EFFECT OF ROOT BOOSTER THROUGH FERTIGATION ON YIELD OF ONION (*Allium cepa L.*), NUTRIENT UPTAKE AND AVAILABILITY IN INCEPTISOLS IN SEMI-ARID REGION OF MAHARASHTRA

by

Mr. MOHAMMAD ALI RASOOLI
(Reg. No. 017/303)

A Thesis submitted to the
MAHATMA PHULE KRISHI VIDYAPEETH
RAHURI – 413 722, DIST. AHMEDNAGAR
MAHARASHTRA, INDIA

in partial fulfillment of the requirements for the degree

of

MASTER OF SCIENCE (AGRICULTURE)

in

IRRIGATION WATER MANAGEMENT

INTER FACULTY DEPARTMENT OF IRRIGATION WATER MANAGEMENT

POST GRADUATE INSTITUTE
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2019

CANDIDATE'S DECLARATION

I hereby declare that this thesis or part
There of has not been submitted
by me or any other person to any
other University or Institution
for a Degree or
Diploma

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Date : / /2019

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This is to certify that the thesis entitled, **"Effect of Root Booster Through Fertigation on Yield of Onion (*Allium cepa L.*), Nutrient Uptake and Availability in Inceptisols in Semi-arid Region of Maharashtra"** submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri Dist. Ahmednagar (M.S.) in partial fulfillment of the requirement for the award of the degree of **MASTER OF SCIENCE (AGRICULTURE) in IRRIGATION WATER MANAGEMENT,** embodies the results of a piece of *bona fide* research work carried out by **Mr. Mohammad Ali Rasooli** under my guidance and supervision and that no part of the thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation have been duly acknowledged.

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ACKNOWLEDGEMENT

It is a great pleasure for me to express my deep sense of gratitude towards those people who have helped me towards the completion of my thesis. I consider myself to be very fortunate person for getting an opportunity to work under the dynamic and able guidance of Dr. ***K. D. Kale****, Assistant Professor of Soil Science & Agricultural Chemistry, Inter Faculty Department of Irrigation Water Management, MPKV, Rahuri who with hard gained treasure of knowledge, constant inspiration, constructive criticism, sustained interest throughout the course of this investigation and scholastic expertise guided me for my M.Sc. (Agri.) work. Words are inadequate to convey my esteemed profound depth of feelings of gratitude to him. I shall prefer to remain ever indebted to him for a lot of good things he had done for me.*

It is my proud privilege to express my sincere and whole hearted thanks to ***Dr. M.G. Shinde****, Head, Inter Faculty Department of Irrigation Water Management, I am also grateful to members of my advisory committee,* ***Dr. B.D. Bhakare,*** *Scientist (Soil), AICRP on Irrigation Water Management,* ***Dr. S. U. Bhoite****, Assistant Professor of Mathematics, Dr.ASCAE & T, MPKV, Rahuri for being in my advisory committee and also for their honest coaching, extensive help and their valuable suggestions and constructive encouragement during the tenure of this research.*

I express my deep sense of honour to ***Dr. K.P. Vishwanatha****, honourable Vice-Chancellor, Mahatma Phule Krishi Vidyapeeth, Rahuri.* ***Dr.A.L. Pharande****, Dean Faculty of Agriculture and Director of Instructions, MPKV, Rahuri and* ***Dr. P.A. Turbamath*** *Associate Dean, Mahatma Phule Krishi Vidyapeeth, Rahuri for providing the all infrastructure facilities for the smooth and successful conduct of research work.*

Words are too meagre to express indebtedness and gratitude towards ***Dr. U. D. Chavan*** *foreign students' advisor for his honesty cooperation, advices and encouragement during course work.*

I must place on record the gratefulness to my respected teachers ***Dr. R. R. Hasure****,* ***Er. S. K. Dingre****,* ***Dr. N. J. Danawale****,* ***Dr. V.P. Patil*** *Assistant Professors of Inter Faculty Department of Irrigation Water Management,* ***Dr. C. A. Nimbalker,*** *professor of Depatment of Statistic,* ***Dr. A. J. Shivagaje****,* ***Dr. V.S. Wani*** *Assistant Professors Department of Statistic, MPKV, Rahuri, and Dr. A. V. Gavali Field Officer (1) Comprehensive Scheme Department of Agril Economic MPKV Rahuri. I am also thankful to other staff of Inter Faculty Department of Irrigation Water Management, for their co-operation from, Mr. Deshmukh, Mr. Suryawanshi, Mr. Pawbake, and Mr. Belhekar and all the staff members of IFD-Irrigation Water Management.*

It is, really beyond my capacity to express my feelings for the overwhelming affection and co-operation that I received from my dear seniors Miss. Pol Jymala Bharat, Miss. Sandhya

Thorat, Sagar Zole and also my junior friends and all my department colleagues for their cheerful, immutable and selfless encouragement throughout the bright and dark phases of my research work.

Colourful blossoms would not have bloomed without the company of my, classmates Mohammad Agha Mullakhill, Khot Appasaheb Dhareppa, Yelwande Suraj Sudam, Aswale Shilpa Sahebrao, Sorte Sayali Shankar, Kapse Vishal Arun, Gagare Dattartray, Gawai Vikas Vijay, for their co-operation moral support and help during my study.

I am deeply thankful to foreign students M. Edris Rahimi, Bismillah Shinwari, Ab. Mujeeb Majeedi, Galaletsang Kwelagobe and Hamimu Idrisa who were the source of constant inspiration and moral support in stepping up my academic career without which it was quite difficult for me to achieve my goal.

I feel immense pleasure in taking this opportunity to express my sincere thanks to Government of Afghanistan and Government of India, particularly ICAR, for facilitating my studies.

I am grateful and express my sincere thanks to Ministry of Rural Rehabilitation and Development and Ministry of Agriculture, Irrigation and livestock for granting me a study leave to undergo this Fellowship Program.

My sincere thanks should go to Razia Hussaini, G.Rasooli Zahidi, Depak Sha, Hyatullah Fazil Sahib and Mujibullah Rahmanyar to assist me during the entering period of India – Afghanistan Fellowship Program.

Lastly, most of my credit of whatever little, I may have achieved today goes to my parents who always stood like a lighthouse for illumination in the pathway of my life and for their sacrifice in moulding me and in building up my educational career and special thanks for my respected wife Fatima Rasooli who was bearing responsibility of my family during my M. Sc. period alone and I am thankful to my dear brother Khirullah Rasooli and my kind sisters Shukrya, Marzia, Razia, Sharifa and Wahida who were the source of constant inspiration and moral support in stepping up my academic career.

I am also deeply obliged to all those authors and scientists, past and present, whose contributions were of immense help to understand these research findings as their literature has been aptly cited to undertaken the present investigation.

While travelling on the path of life and education, many hands pushed me forth, learned hearts put me on the right path, unlighted by their knowledge and experience, I ever remain thankful to them all.

Place: M.P.K.V. Rahuri (M. Ali Rasooli)

Date: / / 2019

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LIST OF ABBREVIATIONS

@	:	At the rate of
%	:	Per cent
^{0}E	:	Degree east
^{0}N	:	Degree north
/	:	Per
C.D.	:	Critical difference
cm	:	Centimeter
CPE	:	Cumulative pan evaporation
^{0}C	:	Degree celsius
DI	:	Drip irrigation
DAT	:	Days after transplanting
dSm^{-1}	:	Desi siemen per meter
EC	:	Electrical conductivity
Ep	:	Pan evaporation
ER	:	Effective rainfall
ETc	:	Crop evapotranspiration
et al.	:	And others
etc.	:	Etcetera
WUE	:	Water use efficiency
Fig.	:	Figure
g	:	gram (s)
GTO	:	Grommet take off
ha	:	hectare
ha-mm	:	Hectare-millimeter
hr	:	Hour (s)
IR	:	Irrigation requirement
RDF	:	Recommended dose of fertilizer
i.e.	:	That is
K	:	Potassium
Kc	:	Crop coefficient
Kg	:	Kilo gram (s)
Kg ha^{-1}	:	kilogram per hectare

Kp	:	Pan coefficient
LDPE	:	Low density poly ethylene
lph	:	Litre per hour
m	:	meter
mm	:	Millimeter
N	:	Nitrogen
No.	:	Number
N.S.	:	Non significant
P	:	Phosphorus
PE	:	Pan evaporation
PVC	:	Polyvinyl chloride
Q	:	Quintal (s)
Rs	:	Rupees
S.E.m (±)	:	Standard error means
viz.,	:	Videlicet (Namely)
M.C	:	Moisture content
Kc	:	Crop factor
T	:	Tonnes

ABSTRACT

EFFECT OF ROOT BOOSTER THROUGH FERTIGATION ON YIELD OF ONION (*Allium cepa* L.), NUTRIENT UPTAKE AND AVAILABILITY IN INCEPTISOLS IN SEMI-ARID REGION OF MAHARASHTRA

by

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A candidate for the degree of

MASTER OF SCIENCE (AGRICULTURE)

in

IRRIGATION WATER MANAGEMENT

2019

Research Guide : K.D. Kale
Department : Interfaculty Department of Irrigation Water Management

The present investigations “Effect of root booster through fertigation on yield of onion (*Allium cepa L.*), nutrient uptake and availability in Inceptisols in semi-arid region of Maharashtra” was conducted at Institutional Farm of Inter-Faculty Department of Irrigation Water Management, Post Graduate Institute, Mahatma Phule Krishi Vidyapeeth, Rahuri during 2017-18. The experiment was carried out in randomized block design involving nine treatments with three replications. The treatments were comprised of combinations of three levels of root booster fertigation *viz.,* 5.0, 7.0 and 9.0 liter of root booster and two levels of conventional fertilizer *viz.,* 75 and 100 % recommended dose.

The soil of the experimental field was silty clay in texture, moderately alkaline in reaction (8.10) with EC- 0.30 dSm^{-1} and low in available nitrogen (173.20 kg ha^{-1}), medium in available phosphorus (16.40 kg ha^{-1}) and very high in available potassium (550 kg ha^{-1}). The results indicated that DI with 100% RD of CF + 9 lit ha^{-1} fertigation of root booster recorded significantly higher growth attributes viz., plant height, number of leaves $plant^{-1}$, dry matter $plant^{-1}$ and neck thickness at 30, 60, 90 DAT and at harvest as compared to other treatments and it was at par with treatment DI with 100%RD of CF + 7 lit ha^{-1} fertigation of root booster.

The drip irrigation with application of 100% RD of conventional fertilizer and 9 lit ha^{-1} fertigation of root booster recorded significantly higher polar diameter and equatorial diameter than other treatments at harvest. However, it was at par with DI with 100%RD of CF + 7 lit ha^{-1} fertigation of root booster.

The average bulb weight, yield of bulb, weight of leaves and bulbs to leaves ratio were significantly higher in DI with 100%RD of CF + 9 lit ha^{-1} fertigation of root booster followed DI with 100%RD of CF + 7 lit ha^{-1} fertigation of root booster. The minimum values were recorded in treatment DI with no fertilizer due to lack of nutrition.

The total irrigation water applied in DI and SI were 341 and 600 mm, respectively. The maximum water use efficiency were observed in DI with 100%RD of CF + 9 lit ha^{-1} fertigation of root booster (131.82 kg ha^{-1} mm) might be due to higher yield obtained and lesser water consumed followed by DI with 100%RD of CF + 7 lit ha^{-1} fertigation of root booster (123.39 kg ha^{-1} mm).

The nutrient uptake (NPK) was significantly maximum in treatments DI with 100%RD of CF + 9 lit ha^{-1} fertigation of root booster (119.0, 55.1 and 103.5 kg ha^{-1}, respectively). However, it was at par with DI with 100%RD of CF + 7 lit ha^{-1} fertigation of root booster at harvest. The minimum values were recorded in treatment DI with no fertilizer. The treatment DI with 100%RD of CF +5 lit ha^{-1} fertigation of root booster recorded maximum availability of N, P and K as 167.0, 175 and 551.0 kg ha^{-1}, respectively at harvest. However, it was at par with DI with 100%RD of CF + 7 lit ha^{-1} fertigation of root booster and DI with 100%RD of CF + 9 lit ha^{-1} fertigation of root booster.

Drip irrigation with 100%RD of CF + 9 lit ha^{-1} fertigation of root booster recorded higher net seasonal income of Rs 257602 ha^{-1}, total net income of Rs 384181 ha^{-1} , net extra income over control of Rs 47285 ha^{-1} and B:C ratio of 3.52 over DI with 100 % RD of CF followed by SI with 100 % RD of CF.

The treatment DI with 75% RD of CF + 9 lit ha^{-1} fertigation of root booster resulted in to lowest rottening, physiological and total weight losses i.e. 4.8, 10.7 and 15.5 per cent, respectively in storability at 180 DAH than all other treatments. The SI with 100% RD of conventional fertilizer recorded significantly maximum physiological, rottening and total weight losses i.e. 12.3, 7.6 and 19.9 per cent, respectively followed by DI with no fertilizer and DI with 100%RD of CF + 9 lit ha^{-1} fertigation of root booster.

From above study, it can be concluded that drip irrigation with 100% RD of CF and fertigation of 9 lit ha^{-1} root booster at weekly interval for eight weeks is the best treatment for improved growth, yield and economical returns from *rabi* onion cultivated in silty clay soils in semi-arid region of Maharashtra.

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1. INTRODUCTION

Onion (*Allium cepa, L.*) is considered to be the second most important vegetable crop grown in the world after tomatoes. It is an indispensable item in every kitchen as vegetable and condiments are used to flavour many of the food stuffs. Therefore, onion is popularly referred as 'Queen of the kitchen'. In addition, onion is used as salad and pickle. Onion is consumed by all classes of people-poor and rich and hence assumes a place of essential item. Onion possess very good nutritive material.

The last half century has seen an exponential growth in the world production of onion bulbs at a rate of approximately 3.6% per year, from 15 million tons in 1960 to 82.9 million tons in 2012 with 4.2 million tons hectares (FAO 2014).

Onion are also valued for their purported health benefits, some of which have been attributed to the presence of organosulphur compounds (Keusgen 2002). Together, the onions culinary versatility, flavour, long storage life and adaptation across agro-ecosystems has made it one of the world's most popular vegetables, and the consequent demand makes it a regularly traded commodity in both domestic and global markets.

Recently onion is being employed by processing industry to a greater extent for preparing dehydrated onion forms like powder and flakes. Onion is extremely important vegetable crop not only for internal consumption but also as highest foreign exchange earner among the fruits and vegetables.

Onions are one of the oldest vegetables in continuous cultivation dating back to at least 4,000 before the Christian Era (BCE). The ancient Egyptians are known to have cultivated this crop along the Nile River. There are no known wild ancestors, however, the center of origin is believed to be Afghanistan and the surrounding region. Onions are among the most widely adapted vegetable crops. They can be grown from the tropics to subarctic regions. This adaptation is primarily due to differing response to day length. Unlike most other species, day length influences blubbing in onions as opposed to flowering. Onions are grouped into three groups based on their response to hours of day length. The short-day varieties bulb with daylengths of 10-13 hours, intermediate varieties bulb with day lengths of 13-14 hours and are found in the mid-temperate regions of this country. Finally, long-day onions are adapted to the most northern climes of the United States as well as Canada and bulb with daylengths greater than 14 hours. (Anonymous 2007).

In India, onion (*Allium cepa, L.*) is one of the most important vegetable crops. In India, total area under cultivation of onion are 1.16 million ha with the total production of 20.2 million tons and productivity of 17.32 ton ha^{-1} (NHRDF). Maharashtra is leading state in onion production with the total area of 0.44 million ha and total production of 5.40 million tons with productivity of 17.3-ton ha^{-1} (Anonymous 2017).

The major onion growing states are Maharashtra, Gujarat, Uttar Pradesh, Rajasthan, Orissa, Karnataka, Tamil Nadu, Madhya Pradesh and Bihar. Maharashtra ranks first in onion production with a share of 18% in terms of productivity. The principal onion growing districts in the Maharashtra State are Satara, Nashik, Jalgaon, Pune, Solapur and Ahmednagar occupy about 94.68 percent of the area under cultivation of onion in the state. Particularly in eastern part of the Satara district of the State *kharif* and *rabi* onion is highest grown by cultivators in certain pocket only.

In Maharashtra onion is grown particularly under Inceptisols and Vertisols. It is observed that the farmers transplant *rabi* onion after the harvest of sugarcane or any *kharif* crop with minimum land cultivation. Moreover, the tendency of farmers has inclined towards growing onion under drip and micro sprinklers on all types of planting systems without much knowledge of proper fertilization.

Nutrition is one of the most important factors which govern the onion production. Onions grow best on fertile & well-drained soils. Mostly sandy loam, loamy sand or sandy soils are also advantageous to sweet onion production. These soils are inherently low in sulfur, which allows greater flexibility in sulfur management to produce sweet onions. Avoid soils with heavy clay content and coarse sandy soils. Clay soils tend to have a higher sulfur content that can lead to pungent onions. Sandy soils are difficult to manage because they require more fertilizer and water.

Onions require more fertilizer than most vegetable crops because fertilization of both plant beds and dry bulb onions must be considered. They respond well to additional fertilizer applied 40-60 days after seeding or transplanting. The method of fertilizer application is very important in obtaining maximum yield, with multiple applications ensuring good yields. This increases the amount of fertilizer used by the plant and lessens the amount lost from leaching. More recent research indicates that good results can be obtained with as few as three fertilizer applications. Preplant fertilizer will vary with the natural fertility and cropping history.

Nitrogen (N) especially in nitrate (NO_3^{2-}) form, is extremely leachable. If too little nitrogen is available, onions can be severely stunted. High nitrogen rates are believed to produce succulent plants that are more susceptible to chilling or freezing injury and disease, and to production of flower stalks. Onions, heavily fertilized with nitrogen, are believed to not store well. Finally, excess nitrogen late in the growing season is believed to delay maturity and causes double centers. Make the final nitrogen application at least 4 weeks prior to harvest. Rates of nitrogen vary depending on soil type, rainfall, irrigation, plant populations, and method and timing of applications. Dry bulb production, from transplanting, requires between 125-150 pounds per acre of nitrogen. It is usually best to incorporate 25-30 percent of the recommended nitrogen prior to planting; apply the remainder in two to three split applications (Anonymous, 2007).

In commercial onion production, available mineral nutrition is managed via fertilizer programs based on regular soil nutrient testing. In particular, nitrogen is the most studied nutrient in onion crop management due to the complexities of the nitrogen cycle, brought about by mineralization, volatilization and leaching, leading to a relatively inefficient uptake of nitrogen by the onion root system (Halvorson *et al*. 2002).

The nutrients needed for onion crop are supplied through organic, inorganic source and through micro-nutrients and bio-fertilizers. These organic manures alone may not be able to meet the nutritional requirement of high yielding cultivars and hence, there is a need for supplementing the use of inorganic fertilizers in judicious ways. Therefore, the adoption of integrated nutrient management strategies holds the key in enhancing the productivity as well as quality of produce. Soil fertilization is the basic condition for adequate mineral supply to the plants.

The adoption of drip irrigation technology has increased the net sown area, net irrigated area and thereby has helped in achieving higher cropping intensity and irrigation intensity. It has been found that there is a significant shift towards crops production. The main reasons have been found as scarcity of human labour and water. As the cropping pattern decides the adoption and suitability of drip irrigation, the analysis of economics of crop cultivation under drip and control has revealed that the drip method of irrigation has a significant impact on resources saving, cost of cultivation, yield of crops and farm profitability. The physical water and energy productivity are significantly high in drip over the flood method of irrigation. One could conclude that the drip has a significant bearing on the private costs and benefits and hence on profit of farmers. Thus, our policy focus may be tilted towards the promotion of drip irrigation in those regions where scarcity of water and labour is alarming and where shift towards wider spaced crops is taking place. (Suresh Kumara and Palanisamib 2010).

Now a day, the application of water soluble fertilizers through drip irrigation system is gaining importance in precision farming. The drip fertigation method is highly efficient method of fertilizer application which is ideally suited for controlling the placement and supply of rate of water soluble fertilizers at the required rate and at the correct time. It also can avoid ground water pollution due to leaching of excessive fertilizers. With saved water and fertilizers more area can be brought under cultivation resulting into increased economical returns from agriculture production. This is a distinct advantage of drip fertigation system which applied water soluble fertilizer to the plant frequently which overcomes the drawback of conventional method. Therefore, in order to enhance agriculture production, it is necessary to shift from the conventional water and fertilizers application methods to more advanced method like drip fertigation.

Drip irrigation is the method of precisely and frequently watering plant which overcomes the drawback of surface irrigation. In drip irrigation method, plant is not subjected to water stress and proper aeration in the root zone is maintained. High water and fertilizer use efficiency can be obtained through drip irrigation system, it is one of effective method which minimize the losses such as conveyance, deep percolation, run-off and soil water evaporation. This method increases the crop yield to 25-30% with saving of irrigation water to the extent of 40-60%. Onion crop is very sensitive to irrigation, since it has got relatively shallow root zone in depth and hence requires more irrigations compared to other vegetable crops. The use of appropriate quantity of irrigation at proper time plays a vital role in enhancing the productivity of onion.

Application of root booster be considered as a good production strategy for obtaining high yields of nutritionally valuable vegetables with lower impact on the environment. Root booster increases root growth, root volume and also promotes higher growth. The data regarding application of root booster through fertigation for onion crop is scanty hence, the present investigation was planned to study the effect of fertigation of root booster on yield of onion, nutrient uptake and availability, economics and storability of onion.

In view of the mentioned aspects the present research work entitled "Effect of Root Booster Through Fertigation on Yield of Onion (*Allium cepa L.*), Nutrient Uptake and Availability in Inceptisols in Semi-arid Region of Maharashtra" was conducted during *rabi* season of 2017-2018 with the following objectives:

1. To study the effect of fertigation of root booster on growth and yield of onion
2. To study the nutrient uptake and nutrient availability in soil
3. To study economics of onion as influenced by fertigation of root booster
4. To study the effect of root booster on storability of onion

2. REVIEW OF LITERATURE

Optimum return and high yield in onion depends on several factors such as soil health, existence of organic matter, inorganic nutrients and fertilizer in a balance amount. In addition, quality of bulbs related to many parameters such as climate, soil, irrigation schedule, appropriate dose of fertilizer application in right time, cultivars, proper weeding, planting season and population of plants per unit of area. Among the mentioned factors which has direct effects on the bulb quality and yield are irrigation and nutrients management. Thus, this literature related to the yield of onion, nutrient uptake and availability in Inceptisols as influenced by root booster fertigation and application of conventional fertilizer is reviewed in this chapter.

2.1. Fertilizer Management in Onion

2.1.1 Growth Characters of Onion

The application of nutrients in a right time and appropriate amount per unit of area has a direct positive effect on vegetative growth of a plant especially in plant height, number of leaves, neck thickness, bulb weight, yield, storage quality of onion bulbs and other characters in onion crop. The various organic and inorganic fertilizers affect the growth of onion crop. Many research workers have done the study work on application of different combinations of nutrients in various concentrations on growth characters of onion crop.

Reddy (1985) reported that the phosphorus alone produces better growth and observed that the number of leaves per plant were more with the application of 45 to 60 kg ha^{-1} P_2O_5 as compared to 30 kg ha^{-1} P_2O_5.

Bhujbal (1989) conducted field experiment on effect of organic, inorganic and bio-fertilizers on growth, yield and storage quality on onion bulbs cv. N-2-4-1. He reported that the highest number of leaves per plant in onion was obtained in the treatment of 60 tones FYM + 100:50:50 NPK kg ha^{-1}.

Singh and Dhankar (1989) studied the effect of nitrogen, phosphorus and zinc on growth, yield and quality of onion. They observed that high nitrogen levels increased plant height in onion.

Pandey and Ekpo (1991) reported the highest plant height (63.9 cm) and number of leaves per plant (13.0) with application of 160 kg N ha^{-1}.

Warade *et al.* (1995) reported that the application of nitrogen @ 125 kg ha^{-1} and phosphorus @ 75 kg ha^{-1} produced significantly maximum plant height, number of leaves, diameter and average weight of onion bulbs.

Deho *et al*. (2002) reported that the application of 80 kg N + 60 kg P_2O_5 + 40 kg K_2O ha^{-1} produced more leaves and largest bulb size in onion.

Tao Guo *et al*. (2006) reported which colonization by Arbuscular Mycorrhizal (AM) fungi made a substantial contribution to onion growth and may not have been directly related to bulb pungency at early stages of plant growth. However, the influence of AM fungi on plant N and P metabolism may have implications for onion flavor at later stages of plant growth.

Mahanthesh *et al*. (2008) conducted a field experiment and revealed that the plants provided with Azospirillum + 100 % NPK (125:50:125 kg ha^{-1}) produced highest bulb yield (339.02 q ha^{-1}) and highest total dry matter production (8,992.78 kg ha^{-1}) under irrigated condition during *rabi* season.

Bose *et al*. (2009) carried out an experiment to study the response of micronutrients viz; zinc, iron and copper a1ongwith growth regulator NAA 30 and 50 ppm on growth and yield of onion significant variations were observed in the response of micronutrients as well as growth regulator on growth, yield traits and economics. Among micronutrients copper 0.5% showed the best response in growth and yield traits viz; height of p1ant (61.35 cm), number of leaves (10.20), neck diameter (1.95 cm), fresh weight of bulb (78.63 g), bulb diameter (4.99 cm) and yield (329.70 q/ha) as compared to other micronutrients over check. Growth regulator NAA 50 ppm gave the highest plant height (61.63 cm), number of leaves l0.25), neck diameter (1.98 cm), fresh weight of bulb (78.71 g), bulb diameter (5.08 cm) and yield per hectare (337.16 q) as compared to NAA 30 ppm over control. In regard to economics optimum net return of Rs. 66099 ha^{-1} with 1.88 B.C ratio was recorded in NAA 50 ppm followed by copper 0.5% Rs.63423 ha^{-1}.

Kadam (2012) reported that the integrated nutrient management system with application of treatment 110:40:60:40 kg NPKS + 7.5 t FYM + 2.5 t PM + 2.5 t VC ha^{-1} significantly affected on size of onion bulbs as average weight of bulb (78.41 g), mean polar diameter (6.22 cm) and mean equatorial diameter (7.87 cm) and also, growth parameters like plant height (68.52 cm) and number of leaves per plant (14.10) in onion were improved.

Manna (2013) conducted a field experiment to investigate the role of boron and zinc on growth, yield and quality of onion and revealed that application of 0.5% boron significantly increased the growth (plant height, 63.93cm and number of leaves per plant, 7.25), yield (30.74 t ha^{-1}) and quality (total soluble solids, 13.45 °Brix and pyruvic acid 5.94 mmol g^{-1}) of onion. Among various levels of zinc 0.5% exhibited the best growth (plant height, 67.25cm and number of leaves per plant, 7.75), yield (33.34 t ha^{-1}) and quality (total soluble solids, 14.57 °Brix and pyruvic acid, 5.86 mmol g^{-1}) attributes of onion. These results suggest that the foliar application of boron and zinc significantly influenced the growth, yield and quality of onion.

Nagwa *et al*. (2013) showed by field experiment that the foliar application of concentrations of bio-regulators and Vitamin E were resulted in the tallest plants and that which carried the highest number of leaves/ plants, fresh and dry weights of leaves, neck and whole plant compared with that plant no treated (control). Moreover, within the above-mentioned treatments the obtained data indicate that, using higher levels of bio-regulators and Vitamin E at (100 ppm) resulted in the better growth of all characters of the onion plants than using the lower level (50 ppm) and water spraying control.

Dingre *et al*. (2015) reported that the 90% ETc and 100% fertigation dose (120:60:60 NPK kg/ha) appears a useful practice to increase onion seed productivity under the semi-arid climate of western India.

Shashi Kumar and Shashidhar (2016) reported that maximum plant height (64.30 cm) was recorded from the plots sprayed with GA_3 @ 60 ppm whereas the higher number of leaves (10.63) noticed in the plot sprayed with lihocin @ 2500 ppm. Significantly higher neck thickness (18.64 mm) and higher dry matter content (16.9 gm/plant) were noticed in the treatment lihocin @ 2500 ppm. Significantly higher yield (54.0 t/ha) was noticed from the plots sprayed with lihocin @ 2500 ppm and the minimum yield (41.2 t/ha) was noticed from the control plot.

Monica Negrea *et al.* (2016) carried out field experiment for three years and results demonstrated that nutrients content varied considerably depending on the fertilization doses and climatic conditions. Most of the studied nutrients in onion samples were significantly influenced by the sole application of NPK fertilizers rates and growth regulators (Aqzyme and Pervaide). Copper (Cu) content revealed a deficiency as compared to the normal level in all variants during the three experimental years. Among the three experimental years were significant differences in mineral content of onion culture, being registered higher values in 2011 both for macronutrients (P, K and Mg) and micronutrients (Fe, Cu, Zn and Mn).

Ravina, Kumari (2017) carried out experiment at Organic Block, Experimental Farm of Department of Vegetable Science, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, (HP) in the Rabi season 2016-2017 with the objective to study the effect of organic nutrient sources on growth of Onion (*Allium cepa L.*) and reported as [Vermicompost @ 8 t ha^{-1} + Jeevamrut (Drenching, 5%)] recorded maximum leaf length (19.93, 42.23 and 59.33 cm at 30, 60 and 90 DAT), number of leaves per plant (3.20, 5.00 and 8.13 at 30, 60 and 90 DAT), number of bulbs per plot (263), equatorial diameter (6.36 cm), polar diameter (5.07 cm), average weight of bulb (73.33 g).

