

**Studies on the Different Planting Dates and Forms of  
Sulphur on Growth, Yield and Quality of Onion**

**THESIS**

SUBMITTED TO THE

**BABASAHEB BHIMRAO AMBEDKAR UNIVERSITY**

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**LUCKNOW**

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**"अत्त दिप भव!"**  
["Be Thy Own Light..."]

*Special dedication of this  
grateful moment to my.....*

*Beloved parents;*

***Mr. Rameshwar Bharti***

**&**

***Mrs. Sunita Bharti***

*That always loves, Cares  
& Supports me.*

***Navaldehy.....***



## **CERTIFICATE**

This to certify that the work recorded in the thesis entitled **“Studies on the Different Planting Dates and Forms of Sulphur on Growth, Yield and Quality of Onion”** by Ms. Navaldey Bharti, Enrolment No. **61/08**, submitted for the degree of **Doctor of Philosophy in Horticulture** to the Department of Applied Plant Science (Horticulture), School for Biosciences and Biotechnology, Babasaheb Bhimrao Ambedkar University (A Central University), Lucknow-226025 (U.P.), India, is a bonafide research work carried out under my personal guidance and supervision. The results of the investigation reported in the thesis have not been submitted for any other degree.

The assistance and help received from various sources during the course of investigation have been duly acknowledged.

**Place: Lucknow**

**Date:**

**(Prof. R.B. Ram)**

**Supervisor**

## **DECLARATION**

I, **Navaldehy Bharti**, **Enrolment No. 61/08**, hereby declare that I am a candidate for the degree of **Doctor of Philosophy in Horticulture**, Department of Applied Plant Science (Horticulture), School for Biosciences and Biotechnology, Babasaheb Bhimrao Ambedkar University, Lucknow have carried my research work entitled **“Studies on the Different Planting Dates and Forms of Sulphur on Growth, Yield and Quality of Onion”**. The Thesis has been submitted for the award of the said degree is my original work.

**Place: Lucknow**

**Date:**

**(Navaldehy Bharti)**

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**Place :Lucknow**

**Date :**

**(NavaldehyBharti)**

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## **LIST OF ABBREVIATIONS**

Anon.	:	Anonymous
B:C	:	Benefit cost ratio
CaSO <sub>4</sub>	:	Calcium sulphate
CD	:	Critical Difference
cm	:	Centimeter
cv.	:	Cultivar
D. F.	:	Degree of freedom
<i>et al.</i>	:	Etalii
Fig.	:	Figure
FYM	:	Farmyard manure
g	:	Gram
ha	:	Hectare
ha <sup>-1</sup>	:	Per hectare
HCl	:	Hydrochloric acid
i.e	:	that is
I.U.	:	International Unit
K	:	Potassium
kg	:	Kilogram
km	:	Kilometer
ml	:	Milliliter
M.S.S.	:	Mean Sum of Square
mm	:	Millimeter
mg	:	Milligram
Mg	:	Miriagram
µm	:	Micromole
HPO <sub>3</sub>	:	Metaphosphoric acid
L.	:	Linneus
Lt	:	liter
Mt	:	Metric ton
t	:	tons
N	:	Normality

N	:	Nitrogen
nm	:	Nanometer
NaHCO <sub>3</sub>	:	Sodium bicarbonate
NaOH	:	Sodium hydroxide
No.	:	Number
O.P	:	Optical Density
P	:	Phosphorus
pH	:	Potential of hydrogen
P., pp.	:	Page/pages
ppm	:	parts per million
RBD	:	Randomized block design
R. H.	:	Relative humidity
Rs.	:	Rupees
S	:	Sulphur
S.E.	:	Standard error difference
Soln.	:	Solution
SO <sub>4</sub> <sup>2-</sup>	:	Sulphate ion
sp.	:	Species
S.S.	:	Sum of square
TSS	:	Total Soluble Solids
<i>viz.</i>	:	videlicet
wt.	:	Weight
°	:	Degree
'	:	Minute
%	:	Percent
/	:	per
μ	:	micro
°C	:	Degree centigrade, Degree celsius
°B	:	Degree Brix

# **Introduction**

# INTRODUCTION

## Chapter - I

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---

Onion (*Allium cepa*L.) is one of the most important commercial vegetable crop has been used as flavouring agent and medicinal cures for about 5000 years. Taxonomic description of common onions belong to the class *Monocotyledoneae*, order *Asparagales*, family *Alliaceae*, genus *Allium* and species *cepa*. Onion has basic chromosome number eight and diploid =16 (**Griffiths et al., 2002**). It is widely cultivated in various parts of the world for thousands of years and distributed over temperate zones in northern countries. Its primary centre of origin comprising North-West India, Afghanistan, the Soviet Republic of Tajik and Uzbek has been documented. It is a bulbous biennial for seed production or perennial herb. Bulbs are formed by swollen leaf sheath at the underground circular stem. **Coolong and Randle (2003)** stated that the bulb is made up of fleshy scales, in which the base are made of few outer leaves without their blades, inner leaf bases in which leaf blades never developed and in the center few sprout leaves, which may form leaves if favorable conditions are provided. Generally, the centrally placed scales in the bulb act as a stronger sink for photosynthate than the scales placed outside during active bulbing (**Mann, 1983**). Leaves are hollow with longitudinal symmetry and arranged in a distichous phyllotaxy. Morphologically onion leaves has two distinct parts. First, the leaf base, which forms a sheath through which the next leaf will arise, while second the leaf blade which is hollow, but becomes closer towards the tip and flattened on its adaxial surface (**DeMason, 1990**). Roots are unbranched and have few if any root hairs. Additionally, its roots are shallow, rarely growing more than 50 cm below the soil surface (**Pierce, 1987**). The inflorescence and plant require vernalization to flower in second year (**Rabinowitch, 1990**). Temperature is the primary factor affecting flowering. Generally, bulbs must be exposed to temperatures between 5 to 10°C for a period of one to two months in order for vernalization to occur. However, if plant is exposed to cool temperatures for a sufficient duration during the first year of its growth, plants will produce a

premature seed stalk and this process is called bolting (**Rubatzky and Yamaguchi, 1997**). Premature bolting may be reversed if onions are suddenly exposed to higher temperatures, the seed stalk will turn into vegetative growth and bulbing will continue (**Rabinowitch, 1990**). The bulbs are red, brown, white and yellow in colour.

It is predominantly, a *rabi* season crop, although, it is also being grown as *khariif* crop and most onion cultivars are sensitive to photoperiod and their range of adaptation is limited. The pungency in onion is due to a volatile oil (allyl propyl disulphide). Onion is used for loss of appetite and prevention of atherosclerosis and age related change in blood vessels. It reduces the risk of gastric cancer. Based on the recent investigations, it was suggested that to prevent atherosclerosis onions should include in the diet. Contemporary studies have shown that onion may inhibit or restrict the platelets aggregation and could interfere with fibrinolysis. Further, clinical studies have also reported that onions low down the lipid levels and inhibit the formation of blood clots. Onions are also cooked along with milk and eaten to clear congestion in the lungs (**Singh et al., 2001**). Characteristic flavour accounts for its popularity. Onion are used as salad, spice and cooked in curries, fried, baked, used in soup making, pickles, and for other purpose.

India is the 2<sup>nd</sup> largest producer of onion i.e. 18.92 MT with an area of 1180.59 ha, in the world next only to China i.e. 226.00 Lakh tons but the productivity of onion in India is very low (16.03 t/ha) as compared to China (22.05 t/ha) in 2014-15 (**Anonymous, 2015**) and other onion growing countries are Pakistan, Bangladesh, Indonesia, Vietnam, Russia, Myanmar, Brazil, U.S.A, Egypt and Turkey. India contributes about 19.90% of onion to the total world production. It is grown in northern as well as Southern part of India. Important onion growing regions are Maharashtra, Karnataka, Gujarat, Bihar, Madhya Pradesh, Andhra Pradesh, Tamil Nadu, and Punjab. It contributes about 15.3% of the total vegetable production in India. It ranks first in area and production among the various vegetable crops grown. Total export of onion is about 117377.22MT worth of Rs. 22189.66 lakhs to the Bangladesh, Malaysia, Sri Lanka, Nepal, Omen, etc. in 2015-2016 (**Anonymous, 2015**). Onion is being cultivated in about 37.24 lakhs hectares in Uttar Pradesh.

Bulb formation in onion is mainly a photoperiodic response but it can also be influenced by other major factors including proper planting schedule, growing temperature, nutrition and irrigation. Based on their photoperiodic length, onions are divided into short-day, intermediate-day, and long-day cultivars that the plants must require in order to initiate

bulbing. Short-day plants start bulb formation when exposed to 11-12 hours photoperiods, whereas long-day cultivars require 14-16 hours day lengths to bulb. Intermediate-day plants require photoperiod lengths of about 13 hours to bulb (**Bosekeng and Coetzer, 2015**). Bulb initiation could be ceased or reversed if plant is exposed to non-inductive photoperiod for a sufficient length of time once bulb initiation started (**Brewster, 1990**). Beside photoperiod length, growing temperature, planting schedule and nutritional factors, particularly sulphur because among six major nutrients three are generally provided in adequate quantity but another one that is sulphur is generally under estimated, also plays a major role in vegetative growth and quality bulb production, especially pungency development (**Jamal et al., 2009 and 2010**). Bolting is a serious physiological disorder which is mainly affected by growing temperature which varies according to planting time varies. Different onion growing regions of India have different planting times in view of the prevailing climatic condition. In North India, sowing time of seed in nursery is October to the middle of November and transplanting time of seedlings is from middle of December to January. In southern region, particularly Maharashtra, October is the sowing time of seed for raising nursery and transplanting in November for *rabi* season. But in southern region, temperature fluctuation is less and winter is mild that's why bolting is not a serious problem as compared to northern part of India where there is a large temperature difference during vegetative growth and bulbing. Early transplanting results in higher yield but majority of the bulb undergoes to bolting due to low temperature during the early stage of its development, while later transplanting results in low yield. Bolted onion decreases the marketable value of the bulbs. So, it requires a proper time adjustment of their transplanting without affecting the yield. Growing temperature also affect the bulbing in onion. Plant grown below 10<sup>0</sup>C temperature would start unreliable bulbing, even if plant is exposed to sufficient inductive photoperiod (**Brewster, 1977**). Although the rate of bulbing is linearly related with increase in temperature but after 30<sup>0</sup>C bulbing tends to decline (**Steer, 1982**).

Planting time not only affect the bulb yield but also the quality traits (pungency, flavour, etc.) of the onion. Generally, both yield and flavour potential are determined by genetical and an environmental factors. Investigation conducted by **McCallum et al.(2001)** found that if same variety is grown in different geographic regions have much variation in flavour. A cultivar with the potential to be mild in pungency can be made more pungent if grown under conditions conducive for maximum flavour production. Conversely, a pungent cultivar can be made milder if grown under conditions which favour minimum

flavour production. Environments which affect flavour intensity are sulphate, growing temperature and water availability. Pungency and flavour of a cultivar will be more if more sulphate available for uptake in the soil. Drier growing conditions and high growing temperatures both result in higher pungency. Conversely, low sulphate availability, growing temperatures and moist conditions will lower onion flavour intensity (**Ketter and Randle, 1998**). Furthermore, yearly fluctuations in onion pungency have also been reported by **Vavrina and Smittle (1993)**. Sugar content in onion can vary with cultivar, location and growing conditions (**Breu, 1996 and Darbyshire, 1978**).

Sulphur is recognized as the fourth major essential plant nutrient after nitrogen, phosphorus and potassium in crops. Although, sulphur is also one of the essential nutrient for plant growth similar to phosphorus, however, this element received little attention in many places, particularly in the cereal crop growing regions as fertilizers and atmospheric inputs supplied adequate amounts of sulphur in the soil. Moreover, day by day areas of sulphur deficiency is becoming widespread throughout the country and world as well due to the use of high-analysis low sulphur fertilizers, low sulphur returns with farmyard manure, high yielding varieties. Liliac plants (onion and garlic) are known for their affinity to sulphur fertilization because sulphur is a constituent of secondary compounds in onion, i.e. allin, cycloallin and thiopropanol (**Raina and Jaggi, 2008**). These secondary compounds not only impart the taste, pungency and medicinal properties of onion but are also important for providing resistance against pests and diseases to the plant in field (**Brown and Morra, 1997 and Bell, 1981**). Sulphur is essential for synthesis sulphur containing amino acids and also important for vegetative growth and bulb development in onion by affecting nitrogen use efficiency (**Anwar et al., 2001**). Sulphur deficiency in Indian soils adversely affects crop production besides recommended dose of nitrogen, phosphorus and potassic fertilizers application. Optimum use of fertilizers containing sulphur improves utilisation of nutrients, especially nitrogen. Favourable influence of sulphur on nitrogen metabolism and mutual interactions between these two elements were reported by **Fimes et al. (2000)**. Recognition of sulphur for higher yield and quality of onion bulbs has also been reported by **Thippeswamy (1993)**. Inadequate supply of sulphur nutrient causes slow crop growth at any stage resulting in yield reduction. The genetic system of onion controls the sulphur uptake and its assimilation into the flavour precursors. Flavour precursor formation begins with the uptake of sulphate ( $\text{SO}_4^{2-}$ ) by the bulb, its reduction to sulphide and subsequently assimilated into cysteine by light-dependent reactions in the leaves of the onion. Glutathione, a tripeptide

of cysteine is then synthesized which is the primary product of the flavour precursor biosynthetic pathway. The pathways leading to the synthesis of each flavour precursor are not fully understood, although sulphur is known to be transformed through several identifiable peptide intermediates, each unique to a specific flavour precursors. There are three different flavour precursors are found in onion *viz.*, 1-propenyl cysteine sulfoxide (usually found in the higher concentration); methyl cysteine sulfoxide (normally found in lesser concentration); and propyl cysteine sulfoxide (found in the lowest concentration). Differences in flavour intensity within a species are due to differences in the precursors concentrations. If there is a higher concentration of the flavour precursors, then greater would be the flavour. Primary products that produced from these flavour precursor decomposition are pyruvate, ammonia and chemically unstable sulphenic acids. Among them sulphenic acids has lachrymator, or tear producing property. The sulphenic acids undergo further rearrangement to form thiosulphinates which are responsible for the characteristic flavour of onions (**Block, 1992**). Pungency in onion is assessed by measuring pyruvic acid, a stable primary compound from the enzymatic decomposition of each of the flavour precursors. It is, however, only an indicator of pungency although pyruvate does not directly contribute to onion flavour (**Ketter and Randle,1998**).

Organic matter in the soil is the primary source of available  $\text{SO}_4\text{-S}$ . Soil of central U.P. is sandy, low in organic matter and found in upper to mid-slope positions are mainly prone to S deficiency since the small amount of  $\text{SO}_4\text{-S}$  released from organic matter is susceptible to leaching loss. Naturally occurring gypsum is used as a sulphur fertilizer in pastures in some districts with soils high in phosphorus at the rate of 100 - 200 kg/ha per annum. Gypsum is also used at higher rates as a soil ameliorant (to improve soil structure) in cropping soils. Where this is done, it will not be necessary to apply additional sulphur. Sulphur fertilizers are most commonly available in either the soluble sulphate or elemental forms (S).  $\text{SO}_4\text{-S}$  is highly mobile in the soil and is the only form of S directly utilized by plants (**Singh, 2008**). Elemental sulphur (S) has the advantages of ready supply, lower production costs and, because of its high analysis, lower transportation cost and fewer drill fills during field operations. Elemental sulphur must be oxidized by soil microbes to  $\text{SO}_4\text{-S}$  before it is available to crops. It provides degradable sulphur to plants and therefore, can have the more advantages over other forms of sulphur fertilizer. Elemental sulphur has high analysis, allowing lower volumes of product, reducing warehousing and freight costs, minimal soil leaching losses until converted to sulphate form, ability to slow release, providing sulphate

sulphur for the entire crop season, build up available sulphur levels in the soil for the following season (larger particles), it saves nutrient, storage and application costs, lower volume of storage for dealers/growers. Moreover, by this study, it can be augmented that which form of sulphur at a particular dose will be low cost effective and beneficial for the farmers without affecting yield and quality of onion and the soil health as well.

Through this present study entitled **“Studies on the Different Planting Dates and Forms of Sulphur on Growth, Yield and Quality of Onion”** an attempt has been made to find out the suitable transplanting date and different doses of sulphur application in the form of sulphate (gypsum) and elementary sulphur effecting crop yield and quality with the following objectives:

1. To find out the suitable date of planting and different form of sulphur on growth and yield of onion.
2. To assess the effect of date of planting and different form of sulphur on quality attributes of onion.
3. To find out the efficacy of date of planting and different form of sulphur on bolting percentage in onion
4. To work out the cost: benefit ratio by applying different form of sulphur at different date of plantings.

**Review  
of  
Literature**

# REVIEW OF LITERATURE

## Chapter - II

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In this chapter an attempt has been made to critically examine the available research findings and review briefly the salient features pertaining to the present investigation in a summarized and classified manner, so as to use it as a background literature. This literature review will focus on the influence of growing temperature prevailing at different transplanting date and sulphur fertilisation in onion.

### **Effect of dates of planting**

Development and performance of onion at all the stages of its growth and development is controlled by temperature (Ansari, 2007). For optimum vegetative growth temperature between 15 to 25 °C is required, however, plant can grow at temperature as below 15 and as above 25 °C (Comrie, 1997). Adaptation of different onion cultivars to an area having different climatic condition mainly depends upon the photoperiodic length of that area and the photoperiodic length requirement of that cultivar (Wiles, 1989). Hutton and Wilson (1986) investigated the effect of six sowing dates on maturity, yield and quality of the onion. Maximum total yield was recorded for 20 June for PLK and 30 May for the ELK cultivars, and declined steadily with later sowing dates. Earlier sowing dates resulted in a high proportion bolted bulbs for both cultivars and severely reduced marketable yield. Decrease in total yield at the later sowing dates was due to decrease in average bulb size. The yield of marketable bulbs declined from 75 t/ha and 57 t/ha for PLK and ELK at the third and second sowing dates respectively, to 30 t/ha and 14 t/ha at the later sowing date. Gill and Singh (1989) reported that planting date affected only seed yield and the highest yield was obtained from Oct. plantings. Kalavathi *et al.* (1990) conducted a field trial using Bellary onion cv. Rampoori Local. He observed that harvesting at 125 days after planting, the highest weight of seeds per head was obtained. Mathankaret *et al.* (1990) evaluated with four planting dates (26 Nov., 11 Dec., 26 Dec. and 10 Jan.) and seven cultivars (Pusa Red, Pusa White Flat,

Pusa Ratnar, SL102, N-53, N-257-9-1 and Selection Local White). He recorded highest plant height (74.7 cm), number of leaves/plant (65.1) number of flower stalks/plant (7.9), and seed yield/ha (27.5 q) resulted from the 26 Nov. planting. **Pandey (1990)** also reported in cultivar Pusa Red that high yield of marketable bulbs (349.7 q/ha) and the highest net return were obtained by transplanting on 1 Jan. and applying 100 kg N/ha. Transplanting on 15 Feb. and applying 50 kg N/ha gave the lowest marketable yield (103.8 q/ha). **Nehra et al. (1990)** noticed that the highest seed quantity in onion was produced by plants raised from bulbs planted on 25 Sep. (14.75 q/ha) and 10 Oct. (14.95 q/ha). Direct seed sowing on 10 Oct. also produced similar amount of seeds (14.38 q/ha) whereas plants raised from seedlings gave the lowest seed yields irrespective of planting date. **Singh et al. (1991)** conducted a trial on onion cultivars Hybrid No. 1, Pusa Red, N-53, Arka Kalyan and Arka Niketan to assess the effect of 3 dates of planting (15 Jan., 30 Jan. and 15 Feb.). Bulb size and yield were greatest with planting on 15 Jan., although the time to maturity was longer. Pusa Red gave the highest yield (184.6 q/ha) and N-53 gave the lowest yield (142.62 q/ha). **Shalaby et al. (1991)** assessed that bolting, average bulb weight and unmarketable yields were generally lowest for the earliest planting date. Total, marketable and exportable yields were generally greatest from 1 Sep. **Kacjan and Osvold (1992)** studied that planting or sowing in May produced the lightest yields with the lowest bulb DM content. **Farghali (1995)** found that planting in October or November significantly increased the number of seed stalk and number of capsules per head compared with planting in September. November planting resulted in the highest seed yield. **Rizk et al. (1996)** observed that early planting resulted in the greatest seed stalk height and diameter, umbel diameter and average number of flowers per umbel. Delaying the time of planting to the last 10 days of November reduced seed yield compared with the other 2 planting-dates treatments. **El-Rehim et al. (1997)** reported that percentage of bolting was significantly reduced by planting in February. Average bulb weight was reduced in February. Plants matured on 17 April for November transplants and on 27 April for February transplants. Bulb weight was reduced by later transplanting dates. **Ha InJong et al. (1998)** investigated the effects of 3 sowing dates for transparent PE film mulch cultivation, 4 sowing dates for non-mulch cultivation and 3 seedling ages on plant growth and yield of onions (cv. Changnyongdaego). On the basis of marketable yield, 5 September was the best time for sowing seeds, and the best time for transplanting was 20-30 October. According to **Jun Kyu et al. (1998)** growth (number of leaves, plant height and sheath length) was greater from earlier planting in spring but plant height was greatest with later planting and sheath length was greatest from planting on 26 September. Bulbing began in early June in both

spring and autumn crops of shallot. Bolting occurred at rates of 3.3-56.7% but only in the autumn crops and was higher with earlier planting. Percentage of bulbs <10 g was higher in spring than in autumn crops. It was also higher from the later plantings in spring and from the earlier plantings in autumn. Total shallot yield per ha was higher from earlier planting but marketable yield was highest from planting on 26 September (41.1 t/ha). **Malik et al. (1999)** studied that influence of the date of bulb planting, bulb cut and pinching of bolt treatments in onion seed crops. The highest yield and quality of seed was recorded for 15 October bulb planting, which was followed by 30 October. In 15 November bulb planting, a decrease in yield and quality of seed was observed during both years. Bulb cut and pinching of bolt treatments adversely affected the seed yield of onion. **Caruso (2000)** compared three planting times (15 March, 21 April, and 29 May, in 1994; 6 April, 9 May, and 5 June, in 1995). Highest crop biomass and leaf area index values were obtained with the first planting time and chemical weed treatment (682.4 g m<sup>-2</sup> and 4.4 m<sup>2</sup>, respectively), just before the decrease caused by leaves drying until harvest. Crop growth rate increased during the first phases of the crop cycle (highest value of 29.8 g m<sup>-2</sup> d<sup>-1</sup> with the third planting time and herbicide treatment) and subsequently decreased. **Mohanty (2001)** evaluated the effect of planting date (1 November, 16 November, 1 December, 16 December, and 31 December) on onion cultivars Arka Kalyan, ArkaNiketan, Pusa Red, Agrifound Dark Red, and Agrifound Light Red and observe that planting on 16 November gave the tallest plants (50.52 cm) with the highest number of leaves per plant (14.85), bulb diameter (5.93 cm), bulb weight (70.78 g), and bulb yield (282.77 q/ha). Further delay in planting resulted in reduced vegetative growth and yield. **Sawant et al. (2002)** found that equatorial and polar bulb diameter were highest in onions planted on 19 April, whereas bulb neck thickness and yield were highest with planting of seedlings on 9 May. Bolting increases with delay in planting up to 19 May, and decreased with further planting delay. Non-reducing sugar content was highest with transplanting on 19 May, 19 September and 19 October. Total soluble solids were highest with planting on 19 March. **Yadav et al. (2002)** Studied the effects of bulb size (4.0-5.0 or 5.5-6.5 cm), spacing (45x30 or 60x30 cm) and planting date (14 October, 24 October, 3 November, 13 November or 23 November) on the performance of onion cv. Kalyanpur Red Round found that large bulbs (5.5-6.5 cm) planted on 3 November at a spacing of 45x30 cm resulted in high number of umbels per plant and highest seed yield (8.20 quintal/ha). However, an optimum seed yield of 7.64 quintal/ha was obtained with large bulbs planted from 24 October to 13 November at a spacing of 45x30 cm. **Singh et al. (2002)** observed that early planting (21 August) resulted in the greatest bulb diameter, neck thickness, specific gravity, juice content, dry weight and

