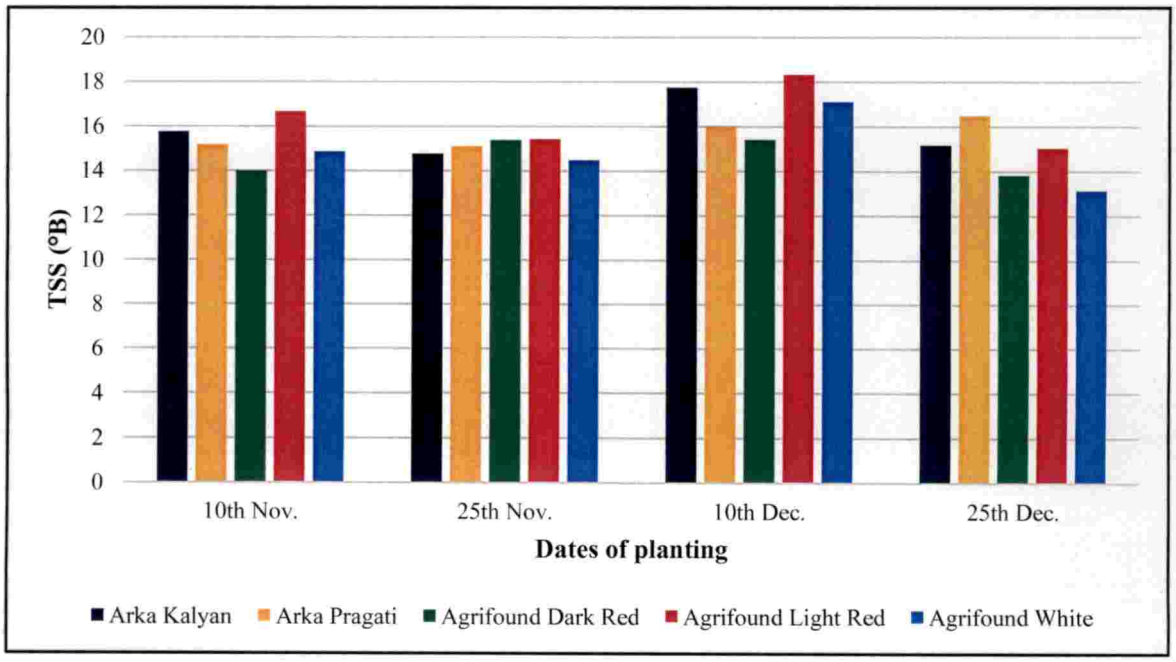


Figure 5. Effect of planting time on TSS (°B) of onion varieties

SUMMARY

6. SUMMARY

The present study on the "Evaluation of varieties and standardization of planting time in onion (*Allium cepa* L.) was carried out in the Department of Vegetable Science, College of Hortculture, Vellanikkara during November-March, 2017-18.

The experiment was carried out with the objective to evaluate the onion varieties suitable for cultivation in the plains of Kerala, to select the suitable planting time for the successful cultivation of onion in the plains of Kerala and to study the effect of varieties, planting time and their interaction on the qualitative and quantitative traits of onion. The experiment was laid out in split plot with four replications. Five onion varieties (Arka Kalyan, Arka Pragati, Agrifound Dark Red, Agrifound Light Red and Agrifound White) were evaluated on four different dates of planting (10^{th} Nov., 25^{th} Nov., 10^{th} Dec. and 25^{th} Dec.).

The salient findings of the study are summarized below:

- Early planting (10^{th} Nov. planting) resulted in bolting in all the varieties except Agrifound White.
- Agrifound White produced globular shaped bulbs which were fully exposed whereas other varieties were having flat globe shaped bulbs in a partially exposed condition.
- Arka Kalyan and Agrifound Dark Red produced attractive dark red skinned bulbs which are preferred in the market. Arka Pragati had a pale red colour. Agrifound Light Red was having a light brown colour.
- All the varieties except Agrifound White were having medium to high pungency.
- There was a significant variation in plant height, number of leaves per plant and leaf girth among the varieties as well as different planting dates, but the interaction effect was non-significant.
- Leaf length was significantly influenced by varieties, planting time and their interactions.

- Among the varieties, Agrifound Dark Red recorded a minimum number of days to reach 75% maturity. Planting on 10th Dec. promoted earliness in Arka Kalyan and Agrifound Dark Red. Planting on 10th and 25th Dec. favoured earliness in Arka Pragati. 25th Nov. and 25th Dec. planting favoured earliness in Agrifound Light Red and Agrifound White.
- Bolting was noticed randomly and was negligible. Agrifound White exhibited a non-bolting behaviour in all the dates of planting.
- Number of plants at harvest was highest in the variety, Arka Kalyan which was on par with that of Agrifound Dark Red and Agrifound White. Among different dates of planting, highest number of plants were recorded in 10th Dec. planting which was on par with that of 25th and 10th Nov. plantings. Interaction effect on the number of leaves at harvest was non-significant.
- Neck thickness varied significantly among different varieties, planting dates, but, the interaction effect was non-significant. Lowest neck thickness was noted in the variety Agrifound White (3.66 cm) which was on par with Agrifound Dark Red (3.90 cm). Varieties when planted on 25th Dec. recorded a lowest neck thickness of 3.54 cm.
- Bulbing percentage was influenced by varieties and planting dates, but the interaction effect on bulbing percentage was non-significant. It was highest in 25th Nov, planting (88.09%) which was followed by 10th Nov. planting (80.36%). Among the varieties, Agrifound Light Red recorded the highest bulbing percentage (76.43%).
- Variation in bulb weight was significant among different planting dates, but it was non-significant among varieties as well as interactions. Highest bulb weight was recorded in 25th Nov. planting (66.20g).
- Variation in number of scales per bulb was non-significant among varieties, planting dates and interactions.
- Total bulb yield was influenced by varieties, planting dates and their interactions. Highest yield was recorded in 25th Nov. planting (1.30kg/m^2) which was on par with 10th Dec. and 10th Nov. plantings. Arka Kalyan