Bhat *et al*. (2018) performed an investigation at the experimental field of Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir (SKUAST-K) during *Rabi* 2015-16 and *Rabi* 2016-17 to find out the effect of different levels of zinc and boron on growth, yield and quality of onion. The experiment was laid out in randomized completely block design with three replications comprising of two factors with four levels of each viz., Zinc (Z), Z0 (control or no zinc), Z_1 (2.5 kg ha^{-1}), Z_2 (5.0 kg ha^{-1}) and Z_3 (7.5 kg ha^{-1}) and Boron (B), B_0 (control or no boron), B_1 (0.5 kg ha^{-1}), B_2 (1.0 kg ha^{-1}) and B_3 (1.5 kg ha^{-1}). The observations were recorded on growth, yield and quality from 10 randomly selected plants of each treatment. Pooled analysis revealed significantly maximum values for plant height (66.07 cm), number of leaves plant^{-1} (10.61) and leaf length (41.36 cm) as compared to other levels including control. Similarly, application of boron @ B_3 (1.5 kg ha^{-1}) recorded significantly maximum values for plant height (64.67 cm), No of leaves plant^{-1} (10.38) and leaf length (41.08 cm) while significantly lowest values for plant height (58.69 cm), No of leaves plant^{-1} (9.06) and leaf length (38.63 cm) were recorded in control. Pooled analysis revealed that zinc @ 7.5 kg ha^{-1} (Z_3) recorded maximum values for polar diameter (6.31 cm), equatorial diameter (6.32 cm), average bulb weight (82.64 g) and total bulb yield (275.5 q ha^{-1}) followed by Z_2 (5.0 kg ha^{-1}). Similarly, application of boron @ 1.5 kg ha^{-1} (B_3) recorded significantly maximum values for polar diameter (5.95 cm), equatorial diameter (6.14 cm), average bulb weight (81.15 g) and total bulb yield (270.29 q ha^{-1}).

2.1.2 Yield and Yield Contributing Characters of Onion

Dixit (1996) conducted a field experiment on response of onion (*Allium cepa L.*) to nitrogen and farm yard manure in dry temperate high hills of Himachal Pradesh and he reported that increasing N application rates increased bulb yield up to 120 kg N ha^{-1}. Higher yields were also obtained with higher FYM rates. Application of 120 kg N with 20 t FYM ha^{-1} increased yields by 42.79 % as compared with control.

Khan *et al*. (2003) had an experiment and were undertaken to determine the effect of spacing on onion cultivation of different varieties. Different spacings were taken as 20 x10 cm, 15x10 cm, 10 x 10 cm, 15 x 7.5 cm, 10 x 7.5 cm and 7.5 x 7.5 cm. Three varieties viz BARI Piaz-1, Taherpuri and Faridpur Bhati were used for study. They reported significantly wider spacing produced higher plant height, leaf length and number of leaves. Bulb length, diameter and weight have same trend in wider spacing. The weight of individual bulb of onion (23.52 g) was increased with the widest spacing (20 x10 cm). On the contrary, yield ha^{-1} was the highest (16.65 t ha^{-1}) at the closest spacing (7.5 x 7.5 cm) and the lowest (10.05 t ha^{-1}) was at widest spacing (20 x 10 cm). But in closer spacing, bulb size was so small that was not suitable for the choice of consumer. On the other hand, wider spacing produced the highest percentage (24.34%) of multiplier bulbs that was not better for storing and consumers demand. So, in respect of economic point of view 15 x 10 cm spacing was recommended in onion cultivation. BARI Piaz-1 performed better in respect of yield and other parameters.

Nasreen *et al.* (2007) conducted field experiment at research field of Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur during *rabi* seasons of 2002-2003 and 2003-2004 to study the effect of nitrogen (0, 80, 120 and 160 kg/ha from urea) and sulphur (0, 20, 40 and 60 kg/ha from gypsum) fertilization on N and S uptake and yield performance of onion (var. BARI Piaz-1). They reported that addition of nitrogen and sulphur fertilizers exerted significant influence on the number of leaves per plant, plant height, diameter of bulb, single bulb weight and yield of onion.

Harne (2011) was conducted a field experiment on Foliar Application of Water-Soluble Fertilizers through Micro Sprinkler on *Rabi* Onion, (M.S) and reported the fertigation of urea phosphate and 100% RDF showed favorable effect on growth and yield attributing characters onion, resulting in higher bulb yield in silty clay loam soil in *rabi* season.

Kadam (2012) indicated that, integrated nutrient management system significantly maximized yield parameters like average weight of bulb by 30.33 % over the recommended dose i.e. control. The significantly highest values in yield contributing characters of onion were also recorded by the treatment of 110:40:60:40 kg NPKS + 7.5 t FYM + 2.5 t PM + 2.5 t VC ha^{-1}.

Manna (2013) reported foliar application of boric acid and zinc sulphate ($ZnSO_4$) significantly improved vegetative growth, yield and quality of onion and dry matter content in bulb was also significantly increased with the application of boron. Foliar application of boron and zinc significantly affected quality parameters of onion in terms of total soluble solid (TSS) and pyruvic acid content.

Deshpande *et al* (2013) conducted a field experiment at the Post Graduate Institute Farm of the Department of Soil Science and Agriculture Chemistry, Mahatma Phule Agriculture University, Rahuri (Maharshtra) to study the effect of increasing rates of potassium (K) fertilizer application on yield, quality and nutrient uptake of onion (Cv.N-2-4-1) and reported that application of 100 kg K_2O ha^{-1} significantly increased total sugar percentage content from 5.89% to 7.32% and highest TSS 8.34 °Brix and application of K_2O, 150 kg ha^{-1} increased highest bulb yield 53.90 t ha^{-1}.

Nagare (2014) reported the increase of onion yield 42.9 % (36.1 t ha^{-1}) due to the application of fertilizers (100:50:50 N: P_2O_5: K_2O Kg ha^{-1} + FYM 20 t ha^{-1}). The increment in onion yield due to the soil application of recommended dose of fertilizers + Fe_2SO_4 + $ZnSO_4$ @ 20 kg ha^{-1} (34.6 ha^{-1}) was to the tune of 37.1%. The foliar application of chelated Fe + Zn @ 1.0% increased onion yield (33.1 t ha^{-1}) by 30.9 %.

Kiros Gebretsadik and N. Dechassa (2015) was conducted a field experiment to study the effect of nitrogen (N) fertilizer rates and intra row spacing on yield of onion (*Allium cepa L.*) cultivar Bombay red. Treatments consisted of a factorial combination of four rates of N (0, 50, 100 and 150 kg N ha^{-1}) and four intra row spacing (4, 6, 8, and 10 cm) with inter row spacing of 20 cm. The experiment was laid out as a randomized complete block design with three replications. The analysis of variance revealed that the main effects of N and intra row spacing significantly affected average fresh bulb weight, bulb diameter, marketable yield, and total bulb yield. 100 kg N ha^{-1} was found the best rate of N to get optimum marketable bulb yield (31.45 t ha^{-1}), total bulb yield (32.84 t ha^{-1}) and average bulb weight (86.50 g). The results also revealed that the intra row spacing of 6 cm was optimum. Combined Spacing of 6 cm x 20 cm with 100 kg N ha^{-1} is the most favourable for onion cultivar Bombay red production at Shire, northern Ethiopia.

Awatef *et al*. (2015) carried out field experiments and reported that, the percentage of N, protein, TSS, P, K and total carbohydrate in bulb tissues were significantly increased by potassium foliar application (thiosulfate) as compared with the control treatment.

Shafeek *et al*. (2015) had two field experiments and their results indicated that the foliar application of yeast extract, seaweeds extract and licorice extract at the same time had the highest stimulation effect on onion plant growth characters i.e. (plant length and number of leaves as well as fresh and dry weight of leaves), total bulb yield and its components as well as content of the percentage of bulb tissues of nitrogen, protein and dry matter compared to the control and other treatments.

Rajat Kumar Singh *et al*. (2017) were conducted a field experiment on effect of levels of nitrogen and spacing's on growth and yield of *rabi* onion and the result revealed that the N4 (140 kg/ha) was found best suitable on growth, yield of onion. The S1 (15×10cm) was found best suitable on growth, yield of onion. The N3 (130 kg) combined with S1(15×10) of nitrogen and spacing was found best suitable on growth, yield of onion.

2.2. Irrigation Water Management in Onion

Mane and Khade (1987) conducted a field experiment at Mahatma Phule Krishi Vidyapeeth, Rahuri (M.S.) on comparative performance of sprinkler and surface method of irrigation on yield of summer onion. They recorded the increase in yield of summer onion to the extent of 24.6% and water saving of 33.3% by sprinkler methods over the best treatment of surface method. The sprinkler irrigation method gave water use efficiency of 1.46 q ha^{-1} cm which was two times more than that obtained under surface method.

Hartz and Hochmuth (1996) showed that higher yield in micro-irrigation (micro-sprinkler and drip) may be due to the fact that micro-irrigation systems enhance the nutrient availability by providing nutrient through fertigation where as in furrow irrigation, fertilizer is applied as basal dose and split dose, which is always vulnerable to leaching. As a result, crop suffers often from inadequate supply of N and sometimes S & P.

Chopade *et al*. (1998) conducted field trials to study the effect of fertilizers and water management to onion at Panjabrao Deshmukh Krishi Vidyapeeth, Akola (M.S.). They found that net irrigation water requirement of onion was 46.27 and 67.13 cm under drip and check basin irrigation, respectively. Thus, water saving in drip over check basin was 31.2%. They also observed that WUE in drip system was highest (10.73 ha cm^{-1}).

Reddell *et al.* (1999) found that the provision of nutrients through conventional methods is slow and thus the methods are unable to immediately cure the plants from nutrients deficiencies immediately after the identification of the deficiency.

Jamal *et al.* (2000) conducted field experiments to determine evaporation production function regarding sprinkler and drip irrigated onions. The results indicated that 20% high yield in onion was achieved by using a drip system as compared to sprinkler system.

More (2000) studied effect of micro-irrigation and N fertigation levels on yield and quality of onion bulbs at Mahatma Phule Krishi Vidyapeeth, Rahuri (M.S.). He reported that yield contributing characters and yield (416 q ha^{-1}) were significantly increased with N fertigation level up to 100% recommended dose of nitrogen. He also reported that the water use efficiency in micro-irrigation system (0.91 q ha^{-1} mm^{-1}) was about three times more than control (0.30 q ha^{-1} mm^{-1}).

Wadatkar *et al*. (2002) studied the response of onion cv. Malav-21 to different irrigation methods at PDKV, Akola, Maharashtra. They reported that water saving in micro-irrigation treatment over the control was 27.3%. Also, the water use efficiency was maximum in micro-sprinkler irrigation (4.20 q ha^{-1} cm). Further, the onion bulb production and consumer acceptance were maximum in the micro-sprinkler treatment (253.52 q ha^{-1}) followed by the trickle (245.58 q ha^{-1}) and drip inline (238.04 q ha^{-1}). The lowest yield was recorded in the control.

Bhonde *et. al*, (2003) conducted experiment on effect of drip irrigation in onion bulb crop during rabi season and concluded that drip irrigation gave better plant stand, higher weight of bulbs and higher yield as compared to flood irrigation with flat or raised bed method.

Mali (2006) at Mahatma Phule Krishi Vidyapeeth, Rahuri (M.S.) studied the effect of micro irrigation systems and planting layouts on growth, yield and economics of garlic and reported that field water use efficiency (52.34 and 46.48 kg ha^{-1} mm^{-1}) was higher in micro sprinkler irrigation with broad bed furrow and flatbed treatments, respectively as compared with all the treatments.

Sankar *et al*. (2008) conducted a field experiment on the effect of micro irrigation on growth, yield and water use efficiency of onion (*Allium cepa L.*) under western Maharashtra conditions and they reported that there was saving of irrigation water of 37.8% in drip and 32.5% in sprinkler system compared with the surface irrigation scheduled at 50 mm cumulative pan evaporation with 7 cm depth. The highest water use efficiency was observed under drip irrigation system.

Mukherjee *et al*. (2010) had a field experiment on role of irrigation and mulch on yield, evapotranspiration rate and water use pattern of tomato (*Lycopersicon esculentum L.*) Finally, they concluded that, under water scarce situation adoption of deficit irrigation clubbed with black polyethylene mulch can be a good option for utilizing water resource most efficiently without significant decrease in yield.

Bagali *et al.* (2012) conducted field experiments for two seasons during summer season of 2004-05 and 2005-06 at Regional Agricultural Research Station Bijapur (Karnataka), on medium deep black soil to study the effect of scheduling of drip irrigation on the growth, yield and water use efficiency of onion. They reported that shorter interval of irrigation i.e. one day interval recorded significantly higher bulb yield (46.93 t ha^{-1}). The 100 per cent PE recorded significantly higher bulb yield (50.92 t ha^{-1}) as compared to 80 and 60 per cent PE and flood irrigation and this reflected in growth and yield parameters also. Significantly higher bulb yield was recorded in one day interval of irrigation at 100 per cent PE (54.91 t ha^{-1}), which was on par with two days interval of irrigation at 100 per cent PE (52.83 t ha^{-1}). Both one day and two days interval of irrigation and 60 per cent PE recorded significantly higher WUE.

Henry *et al*. (2012) at Department of Agricultural Engineering, Ahmadu Bello University, P.M.B., 1044 Zaria, Nigeria studied the effects of regulated deficit irrigation and mulch on yield, water use and crop water productivity of onion and their findings were that with or without mulching, irrigating onion at water application depth of 25% of weekly reference evapotranspiration (WRET) throughout the crop growing season reduces bulb yield by about half of what will be obtained if irrigation was at 100% of WRET. Irrigating onion at water application depths of 50% WRET reduces bulb yield by a quarter, while at water application depth of 75% the reduction in bulb yield will not be significant compared to irrigating at 100% WRET. Mulching with rice straw or black polyethylene material gave a yield increase of about 12–15% compared to a no-mulch condition. White polyethylene material was not as effective in suppressing weed compared to rice straw and black polyethylene. Thus, bulb yield under white polyethylene mulch were not significantly different from a no-mulch condition. The seasonal evapotranspiration of the onion crop was largely influenced by the depths of water applied rather than the mulching. Although mulching was expected to have reduced evaporation, the water conserved may have by use for transpiration, hence no significant differences in surface evapotranspiration of the mulched and no-mulch treatment. Irrigating at 50% and 75% of WRET gives better water productivity in terms of water supply for onion in this study. Mulching with rice straw or black polyethylene also significantly improves the crop water productivity of the onion crop, and is therefore recommended.

Bhatti (2017) conducted a field experiment in the Department of Soil Science and Water Management, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan (HP) during 2015 -16 and 2016 -17. His study focused on ascertaining the effect of different irrigation and N levels on the growth, yield, nutrient content and their uptake, water requirement and water use efficiency in onion. He recorded the twelve treatments combinations comprising four irrigation levels i.e. 4 cm irrigation at IW/CPE ratio 1.2 (I1), 1.0 (I2), 0.8 (I3), 0.6 (I4) and three N levels i.e. 75 (N1), 100 (N2) and 125 per cent (N3) of recommended dose of N, were replicated thrice in a randomized block design (factorial) in plot size of 3 m × 1.5 m and spacing of 15 cm × 10 cm. The irrigation levels I1 and I2 recorded significantly higher yield, nutrient contents and their uptake over I4 level. The plant growth parameters and nutrient uptake were at par under I1 and I2 levels, hence I2 could be considered as efficient irrigation level. Both these levels exhibited higher WUE (110 and 107 kg $ha^{-1}mm^{-1}$) with 372.8 and 358.7 mm of total water requirement.

2.3 Availability and Uptake of Nutrients in Onion

Pankov (1984) reported that K was high in P deficient leaves and observed critical P level being 0.27%. He also reported that in onion optimum content of N, P and K in leaf were 3.4, 0.33 and 2.5%, respectively.

Henriksen (1984) observed that increased nitrogen application to onion crop increased the percentage uptake of nitrogen.

Patel *et al*. (1992) revealed that the N uptake by onion increased remarkably with an increase in N level up to 80 kg ha^{-1} and P uptake was favorably influenced by nitrogen application of 120 kg N ha^{-1}.

Ashok *et al*. (2001) observed that the onion bulb yields significantly increased due to nitrogen application up to 120 kg ha^{-1}. There was significant increase in nitrogen uptake up to 120 kg N ha^{-1} and in phosphorus uptake up to 60 kg P_2O_5 ha^{-1} and potassium uptake up to 80 kg K_2O ha^{-1}.

Sarode *et al.* (2001) reported that the application of fertilizer to onion as per soil test value (150:62:37 NPK kg ha^{-1}) was found to be significantly superior over other fertilizer levels. They concluded that the application of fertilizers as per soil test (150:62:37 NPK kg ha^{-1}) increased both yield and nutrient uptake.

Timothy *et al.* (2004) had a study on effects of nitrogen (N) and sulfur (S) fertility on onion (*Allium cepa L.*) bulb pungency, bulb fresh and dry weight, nutrient uptake and accumulation in the bulb variety ''Granex 33'' and onions were greenhouse grown using nutrient solution culture. A factorial arrangement of solutions containing 1.7, 15.0, and 41.7 mg L^{-1} S and 10, 50, 90, and 130 mg L^{-1} N were used. Bulb pungency and bulb fresh and dry weight were affected by both S and N treatments. Depletion patterns for most of the macronutrients from the nutrient solutions during plant growth were affected by N and S levels, and differed depending on the N and S combinations. In certain N and S combinations magnesium (Mg) and calcium (Ca) usage were unaffected over time. Bulb N levels increased with N fertility and decreased slightly with S availability, while bulb phosphorous levels responded linearly to N fertility. Overall changes in bulb Ca and Mg levels were minor, but were influenced by N and S fertility. Bulb S content was affected by low S and N fertility, decreasing with each. Boron levels in onion bulbs decreased with increasing N and S fertility, while bulb manganese, iron, and zinc concentrations tended to increase with increasing N availability and decrease with increasing S. Potassium, copper, and molybdenum bulb concentrations were unaffected by N or S fertility. These results have the potential of being used as a reference in developing nutritional programs designed for optimal onion performance having specific flavor intensities.

Kumar *et al*. (2006) conducted field experiment to find out the effect of application of N and K levels on uptake of nutrients by the onion with four levels of nitrogen and potassium (0, 50, 100 and 150 kg ha^{-1}) and 100 kg P_2O_5. They revealed that the maximum N content in bulb was from 1.1 to 1.4 %, P content of bulb was from 0.2 to 0.27 % and K content of bulb was from 1.25 to 2.34 %.

Vitekari (2007) revealed that the total N, P_2O_5 and K_2O uptake by onion varied from 12.54 to 61.72, 5.66 to 31.64 and 27.76 to 96.54 kg ha^{-1}, respectively as compared to control and higher uptake of N, P_2O_5, K_2O by onion with 100% recommended dose along with 10 t FYMha^{-1}.

Inal, A. *et al*. (2008) reported that the Cl content of the plants was increased by the Cl supplied and by the reduced forms of N in the nutrient solution.

Fenn *et a*l. (2008) carried out a field experiment and reported increasing Ca^{++} appeared to have an additional function of increasing the mobility of metabolites (dry matter) from the roots. Since more above-ground plant products were produced with the same amount of N, plant N use efficiency was increased.

Bhagwat (2014) reported that among different nutrient management treatments, the treatment T_{10} receiving 110:40:60:40 kg NPKS + 7.5 t FYM + 2.5 t PM + 2.5 t VC ha^{-1} recorded higher potential for total bulb yield (54.63 t ha^{-1}) and marketable bulb yield (53.22 t ha^{-1}). The mean total soluble solids (TSS) observed in the range of 11.06 to 12.93 (°Bri**x**).

Nagare (2014) reported that the application of general dose of fertilizers (100:50:50 N: P_2O_2: K_2O Kg ha^{-1} + FYM 20 t ha^{-1}) and the treatment soil application of recommended dose of fertilizers + Fe_2SO_4 + $ZnSO_4$ @ 20 kg ha^{-1} were found superior for improvement in total soluble solids, reducing and non-reducing sugar in onion.

Ravina, Kumari (2017) carried out field experiment at Organic Block, Experimental Farm of Department of Vegetable Science, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, (HP) in the Rabi season 2016-2017 with the objective to study the effect of organic nutrient sources on growth of Onion (*Allium cepa L.* and reported as [Vermicompost @ 8 t ha^{-1} + Jeevamrut (Drenching, 5%)] recorded N, P, K content in soil (336.16, 62.14 and 362.64 kg ha^{-1}) and N, P, K uptake by plant (151.93, 28.86 and 120.17 kg ha^{-1}).

Bhagwat *et al.* (2018) reported that the fertilizer treatment 110: 40: 60: 40 kg NPKS + 7.5 t FYM + 2.5 t PM + 2.5 t VC+ biofertilizers (*Azospirillum, phosphobacteria* 5 kg each) ha^{-1} recorded higher potential for total bulb yield (54.63 t ha^{-1}) as compared to RDF (33.00 t ha^{-1}). The soil available N, P and K contents in the soil after harvest significantly increased due to the combined application of organic manures, inorganic fertilizers and biofertilizers in integrated manner. The residual soil fertility in respect to organic carbon (0.60%), available sulphur (10.30 mg kg^{-1}), boron (0.58 mg kg^{-1}) and zinc (0.76 mg kg^{-1}) was also significantly improved by various treatments and was found highest in the treatment receiving 110: 40: 60: 40 kg NPKS + 7.5 t FYM

+ 2.5 t PM + 2.5 t VC + biofertilizers (*Azospirillum, phosphobacteria* 5 kg ha each). Total nutrient uptake of nitrogen (103.40 kg ha^{-1}), phosphorus (38.50 kg ha^{-1}), potassium (96.48 kg ha^{-1}), Sulphur (29.22 kg ha^{-1}), boron (162.78 g ha^{-1}) and zinc (385.50 g ha^{-1}) by onion crop were recorded under this treatment which was significantly highest. The results indicated that judicious use of organic manures, inorganic fertilizers and biofertilizers as integrated nutrient management system was found to be useful for enhancing the yield, soil fertility and uptake of various nutrients in *rabi* onion.

2.4. Storability of Onion

Narang and Dastane (1972) studied the keeping quality of bulb onion grown under different conditions of soil moisture, nitrogen and sulfur fertilization. They observed marked increase in sprouting in bulbs grown under low soil moisture regimes.

Rao and Srinivas (1990) studied the storage behavior of' onion as influenced by nitrogen fertilization and he reported that high doses of nitrogen application had adverse effect on storability of onion bulb due to rotting.

According to Yoo *et al*. (1997) the main factor for shoot growth inhibition of onion is storage temperature and especially high temperatures (>27 °C) that result in thermodormancy, whereas increased CO_2 had no significant effect on sprout inhibition.

Grevsen and Sorensen (2004) expressed that cultivar selection and preharvest conditions such as plant establishment methods (transplantation instead of direct sowing) and harvest stage (early harvest when 20–50% of top has fallen down) can reduce sprouting incidence after long-term storage. Other important cultivar features that can affect storability of bulbs include the number and thickness of tunic layers and pungency of inner layers.

Satyendra Kumar *et al*. (2007) an experiment was conducted during two consecutive years (2002-2003) in a semi-arid climatic condition to study the effect of variable irrigation and fertigation on storage behavior of onion (*Allium cepa L.*). They reported that irrigation and fertigation levels significantly influenced physiological loss in weight (%) and sprouting percentage. The bulb grown under low soil moisture regime resulted in higher physiological loss in weight (%) and sprouting. The maximum sprouting percentage 25.49% was recorded under irrigation regime of 0.6 IW: CPE ratio when bulb stored on cemented floor in loose whereas sprouting was highest 12.76% under the irrigation regime of 0.6 IW: CPE ratio, when bulb stored in gunny bags. The higher sprouting as well as physiological loss in weight was found in fertigation level F1 (100 kg N, 50 kg P_2O_5 and 50 kg K_2O ha^{-1}), in which maximum nutrients were applied amongst all fertigation treatments.

Kumar *et al.* (2007) reported that nitrogen application rate can affect both yield and postharvest attributes of storage potential of dry onion bulbs, with rates of 200 kg ha^{-1} of nitrogen resulting in higher bulb size and weight but also having a negative effect on bulb storability.

Therefore, a compromise has to be accepted between higher yields and higher storage potential, and farmers have to decide accordingly.

Mogren (2008) reported that chemical fertilizers can significantly affect storage life and quality of dry bulbs, with most profound the effect of excessive use of nitrogen before harvesting, which delays bulb maturing and results in wide bulb necks and, consequently, in higher water losses and higher susceptibility in pathogen infections during storage. Fertilizer application method and nitrogen source (organic or conventional fertilizers) can significantly affect bulb size without, however, affecting total yield and quercetin content of dry bulbs.

Ullah *et al*. (2008) carried out the experiments at the Regional Agricultural Research Station, Rahmatpur, Barisal during the rabi seasons of 2001-2002 and 2002-2003 to study the impact of different Sulphur levels on bulb yield, storability and economic return of onion and reported that the maximum rotten bulbs 63.75 % were observed in control treatment (without S) and the minimum rotten bulbs 37.04 % were observed in S 45 kg/ha after 180 days of storage because application of Sulphur enhanced the storability of onion bulbs.

Downes *et al.* (2009) reports that onion cultivars vary in storage life; however, the fundamental basis of this variation remains unknown other than largely empirical correlations with traits such as dry matter, pungency, skin quality, and degree of polymerization of non-structural carbohydrates.

Nabi *et al*. (2010) reported that Potassium is also important for quality and storage life of onion bulbs, since increased rates of potassium (75-100 kg ha^{-1}) resulted in lower weight loss percentage and sprouting incidence compared with lower or higher rates.

Tripathi *et al*. (2010) conducted field experiment at National Research Centre on Onion and Garlic, Rajgurunagar (M.S.) to study the effect of various irrigation methods, i.e. drip, mini sprinkler, big sprinkler and surface irrigation on the growth, yield and storage of onion cv. N-2-4-1. They reported that the total storage losses after three months of storage were lowest in drip irrigation 13.38 % and surface irrigation 13.59 %. While higher losses were found in micro-sprinkler irrigation 22.58 % and big sprinkler irrigation 32.25 % systems.

Nabi *et al*. (2013) reported that water loss is the main limiting factor that determines storage duration, since excessive water losses result in both bulb weight losses and quality decrease, which affect the product marketability. The rate of water losses during storage can be affected by preharvest conditions such as curing method and duration.

Seema *et al*. (2013) reported that the onion produced in *kharif* and Late *kharif* season is not suitable for storage while onion produced in summer season can be stored up to 5-6 months and it can be brought in the during market rainy season i.e., from June to Oct. There are certain problems which arise during conventional storage of onion viz. loss in weight, sprouting and rotting of bulb. There are three types onion storage structure developed by NHRDF and domestic onion storage structure located at Kalwan. The construction cost per sq. Ft. of this structure i.e. Traditional onion storage structure, Din Digul onion storage structure, improved low cost onion storage structure developed by NHRDF, and Low-cost onion storage structure (Kalwan) are Calculated. The quantity of onions was stored in different onion storage structure during the last week of May is about 1000 kg. There are some losses such as weight losses, rotting losses and sprouting losses were found to be in storage. This loss was found high in storage structure developed by NHRDF as compared to domestic onion storage structure (Kalwan). The Cost per sq. Ft (Rs) and per kg storage cost against construction cost (Rs) of domestic onion storage structure is less as compare to onion storage structures in NHRDF.

Sharma *et al*. (2014) carried out an experiment where they subjected onion bulbs at ambient conditions immediately after a storage period of 8 months. From the results of their study, it was supported that although under cold storage, most physiological and enzymatic activities were delayed, as soon as onion bulbs were subjected to ambient temperatures, a succession of internal changes was triggered, followed by metabolic and chemical changes such as an increase of quercetin and quercetin glycoside contents, antioxidant activity, and total phenolics and a decrease in sugar content.

Sharma. *et al*. (2015) reported significant changes in flavonol and sugar contents during long-term storage of onion bulb under different light regimes (dark room and glasshouse storage), whereas amino acid content remained unaffected, despite the catabolism of carbohydrates that results in an increase of total nitrogen content.

Said *et al.* (2017) carried out field experiment and reported the bio stimulants significantly increased total yield and bulb weight and decreased cull yield compared to the control. The best treatments were Humic Total, Amino Total, and CaBoron. Control plants had bulb total soluble solids and firmness that were not different from other treatments. The lowest decay rates were from plants receiving Amino Total and CaBoron and the control had the highest bulb weight loss. Onion growth, yield, quality and storage ability may be improved with application of bio stimulants.

Mbulelo *et al.* (2018) had a field experiment as: the experiment was with the short-day onion CVS. Mata Hari (red), Mikado (yellow), Cristalina (white), and Star 5516 (yellow), and nitrogen (N) applied at 0, 30, 60, 90, 120, or 180 kg ha^{-1} were used to determine effects on storage loss of onion bulbs. After harvest, 30 well-cured onion bulbs were selected from treatments and replications and stored at room temperature (20–25°C). Storage moisture loss and disease occurrence were recorded on a weekly basis for 120 days. The N level did not affect bulb storage loss and incidence of black mold caused by Aspergillus niger. Storage loss was affected by cultivar, with ‘Cristalina’ and ‘Mikado’ having overall low, 1.22 % and 1.36 %, respectively storage loss; ‘Mata Hari’ had the lowest storage loss 0.28 %. ‘Mikado’ had higher overall storage loss within the first 4 weeks. Black mold development differed over time on ‘Cristalina,’ ‘Star 5516,’ and ‘Mikado,’ with higher incidence after 13 weeks of storage. ‘Mata Hari’ had the lowest incidence of black mold over time with only 0.83 % by the 13th week of storage. Overall, the amount of N applied to onions had no effect on moisture loss and storability of short-day onions.

2.5. Economics of Onion

Sharma *et al*. (1994) investigated the economics of irrigation scheduling and nitrogen levels on onion yields. They reported that highest yields were observed at the highest irrigation and nitrogen treatment. Benefit-cost ratio increased with increasing levels of irrigation.

More (2000) studied effect of micro-irrigation and N fertigation levels on yield and quality of onion bulbs at Mahatma Phule Krishi Vidyapeeth, Rahuri (M.S.). He reported that yield contributing characters and yield (416 q ha^{-1}) were significantly increased with N fertigation level up to 100% recommended dose of nitrogen. He also reported that the water use efficiency in micro-irrigation system (0.91 q ha^{-1} mm^{-1}) was about three times more than control (0.30 q ha $^{-1}$ mm^{-1}) and maximum benefit: cost ratio (9.39) was recorded in the treatment with drip tape with 125 % recommended dose of N.