total soluble solid content. **Faruq et al. (2003)** reported that the Nov. 22 planting produced the highest yield (25t/ha) by increasing leaf number per plant (11.73), bulb diameter (5.31cm), fresh weight of bulb (59.60g) and dry matter content of bulb (13.44 %). **Sharma et al. (2003)** studied the effects of planting date (31 July, 15 August, 31 August and 15 September) on the yield of onion cv. N-53. Planting on 15 August recorded the greatest bulb diameter (4.68 and 4.80 cm), bulb weight (46.77 and 50.89 g) and plant height (42.97 and 43.14 cm) and the highest average bulb yield (141.09 quintal/ha). Further delay in planting drastically reduced the bulb yield. Planting on 15 September resulted in the greatest neck thickness (1.36 and 1.58 cm). **Hu Wei Hou et al. (2003)** obtained that onion planted in autumn and transplanted in winter exhibited reduced growth rate with late sowing. The optimum sowing date for cultivar Yang chun huang was September 10, whereas that for middle-late cultivars 84-5 and 9866 was September 20. Compared to pre-winter transplanting, post-winter transplanting of cultivars 84-5 and 9866 on September 20 and 30, respectively, recorded higher premature bolting rate and lower mean bulb weight and plot yield. **Leilah et al. (2003)** conducted an experiment on nine local onion cultivars (El-Nobareia, El-Fayoun, El-Gemmeiza, El-Mansoureia, Moshtohor, Namol, New Nucleus 961, Santrees and South El-Tahrir) were transplanted at 20 December, 10 January and 1 February and found that early transplanting (20 December) resulted in increased tubular blade weight, number of days to maturity, bulb weight, culls and marketable yield, bulb length and diameter, and total and non-reducing sugar content. Transplanting on 10 January resulted in increased neck and bulb fresh weight. Late transplanting (February) resulted in the highest bulbing ratio, total soluble solids content, dry matter and reducing sugar percentage. **Aminpour and Bak (2004)** carried out an experiment and found that the number of umbels/m<sup>2</sup>, capsules per umbel and seeds per capsule increased significantly in first and second planting dates compared with the third and fourth planting dates. Among the planting dates, the third had the lowest 1000-seed weight. Field experiment carried out by **Al-Abdulsalam and Hamaiel (2004)** found that there were significant differences in the vegetative growth, yield and yield components in the different planting dates and fertilizer treatments. Planting on 20 October along with the application of potassium gave the best results for number of leaves per plant, leaf area per plant, dry/fresh weight, average bulb weight, bulb yield, bulb shape index. **Singh et al. (2005)** investigated that maximum seed yield (10.95 q/ha) was obtained in 11th October planting followed by 1st October (10.05 q/ha). The bulb diameter (6.0x4.5 cm) and bulb spacing (45x30 cm) had given maximum seed yield of 9.87 q/ha and 9.76 q/ha, respectively. **Gautam et al. (2006)** opined that August

15 transplanting date produced the highest bulb yield (15.31 t/ha) among four transplanting dates. **Al-Moshileh (2007)** registered that early planting showed significantly higher growth values than the later planting in the two growing seasons. 1<sup>st</sup> September planting date produced bigger bulbs than the other planting dates. Early planted onion gave a high total bulb yield, but the plants tended to produce more flower stalks and doubled bulbs. First planting date resulted in higher bolting percentage. The latest planting date showed a highly significant lower percentage of bolting in the two seasons. **Balakrishnan and Selvakumar (2008)** evaluated the optimum time of sowing with suitable hybrids of tropical sugar beet, highest growth, yield attributes and yield were recorded in October first fortnight sowing with Cauvery and it was comparable with October second fortnight of sowing with same hybrid. October sowing with Cauvery hybrid performed better for tropical sugarbeet emergence, establishment, yield and quality. **Woziullahet al. (2008)** conducted a trial on four cultivars viz. Taherpuri, Faridpuri, Zhitka and Kalsikanda were planted at four different date viz. 25 October, 10 November, 25 November and 10 December. Higher seed yield (881.00 kg ha<sup>-1</sup>) and better benefit cost ratio (2.38) were obtained from the cultivar Taherpuri and both parameters were identical with Faridpuri. Earlier planting produced the maximum seed yield (1040.83 kg ha<sup>-1</sup>) and better benefit cost ratio (2.80). **Mahadeen (2008)** observed that onion bulb yield and bulb weight were decreased with delaying planting date. The highest yield was produced with the earliest planting date (Dec. 1). Neck diameter, bulb diameter and bulb height were significantly decreased with delaying planting. The best onion yield in terms of quantity and bulb characters was obtained when onion transplants were planted on Dec. 1 or Dec. 15 at the closest plant spacing under semi-arid conditions. **Resende and De Costa (2008)** evaluated that the March planting showed higher commercial yield (66.5 Mg/ha) than August planting (41.4 Mg/ha). Regarding non-commercial yield (culls), the March planting obtained 6.0 Mg/ha, while August planting recorded 5.4 Mg/ha. **Ud-Deen (2008)** reported that October 30 planting produced the longest plants (62.29 cm) and the highest number of leaves per plant (16.72), bulb volume (32.69 cc), bulb weight per plant (48.85 g) and bulb yield (13.89 t/ha). The similar trend was observed in case of seed yield. The highest number of flowers per umbel (226.6), fruit set (71.16%) and seed yield (383.2 kg/ha) were found in 30 October planting time. **Anisuzzaman et al. (2009)** found that onion planted on 21 November had better agronomic traits contributing towards yield formation. Seed yield (460.81 kg/ha) was highest in the plots planted on 21 Nov. **Boyhan et al. (2009)** reported that, beginning in the first week of November, onions can be transplanted until the end of December with reasonable yield and quality. In 2003–04, total yield of onions transplanted

on 22 Dec. 2003 did not differ from any onions transplanted on earlier dates in November or December. In the 2004–05 season, onions transplanted on 20 Dec. 2004, had lower total yield than onions transplanted in November, but were not different from onions transplanted on 4 Jan. 2005. **Ibrahim and Adesiyun (2009)** stated that onion bulb yields were also found to differ in descending order as follows: November (48 t/ha), December (42 t/ha), January (13.5 t/ha), February (5.5 t/ha) and March (1.5 t/ha). **Haldar et al. (2009)** assessed under different temperature regimes by three plantings in field condition under tropical-humid conditions to assess the possibility of growing onion under early rabi condition in the Gangetic plain of West Bengal. Average day/night temperature of 20 degrees to 21 degrees C coupled with rainless condition has been found suitable for growing early onion in the humid condition in the Gangetic alluvial region of West Bengal. Growing early-rabi onion with planting of seedlings in the first week of October employing the varieties like, Baswant 780, Agrifound Dark Red, Arka Pragati and Phule Safed and harvesting the bulbs during last week of February appeared to be the best. **Nayeet al. (2010)** found that highest plant population was found in 30 July, while maximum plant height and neck thickness of plant was recorded with treatment combination 20 July. Number of leaves per plant and bolting percent did not affected by combination of various planting materials and different date of planting. **Hamid et al. (2010)** ascertained that, variety Red Star had a larger fruit diameter, highest fruit weight and highest yield (t/ha). The highest plant density (71,428 plant ha<sup>-1</sup>) gave the highest and marketable yield. The sowing at October 1st increased the productivity of tomato as it positively influenced the plant height, stem diameter, days to 50% flowering, fruit yield and marketable yield. **Ibrahim (2010)** summarized that January planting was the tallest, (29 cm) with 5 leaves in 2001/2002 and in 2002/2003, October planting produced the tallest plant (37 cm) with 5 leaves. 48t/ha were produced by the November transplant in 2002/2003 and over 40t/ha produced by the December transplant in the same year. In 2001/2002 the highest yield of 40t/ha was produced by the December transplant. **Verma et al. (2011)** reported that planting of onion bulbs on 1st October recorded maximum dry weight of shoot per plant, days to 50% flowering and maturity, length of flower stalk, number of capsules per umbel as well as seed yield per plant. It was at par to 15th October planting but differed significantly with other dates of planting. **Soro et al. (2011)** evaluated that the yields were 19 t ha<sup>-1</sup> and 30 t ha<sup>-1</sup> for the plantations established in September and December, respectively. **Thakur (2011)** standardized proper time of planting and the optimum levels of nitrogen and phosphorus fertilizers for increasing the productivity of the garlic. Early planting of garlic cloves on 30<sup>th</sup> August and 20<sup>th</sup> September resulted in increased plant growth and highest

marketable bulb yield of 25.8 tonnes ha<sup>-1</sup> and 25.6 tonnes ha<sup>-1</sup> respectively. The plant growth as well as marketable bulb yield decreased to 15.6 tonnes ha<sup>-1</sup> with delay in the planting time up to 20<sup>th</sup> November. **Khodadadi (2012)** noticed that the planting date had significant effect on the plant emergence and the final height of plant and seed yield per hectare. Moreover, the highest seed yield belongs to planting date 6 of November with motheral bulb size 65 to 80 mm with the average yield was about 1345.42 kg ha<sup>-1</sup>.

### **Effect of Sulphur on onion**

**Randle and Bussard (1993)** observed that enzymatically formed pyruvic acid correlated poorly with bulb S concentration, which suggests differential partitioning of S into flavor and non-flavor compounds among cultivars. **Rajas et al. (1993)** conducted an experiment on onion cv. Pusa Red to assess the effect of 4 rates of Sulphur (0, 40, 60 and 80 kg/ha). The highest yield (28.11 t/ha) was obtained with 80 kg S/ha. **Singh and Pandey (1995)** assessed the effects of S (0, 20 and 40 ppm) and soil type (10 Inceptisols collected from different soil series in Delhi) on the yield of onions (cv. Pusa Red). Applied S had no significant effect on yield, but S uptake increased with increasing rate of S. Soil type significantly affected yield and S uptake. The highest S uptake (118.9 mg/pot) was observed from a sandy loam soil amended with S at 40 ppm. **Singh et al. (1995)** performed a field experiment with garlic and Sulphur was applied as gypsum, elemental Sulphur, sodium Sulphate or potassium Sulphate, at 0, 25, 50 or 100 kg S/ha. Amongst the S sources, gypsum and potassium Sulphate gave the highest yields and nutrient uptake rates. **Nogueira et al. (1996)** carried out a field experiment on potato cv. Monalisa (summer grown) were given 0-400 kg K<sub>2</sub>O/ha as KCl, K<sub>2</sub>SO<sub>4</sub> or KCl + 1 t gypsum/ha. Mean tuber yields were highest with the combined application of KCl + gypsum. Percentage of cracked tubers was lowest in the plots receiving KCl + gypsum (6.41%) compared with KCl alone (8.01%) or KNO<sub>3</sub> (8.81%). **Singh et al. (1996)** investigated the effects of N (0, 60, 120 or 180 kg/ha) and S (0, 20, 40 or 80 kg/ha) on the growth of onions (cv. Pusa Red). Yield and plant S content significantly increased with increasing rate of S up to 40 kg S/ha. Combined addition of N + S significantly affected yield. **Sumantrakar Tiwari (1997)** examined that Sulphur fertilizers significantly increased all vegetative growth parameters compared to the control except number of leaves/plant at 70 DAT in cv. Pusa Red. Application of CaSO<sub>4</sub> at 24 kg/ha gave the highest values for the following characteristics: number, length, fresh weight and dry weight of leaves; number, length and fresh weight of roots; length, diameter, fresh weight, dry weight and volume of bulbs. All fertilizer sources and application rates significantly

increased the bulb yield at harvest compared to the control, but the highest yield was again obtained after application of  $\text{CaSO}_4$  at 24 kg/ha. **Ammal et al. (2000)** attempted a pot experiment to study the effect of rock phosphate - elemental Sulphur granule (RP-S G) on the yield attributes and yield of onion (cv. Co 4) and black gram (cv. Co 5). The application of RP-SG at the rate of 60 kg  $\text{P}_2\text{O}_5$ /ha had the highest yield for both the crops. **Venkatesh and Satyanarayana (2000)** carried out a laboratory incubation experiment in a Vertisol and an Inceptisol to determine the effect of different sources and rates of S, and time of incubation, on the transformation of available S in soils. Available S content increased with increasing rates of S fertilizers added. Among the different S sources (ammonium Sulphate, single super phosphate, elemental S, gypsum and pyrite) applied to the soil, ammonium Sulphate resulted in the highest S availability, while elemental S and pyrite resulted in the lowest. **Attia (2001)** studied that the application of SFMC, elemental S and micronutrients (Fe, Mn and Zn) significantly enhanced the yield, dry matter percentage, and total N, P, K, Fe, Mn and Zn contents of onion bulbs. Application of 400 kg S before and after transplanting along with micronutrient application resulted in the highest values of the studied parameters. **Ammal and Mathan (2001)** identified that the results of pot and field experiments showed that RP-S G added at 60 kg  $\text{P}_2\text{O}_5$  per ha, significantly enhanced yields of onion and black gram. Nutrient availability and uptake values were also significantly influenced by RP-S G addition. **Sharma et al. (2002)** analysed the effects of S rate (0, 15, 30, 45, and 60 kg/ha) on the yield and nutrient uptake by 28-day-old onion cv. Pusa Red grown on light or heavy-textured soil were also studied in a pot culture experiment. Plant height, bulb diameter, bulb yield, S content, and S uptake increased with the increase in S rate up to 30 kg/ha in heavy-textured soils and up to 45 kg/ha in light-textured soils. **Nasreen et al. (2003)** found that weight of single bulb, bulb diameter and bulb size was more in plant treated with 45 kg S (gypsum) per ha. Although plant receiving 45 or 60 kg S per ha did not differ significantly in weight. Bulb yield was highest for the plant receiving 60 kg per ha followed by 45 kg per ha. **Bloemet et al. (2004)** studied that an increasing Sulphur supply was related to an increasing alliin content in leaves and bulbs of onion and garlic. The alliin content in bulbs could be doubled by S fertilization. A translocation of alliin from leaves to bulbs was found so that time of harvest has a strong influence on the alliin content. At the beginning of plant development high alliin contents were found in leaves, while with bulb development they were translocated into this plant organ. **Jaggi (2004)** evaluated Sulphur (0, 15, 30 or 60 kg/ha) applied through gypsum or the slow-release fertilizer Sulphur 95 on the composition and yield of onion (cv. Patna Red). S application significantly increased bulb and foliage

yields. Bulb yield, bulb N content, and bulb N uptake did not significantly vary with the S source, whereas gypsum had a greater positive effect on S uptake by bulb and foliage, S uptake by bulb + foliage, N uptake by foliage, and N uptake by bulb + foliage than Sulphur 95. **Jaggi (2005)** investigated the effects of Sulphur (15, 30 or 60 kg/ha) applied through gypsum and S<sub>95</sub> on the yield and quality of onion (cv. Patna Red). The highest fresh bulb yield was obtained with 30 kg S/ha (17.5 t/ha). The benefit cost ratio reached 18.4, 32.1 and 18.7 when with 15, 30 and 60 kg S/ha. 30 kg S/ha applied through gypsum was the most effective in the enhancement of onion bulb yield and storage quality. **Nasreen and Huq (2005)** reported that the highest yield was found from the plants treated with 45-60 kg S/ha (gypsum) that was significantly different from other treatments irrespective of years. **Wani and Chattoo (2005)** stated that the effect of sources and rates of Sulphur on yield attributes and yield of garlic cv. Local. Bulb yield and yield attributing characters of garlic increased significantly with increasing rates of Sulphur. The highest bulb yield (168.39 q/ha) was recorded at 50 kg S/ha through gypsum. The yield increased owing to the improvement in yield attributing characters, i.e. bulb diameter, plant height, bulb volume, bulb weight and number of cloves per bulb. Among the sources of Sulphur tested, gypsum proved significantly superior to elemental Sulphur, in terms of garlic bulb yield and yield attributing characters. **Abd-Elfattah (2005)** evaluated the effect of different application rates of Sulphur (0.0, 0.5, 1.0, 2.0 and 3.0 t/acre) at various inoculated periods (1, 2, 3 and 4 weeks) with or without Sulphur-oxidizing bacteria on the availability of P for sandy, clay loam and calcareous soils. Garlic yield increased from 4 to 5.7 t by application of 2 t per acre of Sulphur alone. This shows that application of Sulphur alone has contributed to convert the phosphorus present in soil from insoluble to soluble forms for garlic plant and to be more productive than that treated with 400 kg per acre superphosphate alone. However, the combination between the application of high rate of P and S resulted in increasing the garlic yield from 4 to 7.1 t/acre. **Jaggi (2005)** investigated the effects of S rates (0, 15, 30 and 60 kg/ha) and sources (S<sub>95</sub> and gypsum) on the yield performance of onion cv. Patna Red. The fresh and dry weights of onion yield, plant height, leaf number/plant, and weight per 10 bulbs increased with increasing S rates up to 30 kg/ha. Further increase in rate did not make a difference in yield response. Gypsum was more effective than S<sub>95</sub> as S source. Application of S (as gypsum) at 15, 30 and 60 kg/ha resulted in earnings of Rs. 24, 39 and 18 per Rs spent. **Wani (2005)** evaluated the effect of sources (gypsum and elemental S) and levels (0, 25, 50 and 100 kg/ha) of S on garlic cv. Local. The bulb yield was highest (169.94 q/ha) at 50 kg S/ha. The contents of N, P and S (1.36, 0.64 and 1.08, respectively) were highest at 100 kg

S/ha. Gypsum was superior over elemental S in bulb yield as well as nutrient uptake. **EL-Desuki et al. (2006)** reported that the vegetative growth of onion plants and minerals uptake were increased by adding potassium fertilizer through spraying or soil dressing upto 2 L./fed of potassium oxide or 75 kg potassium sulphate/fed., respectively. Total bulb yield as well as bulb quality were gradually increased with increasing of potassium application up to 2L./fed of potassium oxide as foliar application or 75 kg potassium sulphate/fed. as soil dressing in addition of the recommended dose of potassium fertilizers application. **Jaggi et al. (2006)** conducted a field experiment to study the response of graded levels of sulphur on bulb yields and S uptake by onion and garlic crops applied through Sulphur' 95 and gypsum. An increase in bulb yield of onion and bulb yield of garlic were obtained with S application up to 40 kg ha<sup>-1</sup> over the recommended dose of fertilizers (NPK). Sulphur' 95 was identified superior over gypsum to meet the S requirement of onion and garlic in S deficient soils of Ranchi. S use efficiency was found to be higher by these two crops with Sulphur' 95 than that of gypsum application. **Josephine et al. (2006)** noticed that the highest fresh bulb yield was obtained with 30 kg S/ha (17.5 t/ha). Gypsum was superior to S<sub>29</sub> in terms of benefit:cost ratio (27.1 and 17.4) and fresh bulb yield (16.6 and 13.2 t/ha), but was inferior to S<sub>29</sub> with regard to the percentage of sprouted bulbs (37.0 and 27.4%). The benefit cost ratio reached 18.4, 32.1 and 18.7 when with 15, 30 and 60 kg S/ha. 30 kg S/ha applied through gypsum was the most effective in the enhancement of onion bulb yield and storage quality. **Qureshi and Lawande (2006)** ascertained the effect of sulphur application on 'B 780' onion on its yield, quality and storability. Sulphur was applied as elemental sulphur 15-75 kg/ha along with N (100 kg/ha), P (50 kg/ha) and K (50 kg/ha). Onion responded significantly to sulphur @ 30-75 kg/ha over only NPK. The highest bulb yield 39.1 tonnes/ha with 75 kg/ha was recorded. Sulphur content in bulbs was increased by 48.0% due to 75 kg S/ha over only NPK treatment. Pyruvic acid concentration increased from 3.3 p mol/ml with 75 kg S/ha. Storage losses were reduced by 10.4% over a period of 6 months storage due to application of S @ 45 kg S/ha in comparison to only NPK treatment. Simple linear regression analysis revealed significant negative correlation between the storage losses of onion bulbs taken as dependent variable and pyruvic acid and total soluble solids as independent variables. **Mozumder et al. (2007)** obtained that the plant height, number of leaves/plant, length and diameter of bulb, single bulb weight, yield and profitability were significantly increased with the increased application of sulphur (gypsum) up to the maximum levels (36 kg-S/ha). Sulphur shows a positive correlation (R=0.9313) between S application and bulb yield. **Nasreen et al. (2007)** claimed that addition of nitrogen and sulphur (gypsum) fertilizers exerted significant

influence on the number of leaves/plant, plant height, diameter of bulb, single bulb weight, and yield of onion. The highest yield of onion and the maximum uptake of N and S were recorded by the combined application of 120 kg N and 40 kg S/ha with a blanket dose of 90 kg P<sub>2</sub>O<sub>5</sub>, 90 kg K<sub>2</sub>O, and 5 kg Zn/ha plus 5 tons of cow dung/ha. **Amin et al. (2007)** evaluated the optimum fertilizer dose of onion for greater Faridpur region under AEZ 12. Four different levels of NPKS viz. control, medium yield goal (MYG), high yield goal (HYG) and HYG X 1.3 were tested with Taherpuri variety of onion. The nutrient dose that maximized yield (107-72-90-33 kg NPKS/ha) as well as profit (95-50-70-32 kg NPKS/ha) of onion cultivation was found out from the response curve. **Yasmin et al. (2007)** obtained that Sulphur application increased grain yield in rice and all sources were equally effective under all three conditions (SNF, SF and DF), except gypsum, which was not different from the control under SF and DF conditions. Total sulphur content and fertilizer sulphur content in the grain and straw were not different between S sources. **Skwierawska et al. (2008)** reported that the most beneficial effect on the yields of cabbage, onion and barley was produced by the rates of 40 and 80 kg S/ha. **Jaggi and Raina (2008)** observed that garlic bulb and foliage yield (6.3 and 0.8 t/ha respectively) obtained at 30 kg/ha of sulphur dose was significantly higher over without sulphur (3.7 and 0.5 t/ha respectively) as revealed from two years pooled data. Similarly number of leaves/plant, weight of cloves/5bulbs and weight/100 cloves at the said sulphur dose significantly increased over without sulphur from 10.5 to 11.9, 98.3 to 141.2 g and from 159 to 217 g in respective manner. **Singh (2008)** noticed the response of graded levels of sulphur on bulb yields and S uptake by onion and garlic crops applied through Sulphur 95 and gypsum. An increase of 37.8 q ha<sup>-1</sup> bulb yield of onion and 18.8 q ha<sup>-1</sup> bulb yield of garlic were obtained with S application up to 40 kg ha<sup>-1</sup> over the recommended dose of fertilizers (NPK). Sulphur 95 was identified superior over gypsum to meet the S requirement of onion and garlic in S deficient soils of Ranchi. S use efficiency was found to be higher by these two crops with Sulphur 95 than that of gypsum application. **Degra et al. (2008)** also investigated that the successive rates of S nutrition upto 60 kg/ha markedly enhanced the dry matter, siliquae, seeds/siliqua and seed yield/plant and in both the years. Plant height and 1000-seed weight showed significant response upto 40 kg S/ha and remained at par with higher levels of S nutrition. **Vashisht et al. (2008)** observed that the significantly higher yield was obtained with P and S application at 40 kg P<sub>2</sub>O<sub>5</sub>/ha and 30 kg S/ha, respectively in groundnut. However, higher N uptake response was observed upto 60 kg S/ha. **Virender sardana et al. (2008)** studied the effect of application of sulphur (gypsum as soil application) on the productivity, quality and economic returns under irrigated conditions of