recorded a highest yield of 1.21 kg/ m^2 which was statistically on par with Agrifound Dark Red and Arka Pragati.

- Among the varieties highest marketale yield was noted in Agrifound Dark Red (0.83kg/m^2) which was followed by Arka Kalyan (0.80 kg/m^2) and Arka Pragati (0.74 kg/m^2). 25th Nov. planting recorded a highest marketable yield of 0.96kg/m^2 which was on par with that from 10th Dec. (0.93 kg/m^2) and 10th Nov. (0.76 kg/m^2).
- All the dates of planting except 25th Dec. were found to be statistically on par with respect to total yield and marketable yield for all the five varieties.
- TSS varied significantly among different dates of planting, varieties and their interactions. Highest value of TSS was recorded in Agrifound Light Red (16.37°B) which was statistically on par with Arka Pragati and Arka Kalyan having 15.86°B and 15.70°B respectively. Among different dates of planting, highest TSS was recorded from 10th Dec. planting (16.92°B).
- Even though 25th Nov. planting recorded highest marketable yield, percentage incidence of thrips was highest. Agrifound White was found to be comparatively resistant to the attack of thrips.
- All the five varieties can be recommended for commercial cultivation as they do not differ with each other with respect to marketable yield.
- Considering the consumer preferences, we can recommend Arka Kalyan and Agrifound Dark Red as they are having attractive dark red colour.
- The best time for transplantation was found to be 25th November, which was on par with 10th Nov. and 10th Dec.

As a future line of work, more varieties are to be evaluated at more locations and for conclusive results experiment has to be repeated. Nursery and crop management practices need to be standardised.

REFERENCES

REFERENCES

Abdalla, A. A. 1967. Effect of temperature and photoperiod on bulbing of the common onion *(Allium cepa* L.) under arid tropical conditions of the Sudan. *Exp. Agric.* 3: 137-142.

Ahmed, N., Khan, S.H., Afroza, B., Hussain, K., Qadri, S. and Nazir, G. 2013. Morphological characterization in onion (*Allium cepa* L) for preparation and implementation of plant variety protection (PVP) legislation and distinctness, uniformity and stability (DUS) testing under temperate conditions of Kashmir. *Afr. J. Agric. Res.* 8(14): 1270-1276.

Ali, M., Rab, A., Ali, J., Ahmad, H., Hayat, S., Wali, K., Rashid, A., Ahmad, W. and Muhammad, H. 2016. Influence of transplanting dates and population densities on the growth and yield of onion. *Pure Appl. Biol.* 5(2): 345-354.

Anisuzzaman, M., Ashrafuzzaman, M., Ismail, M.R., Uddin, M.K. and Rahim, M.A. 2009. Planting time and mulching effect on onion development and seed production. *Afr. J. Biotechnol.* 8 (3): 412–416.

Arora, P.N. 1967. Study of the effect of different dates of transplanting of onion seedlings on the bulb development, percentage of bolting and yield of onion bulbs. *Indian J. Agon.* 12: 332-334.

Bailey, S. F. 1938. Thrips of economic importance in California. *Agric. Exp. Stn. Cir.* 2:346-348.

Behera, T.K., Mandal, J., S., Padhiary, A.K., Behera, S., Behera, D.and Rout, R.K. 2017. Assessment of growth, yield and quality of onion genotypes under red and laterite zone of *West Bengal. J. Pharmacol. Phytochem.* 6(6): 493-497.

Bhagchandani, P.M., Pal, N. and Choudhury, B. 1972.You can grow kharif crop of onion in Northern India. *Indian Farming.* 22(4): 24-27.

Bhat, K.L. and Bhushan, A. 2009. Evaluation of onion (*Allium cepa* L.) genotypes under subtropical conditions of Jammu region. *Environ. Ecol.* 27(3): 1178-1180.

Bhatt, R.M., Rao, N.K., Srinvasa, G. and Veere, R. 2006. Response of bulb Onion (*Allium cepa* L.) to water stress: photosynthesis, stomatal conductance and osmotic adjustment. *Indian J. Hortic.* 63 (3): 20–25.

Bhonde, S.R., Srivastava, K.J. and Pandey, U.B. 1992. Evaluation of varieties for growing "Rangda" crop of onion (*Allium cepa* L.) in Nasik area of Maharastra. *Maharastra J.Hortic.* 6(2): 39-42.