Kamble *et al*. (2002) the cost and return structure of onion production in Bellary and Dharwad districts, Karnataka, India was evaluated based on data from 120 sample farms (38 small, 38 mediums, and 44 large farms). Mean per hectare total cost of cultivation in Dharwad district was Rs. 7338.55, 8723.78, and 7916.97 on small, medium and large farms, respectively. In Bellary district, mean per hectare total cost of cultivation was Rs. 9739.39, 11190.37 and 11 874.39 on small, medium and large farms, respectively. Mean per hectare net returns in Dharwad district were Rs. 6602.45, 11 426.97, and 7484.28 on small, medium and large farms, respectively. In Bellary district, mean per hectare net returns were Rs. 6350.13, 4553.60, and 6558.78 on small, medium and large farms, respectively.

Bartolo (2005) studied vegetable crop management and reported that gross economic returns were more with drip irrigation than with furrow irrigation. Economic returns can be maintained by using more efficient drip irrigation system for onion production rather than the inefficient furrow irrigation system with the drip irrigation system. Onion yields were maximized with lower rate of N fertilizer and 72 % less irrigation water than furrow irrigation.

Tripathi *et al*. (2010) conducted field experiment at National Research Centre on Onion and Garlic, Rajgurunagar (M.S.) to study the effect of various irrigation methods, i.e. drip, mini sprinkler, big sprinkler and surface irrigation on the growth, yield and storage of onion cv. N-2-4-1. They reported that reported that the highest B:C ratio (1.98) was found in drip irrigation.

Barakade *et al*. (2011) reported that overall level in Satara district Man, Phaltan, Khandala, Khatav, Koregaon, Wai, Satara, Patan, Jaoli, and Karad tahsils the per hectare cost of cultivation of onion. It is evident percentage share of the total variable cost is Rs. 93500.19 i.e.

91.09 % and fixed cost of production is Rs.9136.85 i.e. 8.90 % to total cost of production. Land preparation 3.09 %, seeds 6.15 %, nursery raising 1.13 %, manures 7.30 %, fertilizers 7.42 %, pesticides 5.65 %, irrigation 4.77 %, transplanting 5.06 %, weeding and hoeing 3.84 %, harvesting and curing 6.67 %, repair and maintained 1.71 %, interest on variable cost 3.75 % and transportation and marketing cost 34.49 % cost of total production. Among the different items of cost, the rental value of land, bullock charges, machine charges, total hired human labor charges, seeds, manures, fertilizers, plant protection and irrigation cost were the major items of cost of cultivation in all small, medium and large farmers. The average net returns obtained by onion growers amounted to Rs.49800.41 per hectare with gross returns of Rs. 152437.45 per hectare. The average yield per hectare onion production 258.50 quintal. The cost of onion production per quintal is Rs.397.04 and net profit per quintal Rs.192.66. The Cost Benefit Ratio comes to about 1:1.48. It is definitely an encouraging return to the farmers only four to five months.

Pawar *et al*. (2013) noted that the high installation cost is major limitation of drip for its adaption by farmers. The costs vary with crop due to changes in emitters and laterals spacing. Drip costs are lowest for widely spaced orchard crops but for close growing vegetables it may be little higher.

Rameez Ahmed Baloch *et al.* (2014) had a study under title of Economic Analysis of Onion (*Allium cepa L.*) Production and Marketing during the year 2014 and reported the onion growers in Awaran Balochistan area obtained on an average per acre earned during the study, Rs.97750.00 on net income, Rs.172800.00 on gross income and Rs.75050.00 on total expenditure in the Awaran Balochistan. Thus, the onion growers in Awaran Balochistan area on a gross income Rs.172800.00 and total expenditure is Rs.75050.00 in the mentioned area, therefore they availed input output ratio of 1:2.30. A net income per acre earned Rs.97750.00 and total expenditure Rs.75050.00 in Awaran Balochistan area, therefore they availed input, output ratio of 1:1.30 from onion growing in the study area.

Patel (2015) reported that net income is the main important factor of profitability of any enterprise. With respect to net income, it is revealed that the average net income per hectare of onion was the highest realized on medium size group being Rs.39726 per hectare followed by large farms Rs.38242 and small farms Rs.35775 per hectare respectively. This shows that net return was found to maximum on medium size of holding and lowest in small size of holding due to efficiency of medium farmers and constraint in small size of holding. Since, in general, farmers have poor economic condition and endowed scarce resources and hence, tried for higher economic return from per rupee investment. It is revealed that the B.C. ratio of onion was the highest on medium size group being 1: 2.02 followed by large farms 1:1.93 and small farms 1:1.86 respectively.

Rajat Kumar Singh *et al.* (2017) were conducted a field experiment on Effect of levels of nitrogen and spacing's on growth and yield of *rabi* onion and the result revealed that weight of marketable bulbs per plot was increased by increasing level of nitrogen.

Pol (2017) conducted a field experiment on growth and yield studies of onion (*Allium cepa L.*) under fertigation during 2015-16 at Mahatma Phule Krishi Vidyapeeth, Rahuri, (M.S) and reported higher cost of cultivation in micro-irrigation and fertigation treatments than conventional irrigation treatments due to the cost of irrigation systems and higher costs of WSF. The 100% drip fertigation treatment gave highest net seasonal income, total net income, net extra income over control, B:C ratio, water productivity and it was followed by 100% fertigation through micro sprinkler. The surface irrigation with 100% CF gave lowest values of all economical parameters than all other treatments.

3. MATERIAL AND METHODS

The present investigation was carried out in *rabi* season of 2017-2018 to study the "Effect of Root Booster Through Fertigation on Yield of Onion (*Allium cepa L.*), Nutrient Uptake and Availability in Inceptisols in Semi-arid Region of Maharashtra". The relevant details of materials used and the methods deployed in conducting the investigation are presented in this chapter.

3.1 Experimental Materials

3.1.1 Experimental Place

The pilot experiment was conducted at Research Farm of Interfaculty Department of Irrigation Water Management, PGI, Mahatma Phule Krishi Vidyapeeth, Rahuri, (M.S.).

3.1.2 Climate

3.1.2.1 General

From geographical standpoint the central campus of Mahatma Phule Krishi Vidyapeeth, Rahuri (MS) is situated in between 19^0 47' and 19^0 57' north latitudes and between 74^0 82' and 74^0 19' east longitudes. The altitude varies from 495 to 565 meters above the mean sea level. This tract laying on the eastern side of Western Ghats and falls under rain shadow areas.

With respect to climate, the central campus falls in semi-arid and subtropical zone with the annual rainfall varying from 307 to 619 mm with the average annual rainfall as 520 mm. However, the precipitation is erratic and ill distributed, 80 % is received during the period from June to September. The rainy days varies from 15-45 days in different years. Most of the rainfall is generally received from South-West Monsoon.

Agro-climatically the area falls in drought prone area of Maharashtra state facing droughts frequently.

3.1.2.2 Nature of Season During Experimental Period

The meteorological data on important weather parameters recorded during the crop growth period at the meteorological observatory of the Central Campus Farm, Mahatma Phule Krishi Vidyapeeth, Rahuri, (MS) are presented in Table 3.1 and Fig 3.1.

The mean maximum temperatures during experimentation period ranged between 28 to 41 ^{0}C, while mean minimum temperatures ranged between 9 to 22 ^{0}C. The relative humidity during morning and evening ranged between 67 and 29 % and between 34 and 13 %, respectively. The wind velocity ranged between 0.26 and 3.74 km hour^{-1}. During the experimental period rainfall was not observed.

3.1.3 Soil

The soil of experimental site was uniform and leveled. It was well drained, silty clay in texture with 75 cm depth. A composite soil sample from 0-30 cm soil layer was collected prior to planting and analyzed for physical and chemical properties. The relevant data on the physical and chemical properties of the experimental site (Table 3.3) along with the analytical methods used are presented in Table 3.2.

3.1.4 Water Source

The source of water for the experimental trail were a storage tank at farm with a 5 HP submersible pump.

Table 3.1 Metrological data recorded during investigation period.

Meteo. Weeks	Date	Temperature (^{0}C)		Sun shine (hrs.)	Relative humidity (%)		ETr mm/day	Wind speed (kmhr^{-1})	Rainfall (mm)
		Max	Min		Morning	Evening			
December, 2017									
52	24-30	29	9	9.9	58	31	2.09	0.43	0
January, 2018									
1	31-6	28	11	8.09	67	30	1.94	0.26	0
2	7-13	28	11	7.8	67	31	2.02	0.34	0
3	14-20	30	14	8.2	66	31	2.26	0.5	0
4	21-27	28	10	9.4	59	28	2.29	0.5	0
5	28-3	30	10	9.5	61	23	2.51	0.74	0
February, 2018									
6	4-10	31	14	8.2	52	22	2.71	1.11	0
7	11-17	30	13	8.9	64	34	2.89	0.89	0
8	18-24	35	17	9	57	23	7.89	0.64	0
9	25-3	35	17	8.6	50	22	3.29	1.1	0
March, 2018									
10	4-10	35	18	7.5	44	20	3.32	1.24	0
11	11-17	33	19	6.8	48	24	3.34	1.33	0
12	18-24	35	17	8.7	45	21	3.75	1.46	0
13	25-31	37	18	9.2	39	14	23.85	1.83	0
April, 2018									
14	1-7	38	20	7.1	42	17	4.08	1.94	0
15	8-14	37	20	8.3	42	22	4.23	1.66	0
16	15-21	39	22	9.9	45	22	5.53	3.31	0
17	22-28	39	19	10.8	29	13	5.16	2.59	0
18	29-5	41	21	10.7	36	17	6.00	3.74	0

Table 3.2 Standard methods used for analysis of physical and chemical properties of soil

Sr. No.	Properties	Method Applied	References
A.	**Physical properties of soil**		
1.	Particle size analysis	International pipette method	Klute (1986)
i.	Fine sand (%)		
ii.	Coarse sand (%)		
iii.	Silt (%)		
iv.	Clay (%)		
v.	Textural class		
2.	Field capacity (%)	Pressure plate apparatus	Richard (1947)
3.	Permanent wilting point (%)	Pressure membrane apparatus	Richard (1947)
4.	Available soil moisture (%)	Derived parameter	-
5.	Bulk density (Mg m^{-3})	Core sample method	Black and Hartage (1986)
6.	Infiltration rate (cm hr^{-1})	Double ring infiltrometer	Klute (1986)
B.	**Chemical properties of soil**		
1.	pH (1: 2.5)	Potentiometry	Piper (1966)
2.	EC (dSm^{-1})	Conductometry	Jackson (1973)
3.	Organic carbon (%)	Wet oxidation	Nelson and Sommers (1982)
4.	Available nitrogen (kg ha^{-1})	Alkaline permanganate method	Subbiah and Asija (1956)
5.	Available phosphorus (kg ha^{-1})	0.5 M $NaHCO_3$ (pH 8.5)	Olsen *et al.* (1954)
6.	Available potassium (kg ha^{-1})	Flame photometer	Hanway and Heidal (1967)
C.	**Plant analysis**		
1.	Preparation of acid extract from plant sample	Binary mixture of H_2SO_4 and 30 % H_2O_2 (1:1)	Parkinson and Allen (1975)
2.	Total-N (%)	Micro kjeldahl method	Jackson (1973)
3.	Total-P (%)	Vanadomolybdate yellow color method in nitric acid	Jackson (1973)
4.	Total-K (%)	Flame photometer	Jackson (1973)

Table 3.3 Physical and chemical characteristics of soil from the experimental site

Sr. No.	Characteristics	Composition
I	**Physical Properties**	
1.	**Particle size analysis**	
i.	Fine Sand (%)	8.0
ii.	Coarse Sand (%)	14.0
iii.	Clay (%)	26.8
iv.	Silt (%)	50.5
v.	Textural Class	Silty clay
2.	Field Capacity (%)	39.20
3.	Permanent Wilting Point (%)	17.90
4.	Available Soil Moisture (%)	21.30
5.	Bulk Density (Mg m^{-3})	1.18
6.	Infiltration Rate (cm hr^{-1})	3.24
II	**Chemical Properties**	
1.	pH (1:2.5)	8.10
2.	EC (1: 2.5) (dSm^{-1})	0.30
3.	Organic Carbon (%)	0.55
4.	Available N (kg ha^{-1})	173.20
5.	Available P (kg ha^{-1})	16.40
6.	Available K (kg ha^{-1})	550.0

Table 3.4 Cropping history of experimental plot

Year	Kharif	Rabi	Summer
2013-14	Sugarcane	Sugarcane	Sugarcane
2014-15	Sugarcane	Sugarcane	Sugarcane
2015-16	Sugarcane	Sugarcane	Sugarcane
2016-17	Soybean	Onion seed	Fallow

3.1.5 Irrigation Set Up

3.1.5.1 Drip Irrigation Set Up

The parts and components of drip irrigation system including suction pipe, pumping unit and delivery pipe were joined and connected to main, sub mains, manifolds, laterals and emitters. The central head unit contained of sand filter, screen filter, back flush assembly, electric motor, pump set, control valve, bypass valve, pressure gauges and fertilizer tank.

The detailed information about the components of drip irrigation system is given in below table.

Sr. No.	Particular	Size/Specifications
1.	Type of main and sub main	Poly-vinyl chloride (PVC)
2.	Type of laterals	Linear Low-Density Polyethylene (LLDPE)
3.	Size of main	75 mm
4.	Size of sub main	63 mm
5.	Size of laterals	16 mm
6.	Type of dripper	Inline dripper
7.	Discharge of emitter	4 lph
8.	Lateral size	16 mm
9.	Number of laterals / plots	4
10.	Spacing between emitters	0.50 m
11.	Spacing between laterals	1.20 m
12.	Irrigation scheduling	Alternate day
13.	Operating pressure	1 kg/cm^2

3.1.5.2 Surface Irrigation

Thus, treatment of T_1 detailed to surface irrigation and branched from main pipe with diameter of 75mm and discharge of 254 Lit/min.

As above mentioned, Irrigation water source was the storage tank which having capacity of 40,000 liters and the irrigation system was operated by 5.0 Hp electric motor pump set provided with bypass assembly.

3.2 Methods

3.2.1 Experimental Details

The investigation of trial containing nine treatments based on sources levels root booster fertigation and levels of conventional fertilizers. The plan of investigation of trail layout is presented in Fig 3.2.

The details of experiment are listed below.

□ Season	*Rabi*, 2017-18
□ Crop and variety	Onion, N-2-4-1
□ Date of seed sowing	16th October 2017
□ Date of Transplanting	30th December, 2017
□ Date of harvesting	4th May, 2018
□ Design	Randomized Block Design
□ Number of treatments	9
□ No. of replications	3
□ Planting methods/ layouts	flat bed
□ Plot size: Gross plot	4.8 m × 8.25 m
□ Net plot	4.5 m × 8.10 m
□ Spacing	15 cm × 7.5 cm
□ Fertilizer dose (RDF)	100:50:50 kg N, P_2O_5, K_2O ha^{-1}
□ Root booster	As per treatments

3.2.2 Treatment Details

T1 - SI with 100% RD of CF (Urea, SSP, MOP)

T2 - DI with 100% RD of CF (Urea, SSP, MOP)

T3 - DI with 100% RD of CF + 5 lit ha^{-1} fertigation of root booster

T4 - DI with 100%RD of CF + 7 lit ha^{-1} fertigation of root booster

T5 - DI with 100%RD of CF + 9 lit ha^{-1} fertigation of root booster

T6 - DI with 75% RD of CF + 5 lit ha^{-1} fertigation of root booster

T7 - DI with 75% RD of CF + 7 lit ha^{-1} fertigation of root booster

T8 - DI with 75% RD of CF + 9 lit ha^{-1} fertigation of root booster

T9 - DI with no fertilizer

DI- drip irrigation, SI- surface irrigation, CF- conventional fertilizer & RD - recommended dose

- Root booster were applied at weekly interval for eight weeks.

3.2.3 Details of Fertilizers Application

3.2.3.1 Sources of Fertilizers

The conventional fertilizers i.e. single super phosphate (SSP), urea and muriate of potash (MOP) were used for drip and surface irrigation, treatments.

3.2.3.2 Conventional Fertilizer Schedule

The conventional Fertilizer were applied in all treatments T_1, T_2, T_3, T_4, T_5, T_6, T_7, and T_8 except T_9 i.e. no fertilizer, the fertilization schedule is presented in Table 3.5 and 3.6.

Table 3.5 Fertilizer schedule for onion

Days after transplanting	Nitrogen (N)		Phosphorus (P)		Potassium (K)	
	%	kg ha^{-1}	%	kg ha^{-1}	%	kg ha^{-1}
Fertilizer application as basal dose (NPK)	50	50	100	50	100	50
Top dressing of urea at 30 days (4 weeks)	50	50	0	0	0	0
Total	**100**	**100**	**100**	**50**	**100**	**50**

3.2.3.3 Conventional Fertilizers

In treatment T_1 to T_8, 50 % of nitrogen and total dose of phosphorus and potassium was applied as a basal and remaining 50 % of nitrogen dose was applied as topdressing at 30 DAT.

3.2.4 Details of Root Booster

Application of root booster be considered as a good production strategy for obtaining high yields of nutritionally valuable vegetables with lower impact on the environment. Root booster increases root growth, root volume and also promotes higher growth. Chemically Root booster contains of Nitrogen -3.5 %, Phosphorus as P_2O_5 -0.4 %, Potassium as K_2O- 0.4 %, organic acid -2 %, total organic matter -40 % and with pH 5.5.

3.2.4.1 Root Booster Fertigation

According to plan the amount of recommended volume of root booster per treatments, made a homogenous solution with water in the portable water tank and by small two-wheeler diesel water pump via drip irrigation system it was injected uniformly to the treatment plots up to eight weeks in weekly interval. The volume of root booster fertigation, frequency and date of application presented in table 3.7 as below.

Table 3.6 Proportion of nutrients applied as per treatment

Treatments	Split	Quantity of fertilizers applied kg/ plot		
		Urea	SSP	MOP
T_1	1	1.249	3.60	0.960
	2	1.249	0.0	0.0
	Total	2.498	3.60	0.960
T_2	1	1.249	3.60	0.960
	2	1.249	0.0	0.0
	Total	2.498	3.60	0.960
T_3	1	1.249	3.60	0.960
	2	1.249	0.0	0.0
	Total	2.498	3.60	0.960
T_4	1	1.249	3.60	0.960
	2	1.249	0.0	0.0
	Total	2.498	3.60	0.960
T_5	1	1.249	3.60	0.960
	2	1.249	0.0	0.0
	Total	2.498	3.60	0.960
T_6	1	0.937	2.70	0.720
	2	0.937	0.0	0.0
	Total	1.874	2.70	0.720
T_7	1	0.937	2.70	0.720
	2	0.937	0.0	0.0
	Total	1.874	2.70	0.720
T_8	1	0.937	2.70	0.720
	2	0.937	0.0	0.0
	Total	1.874	2.70	0.720
T_9	1	0.0	0.0	0.0
	2	0.0	0.0	0.0
	Total	0.0	0.0	0.0

Table 3.7 Application of root booster fertigation for onion

Treatment size 39.6*3=118.8 m^2 Plot size 4.8*8.25=39.6 m^2

No of Treatments		**T_1**	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**	**T_7**	**T_8**	**T_9**
Splits		No root booster	No root booster	5 lit/ha root booster	7 lit/ha root booster	9 lit/ha root booster	5 lit/ha root booster	7 lit/ha root booster	9 lit/ha root booster	No root booster (control)
Date	**Units**	ml	ml	ml	ml	ml	ml	ml	ml	ml
07 Jan 2018	1	-	-	59.4	83.2	106.9	59.4	83.2	106.9	-
14 Jan 2018	2	-	-	59.4	83.2	106.9	59.4	83.2	106.9	-
21 Jan 2018	3	-	-	59.4	83.2	106.9	59.4	83.2	106.9	-
28 Jan 2018	4	-	-	59.4	83.2	106.9	59.4	83.2	106.9	-
04 Feb 2018	5	-	-	59.4	83.2	106.9	59.4	83.2	106.9	-
11 Feb 2018	6	-	-	59.4	83.2	106.9	59.4	83.2	106.9	-
18 Feb 2018	7	-	-	59.4	83.2	106.9	59.4	83.2	106.9	-
25 Feb 2018	8	-	-	59.4	83.2	106.9	59.4	83.2	106.9	-
Total	8	-	-	**475.2**	**665.6**	**855.2**	**475.2**	**665.6**	**855.2**	-

3.2.5 Irrigation Studies

3.2.5.1 Drip Irrigation layout

Drip irrigation systems were laid out as per treatments with pressure compensating drippers. Six rows of onion were planted on each lateral at 15x7.5 cm spacing and spacing between two laterals was 1.2 m and emitter to emitter spacing as 0.5 m was used.

For drip irrigation small control valve was connected at beginning of each treatment to facilitate irrigation. The operating head at emitters was 1.00 kg cm^{-2} or 10 meters of height of water. Quantity of water to be applied as per treatment was calculated by recording daily reference evapotranspiration (ETr).

The application of root booster was done with the help of power tiller operated HTP pump and a tank which was connected to each manifold, at the time of fertigation.

3.2.5.2 Irrigation Water Applied

In case of drip irrigation treatments, the irrigation scheduling was done on the basis of climatological approach. Irrigation was scheduled on alternate days in all drip irrigated treatments.

The quantity of irrigation water was estimated by using formula (ASCE Standardized Reference Evapotranspiration Equation1970's) as given below,

ETc = ETr x Kc

Where,

ETc = Evapo-transpiration of crop (mm/ two days)

ETr = reference evapotranspiration (mm/ two days)

Kc = Crop coefficient (as per crop growth stages Table 3.8)

In cause of surface irrigation, the water requirement of onion was calculated by using following formula.

Where

$$D = CPE\ x\ Kp\ x\ Kc$$

Where:

D = Depth of water to be applied, mm

CPE = Cumulative pan evaporation, mm

Kp = Pan factor (0.7)

Kc = Crop coefficient depending upon growth stages.

(Allen *et al*., 1998).

Table 3.8 Crop coefficient values for onion at various growth stages (Allen *et al*. 1998)

Growth stage	Crop coefficient factor	Crop duration (days)
Initial stage	0.7	0-20
Development stage	1.05	21-42
Mid-season stage	1.05	43-92
End stage	0.75	93-120

The net quantity of water requirement per emitter at every alternate day was calculated by following formula.

V = ETc x Sl x Se x Wa

Where, V = Volume of water per two days in liters

ETc = Evapo-transpiration of crop (mm/two days)

Sl = Spacing between laterals (m)

Se = Spacing between emitters (m)

Wa = Wetted area

3.2.5.3 Operation Time of Drip Irrigation

The average discharge of emitter and emission uniformity of drip system was determined. The time of operation of drip irrigation system was decided by knowing the average discharge of the emitters per plant as below.

$$T = \frac{V}{Eu \ x \ q}$$

Where,

T = Time of operation of the system (hrs)

V = Volume of a water per two days in liter

Eu = Emission uniformity of the system (%)

q = Emitter discharge rate (lph)

3.2.5.4 Seasonal Water Requirement of the Crop (WR)

The seasonal water requirement of the crop was computed by adding measured quantities of irrigation water applied, effective rainfall received during the season and the contribution of the soil moisture from the ground water table as per equation given by Michael (1978).

WR = IR + ER + S

Where,

WR = Seasonal water requirement (cm)

IR = Total irrigation water applied (cm)

ER = Effective rainfall (cm)

S = Soil moisture contribution (cm)

The soil moisture contribution was considered nil as the water table of the experimental field was more than 10 m below soil surface.

3.2.5.5 Computation of Effective Rainfall

Effective rainfall is the part of total rainfall which is used directly or indirectly to meet the evapotranspiration requirement of the crop (Dastane *et al.*, 1970).

In the present study, effective rainfall was computed during irrigation period. The effective rainfall during irrigation period was computed from daily crop evapotranspiration. It was decided whether the received rainfall was sufficient to meet the crop water demand; if not, rest of the crop water demand was fulfilled by irrigation and the entire rainfall was considered as effective rainfall. If the rainfall was greater than the crop water demand, the rainfall equal to crop water demand was considered as the effective rainfall and the difference between rainfall and crop water demand was considered as percolation and surface runoff.

3.2.5.6 Emission Uniformity

The procedure suggested by Keller and Karmelli (1974) was used to determine the emission uniformity (EU) of the drip irrigation system. The operating pressure of 1 kg/cm^2 was maintained constantly at the emitters with the help of control valves. Discharge of the emitters was measured by collecting water in a catch can at each individual lateral from four parts of the plot at inlet, 1/3 down, 2/3 down and at end. These discharges were collected for the period of two minutes. At the end, emission uniformity of drip system was worked out using following formula (Keller and Karmelli, 1974).

$$Eu = 100\ (q\ min)/(q\ avg) + (q\ avg)/(q\ \max)\ x\ 1/2$$

Where:

Eu = Emission uniformity of the system in (%)

q min = Minimum emitter discharge rate(lph)

q avg = Average emitter flow rate (lph)

q max = Average of the highest 1/8th of emitter flow rate (lph)

3.2.5.7 Water Requirement of the Crop

The water requirement of onion was calculated by using (ASCE Standardized Reference Evapotranspiration Equation1970's) as following.

Where

$$ETc = ETr \times Kc$$

Where,

ETc = Evapo-transpiration of crop (mm/ two days)

ETr = reference evapotranspiration (mm/ two days)

Kc = Crop coefficient (as per crop growth stages Table 3.8)

3.2.5.8 Time of Operation

The time of operation for DI treatment was worked out using the relationship given by equation.

$$T = \frac{Water\ requirement\ (lit)}{No\ of\ dripper\ x\ dischacge\ x\ efficiency\ of\ DI}$$

Where,

T = Time of operation, hr.

3.2.5.9 Water Depth

The seasonal water requirement was calculated by summing the depth of water application in all irrigation events during the crop season. The date wise irrigation applied for treatments is given in Appendix- IV and V.

3.2.5.10 Field Water Use Efficiency

The field water use efficiency is the ratio of marketable produce of the crop and seasonal water requirement of crop (Michael, 2010).

$$\text{FWUE} = Y\ (kg\ ha^{-1}) \div WR\ (mm\ )$$

Where,

FWUE = Field Water Use Efficiency, kg ha^{-1} mm

Y = Yield of Crop

WR = Seasonal Water Requirement

3.2.5.11 Conventional Irrigation Method

In surface irrigation treatment, 5.00 cm depth of water was applied at 50 mm CPE. Volume of water applied per plot was computed by using equation,

$$V = D \times L \times W$$

Where,

V = Volume of water applied (lit)

D = Depth of water (mm)

L = Length of plot (m)

W = Width of plot (m)

One pre-sowing irrigation of 6.00 cm was applied in conventional method of irrigation.

3.2.6 Schedule of Cultural Operations

The different agrotechnical operations carried out in the experimental field during crop season of the year 2017-2018 are represented in Table 3.9.

Table 3.9 Details of agrotechnical operations

No	Name of operation	Frequency	Date
1	Ploughing	1	29/10/2017
2	Harrowing	1	29/10/2017
3	Preparation of nursery beds	1	01/11/2017
4	Sowing of seeds on nursery beds	1	05/11/2017
5	Layout of experiment	1	30/12/2017
6	Transplanting of seedlings	1	30/12/2017
7	Irrigation after transplanting	1	30/12/2017
8	Subsequent irrigation		As per treatments
9	Fertilizer application as basal dose (NPK)	1	30/12/2017
10	Top dressing of urea	1	02/03/2018
11	Gap filling	1	15/01/2018
12	Weeding	2	14/02/2017, 14/03/2017
13	Root booster fertigation	8	07, 14, 21, 28/01/2017 04, 11, 18, 25/02/2017
14	Harvesting	1	04,05/05/2016,

3.2.7 Agronomic Details

3.2.7.1 Crop and Variety

The onion (*Allium cepa L.*) variety N-2-4-1, which had generated by Mahatma Phule Krishi Vidyapeeth, Rahuri was used as a seed of test crop in this investigation.

3.2.7.2 Land Preparation

The land was prepared by one ploughing with tractor- drawn mould board plough followed by two harrowing with disc harrow.

3.2.7.3 Seeds

The seed rate of N-2-4-1, variety of *rabi* onion from Mahatma Phule Krishi Vidyapeeth, Rahuri was used and the seed rate was 8 kg ha^{-1}.

3.2.7.4 Plant Protection Measures

Plant protection schedule consisting of Curacron (Profenophos 50 % EC), Regent (Fipronil 5% SC), Marshal (Carbosulfan 25 % EC), Dithane M-45 (Manocozeb 75 % WP), Folicur (Tebuconazole 250 EC) and Companion (Mancozeb 63% +Carbendazim 12%) were applied for control of pests like aphids and fungus. The plots were kept free of weeds by two hand weeding.

Table 3.10 Pesticide spraying schedule

Date	Spraying solution	Name of pest and disease
29 / 01 /2018	Curacron (Profenophos 50 % EC) 500 ml/ 250 lit. water +Dithane M-45 (Manocozeb 75 % WP) 750 gm/ 250 lit. water	Control of aphids, hoppers, jassids and leaf spot
29 / 04 /2018	Regent (Fipronil 5% SC) 250 ml/ 125 lit. water +Folicur (Tebuconazole 250 EC) 250 ml/ 250 lit. water	Control of aphids, green leaf hopper and leaf spot
30 / 03 /2018	Marshal (Carbosulfan 25 % EC) 500 ml/ 250 lit. water + Companion (Mancozeb 63% +Carbendazim 12%)750 gm/ 250 lit. water	Control of aphids and leaf spot

3.2.7.5 Gap Filling

The requisite population per unit area was maintained by gap filling on 20th DAT.

3.2.8 Biometric Observations

The different biometric observations were recorded on five randomly selected plants from each plot (Table 3.11).

3.2.8.1 Sampling Technique

For recording various observations, five plants were randomly selected from each net plot and tagged for identification. The detail schedule adopted for recording various observations are given in Table 3.11.

3.2.8.2 Growth Parameters

The details of the growth observations were recorded on randomly selected five plants during course of investigation.