mustard. Increase in seed yield with soil application of 20 kg S/ha as gypsum. Net returns and B: C ratio were higher with basal application of 20 kg S/ha followed by soil application of gypsum to supply 40 kg S/ha. Application of gypsum reduced the glucosinolate content in defatted seed meal. **Ullah *et al.* (2008)** confirmed that sulphur application had significant effect on yield components and bulb yield of onion. The highest bulb yields (19.75 and 19.88 t/ha) were obtained from sulphur levels between 60 and 75 kg/ha. Weight of single bulb was the highest in plants treated with 75 kg S/ha. Plant receiving 45 or 60 kg S/ha had significant effect on single bulb weight. Plants treated with 75 kg S/ha showed that the largest bulb diameter. The maximum bulb yield was observed with 75 kg S/ha followed by 60 kg S/ha. **Al-Fraihat (2009)** reported that, sulphur fertilization significantly affected plant height and number of green leaves/plant. Increasing sulphur levels increased these parameters without significant difference between 50 and 100 kg S/ha in most cases effect of sulphur fertilizer, data showed that application at 100 kg S/ha achieved the highest total yield, i.e., 13.91 and 11.07 t/ha as well as marketable yield of bulb (11.81 and 8.43 t/ha) in the first and second seasons, respectively. Also, applying 100 kg S/ha produced the highest values of culls yield (2.13 and 2.63 t/ha) and TSS % (14.37 and 14.49%) in both seasons, respectively. **Farooqui *et al.* (2009)** claimed that application of 60 kg S ha<sup>-1</sup> significantly increased yield attributes (Table-2) like neck thickness (0.7250 cm), bulb diameter (4.87 cm), number of cloves per bulb (23.08), fresh weight of 20 cloves (36.67 g), dry weight of 20 cloves (13.85g), fresh weight of bulb (48.06 g), dry weight of bulb (23.42 g) and bulb yield q ha<sup>-1</sup> (160.54) in comparison to lower doses of sulphur. **Skwierawska and Zawartka (2009)** determined the influence of increasing rates of sulphur on the dynamics of available phosphorus in soil. The dose 120 kg.ha<sup>-1</sup> of S-SO<sub>4</sub> caused a significant increase in the concentration of available sulphur in soil in the 0-40 and 40-80 cm layers. **Channagoudra *et al.* (2009)** studied the response of onion to different levels of irrigation and sulphur in alfisols. Application of 40 kg S ha<sup>-1</sup> recorded significantly higher bulb yield (170.60 q ha<sup>-1</sup>) compared to other sulphur levels but was at par with application of 60 kg S ha<sup>-1</sup>. But significantly higher TSS (12.26 per cent) and pyruvic acid (3.1 µm/g) content in onion bulb were recorded in 60 kg S ha<sup>-1</sup> compared to other sulphur levels but was at par with 40 kg S ha<sup>-1</sup>. **Lee *et al.* (2009)** noticed that Sulphur nutrition has a strong influence on onion pungency, and the production of sweet onions in the high-Sulphur soil of Texas. Pyruvic acid, bulb weight, extractable S in soil and total S in bulb, soluble solids content (SSC), flavor precursor compounds [also called S-alk(en)yl-L-cysteine-sulfoxides (ACSOs)], and total sugars were measured. The pyruvic acid level of onions was not increased by the S

applications and showed no significant correlation with soil S levels in any of the cultivars at locations having 30 or 235 ppm S. The SSC, total S in bulbs, total sugars, and total ACSO content also showed no correlation with the S applications and soil S levels. Onion pungency and content of flavor precursor compounds were significantly influenced by cultivar and cultivar x location interaction. **Lee et al. (2009)** conducted a study to characterize short day onions of 3 pungency levels with regard to the composition of flavor related compounds. The flavor precursor contents ranged from 0.03 to 0.16 mg/g fresh weight (FW) for MCSO, 0.07 to 0.65 mg for 1-PeCSO, and 0.12 to 0.77 mg in total, and precursor contents increased with the pungency levels. Onions of different pungency levels did not differ in the contents of individual or total free amino acids, and the most abundant amino acids were glutamine and arginine. The total sugar contents ranged from 50 to 75 mg/g FW, and total S contents (3.5 to 5.1 mg/g dry weight) were not correlated with the pungency levels. Onion pungency is primarily determined by the content of flavor precursor compounds and not by total S, total sugars, or individual/total free amino acids in short day bulbs. **Bhagat and Chetti (2009)** revealed that with an increase in both sulphur and magnesium levels, there was increase in both the nutrients. The maximum chlorophyll content and NRA (nitrate reductase activity) were recorded in 80 kg/ha sulphur compared to all other treatments. Pungency content and total soluble solids also followed similar trend with 80 kg/ha sulphur. **Rastegar and Ganjehie (2009)** stated that bulb yield was affected by year, cultivar and sulphur fertilizer amount, but number of foliar applications had no effect on bulb yield. Application of 150 kg ha<sup>-1</sup> sulphur fertilizer decreased nitrate concentration in bulbs, but two foliar applications of micronutrient fertilizer increased significantly the concentration of nitrate in bulbs of cultivar Ghermez Azarshahr of onion. **Jaggi and Sharma (2010)** examined the response of onion (*Allium cepa* var. Patna red) at four sulphur levels (0, 15, 30 and 60 kg ha<sup>-1</sup>) applied through Gypsum and S<sup>95</sup>. The analysis was done to allocate the limited availability of sulphur for maximizing net profit over fertilizer cost. The results show that the dose of sulphur under its full availability is 43.02 kg ha<sup>-1</sup>. But under its scarce availability, the maximum benefit would occur when it is applied upto 32.11 kg ha<sup>-1</sup> followed by even distribution of fertilizer i. e. 20 kg ha<sup>-1</sup>. The returns following sulphur application at these rates, would be Rs 69,340, 73,092 and 68,700 ha<sup>-1</sup> respectively. **Zeinani et al. (2010)** summarized that effect of Sulphur fertilizer on the yield and bulb mean weight was significant at the 5% level, and the highest yield and bulb mean weight was obtained at 200 kg/ha Sulphur with *Thiobacillus*. The increase in yield and mean bulb weight was in accordance with the increase in above ground fresh weight. Furthermore, characteristics as diameter and height of the bulbs as well as the

thickness of the bulb neck were affected by the Sulphur treatments. Sulphur had positive effects on the total soluble solids (TSS), bulb dry matter (DM), bulb firmness and pyruvic acid of the bulbs as quality properties. Increasing of Sulphur up to 150 kg/ha resulted in increase of TSS, DM, bulb firmness and pyruvic acid of the bulbs. Sulphur at 200 and 250 kg/ha levels resulted in decrease of TSS, DM, bulb firmness and pyruvic acid. **Farhadet al. (2010)** observed that application of sulphur (gypsum) @ 20 kg/ ha produced the highest plant height, seed yield, 1000-seed weight and straw yield. Potassium in combination with Sulphur showed significant effect on yield and yield attributes of soybean. Combined application of Potassium @ 40 kg/ ha and sulphur @ 20 kg/ha resulted the highest seed yield, plant height, 1000-seed weight, straw yield, protein and oil contents of soybean. **Losaket al. (2010)** explored that interactive effects of two doses of nitrogen and two levels of soil sulphur on onion yields, nitrate content and concentration of the amino acids cysteine and methionine under accurately controlled conditions. The higher sulphur content ( $S_1$ ) increased yields by 7.0-8.4% compared with  $S_0$  for both doses of nitrogen. High sulphur reduced the nitrate content of onions by 19.3-20.5% depending on nitrogen dose. Soil sulphur content did not change the cysteine content but higher sulphur content in combination with higher nitrogen dose ( $N_2$ ) significantly increased the methionine content, by 18.7-40.7% compared with the other treatments. Joint fertilisation with nitrogen and sulphur is thus a suitable measure to increase onion yield and quality since it stabilises or increases the content of sulphur amino acids and reduces the level of undesirable nitrates. **Sharma et al. (2011)** reported that highest tuber yield, large size and medium size tuber yield, dry matter content, specific gravity, sugar content and starch content were found with the application of S 45 kg/ha. **Thomas et al. (2011)** investigated the regulation of sulphur assimilation in onion at the biochemical level. S-supply negatively influenced adenosine-5'-phosphosulphate (APS) reductase (APR) enzyme activity in both cultivars at bulbing only, and a higher abundance of APR was observed in both cultivars at bulbing in response to low S-supply. In contrast, S-supply significantly influenced ATP sulphurylase (ATPS) activity in leaf tissues of W202A only, and only at bulbing, while an increase in abundance in response to high S-supply was observed for both cultivars at bulbing. ATPS enzyme activity and accumulation was shown to decrease significantly in roots at bulbing in the S-deficient treatment in both cultivars, a difference that was only supported by western analyses in W202A. **McCallum et al. (2011)** examined that the variation in sulphate assimilation in onion (*Allium cepa* L.) and accumulation due to plant genotype and Sulphur nutrition. Accumulation of total S and alk(en)yl cysteine sulfoxide flavour precursors was significantly higher under S+ conditions.

Leaf Sulphate and cysteine levels were significantly higher in 'W202A' and under S+. Glutathione levels were reduced by S- treatment but were not affected by genotype, suggesting that thiol pool sizes are regulated differently in mild and pungent onions. **Dudhat *et al.* (2011)** reported that there were significant effects of sulphur sources on bulb yield. Significantly the highest bulb yield of 320.98, 415.63 and 383.21 q ha<sup>-1</sup> were recorded with the use of element sulphur, whereas, various levels of sulphur could not exert any significant effect on the bulb yield during individual years as well as in pooled results. Among various sources, the maximum net returns of 35,676 Rs.ha<sup>-1</sup> and benefit cost ratio of 0.87 were recorded by elemental sulphur and among various levels, the maximum net returns of 31,107 Rs.ha<sup>-1</sup> was secured by the application of sulphur @ 60 kg ha<sup>-1</sup>. **Forney *et al.* (2010)** reported that the increased Sulphur content was an increase in onion pungency/flavor measured as increased pyruvate content in macerated onion tissue and changes in S-alk(en)yl cysteine sulfoxides (ACSO) content. Pyruvate increased an average of 35% in onions receiving S-fertilization compared to controls.

**Materials**  
**and**  
**Methods**

# MATERIALS AND METHODS

## Chapter - III

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An investigation entitled "**Studies on the Different Planting Dates and Forms of Sulphur on Growth, Yield and Quality of Onion**" was conducted during the years 2012-2013 and 2013-2014, respectively. The experiment was carried out at the Horticulture Research Farm-I of the Department of Applied Plant Science (Horticulture), Babasaheb Bhimrao Ambedkar University, Vidya Vihar, Rae Bareli Road, Lucknow.

This chapter gives a detail picture of the methods & materials used and experimental techniques adopted during the entire course of investigation. The climatic and edaphic conditions prevailing therein during the crop period have also been presented at an appropriate place with suitable tables and diagrams. The details of the methodology adopted in this investigation have been presented under the following heads:

### **3.1 Location of the Experiment**

The experiment was carried out at the Horticulture Research Farm-I of Department of Applied Plant Science (Horticulture), Babasaheb Bhimrao Ambedkar University, Vidya Vihar, Rae Bareli Road, Lucknow (U.P.), India. The location of the farm is situated in the main campus of the University. The experimental field is located approximately 10 km from Lucknow railway station on the Rae Bareli Road towards the south city of the Lucknow. It is also well connected by the Bijnore-Kanpur Road. Geographically, the experimental site lies in the central part of the Uttar Pradesh and located at 26° 46' North latitude and 80° 55' East longitude at an elevation of 129 meters above the Mean Sea Level.

### **3.2 Climatic and Weather Conditions**

Lucknow region in Uttar Pradesh has a subtropical climate prevailing in Central part of U.P. with both the extreme of winter and summer temperatures. During major part of the

year, the climate of the district is influenced by the prevalence of dry air of the continental type. The cold season started from the end of November to the beginning of the March. The hot season prevails from April to June. The climate of the region is subtropical with maximum temperature ranging from 29.3 °C to 45 °C in summer and the minimum temperature ranging from 3.5 °C to 12 °C and relative humidity (RH) is 50-77% in different seasons of the year coupled with hot dry summer (Loo) and cold winter. It receives an average rainfall is 700 mm, most of which is received from July to mid September, distributed over a period of about 100 days with the peak period between July-August. It also receives scattered showers during winter. In general, the temperatures range from 5 °C to 42 °C. The coldest month of the year is January.

The mean of weekly values of important weather parameters prevailing during the period of investigation (2012-2014) were recorded at the meteorological observatory of Indian Institute of Sugarcane Research (ICAR), Dilkusha, Rae Bareli Road, Lucknow. The concerned data is presented in Table - 3.1 and graphically represented in Figure - 3.1.

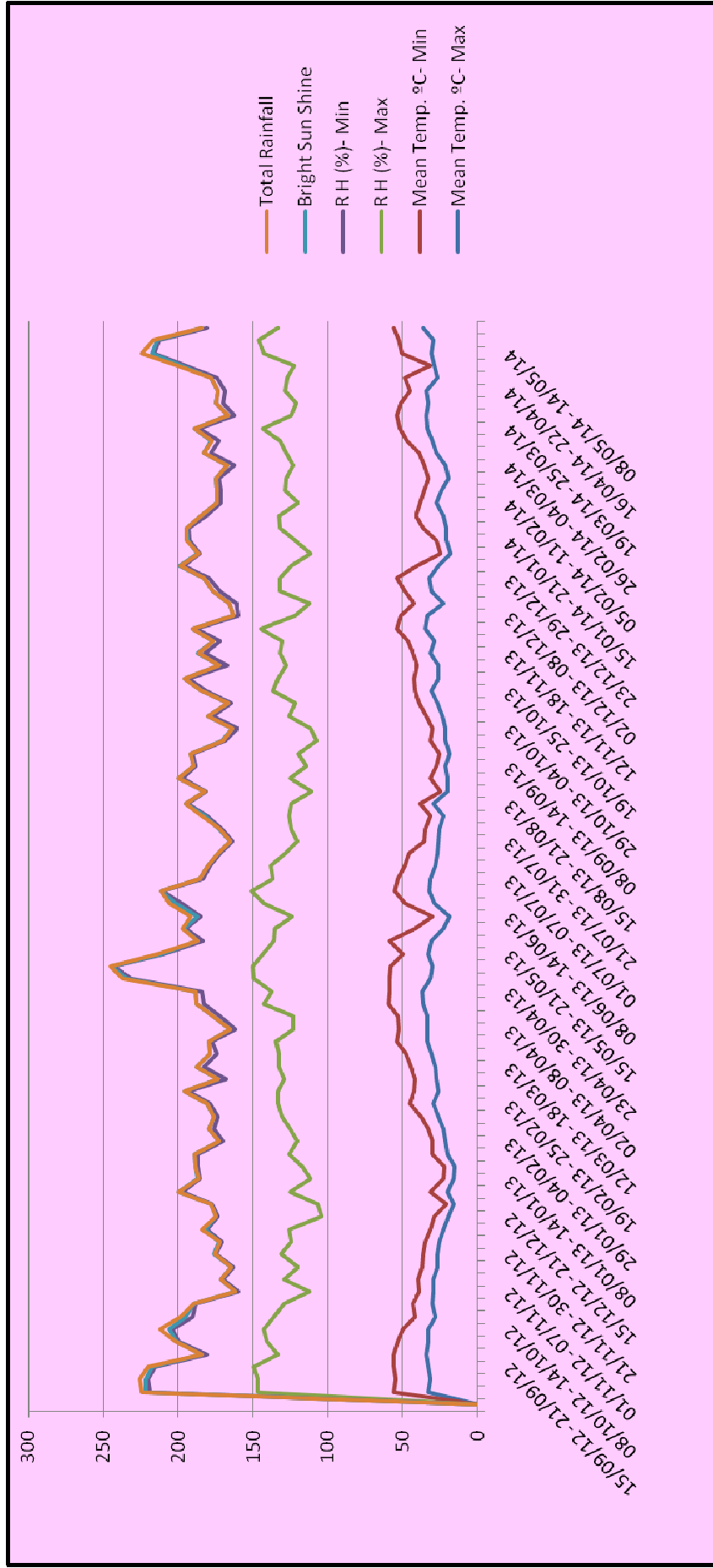
### **3.3 Edaphic Conditions of the Experimental Site**

The soil type is loamy clay. A composite soil samples collected randomly from the onion field at the Horticulture Research Farm-I up to depth of 0-15 cm before transplanting the seedlings. These samples mixed together, dried in air and powdered and again samples were mixed thoroughly. The representative samples, each of 5 g soil for each analysis were taken and the same were analyzed in the Laboratory of Regional Research Station of Central Soil Salinity Research Institute, Lucknow in order to determine the initial fertility level of the soil. The salient data on soil analysis and methods employed are furnished in Table 3.2.

**Table: 3.1 Average weekly meteorological data from September 2012 to March 2014**

Month	Date	Maximum	Minimum	Maximum	Minimum	Sun Shine (hours/day)	Rainfall (mm)
<b>Sep. 2012</b>	01-07	33.31	22.53	91.29	72.00	2.70	2.86
	08-14	31.93	22.36	93.00	73.29	1.34	6.74
	15-21	32.91	22.59	94.14	66.29	1.49	2.97
	21-30	34.48	21.29	77.67	47.89	3.17	0.00
<b>Oct. 2012</b>	01-07	32.93	20.07	87.86	59.57	1.00	0.69
	08-14	32.91	16.69	93.29	61.57	1.81	5.77
	15-21	28.19	13.19	94.86	54.57	4.56	3.60
	21-31	30.59	12.70	86.00	59.60	0.83	0.00
<b>Nov. 2012</b>	01-07	29.40	9.61	73.71	47.43	1.69	0.00
	08-14	29.51	9.93	90.29	40.29	1.70	0.00
	15-21	27.21	9.71	82.86	43.57	1.49	0.00
	21-30	27.00	9.43	95.11	43.33	1.19	0.00
<b>Dec. 2012</b>	01-07	25.37	9.57	89.57	46.29	1.87	0.00
	08-14	22.70	8.84	94.86	54.71	1.33	1.77
	15-21	19.64	8.96	76.14	69.00	1.54	0.00
	21-31	15.95	5.17	86.20	70.30	0.72	0.00
<b>Jan. 2013</b>	01-07	20.1	11.4	94	72	2.4	00
	08-14	16.4	6.5	89	74	1.0	00
	15-21	15.7	6.7	95	70	1.4	00
	22-28	20	10.5	96	61	1.8	00
<b>Feb. 2013</b>	29-04	21.8	8.2	91	49	2.9	00
	05-11	22.9	10.4	92	51	3.3	00
	12-18	26.3	11.6	93	43	2.3	00
	19-25	29.7	15.2	89	45	2.4	00
<b>Mar. 2013</b>	26-04	26.2	16.2	91	60	2.7	00
	05-11	27.6	13.9	88	39	5.3	00
	12-18	28.4	15.8	89	50	4.7	00
	19-25	31.3	16.8	85	41	5.0	00
	26-01	34	19.7	81	43	2.3	00
<b>Apr. 2013</b>	02-08	33.4	19.4	71	38	3.9	00
	09-15	33.9	19.4	70	49	4.6	00
	16-22	36.2	23	84	40	4.6	00
	23-29	37.1	21.5	79	47	3.7	00
<b>May. 2013</b>	01-07	31.91	26.53	91.29	72.00	2.70	2.86
	08-14	30.17	27.36	93.00	73.29	1.34	6.74
	15-21	33.08	16.59	94.14	66.29	1.49	2.97
	21-30	31.28	17.29	77.67	47.89	3.17	0.00
<b>Jun. 2013</b>	01-07	22.93	19.07	93.86	59.57	1.00	0.69
	08-14	18.91	11.69	93.29	61.57	1.81	5.77
	15-21	29.29	19.19	94.86	54.57	4.56	3.60
	21-30	32.59	22.70	96.00	59.60	0.83	0.00
<b>Jul. 2013</b>	01-07	31.40	21.61	83.71	47.43	1.69	0.00
	08-14	28.51	19.93	90.29	40.29	1.70	0.00
	15-21	27.21	18.71	82.86	43.57	1.49	0.00
	21-31	26.20	9.43	85.11	43.33	1.19	0.00
<b>Aug. 2013</b>	01-07	25.37	9.57	89.57	46.29	1.87	0.00
	08-14	22.70	8.84	94.86	54.71	1.33	1.77
	15-21	29.64	8.96	86.14	69.00	1.54	0.00
	21-31	19.95	5.17	86.20	70.30	0.72	0.00
<b>Sep. 2013</b>	01-07	20.1	11.4	94	72	2.4	00
	08-14	21.4	6.5	87	74	1.0	00
	15-21	18.7	6.7	95	70	1.4	00
	22-28	21.3	10.5	76	61	1.8	00





**Fig.3.1: Weekly basis meteorological data recorded during the period (September 2012 to May 2014) the course of investigation**

**Table 3.2: Available nutrients in the soil before transplanting**

<b>Soil properties</b>	<b>2012-13</b>	<b>2013-14</b>	<b>Methods employed</b>
Bulk Density	1.28	1.32	Tube core method (Baruah & Barthakur, 1998)
pH	8.53	8.21	Jackson (1973)
Organic Carbon (%)	0.40	0.43	Walkley and Black's rapid titration method (Piper, 1966)
Available Nitrogen (kg/ha)	348.03	323.48	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
Available Phosphorus (kg/ha)	19.36	20.38	Olsen <i>et al.</i> (1954) method
Available Potassium (kg/ha)	113.08	116.15	Ammonium acetate (1N) extraction and determining by using flame photometer (Jackson, 1973)
Sulphur (kg/ha)	10.48	11.69	Tandon (1993)

### **3.4 Experimental Details**

The details of experiment are given under the following heads:

#### **3.4.1 Design and Layout**

The experiment was laid out in Factorial Randomized Block Design with twenty one main plots and replicated thrice. The plan of layout is given in Figure 3.2.

#### **3.4.2 Treatment Details**

There were two factors comprising **dates of planting** and **three doses of two form of sulphur** with recommended dose of nitrogen, phosphorous and Potassium which were common to all the treatments. Following are the treatment combinations (Table 3.3):

##### **Factors**

##### **A. Planting Dates:**

There was three planting dates:

- First fortnight of November
- First fortnight of December

##### **Notations**

P<sub>1</sub>

P<sub>2</sub>

- First fortnight of January P<sub>3</sub>

### **B. Sulphur:**

Thus, there were three doses of both elemental sulphur and gypsum:

- 0 kg/ha S<sub>0</sub>
- 20kg/ha S<sub>1</sub>
- 40kg/ha S<sub>2</sub>
- 60kg/ha S<sub>3</sub>
- 0 kg/ha G<sub>0</sub>
- 20kg/ha G<sub>1</sub>
- 40kg/ha G<sub>2</sub>
- 60kg/ha G<sub>3</sub>

### **3.4.3 Plot Size**

Gross : 2.00 m x 1.50 m

Net : 1.50m x 1.00 m

### **3.4.4 Spacing**

The seedlings were transplanted at the standardized spacing of 15cm x 10cm.