Bijarniya, N.K., Jat, M.L., Patel, B.A. and Bana, M.L. Effect of age of seedling and dates of transplanting on growth, yield and quality of onion (*Allium Cepa L.*) in *Rabi* under North Gujarat condition. *J.Rural Agric. Res.* 5(2): 38-42.

Bindu, B. and Podikunju, B. 2016. Evaluation of onion (*Allium cepa* L.) varieties for suitability in Kollam district of Kerala. *Short communication.* 5: 117-118.

Biswas, S.K., Torrance, R.L, Sarker, P.K. and Alom, M.S. 2010. Yield and storability of onion (*Allium cepa* L.) as affected by varying levels of irrigation. *Bangladesh J. Agric. Res.* 35(2): 247-255.

Boyhan, G.E., Torrance, R.L., Riner, C.M., Cook, M.J., Dollar, M.A., Curry, D.S. 2014. Evaluation of onion cultivars and cultural practices suitable for South Georgia. Int. *J. Veg.Sci.* 20(2):150-184.

Brewster, J.L. 1977. The physiology of the onion. *Hortic. Abstr.* 47: 17-23.

Caruso, G., Conti, S., Villari, G., Borrelli, C., Melchionna, G., Minutolo, M., Russo, G. and Amalfitano, C. 2014. Effects of transplanting time and plant density on yield, quality and antioxidant content of onion (*Allium cepa* L.) in southern Italy. *Sci.Hortic.*166: 111–120.

Chandrika, V. and Reddy, D.S. 2011. Response of onion genotypes (*Allium cepa* L.) to varied planting patterns in Southern agro-climatic zone of Andhra Pradesh. *J. Res. ANGRAU.* 39(3): 21-25.

Chory, J., Chatterjee, M., Cook, R.K., Elich, T., Fankhauser, C., Li, J., Nagpal, P., Neff, M., Pepper, A., Poole, D., Reed, J., and Vitart, V. *1996. From seed germination to flowering, light controls plant development via the pigment phytochrome.* Proceedings of National Academic Science *USA* 93: 12066-12071.

Coolong, T. and Randle, M.W. 2006. The influence of root zone temperature on growth and flavour precursors in *Allium cepa* L. *J. Hortic. Sci. and Biotechnol.* 81(2): 199-204.

Cramer, C.S. 2003. Performance of fall-sown onion cultivars using four seeding dates. *J. Am. Soc. Hortic. Sci.* 128(4): 472-478.

Das, T.K. 2008. Effect of seedling age and variety on the yield of *Kharif* Onion. *Orissa J. Hortic.* 36(1): 126-127.

Daymond, A.J.,. Wheeler, T. R., Hadley, P., Ellis, R. H. and Morison, J. I. L. 1997. The growth, development and yield of onion (*Allium cepa* L.) in response to temperature and CO2, *J. Hortic. Sci.* 72(1):135-145.

Dev, H. 2009. Performance of *kharif* onion varieties in lower hills of Himachal Pradesh. *Haryana J. Hortic. Sci.* 38: 122-124.

Dev, H. 2011. Standardization of planting time and spacing in onion (*Allium cepa* L.) under sub-tropical conditions of Himachal Pradesh. *Indian J. Hill Farming.* 24: 7-9.

Devi, L.M.V. and Sankar, R.C. (2003). Effect of planting time on bulb growth and yield of onion cultivars. *The Andhra Agricultural University J.* 50 (1-2): 97-100.

Devulkar N.G., Bhanderi, D.R., More, S.J., and Jethava, B.A. 2015. Optimization of yield and growth in onion through spacing and time of planting. *Green Farming*. 6 (2): 305-307.

Dewangan, S. 2011. Evaluation of different kharif onion genotypes in Chhattisgarh plains. Msc (Ag.) thesis, Indira gandhi Krishi Vishwavidyalaya Raipur, 116p.

DGCIS [Directorate General of Commercial Intelligence and Statistics] 2017. India's Export of Principal Commodities. Available: www.dgciskol.nic.in. [30 Dec. 2017]

DOGR [Directorate of Onion and Garlic Research] 2017. DOGR home page [on line]. Available: http://www.dogricar.org. [27 Dec. 2017].

Dwivedi, Y.C., Kushwah, S.S. and Sengupta, S.K. 2012. Evaluation of onion varieties for growth, yield and quality traits under agro-climatic conditions of Kymore plateau. *Agric. Sci. Digest*. 32(4): 326-328.

Enciso, J., Wiedenfeld, B., Jifon, J. and Nelson, S. 2009. Onion yield and quality response to two irrigation scheduling strategies. *Sci. Hortic*. 120: 301-305.

Finch-savage, W.E. 1986. Effects of soil moisture and temperature on seedling emergence from natural and pre-germinated onion seeds. *J. Agric. Camb*. 107: 249-256.

Ganiger, V.M., Goudappanavar, B., Gondi, S., Bhuvaneshwari, G. and Nanjappanavar, A. 2017. Evaluation of onion varieties for growth, bulb yield and quality parameters for northern dry zone of Karnataka. *Green farming*. 8(4): 1009-1011.