3.2.8.2.1 Height of plant

Height of plants were recorded four times by measuring the length of shoot from its base near the ground level up to the tip of the largest leaf at 30 days interval from 30th DAT up to the harvest.

3.2.8.2.2 Number of functional leaves

The total number of functional leaves per plant recorded continuously at 30 days intervals from 30th DAT up to the harvest.

3.2.8.2.3 Dry matter content

One plants per plot were sampled randomly for determination of total dry matter in respect of the component parts i.e. leaves and bulb. The leaves and bulb chopped into small pieces, packed into brown paper bags and labeled properly and air dried first and then dried in hot air oven at about 65 ^{0}C temperature for 24 hours. The final constant weight was recorded. The dry matter was taken at 30 days interval from 30th DAT up to the harvest.

3.2.8.2.4 Neck thickness of bulb

Neck thickness of five bulbs which randomly selected were recorded by Vernier caliper at 30 days interval from 60th, 90th DAT up to the harvest.

3.2.8.2.5 Root spread

Root spread of one plant per replication which was randomly selected were recorded to cm.

3.2.8.2.6 Root length

Root Length of one plant per replication which was randomly selected were recorded to cm.

3.2.8.3 Yield and Yield Contributing Characters

3.2.8.3.1 Polar diameter of bulb

Polar diameter of five randomly selected bulbs were recorded by Vernier caliper at harvest in cm.

3.2.8.3.2 Equatorial diameter of bulb

Diameter of five randomly selected bulbs were recorded by Vernier caliper at harvest in cm.

3.2.8.3.3 Average bulb weight

The average bulb weight of five bulbs in gram from each plot were recorded.

3.2.8.3.4 Yield of onion bulbs

The weight of harvested bulbs was recorded for each plot separately. The yield of onion bulbs on hectare basis calculated for each treatment.

3.2.8.3.5. Leaves yield

The fresh weight of leaves was worked out by deducting the total fresh weight of bulb from the corresponding total weight of bulb along with top of onion from each plot. These data were used for the calculation of bulb to leaves ratio.

3.2.8.3.6 Bulb to leaves ratio

The ratio computed from the yield of bulb and leaves in corresponding treatment

Table 3.11 Schedule of biometric observations

No	Observation	Time of observation	No of plants selected
A.	Growth observations		
1.	Height of plant (cm)	At 30, 60, 90, DAT and at harvesting	5 random plants per net plot
2.	Number of functional leaves per plant		5 random plants per net plot
3.	Dry matter content	At 30, 60, 90, DAT and at harvesting	1 random plant per net plot
4.	Neck thickness of bulb (cm)		5 randomly tagged plant
5.	Root length of bulbs in (cm)		One randomly tagged plant
6.	Width root spread of bulbs in (cm)		One randomly tagged plant
B.	**Yield and yield contributing characters**		
1.	Polar diameter of bulb	At harvesting	5 randomly tagged plant
2.	Equatorial diameter of bulb		5 randomly tagged plant
3.	Average bulb weight		5 randomly selected bulbs
4.	Yield of onion bulbs tons per hectare		On the basis of treatments' plot calculated per hectare
5.	Leaves yield tons per hectare		Calculated per hectare
6.	Bulb to leaves ratio		Calculated per hectare
D.	**soil and plant analysis**		
1.	Initial N, P and K availability in soil	At planting	5 randomly soil samples were collected and analyzed
2.	Availability of N, P and K in soil (kg ha^{-1})	At 30, 60, 90, DAT and at harvesting	5 soil samples were collected from each treatment
3.	Uptake of N, P and K by crop (kg ha^{-1})		One randomly selected sample per net plot

3.2.9 Methods of Quality Parameters Analysis

3.2.9.1 Total Soluble Solids

Total soluble solids measured from each treatment sample by hand refractometer (designed and invented by Emanuel Goldberg). At first juice were extracted from onion bulb samples then two drops of juice applied in the panel of hand refractometer and covered slowly the plate then the TSS were recorded.

3.2.9.2 Reducing Sugars and Non-reducing Sugars

Reducing sugars and non-reducing sugars were determined by the method of Somogyi Nelson (1944) from each treatments' bulb samples and recorded.

3.2.10 Soil and Plant Analysis

3.2.10.1 Soil Analysis

The methods of Initial physical properties of soil analysis mentioned were in table 3.3 initial and periodical chemical soil properties, at first soil samples were collected before planting as initial sample and after planting periodically at 30, 60, 90 DAT and at harvest and analyzed for available N, P and K content. The methods used for soil analysis are shown in Table 3.2.

3.2.10.2 Plant Analysis

Plant samples were collected periodically for nutrient uptake at 30, 60, 90 DAT and at harvest and analyzed for total N, P and K content. The methods used for plant analysis are shown in Table 3.2.

3.2.10.3 Uptake of Nutrients

The uptake of major nutrients was worked out by multiplying dry matter accumulation to N, P and K concentration at different growth stages of crop by using the following equation

$$Nutrient\ uptake\ (kgha^{-1}) = \frac{Total\ dry\ matter\ (kg\ ha^{-1})\ x\ \%\ Concentration\ of\ element}{100}$$

4.2.10.4 Nutrient Use Efficiency

The nutrient use efficiency was worked out by the following formula

$$NUE\ (kg\ yeild\ kg^{-1}\ nutrient) = \frac{(kg\ yield\ ha^{-1} in\ treatment - kg\ yeild\ ha^{-1}\ in\ control)}{Nutrient\ dose\ kgha^{-1}}$$

3.2.11 Storage Studies

10 kg healthy onion bulbs from each treatment were stored in plastic crates up to 180 days for periodical observation. The observation on sprouting, rotting and physiological weight loss was recorded at 30, 60, 90, 120, 150 and 180 days after harvest.

3.2.11.1 Rottening Losses

The rotted onion bulb was separated and weighed and percent loss in weight due to rotting determined at every stage of periodical observation.

3.2.11.2 Physiological Losses

At 30 days periodical interval the stored bulb sample was weighed and physiological weight losses of onion bulb was recorded at 30, 60, 90, 120, 150 and 180 days after harvesting.

3.2.11.3 Total Weight Losses

At every stage of periodical observation, percentage of total loss in weight of onion bulbs due to rotting and physiological loss in weight together worked out from above observation for each treatment separately.

3.2.12 Economics

The output of a project is mostly evaluated on net-return and the economic viability of the project planned. The outcome of such analysis provides the essential information and data regarding the total cost to be invested and total benefits that can be obtained from the project. Total cost of production was considered to work out the benefit: cost ratio.

3.2.12.1 Cost of Cultivation

The cost of cultivation for several treatments was worked out by considering the expenditure required for different inputs in each treatment.

The variable expenditure included paid costs as hired daily labour, machinery, seeds, fertilizers, water cost, supervision fees and interest on working capital. The current rates/charges at time of investigation were taken for estimating cost of cultivation.

3.2.12.2 Net Seasonal Income

The net Seasonal income of onion per hectare was worked out by considering the income from produce which deducted the seasonal cost per hectare onion crop.

$$Net\ seasonal\ income = income\ from\ produce - seasonal\ cost$$

3.2.12.3 Total Net Income

The Total net income (Rs ha^{-1}) as affected by different treatments were calculated by addition of the corresponding values of the net seasonal income and additional net income.

3.2.12.4 Net Extra Income Over Control

The net extra income over control (Rs ha^{-1}) as affected by different treatments were calculated by subtracting the corresponding values of the net seasonal income from the value of net seasonal income.

3.2.12.5. Benefit: Cost Ratio

The B:C ratio was calculated for each treatment by using below equation.

$$Benefit\ cost\ ratio = \frac{\text{Gross income (Rs } ha^{-1})}{Total\ cost\ of\ cultivation\ (Rs\ ha^{-1})}$$

3.2.12.6. Additional Area Under Drip System

The water saved in drip irrigated treatment can further be used to irrigate more area. The additional area under drip was worked out by dividing the difference of water use with control by respective treatment in mm.

$$Additional\ area = \frac{Water\ use\ in\ surface\ irrigation - Water\ use\ in\ drip\ irrigation}{Water\ use\ in\ drip\ irrigation}$$

3.2.12.7 Net Income mm^{-1} of Water (water productivity)

Net income per mm of water was worked out by dividing the net return (Rs ha^{-1}) to the total water used by related treatments. This was worked out for each treatment.

$$Net\ income\ per\ mm\ of\ water = Net\ seasonal\ income\ \div Water\ used\ per\ (mm)$$

3.2.13 Statistical Analysis

The statistical analysis of the data from each parameter was calculated by the statistical method known as randomized block design. The standard error (S.E.) of the mean was worked out. Wherever the results were significant, the critical difference (C.D.) at 5 % level of significance was worked out. The data are appropriately represented with graphs and figures at suitable places. The statistical analyses applied by using the standard method of variance as proposed by Panse and Sukhatme (1967).

4. RESULTS AND DISCUSSION

The field experiment entitled "Effect of Root Booster Through Fertigation on Yield of Onion (*Allium cepa L.*), Nutrient Uptake and Availability of Inceptisols in Semi-Arid Region of Maharashtra" was carried out in *rabi* season of 2017-2018 at Research Farm of Interfaculty Department of Irrigation Water Management, Post Graduate Institute Mahatma Phule Krishi Vidyapeeth Rahuri, Dist, Ahmednagar. The details of results obtained from this investigation are presented and discussed in this chapter. While discussing results of present investigation, the findings of earlier researchers on the subject, have been taken in to consideration.

4.1 Growth Characters

The data regarding growth studies of onion includes various biometric observations recorded for various growth characters viz., plant height, number of leaves per plant, dry matter content, neck thickness, root spread and root length. The research findings on these aspects are presented in Table 4.1 to 4.6.

4.1.1 Plant Height

The data regarding the effect of different levels of root booster fertigation and conventional fertilizer on periodical plant height of onion are presented in Table 4.1 and graphically depicted in Fig. 4.1.

Table 4.1 Mean plant height of onion as influenced by different treatments

Sr. No.	**Treatments Detail**	**Plant height (cm)**			
		30 DAT	60 DAT	90 DAT	At harvest
T_1	SI with 100% RD of CF (Urea, SSP, MOP)	49.60	55.53	66.40	57.80
T_2	DI with 100% RD of CF (Urea, SSP, MOP)	47.07	53.40	64.93	56.47
T_3	DI with 100% RD of CF + 5 lit ha^{-1} fertigation of root booster	47.07	53.80	65.53	57.10
T_4	DI with 100%RD of CF + 7 lit ha^{-1} fertigation of root booster	53.80	58.87	69.13	58.40
T_5	DI with 100%RD of CF + 9 lit ha^{-1} fertigation of root booster	54.00	62.73	73.60	61.60
T_6	DI with 75% RD of CF + 5 lit ha^{-1} fertigation of root booster	44.40	49.73	61.53	54.20
T_7	DI with 75% RD of CF + 7 lit ha^{-1} fertigation of root booster	45.47	51.47	62.67	55.40
T_8	DI with 75% RD of CF + 9 lit ha^{-1} fertigation of root booster	46.40	52.13	53.00	56.00
T_9	DI with no fertilizer	44.13	49.53	50.13	43.67
	S.Em. +	1.37	1.48	1.51	1.20
	CD at 5 %	4.10	4.43	4.55	3.60
	General Mean	**47.99**	**54.13**	**62.99**	**54.71**

The observations on plant height was commenced after 30 days after sowing (DAS), and it was continued up to harvest at 30 days interval. The overall mean of plant height increased rapidly with advancement in the age of crop and it was 47.99, 54.13, 62.99 and 54.11 cm at 30, 60, 90 days after transplanting and at harvest, respectively.

The effect of levels of root booster fertigation on plant height influenced significantly with increase in rate of root booster application which combined with conventional fertilizer. The significantly higher plant height 54 cm was recorded with treatment T_5 100%RD of CF + 9 lit ha^{-1} fertigation of root booster over other treatments; however, it was at par with T_4 treatments at 30 DAT. Similar trends in plant height was observed at 60, 90 DAT and at harvesting of onion. The plant height was higher in T_5 treatment as compared at T_1 (SI with 100% RD of CF) and T_2 (DI with 100 % CF) may be due to the effect of root booster on growth of onion crop which resulted in increase of plant height. At harvest stage the height of plant decreased due to completion of growth development stage and top of the leave dried.

Treatment T_9 (DI with no fertilizer) recorded lower plant height at all growth stages of growth of crop. Similar results were reported by Shashi Kumar and Shashidhar (2016) in onion. They reported that application of growth regulators and bio stimulants (GA3 @ 60 ppm) resulted in the tallest plant height and maximum number of leaves per plant in onion compared to control.

4.1.2 Number of Leaves Plant^{-1}

Data regarding number of leaves per plant as influenced by different treatments is presented in Table 4.2. The observations on number of functional leaves plant^{-1}was commenced after 30 days after transplanting (DAT), and it was continued up to harvest, at 30 days interval.

The overall mean number of leaves per plant showed increasing trend with advancement in the age of crop. The mean number of leaves per plant were 7.96, 9.00, 10.76 and 8.60 at 30, 60, 90 days after transplanting and at harvest respectively.

The effect of levels of root booster fertigation and conventional fertilizer on number of leaves per plant is graphically depicted in Fig. 4.2. The results clearly revealed that a considerable variation between numbers of leave per plant was recorded during the crop growing period for different treatments.

At 30 DAT, the number of functional leaves per plant influenced significantly under different treatments. The significantly higher number of functional leaves (9) was recorded in treatment T_5 (DI with 100%RD of CF + 9 lit ha^{-1} fertigation of root booster) as compared to SI with

100 % CF (T_1) and DI with 100 % CF (T_2). However, it was at par with T_4 (DI with 100%RD of CF + 7 lit ha^{-1} fertigation of root booster) as 8.40.

Table 4.2 Mean number of leaves $plant^{-1}$ of onion as influenced by different treatments

Sr. No.	Treatment Detail	Number of leaves $plant^{-1}$			
		30 DAT	60 DAT	90 DAT	At harvest
T_1	SI with 100% RD of CF (Urea, SSP, MOP)	8.27	9.33	11.67	9.00
T_2	DI with 100% RD of CF (Urea, SSP, MOP)	8.00	9.00	10.87	8.40
T_3	DI with 100% RD of CF + 5 lit ha^{-1} fertigation of root booster	8.13	9.20	11.07	9.07
T_4	DI with 100%RD of CF + 7 lit ha^{-1} fertigation of root booster	8.40	9.67	12.00	9.47
T_5	DI with 100%RD of CF + 9 lit ha^{-1} fertigation of root booster	9.00	9.87	13.00	10.60
T_6	DI with 75% RD of CF + 5 lit ha^{-1} fertigation of root booster	7.53	8.47	9.33	7.33
T_7	DI with 75% RD of CF + 7 lit ha^{-1} fertigation of root booster	7.73	8.53	9.67	7.73
T_8	DI with 75% RD of CF + 9 lit ha^{-1} fertigation of root booster	7.93	8.80	10.53	7.80
T_9	DI with no fertilizer	6.60	7.80	8.67	7.60
	S.Em. +	0.20	0.13	0.36	0.40
	CD at 5 %	0.63	0.40	1.08	1.20
	General Mean	**7.96**	**9.00**	**10.76**	**8.60**

The results clearly indicated that there is a little difference between the numbers of leaves per plant with increase in root booster fertigation and CF levels. However, the minimum number of functional leaves (6.6) was recorded in T_9 (DI with no fertilizer). Similar trend in number of leaves was observed at 60, 90 DAT and at harvest of onion. Similar results were obtained by Bhat *et al,* (2018) and Shashi Kumar and Shashidhar (2016) who found that plot sprayed with lihocin @ 2500 ppm resulted the higher number of leaves (10.63) per plant of onion. Treatment T_9 i.e. (DI with no fertilizer) recorded lower number of leaves per plant in all the stages of crop growth. It may be due to lack of nutrients for plant growth.

4.1.3 Dry Matter Content in onion

Data regarding dry matter content as influenced by root booster fertigation and conventional fertilizer application is presented in Table 4.3 and graphically depicted in Fig. 4.3. The observations on dry matter content were commenced after 30 (DAT) of seedling, and it was continued up to harvest. The mean dry matter content was 2.26, 4.32, 10.05 and 12.67 g plant^{-1} at 30, 60, 90 DAT and at harvest of onion, respectively.

Dry matter is the outcome of photosynthesis reaction after elimination through respiratory and anabolic process. The overall mean of dry matter content per plant increased with advancement of the age of crop and showing linear relationship.

Table 4.3 Mean dry matter content in onion as influenced by different treatments

Sr. No.	Treatments Detail	Dry matter in onion (g) plant^{-1}			
		30 DAT	60 DAT	90 DAT	At harvest
T_1	SI with 100% RD of CF (Urea, SSP, MOP)	2.58	4.68	11.14	14.23
T_2	DI with 100% RD of CF (Urea, SSP, MOP)	2.22	4.50	9.87	13.10
T_3	DI with 100% RD of CF + 5 lit ha^{-1} fertigation of root booster	2.31	4.62	10.19	13.30
T_4	DI with 100%RD of CF + 7 lit ha^{-1} fertigation of root booster	2.75	4.88	12.04	15.07
T_5	DI with 100%RD of CF + 9 lit ha^{-1} fertigation of root booster	3.48	5.09	13.31	16.01
T_6	DI with 75% RD of CF + 5 lit ha^{-1} fertigation of root booster	2.05	4.04	8.54	10.30
T_7	DI with 75% RD of CF + 7 lit ha^{-1} fertigation of root booster	2.10	4.10	8.70	11.51
T_8	DI with 75% RD of CF + 9 lit ha^{-1} fertigation of root booster	2.15	4.40	9.18	12.66
T_9	DI with no fertilizer	0.70	2.61	7.50	7.82
	S.Em. +	0.24	0.08	0.42	0.34
	CD at 5 %	0.73	0.25	1.27	1.00
	General Mean	**2.26**	**4.32**	**10.05**	**12.67**

In general, mean total dry matter accumulation by onion crop was increased gradually at every phase of crop growth till harvesting due to rapid biomass improvement including bulb development at later stages of crop growth.

Treatment T_5 (DI with 100%RD of CF + 9 lit ha^{-1} fertigation of root booster) produced significantly more dry matter (3.48, 5.09, 13.31 and 16.01 g plant^{-1}) as compared to SI with 100 % CF (T_1) and DI with 100% CF (T_2), however, it was par at T_4 i.e. DI with 100%RD of CF + 7 lit ha^{-1} fertigation of root booster (2.75 g plant). This may be due to adequate availability of nutrients through CF and proper growth of root due to root booster which helped in uptake of nutrients that ultimately reflected in dry matter production. Similar results of dry matter accumulation were also reported at 60, 90 DAT and at harvest of onion, respectively the lowest dry matter content was observed in T_9 (DI with no fertilizer) may be due to low nutrients availability for crop growth.

These results are in close conformation with Deho *et al*. (2002) and Mahanthesh *et al*. (2008) that they reported Azospirillum + 100 % NPK (125:50:125 kg ha^{-1}) produced total dry matter production (8,993 kg ha^{-1}) under irrigated condition during *rabi* season. Similar results were also reported by Nagwa *et al,* (2013) who reported that foliar application of bio-regulator and vitamin E resulted in higher dry matter accumulation in onion crop.

4.1.4 Neck Thickness of Bulbs

The effect of levels of root booster fertigation and conventional fertilizer on neck thickness has influenced significantly the neck thickness of onion bulbs which increased up to 90 DAT there after minor decreases in neck thickness at harvest was observed. The mean neck thickness was 0.92, 1.67, 1.85 and 0.97 cm at 30, 60, 90 DAT and at harvest of onion respectively.

Table 4.4 Mean neck thickness of onion bulb as influenced by different treatments

Sr. No.	Treatment Detail	Neck thickness of bulbs (cm)			
		30 DAT	60 DAT	90 DAT	Harvest
T_1	SI with 100% RD of CF (Urea, SSP, MOP)	0.96	1.72	1.90	1.15
T_2	DI with 100% RD of CF (Urea, SSP, MOP)	0.90	1.68	1.86	0.95
T_3	DI with 100% RD of CF + 5 lit ha^{-1} fertigation of root booster	0.94	1.70	1.92	1.01
T_4	DI with 100%RD of CF + 7 lit ha^{-1} fertigation of root booster	1.03	1.75	2.00	1.20
T_5	DI with 100%RD of CF + 9 lit ha^{-1} fertigation of root booster	1.15	1.82	2.05	1.27
T_6	DI with 75% RD of CF + 5 lit ha^{-1} fertigation of root booster	0.84	1.61	1.81	0.72
T_7	DI with 75% RD of CF + 7 lit ha^{-1} fertigation of root booster	0.86	1.62	1.83	0.86
T_8	DI with 75% RD of CF + 9 lit ha^{-1} fertigation of root booster	0.88	1.65	1.85	0.89
T_9	DI with no fertilizer	0.75	1.50	1.41	0.60
	S.Em. +	0.04	0.03	0.04	0.03
	CD at 5 %	0.12	0.09	0.13	0.10
	General Mean	**0.92**	**1.67**	**1.85**	**0.97**

The significantly maximum neck thickness (2.05 cm) was recorded in treatment T_5 (DI with 100%RD of CF + 9 lit ha^{-1} fertigation of root booster) as compared to SI with 100% CF (T_1) and DI with 100% CF (T_2); however, it was at par with T_4. i.e. (2.0 cm). The higher yield in treatment T_5 may be due to effect of root booster on growth of onion crop. The results clearly indicated that there is a little difference between the neck thickness of bulbs with increase in root booster fertigation and conventional fertilizer application. However, the minimum neck thickness of bulbs (1.41) was recorded in T_9 (DI with no fertilizer) may be due to the shortage of nutrients during crop growth period. At harvesting the neck thickness decreased in all treatment’s bulbs. These results are in close confirmation with Bose *et al*. (2009). They reported that with increase in application of growth regulators increased all growth parameters including neck thickness.

4.1.5 Root Spread

The effect of different fertigation levels of root booster fertigation and conventional fertilizer on root spread of onion is presented in Table 4.5 and graphically depicted in Fig. 4.5. The effect of root booster influenced significantly on root spread at all growth stages of crop. The result showed that with advancement in the age of crop the root spread of onion continually increased. The mean root spread of onion was 4.33, 5.67 and 9.00 cm at 60, 90 days after transplant and at harvest, respectively.

Table 4.5 Mean root spread of onion as influenced by different treatments

Sr. No.	Treatments Detail	Root spread of onion (cm)		
		60 DAT	**90 DAT**	**Harvest**
T_1	SI with 100% RD of CF (Urea, SSP, MOP)	7.0	11.1	13.3
T_2	DI with 100% RD of CF (Urea, SSP, MOP)	6.9	10.2	13.0
T_3	DI with 100% RD of CF + 5 lit ha^{-1} fertigation of root booster	6.8	9.3	12.8
T_4	DI with 100%RD of CF + 7 lit ha^{-1} fertigation of root booster	7.4	12.2	14.8
T_5	DI with 100%RD of CF + 9 lit ha^{-1} fertigation of root booster	7.9	13.3	16.2
T_6	DI with 75% RD of CF + 5 lit ha^{-1} fertigation of root booster	6.6	9.5	11.8
T_7	DI with 75% RD of CF + 7 lit ha^{-1} fertigation of root booster	6.7	10.1	12.5
T_8	DI with 75% RD of CF + 9 lit ha^{-1} fertigation of root booster	6.8	11.2	13.0
T_9	DI with no fertilizer	5.0	7.1	8.0
	S.Em. +	0.23	0.60	0.8
	CD at 5 %	0.70	1.80	2.4
	General Mean	**6.79**	**10.44**	**12.82**

The results revealed that treatments T_5 i.e. DI with 100%RD of CF + 9 lit ha^{-1} fertigation of root booster recorded significantly higher root spread of 7.9, 13.3 and 16.2 cm at 60, 90 and at harvest, respectively as compared to SI with 100% RD of CF (T_1) and DI with 100% RD of CF (T_2); however, it was at par with treatment T_4 . The higher root spread in T_5 treatment as compared to T_1 and T_2 might be due to supply of nutrients and some growth promoting substances like organic acids which promoted the root growth at all growth stages of crop (Said *et al.* 2017). The lowest root spread was observed in T_9 (5.00, 7.10 and 8.00 cm) this may be due to low nutrients availability for crop growth as no nutrients and root booster was applied for crop growth.

4.1.6 Root Length

Data regarding periodical root length of onion as influenced by different treatments is presented in Table 4.6. and graphically depicted in Fig. 4.6. The observations on root length was commenced after 60 days after transplanting (DAT), and it was continued up to harvest, at 30 days interval.

The overall mean root length per plant increased with advancement in the age of crop. The mean root length per plant were 11.20, 12.81 and 14.26 cm at 60, 90 days after transplanting and at harvest of onion, respectively.

Table 4.6 Mean root length of onion as influenced by different treatments

Sr. No.	Treatments Detail	Root length (cm)		
		60 DAT	**90 DAT**	**Harvest**
T_1	SI with 100% RD of CF (Urea, SSP, MOP)	12.00	13.50	15.50
T_2	DI with 100% RD of CF (Urea, SSP, MOP)	11.80	12.53	15.00
T_3	DI with 100% RD of CF + 5 lit ha^{-1} fertigation of root booster	12.00	13.00	15.00
T_4	DI with 100%RD of CF + 7 lit ha^{-1} fertigation of root booster	14.00	15.00	16.00
T_5	DI with 100%RD of CF + 9 lit ha^{-1} fertigation of root booster	15.00	17.67	19.00
T_6	DI with 75% RD of CF + 5 lit ha^{-1} fertigation of root booster	9.00	10.13	11.00
T_7	DI with 75% RD of CF + 7 lit ha^{-1} fertigation of root booster	10.00	12.00	13.33
T_8	DI with 75% RD of CF + 9 lit ha^{-1} fertigation of root booster	12.50	14.00	15.70
T_9	DI with no fertilizer	5.00	9.00	9.00
	S.Em. +	0.83	1.22	1.10
	CD at 5 %	2.50	3.67	3.30
	General Mean	**11.26**	**12.98**	**14.39**

The effect of root booster fertigation levels on root length influenced significantly with increase in rate of root booster application and conventional fertilizers. The results indicated that treatment T_5 i.e. DI with 100%RD of CF + 9 lit ha^{-1} fertigation of root booster recorded significantly higher root length (15, 17.67 and 19 cm) over all other treatments at 60, 90 and at harvest, however it was at par with T_4 and T_8 respectively, this higher root length may be due to application of conventional fertilizers and fertigation of root booster which helps in proper root development as compared to other treatments. Treatment T_9 (DI with no fertilizer) which impacted low rate of root length may be due to inadequate supply of nutrients. Similar results were reported by Deshpande *et al.* (2013).

4.2 Yield and Yield Contributing Characters

The data relevant to yield contributing characters viz., polar diameter and equatorial diameter, average bulb weight (g), yield of bulb (t ha^{-1}), leaves yield (t ha^{-1}) and bulb to leave ratio was recorded during the present investigation and results are summarized character wise as below.

4.2.1 Polar and Equatorial Diameter of Bulb

The polar and equatorial diameter of onion bulbs as influenced by different levels of root booster fertigation and conventional fertilizer are presented in Table 4.7 and depicted in Fig. 4.7.

The polar and equatorial diameter of onion bulbs continued to increase up to harvest. This was due to translocation of biomass and reduction in neck thickness at harvest stage.

The result shows that the polar and equatorial diameter of onion bulb was significantly influenced due to different treatment of root booster fertigation and CF.

Table 4.7 Mean polar and equatorial diameter of onion bulbs as influenced by different Treatments

Sr. No.	Treatments Detail	Polar diameter of bulb at harvest (cm)	Equatorial diameter of bulb at harvest (cm)
T_1	SI with 100% RD of CF (Urea, SSP, MOP)	5.45	7.00
T_2	DI with 100% RD of CF (Urea, SSP, MOP)	5.22	6.85
T_3	DI with 100% RD of CF + 5 lit ha^{-1} fertigation of root booster	5.34	6.97
T_4	DI with 100%RD of CF + 7 lit ha^{-1} fertigation of root booster	5.56	7.16
T_5	DI with 100%RD of CF + 9 lit ha^{-1} fertigation of root booster	5.71	7.52
T_6	DI with 75% RD of CF + 5 lit ha^{-1} fertigation of root booster	4.99	6.32
T_7	DI with 75% RD of CF + 7 lit ha^{-1} fertigation of root booster	5.09	6.49
T_8	DI with 75% RD of CF + 9 lit ha^{-1} fertigation of root booster	5.14	6.67
T_9	DI with no fertilizer	4.77	5.99
	S.Em. +	0.06	0.15
	CD at 5 %	0.18	0.46
	General Mean	**5.25**	**6.78**

The significantly higher polar diameter 5.71 cm and equatorial diameter 7.52 cm was observed in treatment T_5 i.e. DI with 100%RD of CF + 9 lit ha^{-1} fertigation of root booster as compared to SI with 100% CF (4.45 and 7.00 cm) and DI with 100% CF (5.22 and 6.85 cm). However, it was at par to T_4. These results are similar to the reports by Bhat *et al*. (2018) and Bhose *et al*. (2009) reported that with increasing application of growth regulators will increase the polar and equatorial diameter of onion bulbs. The lowest polar and equatorial diameter 4.77 and 5.99 cm was observed in T_9 (DI with no fertilizer treatment) due to low nutrients availability for crop growth.

4.2.2 Average Bulb Weight

The data related to average bulb weight (g), yield of bulb (t ha^{-1}), yield of onion leaves (t ha^{-1}) and bulb to leaves ratio as influenced by different treatments is presented in Table 4.7 and average bulb weight (g) depicted in Fig. 4.8.

The mean average bulb weight and yield of onion bulbs recorded were 55.04 g and 36.69 t ha^{-1}, respectively. Whereas mean yield of onion leaves was 6.27 t ha^{-1} and bulb to leaves ratio recorded was 6.13.