### **3.4.5 Description of the Crop Variety**

In the present investigation, cultivar Pusa Red was used, which is large size, high yielding and less bolting type variety and best suited for growing in sub-tropical region under both rainfed and irrigated conditions. The variety is also having the good keeping quality. Seeds were collected from the Seed Production Unit of Indian Agricultural Research Institute, Pusa New Delhi.

## **3.5 Cultural Operations**

### **3.5.1 Land Preparations**

A piece of land measuring 29.05 m in length and 8.50 m in width was demarked at the experimental farm of Babasaheb Bhimrao Ambedkar, University. The land was ploughed thrice, harrowed and levelled properly after crushing the clods. The plots were then laid out as per the plan of experiment.

S. No.	Treatments	Notations	Treatment Combinations
1	T <sub>1</sub>	P <sub>1</sub> S <sub>0</sub> G <sub>0</sub>	15 <sup>th</sup> November
2	T <sub>2</sub>	P <sub>1</sub> S <sub>1</sub>	15 <sup>th</sup> November + Elemental Sulphur (20 kg/ha)
3	T <sub>3</sub>	P <sub>1</sub> S <sub>2</sub>	15 <sup>th</sup> November + Elemental Sulphur (40 kg/ha)
4	T <sub>4</sub>	P <sub>1</sub> S <sub>3</sub>	15 <sup>th</sup> November + Elemental Sulphur (60 kg/ha)
5	T <sub>5</sub>	P <sub>1</sub> G <sub>1</sub>	15 <sup>th</sup> November + Gypsum (20 kg/ha)
6	T <sub>6</sub>	P <sub>1</sub> G <sub>2</sub>	15 <sup>th</sup> November + Gypsum (40 kg/ha)
7	T <sub>7</sub>	P <sub>1</sub> G <sub>3</sub>	15 <sup>th</sup> November + Gypsum (60 kg/ha)
8	T <sub>8</sub>	P <sub>2</sub> S <sub>0</sub> G <sub>0</sub>	15 <sup>th</sup> December
9	T <sub>9</sub>	P <sub>2</sub> S <sub>1</sub>	15 <sup>th</sup> December + Elemental Sulphur (20 kg/ha)
10	T <sub>10</sub>	P <sub>2</sub> S <sub>2</sub>	15 <sup>th</sup> December + Elemental Sulphur (40 kg/ha)
11	T <sub>11</sub>	P <sub>2</sub> S <sub>3</sub>	15 <sup>th</sup> December + Elemental Sulphur (60 kg/ha)
12	T <sub>12</sub>	P <sub>2</sub> G <sub>1</sub>	15 <sup>th</sup> December + Gypsum (20 kg/ha)
13	T <sub>13</sub>	P <sub>2</sub> G <sub>2</sub>	15 <sup>th</sup> December + Gypsum (40 kg/ha)
14	T <sub>14</sub>	P <sub>2</sub> G <sub>3</sub>	15 <sup>th</sup> December + Gypsum (60 kg/ha)
15	T <sub>15</sub>	P <sub>3</sub> S <sub>0</sub> G <sub>0</sub>	15 <sup>th</sup> January
16	T <sub>16</sub>	P <sub>3</sub> S <sub>1</sub>	15 <sup>th</sup> January + Elemental Sulphur (20 kg/ha)
17	T <sub>17</sub>	P <sub>3</sub> S <sub>2</sub>	15 <sup>th</sup> January + Elemental Sulphur (40 kg/ha)
18	T <sub>18</sub>	P <sub>3</sub> S <sub>3</sub>	15 <sup>th</sup> January + Elemental Sulphur (60 kg/ha)
19	T <sub>19</sub>	P <sub>3</sub> G <sub>1</sub>	15 <sup>th</sup> January + Gypsum (20 kg/ha)
20	T <sub>20</sub>	P <sub>3</sub> G <sub>2</sub>	15 <sup>th</sup> January + Gypsum (40 kg/ha)
21	T <sub>21</sub>	P <sub>3</sub> G <sub>3</sub>	15 <sup>th</sup> January + Gypsum (60 kg/ha)

**Table 3.3: TREATMENT COMBINATIONS**

### **3.5.2 Nursery Raising and Transplanting**

Nursery of the crop was raised at Horticulture Research Farm under the shade net house to protect the seedlings from high sunlight and heat intensity. Seed beds of 3.0m x 1.0m were prepared and were properly sterilised by drenching with fungicide (Captan @ 5 g/ lit. of water) to protect the seedlings from soil borne diseases. Seeds were sown on three different dates namely on 15<sup>th</sup> September, 15<sup>th</sup> October and 15<sup>th</sup> November in three isolated beds followed by transplanting at three different dates *i.e.* on 15<sup>th</sup> November, 15<sup>th</sup> December and 15<sup>th</sup> January, respectively in both the consecutive years of 2012-13 and 2013-14. Seedlings were transplanted after two months of seed sowing.

### **3.5.3 Fertilizers Application**

At the time of field preparation FYM (20 t/ha) was incorporated in the field. Recommended dose of NPK (120:60:80) were given to each treatment in the form of urea, single super phosphate and muriate of potash. One third dose of nitrogen, full dose of phosphorus and potash were applied as basal dose at the time of final field preparation, while two third of nitrogen was applied in two-split doses at one month interval. Similarly, elemental sulphur and gypsum were applied as basal dose (at the rate of 20, 40 and 60 kg/ha of each) according to treatment combinations.

### **3.5.4 Gap Filling**

Even after keeping complete care in the field about 2% of mortality was observed, especially in first date of transplanting. The seedlings, which could not perform well, were replaced by the new healthy one to ensure optimum plant population.

### **3.5.5 After Care**

Six manual weedings were done to keep the plots free of weed and different plant protection measures as per package of practices were taken up during the experimentation.

### **3.5.6 Harvesting**

At the neck-fall stage and complete development of the bulbs, bulbs were dugout from each plot of different treatments. The bulbs were separated from rest of the plant part and cured properly under shade.

### **3.6 Observations Recorded**

Ten plants were selected randomly and tagged in each plot for recording the data on various parameters. Before and after harvesting, the observations on the following traits were recorded.

#### **3.6.1 Physical Attributes**

##### **3.6.1.1 Plant height (cm)**

The height of sampled plants were measured at 30, 60 and 90 days after transplanting from the ground level of the plant with the help of measuring scale and the average height of these plants were computed and the mean values reported finally in centimeters.

##### **3.6.1.2 Number of leaves per plant**

Total number of leaves of each selected plants under various treatments were recorded at 30, 60 and 90 days by counting them manual and the average was calculated for further statistical analysis and reporting.

##### **3.6.1.3 Neck thickness (cm)**

Neck thickness of the ten bulbs was measured at 30, 60 and 90 days by using Digital Vernier Callipers (Mitutoyo Corporation) and the means were expressed in cm.

##### **3.6.1.4 Bulb length (cm)**

The polar length of the ten bulbs was recorded after harvesting by using Digital Vernier Callipers and the means were worked out and expressed in cm.

##### **3.6.1.5 Bulb diameter (cm)**

The equatorial length of the ten bulbs was recorded after harvesting by using Digital Vernier Callipers and the means were worked out and given in cm.

##### **3.6.1.6 Bulb size (cm<sup>2</sup>)**

The size of the ten individual bulbs was noted down and the average of ten bulbs was expressed as mean bulb size (cm<sup>2</sup>).

##### **3.6.1.7 Bulb weight (g)**

The weight of the ten individual bulbs was taken and the average of ten bulbs was expressed as mean bulb weight (g).

#### **3.6.1.8 Bolting percentage (%)**

Bolting percentage was computed among the total number of plants per plot.

#### **3.6.1.9 Yield per plot (kg)**

The bulbs from net plot were dugout and weight of ten bulbs in each plot was taken and expressed in kg/ha.

#### **3.6.1.10 Total yield and marketable yield per hectare (t/ha)**

The yield per plot were computed in total yield per hectare was expressed in tons/ha. Marketable yield per hectare was computed after deducting bolting percentage per hectare.

### **3.6.2 Bio-chemical attributes**

Onion samples were analyzed for the biochemical parameters after harvesting.

#### **3.6.2.1 Total Soluble Solids (<sup>0</sup>Brix)**

The Total Soluble Solids were determined by using a Digital Refractometer (Hanna instruments). A small piece of onion was taken in muslin cloth and crushed. The refractometer was wiped clear with a moist muslin cloth. A drop of juice of the crushed onion was taken on the refractometer and the value was read. Values thus obtained were expressed in <sup>0</sup>Brix (AOAC, 1980).

#### **3.6.2.1 Ascorbic acid (mg/100g)**

The ascorbic acid in fresh crushed onion juice was estimated by using 2,6-dichlorophenol-indophenol dye by visual titration method (Ranganna, 2007). For estimation of ascorbic acid, 2g of onion juice was taken in a conical flask, blend with 18 ml of 3% HPO<sub>3</sub> i. e. Metaphosphoric acid (30 g of HPO<sub>3</sub> and 80 ml glacial acetic acid present

in 1 lt.) was added and keep it for 10 minutes incubation. The solution was mixed well and filters with Whatman Paper No. 44. By taking 2 ml of filter and added 5 ml HPO<sub>3</sub>. The mixture was titrated against 2,6-dichlorophenol-indophenol dye to a definite light pink colour, which persisted for thirty seconds. The entire value was recorded. The dye solution was standardized by titrating it against freshly prepared ascorbic acid (containing 50 mg ascorbic acid in 50 ml of 3% HPO<sub>3</sub> solution). Ascorbic acid was calculated by using the following formula.

$$\text{Ascorbic acid (mg/100g)} = \frac{\text{Titre value} \times \text{Dye factor} \times \text{volume made up} \times 100}{\text{Volume of sample taken for estimation} \times \text{weight or volume of sample taken}}$$

### 3.6.2.2 Pyruvic acid (µm/g)

#### Preparation of Reagents

##### 5% TCA

50 grams trichloroacetic acid was dissolved in distilled water to make the requisite volume of 1000 ml.

##### 2 4-DNPH {0.125% MPH in 2 NHCL}

Dissolved 0.125 grams of 2,4-dinitrophenylhydrazine in 1000 ml of 2 N HCl solution. To make 2 N HCL Solution, diluted 228 ml of 37.8% HCl to 1000 ml of distilled water.

##### 0.6 N NaOH

24 g of NaOH dissolved in distilled water to make 1000 ml.

#### Part A

##### Pyruvic acid standard curve

A standard curve of known concentration of pyruvic acid was prepared.

Five 500 ml volumetric flasks with the following stock concentrations of pyruvate: **0.1 M**, **0.100 µmoles/ml**, **0.050 µmoles/ml**, **0.025 µmoles/ml**, and **0.010 µmoles/ml** were taken.

Following solutions were made.

**0.1 M sodium pyruvate/ml:** 1.1 gram of sodium pyruvate salt added to 100 ml distilled water in a 500 ml volumetric flask.

**0.2  $\mu$ moles pyruvate/ml:** 2 ml of 0.1 sodium pyruvate added to 1000 ml of distilled water in a 1 L volumetric flask.

**0.100  $\mu$ moles pyruvate/ml:** 50 ml of 0.2  $\mu$ moles sodium pyruvate added to 100 ml of distilled water in a 500 ml volumetric flask.

**0.050  $\mu$ moles pyruvate/ml:** 25 ml of 0.2  $\mu$ moles pyruvate added to 100 ml of distilled water in a 500 ml volumetric flask.

**0.025  $\mu$ moles pyruvate/ml:** 12.5 ml of 0.2  $\mu$ moles pyruvate added to 100 ml of distilled water in a 500 ml volumetric flask.

**0.010  $\mu$ moles pyruvate/ml:** 5 ml of 0.2  $\mu$ moles pyruvate added to 100 ml of distilled water in a 500 ml volumetric flask.

Six spectrophotometer tubes were numbered from 1 to 6 and 4 ml of each stock solution added to one spectrophotometer tube.

**Tube 1:** 4 ml of distilled water was added. This tube used as a blank for calibration.

**Tube 2:** 4 ml of the 0.2  $\mu$ moles/ml solution added to Tube 2.

**Tube 3:** 4 ml of the 0.100  $\mu$ moles/ml stock solution added.

**Tube 4:** 4 ml of the 0.050  $\mu$ moles/ml solution added.

**Tube 5:** 4 ml of the 0.025  $\mu$ moles/ml solution added.

**Tube 6:** 4 ml of the 0.010  $\mu$ moles/ml solution added.

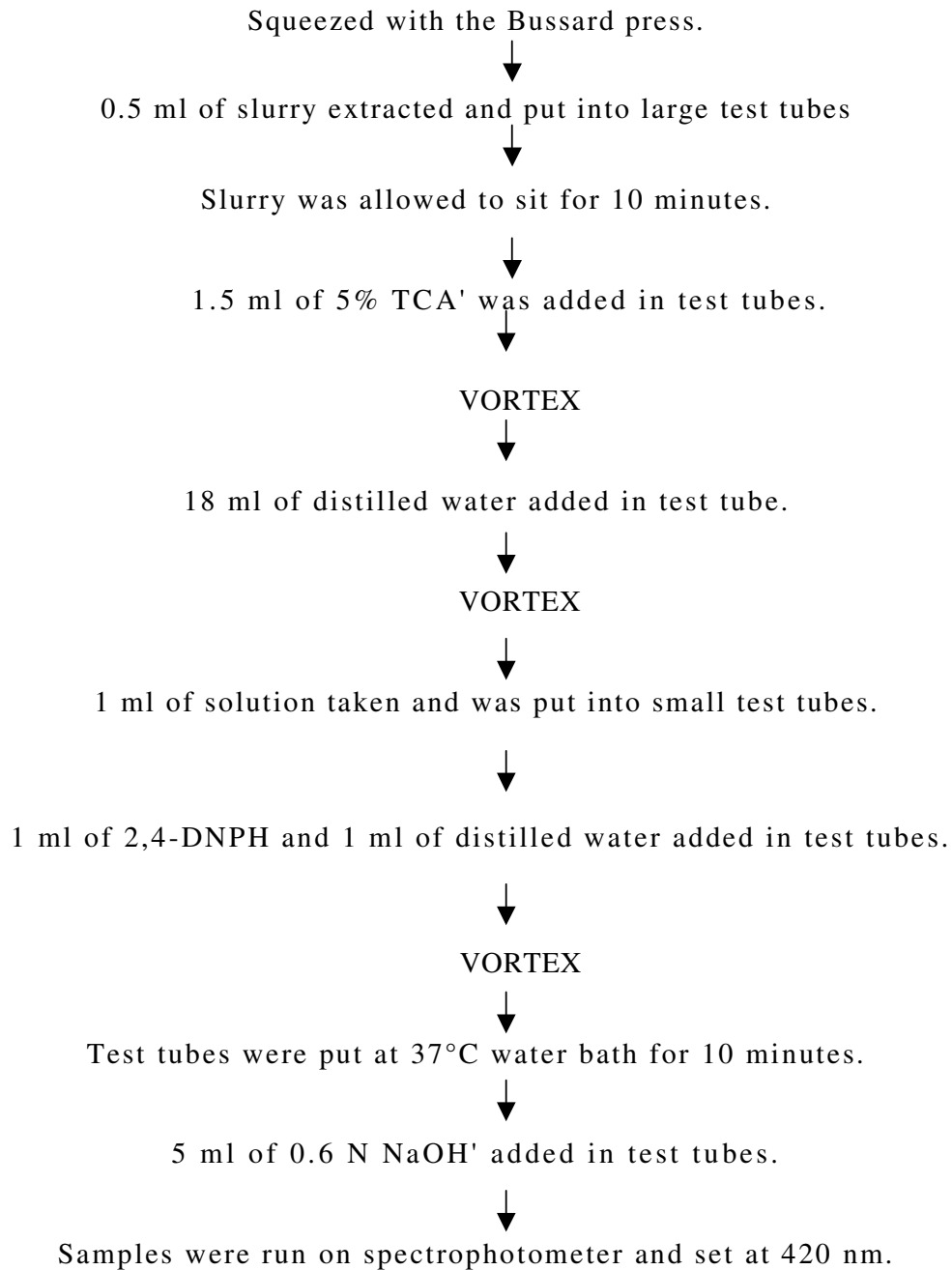
Percent transmittance was measured for each of the pyruvate standards. Data recorded and graph was plotted for the pyruvate concentration ( $\mu$ moles/ml) on the x-axis and percent transmittance (optical density - O.D.) on the y-axis and a standard curve constructed to read the transmittance of samples.

## **Part B**

### **Procedure of onion sample preparation**

A core sample or wedge was taken.





## **Part C**

### **Pyruvic acid Determination**

#### **Procedure:**

- **Tube 7:** 1 ml of the fresh onion sample in 5% TCA solution was taken in small test tube.
- 1 ml of 0.0125% 2,4-dinitrophenylhydrazine (2,4-DNPH) reagent and 1 ml of distilled water added to test tube 7.

- Test tube was covered with Parafilm and vortex and placed in a 37°C water bath.
- Mixture were allowed to react for 10 minutes.
- 5 ml of 0.6 N NaOH added to test tube again vortex.
- 5 ml of the solutions (Tube 7) taken into a spectrophotometer tube and the percent transmittance was read for the sample at 420 nm. Data recorded for the sample and process is repeated for the other samples. The standard curve from *Part A* used to estimate the pyruvate concentration for all samples.

### Calculations:

$$\mu\text{moles pyruvate/g tissue} = \mu\text{moles/mL (read from standard curve)} \times \text{Total Dilution}$$

### 3.6.2.3 Sugars (%)

Sugar was estimated by the method of "**Lane and Eynon**" (1923). For estimation of reducing sugar 10 g of fresh onion was homogenized in Waring Blender using distilled water. Filter the mixture with Whatman Paper No. 40. The final volume was made up to 250 ml. 5 ml of Fehling 'A' (containing 34.64g of crystalline copper sulphate in 500 ml of water) and 5 ml Fehling 'B' (containing 173g sodium potassium tetraborate and 50 g of NaOH in 500 ml of water) solution were taken in conical flask and titrated in boiling conditions against the aliquot present in the burette using methylene blue as a indicator. A brick red colour obtained due to precipitation of cuprous oxide indicates the end- point. The volume of the solution was noted for the calculation of reducing sugar. Standardized the 1:1 mixture of Fehling 'A' and Fehling 'B' solution used above 0.2% standard dextrose solution.

Estimation of reducing sugar was done by using the following formula-

$$\% \text{ Reducing Sugar} = \frac{\text{mg of Dextrose} \times \text{Volume made up} \times 100}{\text{Titre} \times \text{weight of sample taken} \times 1000}$$

### Total sugars and Non-reducing Sugar

For the total sugars 50 ml of aliquot was mixed with 5 ml of dilute HCL (3:1, water and conc. HCL) and whole mixture was kept overnight for hydrolysis. After 24 hours neutralizes, the sample with NaHCO<sub>3</sub> and volume was made up to 100 ml filled this into burette and titrated against Fehling 'A' and Fehling 'B' solution as an above for determination of reducing sugar as invert sugar.

$$\% \text{ Non-reducing sugar} = (\% \text{ Total invert sugar} - \% \text{ Reducing Sugar})$$

$$\% \text{ Total sugars} = \% \text{ Non- Reducing Sugar} + \% \text{ Reducing Sugar}$$

### 3.7 Benefit : Cost ratio

Based on the prevailing prices of inputs at the time of their usage and market price of the produce at the time of their dispatch, the B:C ratio and net profit was worked out using the following formula:

$$\text{Net profit per ha (Rs./ha)} = \text{Gross income (Rs./ha.)} - \text{Cost of cultivation (Rs./ha)}$$

$$\text{Benefit: Cost ratio} = \frac{\text{Gross returns (Rs./ha)}}{\text{Cost of cultivation (Rs./ha)}}$$

Gross Income (Rs./ha): Gross income was taken as total income from sale price of onion .

### 3.8 Statistical Analysis

Data were subjected to statistical analyses in the different sets of the experiments and calculated as method suggested by **Panse and Sukhatme (1985)**. The standard error (SEm±) for the difference of treatments means were computed as follows:

$$a) \text{SEm}\pm = \sqrt{\text{EMSS}/V}$$

Where,

EMSS is error mean sum of squares

$$r = \frac{\text{Total number of experimental units}}{\text{Levels of factor}}$$

$$\text{CD} = t\sqrt{2\text{EMSS}/r}$$

Where, t (5%) = value from (±) Table (Fisher's table) for error degrees of freedom at 5% level of probability.

# **Experimental Findings**

# EXPERIMENTAL FINDINGS

## Chapter - IV

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This chapter deals with the experimental findings obtained during the course of investigations. The experiments were conducted as per methods elaborated in the preceding chapter. The experiment pertinent to three transplanting dates namely 15<sup>th</sup> November, 15<sup>th</sup> December and 15<sup>th</sup> January of the year 2012-13 and 2013-14 and having three levels of elemental sulphur and gypsum (20 kg/ha, 40 kg/ha and 60 kg/ha) each along with control (only recommended dose of NPK). The response of onion crop to different treatments has been illustrated by using tables and graphs at appropriate places. The experimental findings are presented in this chapter.

### 4.1 PHYSICAL ATTRIBUTES

#### 4.1.1. Plant height at 30 DAT

The data obtained regarding to plant height under the influence of transplanting dates, sulphur fertilisation and their interaction has been clearly displayed in Table 4.1 and graphically in Figure 4.1.

Early in the experiment there was a significant growth differences were observed in plant height at different dates of planting. The maximum plant height 31.35 cm and 32.07 cm were noted with the treatment P<sub>1</sub> (15<sup>th</sup> November) in 2012-13 and 2013-14 respectively. However, the minimum values 25.53 cm and 26.15 cm were recorded in late planting *i.e.* P<sub>3</sub> (15<sup>th</sup> January) while the optimum plant height 29.94 cm and 30.31 cm was obtained in P<sub>2</sub> (15<sup>th</sup> December) planting in both the year of experimentation.

Similarly, data indicated that plant height was also significantly influenced by different levels of elemental sulphur and gypsum. The maximum values for plant height 32.00 cm and 32.25 cm was found in elemental sulphur S<sub>2</sub> (NPK + 40 kg/ha) while plant

height 31.47 cm and 31.70 cm found in elemental sulphur S<sub>3</sub>(NPK + 60 kg/ha) which was at par with S<sub>2</sub> in both the year.

Combined effect of three dates of transplanting and different level of sulphur has no significant effect noticed on the plant height in both the years of experiment.

#### 4.1.2. Plant Height at 60 DAT

The data recorded on plant height after 60 days of transplanting depicted in Table 4.2 and graphically presented in Figure 4.2 revealed that there was significant difference in plant height. Maximum plant height 52.50 cm and 53.20 cm were observed in P<sub>1</sub> (15<sup>th</sup> November) while minimum plant height 50.48 cm and 50.45 cm were found in P<sub>3</sub> (15<sup>th</sup> January) in both the consecutive years.