Gautam, I.P., Khatri, B. and Paudel, G.P. 2006. Evaluation of different varieties of onion and their transplanting times for off-season production in mid hills of Nepal. *Nepal Agric. Res. J.* 7:21-26.

Giri, S., Thapa, U. and Maity, T.K. 2009. Evaluation of onion cultivars during *kharif* season in the plains of West Bengal. *Indian Agric*. 53: 97-98.

Gupta, R.P., Srivastava, K.J. and Pandey, U.B. 1994. Diseases and insect pests of onion in India. *Acta Hortic*. 358: 265-269.

Haldar, A., Karak, C., Naik, A., Samanta, M.K. and Hazra, P. 2009. Identification of suitable early rabi onion varieties under West Bengal condition. *J. Crop. Weed*. 5(1):124-129.

Hamma, L.L. 2013. Growth and yield of onion as influenced by planting dates and mulching types in Samaru. *Int. J. Adv. Agric. Res*. 1: 22-26.

Heath, 0. V. S., and Holdsworth, M. 1948. Morphogenic factors as exemplified by the onion plant. *Symp. Soc. Exp. Biol.* 2:326-350.

Heath, O.V.S. 1945. Formative effects of environmental factors as exemplified in the development of the onion plant. *Nat.* 155: 623-626.

Hirave, P.S., Wagh, A.P, Alekar, A.N. and Kharde, R.P. 2015. Performance of red onion varieties in *kharif* season under Akola conditions. *The Ecosan.* 8: 381-384.

Hiray, S. A. 2001. Effect of nitrogen levels, spacing and planting dates on the growth, yield and quality of onion bulbs (*Allium cepa* L.) cv. N-53 under heavy rainfall zone – I under South Gujarat condition. M. Sc. (Agri.) Thesis, Gujarat Agricultural University, Sardarkrushinagar. 73p.

Hiremath, S. M. and Nagaraju, M. V. 2009. Evaluation of front line demonstration trials on onion in Haveri district of Karnataka. *Karnataka J. Agric. Sci*. 22: 1093-1094.

Holdsworth, M. and Heath, O.V.S. 1950. Studies in the physiology of the onion plant. IV. The influence of day-length and temperature on the flowering of the onion plant. *J. Exp. Bot*. 1: 353-375.

Ibrahim, N.D. and Adesiyun, A.A. 2009. Effects of staggered planting dates on the control of *Thrips tabaci* Lindeman and yield of onion in Nigeria

Izquierdo, J.A., Maeso, C.R. and Villanmil, J. 1981. Effects of sowing and transplanting dates on yields of valenciana type onion. *Investigations Agron.* 2: 34-37.

Jadhav, R.S., Shinde, N.N., Sontakke, M.B. 1990. Performance of onion (*Allium cepa* L.) varieties in rabi season. *Prog. Hortic.* 22: 84-86.

Jain, B.P and Sarkar, S.K. 2002. Evaluation of onion varieties in *kharif* season. *Indian Agric.* 46(1/2): 49-53.

Kandil, A.A., Sharief, A.E. and Fathalla, F.H. 2013. Effect of transplanting dates of some onion cultivars on vegetative growth, bulb yield and its quality. *Sci J. Crop Prod.* 2(3): 72-82.

Kanton, R.A.L., Abbey, L. and Gbene, R.H. 2003. Irrigation schedule affects onion (*Allium cepa* L.) growth, development, and yield. *J. Veg. Crop Prod.* 9: 3-11.

Kato, T. 1964. Physiological studies on bulbing and dormancy of onion plant. 111. Effects of external factors on the bulb formation and development. *J. Jpn Soc. Hortic. Sci.* 33:53-61.

Khan, M.A., Hansan, M.K., Miah, M.A.J., Aiam, M.M. and Masum, A.S.M.H. 2001.Effect of plant spacing on the growth and yield of different varieties of onion. *Pakistan J. Biol. Sci.* 6:1582-85.

Khar, A., Devi, A., Lawande, K.E., Mahajan, V. and Kulkarni, P.M. 2000. Evaluation of US and Indian commercial hybrids under Indian conditions. *Acta Hortic.* 10: 1-2.

Khokhar, K.M. 2008. Effect of set-size and planting time on the incidence of bolting, bulbing, and seed yield in two onion cultivars. *J. Hortic. Sci. Biotechnol.* 71(2): 207-210.

Khurana, S.C., Kumar, R., Bhutani, R.D., Bhatia, A.K. and Dudi B.S. 2003. Effect of sowing time on *kharif* onion (*Allium cepa* L.) set production. *Haryana J. Hortic. Sci.* 32(1/2): 134-137.

Koriem, S.O., El-koliey, M.M.A. and Wahba, M.F. 1994. Onion bulb production from "Shandwell" sets as affected by soil moisture stress. *Assiut J. Agric. Sci*. 25: 185–193.

Kumar, H., Singh, J.V., Kumar, A. and Singh, M. 1998. Influence of time of transplanting on growth and yield of onion (*Allium cepa* L.) var. Patna Red. *Indian J. Agric. Res.* 32 (1): 6-10.

Kumar, S., Imtiyaz, M., Kumar, A. and Singh, R. 2007. Response of onion (*Allium cepa* L.) to different levels of irrigation water. *Agric. Water Manag*. 89(1–2): 161–166.