The average bulb weight of onion was influenced significantly due to different treatments at harvest. The significantly maximum average weight of onion bulbs was obtained in T_5 i.e. DI with 100% CF + 9 lit ha^{-1} fertigation of root booster (67.46 g) as compared to SI with 100% RD of CF (60.20 g) and DI with 100% CF (57.67 g). However, it was at par with T_4 (63.15 g). This may be due to application of conventional fertilizer and fertigation of root booster which helps in proper bulb development as compared to other treatments. Treatment T_9 (DI with no fertilizer) which resulted into low rate of bulb weight (26.44g) may be due to inadequate supply of nutrients. These results are in close conformation with Pol (2017) and Warade *et al.* (1995) reported that with increase in levels of fertilizers will increase the average bulb weight of onion.

Table 4.8 Yield and yield contributing parameters of onion as influenced by different treatments

Sr. No.	Treatments Details	Average bulb weight (g)	Bulb yield (t ha^{-1})	Yield of onion leaves (t ha^{-1})	Bulb to leaves ratio	% increase in yield over T_2
T_1	SI with 100% RD of CF (Urea, SSP, MOP)	60.20	39.07	6.45	6.33	1.60
T_2	DI with 100% RD of CF (Urea, SSP, MOP)	57.67	38.45	6.20	6.20	-
T_3	DI with 100% RD of CF + 5 lit ha^{-1} fertigation of root booster	61.03	40.69	6.50	6.26	5.80
T_4	DI with 100%RD of CF + 7 lit ha^{-1} fertigation of root booster	63.15	42.10	6.60	6.58	9.50
T_5	DI with 100%RD of CF + 9 lit ha^{-1} fertigation of root booster	67.46	44.98	6.75	6.66	17.00
T_6	DI with 75% RD of CF + 5 lit ha^{-1} fertigation of root booster	50.26	33.51	5.90	5.68	-
T_7	DI with 75% RD of CF + 7 lit ha^{-1} fertigation of root booster	51.97	34.65	6.00	5.78	-
T_8	DI with 75% RD of CF + 9 lit ha^{-1} fertigation of root booster	55.12	36.75	6.10	6.02	-
T_9	DI with no fertilizer	26.44	17.62	5.80	5.66	-
	SEm(+)	1.86	1.24	0.10	0.04	-
	CD @5%	5.58	3.72	0.32	0.16	-
	General Mean	**54.81**	**36.65**	**6.26**	**6.13**	**-**

4.2.3 Yield of Bulb

The data pertaining to bulb yield of onion is presented in Table 4.8 and graphically depicted in Fig 4.9. The yield of onion bulbs influenced significantly due to different root booster fertigation and conventional fertilizer treatments. The significantly maximum bulb yield of onion was recorded in treatment T_5 i.e. DI with 100% RD of CF + 9 lit ha^{-1} fertigation of root booster 44.98 t ha^{-1} as compared to SI with 100% RD of CF (39.07 t ha^{-1}) and DI with 100% CF (38.45 t ha^{-1}). However, it was at par with T_4 (DI with 100%RD of CF + 7 lit ha^{-1} fertigation of root booster, 42.10 t ha^{-1}). The percent increase in yield in treatment T_5 due to application of 9 lit/ ha root booster fertigation over treatment T_2 was 17.00 % followed by T_4 (9.50 %).

The adequate availability of nutrients throughout the growth and development period due to fertigation of root booster and application of conventional fertilizer under drip irrigation T_5 could have helped for more uptake of nutrients which ultimately reflected in higher yields. Similar results were also reported by Dixit (1996) and Nagare (2014). The lowest yield of onion was recorded in T_9 (DI with no fertilizer treatment, 17.62 t ha^{-1}) may be due to less nutrient availability during crop growth period.

4.2.4 Yield of Onion Leaves

The data pertaining to yield of onion leaves as influenced by different treatments is presented in Table 4.8 and graphically depicted in Fig 4.10. The yield of onion leaves influenced significantly due to different root booster fertigation doses and conventional fertilizer treatments. The maximum yield of onion leaves was obtained in T_5 i.e. DI with 100% RD of CF + 9 lit ha^{-1} fertigation of root booster (6.75 t ha^{-1}) as compared to (T_1) and (T_2) without root booster fertigation treatment was significantly higher than all other treatments. However, it was at par with T_4 (6.60 t ha^{-1}), T_3 (6.50 t ha^{-1}) and T_1 (6.45 t ha^{-1}). These results are in close conformation with Pol (2017). The lowest yield of onion was recorded in T_9 (DI with no fertilizer treatment 5.80 t ha^{-1}) due to lack of nutrition.

4.2.5 Bulb to Leaves Ratio

The data related to (bulbs to leaves ratio) is presented in Table 4.8 and graphically depicted in Fig 4.11, The bulbs to leaves ratio influenced significantly due to different levels of root booster fertigation doses and conventional fertilizer treatments.

The significantly maximum bulb to leaves ratio of 6.66 was obtained in T_5 i.e. DI with 100% RD of CF + 9 lit ha^{-1} fertigation of root booster which was significantly higher than all other treatments except T_4 (6.58). The lowest bulbs to leaves ratio was recorded in treatment T_9 (5.66) due to inadequate nutrition.

4.3 Quality Parameters of Onion Bulb

4.3.1 Total Soluble Solids (TSS)

The data pertaining to total soluble solids (TSS) of onion bulb, reducing sugar and non-reducing sugar is presented in Table 4.9 and graphically depicted in Fig 4.12.

Two onion bulbs were randomly selected from each treatment. The onion bulbs were chopped and the juice was extracted, cleaned and brix reading was recorded with the help of Hand Refractometer having Erma-Japan scale in the range of 032. The brix readings were recorded treatment wise.

The mean total soluble solids were observed in the range of 7.5 to 8.9 °Brix. The TSS of the onion differ significantly due to root booster fertigation over application of conventional fertilizers. The treatment T_5 recorded significantly highest TSS (8.9 °Brix) over other treatments. However, it was at par with T_4, T_1 and T_3. These results are in agreement with those reported by Awatef *et al*. (2015). The lowest total soluble solids of onion were recorded in T_9 (7.5 °Brix).

Table 4.9 Quality parameters of onion bulb as influenced by different treatments

Sr. No.	Treatments Detail	Total Soluble Solids (°Brix)	Reducing Sugar (%)	Non-reducing Sugar (%)	Total Sugar (%)
T_1	SI with 100% RD of CF (Urea, SSP, MOP)	8.60	2.57	4.37	6.94
T_2	DI with 100% RD of CF (Urea, SSP, MOP)	8.30	2.52	4.27	6.79
T_3	DI with 100% RD of CF + 5 lit ha^{-1} fertigation of root booster	8.50	2.55	4.34	6.89
T_4	DI with 100%RD of CF + 7 lit ha^{-1} fertigation of root booster	8.80	2.60	4.42	7.05
T_5	DI with 100%RD of CF + 9 lit ha^{-1} fertigation of root booster	8.90	2.65	4.50	7.15
T_6	DI with 75% RD of CF + 5 lit ha^{-1} fertigation of root booster	7.80	2.42	4.11	6.53
T_7	DI with 75% RD of CF + 7 lit ha^{-1} fertigation of root booster	8.00	2.46	4.18	6.64
T_8	DI with 75% RD of CF + 9 lit ha^{-1} fertigation of root booster	8.10	2.48	4.21	6.69
T_9	DI with no fertilizer	7.50	2.37	4.01	6.38
	S.Em.(+)	0.15	0.017	0.027	0.033
	CD @5%	0.45	0.050	0.08	0.10
	GM	**8.28**	**2.51**	**4.27**	**6.78**

4.3.2 Reducing Sugar

The data pertaining to reducing sugar bulb is presented in Table 4.9 and graphically depicted in Fig 4.13. The mean reducing sugar of bulb as influenced by different treatments is 2.51%.

The maximum reducing sugar in onion bulb was recorded in treatment T_5 i.e. DI with 100% RD of CF + 9 lit ha^{-1} fertigation of root booster of 2.65 %, It was significantly maximum than all other treatments except T_4 (2.60 %) due to fertigation of root booster and conventional fertilizer application. Similar results were also reported by Deshpande *et al* (2013) and Nagare (2014).

4.3.3 Non-reducing Sugar

The data pertaining to non-reducing sugar in bulb is presented in Table 4.9 and graphically depicted in Fig 4.13. The mean reducing sugar in bulb observed in the range of 4.01 - 4.50 %, The significantly maximum non-reducing sugar in bulb was recorded in treatment T_5 i.e. DI with 100% RD of CF + 9 lit ha^{-1} fertigation of root booster (4.5 %), as compared to SI with 100% CF and DI with 100% CF and without root booster fertigation. However, it was at par with T_4. This may be due to availability of nutrients in adequate quantity due to application of 100 % CF and root booster. These results are in close conformation with Deshpande *et al.* (2013).

4.4 Irrigation Studies

4.4.1 Irrigation Water Applied

The total water applied of onion under different irrigation methods ranged from 341 to 600 mm presented in Table 4.10 and graphically depicted in Fig 4.14. The drip method of irrigation resulted into lowest water use (341 mm) as compared to surface method of irrigation (600 mm) and thus resulted in 76.0 % water saving in drip irrigation as compared to surface irrigation (Table 4.10). Water requirement in drip was less as compared with average water requirement under conventional method of onion, because water was directly applied in root zone which increased water application efficiency and water lost through percolation, infiltration, evaporation etc. was avoided. Similar results were reported by Wadatkar *et al*. (2002).

Table 4.10 Irrigation water applied

Sr. No.	Treatments	Total water applied (mm)	Water saving %	WUE (kg ha^{-1} mm)
T_1	SI with 100% RD of CF (Urea, SSP, MOP)	600	-	65.12
T_2	DI with 100% RD of CF (Urea, SSP, MOP)	341	76.0	112.68
T_3	DI with 100% RD of CF + 5 lit ha^{-1} fertigation of root booster	341	76.0	119.26
T_4	DI with 100%RD of CF + 7 lit ha^{-1} fertigation of root booster	341	76.0	123.39
T_5	DI with 100%RD of CF + 9 lit ha^{-1} fertigation of root booster	341	76.0	131.82
T_6	DI with 75% RD of CF + 5 lit ha^{-1} fertigation of root booster	341	76.0	98.21
T_7	DI with 75% RD of CF + 7 lit ha^{-1} fertigation of root booster	341	76.0	101.54
T_8	DI with 75% RD of CF + 9 lit ha^{-1} fertigation of root booster	341	76.0	107.71
T_9	DI with no fertilizer	341	76.0	51.65

4.4.2 Water Use Efficiency (WUE)

The data relevant to water use efficiency (WUE) as influenced by different treatments is depicted in Table 4.10 and graphically is given in Fig 4.15. The WUE can be increased either by increasing the numerator (crop yield) or by decreasing the denominator. The numerator, being plant production, depends on such plant factors as enhancement due to photosynthesis versus losses due to diseases and pests. Hence, water use efficiency can be influenced by such means as pest, disease control, availability and uptake of nutrients. The maximum value of WUE (131.82 kg ha^{-1} mm) was obtained in T_5 i.e. DI with 100%RD of CF + 9 lit ha^{-1} fertigation of root booster due to more yield and followed by T_4 (123.39 kg ha^{-1} mm). Minimum values of WUE (51.65 kg ha^{-1} mm) was obtained in T_9 (DI with no fertilizer) treatment. These results are in close conformation with Chopade *et al*. (1998) and More (2000).

4.5 Effect of Root Booster Fertigation on Nutrient Availability

Periodical nutrient availability in soil was found to be influenced significantly due to different treatments. The N, P and K availability was significantly different for all treatments as the fertilizers were applied in basal dose and 50 % N at 30 DAT and also fertigation of root booster in 8 weeks at weekly interval to onion crop. In crop growth period maximum nutrient availability was observed at 60 days after transplanting. The treatment T_5 (DI with 100%RD of CF + 9 lit ha^{-1} fertigation of root booster) recorded maximum availability of N, P and K as 207, 31.8 and 570 kg ha^{-1}, respectively at 60 DAT. The lowest N, P and K availability was observed in T_9 (DI with no fertilizer) as 161.4, 15 and 306 kg ha^{-1} at 60 DAT. The initial fertility status of soil was available N 173.20 (kg ha^{-1}), P 16.40 (kg ha^{-1}) and K 550.0 (kg ha^{-1}).

4.5.1 Availability of Nitrogen in Soil

The periodical average availability of nitrogen (Kg ha^{-1}) at 30, 60, 90 DAT and at harvest was found to be influenced under different treatments. The average nitrogen availability in the root zone soil of onion was found to be influenced by period, root booster and conventional fertilizers (Table 4.11 and graphically given in Fig. 4.16).

The nitrogen availability was increased with period from transplanting in all treatments up to 60 DAT and there after decreased up to harvesting stage in all the treatments. The decreased nitrogen availability in soil after 60 DAT may be due to higher uptake of nitrogen by plants at bulb formation and bulb maturation stage. The root booster fertigation had influenced the nitrogen availability in soil up to some extent.

At 30 DAT, treatment T_5 i.e. DI with 100%RD of CF + 9 lit ha^{-1} fertigation of root booster (195 kg $ha^{-1)}$ recorded significantly higher nitrogen availability of 195.0 kg ha^{-1} as compared to SI with 100% CF(192.0 kg ha^{-1}) and DI with 100% CF (192.20 kg ha^{-1}); however, it was at par with T_4 (194.3 kg ha^{-1}) and T_3 (193.5 kg ha^{-1}). The fertigation of root booster and application of 100% RD of conventional fertilizers was the reason for higher nitrogen availability in soil under T_5, T_4 and T_3 treatments. Similar trend of N availability was observed at 60 DAT of onion.

At harvest, treatment T_3 (DI with 100%RD of CF + 5 lit ha^{-1} fertigation of root booster) recorded significantly maximum nitrogen availability as 167 kg ha^{-1} in soil than all other treatments; however, it was at par with T_4 (165.8 kg ha^{-1}) and T_5 (165.6 kg ha^{-1}). Similar trend of N availability was observed at 90 DAT. The decrease in N availability at harvest may be due to uptake of nutrients by the crop for development of bulbs. These results are in close conformity with those reported by Pol (2017) and Ashok *et al.* (2001).

Table 4.11 Periodical Availability of Nitrogen in Soil

Sr. No.	Treatments Details	Nitrogen availability (kg ha^{-1})			
		30 DAT	**60 DAT**	**90 DAT**	**At harvest**
T_1	SI with 100% RD of CF (Urea, SSP, MOP)	192.00	204.00	185.00	164.00
T_2	DI with 100% RD of CF (Urea, SSP, MOP)	192.20	204.20	185.20	164.20
T_3	DI with 100% RD of CF + 5 lit ha^{-1} fertigation of root booster	193.50	205.00	188.00	167.00
T_4	DI with 100%RD of CF + 7 lit ha^{-1} fertigation of root booster	194.30	206.50	186.70	165.80
T_5	DI with 100%RD of CF + 9 lit ha^{-1} fertigation of root booster	195.00	207.00	186.00	165.60
T_6	DI with 75% RD of CF + 5 lit ha^{-1} fertigation of root booster	188.00	200.00	181.00	160.00
T_7	DI with 75% RD of CF + 7 lit ha^{-1} fertigation of root booster	186.50	198.50	179.50	158.50
T_8	DI with 75% RD of CF + 9 lit ha^{-1} fertigation of root booster	186.40	198.40	179.40	158.40
T_9	DI with no fertilizer	173.40	161.40	142.40	121.40
	SEm(+)	0.50	0.67	0.60	0.47
	CD @5%	1.50	2.00	1.80	1.40
	General Mean	**189.03**	**198.33**	**179.27**	**157.26**

4.5.2 Availability of Phosphorus in Soil

The data regarding periodical soil available phosphorus was influenced significantly due to different treatments. The average phosphorus availability in the root zone soil of onion was found to be influenced by period, root booster and conventional fertilizers (Table 4.12 and graphically given in Fig. 4.17).

The P availability was decreased with increase of age of crop. The decreased P availability in soil after 60 DAT may be due to higher uptake of P by plants at bulb formation and bulb maturation stage. All recommended amount of P fertilizer was applied in basal dose. However, the availability of P significantly improved in growth parameters of plant and yield of crop.

There was significant difference in phosphorus availability at 30 DAT and significantly maximum phosphorus availability was observed in treatment T_5 i.e. DI with 100%RD of CF + 9 lit ha^{-1} fertigation of root booster as 35 kg ha^{-1}. However, it was at par with T_4 (34.0 kg ha^{-1}) and T_3 treatment (33.70). In treatments T_5 and T_4 maximum P availability might be due to fertigation of root booster and application of 100% recommended dose of conventional fertilizers as basal dose increased P availability as compared to other treatments. Similar trend of P availability was observed at 60 DAT of onion.

Table 4.12 Periodical Availability of Phosphorus in Soil

Sr. No.	Treatments Details	Phosphorus availability (kg ha^{-1})			
		30 DAT	60 DAT	90 DAT	At harvest
T_1	SI with 100% RD of CF (Urea, SSP, MOP)	33.00	29.6	23.2	15.5
T_2	DI with 100% RD of CF (Urea, SSP, MOP)	33.20	29.7	23.7	15.4
T_3	DI with 100% RD of CF + 5 lit ha^{-1} fertigation of root booster	33.70	30.5	25.2	17.5
T_4	DI with 100%RD of CF + 7 lit ha^{-1} fertigation of root booster	34.00	31.2	24.7	17.2
T_5	DI with 100%RD of CF + 9 lit ha^{-1} fertigation of root booster	35.00	31.8	24.4	16.7
T_6	DI with 75% RD of CF + 5 lit ha^{-1} fertigation of root booster	28.20	24.8	18.5	15.1
T_7	DI with 75% RD of CF + 7 lit ha^{-1} fertigation of root booster	29.70	26.1	20	15.7
T_8	DI with 75% RD of CF + 9 lit ha^{-1} fertigation of root booster	29.80	27.3	20.8	16.5
T_9	DI with no fertilizer	16.40	15	14.8	13.2
	SEm(+)	0.45	0.43	0.44	0.37
	CD @5%	1.36	1.28	1.31	1.11
	General Mean	**30.33**	**27.33**	**21.70**	**15.87**

At harvest, significantly maximum P availability observed in treatment T_3 i.e. DI with 100%RD of CF + 5 lit ha^{-1} fertigation of root booster as (17.5 kg ha^{-1}). However, it was at par with T_4 (17.2 kg ha^{-1}) and T_5 (16.7 Kg ha^{-1}). P availability decreased at harvest might be due to more uptake by the plants. Similar results of P availability in soil was observed at 90 DAT. These results are in close conformity with those reported Ravina Kumari (2017) and Reddy (1985).

Treatment T_9 (DI with no fertilizer) recorded lowest nitrogen availability in soil (16.4, 15.0, 14.8 and 13.2 kg ha^{-1}, respectively.) at all stages of crop growth.

4.5.3 Availability of Potassium in Soil

The periodical average availability of potassium (kg ha^{-1}) at 30, 60, 90 DAT and at harvest was found to be influenced under different treatments. The average potassium availability in the root zone soil of onion was found to be influenced by period, root booster and conventional fertilizers (Table 4.13 and graphically given in Fig. 4.18).

The K availability in soil decreased with period from 30 DAT and this process was continued up to harvesting stage in all the treatments. The decreased K availability in soil after 30 DAT may be due to higher uptake of K by plants because of plant growth, bulb formation and bulb maturation stage.

The treatment differences in potassium availability in soil due to levels of root booster and conventional fertilizer were significant at all growth stages. At 30 DAT, T_5 (DI with 100%RD of CF + 9 lit ha^{-1} fertigation of root booster) showed significantly maximum potassium availability (581 kg ha^{-1}) in the soil over all other treatments, however, it was at par with T_4 (579 kg ha^{-1}). In T_5 and T_4 availability of K might be more due to effect of fertigation of 9 and 7 lit ha^{-1} of root booster and application of 100% RD of conventional fertilizers rather than other treatments. However, application of full dose of K as a basal dose resulted into more K availability at 30 DAT. Similar trend of K availability in soil at 60 DAT were observed. These results are in close conformity with those reported Pol (2017) and Reddy (1985).

Table 4.13 Periodical Availability of Potassium in Soil

Sr. No.	Treatments Details	Potassium availability (kg ha^{-1})			
		30 DAT	**60 DAT**	**90 DAT**	**At harvest**
T_1	SI with 100% RD of CF (Urea, SSP, MOP)	570.00	561.00	547.00	543.00
T_2	DI with 100% RD of CF (Urea, SSP, MOP)	572.00	563.00	548.00	545.00
T_3	DI with 100% RD of CF + 5 lit ha^{-1} fertigation of root booster	577.00	565.00	558.00	551.00
T_4	DI with 100%RD of CF + 7 lit ha^{-1} fertigation of root booster	579.00	567.00	554.50	549.00
T_5	DI with 100%RD of CF + 9 lit ha^{-1} fertigation of root booster	581.00	570.00	550.00	547.00
T_6	DI with 75% RD of CF + 5 lit ha^{-1} fertigation of root booster	572.00	551.00	533.00	529.00
T_7	DI with 75% RD of CF + 7 lit ha^{-1} fertigation of root booster	574.00	552.00	535.00	531.00
T_8	DI with 75% RD of CF + 9 lit ha^{-1} fertigation of root booster	576.00	554.00	537.00	533.00
T_9	DI with no fertilizer	550.00	536.00	526.00	520.00
	SEm(+)	0.66	1.32	1.17	1.00
	CD @5%	1.98	4.00	3.50	3.00
	General Mean	**572.33**	**557.67**	**543.21**	**538.67**

At harvest, treatment T_3 (DI with 100% RD of CF + 5 lit ha^{-1} fertigation of root booster) recorded significantly maximum K availability of 551.00 kg ha^{-1} over all other treatments. However, it was at par with T_4 (549.00 kg ha^{-1}) and T_5 (547.00 kg ha^{-1}). The lowest K availability in soil was recorded in T_9 (520.00 kg ha^{-1}) might be due to no application of fertilizer. Similar trend of K availability was observed at 90 DAT of onion.

4.6 Effect of Root Booster Fertigation on Nutrient Uptake

The total uptake of nutrients was found to be influenced significantly due to different treatments. The total N, P and K uptake was increased with period from 30 DAT up to harvesting stage and maximum uptake of N, P and K by onion was observed at harvesting stage.

The NPK uptake was improved significantly in drip irrigation treatments. However, amongst different root booster treatments, total uptake of all three major nutrients was increased significantly over T_1 (SI with 100% RD of CF).

4.6.1 Nitrogen Uptake

The uptake of total nitrogen as influenced by different treatments is presented in Table 4.14 and Fig. 4.19. The periodical nitrogen uptake increased with increase in age of the crop and maximum uptake was observed at harvesting stage.

Table 4.14. Periodical Uptake of Nitrogen by Onion

Sr. No.	Treatments Details	Nitrogen uptake (kg ha^{-1})			
		30 DAT	**60 DAT**	**90 DAT**	**At harvest**
T_1	SI with 100% RD of CF (Urea, SSP, MOP)	6.8	32.9	71.63	113.1
T_2	DI with 100% RD of CF (Urea, SSP, MOP)	6.5	29.8	71.91	106.4
T_3	DI with 100% RD of CF + 5 lit ha^{-1} fertigation of root booster	6.9	33.9	73.4	115.4
T_4	DI with 100%RD of CF + 7 lit ha^{-1} fertigation of root booster	7.1	36.9	76.7	116.5
T_5	DI with 100%RD of CF + 9 lit ha^{-1} fertigation of root booster	7.5	38.7	78.0	119.0
T_6	DI with 75% RD of CF + 5 lit ha^{-1} fertigation of root booster	6.3	25.2	76.5	97.3
T_7	DI with 75% RD of CF + 7 lit ha^{-1} fertigation of root booster	6.4	26.8	67.5	100.1
T_8	DI with 75% RD of CF + 9 lit ha^{-1} fertigation of root booster	6.5	27	68.4	104.1
T_9	DI with no fertilizer	4.3	18.1	35.8	65.2
	SEm(+)	0.17	0.6	0.50	1.57
	CD @5%	0.50	1.81	5.5	4.70
	GM	6.48	29.92	68.87	104.13

Total nitrogen uptake differed significantly as influenced by different treatments at all growth stages of onion. At 30 DAT, the uptake of total N was observed significantly highest in treatment T_5 (DI with 100%RD of CF + 9 lit ha^{-1} fertigation of root booster) as 7.5 kg ha^{-1} over all other treatments. However, it was at par withT_4 (7.1 kg). The highest N uptake in treatment T_5 might be due to application of 9 lit ha^{-1} fertigation of root booster and DI with 100% RD of CF which increased the N availability in root zone as compared to SI with 100% RD of CF (T_1) and DI 100% RD of CF (T_2). The lowest nitrogen uptake (4.3 kg ha^{-1}) was recorded in treatment T_9 (DI with no fertilizer). Similar trend of N uptake was observed at 60 DAT of onion crop.

At harvest, significantly maximum N uptake of 119.0 kg ha^{-1} was recorded in treatment T_5 (DI with 100%RD of CF + 9 lit ha^{-1} fertigation of root booster). However, it was at par withT_4

(116.5 kg ha^{-1}), T_3(115.4 kg ha^{-1}), similar trend of total N uptake was observed at 90 DAT of onion. These results are is close conformity with the results of Pol (2017) and Henriksen (1984).

4.6.2 Phosphorus Uptake

The uptake of phosphorus as influenced by different treatments is presented in Table 4.15 and Fig. 4.20. The periodical P uptake increased with increase in age of the crop and maximum uptake was observed at harvesting stage. Total phosphorus uptake differed significantly in all the treatments due to root booster fertigation and conventional fertilizer treatments.

The total uptake of P at 30 DAT was observed significantly highest in treatment T_5 (DI with 100%RD of CF + 9 lit ha^{-1} fertigation of root booster) as 5.5 kg ha^{-1}. However, it was at par with T_4 (DI with 100%RD of CF + 7 lit ha^{-1} fertigation of root booster) i.e. 5.3 kg ha^{-1} and T_3 (DI with 100%RD of CF + 7 lit ha^{-1} fertigation of root booster) i.e. 5.2 kg ha^{-1}.

At 60 DAT, treatment T_5 recorded significantly maximum P uptake over all other treatments, however, it was at par with T_4 (20.1 kg). The P uptake was improved significantly in drip irrigation with root booster and 100 % RD of CF treatment (T_5) over surface method of irrigation (5.0 kg ha^{-1}).

Table 4.15 Periodical Uptake of Phosphorous in Onion

Sr. No.	Treatments Details	Phosphorous uptake (kg ha^{-1})			
		30 DAT	60 DAT	90 DAT	At harvest
T_1	SI with 100% RD of CF (Urea, SSP, MOP)	5.0	17.5	36.5	43.1
T_2	DI with 100% RD of CF (Urea, SSP, MOP)	4.3	16.9	35.9	39.2
T_3	DI with 100% RD of CF + 5 lit ha^{-1}fertigation of root booster	5.2	18.9	37.9	48.3
T_4	DI with 100%RD of CF + 7 lit ha^{-1} fertigation of root booster	5.3	20.1	40.2	53.4
T_5	DI with 100%RD of CF + 9 lit ha^{-1} fertigation of root booster	5.5	22.3	43.8	55.1
T_6	DI with 75% RD of CF + 5 lit ha^{-1} fertigation of root booster	4.0	14.9	30.4	36.1
T_7	DI with 75% RD of CF + 7 lit ha^{-1} fertigation of root booster	4.1	15.1	32.8	37.5
T_8	DI with 75% RD of CF + 9 lit ha^{-1} fertigation of root booster	4.2	15.9	34.2	39.4
T_9	DI with no fertilizer	1.8	10.39	20.3	28.5
	SEm(+)	0.14	0.73	1.63	0.57
	CD @5%	0.42	2.20	4.09	1.70
	GM	**4.38**	**16.89**	**34.67**	**42.29**

The maximum P uptake at harvest (55.1 kg ha^{-1}) was found in treatment T_5 (DI with 100%RD of CF + 9 lit ha^{-1} fertigation of root booster), however, it was at par with T_4 (53.4 kg ha^{-1}). The lowest total P uptake was recorded in T_9 (DI with no fertilizer) as 28.5 kg ha^{-1}. These results are in close conformity with the results of Vitekari (2007) and Pol (2017).

The maximum uptake of phosphorus was observed in treatment of DI with 100%RD of CF + 9 lit ha^{-1} fertigation of root booster in all growth stages of onion. This might be due to fertigation of root booster and application of conventional fertilizers during important crop growth stages helped to improve the P uptake.

4.6.3 Potassium Uptake

The uptake of potassium as influenced by different treatments is presented in Table 4.16 and Fig. 4.21. The periodical K uptake increased with increase in age of the crop and maximum uptake was observed at harvesting stage. Total K uptake differed significantly in all the treatments due to root booster fertigation and conventional fertilizer treatments. At 30 DAT, treatment T_5 recorded significantly maximum potassium uptake of 5.70 kg ha^{-1} over all other treatments, except T_4 (5.20 kg ha^{-1}) and T_3 (4.60 kg ha^{-1}).

Table 4.16 Periodical Uptake of Potassium in Onion

Sr. No.	Treatments Details	Potassium uptake (kg ha^{-1})			
		30 DAT	60 DAT	90 DAT	At harvest
T_1	SI with 100% RD of CF (Urea, SSP, MOP)	4.60	23.10	71.80	96.50
T_2	DI with 100% RD of CF (Urea, SSP, MOP)	4.30	22.40	70.10	95.20
T_3	DI with 100% RD of CF + 5 lit ha^{-1} fertigation of root booster	4.60	24.20	73.20	99.20
T_4	DI with 100%RD of CF + 7 lit ha^{-1} fertigation of root booster	5.20	27.40	75.40	101.00
T_5	DI with 100%RD of CF + 9 lit ha^{-1} fertigation of root booster	5.70	28.20	76.20	103.50
T_6	DI with 75% RD of CF + 5 lit ha^{-1} fertigation of root booster	4.00	19.20	67.20	89.20
T_7	DI with 75% RD of CF + 7 lit ha^{-1} fertigation of root booster	4.10	20.40	68.30	91.60
T_8	DI with 75% RD of CF + 9 lit ha^{-1} fertigation of root booster	4.20	21.30	69.40	92.00
T_9	DI with no fertilizer	2.90	16.30	35.20	55.00
	SEm(+)	0.37	1.32	1.00	1.17
	CD @5%	1.10	4.0	3.0	3.50
	GM	**4.40**	**22.50**	**67.42**	**91.74**

At 60 DAT, treatment T_5 recorded significantly maximum K uptake of 28.20 kg ha^{-1} over all other treatments, however, it was at par with T_4 (27.40 kg ha^{-1}) and T_3 (24.20 kg ha^{-1}). Similar trend of total K uptake was recorded at 90 DAT. The uptake was improved significantly in drip irrigation with root booster fertigation and CF treatment (T_5) over surface method of irrigation (T_1) and drip irrigation without root booster fertigation this trend might be due to fertigation of root booster which helps to release the nutrients at different growth stages of onion.