Plant height was also significantly influenced by different level of elemental sulphur and gypsum fertilisation. After 60 days of transplanting maximum plant height 53.88 cm and 54.36 cm were observed with elemental sulphur S<sub>2</sub> (NPK + 40 kg/ha) in both the years followed by gypsum G<sub>2</sub>(NPK + 40 kg/ha) *i.e.* 52.65 cm in 2012-13 and elemental sulphur S<sub>3</sub> (NPK + 60 kg/ha) *i.e.* 53.36 cm in 2013-14. The lower values 47.13 cm and 47.69 cm was observed in control S<sub>0</sub>G<sub>0</sub>(no application of elemental sulphur or gypsum).

Interactive effect of different transplanting times and levels of sulphur fertilisation did not show any significant differences among the treatments.

#### 4.1.3 Plant Height at 90 DAT

The data registered on plant height after 90 days of transplanting due to effect of the different combination of transplanting dates and sulphur fertilisation have been described in Table 4.3 and graphically in Figure 4.3.

The record embodied in the table indicated that different transplanting dates and sulphur fertilisation continuously played a significant role after 90 days of transplanting. The plant height 73.18 cm and 73.50 cm remains highest in early transplanting P<sub>1</sub> (15<sup>th</sup> November) and gradually decreases towards delayed transplanting and lowest plant height 60.39 cm and 61.07 cm was observed in P<sub>3</sub> (15<sup>th</sup> January) in both the consecutive years, respectively.

Similarly, the plant growth 68.26 cm and 68.99 cm remains maximum under same treatment of elemental sulphur S<sub>2</sub> (NPK + 40 kg/ha) followed by elemental sulphur S<sub>3</sub> (NPK + 60 kg/ha) *i.e.* 67.37 cm and 68.03 cm in both the years of experimentation, respectively while the least plant height 63.00 cm and 63.92 cm was noted in control S<sub>0</sub>G<sub>0</sub>(no application of sulphur fertilisation).

Plant height remains unaffected after 90 days of transplanting due to conjunctive use of different treatments. Data indicated that combined effect of transplanting dates and sulphur fertilisation had not significantly affect the plant height.

#### **4.1.4. Number of Leaves at 30 DAT**

The data analysed for number of leaves at 30 DAT under the influence of transplanting dates, sulphur fertilisation and their interaction has been clearly displayed in Table 4.4 and graphically in Figure 4.4.

In early period of experiment there was a significant difference was observed in number of leaves at different dates of planting. The maximum number of leaves 3.97 and 3.96 were noted in treatment P<sub>1</sub> (15<sup>th</sup> November) during both the year 2012-13 and 2013-14 respectively. However, the lowest values 3.56 and 3.60 were recorded in late planting *i.e.* P<sub>3</sub> (15<sup>th</sup> January) while the optimum number of leaves 3.87 and 3.80 was obtained in P<sub>2</sub> (15<sup>th</sup> December) planting in both the years of experimentation.

Similarly, data indicated that number of leaves was also significantly influenced by different levels of elemental sulphur and gypsum fertilisation. The maximum value for number of leaves 4.41 and 4.33 was found in elemental sulphur S<sub>2</sub> (NPK + 40 kg/ha) while lowest number of leaves 3.33 and 3.56 was found in gypsum G<sub>1</sub> (NPK + 20 kg/ha) except control S<sub>0</sub>G<sub>0</sub> during both the years.

Combined effect of three dates of transplanting and different level of sulphur has no significant effect noticed on the number of leaves in both the years of experiment.

#### **4.1.5. Number of Leaves at 60 DAT**

Data pertaining to average number of leaves per plant influenced by transplanting dates and sulphur fertilisation and their interaction have been displayed in Table 4.5 and graphically presented in Figure 4.5.

The average number of leaves per plant was significantly affected by different transplanting time. Maximum number of leaves 7.02 and 7.08 were found at early transplanting on P<sub>1</sub> (15<sup>th</sup> November) and lowest leaves 5.59 and 5.13 counting were found as we followed delayed transplanting P<sub>3</sub> (15<sup>th</sup> January) in both the years, respectively.

Data referred in Table 4.5 also registered significant variation in the average number of leaves under the influence of different levels of sulphur fertilisation. Elemental sulphur S<sub>2</sub> (NPK + 40 kg/ha) resulted in highest number of leaves per plant 7.25 and 7.03 followed by elemental sulphur S<sub>3</sub> (NPK + 60 kg/ha) *i.e.* 6.16 during the year 2012-13 and 6.57 in gypsum G<sub>2</sub> (NPK + 40 kg/ha) during the year 2013-14, while the lowest value 4.00 and 4.45 were noted in control S<sub>0</sub>G<sub>0</sub> in both the consecutive years, respectively.

Combined effect of transplanting dates and sulphur fertilisation also significantly affect the number of leaves produced per plant. Treatment combination P<sub>1</sub>S<sub>2</sub> (15<sup>th</sup> November + NPK + 40kg/ha) results better 8.53 and 8.43 during both the years respectively as compared to the rest of the treatment combinations.

#### **4.1.6. Number of Leaves at 90 DAT**

Data referred in Table 4.6 and Figure 4.6 depicted the average number of leaves after 90 days of transplanting as influenced by different transplanting dates and levels of sulphur fertilisation.

Data showed that after 90 days of transplanting early transplanting P<sub>1</sub> (15<sup>th</sup> November) remains performed better to the number of leaves per plant 10.48 and 10.40 as compared to the other two planting dates. Data clearly showed that number of leaves count gradually decreases as the transplanting is delayed.

Similarly, number of leaves 10.20 and 10.13 performed better under the influence of elemental sulphur S<sub>2</sub> (NPK + 40 kg/ha) followed by elemental sulphur S<sub>3</sub> (NPK + 60 kg/ha) in which the number of leaves are 9.48 during the year 2012-13 and gypsum G<sub>2</sub> (NPK + 40 kg/ha) *i.e.* 9.46 and elemental sulphur S<sub>3</sub> (NPK + 60 kg/ha) *i.e.* 9.45 in the successive year 2013-14, while minimum number 7.38 and 7.32 were observed in control S<sub>0</sub>G<sub>0</sub> in both the years, respectively.

Interactive effect of the combined treatment P<sub>1</sub>S<sub>2</sub> (15<sup>th</sup> November + NPK + 40kg/ha) on number of leaves was also significant in which the maximum number of leaves 11.70 and 11.53 were found followed by gypsum P<sub>1</sub>G<sub>2</sub> (15<sup>th</sup> November + NPK + 40 kg/ha) *i.e.* 11.46 in the year 2012-13 while P<sub>1</sub>S<sub>3</sub> (15<sup>th</sup> November + NPK + 60 kg/ha) *i.e.* 11.23 in the successive year 2013-14.

#### **4.1.7. Neck Thickness at 30 DAT**

The data obtained for neck thickness at 30 DAT under the effect of transplanting dates, sulphur fertilisation and their interaction has been displayed in Table 4.7 and graphically in Figure 4.7.

After initial one month of the crop growth there was a significant difference was observed in neck thickness at different dates of planting. The maximum neck thickness 0.93 cm and 0.97 cm was noted in treatment P<sub>1</sub> (15<sup>th</sup> November) during both the year in 2012-13 and 2013-14, respectively. However, the lowest values 0.76 cm and 0.73 cm were recorded in late planting *i.e.* P<sub>3</sub> (15<sup>th</sup> January) while the optimum neck thickness 0.81 cm and 0.88 cm was obtained in P<sub>2</sub> (15<sup>th</sup> December) planting in both the year of experimentation.

Similarly, data indicated that neck thickness was also significantly influenced by different levels of elemental sulphur and gypsum fertilisation. The maximum neck thickness 0.99 cm and 1.04 cm was found in elemental sulphur S<sub>2</sub> (NPK + 40 kg/ha) while lowest figure 0.61 cm and 0.66 cm was obtained for control during both the year.

Combined effect of three dates of transplanting and different level of sulphur has no significant effect noticed on the number of leaves in both the years of experiment.

#### **4.1.8. Neck Thickness at 60 DAT**

Data pertaining to neck thickness influenced by transplanting dates and sulphur fertilisation and their interaction have been arranged in Table 4.8 and graphically displayed in Figure 4.8.

The average neck thickness was significantly affected by different transplanting date. Maximum neck thickness 1.77 cm and 1.81 cm were found at early transplanting on P<sub>1</sub> (15<sup>th</sup> November) and lowest values for neck thickness 1.52 cm and 1.50 cm were found as we followed delayed transplanting P<sub>3</sub> (15<sup>th</sup> January) in both the years, respectively.

Data referred in Table 4.8 also registered significant variation in the average neck thickness under the influence of different level of sulphur fertilisation. Elemental sulphur S<sub>2</sub> (NPK + 40 kg/ha) resulted in highest neck thickness 1.78 cm and 1.83 cm followed by elemental sulphur S<sub>3</sub> (NPK + 60 kg/ha) *i.e.* 1.72 cm during the year 2012-13 and 1.73 cm in the year 2013-14, while the lowest value 1.31 cm and 1.36 cm were noted in control S<sub>0</sub>G<sub>0</sub> in both the consecutive years, respectively.

Combined effect of transplanting dates and sulphur fertilisation also significantly affect the neck thickness per plant. Treatment combination P<sub>1</sub>S<sub>2</sub> (15<sup>th</sup> November + NPK + 40kg/ha) results better 1.96 and 2.00 during both the years respectively as compared to the rest of the treatment combinations.

#### **4.1.9. Neck Thickness at 90 DAT**

The data computed for neck thickness at 90 DAT under the effect of transplanting dates, sulphur fertilisation and their interaction has been displayed in Table 4.9 and graphically in Figure 4.9.

After three month of the crop growth there was a significant difference was observed in neck thickness at different dates of planting. The maximum neck thickness 2.44 cm and 2.53 cm was noted in treatment P<sub>1</sub> (15<sup>th</sup> November) during both the year in 2012-13 and 2013-14, respectively. However, the lowest values 2.23 cm and 2.24 cm were recorded in late planting *i.e.* P<sub>3</sub> (15<sup>th</sup> January) while the optimum neck thickness 2.35 cm and 2.37 cm was obtained in P<sub>2</sub> (15<sup>th</sup> December) planting in both the year of experimentation.

Similarly, data indicated that neck thickness was also significantly influenced by different levels of elemental sulphur and gypsum fertilisation. The maximum neck thickness 2.48 cm and 2.54 cm was found in elemental sulphur S<sub>2</sub> (NPK + 40 kg/ha) while lowest figure 2.09 cm and 2.19 cm was obtained for control S<sub>0</sub>G<sub>0</sub>during both the year.

Combined effect of three dates of transplanting and different level of sulphur has no significant effect noticed on the number of leaves in both the years of experiment.

#### **4.1.10. Bulb Weight**

Data recorded towards the bulb weight after harvesting due to the effect of different transplanting dates, sulphur levels and their interaction have been summarized in Table 4.10 and graphically displayed in Figure 4.10.

Data clearly marked out that different transplanting dates significantly affected the bulb weight. Maximum bulb weight 75.47 g and 77.52 g were measured in early transplanting P<sub>1</sub>(15<sup>th</sup> November) while optimum weight 65.75 g and 67.94 g was found in mid-season planting P<sub>2</sub>(15<sup>th</sup> December) and minimum weight 51.12 g and 56.12 g was measured in late transplanting P<sub>3</sub>(15<sup>th</sup>January) in both the consecutive years, respectively.

Table 4.10 highlights that the different levels of sulphur also significantly affect the bulb weight. The trend of the data was similar in both the years of investigation. The

maximum bulb weight 70.36 g and 75.91 g were recorded during 2012-13 and 2013-14, respectively with the application of elemental sulphur S<sub>2</sub> (NPK + 40 kg/ha) followed by gypsum G<sub>2</sub> (NPK + 40 kg/ha) *i.e.* 68.05 g and 72.61 g while minimum weight were measured in control S<sub>0</sub>G<sub>0</sub> with no application of elemental sulphur or gypsum in both the years.

Data also clearly indicated that there was a significant variation in bulb weight due to interaction between different levels of sulphur fertilisation applied in all the three planting dates. Treatment combination P<sub>1</sub>S<sub>2</sub> (15<sup>th</sup> November + NPK + 40kg/ha) measured highest value of bulb weight 83.22 g and 87.55 g in both the years. However, second year 2013-14 has slightly more bulb weight as compared to the previous year. Minimum bulb weight 46.37 g and 49.03 g was found in late transplanting with no sulphur fertilisation P<sub>3</sub>S<sub>0</sub>G<sub>0</sub> (15<sup>th</sup> January + no elemental sulphur and gypsum).

#### **4.1.11. Bulb Length**

Data gathered on account of bulb length under the influence of different transplanting time and sulphur fertilisations and interaction of different sulphur fertilisation levels at different planting dates has been arranged in Table 4.11 and graphically presented in Figure 4.11.

It is evident from the data summarized in Table 4.11 that the bulb length was significantly showed variation while transplanting at different interval of time. Early transplanting P<sub>1</sub> (15<sup>th</sup> November) obtained maximum bulb length 6.17 cm and 6.30 cm and bulb length decreases as the planting was delayed and it was minimum 4.81 cm and 5.07 cm in late transplanting P<sub>3</sub> (15<sup>th</sup> January) in 2012-13 and 2013-14, respectively.

Similarly, Table 4.11 also indicated that bulb length was also significantly affected by different sulphur fertilisations. Application of elemental sulphur S<sub>2</sub> (NPK + 40 kg/ha) measured maximum bulb length 5.82 cm and 6.17 cm followed by elemental sulphur S<sub>3</sub> (NPK + 60 kg/ha) *i.e.* 5.68 cm during the year 2012-13 and G<sub>2</sub> (NPK + 40 kg/ha) *i.e.* 5.93 cm and elemental sulphur S<sub>3</sub> (NPK + 60 kg/ha) *i.e.* 5.92 cm during the year 2013-14. The minimum bulb length 4.75 cm and 4.57 cm were measured in control S<sub>0</sub>G<sub>0</sub> in both consecutive years, respectively.

It is quite obvious from the Table 4.11 that bulb length was significantly affected by interaction between the planting dates and sulphur fertilisation. The treatment combination P<sub>1</sub>S<sub>2</sub> (15<sup>th</sup> November + NPK + 40kg/ha) measured maximum bulb length 6.39 cm and 6.79 cm

in both the years respectively. However, second year 2013-14 has slightly more bulb length as compared to the previous year. Minimum bulb length 4.82 cm and 4.37 cm was found in late transplanting with no sulphur fertilisation  $P_3S_0G_0$  (15<sup>th</sup> January + no elemental sulphur and gypsum) in both the years, respectively.

#### **4.1.12. Bulb Diameter**

Data compiled on bulb diameter under the influence of different transplanting time and sulphur fertilisations and their interaction has been arranged in Table 4.12 and graphically presented in figure 4.12.

It is apparent from the Table 4.12 that the transplanting time also significantly influenced the bulb diameter. Perusal of data revealed that the maximum bulb diameter 6.84 cm and 6.94 cm were noticed in early transplanting  $P_1$  (15<sup>th</sup> November) while the minimum bulb diameter 5.38 cm and 5.52 cm were measured in late transplanting  $P_3$  (15<sup>th</sup> January) in 2012-13 and 2013-14, respectively.

Similarly, as transplanting dates, different sulphur fertilisation levels also significantly affect the bulb diameter. Application of elemental sulphur  $S_2$  (NPK + 40 kg/ha) obtained maximum bulb diameter 6.51 cm and 6.80 cm followed by elemental sulphur  $S_3$  (NPK +  $S^0$  60 kg/ha) in which bulb diameter was 6.37 cm and 6.59 cm during the year 2012-13 and 2013-14 respectively. Minimum bulb diameter 5.32 cm and 5.11 cm was found in control  $S_0G_0$  with no sulphur fertilisation.

It is quite clear from the data furnished in Table 4.12 that different levels of sulphur fertilisation applied at different planting time interact significantly. Highest value for bulb diameter was noted in treatment combination  $P_1S_2$  (15<sup>th</sup> November + NPK + 40kg/ha) in which maximum bulb diameter 7.15 cm and 7.59 cm in both the years respectively. However, second year 2013-14 has measured more bulb length as compared to the previous year 2012-13. Minimum bulb diameter 4.51 cm and 4.61 cm was found in late transplanting with no sulphur fertilisation  $P_3S_0G_0$  (15<sup>th</sup> January + no elemental sulphur and gypsum) in both the year of experimentation.

#### **4.1.13. Bulb Size**

Mean value on account of bulb size due to different transplanting time, sulphur fertilisation and their interaction have been presented in Table 4.13 and graphically in Figure 4.13.

Critical analysis of data mentioned in Table 4.13 brought tangible impact on bulb size due to transplanting at different time period. Maximum bulb size 41.53 cm<sup>2</sup> and 42.66 cm<sup>2</sup> was observed in early planting P<sub>1</sub> (15<sup>th</sup> November) while optimum bulb size 33.28 cm<sup>2</sup> and 34.27 cm<sup>2</sup> was found at peak planting time P<sub>2</sub> (15<sup>th</sup> December) and bulb size 27.28 cm<sup>2</sup> and 27.45 cm<sup>2</sup> was lowest as the transplanting delayed P<sub>3</sub> (15<sup>th</sup> January) in both the years, respectively.

Bulb size was also significantly affected due to application of different sulphur fertilisation levels. Maximum bulb size 37.66 cm<sup>2</sup> and 40.68 cm<sup>2</sup> was found in elemental sulphur S<sub>2</sub> (NPK + 40 kg/ha) which is *at par with* elemental sulphur S<sub>3</sub> (NPK + 60 kg/ha) *i.e.* 36.08 cm<sup>2</sup> and 38.47 cm<sup>2</sup>. The lowest measure for bulb size was obtained in control S<sub>0</sub>G<sub>0</sub> with no sulphur fertilisation during the year 2012-13 and 2013-14.

Although, combined effect of transplanting dates and sulphur fertilisation had not given any significant variation in bulb size in both the year.

#### **4.1.14. Bolting Percentage**

Data assembled in Table 4.14 and displayed in Figure 4.14 interpret the effect of transplanting at different time interval, elemental sulphur and gypsum fertilisation and their interaction on the bolting percentage in onion.

A cursory glance over the data portrayed in Table 4.14 demonstrated that bolting percentage was very significantly affected by transplanting of seedlings at different times. The maximum plant showed bolting 6.19 % and 6.28 % while early transplanting P<sub>1</sub> (15<sup>th</sup> November). Transplanting at the mid-season P<sub>2</sub> (15<sup>th</sup> December) showed slight fall in bolting 5.00 % and 4.66 % whereas bolting percentage 0.28 % and 0.04 % falls drastically in late transplanting P<sub>3</sub> (15<sup>th</sup> January) in both the year 2012-13 and 2013-14, respectively.

Data indicated that bolting was not significantly affected by either elemental sulphur fertilisation or gypsum in both year of experiment.

Similarly, transplanting time and sulphur fertilisation did not bring any tangible effect on bolting percentage in both consecutive years.

#### **4.1.15. Yield Per Plot**

Data compiled on account of yield per plot as influenced by different transplanting dates and sulphur fertilisation and their interaction have been presented in Table 4.15 and graphically showed in Figure 4.15.

On examined the data it was found that there was a marked variation in yield per plot. The highest yield 5.45 kg and 5.27 kg was noted in early transplanting P<sub>1</sub> (15<sup>th</sup> November) while lowest yield 3.76 kg and 3.88 kg was found in late transplanting P<sub>3</sub>(15<sup>th</sup> January) in both the years, respectively.

Data also indicated that application of different level of sulphur fertilisation had significant variation in yield per plot. The maximum yield per plot 4.99 kg and 4.93 kg was found in elemental sulphur S<sub>2</sub> (NPK + 40 kg/ha) which is *at par with* yield of elemental sulphur S<sub>3</sub> (NPK + 60 kg/ha) *i.e.* 4.82 kg during the year 2012-13 and gypsum G<sub>2</sub> (NPK + 40 kg/ha) *i.e.*4.74 kg and elemental sulphur S<sub>3</sub> (NPK + 60 kg/ha) *i.e.*4.75 kg during the year 2013-14. The lowest yield 4.27 kg and 4.25 kg was obtained in control S<sub>0</sub>G<sub>0</sub>with no sulphur fertilisation during the year 2012-13 and 2013-14, respectively.

Although, conjoint effect of transplanting dates and sulphur fertilisation had not given any significant variation in yield per plot in both the consecutive years.

#### **4.1.16. Total Yield and Marketable Yield Per Hectare**

Data gathered on account of total yield and marketable yield per hectare as influenced by different transplanting time seedlings, sulphur fertilisation and their interaction have been depicted in Table 4.16 and graphically illustrated in Figure 4.16 (a) and 4.16 (b).

It is evident from the data that there was a marked variation in total yield per hectare during both the years of experimentation. Highest total yield per hectare 36.33 tons and 35.17 tons was recorded in early planting P<sub>1</sub> (15<sup>th</sup> November) and total yield decreases as the transplanting time was delayed. The minimum total yield 52.08 tons and 25.99 tons were recorded in P<sub>3</sub> (15<sup>th</sup> January). Similarly, marketable yield 34.09 tons and 32.97 tons was highest in early planting P<sub>1</sub> (15<sup>th</sup> November) and minimum values 25.01 tons and 25.97 tons recorded for marketable yield in late planting P<sub>3</sub> (15<sup>th</sup> January) in both the consecutive years, respectively.

Data embodied in the Table 4.16 indicated that different levels of sulphur fertilisation also have a significant variation on total yield and marketable yield per hectare. Highest total yield per hectare 33.25 tons and 32.91 tons was recorded in elemental sulphur S<sub>2</sub> (NPK + 40

kg/ha) which is *at par with* yield after application of elemental sulphur  $S_3$  (NPK + 60 kg/ha) *i.e.* 32.17 tons during the year 2012-13 and elemental sulphur  $S_3$  (NPK + 60 kg/ha) *i.e.* 31.81 tones and gypsum  $G_2$  (NPK + G 40 kg/ha) *i.e.* 31.70 tones during the year 2013-14. The lowest total yield 4.27 kg and 4.25 kg was obtained in control  $S_0G_0$  with no sulphur fertilisation during the year 2012-13 and 2013-14, respectively. In the same way, marketable yield 31.96 tons and 31.80 tons was maximum in elemental sulphur  $S_2$  (NPK + 40 kg/ha) and minimum marketable yield 27.44 tons and 27.24 tons was found in control  $S_0G_0$  (no sulphur fertilisation) during 2012-13 and 2013-14, respectively.

Although, interactive effect of transplanting dates and sulphur fertilisation had not given any significant variation in yield per plot in both the consecutive years 2012-13 and 2013-14.

#### **4.1.17. Economic Feasibility of Treatments**

Data computed on account of benefit cost ratio of production of onion bulbs as influenced by the different planting dates, sulphur fertilisation and their interaction have been depicted in Table 4.17.

Maximum cost of cultivation Rs. 1,99,813 was recorded under the treatment  $P_2S_1$  (15<sup>th</sup> December + NPK + 20 kg/ha) in 2012-13 and  $P_3S_3$  (15<sup>th</sup> January + NPK + 60 kg/ha) Rs. 1,99,691 in 2013-14 while minimum cost of cultivation Rs. 1,90,296 during the year of investigation *i.e.* 2012-13 and 2013-14 was worked out with treatment  $P_2S_2$  (15<sup>th</sup> December + NPK + 40 kg/ha) and  $P_3G_1$  (15<sup>th</sup> January + NPK + 20 kg/ha), respectively.