Kumbhkar, B.R., Patel, N.M. and More, S.G. 2017. Influence of dates of transplanting on growth, yield and quality of onion (*Allium cepa* L.). *Bull. Env. Pharmacol. Life Sci.* 6: 517-518.

Lawande, K.E. and Mahajan, V. 2011. *Genetic diversity and crop improvement in onion and garlic. In Souvenir: Exploiting Spices Production Potential of the Deccan Region*. SYMSAC-VI 8-10 December (Dharwad: Indian Society for Spices), p.19-40.

Lawande, K.E. and Murkute, A.A. 2011. Initiatives in onion and garlic cool chain management. *Proceedings of National Symposium on Postharvest Packaging, Cold-chain Logistics and Instrumentation Techniques for Quality and Safety of Perishables*. December 19-20, 2011. Central Institute of Post-Harvest Engineering and Technology, Ludhiana, India, 183p.

Lee, E.J. and Suh, J.K. 2009. Effect of temperature on growth, pyruvic acid and sugar contents in onion bulbs. *Kor. J. Hortic. Technol.* 27(4): 554-559.

Leskovar, D.I. and Agehara, S. 2012. Crop co-efficient based deficit irrigation and planting density for onion: growth, yield, and bulb quality. *Hortic. Sci.* 47(1): 31-37.

Lewis, T. 1973. *Thrips, their Biology, Ecology and Economic Importance.* Academic Press, London, 349p.

Mahadeen, A.Y. 2009. Effect of planting date and plant spacing on onion (*Allium cepa*. L.) yield under rain-fed in semi-arid conditions of Jordan. *Bull. Faculty of Agric. Cairo University*. 59(3): 236-240.

Mahajan, V. and Gopal, J. 2012. Onion and garlic as nutritional and therapeutic ingredients daily diet. *Shodh Chintan,* 28-31 May. 2012.

Mahajan, V. and Gupta, A.J. 2016. Development of photo and thermo-insensitive cultivars of short day onion in India. In: Gokce, A.F. (ed.), *Edible Alliaceae.* Proceedings of the eighth international symposium, DOGR, Pune, pp. 61-68.

Mahanthesh, B., Harshavardhan, M., Sjjan, P.M.R., Janardhan, G. and Vishnuvardhana. 2009. Evaluation of onion varieties/hybrids for dry matter production and yield in kharif season under irrigated condition in central dry zone of Karnataka. *Asian J. Hortic.* 4: 10-12.

Martin de Santa Olalla, F.J., Domı´nguez-Padilla, A. and Lopez, R. 2004. Production and quality of onion crop (*Allium cepa* L.) cultivated under controlled deficit irrigation conditions in a semi-arid climate. *Agric. Water Manag.* 68: 77–89.

McCollum, G.D. 1976. Evolution of crop plants, ed. N.W. Simmonds, Longman, London and New York, pp. 186-90

Menon, J.S., Prameela, P., Mohan, L.K., and Karippai, R.S. 2016. Performance evaluation of onion (*Allium cepa* L.) varieties in tropical plains of Thrissur district, Kerala. *J. Trop. Agric.* 54(1):66-70.

Mettananda, K.A. and Fordham, R. 1999. The effects of plant size and leaf number on the bulbing of tropical short day onion cultivars (*Allium cepa* L.) under controlled environments in the United Kingdom and tropical field conditions in Sri Lanka. *J. Hortic. Sci. Biotechnol.* 74: 622-631.

Milthorpe, F.L. and Horowitz, B. 1943. The effect of length of day and temperature on the flowering, seed production and growth of vegetables. *Agric. Gazette New South Wales*. 54: 53-57.

Misu, M.P., Rahim, A., Hossen, K., Karim, R. and Islam, M. 2018. Effects of planting dates on growth and yield of winter onion. *Int. J. Agron. Res.* 12: 11-19.

Mohanta, S.and Mandal, J. 2014. Growth and yield of *kharif* onion (*Allium cepa* L.) as influenced by dates of planting and cultivars in red and laterite zone of West Bengal. *HortFlora Res. Spectr.* 3(4): 334-338.

Mohanty, B.K. 2001. Effect of planting time on the performance of onion cultivars. Veg. Sci. 28(2): 140-142.

Mohanty, B.K. and Prusti, A.M. 2002. Varietal performance of onion in rainy season. *Indian J. Agric. Res*. 36(3):222-224.

Mohanty, B.K., Barik, J. and Dora, D.K. 1990. Effect of time of transplanting and age of seedlings on yield of onion (*Allium cepa* L.). Onion Newsl. Trop. 7:41-43.

Mohanty, B.K., Hossain, M. M. and Prusti, A. M. Varietal assessment of common onion for horticultural traits during kharif season. *Orissa J. Hortic*. 28(2): 8-11.

Mondal, M.F., Brewster, J.L., Morris, G.E.L. and Butter, H.A. 1986. Bulb development in onion (*Allium cepa* L.) effect of plant density and sowing date in field conditions. *Ann. Bot.* 58: 187-195.

Montano, J.D., Fuchs, M., Nault, B.A., Fail, J. and Shelton, A.M. 2011. Onion Thrips (Thysanoptera: Thripidae): A Global Pest of Increasing Concern in Onion. *J. Econ. Entomol.* 104: 1–13.