The maximum K uptake at harvest (103.50 kg ha^{-1}) was found in treatment T_5 (DI with 100%RD of CF + 9 lit ha^{-1} fertigation of root booster), however, it was at par with T_4 (101.00 kg ha^{-1}). The lowest total K uptake was recorded in T_9 (DI with no fertilizer) as 55.00 kg ha^{-1}. These results are in close conformity with the results of Pol (2017) and Kumar *et al* (2006).

4.6.4 Nutrient Use Efficiency

The nutrient use efficiency was found to be influenced significantly due to different treatments of application of conventional fertilizer and root booster fertigation (Table 4.17 and Fig. 4.22).

The maximum nutrient use efficiency (136.80 kg yield kg $^{-1}$ of nutrient applied) was observed in treatment T_5 followed by T_8 (127.5 kg yield kg $^{-1}$ of nutrient applied) and T_4 (122.4 kg yield kg $^{-1}$ of nutrient applied). The lowest nutrient use efficiency of 104.15 kg yield kg^{-1} nutrient applied was observed in T_2 (104.15). These results are in confirmation with research finding of Bharambe *et al.* (1997).

Table 4.17 Nutrient use efficiency contributing parameters of onion as influenced by different treatments

Sr. No.	Treatments Details	Nutrient use efficiency (kg yield kg^{-1} nutrient applied)
T_1	SI with 100% RD of CF (Urea, SSP, MOP)	107.25
T_2	DI with 100% RD of CF (Urea, SSP, MOP)	104.15
T_3	DI with 100% RD of CF + 5 lit ha^{-1} fertigation of root booster	115.35
T_4	DI with 100%RD of CF + 7 lit ha^{-1} fertigation of root booster	122.40
T_5	DI with 100%RD of CF + 9 lit ha^{-1} fertigation of root booster	136.80
T_6	DI with 75% RD of CF + 5 lit ha^{-1} fertigation of root booster	105.86
T_7	DI with 75% RD of CF + 7 lit ha^{-1} fertigation of root booster	106.87
T_8	DI with 75% RD of CF + 9 lit ha^{-1} fertigation of root booster	127.5
T_9	DI with no fertilizer	0

4.7 Storage Studies

Data pertaining to the various parameters of storage losses recorded at an interval of 30 days after harvest of onion crop up to the 180 days are presented in Table 4.17, 4.18 and 4.19 and graphically depicted in Fig. 4.23, 4.24 and 4.25.

4.7.1 Rottening Losses in Onion

The data related to the rottening losses in onion during storage is presented in Table 4.18 and graphically depicted in Fig 4.23.

Table 4.18. Mean percent of rottening losses in onion as influenced by different treatments

Sr. No.	Treatments Details	Rottening losses (%)		
		120 DAH	150 DAH	180 DAH
T_1	SI with 100% RD of CF (Urea, SSP, MOP)	3.5	6.5	7.6
T_2	DI with 100% RD of CF (Urea, SSP, MOP)	2.2	3.5	5.4
T_3	DI with 100% RD of CF + 5 lit ha^{-1} fertigation of root booster	1.9	3.3	5.5
T_4	DI with 100%RD of CF + 7 lit ha^{-1} fertigation of root booster	1.4	3.8	5.7
T_5	DI with 100%RD of CF + 9 lit ha^{-1} fertigation of root booster	2.7	4.2	6.0
T_6	DI with 75% RD of CF + 5 lit ha^{-1} fertigation of root booster	2.7	3.6	5.3
T_7	DI with 75% RD of CF + 7 lit ha^{-1} fertigation of root booster	1.8	3.4	5.3
T_8	DI with 75% RD of CF + 9 lit ha^{-1} fertigation of root booster	2.0	3.2	4.8
T_9	DI with no fertilizer	3.5	4.4	7.2
	SEm(+)	0.10	0.07	0.05
	CD @5%	0.31	0.19	0.16
	GM	**2.41**	**3.99**	**5.87**

The total rottening losses in stored bulb were significantly influenced due to different levels of root booster fertigation and application of conventional fertilizer. The treatment T_1 (SI with 100% RD of CF) recorded significantly maximum total rottening losses (7.6 %), over all treatments; however, it was par with T_9 and T_5. Minimum rottening losses were recorded in DI with 75 % CF+ 9 lit ha^{-1} fertigation of root booster (4.8 %).

Maximum rottening losses was recorded in surface irrigation with 100 % CF might be due to higher irrigation and fertilizer application to the crop during production phase as compared to drip irrigation system which accelerated the rottening during storage. These results are close conformity with the results of Tripathi *et al* (2010). The no fertilizer treatments (T_9) also recorded higher rottening losses as compared with drip system might be due to inadequate nutrition. Similar results were also reported by Ullah *et al* (2008) at Regional Research Station Rahmatpur, Barisal.

4.7.2 Physiological and Sprouting Losses in Onion

The data related to the physiological and sprouting losses in onion during storage is presented in Table 4.19 and graphically depicted in Fig 4.24. The total physiological and sprouting losses in stored bulb were significantly influenced due to different levels of fertigation of root booster and application of conventional fertilizer.

The treatment T_1 (SI with 100% RD of CF) recorded significantly maximum total physiological and sprouting losses (12.3 %) over all other treatments; however, it was at par with T_9 (12.1 %) and T_5 (12.0%). Minimum physiological and sprouting losses were recorded in DI with 75 % CF+ 9 lit ha^{-1} fertigation of root booster (10.7 %).

Maximum physiological and sprouting losses were recorded in surface irrigation treatment might be due to higher irrigation and fertilizer application to the crop during production phase which accelerated the sprouting during storage as compared other treatments. These results are close conformity with the results of Tripathi *et al* (2010) and Kumar *et al* (2007) reported higher levels of irrigation and fertilization significantly influenced the physiological and sprouting losses in onion.

Table 4.19. Mean percent physiological and sprouting losses in onion as influenced by different treatments

Sr. No.	Treatments Details	Physiological and sprouting losses (%)		
		120 DAH	**150 DAH**	**180 DAH**
T_1	SI with 100% RD of CF (Urea, SSP, MOP)	10.0	11.3	12.3
T_2	DI with 100% RD of CF (Urea, SSP, MOP)	5.7	9.3	11.4
T_3	DI with 100% RD of CF + 5 lit ha^{-1} fertigation of root booster	6.2	9.5	11.5
T_4	DI with 100%RD of CF + 7 lit ha^{-1} fertigation of root booster	6.8	9.5	11.6
T_5	DI with 100%RD of CF + 9 lit ha^{-1} fertigation of root booster	8.2	9.7	12.0
T_6	DI with 75% RD of CF + 5 lit ha^{-1} fertigation of root booster	7.4	9.8	11.3
T_7	DI with 75% RD of CF + 7 lit ha^{-1} fertigation of root booster	5.9	8.0	11.2
T_8	DI with 75% RD of CF + 9 lit ha^{-1} fertigation of root booster	7.1	8.8	10.7
T_9	DI with no fertilizer	8.6	10.1	12.1
	SEm(+)	0.60	0.53	0.27
	CD @5%	1.80	1.60	0.80
	GM	7.47	9.56	11.57

4.7.3 Total Weight Loss in Onion

Data related to total weight loss in onion bulbs during the storage period are presented in Table 4.20 and graphically depicted in Fig 4.25. The total weight losses in stored bulb were significantly influenced due to different levels of fertigation of root booster and application of conventional fertilizer.

Significantly maximum total loss in weight (19.9 %) was recorded in T_1 i.e. SI with 100% RD of CF over all other treatment, however it was at par with T_9 (19.3) and T_5 (18.0) when onion bulbs were kept in plastic perforated container for 6 months of storage. Minimum total losses were recorded in DI with 75 % CF+ 9 lit ha^{-1} fertigation of root booster (15.5 %).

The higher weight loss during storage in T_1 and T_5 may be attributed to higher application of nutrients and higher amount of water which increased the uptake of nitrogen by the crop which may cause rotting of bulb in storage. Whereas in T_9 (DI with no fertilizer) due to non-availability of nutrients for the crop growth, the storage loss was more. These results are in close conformity with those reported by Kumar *et al* (2007).

Table 4.20. Mean total weight losses in onion as influenced by different treatments

Sr. No.	Treatments Details	Total weight losses (%)		
		120 DAH	150 DAH	180 DAH
T_1	SI with 100% RD of CF (Urea, SSP, MOP)	13.5	17.80	19.9
T_2	DI with 100% RD of CF (Urea, SSP, MOP)	7.9	12.80	16.8
T_3	DI with 100% RD of CF + 5 lit ha^{-1} fertigation of root booster	10.1	12.80	17.0
T_4	DI with 100%RD of CF + 7 lit ha^{-1} fertigation of root booster	8.1	13.30	17.3
T_5	DI with 100%RD of CF + 9 lit ha^{-1} fertigation of root booster	10.9	13.90	18.0
T_6	DI with 75% RD of CF + 5 lit ha^{-1} fertigation of root booster	10.1	13.40	16.6
T_7	DI with 75% RD of CF + 7 lit ha^{-1} fertigation of root booster	7.7	11.40	16.5
T_8	DI with 75% RD of CF + 9 lit ha^{-1} fertigation of root booster	9.1	12.00	15.5
T_9	DI with no fertilizer	12.1	14.50	19.3
	SEm(+)	0.90	1.43	0.80
	CD @5%	2.70	4.30	2.40
	GM	**9.94**	**13.54**	**17.43**

4.8. Economics

The data regarding the cost of cultivation, net seasonal income, total net income, net extra income over control and B:C ratio (Appendix I to III) of onion as influenced by different treatments are presented in (Table 4.21).

4.8.1 Seasonal Cost of Cultivation

The cost of cultivation of drip irrigated treatments was observed higher than surface irrigated treatments due to higher cost of installation of drip irrigation systems (Table 4.21 and Appendix-I to III).

Cost of fertilizer and root booster was different, as full recommended dose of fertilizer was not applied in all the treatments. The highest cost of cultivation was recorded in treatment T_5 (DI with 100%RD of CF + 9 lit ha^{-1} fertigation of root booster) as Rs.102211 followed by T_4 (DI with 100%RD of CF + 7 lit ha^{-1} fertigation of root booster) as Rs. 101106. The lowest cost of cultivation was observed in T_1 (Rs.90240).

4.8.2 Net Seasonal Income

The data regarding the net seasonal income were presented in Table 4.21 indicated that the maximum value ha^{-1} were observed in treatment T_5 (DI with 100%RD of CF + 9 lit ha^{-1} fertigation of root booster) as Rs 257602 ha^{-1} due to higher bulb yield followed by treatment T_4 (DI with 100%RD of CF + 7 lit ha^{-1} fertigation of root booster) as Rs 235694 ha^{-1}. Treatment T_9 gave lowest yield of bulb hence the net seasonal income was also lowest as Rs 49498 ha^{-1} among all treatments (Table. 4.20). These results are in close conformity with the results of Pawar *et al.* (2013) and Bartolo (2005).

4.8.3 Total Net Income

The additional area that can be brought under irrigation due to water saving by drip irrigation was taken into consideration while determining the total net income.

Treatment T_5 (DI with 100%RD of CF + 9 lit ha^{-1} fertigation of root booster) recorded highest total net income of as Rs 384181 ha^{-1} which was followed by T_2 (DI with 100%RD of CF) as Rs 361028 ha^{-1}. It was highest in T_5 due to increased bulb yield. The lowest value was observed in treatment T_9 (DI with no fertilizer) as Rs 69180 ha^{-1}. (Table. 4.21). These results are in close conformity with the results of Pol (2017) and More (2000).

4.8.4 Net Extra Income Over Control

The net extra income over control treatment of Rs 47285 was highest in treatment T_5 (DI with 100%RD of CF + 9 lit ha^{-1} fertigation of root booster), followed by T_4 (DI with 100%RD of CF + 7 lit ha^{-1} fertigation of root booster) as Rs 25377 and T_3 (DI with 100%RD of CF + 5 lit ha^{-1} fertigation of root booster) Rs 15197. The lowest value of net extra income over control as Rs 12003 was recorded in T_1 (SI with 100 % RD of CF) treatment.

4.8.5 B:C Ratio

The treatment is said to be profitable when the B:C ratio is more than 1 and if it is less than 1, then treatment shows more expenditure than income i.e. not profitable and if its value is 1 then there is no loss or profit.

All treatments recorded B:C ratio between 1.54 to 3.52 maximum value of B:C ratio was recorded in treatment T_5 (DI with 100% RD of CF + 9 lit ha^{-1} fertigation of root booster) i.e. 3.52 followed by T_1 (3.46) and T_4 (3.33). These results are in close conformity with the results of Pol (2017) and Tripathi *et al* (2010) reported highest B:C ratio under drip irrigation as compared to surface irrigation method (Table 4.21).

4.8.6 Water Productivity

Maximum value of water productivity as Rs 755.4 ha^{-1} mm was recorded in T_5 (DI with 100%RD of CF + 9 lit ha^{-1} fertigation of root booster), followed by T_4 (DI with 100%RD of CF + 7 lit ha^{-1} fertigation of root booster) as Rs 691.2 ha^{-1} mm; whereas, conventional method of irrigation T_1(100% CF under SI) resulted into water productivity of Rs 370.5 ha^{-1} mm (Table 4.21 and Fig 4.26). The lowest value was observed in T_9 (Rs. 145.1 ha^{-1} mm). These results are close conformity with the results reported by More (2000).

Table 4.21 Economics of onion as influenced by different treatments

Sr. No.	Treatments Details	Seasonal cost of cultivation (Rs ha^{-1})	Net seasonal income (Rs ha^{-1})	Total net income (Rs ha^{-1})	Net extra income over control T_2 (Rs)	B:C Ratio	Water productivity (Rs ha^{-1}mm)
T_1	SI with 100% RD of CF (Urea, SSP, MOP)	90240	222320	222320	12003	3.46	370.53
T_2	DI with 100% RD of CF (Urea, SSP, MOP)	97256	210317	361028	0	3.16	616.77
T_3	DI with 100% RD of CF + 5 lit ha^{-1} fertigation of root booster	100006	225514	337127	15197	3.25	661.33
T_4	DI with 100%RD of CF + 7 lit ha^{-1} fertigation of root booster	101106	235694	351551	25377	3.33	691.18
T_5	DI with 100%RD of CF + 9 lit ha^{-1} fertigation of root booster	102211	257602	384181	47285	3.52	755.43
T_6	DI with 75% RD of CF + 5 lit ha^{-1} fertigation of root booster	98569	169511	250667	-40806	2.72	497.10
T_7	DI with 75% RD of CF + 7 lit ha^{-1} fertigation of root booster	99669	177505	264892	-32812	2.78	520.54
T_8	DI with 75% RD of CF + 9 lit ha^{-1} fertigation of root booster	100769	193225	288303	-17092	2.92	566.64
T_9	DI with no fertilizer	91499	49498	69180	-160819	1.54	145.15

5. SUMMARY AND CONCLUSIONS

A field experiment on "Effect of Root Booster Through Fertigation on Yield of Onion (*Allium cepa L.*), Nutrient Uptake and Availability in Inceptisols in Semi-arid Region of Maharashtra" was conducted during 2017-18. The experiment was conducted at the instructional Farm of Interfaculty Department of Irrigation Water Management, PGI, Mahatma Phule Krishi Vidyapeeth, Rahuri, District Ahmednagar, Maharashtra, India.

The experiment was laid out in Randomized Block Design with three replications. The experiment consisted of nine treatments. The soil of the experimental site was uniform and levelled. The soil was well drained silty clay in texture with 75 cm depth with low in available nitrogen (173.20 kg ha^{-1}), medium in available phosphorus (16.40 kg ha^{-1}) and very high in available potassium (550 kg ha^{-1}). The soil was slightly alkaline in reaction with pH as 8.10. The values of field capacity, permanent wilting point, bulk density and infiltration rate, available soil moisture and electrical conductivity were 39.20 %, 17.90 %, 1.27 Mg m^{-3}, 3.24 cm hr^{-1}, 21.30 % and 0.30 dSm^{-1}, respectively.

Transplanting of onion was done on 30^{th} December, 2017 at 15 x 7.5 cm spacing. One lateral per six rows of crop was laid out in drip irrigation system. The irrigations were provided as per requirement. The cultural operations and plant protection measures were carried out timely.

The observations on periodical growth and yield contributing characters were recorded. The plant and soil samples were collected periodically to estimate the nutrient availability in soil and uptake by plants. Chemical analysis for estimation of N, P and K in soil and plant was carried out. Some of the findings emerged are summarized below.

5.1 Summary

5.1.1 Effect of Root Booster Fertigation and Application of Conventional Fertilizer on Growth and Yield Attributing Characters

Drip irrigation with 100% RD of CF + 9 lit ha^{-1} fertigation of root booster recorded significantly higher growth attributes viz., plant height, number of leaves $plant^{-1}$, dry matter $plant^{-1}$ and neck thickness at 30, 60, 90 DAT and at harvest as compared to other treatments and it was at par with treatment T_4 (DI with 100%RD of CF + 7 lit ha^{-1} fertigation of root booster). More plant height in T_5 among all treatments might be due to application of 100 % RD of conventional fertilizer and 9 lit ha^{-1} fertigation of root booster at proper stages of plant growth. Minimum values of growth attributes were recorded in T_9 (DI with no fertilizer) due to lack of nutrition.

The post harvest studies viz., polar diameter and equatorial diameter were significantly influenced due to different treatments. The drip irrigation with application of 100% RD of conventional fertilizer and 9 lit ha^{-1} fertigation of root booster (T_5) recorded significantly higher polar diameter and equatorial diameter than other treatments at harvest of crop and it was at par with T_4 (DI with 100%RD of CF + 7 lit ha^{-1} fertigation of root booster).

The average bulb weight (g), yield of bulb (t ha^{-1}), weight of leaves (t ha^{-1}) and bulbs to leaves ratio were significantly higher in DI with 100%RD of CF + 9 lit ha^{-1} fertigation of root booster followed T_4 (DI with 100%RD of CF + 7 lit ha^{-1} fertigation of root booster). The minimum values were recorded in T_9 treatment (DI with no fertilizer) due to lack of nutrition.

5.1.2 Water Studies

The water requirement for onion under drip and surface irrigation was 341 mm and 600 mm, respectively resulting into 76.0 % water saving in drip irrigation system. In drip irrigation system water was directly applied to root zone which increased the water use efficiency and water lost through percolation, infiltration, evaporation etc. was avoided and resulted into considerable water saving. The maximum water use efficiency in T_5 (DI with 100%RD of CF + 9 lit ha^{-1} fertigation of root booster) might be due to higher yield obtained and lesser water consumed.

5.1.3 Nutrient Availability in Soil

The N, P and K availability in soil increased with period from transplanting of seedling in all treatments up to 60 DAT and decreased at 90 DAT and harvesting stage. The decreased NPK availability after 60 DAT may be due to higher uptake of NPK by plants at bulb formation and bulb development stage. The significantly maximum nutrient availability was observed in treatment T_5 (DI with 100%RD of CF + 9 lit ha^{-1} fertigation of root booster) followed by T_4 and T_3 at 30 and 60 DAT. However, at 90 DAT and at harvest treatment T_3 recorded maximum NPK availability as compared to T_5 might be due to less nutrient uptake by the crop. Treatment T_9 (DI with no fertilizer) was recorded less availability of nutrients in all periodical observation it might be due to no fertilizer application.

5.1.4 Nutrient Uptake by Plant

The significantly maximum uptake of nitrogen, phosphorus and potassium was found in treatment T_5 (DI with 100%RD of CF + 9 lit ha^{-1} fertigation of root booster) at all growth stages. The higher uptake may be due to drip irrigation with 100% RD of conventional fertilizers and 9 lit ha^{-1} fertigation of root booster which helped to increase nutrient uptake. In treatment T_9 (DI with no fertilizer), lowest value of nitrogen, phosphorus and potassium uptake was observed at all the stages of onion crop.

5.1.5 Nutrient use efficiency

The maximum nutrient use efficiency (136.80 kg yield kg^{-1}) was observed treatments T_5 (DI with 100%RD of CF + 9 lit ha^{-1} fertigation of root booster) over all other treatments. The lowest nutrient use efficiency (104.15 kg yield kg^{-1}) was observed in treatments T_2 (DI with 100 % RD of CF).

5.1.6 Storage of onion

The storage losses i.e. rottening, physiological and total weight losses in stored onion were higher in surface irrigation treatment T_1 followed by T_9 and T_5, respectively. The minimum storage losses i.e. rottening, physiological and total weight losses in stored onion were observed in treatment T_8.

5.1.7 Economics of onion

Cost of cultivation was observed higher in drip irrigation with fertigation of root booster treatments than conventional irrigation treatments (SI) due to the cost of irrigation systems and higher costs of root booster. Treatment T_5 (DI with 100%RD of CF + 9 lit ha^{-1} fertigation of root booster) gave highest net seasonal income, total net income, net extra income over control, B:C ratio and water productivity, it was followed by T_4 and T_3 whereas, T_9 (DI with no fertilizer) gave lowest values for all economical parameters.

5.2 Conclusions

1. DI with 100%RD of CF + 9 lit ha^{-1} fertigation of root booster recorded significantly higher values for all growth and yield attributing characters; however, it was at par with DI with 100%RD of CF + 7 lit ha^{-1} fertigation of root booster and DI with 100% RD of CF + 5 lit ha^{-1} fertigation of root booster in many observations.

2. The nutrient uptake was significantly maximum in treatment DI with 100%RD of CF + 9 lit ha^{-1} fertigation of root booster over DI with 100% RD of CF (Urea, SSP, MOP) and SI with 100% RD of CF (Urea, SSP, MOP). The treatment DI with 100%RD of CF + 5 lit ha^{-1} fertigation of root booster recorded maximum availability of N, P and K as 167.0, 17.5 and 551.0 kg ha^{-1}, respectively at harvest.

3. The highest yield of onion (44.98 t ha^{-1}) was obtained in treatment 100%RD of CF + 9 lit ha^{-1} fertigation of root booster were applied with drip irrigation system. However, it was at par with DI with 100%RD of CF + 7 lit ha^{-1} fertigation of root booster.

4. All the drip treatments (341 mm) used the lowest amount of water as compared to surface method of irrigation (600 mm) with 76 % water saving as compared to surface irrigation.

5. Drip irrigation with 100%RD of CF + 9 lit ha^{-1} fertigation of root booster recorded higher net seasonal income of Rs 257602 ha^{-1}, total net income of Rs 384181 ha^{-1}, net extra income over control of Rs 47285 ha^{-1} and B:C ratio of 3.52 over DI with 100 % RD of CF followed by SI with 100 % RD of CF.

6. The treatment DI with 75% RD of CF + 9 lit ha^{-1} fertigation of root booster resulted in to lowest rottening, physiological and total weight losses i.e. 4.8, 10.7 and 15.5 per cent, respectively in storability at 180 DAH than all other treatments. The SI with 100% RD of conventional fertilizer recorded significantly maximum rottening, physiological and total weight losses i.e. 7.6, 12.3 and 19.9 per cent, respectively followed by DI with no fertilizer and DI with 100%RD of CF + 9 lit ha^{-1} fertigation of root booster.

From above study, it can be concluded that drip irrigation with 100% RD of CF and fertigation of 9 lit ha^{-1} root booster at weekly interval for eight weeks is the best treatment for improved growth, yield and economical returns from *rabi* onion cultivated in silty clay soils in semi-arid region of Maharashtra.

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7. APPNDICES

Appendix-I: Cost of cultivation of onion (Rs) as influenced by different treatments

	Treatments	**T_1 SI**		**T_2 DI**		**T_3 DI**		**T_4 DI**		**T_5 DI**		**T_6 DI**		**T_7 DI**		**T_8 DI**		**T_9 DI**	
	Items cost/charges	Qty	Cost (Rs.)	Qty	Cost (Rs.)	Qty	Cost (Rs.)	Qty	Cost (Rs.)	Qty	Cost (Rs.)	Qty	Cost (Rs.)	Qty	Cost (Rs.)	Qty	Cost (Rs.)	Qty	Cost (Rs.)
1	Ploughing @ 4000 ha^{-1}	1	4000	1	4000	1	4000	1	4000	1	4000	1	4000	1	4000	1	4000	1	4000
2	Harrowing @ 2000 ha^{-1}	1	2000	1	2000	1	2000	1	2000	1	2000	1	2000	1	2000	1	2000	1	2000
3	Onion seed @ 1200 kg^{-1}	7	8400	7	8400	7	8400	7	8400	7	8400	7	8400	7	8400	7	8400	7	8400
4	Pesticide/ insecticide	1	4500	1	4500	1	4500	1	4500	1	4500	1	4500	1	4500	1	4500	1	4500
5	Electricity		950		750		750		750		750		750		750		750		750
6	Water		380		200		200		200		200		200		200		200		200
7	Labour 250 day^{-1}	210	52500	200	50000	200	50000	200	50000	200	50000	200	50000	200	50000	200	50000	200	50000
8	Fertilizer charges																		
	Urea @ 6 Kg^{-1}	217	1302	217	1302	217	1302	217	1302	217	1302	163	976	163	976	163	976	0	0
	SSP @ 8 Kg^{-1}	313	2504	313	2504	313	2504	313	2504	313	2504	235	1880	235	1880	235	1880	0	0
	MOP @ 17 Kg^{-1}	84	1428	84	1428	84	1428	84	1428	84	1428	63	1071	63	1071	63	1071	0	0
9	Root booster **@ 500** $Liter^{-1}$	0	0	0	0	5	2500	7	3500	9	4500	5	2500	7	3500	9	4500	0	0
10	**A**. Working capital.		77964		75084		77584		78584		79584		76277		77277		78277		69850
11	**B**. Interest on working capital @10 %		7796	0	7508	0	7758	0	7858	0	7958	0	7628	0	7728	0	7828	0	6985
12	**C**. Rental value of land		3000		3000		3000		3000		3000		3000		3000		3000		3000
	Total cost (**A+B+C**)		88760		85592		88342		89442		90542		86905		88005		89105		79835

Appendix-II: Economics of onion crop (Rs)

Sr.No	Items	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9
1	Fixed cost irrigation system (Rs Season ha^{-1})	1480	11664	11664	11664	11669	11664	11664	11664	11664
2	Operational cost (Rs)	88760.4	85592.4	88342.4	89442.4	90542.4	86904.7	88004.7	89104.7	79835
3	Seasonal cost (Rs ha^{-1})	90240	97256	100006	101106	102211	98569	99669	100769	91499
4	Water used (mm)	600	341	341	341	341	341	341	341	341
6	Yield of onion (t ha^{-1})	39.07	38.45	40.69	42.10	44.98	33.51	34.65	36.75	17.62
7	Selling price (Rs t^{-1})	8000	8000	8000	8000	8000	8000	8000	8000	8000
8	Income from produce (Rs ha^{-1})	312560	307573	325520	336800	359813	268080	277173	293993	140997
9	Net seasonal income (Rs ha^{-1})	222320	210317	225514	235694	257602	169511	177505	193225	49498
10	Additional area	0.0	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76
11	Additional expenditure	0.0	47585	48930.7	49468	50010	48227	48766	49304	44768
12	Additional income	0.0	150488	159269.1	164788	176048	131165	135614	143844	68986
13	Additional net income	0.0	150488	111683.9	115857	126579	81155	87387	95078	19683
14	Total net income	222320	361028	337127	351551	384181	250667	264892	288303	69180
15	Net Extra income over control	12003	0	15197	25377	57285	-40806	-32812	-17092	-160819
16	B:C Ratio	3.46	3.16	3.25	3.33	3.52	2.72	2.78	2.92	1.54
17	WUE (kg ha^{-1}mm)	65.12	112.68	119.26	123.39	131.82	98.21	101.54	107.71	51.65
18	Water Productivity (Rs mm^{-1} of water used)	370.5	616.8	661.3	691.2	755.4	494.1	520.5	566.6	145.1

APPENDIX-III: Economics of surface and drip irrigation for onion crop

Sr. No,	Items	Cost (Rs)	Life (years)	Depreciation= (OC-JV)/L	Interest @ 12% pa (Rs)	Repair & maintenance @ 2 % pa
I	**Surface Irrigation**					
1	Centrifugal pump set (5HP) & accessories	8000	20	360	960	160
	Total annual cost	**1480**				
II	**Drip Irrigation**					
2	Centrifugal pump set (5HP) & accessories	8000	20	360	960	160
3	Screen Filter	3000	10	270	360	60
4	Bypass	1000	10	90	120	20
5	Fertilizer tank	5000	10	450	600	100
6	PVP pipe, 90 mm (main-50 m/ha) @ 70 Rs/m	3500	10	558	420	70
7	PVP pipe, 63 mm (submain-51m/ ha) @ 45 Rs/m	2295	10	206.5	275.4	45.9
8	PVP pipe, 40 mm (manifold-200 m) @ 36 Rs/m	7200	10	648	864	144
9	LDPE lateral 16 mm (8333 m) @ 10.60 Rs/m	88330	7	11357	10599	1767
10	GTO for LDPE lateral 16 mm @ 3 Rs/unit (for 180 laterals)	540	7	69	64.8	10.8
11	LDPE end caps @ 2 Rs/unit (for 180 laterals)	360	7	46	43.2	7.2
12	PVC fittings	1000	7	128.5	120	20
13	Pressure gauge	1662	7	214	199	33
14	Valves	1000	7	128.5	120	20
15	Total fixed cost	122887		14101	14746	2458
16	Installation @ 3% of total cost	3687				
	Total annual cost	**Rs 34992 ha^{-1}**				
	Total seasonal cost	**Rs 11664 ha^{-1}**				

Appendix-IV Crop water requirement of onion under drip irrigation

Sr. No.	Date	ETr	CETr	Kc	Rainfall	CWR (mm)
	Initial Stage 0-20 DAT					
1	30.12.2017	4.20	7.68	0.7	0	5.4
2	31.12.2017	3.48		0.7	0	
3	1.01.2018	3.20	6.6	0.7	0	4.6
4	2.01.2018	3.40		0.7	0	
5	3.01.2018	3.30	6.5	0.7	0	4.6
6	4.01.2018	3.20		0.7	0	
7	5.01.2018	3.10	6.5	0.7	0	4.6
8	6.01.2018	3.40		0.7	0	
9	7.01.2018	3.60	6.7	0.7	0	4.7
10	8.01.2018	3.10		0.7	0	
11	9.01.2018	2.90	6.1	0.7	0	4.3
12	10.01.2018	3.20		0.7	0	
13	11.01.2018	3.40	6.5	0.7	0	4.6
14	12.01.2018	3.10		0.7	0	
15	13.01.2018	2.97	6.17	0.7	0	4.3
16	14.01.2018	3.20		0.7	0	
17	15.01.2018	2.80	5.25	0.7	0	3.7
18	16.01.2018	2.45		0.7	0	
19	17.01.2018	2.52	5.72	0.7	0	4.0
20	18.01.2018	3.20		0.7	0	
	Development Stage 21-50 DAT					
21	19.01.2018	2.80	6.2	1.05	0	6.5
22	20.01.2018	3.40		1.05	0	
23	21.01.2018	2.68	5.58	1.05	0	5.9
24	22.01.2018	2.90		1.05	0	
25	23.01.2018	3.20	6	1.05	0	6.3
26	24.01.2018	2.80		1.05	0	
27	25.01.2018	3.40	6.6	1.05	0	6.9
28	26.01.2018	3.20		1.05	0	
29	27.01.2018	2.90	5.48	1.05	0	5.8
30	28.01.2018	2.58		1.05	0	
31	29.01.2018	2.41	4.94	1.05	0	5.2
32	30.01.2018	2.53		1.05	0	
33	31.01.2018	2.21	5.02	1.05	0	5.3
34	1.02.2018	2.81		1.05	0	
35	2.02.2018	2.99	5.72	1.05	0	6.0
36	3.02.2018	2.73		1.05	0	
37	4.02.2018	2.61	5.34	1.05	0	5.6
38	5.02.2018	2.73		1.05	0	

Appendix-IV contd…..