Highest gross income of Rs. 8,51,180 in 2012-13 and Rs. 8,61,389 in 2013-14 were obtained with  $P_1S_2$  (15<sup>th</sup> November + NPK + 40 kg/ha). The minimum gross return of Rs. 5,16,180 and Rs. 5,23,770 during 2012-13 and 2013-14 were obtained under  $P_3S_0G_0$  (15<sup>th</sup> January) and  $P_3G_1$  (15<sup>th</sup> January + NPK + 20 kg/ha), respectively.

Highest net return of Rs. 6,59,284 and Rs. 6,59,384 during 2012-13 and 2013-14, respectively were obtained with  $P_1S_2$  (15<sup>th</sup> November + NPK + 40 kg/ha). The lowest net return of Rs. 3,17,764 in 2012-13 and Rs. 3,27,905 in 2013-14 were obtained under  $P_3S_0G_0$  (15<sup>th</sup> January) and  $P_3G_1$  (15<sup>th</sup> January + NPK + 20 kg/ha) during both the year.

Data clearly indicate that maximum benefit cost ratio 3.48 in 2012-13 and 3.43 in 2013-14 was computed in early planting  $P_1S_2$  (15<sup>th</sup> November + NPK + 40 kg/ha) followed by  $P_1S_3$  (15<sup>th</sup> November + NPK + 60 kg/ha) *i.e.* 3.39 and 3.30, respectively in both the year. The

minimum benefit cost ratio 1.58 and 1.65 was observed in late planting  $P_3S_0G_0$  (15<sup>th</sup> January without sulphur fertilisation) during both the consecutive years.

## IV.2. BIO-CHEMICAL ATTRIBUTES

### 4.2.1. Total Soluble Solids

The mean values obtained on total soluble solids content of onion bulb as affected by different planting dates, sulphur fertilisation and their interaction have been presented in Table in 4.18 and graphically in Figure 4.17.

The data in Table 4.18 revealed that the transplanting dates had significant effect on total soluble solids content of bulb. The maximum TSS 14.78<sup>0</sup>Brix and 15.42<sup>0</sup>Brix was found in early transplanting  $P_1$  (15<sup>th</sup> November) and TSS content was gradually decreases as the transplanting was delayed. Minimum TSS 12.03<sup>0</sup>Brix and 12.40<sup>0</sup>Brix were found in late transplanting  $P_3$  (15<sup>th</sup> January) in 2012-13 and 2013-14, respectively.

Data furnished in Table 4.18 pointed out that different level of sulphur fertilisation also had significant effect on TSS content in onion bulbs. Highest TSS content 14.67<sup>0</sup>Brix and 15.39<sup>0</sup>Brix were observed in elemental sulphur  $S_3$  (NPK + 60 kg/ha) which is *at par with* elemental sulphur  $S_2$  (NPK + 40 kg/ha) *i.e.* 14.10<sup>0</sup>Brix during the year 2012-13 and elemental sulphur  $S_2$  (NPK + 40 kg/ha) *i.e.* 14.48<sup>0</sup>Brix and gypsum  $G_2$  (NPK + 40 kg/ha) *i.e.* 14.44<sup>0</sup>Brix during the year 2013-14. The lowest TSS value 11.71<sup>0</sup>Brix and 12.20<sup>0</sup>Brix was measured in control  $S_0G_0$  with no sulphur fertilisation during the year 2012-13 and 2013-14, respectively.

Interactive effect of transplanting dates and sulphur fertilisation also had a significant effect on the TSS content of onion bulbs. Treatment combination  $P_1S_3$  (15<sup>th</sup> November + NPK + 60kg/ha) had maximum TSS content 15.97<sup>0</sup>Brix and 16.87<sup>0</sup>Brix in both the years respectively. However, second year 2013-14 has measured more TSS as compared to the previous year 2012-13. Minimum TSS content 10.36<sup>0</sup>Brix and 10.73<sup>0</sup>Brix was found in late transplanting with no sulphur fertilisation  $P_3S_0G_0$  (15<sup>th</sup> January + no elemental sulphur and gypsum) in both the year of experimentation.

### 4.2.2. Ascorbic Acid

Data regarding the average ascorbic acid content of onion bulb under the influence of different transplanting time and sulphur fertilisation levels and their interactions are clearly interpreted in Table 4.19 and graphically in Figure 4.18.

Data shown in Table 4.19 describes that the transplanting dates had significant effect on ascorbic acid content of bulb. Early transplanting P<sub>1</sub> (15<sup>th</sup> November) results in highest ascorbic acid content 12.45 mg/100g and 12.64 mg/100g and it was gradually decreases as the transplanting was delayed. Minimum ascorbic acid content 8.21 mg/100g and 8.27 mg/100g were found in late transplanting P<sub>3</sub> (15<sup>th</sup> January) in both the consecutive years, respectively.

Data depicted in Table 4.19 clearly indicated that different level of sulphur fertilisation had a significant effect on ascorbic acid content in onion bulbs. Maximum ascorbic acid 11.86 mg/100g and 11.96 mg/100g were found in elemental sulphur S<sub>2</sub> (NPK + 40 kg/ha) which is *at par with* elemental sulphur S<sub>3</sub> (NPK + 60 kg/ha) *i.e.* 11.74 mg/100g during the year 2012-13 and gypsum G<sub>2</sub> (NPK + 40 kg/ha) *i.e.* 11.76 mg/100g during the year 2013-14. The lowest content of ascorbic acid 8.84 mg/100g and 8.85 mg/100g was measured in control S<sub>0</sub>G<sub>0</sub> with no sulphur fertilisation during the year 2012-13 and 2013-14, respectively.

Combined effect of transplanting dates and sulphur fertilisation also had a marked effect on the ascorbic acid in onion bulbs. Treatment combination P<sub>1</sub>S<sub>2</sub>(15<sup>th</sup> November + NPK + 40kg/ha) had maximum ascorbic acid 13.39 mg/100g and 14.02 mg/100g in both the consecutive years respectively. However, second year 2013-14 has measured more ascorbic acid as compared to the year 2012-13. Minimum ascorbic acid 6.65 mg/100g and 7.32 mg/100g was found in late transplanting with no sulphur fertilisation P<sub>3</sub>S<sub>0</sub>G<sub>0</sub>(15<sup>th</sup> January + no elemental sulphur and gypsum) in both the years, respectively.

#### **4.2.3. Pyruvic Acid**

Data computed regarding pyruvic acid content in onion while transplanting at different dates and applying different levels of sulphur fertilisation from different source and the interaction between them has been clear-cut presented in Table 4.20 and graphically in Figure 4.19.

Data in the referred Table 4.20 indicated that changes in the pyruvic acid content in onion bulbs was very significantly affected by transplanting of seedlings at different time interval. The minimum pyruvic acid 4.80µm/g and 4.74 µm/g production in onion bulbs was found in early transplanting P<sub>1</sub> (15<sup>th</sup> November) and optimum pyruvic acid content 5.57µm/g and 5.47 µm/g in P<sub>2</sub>(15<sup>th</sup> December) transplanting while maximum synthesis of pyruvic acid

7.04 $\mu\text{m/g}$  and 6.78 $\mu\text{m/g}$  was occur in late planting P<sub>3</sub>(15<sup>th</sup> January) in both the consecutive years, respectively.

Similarly, as transplanting time, pyruvic acid content also varied significantly in onion bulbs under the influence of different level of sulphur fertilisation from different sources (elemental sulphur and gypsum). Higher dose of elemental sulphur results in maximum pyruvic acid formation in onion bulbs. The minimum 3.97  $\mu\text{m/g}$  and 4.02 $\mu\text{m/g}$  production was found in control (S<sub>0</sub>G<sub>0</sub>) while maximum synthesis 6.57 $\mu\text{m/g}$  and 6.72 $\mu\text{m/g}$  was observed in elemental sulphur S<sub>3</sub> (NPK + 60 kg/ha) which is *at par with* elemental sulphur G<sub>3</sub> (NPK + 60 kg/ha)*i.e.* 6.33 $\mu\text{m/g}$  and 6.22 $\mu\text{m/g}$  in both the years, respectively.

Likewise, transplanting date and sulphur fertilisation, pyruvic acid also showed a marked variation due to simultaneous interaction between them. The minimum production 3.71 $\mu\text{m/g}$  and 3.11 $\mu\text{m/g}$  was occur in P<sub>1</sub>S<sub>0</sub>G<sub>0</sub>(15<sup>th</sup> November + no elemental sulphur and gypsum) while maximum 8.11 $\mu\text{m/g}$  and 7.97 $\mu\text{m/g}$  production was found in P<sub>3</sub>S<sub>3</sub>(15<sup>th</sup> January + NPK + 60kg/ha) in both the consecutive years, respectively.

#### 4.2.4. Reducing Sugar

Data pertaining to reducing sugar percentage influenced by different transplanting dates, sulphur fertilisations and their interaction have been portrayed in Table 4.21 and graphically presented in Figure 4.20.

Critical analysis of the data revealed that seedling transplanted at different transplanting dates results in significant changes in reducing sugar percentage in onion bulbs. The maximum content of reducing sugar 5.14 % and 5.07 % were found in early transplanted bulbs P<sub>1</sub> (15<sup>th</sup> November) and it gradually decreases as the transplanting was delayed. The minimum reducing sugar percentage 2.71 % and 2.74 % was found in late transplanting P<sub>3</sub>(15<sup>th</sup> January) during the year 2012-13 and 2013-14, respectively.

Data displayed in the referred table indicated that there was a significant variation in reducing sugar percentage under the influence of different levels sulphur fertilisations. The highest reducing sugar percentage 4.61 % and 4.57 % was analysed in elemental sulphur S<sub>1</sub> (NPK +20 kg/ha) which was *at par with* gypsum G<sub>1</sub> (NPK + 20 kg/ha)*i.e.* 4.49 % and 4.35 % while minimum synthesis was found in control S<sub>0</sub>G<sub>0</sub> (only NPK without elemental sulphur or gypsum fertilisation) during both the consecutive years.

Albeit, there was no significant variation was found due to interaction between different transplanting dates and levels of sulphur fertilisation in both the years.

#### **4.2.5. Non-reducing Sugar**

Data assembled in connection with non-reducing sugar percentage as affected by different transplanting dates, sulphur fertilisations and their interaction have been presented in Table 4.22 and graphically displayed in Figure 4.21.

Data in referred Table 4.22 revealed that seedling transplanted at different transplanting dates resulted in significant variation in non-reducing sugar percentage in onion. The maximum synthesis of non-reducing sugar 6.75 % and 6.80 % were found in December transplanted bulbs P<sub>2</sub> (15<sup>th</sup> December) while minimum non-reducing sugar percentage 6.02 % and 6.06 % was found in early transplanting P<sub>1</sub> (15<sup>th</sup> November) during the year 2012-13 and 2013-14, respectively.

The referred table indicated that there was a significant variation in non-reducing sugar percentage under the influence of different levels sulphur fertilisations. The maximum non-reducing sugar percentage 6.92 % and 6.96 % was analysed in elemental sulphur S<sub>1</sub> (NPK + 20 kg/ha) which was *at par with* gypsum G<sub>1</sub> (NPK + 20 kg/ha) *i.e.* 6.84 % and 6.81 % while minimum 5.84 % and 5.88 % synthesis was found in control S<sub>0</sub>G<sub>0</sub>(only NPK without elemental sulphur or gypsum fertilisation) during both the consecutive years, respectively.

Interaction between different transplanting dates and levels of sulphur fertilisation also resulted in marked variation in non-reducing sugar synthesis in bulbs. Treatment combination P<sub>2</sub>S<sub>1</sub>(15<sup>th</sup> December + NPK +20kg/ha) produces bulbs with highest non-reducing 7.24 % and 7.30 % which is *at par with* 7.05 % and 7.12 % in P<sub>2</sub>G<sub>1</sub> (15<sup>th</sup> December + NPK + 20kg/ha) while minimum non-reducing percentage 5.44 % 5.50 % was found in P<sub>1</sub>S<sub>0</sub>G<sub>0</sub>(15<sup>th</sup> November + no elemental sulphur and gypsum)in both the years.

#### **4.2.6. Total Sugars**

Data collected regarding total sugars content under the influence of different transplanting dates, sulphur fertilisations and their interaction have been depicted in Table 4.23 and graphically presented in Figure 4.22.

It is interpreted from the data presented in referred table that seedling transplanted at different transplanting dates results in significant changes in total sugars content in onion bulbs. The maximum content of total sugars 11.52 % and 11.59 % were observed in early

transplanted bulbs P<sub>1</sub> (15<sup>th</sup> November) and it gradually decreases as the transplanting was delayed. The minimum total sugars 9.11 % and 9.10 % was found in late transplanting P<sub>3</sub> (15<sup>th</sup> January) during the year 2012-13 and 2013-14, respectively.

Data indicated that there was a significant variation in total sugars content under the influence of different levels sulphur fertilisations. The maximum synthesis of total sugars 11.53 % and 11.50 % was analysed in elemental sulphur S<sub>1</sub> (NPK + 20 kg/ha) which was *at par with* gypsum G<sub>1</sub> (NPK + 20 kg/ha) *i.e.* 11.19 % and 11.09 % while minimum synthesis was found in control S<sub>0</sub>G<sub>0</sub>(only NPK without elemental sulphur or gypsum fertilisation) during both the consecutive years, respectively.

Data also depicted that there was a significant changes in total sugars production due to interaction between different transplanting dates and levels of sulphur fertilisation in both the years. The maximum 12.64 % and 12.52 % production of total sugars was found in treatment combination P<sub>1</sub>S<sub>1</sub> (15<sup>th</sup> November + NPK + 20kg/ha) which was *at par with* 12.23 % and 12.10 % in P<sub>1</sub>G<sub>1</sub> (15<sup>th</sup> November + NPK + 20kg/ha) while minimum total sugars 8.35 % 8.48 % was found in P<sub>3</sub>S<sub>0</sub>G<sub>0</sub>(15<sup>th</sup> January + no elemental sulphur and gypsum) in both the years, respectively.

# Discussion

# DISCUSSION

## Chapter - V

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In this chapter, we are going to discuss the result obtained during the course of investigation in order to clarify the finding of the present study. After critically examine the data we have found that there are various points need to be discussed with the findings of the other workers. The observation on growth characters and quality traits under the influence of planting dates and sulphur fertilisation offer information of paramount importance to the research workers as well as the commercial growers or farmers. Result obtained in the previous chapter is discussed here in with possible reasons for the findings with supporting evidences. After critical discussion we are certainly able to conclude the findings with important achievements. To understand easily the whole discussion has been categorized into major heads in accordance with the objectives.

### **Effect of Transplanting Dates on Vegetative Growth and Yield of Onion**

Onion crop growth and yield depends on both genetic and environmental factors (climate, temperature, rainfall, sunlight, soil and nutritional factors). Among these factors the growing temperature (which varies with different transplanting time) and nutritional factors are most important. Generally, it has seen that the potential of crop growth is fully exploited in favourable environmental condition but it is not essential that if environment favours the yield it also favours the quality and *vice-versa* (Amin and Rahim, 1995). In onion as early transplanting reported by various workers results in high yield and quality bulbs as compared to delayed transplanting. Anisuzzaman *et al.* (2009) also reported that onion transplanted on 21<sup>st</sup> November had performed better in growth and yield. Present investigation also contributes the previous works that early transplanted seedlings results in vigorous plant growth in terms of plant height, number of leaves and neck thickness. These results are might be due to favourable low average temperature in early transplanting and high average temperature in late planting date during the growth period which led to decrease in plant growth and yield as the planting is delayed. The latest planting date showed the lowest

growth parameters values, may be due to the short period allowed for growth which is in conformity of the findings of **Al.-Moshileh (2007)** who reported that early planting showed significantly higher growth values than the later planting in the two growing seasons. **Neeraja et al. (2000)** indicated that enhanced crop growth rate of onion resulted in efficient metabolism, thereby increased the sink capacity. Higher metabolism greater photosynthates mobilization and better source sink relationship helped to produce higher yield by planting on 16<sup>th</sup> November. **Mahadeen (2008)** also found that neck thick diameter, bulb diameter and bulb weight were significantly decreased with delaying planting. Bulb initiation in onion starts when minimum day lengths are met. It might be possible that suitable weather condition gives a stimulatory effect to vegetative growth which accelerates the photosynthesis (**Ansari, 2007** and **Patil et al., 2012**). Research conducted by **Kandil et al. (2013)** also found that December transplanting is best over transplanting in January. If the cultivar is same then bulb initiation will occur more or less same time. However, temperature also effect bulb initiation slightly. As the bulb initiation starts new leaf formation ceases, so early transplanted seedlings produce more leaves as compared to later transplanting of the seedlings (**Brewster, 1994**). So, it becomes critical for a plant to develop sufficient leaves before the bulb initiation. Leaf growth and canopy development requires a minimum or base temperature of 6<sup>0</sup>C, below which growth of leaf ceases. The relative leaf growth rate has a linear relationship with the temperature from 6 – 20<sup>0</sup>C. Early transplanted crop is taller than late transplanted due to longer vegetative growth period which intercept more solar radiation in turn increase rate of photosynthesis which eventually increase bulb fresh weight (**Cramer, 2003**). Recent research conducted by **Bosekeng and Coetzer (2015)** also supported the finding of this investigation. As the minimum required day length has reached the apical meristem no further bladed leaf formation occur but only non-bladed fleshy leaf sheaths are formed at the base which ultimately form the bulb (**Brewster, 1997**). Onion transplanted at different time will develop bulbs at more or less same time as their day length requirement completed. Early transplanted seedlings therefore, have longer growing period, larger plant and larger bulb size. Bulb size of the onion depends on the physiological factors and adequate thermal time before bulb initiation (**Lancaster et al., 1996**). Large bulb size in early transplanting is due to maximum number of leaves which are the main supplier of photosynthates for bulb growth (**Mettananda and Fordham, 1999**) and **Valenzuela et al. (1999)**. **Brewster (2008)** reported that conversion of sucrose to reducing sugars increases the osmotic potential of the sheath cells as a result water moves in and cells expanded. In this study neck thickness was decreases as the transplanting was delayed which might be due to

more water and photosynthates transported from leaves to leaf sheath during longer growing period. **Gonzalez (1997)** reported that neck diameter has increased as the transplanting was delayed but, this result was due to more water availability in early transplanting (7 July) compared to late transplanting time (5 September). **Boyhan (2009)** also reported that November transplanting gives reasonable yield and quality of bulbs as compared to December transplanting. The total yield and marketable yield was highest in early transplanted bulbs due to increase in yield attributing traits during the early transplanting as compared to the optimum and late transplanting dates. **Pandey (1990)** also found the same result of maximum marketable yield during early transplanting in cultivar Pusa Red as compared to February transplanting.

### **Effect of Transplanting Dates on Biochemical Attributes of Onion**

Growing environment as affect the growth and yield also significantly affect the quality characteristics. From the present investigation it is clearly proved that different biochemical traits showed significant variation while transplanting at different dates. With the delay in planting TSS, ascorbic acid, total sugars and reducing sugar were gradually decreases while pyruvic acid increases linearly with increasing temperature. These variation in biochemical traits clearly indicated that growing temperature affect differently to different biochemical processes. Flavour potential in onion are depends upon genetic and multiple environmental factors. It may vary in different growing environment (**McCallum *et al.*, 2001**). The soluble solid content of mature bulbs had a negative linear response to increasing temperature (**Coolong and Randle, 2003**). Total sugars and reducing sugar were decreased with delay in planting. Total sugars and reducing sugar content was highest at low temperature and exceptionally low at high growing temperature (**Lee and Suh, 2009**). Non-reducing sugar content decreased at late transplanting this might be due to inversion of non-reducing sugar to reducing sugar because of increase in respiration due to high temperature (**Jeong *et al.*, 1996**). **Lee and Suh (2009)** reported that pyruvic acid content is highest at temperature condition 20<sup>0</sup>C because biosynthesis of cysteine activates effectively at temperature condition of 20<sup>0</sup>C (**Choi and Yang, 1974**). But, this result is different due to onion pungency increases which are broadly due to high temperature at late planting **Platenius and Knott (1941)**. Other workers also reported the same response **Yamaguchi *et al.* (1975)**. Temperature affects both the accumulation of total sulphur as well as total organic sulphur which are responsible for deciding the flavor. As the bulb grown at higher temperature for longer period its pungency increases four times more due to accumulation of

organically bound sulphur (**Coolong and Randle, 2003**). At low temperature sulphate did not undergo the flavor biosynthetic pathway (**Freeman and Mossadeghi, 1970**) and **Randle (1995)**. Most of the research reported that accumulation of organically bound sulphur does not depend upon the developmental stage. Maximum content of ascorbic acid in early planting might be due to maximum sugar synthesis (reducing sugar) during photosynthesis which is responsible for the synthesis of ascorbic acid. Ascorbic acid is found in plants where it is synthesized from glucose (**Stone, 1972**). The ascorbate pool is increased in leaves grown at high light intensity and at low temperature. In barley leaves, the ascorbate pool is correlated with photosynthetic capacity and with the supply of soluble carbohydrates (**Smirnoff and Pallanca, 1996**).

### **Effect of Transplanting Dates on Bolting Percentage of Onion**

Bolting is an important plant development phase if grown biennially for seed production but it is worst for the crop grown for bulb production because it reduces the marketable yield and quality of bulb. Premature bolting occurs in bulbs because of exposure to low temperature. If seedlings are transplanted very early then plant will favour weather condition for growth and development and plant accumulates sufficient food in small bulbs which favours bolting, that is the reason why plant undergoes premature bolting while transplanting in month of November and December in North India where winter is prolonged and very cold. Bolting is not only affected by the low temperature exposure but also due to varietal characteristic. The present study also recorded bolting percentage was higher in November and December transplanting while it was negligible in January transplanting. **Madisa and Midmore (1994)** reported that percentage of bolting was highest in early planting and decreased as the planting is delayed. Low temperature sensitivity is linearly related to the age of the plant (**Cramer, 2003**). Number of leaves and plant size also determines the bolting percentage. If the plant size at which the number of leaves seven to ten at the bulb initiation stage or first leaf fall plant is more sensitive to bolting percentage induced by low temperature (**Khokhar et al., 2007**). In this study bolting percentage in November transplanting is approximately same as in December transplanting which is the normal transplanting time of India. So, if transplanting time is shifted to one month earlier than the normal there has been no significant change in bolting percentage. Although there was a significant increase in total yield as well as marketable yield was found due to this shifting of transplanting time one month earlier. November transplanting resulted in maximum marketable yield than December transplanting due to slight variation in bolting

percentage in both the transplanting date. However, in late transplanting occurrence of bolting is either very less or negligible, but during the bulb initiation plant size still very small as a result very small bulbs are developed (**Cramer, 2003**). High numbers of seed stems and doubles at low temperature when plants have sufficient leaf numbers to respond to these conditions and enter a sexual phase (**Boyhan et al., 2004**). **Agic et al. (2007)** also reported the same result in Macedonia. It would be more beneficial to select less or no bolting type cultivar to get high yield in November transplanting. Therefore, transplanting time and cultivar selection should be taken into consideration for a specific area to obtain maximum production potential with less bolting.