Mosleh ud-deen, M.D. 2008. Effect of mother bulb size and planting time on growth, bulb and seed yield of onion. *Bangladesh J. Agric. Res.* 33(3): 531-537.

Naik, M.N., Rao, B.G. and Srihari, G. 2012. Evaluation of onion varieties under central telengana conditions of Andhra Pradesh. *J. Res. ANGRAU.* 40(4): 79-80.

Nayee, D.D., Verma, L.R. and Sitapara, H.H. (2010). Effect of various planting materials and different dates of planting on growth and bolting of *Kharif* onion (*Allium cepa* L) cv. Agrifound Dark. *Asian J. Hortic.* 5: 189-191.

NHB [National Horticulture Board] 2016. Indian Horticulture Database., Govt of India, Gurgaon, New Delhi. Available: http://nhb.gov.in/database-2016.pdf. [24 Dec. 2017]

NHRDF [National Horticultural Research and Development Foundation] 2017. NHRDF home page [on line]. Available: http://www.nhrdf.org/en-usOnion. [21 Dec. 2017].

Okporie, E.O. and Ekpe, L.I. 2008. Effect of photoperiod on the growth and bulbing of tropical onion (*Allium cepe* L.) varieties. *World J. Agric. Sci.* 4(1):36-39.

Pandey, U.B., Sing, L. and Kumar, R. 1990. Studies on the effect of dates of transplanting and levels of nitrogen on yield and quality of onion (*Allium cepa* L.). *Newsl. Associated Agricultural Development Foundation.* 10:10-12.

Patil, A.M. 2012. Studies on onion basal rot caused by fusarium oxysporum Schlecht Fr f. sp. cepae (Hans.) Snyd. and Hans. M.Sc. Thesis, UAS, Dharward, 64p.

Patil, D.G., Dhake, A.V., Sane, P.V. and Subramaniam, V.R. 2012. Studies on different genotypes and transplanting dates on bulb yield of high solid white onion (*Allium cepa* L.) under short-day conditions.

Patil, R.S., Sood, V., Garande, V.K. and Masalkar, S.D. 2003. Studies on natural top fall in rangda (i.e. late kharif) onion. *Agricultural-Science-Digest*. 23(1): 47-49

Pelter, G.Q., Mittelstad, R. and Redulla, C.A. 2004. Effects of water stress at specific growth stage on onion bulb yield and quality. *Agric. Water Manage*. 60 (2): 107–115.

Prasad, B., Maji, S. and Meena, K.R. 2017. Effect of date of transplanting and mulching on growth, yield and quality of onion (*Allium cepa* L.) cv. Nasik Red. *J. Appl. Nat. Sci*. 9: 94-101.

Rabinowitch, H.D. and Currah, L. 2002. *Allium Crop Science: Recent Advances*. CABI publishing, London, 515p.

Rajpurohit, S. 2016. Performance studies of different kharif onion *(Allium cepa* L.) varieties under Malwa Plateau condition. Msc (Hort.) thesis, Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior, 69p.

Rayyan, A., Akash, M.W. and Gianquinto, G. 2012. Onion Seed Germination as Affected by Temperature and Light. *Int. J. Veg. Sci*. 18: 49-63.

Rueda, A., Badenes-Perez, F.R. and Shelton, A.M. 2008. Developing economic thresholds for onion thrips in Honduras. *Crop Prot*. 26: 1099-1107.

Ruiter, J.M.D. 1986. The effect of temperature and photoperiod on onion bulb growth and development. *Proceedings Agronomy Society of N .Z*, Plant Physiology Division, DSIR, Palmerston North. 16p.

Sarada, C., Giridhar, K. and Rao, N.H. 2009. Varietal performance of Onion (*Allium cepa* L.) in black soils. *Ann. Plant Physiol*. 23 (2): 266-267.

Sarkar, R.K., Kharga, B.D., Pandit, T.K., Thapa, A.D. and Moktan, M.W. 2015. Evaluation of onion (*Aliium cepa* L.) varieties for growth, yield and quality traits under hill agro-climatic conditions of West Bengal. *Environ. Ecol.* 33(2A): 956-959.

Seshadri, V.S. and Chatterjee, S.S. 1996. The history and adaptation of some introduced vegetable crops in India. *Veg. Sci.* 23 (2): 114-140.

Sharma, D. and Dogra, B.S. Evaluation of *kharif* onion varieties and transplanting time for production under North-Western mid Himalayan region. *Indian J. Hortic.* 74(3): 405-409.

Sharma, D. and Jarial, K. 2017. Effect of different varieties and planting time on *kharif* onion production in lower Shivalik hills of Himachal Pradesh. *Curr. Agric. Res. J.* 5(1): 74-80.

Sharma,A.K. 2009. Evaluation of onion varieties in *kharif* season under sub mountain low hill conditions of Himachal Pradesh. *Ann. Hortic.* 2: 191-193.

Shock, C.C., Feibert, E.B.G. and Saunders, L.D. 1998. Onion yield and quality affected by soil water potential as irrigation threshold. *Hortic. Sci.* 33(7): 1188–1191.