Sr. No.	Date	ETr	CETr	Kc	Rainfall	CWR (mm)
39	6.02.2018	2.66	5.33	1.05	0	5.6
40	7.02.2018	2.67		1.05	0	
41	8.02.2018	2.53	5.18	1.05	0	5.4
42	9.02.2018	2.65		1.05	0	
43	10.02.2018	3.53	6.73	1.05	0	7.1
44	11.02.2018	3.20		1.05	0	
45	12.02.2018	3.18	6.34	1.05	0	6.7
46	13.02.2018	3.16		1.05	0	
47	14.02.2018	3.28	6.47	1.05	0	6.8
48	15.02.2018	3.19		1.05	0	
49	16.02.2018	3.26	6.64	1.05	0	7.0
50	17.02.2018	3.38		1.05	0	
Mid-season stage 51-92 DAT						
51	18.02.2018	3.20	6.39	1.05	0	6.7
52	19.02.2018	3.19		1.05	0	
53	20.02.2018	3.12	6.36	1.05	0	6.7
54	21.02.2018	3.24		1.05	0	
55	22.02.2018	3.36	6.55	1.05	0	6.9
56	23.02.2018	3.19		1.05	0	
57	24.02.2018	3.26	6.4	1.05	0	6.7
58	25.02.2018	3.14		1.05	0	
59	26.02.2018	3.70	7.33	1.05	0	7.7
60	27.02.2018	3.63		1.05	0	
61	28.02.2018	3.40	7	1.05	0	7.4
62	1.03.2018	3.60		1.05	0	
63	2.03.2018	3.49	7.02	1.05	0	7.4
64	3.03.2018	3.53		1.05	0	
65	4.03.2018	3.46	7.02	1.05	0	7.4
66	5.03.2018	3.56		1.05	0	
67	6.03.2018	3.45	7.59	1.05	0	8.0
68	7.03.2018	4.14		1.05	0	
69	8.03.2018	4.16	8.21	1.05	0	8.6
70	9.03.2018	4.05		1.05	0	
71	10.03.2018	3.05	6.55	1.05	0	6.9
72	11.03.2018	3.50		1.05	0	
73	12.03.2018	3.53	7.02	1.05	0	7.4
74	13.03.2018	3.49		1.05	0	
75	14.03.2018	3.54	7.24	1.05	0	7.6
76	15.03.2018	3.70		1.05	0	

Appendix-IV contd…..

Sr. No.	Date	ETr	CETr	Kc	Rainfall	CWR (mm)
77	16.03.2018	3.67	7.17	1.05	0	7.5
78	17.03.2018	3.50		1.05	0	
79	18.03.2018	3.94	7.76	1.05	0	8.1
80	19.03.2018	3.82		1.05	0	
81	20.03.2018	4.02	7.69	1.05	0	8.1
82	21.03.2018	3.67		1.05	0	
83	22.03.2018	3.42	7.73	1.05	0	8.1
84	23.03.2018	4.31		1.05	0	
85	24.03.2018	4.05	8.1	1.05	0	8.5
86	25.03.2018	4.05		1.05	0	
87	26.03.2018	4.47	8.94	1.05	0	9.4
88	27.03.2018	4.47		1.05	0	
89	28.03.2018	3.93	8.49	1.05	0	8.9
90	29.03.2018	4.56		1.05	0	
91	30.03.2018	4.28	8.56	1.05	0	9.0
92	31.03.2018	4.28		1.05	0	
Late season stage 93-120 DAT						
93	1.04.2018	3.68	8.28	0.75	0	6.2
94	2.04.2018	4.60		0.75	0	
95	3.04.2018	4.42	9.18	0.75	0	6.9
96	4.04.2018	4.76		0.75	0	
97	5.04.2018	3.93	8.46	0.75	0	6.3
98	6.04.2018	4.53		0.75	0	
99	7.04.2018	3.62	7.88	0.75	0	5.9
100	8.04.2018	4.26		0.75	0	
101	9.04.2018	4.73	8.81	0.75	0	6.6
102	10.04.2018	4.08		0.75	0	
103	11.04.2018	4.51	8.7	0.75	0	6.5
104	12.04.2018	4.19		0.75	0	
105	13.04.2018	4.44	9.04	0.75	0	6.8
106	14.04.2018	4.60		0.75	0	
	Irrigation stopped two weeks before harvest					
	Harvesting date: 04/05/2018					341.2

Appendix-V Crop water requirement of onion under surface irrigation

Sr. No.	Date	Epan (mm)	CPE (mm)	Kc	Kp	Rainfall	CWR (mm)
	Initial Stage 0-20 DAT						
1	30.12.2017	3.8	48.3	0.7	0.7	0	50
2	31.12.2017	3.5		0.7	0.7	0	
3	1.01.2018	3.8		0.7	0.7	0	
4	2.01.2018	4.2		0.7	0.7	0	
5	3.01.2018	4.5		0.7	0.7	0	
6	4.01.2018	3.6		0.7	0.7	0	
7	5.01.2018	3.4		0.7	0.7	0	
8	6.01.2018	3.8		0.7	0.7	0	
9	7.01.2018	3.6		0.7	0.7	0	
10	8.01.2018	3.2		0.7	0.7	0	
11	9.01.2018	3.8		0.7	0.7	0	
12	10.01.2018	3.5		0.7	0.7	0	
13	11.01.2018	3.6		0.7	0.7	0	
14	12.01.2018	4	48.1	0.7	0.7	0	50
15	13.01.2018	4.4		0.7	0.7	0	
16	14.01.2018	4.8		0.7	0.7	0	
17	15.01.2018	4.5		0.7	0.7	0	
18	16.01.2018	4		0.7	0.7	0	
19	17.01.2018	4.2		0.7	0.7	0	
20	18.01.2018	4.4		0.7	0.7	0	
Development Stage 21-50 DAT							
21	19.01.2018	5		1.05	0.7	0	
22	20.01.2018	4.6		1.05	0.7	0	
23	21.01.2018	4.2		1.05	0.7	0	
24	22.01.2018	4		1.05	0.7	0	
25	23.01.2018	5.2	53.5	1.05	0.7	0	50
26	24.01.2018	5.4		1.05	0.7	0	
27	25.01.2018	4.8		1.05	0.7	0	
28	26.01.2018	4.4		1.05	0.7	0	
29	27.01.2018	4.6		1.05	0.7	0	
30	28.01.2018	4.5		1.05	0.7	0	
31	29.01.2018	4.2		1.05	0.7	0	
32	30.01.2018	4.8		1.05	0.7	0	
33	31.01.2018	5.2		1.05	0.7	0	
34	1.02.2018	5.6		1.05	0.7	0	
35	2.02.2018	4.8		1.05	0.7	0	
36	3.02.2018	5.4	52.5	1.05	0.7	0	50
37	4.02.2018	5.5		1.05	0.7	0	
38	5.02.2018	5.2		1.05	0.7	0	

Appendix-V contd…..

Sr. No.	Date	Epan (mm)	CPE (mm)	Kc	Kp	Rainfall	CWR (mm)
39	6.02.2018	5.6		1.05	0.7	0	
40	7.02.2018	4.4		1.05	0.7	0	
41	8.02.2018	3.8		1.05	0.7	0	
42	9.02.2018	5		1.05	0.7	0	
43	10.02.2018	5.6		1.05	0.7	0	
44	11.02.2018	5.8		1.05	0.7	0	
45	12.02.2018	6.2		1.05	0.7	0	
46	13.02.2018	5.2	50.1	1.05	0.7	0	50
47	14.02.2018	5.6		1.05	0.7	0	
48	15.02.2018	4.8		1.05	0.7	0	
49	16.02.2018	4.5		1.05	0.7	0	
50	17.02.2018	5.2		1.05	0.7	0	
Mid-season stage 51-92 DAT							
51	18.02.2018	5.6		1.05	0.7	0	
52	19.02.2018	6.2		1.05	0.7	0	
53	20.02.2018	6.6		1.05	0.7	0	
54	21.02.2018	6.4		1.05	0.7	0	
55	22.02.2018	5.8	48.8	1.05	0.7	0	50
56	23.02.2018	6		1.05	0.7	0	
57	24.02.2018	5.6		1.05	0.7	0	
58	25.02.2018	5.4		1.05	0.7	0	
59	26.02.2018	6.4		1.05	0.7	0	
60	27.02.2018	6.8		1.05	0.7	0	
61	28.02.2018	6.2		1.05	0.7	0	
62	1.03.2018	6.6		1.05	0.7	0	
63	2.03.2018	7.7	50.7	1.05	0.7	0	50
64	3.03.2018	6.8		1.05	0.7	0	
65	4.03.2018	6.4		1.05	0.7	0	
66	5.03.2018	5.8		1.05	0.7	0	
67	6.03.2018	6.2		1.05	0.7	0	
68	7.03.2018	5.6		1.05	0.7	0	
69	8.03.2018	6.2		1.05	0.7	0	
70	9.03.2018	6		1.05	0.7	0	
71	10.03.2018	6.4	48.1	1.05	0.7	0	50
72	11.03.2018	6.2		1.05	0.7	0	
73	12.03.2018	6.8		1.05	0.7	0	
74	13.03.2018	7.2		1.05	0.7	0	
75	14.03.2018	7.8		1.05	0.7	0	
76	15.03.2018	6.5		1.05	0.7	0	
77	16.03.2018	7.2		1.05	0.7	0	
78	17.03.2018	6.8	50.6	1.05	0.7	0	50

Appendix-V contd….

Sr. No.	Date	Epan (mm)	CPE (mm)	Kc	Kp	Rainfall	CWR (mm)
79	18.03.2018	7		1.05	0.7	0	
80	19.03.2018	7.4		1.05	0.7	0	
81	20.03.2018	6.8		1.05	0.7	0	
82	21.03.2018	7.2		1.05	0.7	0	
83	22.03.2018	7.8		1.05	0.7	0	
84	23.03.2018	7.6		1.05	0.7	0	
85	24.03.2018	6.8	47	1.05	0.7	0	50
86	25.03.2018	6.2		1.05	0.7	0	
87	26.03.2018	7.8		1.05	0.7	0	
88	27.03.2018	8.2		1.05	0.7	0	
89	28.03.2018	8.8		1.05	0.7	0	
90	29.03.2018	9.2		1.05	0.7	0	
91	30.03.2018	8.6	50.3	1.05	0.7	0	50
92	31.03.2018	8.4		1.05	0.7	0	
93	1.04.2018	8.8		1.05	0.7	0	
Late season stage 93-120 DAT							
94	2.04.2018	8.5		0.75	0.7	0	
95	3.04.2018	7.8		0.75	0.7	0	
96	4.04.2018	8.2		0.75	0.7	0	
97	5.04.2018	8	50.5	0.75	0.7	0	50
98	6.04.2018	7.5		0.75	0.7	0	
99	7.04.2018	5.8		0.75	0.7	0	
100	8.04.2018	6.6		0.75	0.7	0	
101	9.04.2018	7		0.75	0.7	0	
102	10.04.2018	7.6		0.75	0.7	0	
103	11.04.2018	18		0.75	0.7	0	
104	12.04.2018	8.4		0.75	0.7	0	17 days before harvesting irrigation to crop stopped.
105	13.04.2018	8.8		0.75	0.7	0	
106	14.04.2018	9.4		0.75	0.7	0	
107	15.04.2018	10		0.75	0.7	0	
108	16.04.2018	10.4		0.75	0.7	0	
109	17.04.2018	9.8		0.75	0.7	0	
110	18.04.2018	7.6		0.75	0.7	0	
111	19.04.2018	10.2		0.75	0.7	0	
112	20.04.2018	11.6		0.75	0.7	0	
113	21.04.2018	12.2		0.75	0.7	0	
114	22.04.2018	11.4		0.75	0.7	0	
115	23.04.2018	11.8		0.75	0.7	0	
116	24.04.2018	12.8		0.75	0.7	0	
117	25.04.2018	12.8		0.75	0.7	0	
118	26.04.2018	13.2		0.75	0.7	0	
119	27.04.2018	12.6		0.75	0.7	0	
120	28.04.2018	13.8		0.75	0.7	0	
Total		785.3					600

8. VITA

Mr. Mohammad Ali Rasooli
A candidate for the degree
of
MASTER OF SCIENCE (AGRICULTURE)
in
IRRIGATION WATER MANAGEMENT
2019

Title of thesis		:	"Effect of Root Booster Through Fertigation on Yield of Onion (*Allium cepa* L.), Nutrient Uptake and Availability in Inceptisols in Semi-arid Region of Maharashtra"
Major field			Irrigation Water Management
Biographical Information		:	
Personal	Date of Birth	:	02 July 1973
	Father's Name	:	Bostan Ali
	Place of Birth	:	Ghazni Province, Afghanistan
Education		:	Completed B.Sc. (Agri) from Kabul University Faculty of Agriculture in 2007
		:	Graduated from 12th class Ghazi High School in 1989
Address		:	Fifth District, Naizbik, Kabul, Afghanistan
	Email id	:	mohdalirasooli@yahoo.com
	Contact Number	:	+93 779149040 / +93 779149041

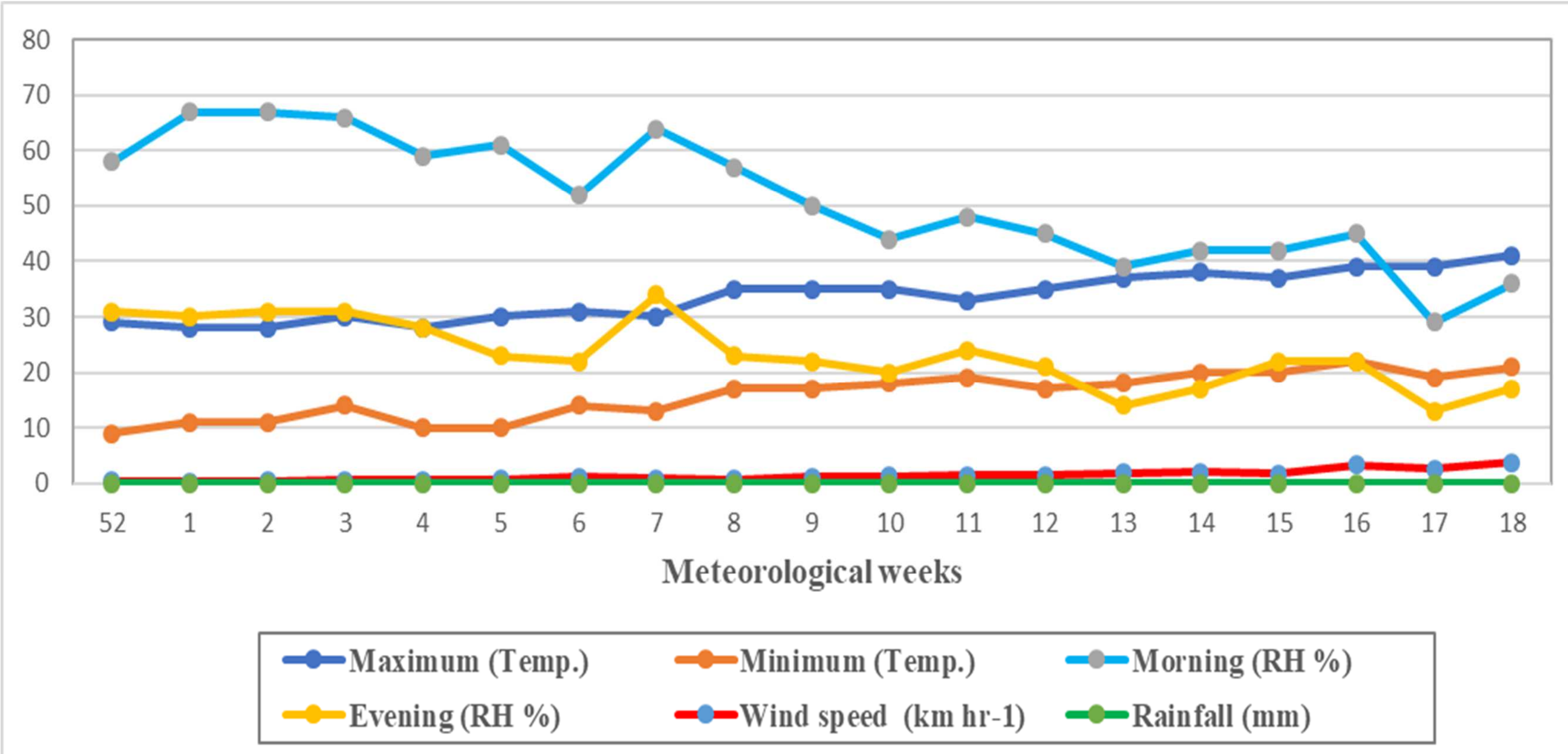
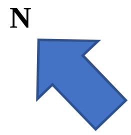


Fig. 3.1 Details of meteorological data during experimental period



Design : **Randomized Block Deaign**

Treatments : **Nine**

Replications : **Three**

Gross Plot Size : **4.8 m x 8.25 m**

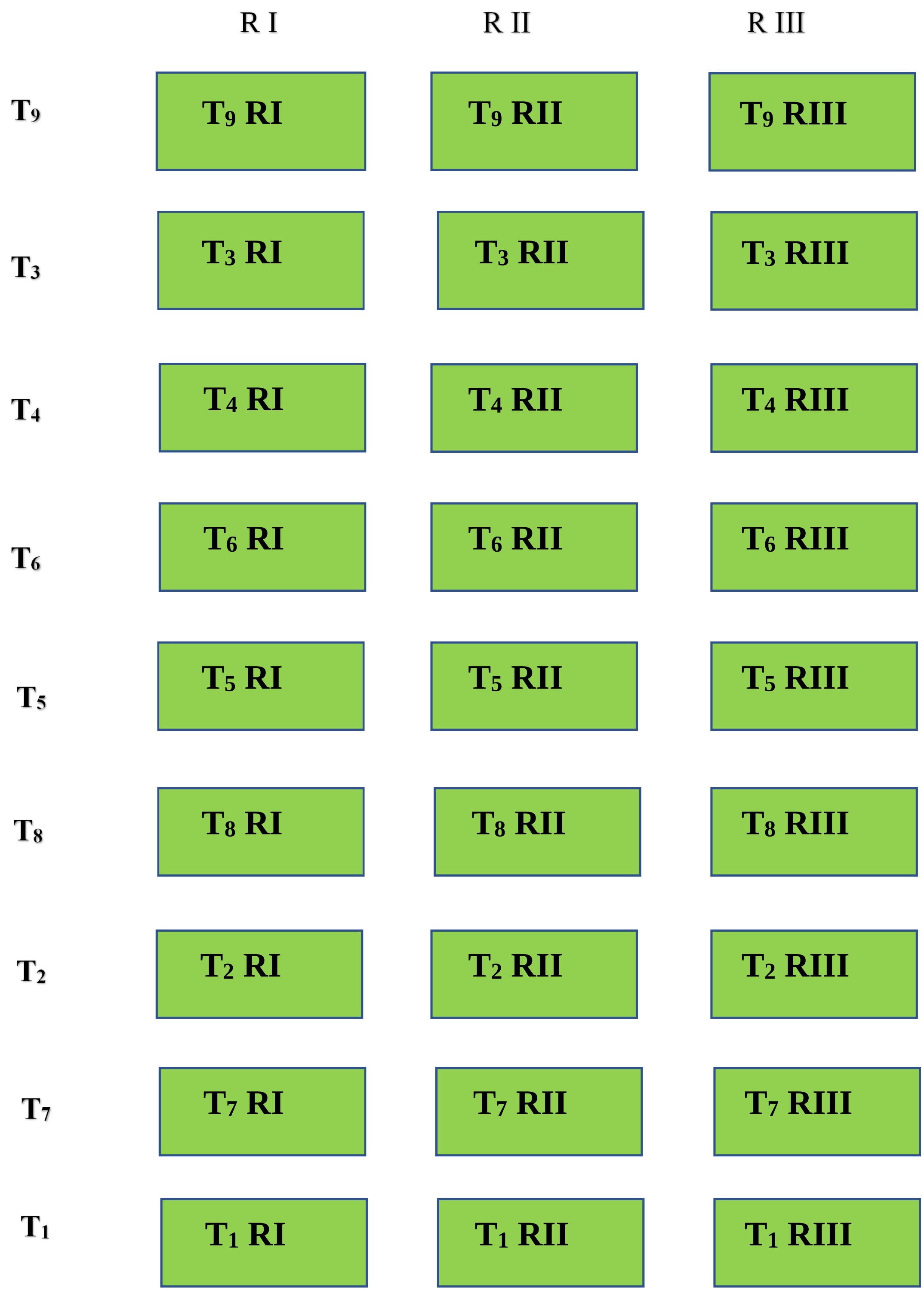


Fig 3.2 Layout of Field Experiment

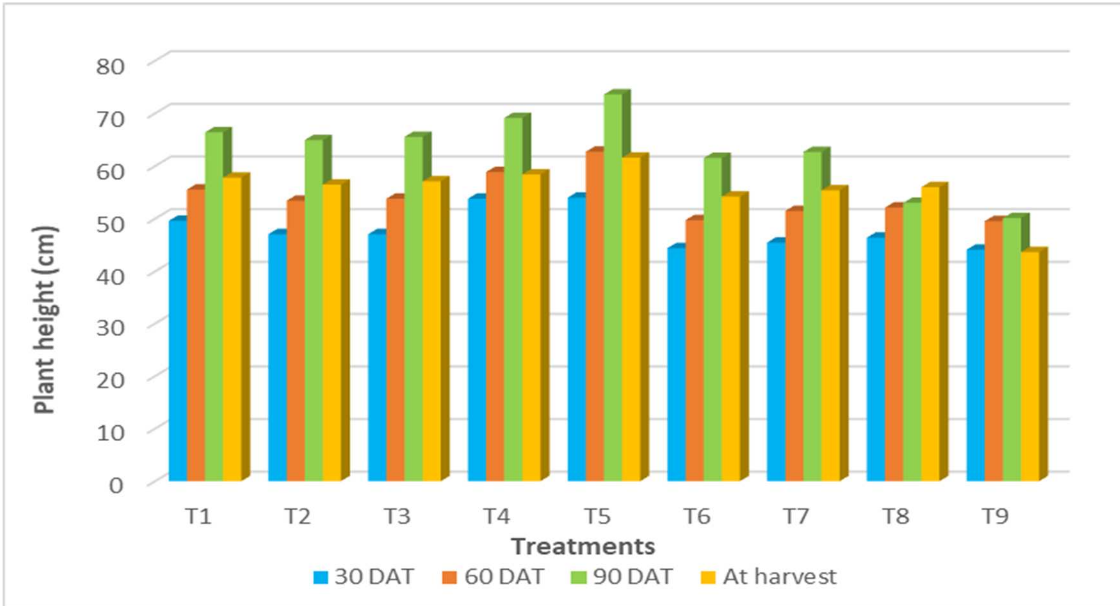


Fig. 4.1 Periodical plant height of onion as influenced by different treatments

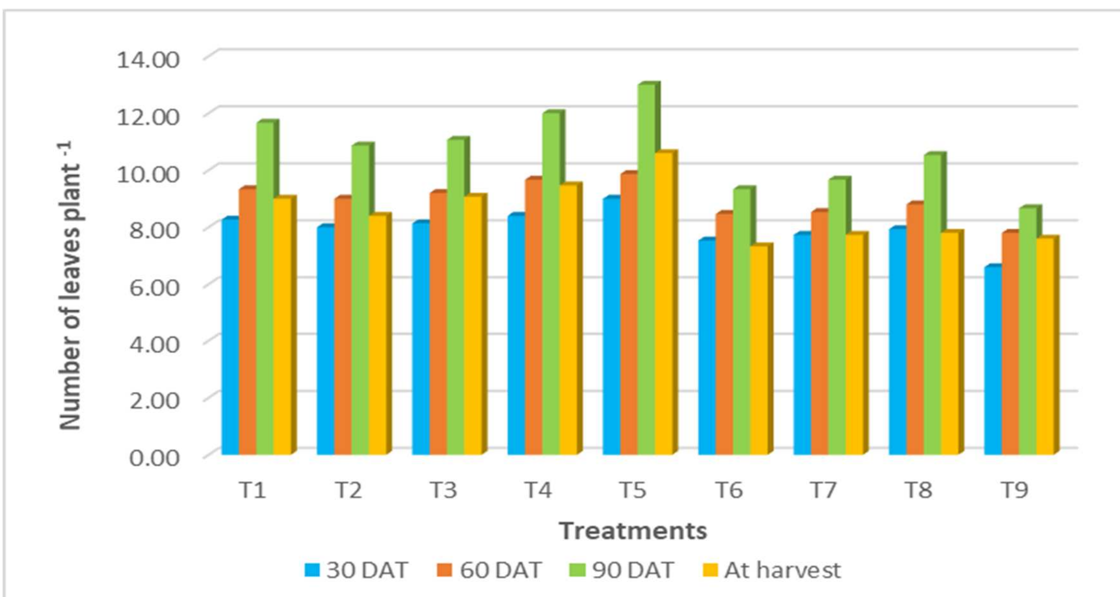


Fig. 4.2 Periodical number of leaves plant^{-1} as influenced by different treatments

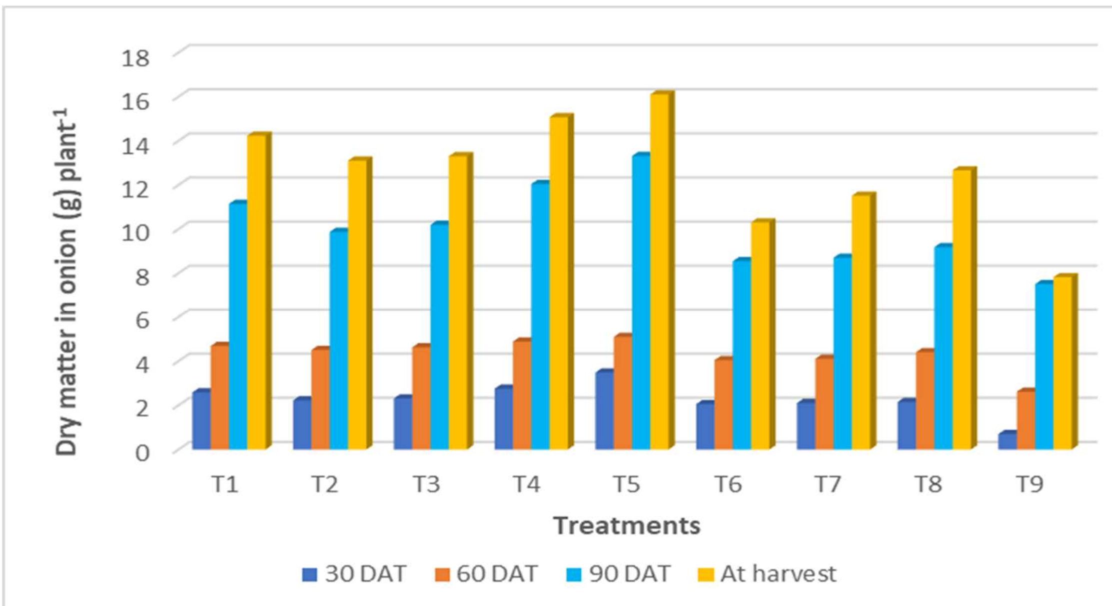


Fig 4.3 Mean dry matter content of onion as influenced by different treatments

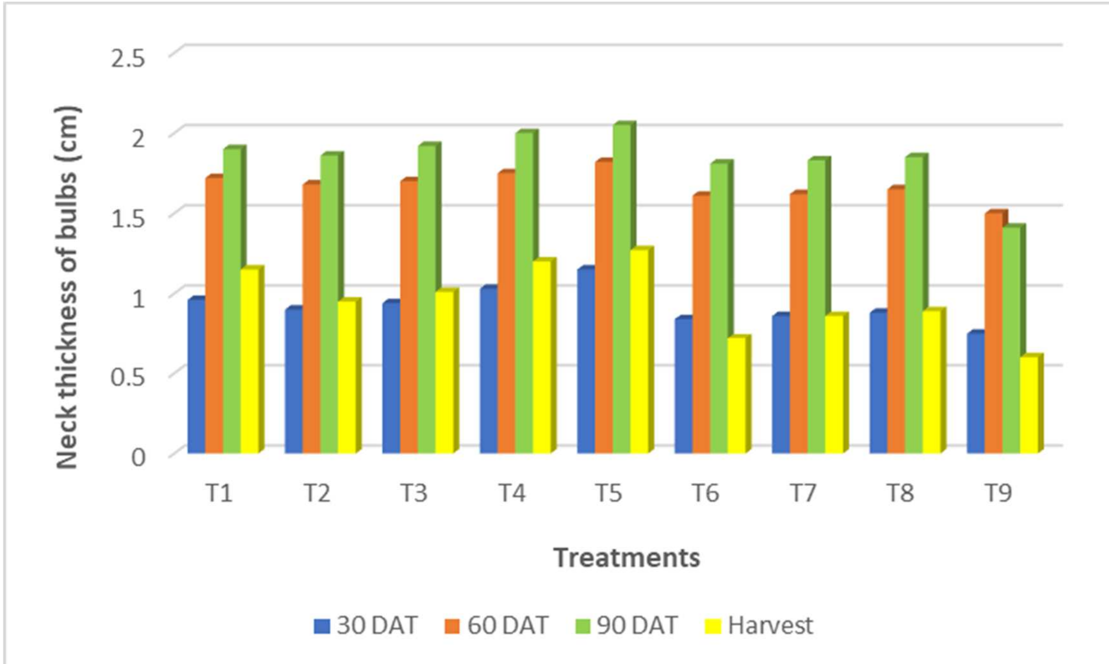


Fig. 4.4 Periodical mean neck thickness of bulbs as influenced by different treatments