### **Effect of Elemental Sulphur and Gypsum on Vegetative Growth and Yield of Onion**

Sulphur is an important secondary major nutrient which plays an important role in plant growth and development (**Jamal et al., (2009 & 2010) and Scherer (2009)**). Sulphur is best known for the synthesis of essential amino acids like methionine (21% S) and cysteine (27% S), protein and chlorophyll synthesis as well. In the present study, elemental sulphur has a significant effect on the vegetative growth, bulb development and yield of the onion as compared to the gypsum application. The response of gypsum mediated sulphur fertilization is lower as compared to elemental sulphur because low solubility of gypsum in the soil and as in turn less availability of  $\text{SO}_4^{2-}$  for crop because of leaching loss and **Singh (2008)** reported that maximum increase in growth and bulb yield of the crop was evident upto 40 kg/ha elemental sulphur as compared to gypsum. **Ahmad and Abdin (2000)** demonstrated that high S fertilization increases rubisco, chlorophyll and protein contents in fully expanded upper leaves of *Brassica juncea* L. which implies a better photosynthetic activity in comparison with plants grown with low or without sulphur. If the level of Rubisco decreases it affect the photosynthesis and the decline in chlorophyll results in breakdown of photosynthesis if sulphur is deficient. **Fazili et al. (2008)** also reported that lack of sulphur limits the availability of nitrogen. **Janzen and Bettany (1984)** found that ratio of available nitrogen to sulphur should be 7:1 below which seed yield of mustard decreases. A similar result in increase of bulb yields and sulphur uptake by onion and garlic with sulphur has also been reported by **Jaggi (2004)**. **O'Connor and Vartha (1969)** reported that heavy dose of gypsum reduced the yield of hay when soil is deficient in nitrogen. **Cram (1990)** observed that in a protein there is fix nitrogen to sulphur ratio *i.e.*, 15:1. A slight imbalance in this ratio may significantly alter the protein metabolism. **Aulakh et al. (1977)** also investigated that the grain yield in mustard increases significantly with the application of 30 kg sulphur per

hectare supplied as gypsum. The combined application of S and N had significant effect on the concentration and S and N absorption and yield (**Aulakh et al., 1980**). As sulphur not directly controls the photosynthesis but it influenced the process significantly through nitrogen availability which has very important role in photosynthesis and in turn the vegetative growth of the plant and biomass accumulation. **Chandra and Pandey (2013)** found that plant height and number of leaves declines at sulphur deficient and toxic condition. Bulb weight significantly affected in low sulphur application compared to high dose. Both low (20 kg/ha) and high (60 kg/ha) dose of sulphur causes sulphur-nitrogen imbalance in the plant. But **Farooqui et al. (2009)** investigated that application of 60 kg S/ha significantly increased neck thickness, bulb diameter, number of cloves per bulb, fresh weight of 20 cloves, dry weight of 20 cloves, fresh weight of bulb, dry weight of bulb and bulb yield in comparison to lower doses of sulphur. Sulphate affects the nitrate assimilation pathway by regulating the nitrate reductase (**Pal et al., 1976 and Friedrich and Schrader 1978**). **Ahmad et al. (2007)** also observed that sulphur availability not only regulate the nitrate reductase but, also has important role in regulating ATP-sulphurylase.

#### **Effect of Elemental Sulphur and Gypsum on Biochemical Attributes**

In this investigation sulphur fertilisation has more prominent effect on biochemical composition of the plant as compared to plant growth, bulb development and yield of the bulbs. Reducing sugar increases in bulb up to 40 kg/ha sulphur application but decreases in further increase due to toxicity while non-reducing sugar and total sugars was highest at low dose of sulphur application and ascorbic acid content decreases as dose of sulphur increases whereas TSS and pyruvic acid concentration increases linearly with dose of elemental sulphur and gypsum. Although, gypsum was less efficient in influencing the biochemical traits as compared to elemental sulphur (because solubility of gypsum is very less as compared to elemental sulphur in the soil) but it follows the same trend as elemental sulphur. Application of 60 kg elemental sulphur per hectare recorded the maximum content of TSS. Sulphur application is linearly correlated with the TSS. Such an increasing trend of TSS was also reported by **Kumar and Singh (1992)**. This increase in TSS might be due to increased synthesis of primary flavour compounds having sulphur containing amino acids whose production increases with increase in sulphur dose. Same trend of increasing TSS was also observed in gypsum mediated sulphur application but the content of TSS was less as compared to elemental sulphur. **Zeinani et al. (2010)** sulphur had positive effects on the total soluble solids and pyruvic acid of the bulbs as quality properties. At low sulphur level, sugar

metabolism in onion and garlic was affected by reduced chlorophyll content and rubisco levels which in turn reduce the capacity to harvest and utilise solar energy and sugar production was ceased in rice (**Resurreccion *et al.*, 2002; Lunde *et al.*, (2008)**). Incorporation of sulphur in the field increased the pungency of short day onions (**Freeman and Mossadeghi, 1970; Patterson (1979)**). **Channagoudra *et al.* (2009)** also reported that higher TSS and pyruvic acid content in onion bulb were recorded in 60 kg S/ha compared to other sulphur levels but was at par with 40 kg S/ha. **Bhagat and Chetti (2009)** also revealed that maximum pungency content and total soluble solids found with 80 kg/ha sulphur. **Randle (1992a)** reported that sulphur nutrition affect the concentration of total and individual non-structural water soluble carbohydrates and showed that ‘Granex 33’ bulbs accumulated more sucrose, glucose and fructose when grown with low than high sulphur nutrition. The decrease in sugar and starch in bulbs of onion deficient and toxic plants was more prominent than garlic (**Chandra and Pandey, 2013**). **Sharma *et al.* (2011)** also reported similar results of maximum sugar content at 45 kg/ha sulphur in potato. Onion becomes saturated when sulphur is supplied in sufficiently in high amount. At high levels, pungency no longer responds to increase in sulphur fertility (**Hamilton *et al.*, 1998**). Although, synthesis of ascorbic acid is not directly affected by sulphur fertilization but the status of sulphur affect the N uptake and metabolism in plants (**Janzen and Bettany, 1984**), which is responsible for sugar and ascorbic acid synthesis. **Adiloglu *et al.* (2013)** found that vitamin C is inversely correlated with the sulphur application in canola plant. Same results were determined by **Elwan and Abd-El-Hamed (2011)** in different vegetables.

### **Effect of Transplanting Dates, Elemental Sulphur and Gypsum on Economics of Onion**

The acceptance of any agricultural recommendation after the research will mainly depends upon its economic viability and recommendation pertaining to scientific crop management will not be adopted by the farmers unless treatments are economically viable. The economic analysis of the different treatment combinations in this investigation showed that highest benefit-cost ratio was observed in treatment combination 15<sup>th</sup> November + 40 kg elemental sulphur per hectare. This is mainly because early transplanting (15<sup>th</sup> November) has significantly increased the bulb yield over normal transplanting time (15<sup>th</sup> December) with a very slight variation in bolting percentage compared to normal planting date (15<sup>th</sup> December). High benefit cost ratio in early planting also due to less irrigation required during

the plant growth as compared to later planting because demand of water is increased due to increase in temperature in the March, April, May and June. Although, the cost of gypsum is very less as compared to elemental sulphur but gypsum is very bulky, produce low yield and quality bulbs due to low solubility in the soil. But its harmful effect on the soil for long term can't be ignored at any cost. Moreover, same quantity of elemental sulphur is much more efficient as compared to the same quantity of gypsum. **Jaggi and Sharma (2010)** reported that maximum benefit cost ratio was found in application of 30 kg/ha elemental sulphur application. **Dudhat *et al.* (2011)** computed maximum net returns and benefit cost ratio by elemental sulphur 60 kg/ha among various levels. Although, **Virendersardana *et al.* (2008)** observed that net returns and B:C ratio were higher with basal application of 20 kg S/ha followed by soil application of gypsum to supply 40 kg S/ha.

# **Summary and Conclusions**

## SUMMARY AND CONCLUSION

### Chapter VI

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The results obtained from the present investigation entitled “**Studies on the Different Planting Dates and Forms of Sulphur on Growth, Yield and Quality of Onion**” was undertaken on the Horticulture Research Farm-I of Department of Applied Plant Science, Babasaheb Bhimrao Ambedkar University, Lucknow. The salient findings emanating from the present investigation are summarized below:

- The highest plant height at 30, 60 and 90 days (34.84 cm, 54.68 cm and 75.72 cm in the year 2012-13 and 35.17 cm, 55.88 cm and 76.12 cm in the year 2013-14), respectively after planting was recorded in early planting date P<sub>1</sub>(15<sup>th</sup> November) with elemental sulphur S<sub>2</sub>(40 kg/ha) and there was a gradual decrease in plant height as the planting delayed while lowest plant height (20.29 cm and 56.24 cm in the year 2012-13 and 21.29 cm, 45.79 cm and 56.24 cm in 2013-14 ) was recorded in late planting P<sub>3</sub> (15<sup>th</sup> January) with no application of elemental sulphur or gypsum in both the consecutive years.
- Maximum number of leaves (4.63, 8.53 and 11.70 in 2012-13 and 4.60, 8.43 and 11.53 in 2013-14) at 30, 60 and 90 days, respectively after planting was counted in early planting P<sub>1</sub>(15<sup>th</sup> November) with elemental sulphur S<sub>2</sub>(40 kg/ha) and counting decreases linearly with the planting time and minimum number of leaves (2.53, 4.00 and 6.10 in 2012-13 and 3.00, 4.23 and 6.20 in 2013-14) were counted in late planting P<sub>3</sub> (15<sup>th</sup> January) without application of elemental sulphur or gypsum during both the years.
- The maximum neck thickness (1.05 cm, 1.96 cm and 2.63 cm in 2012-13 and 1.11 cm, 2.00 cm and 2.70 cm in 2013-14) was measured in early planting P<sub>1</sub>(15<sup>th</sup> November) with elemental sulphur S<sub>2</sub>(40 kg/ha) at 30, 60 and 90 days, respectively after transplanting and

decrease in neck thickness was recorded in late planting  $P_3$  (15<sup>th</sup> January) with no sulphur application in both the year.

- Maximum bulb weight (83.22 g and 87.55 g) after harvesting was weighed in early planted seedlings with the application of elemental sulphur  $P_1S_2$  (15<sup>th</sup> November + 40 kg/ha) in 2012-13 and 2013-14, respectively and slight decrease in bulb weight was recorded in  $P_2$  (15<sup>th</sup> December) planting while minimum bulb weight (46.37g and 49.03g) was weighed in late planting  $P_3S_0G_0$  (15<sup>th</sup> January + no sulphur fertilization) in both the year, respectively.
- Maximum bulb length (6.39cm and 6.79cm) was measured in early planting with the application of elemental sulphur  $P_1S_2$  (15<sup>th</sup> November + 40 kg/ha) while the minimum bulb length (4.14cm and 4.37cm) was measured in late planting  $P_3S_0G_0$  (15<sup>th</sup> January + no sulphur application) during both the consecutive years, respectively.
- Maximum bulb diameter (7.15 cm and 7.59 cm) was also measured in early planting with the application of elemental sulphur  $P_1S_2$  (15<sup>th</sup> November + 40 kg/ha) whereas the minimum bulb diameter (4.51 cm and 4.61 cm) was measured in delayed planting  $P_3S_0G_0$  (15<sup>th</sup> January with no sulphur fertilization) in the year 2012-13 and 2013-14, respectively.
- The maximum bulb size (44.84 cm<sup>2</sup> and 49.05 cm<sup>2</sup>) after harvesting was recorded in  $P_1S_2$  (15<sup>th</sup> November + 40 kg/ha) and bulb size gradually decreased as planting delayed in both the years. Minimum bulb size (20.37 cm<sup>2</sup> and 19.79 cm<sup>2</sup>) was recorded in  $P_3S_0G_0$  (15<sup>th</sup> January with no sulphur fertilization) during the year 2012-13 and 2013-14, respectively.
- Bolting percentage was minimum or negligible (0.28% and 0.04%) in late planting  $P_3$  (15<sup>th</sup> January) whereas bolting percentage was computed highest (6.19% and 6.28%) in early planting  $P_1$  (15<sup>th</sup> November) followed by  $P_2$  (15<sup>th</sup> December) planting (5.00% and 4.90%) in both the years, respectively.
- Maximum yield per plot (5.84 kg and 5.67 kg) and total yield per hectare (38.94 t and 37.83 t) were recorded in early planting with the application of elemental sulphur  $P_1S_2$  (15<sup>th</sup> November + 40 kg/ha) and yield decreases gradually with the delay in planting time. Minimum yield per plot (3.47 kg and 3.59 kg) and per hectare (23.17 t and 23.97 t) were recorded in late planting  $P_3S_0G_0$  (15<sup>th</sup> January with no sulphur fertilization) during both the consecutive years, respectively.

- Highest marketable yield (36.49 tons and 35.82 tons) was found in treatment combination P<sub>1</sub>S<sub>2</sub> (15<sup>th</sup> November +40 kg/ha) while minimum marketable yield (23.02 tons and 23.89 tons) was observed in later planting P<sub>3</sub>S<sub>0</sub>G<sub>0</sub> (15<sup>th</sup> January with no sulphur fertilization) during 2012-13 and 2013-14, respectively.
- The highest benefit cost ratio (3.48 and 3.43) was observed in early planted seedlings treated with elemental sulphur P<sub>1</sub>S<sub>2</sub> (15<sup>th</sup> November + 40 kg/ha) whereas minimum benefit cost ratio (1.58 and 1.65) was found in P<sub>3</sub>S<sub>0</sub>G<sub>0</sub> (15<sup>th</sup> January with no sulphur fertilization) during both the consecutive years 2012-13 and 2013-14, respectively.
- Early transplanting with elemental sulphur P<sub>1</sub>S<sub>3</sub> (15<sup>th</sup> November + 60 kg/ha) resulted in higher total soluble solids content (15.97 and 16.87 °Brix) in the bulb and decreases linearly with delay in planting time. Lowest total soluble solids content (10.36 and 10.73 °Brix) were observed in late planting P<sub>3</sub>S<sub>0</sub>G<sub>0</sub> (15<sup>th</sup> January with no sulphur fertilization) during the year 2012-13 and 2013-14, respectively.
- Highest content of ascorbic acid (13.39 and 14.02 mg/100g) was estimated in P<sub>1</sub>S<sub>2</sub> (15<sup>th</sup> November + 40 kg/ha) and lowest ascorbic acid content (6.65 and 7.32 mg/100g) in last planting date P<sub>3</sub>S<sub>0</sub>G<sub>0</sub> (15<sup>th</sup> January with no sulphur fertilization) in both the years, respectively.
- Minimum pyruvic acid content (3.71 and 3.11 µm/g) was found in early planting P<sub>1</sub>S<sub>0</sub>G<sub>0</sub> (15<sup>th</sup> November with no sulphur application) whereas maximum pyruvic acid (8.11 and 7.97 µm/g) was found in late planting with elemental sulphur P<sub>3</sub>S<sub>3</sub> (15<sup>th</sup> January + 60 kg/ha) during the year 2012-13 and 2013-14, respectively.
- Maximum reducing sugar (5.81 and 5.74%) and total sugars (12.64 and 12.52%) were observed in early planting and elemental sulphur P<sub>1</sub>S<sub>1</sub> (15<sup>th</sup> November + 20 kg/ha) whereas minimum values for reducing sugar (2.03 and 2.21%) and total sugars (8.35 and 8.48%) were noted in late planting P<sub>3</sub>S<sub>0</sub>G<sub>0</sub> (15<sup>th</sup> January with no sulphur fertilization) during the year 2012-13 and 2013-14, respectively.
- Highest content of non reducing sugar (7.24 and 7.30%) was recorded in P<sub>2</sub>S<sub>1</sub> (15<sup>th</sup> December + 20 kg/ha) while minimum non reducing sugar content (5.44 and 5.50%) was estimated in early planting P<sub>1</sub>S<sub>0</sub>G<sub>0</sub> (15<sup>th</sup> November with no sulphur fertilization) during both the years, respectively.

## **CONCLUSION**

The overall results obtained from present investigation clearly revealed that planting time and sulphur fertilization are among the critical factors determining the yield and quality traits of onion. The early planting (15<sup>th</sup> November) of seedling exposed to longer favourable growth period as compared to later transplanted seedlings before bulb initiation which results in vigorous plants producing larger bulbs. Although, early planting results in more bolted bulb production but the percentage of bolting doesn't differ very much with normal planting time (15<sup>th</sup> December) as a result early planted seedlings gives the higher total yield and marketable yield compared to December planting. Therefore, optimum planting time according to specific area should be determined to avoid quality problem associated with early or late planting dates.

Another factor which contributes the yield and quality is sulphur fertilization with appropriate dose. Sulphur fertilization mainly affects the quality of bulbs along with yield. Elemental sulphur gives the best result as compared to gypsum mediated sulphur application for each and every parameter. Optimum dose of elemental sulphur 40 kg/ha is much more economical to get higher bulb yield and exhibited better quality of bulbs in comparison to rest of the other higher and lower doses of sulphur application. Early planting supplemented with 40 kg/ha elemental sulphur results in higher yield and quality bulb production. Thereby proper nutrient balance and optimum time adjustment seems to be obtain quality bulbs under Lucknow conditions. However, before recommendation to the farmers for commercial cultivation, research trial needs further repetition.

## **FUTURE LINE OF WORK**

- Need to develop a nursery raising technique to get the healthy seedling in the month of September to prevent the nursery seedlings with high temperature, humidity, sun intensity as crop is susceptible to fungal infection.
- Although, there is a high yield in transplanting one month before than normal time period, there is need to access the storability of the bulb because early transplanted bulb has more moisture content which may decrease the shelf life.
- Need to collect, conserve and develop the less bolting type of germplasms.

# **Bibliography**

## BIBLIOGRAPHY

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- Abd-Elfattah, A.; Rasheed, M. A. and Shafei, A. M. (2005).** Phosphorus availability as influenced by different application rates of elemental sulphur to soils. *Egyptian Journal of Soil Science*. 45(2): 199-208.
- Adiloglu, S.; Açıkgöz, F.E. and Adiloglu, A. (2013).** The effect of increasing dose of sulfur application of some nutrient elements, Vitamin C, protein contents and biological properties of canola plant (*Brassica napus* L.). *Journal of Tekridag Agriculture faculty*. 10(3): 59-63.
- Agic, R.; Popsimonova, G.; Jankulovski, D. and Martinovski, G. (2007).** Winter onion susceptibility to premature bolting depending on the variety and the sowing date. *Acta Hort*. 729: 271-276.
- Ahmad, S.; Fazli, I.S.; Jamal, A.; Iqbal, M. and Abdin, M.Z. (2007)** Interactive effect of sulphur and nitrogen on nitrate reductase and ATP-Sulphurylase activities in relation to seed yield from *Psoralea corylifolia* L. *J. Plant Biol*. 50: 351-357.
- Ahmed, A. and Abdin, A. Z. (2000).** Interactive effect of sulphur and nitrogen on the oil and protein contents and on the fatty acid profiles oil in the seeds of rapeseed (*Brassica campestris* L.) and mustard (*Brassica juncea* L. Czern. And Coss.). *Journal of agronomy and crop science*. 185: 49-54.
- Al-Abdulsalam, M. A. and Hamaiel, A. F. (2004).** Effect of planting dates and compound fertilizers on growth, yield and quality of Hassawi onion under Al-Hassa oasis conditions. *Scientific Journal of King Faisal University (Basic and Applied Sciences)*; 5(1): 65-79.
- Al-Fraihat, A. H. (2009).** Effect of Different Nitrogen and Sulphur Fertilizer Levels on Growth, Yield and Quality of Onion (*Allium cepa*, L.). *Jordan Journal of Agricultural Sciences*. 5(2): 155-166.

- Al-Moshileh, A. M. (2007).** Effects of planting date and irrigation water level on onion (*Allium cepa* L.) production under Central Saudi Arabian conditions. *Scientific Journal of King Faisal University (Basic and Applied Sciences)*. 8(1): 75-85.
- Amin, M. R.; Hasan, M. K.; Naher, Q.; Hossain, M. A. and Noor, Z. U. (2007).** Response of Onion to NPKS Fertilizers in Low Ganges River Flood Plain Soil. *Int. J. Sustain. Crop Prod.* 2(1): 11-14.
- Amin, M.M.U. and M.A. Rahim, (1995).** Effect of plant density, planting time and nitrogen on the growth weight and yield of onion. *Progress. Agric.*, 6: 69-75.
- Aminpour, R. and Bak, A. M. (2004).** Effect of planting date and intra-row spacing on seed yield and germination of onion (*Allium cepa* L. cv. Texas Early Grano 502). *Pajouhesh-va-Sazandegi: In Agronomy & Horticulture*. 62: 64-69.
- Ammal, U. B. and Mathan, K. K. (2001).** Development and evaluation of effectiveness of sulphur based phosphatic fertilizer on soil and crop. *Fertilizer News*. 46(7): 31-38.
- Ammal, U. B.; Mathan, K. K. and Mahimairaja, S. (2000).** Effect of different levels of rock phosphate sulphur granule on growth and yield of onion and black gram. *Journal of Tropical Agriculture*. 38(1): 55-58.
- Anisuzzaman, M.; Ashrafuzzaman, M.; Ismail, Mohd.R.; Uddin, M. K. and Rahim, M. A. (2009).** Planting time and mulching effect on onion development and seed production. *African Journal of Biotechnology*. 8(3): 412-416.
- Anonymous.(2014).** National Horticulture Board.[http://nhb.gov.in/area%20\\_production.html](http://nhb.gov.in/area%20_production.html)
- Ansari, N. A. (2007).** Effect of density, cultivars and sowing date on onion sets production. *Asian J. of Plant Sci.* 6 (7): 1147-1150.
- Anwar, M. N.; Sarker, J. U.; Rahman, M.; Islam, M.A. and Begum M. (2001).** Response of onion to nitrogen, phosphorus, potassium, sulphur and zinc. *Bangladesh J. Environ. Sci.* 7: 68-72.
- AOAC.(1980).** Official method of analysis AOAC (International Association of Official Analytical Chemists). Washington, D.C; pp.108.
- Attia, K. K. (2001).** Influence of filter mud cake, elemental sulphur applications and micronutrients fertilization on yield and nutrient content of onion. *Assiut Journal of Agricultural Sciences*. 32(5): 105-120.
- Aulakh, M.S.; Pasricha N.S. and Sahota, N.S. (1977).** Nitrogen-sulfur relationship in brown sarson and Indian mustard. *Ind J Agric Sci.* 47: 249-253.