Singh, L., Singh, S.P. and Mishra, P.K. (1992). Evaluation of onion varieties at Karnal. *Newsletter-Associated Agricultural Development Foundation*, 11 (3): 3-4.

Singh, A.K and Singh, V. 2002. Influence of set size and time of planting on the growth, yield and grade of *kharif* onion bulbs. *Ann. Agric. Res.* 23(4): 654-658.

Singh, M. and Yadav, H.S. 1987. Effect of time of transplanting and role of growth regulators on yield of onion. *Veg. Sci.* (2): 10-12.

Singh, R.K., Bhonde, S.R. and Gupta, R.P. 2011. Performance studies on onion (*Allium cepa*) promising lines for yield and quality. *Green Farming*. 2(2): 170-172.

Sorensen, J.N. and Grevsen, K. 2001. Sprouting in bulb onions (*Allium cepa* L.) as influenced by nitrogen and water stress. *J. Hortic. Sci. Biotechnol.*76:501–506.

Srinivas, P.S. and Lawande, K.E. 2004. Impact of planting dates on Thrips tabaci Lindeman infestation and yield loss in onion (*Allium cepa* L.). *Pest manag. Hortic. Ecosyst*. 10: 11-18.

Steer, B. T. 1980. The bulbing response to day length and temperature of some Australasian cultivars of onion *(Allium cepa* L.). *Aust. J. Agric. Res.* 31:511-518.

Steer, B.T. 1980. The role of night temperature in the bulbing of onion (*Allium Cepa* L.). *Aust. J. Agric. Res*. 31: 519-523.

Steer, B.T. 1982. The effect of growth temperature on dry weight and carbohydrate content of onion (*Allium cepa* L. cv. Creamgold) bulbs. *Aust. J. Agric.Res.* 33(3): 559-563.

Tarai, R.K., Panda, P.K., Behera, S.K., Beura, J.K., Mohapatra, K.C. and Sahoo, T.R. 2015. Varietal performance of onion in the western undulating zone of Odisha. Int. J. Sci. Res. Eng. Stud. 2: 1-4.

Terabun, M. 1971. Studies on bulb formation in onion plants. *J. Jpn. Soc. Hortic. Sci.* 40: 50-56.

Tesfay, S.Z., Bertling, I., Odindo, A.O., Greenfield and Workneh, T.S. Growth responses of tropical onion cultivars to photoperiod and temperature based on growing degree days. *Afr. J. Biotechnol*. 10(71): 15875-15882.

Thamburaj, J.S. and Singh, N. 2000. *Vegetables, Tuber crops and Spices*. Indian Council of Agricultural Research, New Delhi, 469p.

Thompson, H.C. and Smith, O. 1938. Seedstalk and bulb development in the onion (Allium cepa L.). Cornell University Agricultural Experiment station Bull. 21p.

Tripathi, P.C. and Lawande, K.E. 2008. *Kharif* Onion Production Technology. *Technical Bulletin No. 18, National Research Centre for Onion and Garlic,* Rajgurunagar, Maharashtra, India, 34 p.

Umamaheswarappa, P., Naik, A.H.K. and Nataraja, M. 2015. Evaluation of onion (*Allium cepa* L.) genotypes for growth, yield and quality parameters under central dry zone of Karnataka. *Environ. Ecol.* 33(2): 992-995.

Vaghela, K.Z., Verma, P., Pawar, Y. and Limbachiya, T.B. 2017. Effect of date of transplanting, method of cultivation and varieties on growth, yield and quality of white onion (*Allium cepa* L). *Int. J. Farm. Sci.* 7(4): 6-10.

Verma, T.S., Chandranand, K.D., and Lakhanpal. 1993. Standardization of sowing and planting times for the maximization of bulb production in onion cv. Brown Spanish. *Veg. Sci.* 20(2): 104-108.

Wagh, B.K. 1988. Effect of date of planting on growth, yield and qualityf onion (*Allium cepa* L.) Baswant (N-780). MSc (Hort) thesis, Mahatma phule agricultural university, Ahmednagar. 84p.

Wickramasinghe, U.L., Wright, C.J. and Currah, L. 2000. Bulbing responses of two cultivars of red tropical onions to photoperiod, light integral and temperature under controlled growth conditions. *J. Hortic. Sci. and Biotechnol.* 75(3): 304-311.

Wurr, D.C.E., Hand, D.W., Edmondson, R.N., Fellows, M.A. and Cribb, D.M. 1998. Climate change: a response surface study of the effects of CO2 and temperature on the growth of beetroot, carrots and onions. *J. Agric. Sci.* 131:125-133.

Yadav, S.S., Khan, B.H. and Yadav. 2010. Studies of onion varieties in kharif season. *J. Plant Anim. Sci.* 25: 38-40.