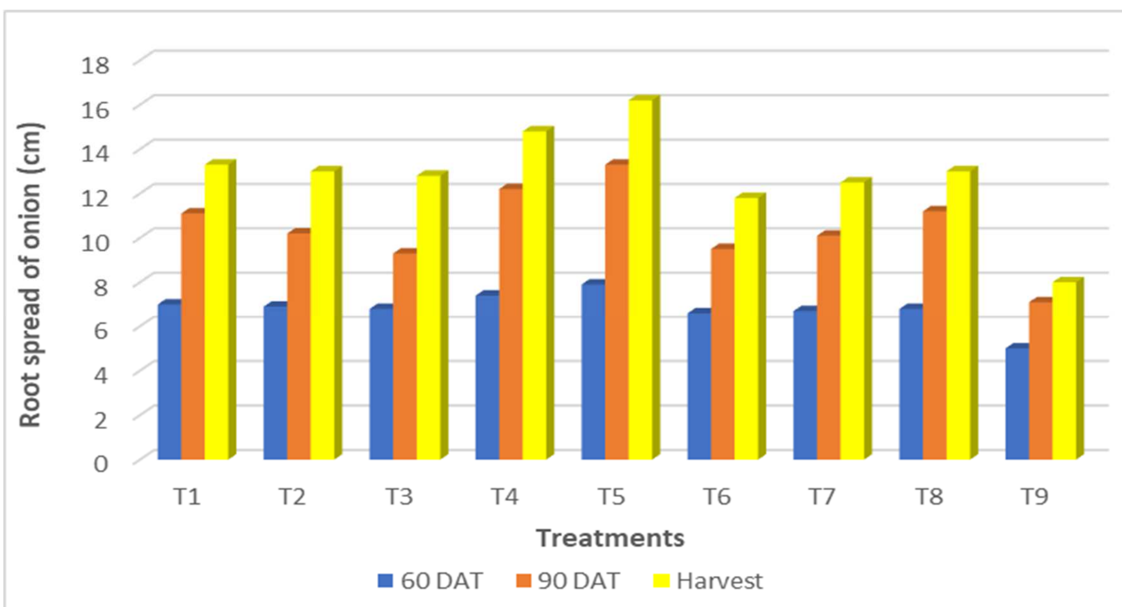


Fig. 4.5 Periodical mean root spread of onion as influenced by different treatments

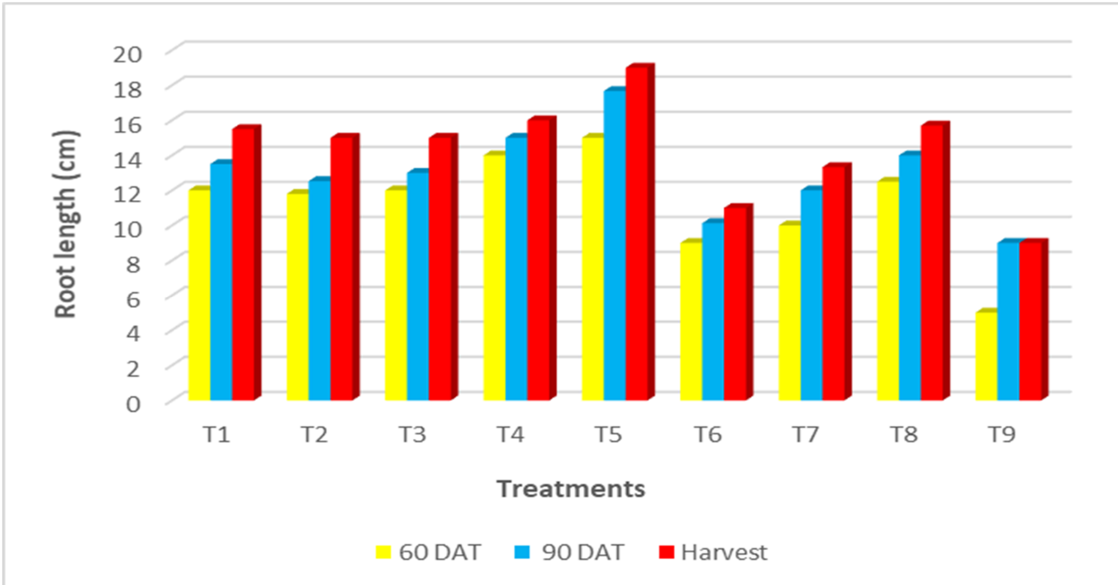


Fig. 4.6 Mean root length of onion as influenced by different treatments

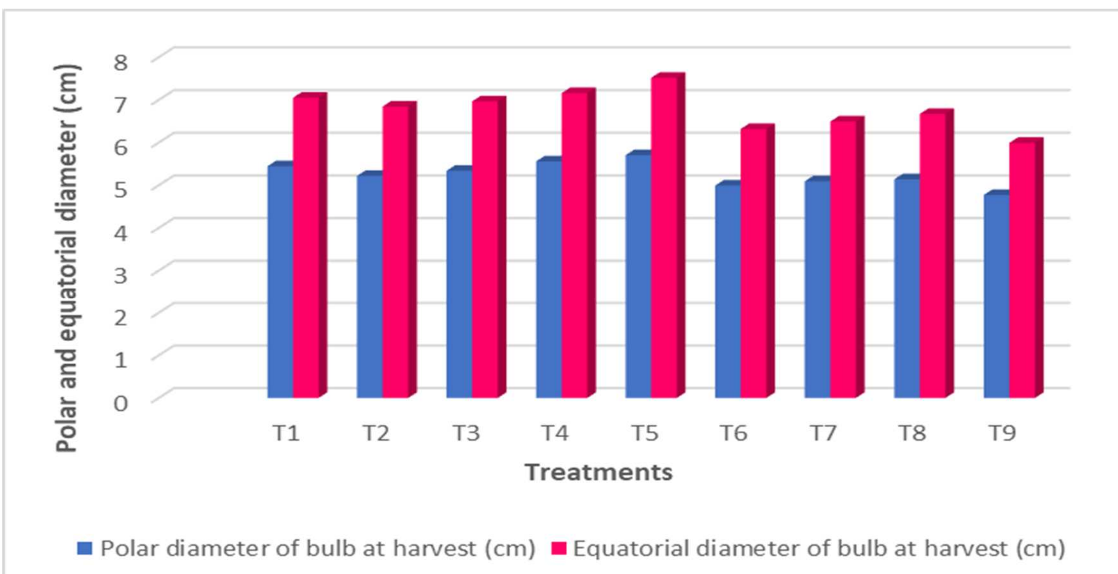


Fig. 4.7 Mean polar and equatorial diameter of onion bulbs as influenced by different treatments

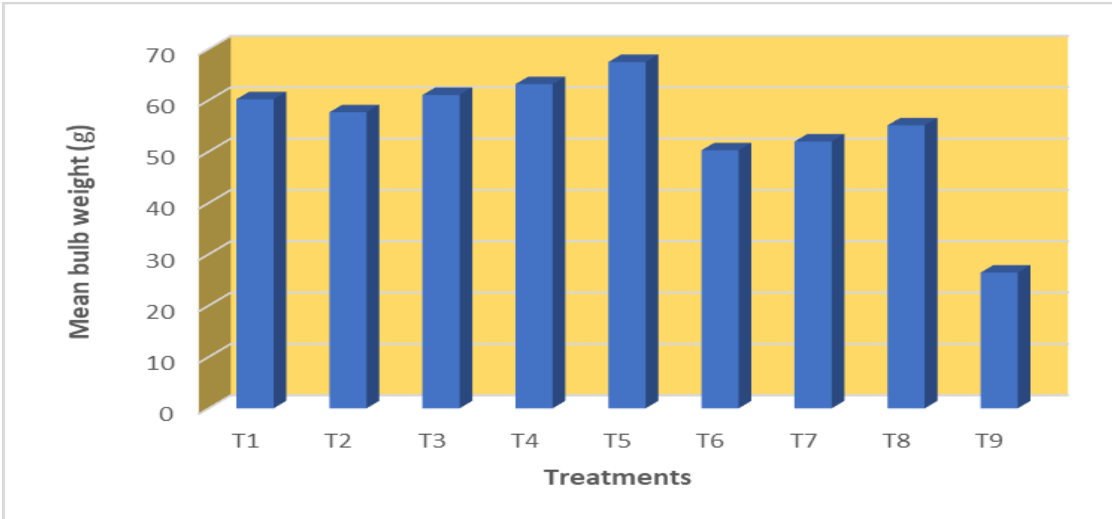


Fig. 4.8 Mean average bulb weight as influenced by different treatments

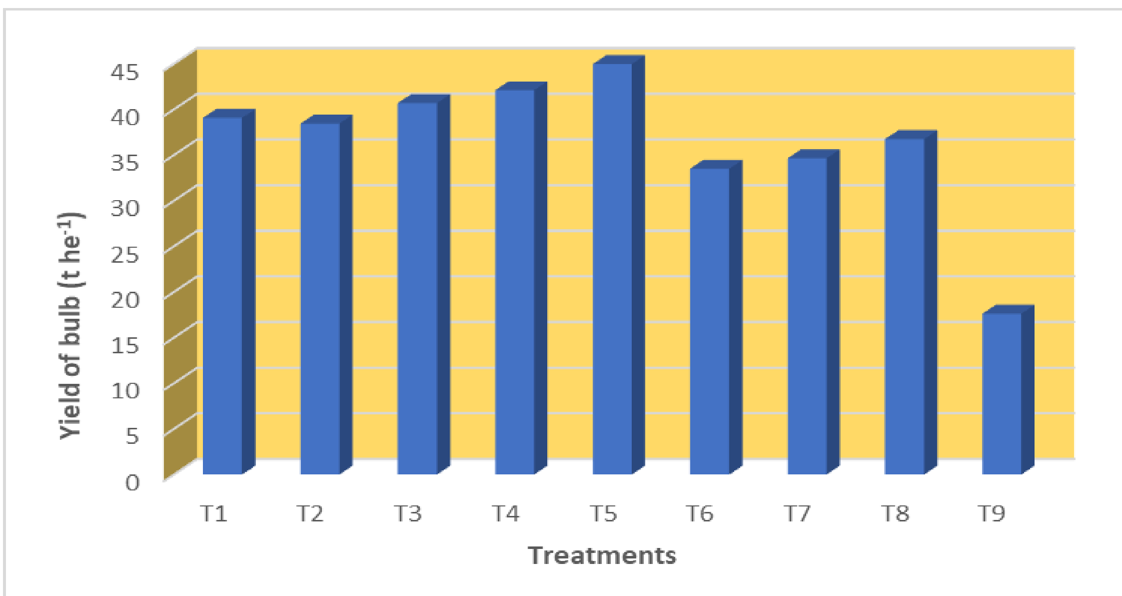


Fig 4.9 Yield of onion bulb as influenced by different treatments

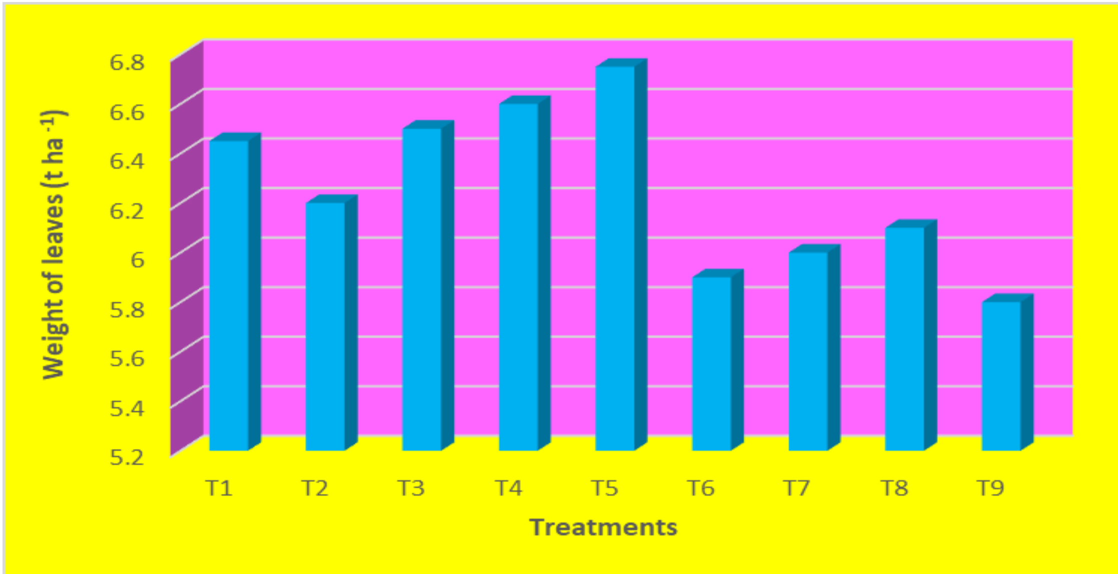


Fig 4.10 Weight of leaves as influenced by different treatments

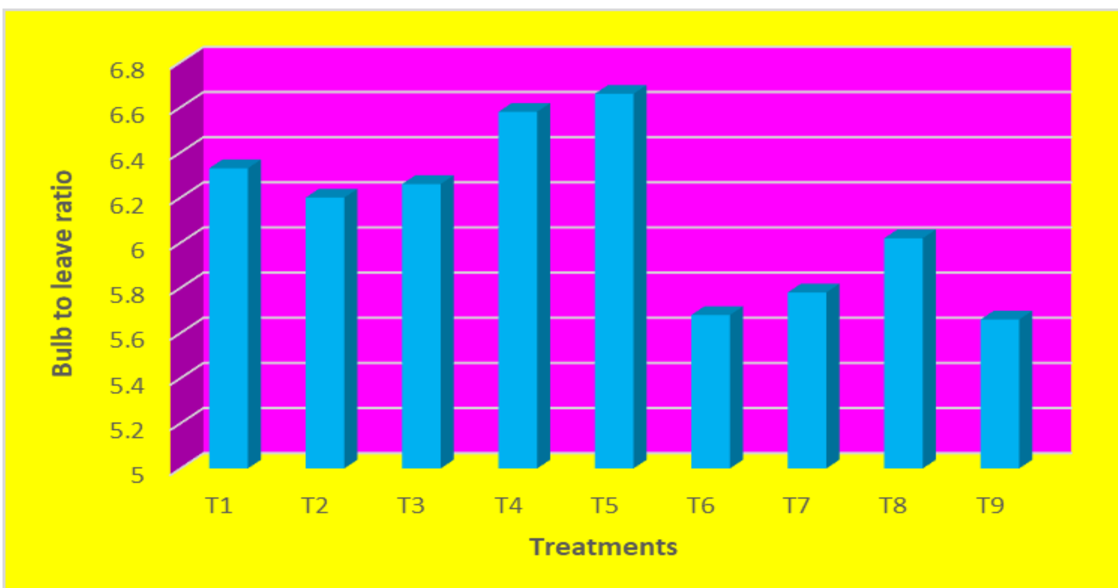


Fig 4.11 Bulb to leaves ratio as influenced by different treatments

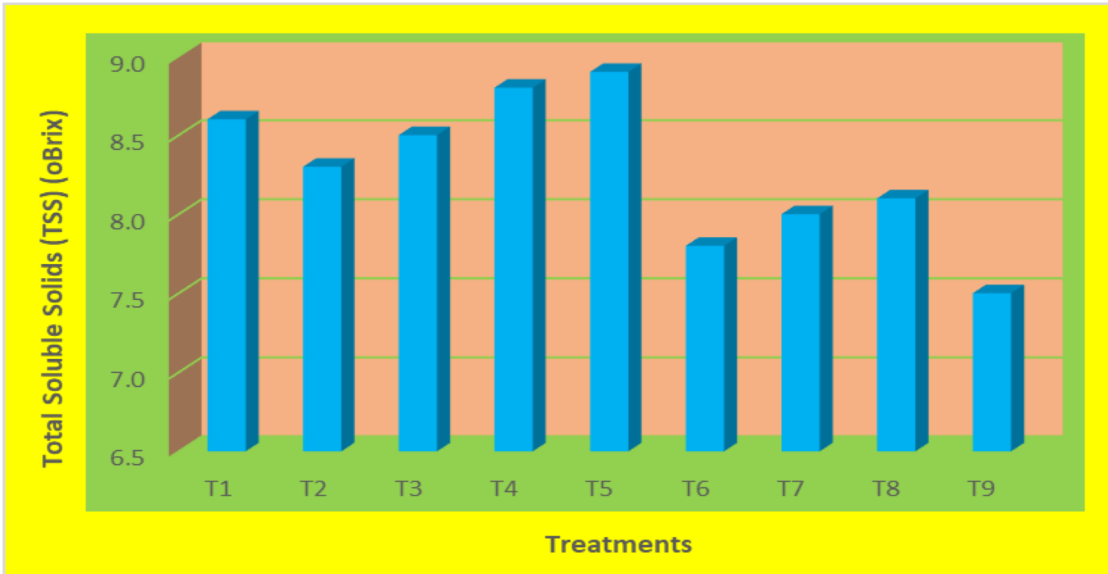


Fig 4.12 Total soluble solids (°Brix) of onion bulb as influenced by different treatments

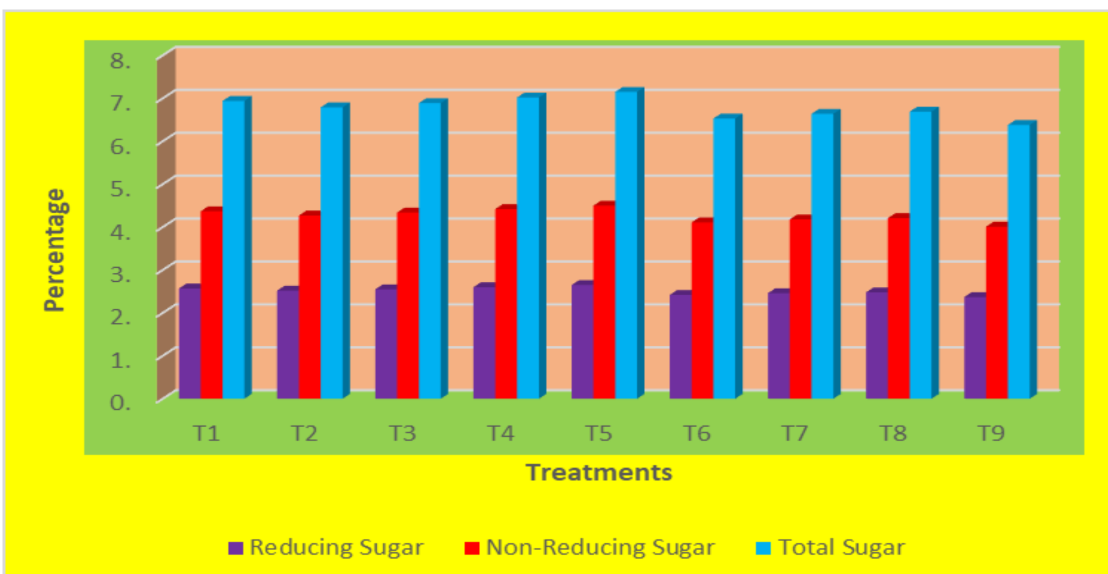


Fig 4.13 Percent of Reducing & Non-Reducing sugar in onion bulb as influenced by different treatments

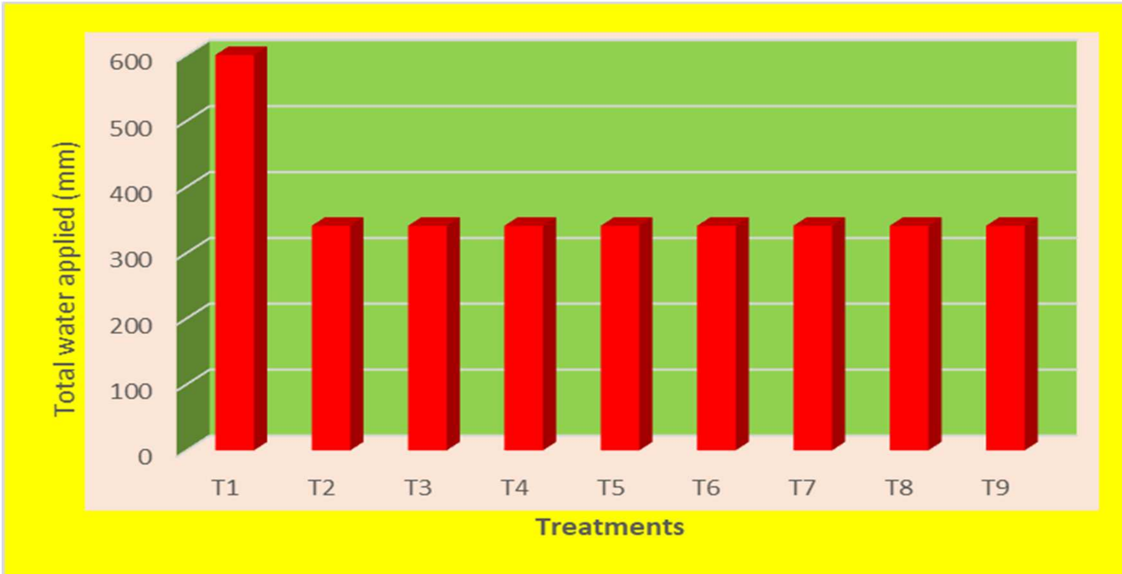


Fig 4.14 Total water applied as influenced by different treatments

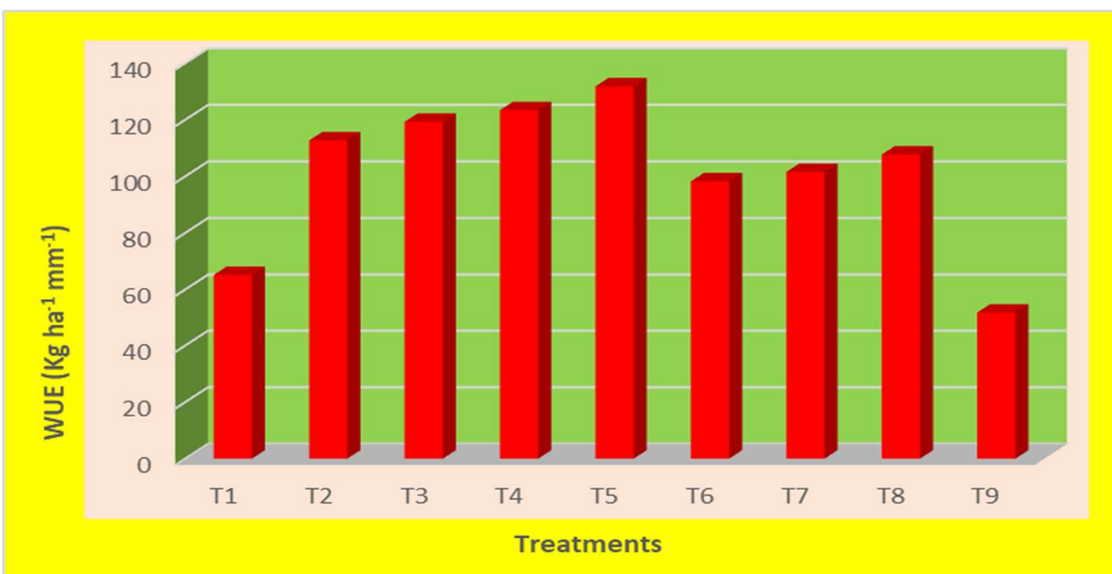


Fig 4.15 Water Use Efficiency as influenced by different treatments

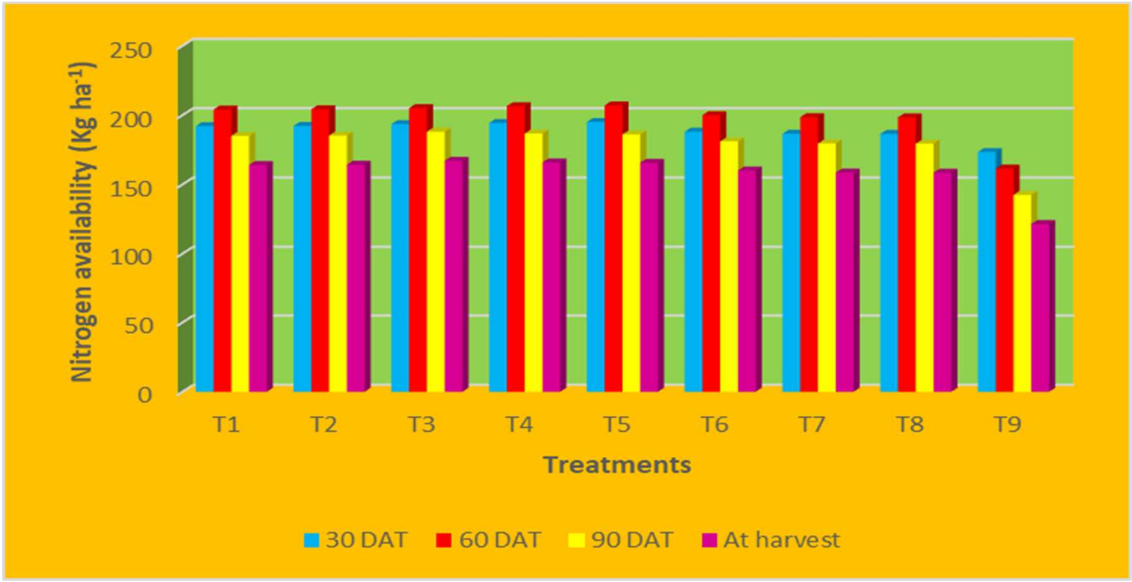


Fig 4.16 Periodical availability of nitrogen in soil

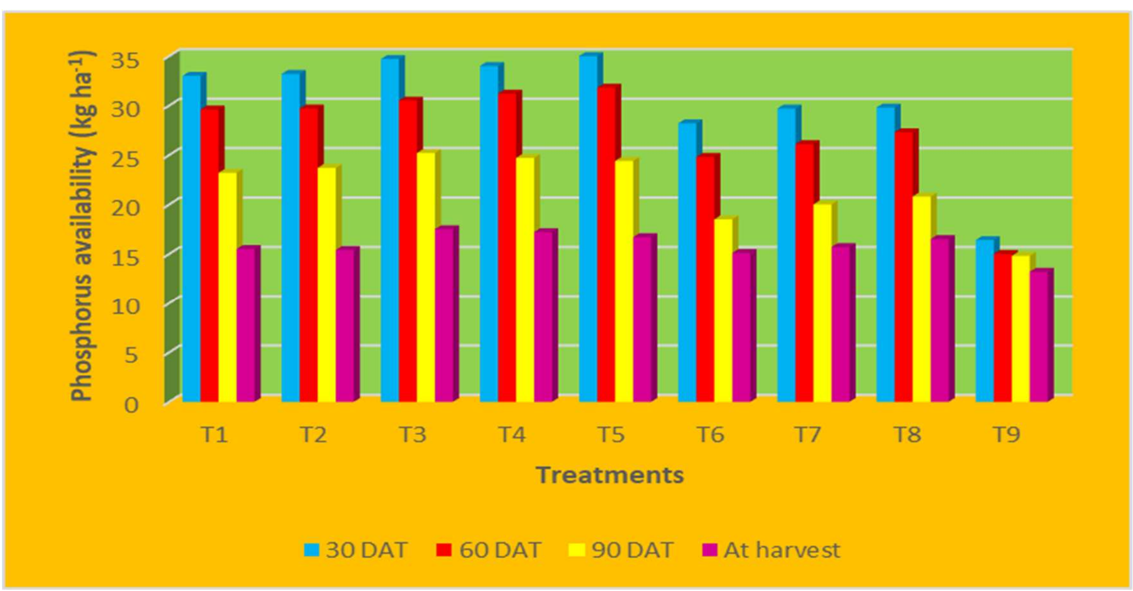


Fig 4.17 Periodical availability of phosphorus in soil