APPENDICES

APPENDIX I

Standard week	Weather data of experimental site (Sep.-Mar., 2017-18)				
	Temperature Max. (°C)	Temperature Min. (°C)	Sun shine hours	Relative humidity (%)	Rain fall (mm)
39	31.2	22.9	4.1	82	039.0
40	31.4	22.8	4.1	84	061.1
41	31.9	22.8	4.5	82	014.6
42	30.9	22.2	3.9	87	056.0
43	32.0	21.5	6.0	78	050.5
44	33.5	22.7	7.4	70	029.9
45	32.3	21.9	5.7	73	003.5
46	32.8	20.8	6.7	75	000. 0
47	33.8	21.6	6.8	73	025.0
48	32.0	22.5	4.3	71	011.5
49	32.8	21.0	7.3	73	000.0
50	32.7	21.4	5.1	72	000.0
51	32.3	21.5	9.1	54	000.0
52	32.8	20.3	9.4	52	000.0
1	33.2	19.8	8.8	58	000.0
2	32.7	21.8	7.4	56	000.0
3	33.8	20.7	8.6	48	000.0
4	34.1	21.4	8.1	53	000.0
5	34.3	20.5	9.0	37	000.0
6	35.3	22.3	8.5	59	005.2
7	35.3	22.3	9.4	51	000.0
8	36.3	22.5	10.8	42	000.0
9	37.7	23.1	9.9	43	000.0
10	38.2	23.5	9.6	47	000.0
11	35.7	24.4	6.0	67	013.1
12	35.8	24.1	7.9	64	020.1
13	36.1	25.0	6.7	67	000.0

ABSTRACT

Evaluation of varieties and standardization of planting time in onion (*Allium cepa* L.)

By

ARUNA S.

(2016-12-002)

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the

Requirement for the degree of

Master of Science in Horticulture

(VEGETABLE SCIENCE)

Faculty of Agriculture

Kerala Agricultural University, Thrissur

Department of Vegetable Science
COLLEGE OF HORTICULTURE
VELLANIKKARA, THRISSUR - 680 656
KERALA, INDIA
2018

ABSTRACT

Onion (*Allium cepa* L.) belonging to the family Alliaceae is one of the oldest vegetables in world and has been cultivated for more than 5000 years. It is an important and indispensable item in every kitchen as vegetable, spice and condiment. It is used as salad and cooked in various ways. Besides fresh consumption, onion provides a good raw material for processing industry as it can be processed in the form of dehydrated powder, rings, shreds, onion vinegar etc.

The present experiment entitled "Evaluation of varieties and standardization of planting time in onion (*Allium cepa* L.)" was conducted at the Department of Vegetable Science, College of Horticulture, Vellanikkara during November-March, 2017-18. The major objectives of the study were to identify the best variety and planting time in onion for the plains of Kerala, and to study the effect of varieties, planting time and their interaction on the qualitative and quantitative traits of onion. Five onion varieties were evaluated in four different dates of planting with an interval of fifteen days which was commenced from 10th November to 25th December 2017 in a split plot design with four replications.

There were no variations among different dates of planting for qualitative traits such as bulb shape, bulb skin colour, bulb flesh color, etc. Vegetative characters such as plant height and leaf length were maximum in Arka Kalyan (50.47 cm and 46.47 cm respectively), whereas number of leaves was highest in Agrifound Dark Red (8.31). Leaf girth was maximum in Agrifound Light Red (3.35 cm). Among different dates of planting, plant height (51.05 cm) and number of leaves (8.50) were maximum in 10th December planting. Leaf length was highest in 25th November planting (46.60 cm) while leaf girth was maximum in 10th November planting (3.49 cm).

Agrifound Dark Red recorded a minimum number of days (64.25) to reach 75% maturity. Among different planting dates, the plants in 10th December planting took minimum days (63.4) to reach 75% maturity. In the interactions between planting dates and varieties, Agrifound Dark Red planted on 10th December took minimum number of days (60) to reach maturity. Plant stand

(39.63), neck thickness (4.16 cm) and bulbing percentage (70.76%) were highest in the variety Arka Kalyan.

Average bulb weight varied significantly among different dates of planting. Highest average bulb weight was obtained when the planting was done on 25th November (66.2g). Average bulb weight ranged from 18g to 73.5g. There was no significant difference in number of scales among varieties, planting time and their interactions.

Total Soluble Solids was highest in the variety, Agrifound Light Red (16.37°B). Among different planting dates, bulbs from 10th December planting recorded the highest TSS (16.92°B). Among the interactions, highest TSS was noted for Agrifound Light Red planted on 10th December (18.32°B). All the varieties were having medium to high pungency except Agrifound White in all the dates of planting.

Total yield and marketable yield per plot varied significantly among different dates of planting. Among different dates of planting, marketable yield was highest in 25th November planting (0.96kg/plot). Among the interactions between varieties and planting dates, all the dates of planting except 25th Dec. were found to be statistically on par with respect to marketable yield for the varieties such as Arka Kalyan, Arka Pragati, Agrifound Dark Red and Agrifound Light Red. Planting on 25th Nov. and 10th Dec. were found to be superior and on par with respect to marketable yield in Agrifound White.

All the five varieties can be recommended for commercial cultivation as they do not differ with each other with respect to marketable yield. Considering the consumer preferences, we can recommend Arka Kalyan and Agrifound Dark Red as they are having attractive dark red colour. The best time for transplantation was found to be 25th November, which was statistically on par with 10th November and 10th December. As a future line of work, more number of varieties are to be evaluated, nursery and crop management practices need to be standardised, and for conclusive results experiment has to be repeated.