- Aulakh, M.S.; Pasricha, N.S. and Sahota, N.S. (1980).** Yield, nutrient concentration and quality of mustard crops as influenced by nitrogen and sulphur fertilizers. *J. Agric Sci Camb.* 94: 545-549.
- Balakrishnan, A. and Selvakumar, T. (2008).** Effect of time of sowing and hybrids on growth and yield of tropical sugarbeet]. *Res. on Crops* 9 (3): 588-592.
- Baruah, T.C. and Barthakur, H.P. (1998).** A Textbook of Soil Analysis. Vikash Publishing House Pvt. Ltd., New Delhi, India. pp. 13-14.
- Bell, A. A. (1981).** Biochemical mechanism of disease resistance. *Ann. Rev. Plant Physiol.* 32: 2 1-81.
- Bhagat, K. and Chetti, M. B. (2009).** Influence of sulphur and magnesium on bulb yield and biochemical parameters in onion. *Indian Journal of Horticulture.* 66(2): 215-219.
- Block, E. (1992).** The organosulfur chemistry of the genus *Allium*-Implications for the organic chemistry of sulfur. *Angew. Chem. Intl. Ed. Engl.* 31:1135- 1178.
- Bloem, E.; Haneklaus, S. and Schnug.(2004).** Influence of nitrogen and sulfur fertilization on the alliin content of onions and garlic. *Journal of Plant Nutrition.* 27(10): 1827-1839.
- Bosekeng and Coetzer.(2015).** Response of onion (*Allium cepa*L.) to sowing date and plant population in the central Free State, South Africa. *African Journal of Agricultural Research.* 10(4): 179-184.
- Boyhan, G.; Torrance, R.; Blackley, R.; Cook, J.; Hill, R. and Paulk, J. (2004).** Vidalia onion variety trials 2003–2004. *Georgia Onion Res.-Ext. Rpt.* No. 3:1–4.
- Boyhan, G.E.; Torrance, R. L.; Cook, J.; Riner, C. and Hill C. R. (2009).** Variety effect on transplanted short-day onion production. *Hort Technology.* 19(1):66-71.
- Breu, W. (1996).** *Allium cepa* L. (onion) part 1: chemistry and analysis. *Phytomedicine* 3:293-306.
- Brewster, J.L. (1977).** The physiology of the onion. *Hort. Abstr.* 47:102-112.
- Brewster, J.L. (1990).** Physiology of crop growth and bulbing, p.53-81. In: H. D. Rabowitch and J.L. Brewster (eds). *Onions and Allied Crops.* Vol. 1. CRC Press, Boca Raton, Fla.
- Brewster, J.L. (1994).** Onion and other vegetable alliums, 1<sup>st</sup> edition, CAB international, Wallingford, pp. 63-83.
- Brewster, J.L. (1997).** Onions and garlics. In: H.C. Wien (ed.). The physiology of vegetable crops. CAB International, Wallingford, United Kingdom.

- Brewster, J.L. (2008).** Onions and other vegetable alliums. 2nd edn., CAB International, Wallingford, United Kingdom.
- Brown, P.D. and Morra, M.J. (1997).**Control of soil-born plant pests using glucosinolate containing plants. *Adv. Agronomy* 61:161-231.
- Caruso, G. (2000).** Relationships among planting time, chemical weed control and weed cover in onion (*Allium cepa* L.).*Acta Horticulturae* 533: 215-228.
- Chandra, N. and Pandey, N.(2013).**Effect of sulphur on the growth, dry matter, tissue sulphur and carbohydrate concentration of *Allium Sativum* L and *Allium cepa* L. *Indian J of Agric. Biochem.* 26 (2): 182-186.
- Channagoudra, R.F.;Prabhudeva, A. and Kamble, A.S. (2009).**Response of onion (*Allium cepa*L.) to different levels of irrigation and sulphur in alfisols of northern transitional tract of Karnataka. *Asian J. Hort.*, Vol. 4 (1): 152-155.
- Choi, Y. J. and Yang, H. C. (1974).**Studies on cysteine desulfhydrase produced by bacteria.(Part II) enzymetic preparation of L-cystiene. *Korean J. Appld. Microbiol. Bioeng.* 2: 45-50.
- Comrie, A.G. (1997).** Climatic and soil requirements for onions. Onions B.1, Agricultural Research Council, Vegetable and Ornamental Plant Institute, Pretoria, South Africa.
- Coolong, T. W. and Randle, W. M. (2003).**Temperature influences flavor intensity and quality in 'Granex 33' onion. *J. Amer. Soc. Hort. Sci.*128 (2):176–181.
- Cram, W.J. (1990).** Uptake and transport of sulphate. In: Rennenberg H (ed.) Sulphur Nutrition and Assimilation in Higher Plants. SPB Acadmic Publishing, The Hague, The Netherlands, pp, 3-11.
- Cramer, C.S. (2003).**Performance of fall-sown onion cultivars using four seeding dates.*J. Amer. Soc. Hort. Sci.* 128:472-478.
- Darbyshire, J. (1978).** Changes in carbohydrate content of onion bulbs stored for various times at different temperatures. *J. Amer. Soc. Hort. Sci.* 53:195-201
- Degra, B. L.;Pareek and R. K. Shivran.(2008).** **Effect of sulphur and integrated weed management on productivity and quality of Indian mustard (*Brassica juncea*) and succeeding fodder pearl millet.** *Res. on Crops* 9 (3): 573-577.
- DeMason, D.A. (1990).**Morphology and Anatomy of *Allium*. In: H. D. Rabowitch and J.L. Brewster (eds.). *Onions and Allied Crops.* 3: 27-52. CRC Press, Boca Raton, Fla.
- Dudhat, M. S.; Chovatia, P. K.;Sheta, B. T. and Thesiya, N. M. (2011).** Effect of sources and levels of sulphur fertilizers on bulb yield of onion (*Allium cepa* L.). *International Journal of Plant Sciences.* 6(1): 134-136.

- EL-Desuki, M.; Abdel-Mouty, M.M. and Ali, A.H. (2006).**Response of onion plants to additional dose of potassium application. *Journal of Applied Science Research*, 2(9): 592-597.
- El-Rehim, G. H. A.; Ahmed, F. A.; Shalaby, G. I. and Waly, A. A. (1997).** Effect of transplanting date and planting density on bulb yield and quality of Giza 20 onion in upper Egypt. *Egyptian Journal of Agricultural Research*. 75(3): 681-695.
- Elwan, M. W. M. and Abd El-Hamed, K. E. (2011).** Influence of nitrogen form, growing season and sulfur fertilization on yield and the content of nitrate and vitamin C of broccoli. *Scientia Horticulturae* 27: 181–187.
- Farghali, M. A. (1995).** Effect of planting date and clipping of mother-bulb on seed yield of onion under Assiut conditions. *Assiut Journal Agricultural Sciences*. 26(2): 81-91.
- Farhad, I.S.M.; Islam, M.N.;Hoque, S. and Bhuiyan, M.S.I. (2010).**Role of Potassium and Sulphur on the Growth, Yield and Oil Content of Soybean (*Glycine max* L.)*Academic Journal of Plant Sciences* 3 (2): 99-103.
- Farooqui, M.A.; Naruka, I.S.; Rathore, S.S.; Singh, P.P. and Shaktawat, R.P.S. (2009).**Effect of nitrogen and sulphur levels on growth and yield of garlic (*Allium sativum*L.) *As. J. Food Ag-Ind.*, Special Issue, S18-23
- Faruq, M.O.; Alam, M.S.; Rahman, M.;Alam, M.S. and Sharfuddin, A.F.M. (2003).**Growth, yield and storage performance of onion as influenced by planting time and storage condition.*Pakistan Journal of Biological Sciences*. 6(13): 1179-1182
- Fazili, I.S.; Jamal, A.; Ahmad, S.; Masoodi, M.; Khan, J.S. and Abdin, M.Z. (2008).**Interactive effect of sulphur and nitrogen on nitrogen accumulation and harvest in oilseed crops differing in nitrogen assimilation potential. *J Plant Nutri*. 31: 1203-1220.
- Fismes, J.; Vong, P.C.;Guckert, A. and Frossard, E. (2000).** Influence of sulfur on apparent N-use efficiency, yield and quality of oilseed rape (*Brassica napus* L.) grown on a calcareous soil. *European Journal of Agronomy*. 12:127–141.
- Forney, C.F.; Jordan, M.A.; Campbell-Palmer, L.; Fillmore, S.; McRae, K. and Best, K. (2010).** Sulfur fertilization affects onion quality and flavor chemistry during storage. *ISHS Acta Horticulturae*. 877:VI International Postharvest Symposium.
- Freeman, G.G. and Mossadeghi, N. (1970).**Effect of sulphate nutrition on flavour components of onion (*Allium cepa*).*J. Sci. Food Agr*. 21:610-615.

- Friedrich, J.W. and Schrader, L.E. (1978).** Sulphur deprivation and nitrogen metabolism in maize seedlings. *Plant Physiol.* 61: 900-903.
- Gautam, I. P.; Khatri B. and Paudel, G. P. (2006).** Evaluation of different varieties of onion and their transplanting times for off-season production in mid hills of Nepal. *Nepal Agric. Res. J.* vol.7.
- Gill, S. S. and Singh, H. (1989).** Effect of bulb size and dates of planting on growth parameters and seed yield of onion. *Seed Research.* 17(1): 11-15.
- González, M. I. (1997).** Effect of sowing date on the production of three storage varieties of onion in the eight regions of Chile. *Acta Hort.* 433:549-554.
- Griffiths, G.; Trueman, L.; Crowther, T.; Thomas, B. and Smith, B. (2002).** Onions a global benefit to health. *Phytother. Res.* 16: 603-615.
- Ha InJong; SuhJunKyu; Hwang HaeJun; Kim WooIl and Kim ByungSoo (1998).** Effect of sowing date and seedling age at planting on growth and yield for growing plug seedlings in onion (*Allium cepa* L.). *RDA Journal of Horticulture Science* (I). 40(2): 90-97.
- Haldar, A.; Karak, C.; Naik, A.; Samanta, M. K. and Hazra, P. (2009).** Identification of suitable early rabi onion varieties under West Bengal condition. *Journal of Crop and Weed.* 5(1): 131-135.
- Hamid, A. A.; Salih, S. O.; Abdalla, A. E. and Naim, A. M. El. (2010).** Effect of sowing date and plant density on growth and yield of tomato (*Lycopersicon esculentum*, Mill.) *Research Journal of Agriculture and Biological Sciences*, 6(5): 665-669.
- Hamilton, B. K.; Yoo, K. S. and Pike, L. M. (1998).** Changes in pungency of onions by soil type, sulphur nutrition and bulb maturity. *Sci. Hort.* 74:249-256.
- Hu Wei Hou; XiLin Wang and JianJun Chen Yu. (2003).** Effects of different sowing dates and post-winter field planting on growth and yield of onion (*Allium cepa* L.). *Acta Agriculturae Shanghai* 19(4): 57-60.
- Hutton, R. C. and Wilson, G. J. (1986).** Onion: Effect of sowing date on maturity, yield, and quality of 'Pukekohe Longkeeper' and 'Early Longkeeper'. *New Zealand Journal of Experimental Agriculture, Vol. U:* 453-457.
- Ibrahim, N. D. (2010).** Growth and yield of onion (*Allium cepa* L.) in Sokoto, Nigeria. *Agriculture and Biology Journal of North America*, 1(4): 556-564.
- Ibrahim, N. D. and Adesiyun, A. A. (2009).** Effects of staggered planting dates on the control of *Thrips tabaci* Lindeman and yield of onion in Nigeria. *African Agricultural Research.* 4(1): 33-39.

- Jackson, M.L. (1973).** Soil Chemical Analysis. Prentice Hall, New Delhi, pp.120.
- Jaggi, R. C. (2004).**Effect of sulphur levels and sources on composition and yield of onion (*Allium cepa*). *Indian Journal of Agricultural Sciences*. 74(4): 219-220.
- Jaggi, R. C. (2004).***Fertil.News*. 49 (5): 31-35.
- Jaggi, R. C. (2005).**Sulphur as production and protection agent in onion (*Allium cepa*). *Indian Journal of Agricultural Sciences* 75(12): 805-808.
- Jaggi, R. C. (2005).**Sulphur levels and sources affecting yield and yield attributes in onion (*Allium cepa*). *Indian Journal of Agricultural Sciences*. 75(3): 154-156.
- Jaggi, R. C. and Sharma, R. K. (2010).**Sulphur management in onion (*Allium cepa*) cultivation in hills of Himachal Pradesh. *Journal of Environmental Biology*. 31(3): 391-393.
- Jaggi, R. C.; Sharma, R. K. and Gupta, Sonika. (2006).**Comparative response of onion (*Allium cepa*) to two sources of sulphur. *Indian Journal of Agricultural Sciences*. 76(3): 145-147.
- Jaggi, R.C. and Raina, S.K. (2008).**Direct, residual and direct + residual effects of sulphur in garlic (*Allium sativum*) – maize (*Zea mays*) cropping sequence. *Journal of Environmental Biology*. 29(1): 85-88.
- Jamal, A.; Ko K.; Kim, H.S.; Cho, Y.K.; Joung, H. and Ko K. (2009).** Role of genetic factors and environmental conditions in recombinant protein production for plant molecular biofarming. *Biotech Advan* 27: 914-923
- Jamal, A.; Moon, Y.S. and Abdin M.Z. (2010).**Enzyme activity assessment of peanut (*Arachis hypogea*) under slow-release sulphur fertilization. *Aust J Crop Sci* 4(3):169-174.
- Janzen H.H. and Bettany, J.R. (1984).** Sulfur nutrition of rapeseed. Influence of fertilizer nitrogen and sulfur rates. *Soil. Sci. Soc. Am. J.* 48: 100-107.
- Jeong, C. S.; Yeung, H. K.; Yoo, K. C. and Nagaoka, M. (1996).** Effect of light intensities and temperature on capsaicin and sugar contents of each growth stage in *Capsicum annuum* L. *J. Agri. Sci.* 7: 69-78.
- Josephine, V. H.; Haripriya, K. and Sriramachandrasekharan, M. V. (2006).** Response of onion to sulfur fertilization in typical tuffaceous soil. *Journal of Interacademia*. 10(4): 508-510.

- JunKyu, S. and YoungWoo, R. (1998).** Effect of planting date under spring and autumn culture on the growth and yield of shallot (*Allium cepa* var. *ascalonicum* Baker). *RDA Journal of Horticulture Science (I)*. 40(2): 98-104.
- Kacjan, N. and Osvald, J. (1992).**The effect of sowing and planting dates on the yield and quality of onions (*Allium cepa* L.).*Zbornik Biotehniske Fakultete Univerze Edvarda Kardelja v Ljubljani*.59: 113-119.
- Kalavathi, D.;Vanangamudi, K. and Ramamoorthy, K. (1990).**Influence of date of harvest and method of bulb planting on the seed quality in Bellary onion. *Madras Agricultural Journal*. 77 (2): 61-63.
- Kandil, A.A.;Sharief, A.E. and Fathalla, F.H. (2013).**Effect of transplanting dates of some onion cultivars on vegetative growth, bulb yield and its quality. *Sci J. Crop Prod*. 2(3):72-82.
- Ketter, C. A. T. and Randle, W. M. (1998).** Pungency Assessment in Onions.*Proceedings of the 19th Workshop/Conference of the Association for Biology Laboratory Education*. Tested studies for laboratory teaching. 19:177-196.
- Khodadadi, M. (2012).** The effects of planting date and motheral bulb size on quantitative and qualitative seed traits of onion red variety. *International Journal Agriculture: Research and Review*. 2(4): 324-327.
- Khokhar, K.M.; Hadley, P. and Pearson, S. (2007).**Effect of cold temperature durations of onion sets in store on the incidence of bolting, bulbing and seed yield. *Sci. Hortic*. 112:16-22.
- Kumar, A. and Singh, O. (1992).**Dry matter accumulation in sulphur deficient onion plants. *Indian J. Agric. Res*. 26(2): 107-109.
- Lancaster, J.E.; Triggs, C.M.; De Ruiter, J.M. and Gandar, P.W. (1996).**Bulbing in onions: photoperiod and temperature requirements and prediction of bulb size and maturity. *Ann. Bot*. 78: 423-430.
- Lane and Eynon.(1923).** Determinations of sugars by Fehling solution with methylene blue as an indicator. *J. Soc. Chem. Ind*. 42:32.
- Lee, E. J. and Suh, J. K. (2009).**Effect of temperature on growth, pyruvic acid and sugar contents in onion bulbs. *Kor. J. Hort. Sci. Technol*. 27(4):554-559.
- Lee, E. J.; Yoo, K. S.;Jifon, J. and Patil, B. S. (2009).**Application of extra sulfur to high-sulfur soils does not increase pungency and related compounds in short day onions. *Scientia Horticulturae* 123(2): 178-183.

- Lee, E. J.; Yoo, K. S.; Jifon, J. and Patil, B. S. (2009).**Characterization of short day onion cultivars of 3 pungency levels with flavor precursor, free amino acid, sulfur, and sugar contents. *Journal of Food Science*. 74(6): C475-C480.
- Leilah, A. A.; El-Kalla, S. A.; Mostafa, A. K. and Afifi, H. M. A. (2003).** Performance of some local Egyptian onions strains under different planting dates. *Scientific Journal of King Faisal University (Basic and Applied Sciences)*. 4(1): 119-136.
- Losak, T.; Hlusek, J.; Kracmar, S. and Martensson, A. (2010).**Effect of nitrogen and sulphur fertilisation on yields, nitrates and cysteine and methionine content in onion (*Allium cepa* L.). *Acta Horticulturae* 852: 297-304.
- Lunde, C.; Zygaldó, A.; Simonsen, H.T.; Nielsen, P.L.; Blennow, A. and Haldrup, A. (2008).** Sulfur starvation in rice: the effect on photosynthesis, carbohydrate metabolism, and oxidative stress protective pathways. *Physiology plant*, 134(3): 508-521.
- Madisa, M. E. and Midmore, D. J. (1994).**The effect of planting date, set size and spacing on the yield of onion (*Allium cepa* L.) in Botswana. International symposium on allium for the tropics, Bangkok, Thailand. *Acta Horticulturae*.358: 353-357.
- Mahadeen, A. Y. (2008).**Effect of planting date and plant spacing on onion (*Allium cepa* L.) yield under rain-fed in semi-arid conditions of Jordan. *Bulletin of Faculty of Agriculture*. 59(3): 236-240.
- Malik, Y. S.; Singh, N. and Nehra, B. K. (1999).** Effect of planting time, bulb cut and pinching of bolt treatments on yield and quality of onion seed. *Vegetable Science*. 26(2): 143-145.
- Mann, J.D. (1983).** Translocation of photosynthate in bulbing onions. *Aust. J. Plant. Physiol.* 10:515-521.
- Mathankar, V. B.; Sadawarte, K. T.; Kale, P. B. and Kulwal, L. V. (1990).** Effect of dates of planting on seed production of some varieties of onion under Akola conditions. *PKV Research Journal* 14(1): 27-30.
- McCallum, J. A.; Grant, D. G.; McCartney, E. P.; Scheffer, J.; Shaw, M. L. and Butler R. C. (2001).** Genotypic and environmental variation in bulb composition of New Zealand adapted onion (*Allium cepa*) germplasm. *N. Z. J. of Crop and Hort. Sci.* 29:149-158.
- McCallum, J.; Thomas, L.; Shaw, M.; Pither-Joyce, M.; Leung, S.; Cumming, M. and McManus, M. T. (2011).** Genotypic variation in the sulfur assimilation and

- metabolism of onion (*Allium cepa* L.) I. Plant composition and transcript accumulation. *Phytochemistry*. 72(9): 882-887.
- Mettananda, K.A. and Fordham, R. (1999).** The effects of plant size and leaf number on the bulbing of tropical short-day onion cultivars (*Allium cepa*L.) under controlled environments in the United Kingdom and tropical field conditions in Sri Lanka. *J. Hort. Sci. Biotechnol.* 74: 622-631.
- Mohanty, B. K. (2001).** Effect of planting time on the performance of onion cultivars. *Vegetable Science*. 28(2): 140-142.
- Mozumder, S. N.; Moniruzzaman, M. and Halim, G. M. A. (2007).** Effect of N, K and S on the Yield and Storability of Transplanted Onion (*Allium cepa*L.) in the Hilly Region. *J Agric Rural Dev.* 5(1&2): 58-63.
- Nasreen, S. and Imamul Huq, S. M. (2005).** Effect of sulphur fertiuzation on yield, Sulphur content and uptake by onion. *Indian J. Agric. Res.*, 39 (2): 122 - 127.
- Nasreen, S.; Haque, M. M.; Hossain, M. A. and Farid, A. T. M. (2007).** Nutrient Uptake and Yield of Onion as Influenced by Nitrogen and Sulphur Fertilization. *Bangladesh J. Agril. Res.* 32(3): 413-420
- Nasreen, S.; Imamul Huq, S.M. and Hossain, Mohd. A. (2003).** Sulphur effect on Growth Response and Yield of Onion. *Asian J. of Plant Sciences*. 2 (12): 897-902.
- Nayee, D. D.; Varma, L. R. and Sitapara, H. H. (2010).** Effect of various planting materials and different date of planting on yield and quality of *Kharif* onion (*Allium cepa* L.) cv. Agrifound Dark Red. *Asian Journal of Horticulture*. 5(1):189-191.
- Neeraja, G.; Reddy, K. M.; Shanna, P. S. and Rao, Y.P. (2000).** Physiological analysis of growth and yield in onion (*Allium cepa*L.) as influenced by irrigation and nitrogen. *Ann. Agric. Res.* 21(2): 199-205.
- Nehra, B. K.; Pandita, M. L. and Singh, K. (1990).** Effect of planting material and date of planting on bolting and seed yield of onion (*Allium cepa*L.). *Vegetable Science*. 17(2): 195-197.
- Nogueira, F. D.; Padua, J. G.; de Guimaraes, P. T. G.; Paula, M. B. and de Silva, E. B.(1996).** Potato yield and quality under potassium and gypsum levels in south eastern Brazil. *Communications in Soil Science and Plant Analysis*. 27(9): 2453-2475.
- O'Conner, K.F. and Vartha, E.W. (1969).** Responses of grasses to sulfur fertilizers. *Plant and Soil*. 60(3): 451-459.

- Olsen, S.P.; Cole, C.V.; Watanabe, F.S. and Dean, L.A. (1954).** Estimation of available phosphorus in soil by extracting with sodium bicarbonate. U.S. Department of Agriculture Circular, p. 939.
- Pal, U.R.; Gosset, D.R.; Sims, J.L. and Legett, J.E. (1976).** Molybdenum and sulphur nutrition effects on nitrate reductase in barley tobacco. *Can. J. Bot.* 54: 2014-2022.
- Pandey, U. B.; Singh L. and Kumar, R. (1990).** Studies on the effect of dates of transplanting and levels of nitrogen on yield and quality of onion (*Allium cepa* L.). *Associated Agricultural Development Foundation* 10(3): 10-12.
- Pansee, V.G. and Sukhatme, P. V. (1985).** Statistical methods for agricultural workers, ICAR, New Delhi.
- Paterson, D.R. (1979).** Sulfur fertilization effects on onion yield and pungency. Texas Agr. Expt. Sta. *Prog. Rpt.* 3551.
- Patil, D. G.; Dhake, A.V.; Sane, P.V. and Subramaniam, V.R. (2012).** Studies on different genotypes and transplanting dates on bulb yield of high solid white onion (*Allium cepa* L.) under short-day conditions. *Acta Hort.* 969: 143-148.
- Peirce, L.J. (1987).** Vegetables: Characteristics, Production and Marketing. John Wiley and Sons. New York, NY.
- Piper, C.S. (1966).** Soil and Plant Analysis. Hans Publication, Bombay, p. 368.
- Platenius, H. and Knott, J. E. (1941).** Factor effecting onion pungency. *J. Agr. Res.* 62: 371-379.
- Qureshi, A. A. and Lawande, K. E. (2006).** Response of onion (*Allium cepa*) to sulfur application for yield, quality and its storability in S-deficient soils. *Indian Journal of Agricultural Sciences.* 76(9): 535-537.
- Rabinowitch, H. (1990).** Physiology of Flowering. In: H. D. Rabowitch and J.L. Brewster (eds.). *Onions and Allied Crops.* Vol. 3:113-134. CRC Press. Boca Raton, Fla.
- Raina, S.K. and Jaggi, R.C. (2008).** Effects of sulphur in presence and absence of farmyard manure on onion (*Allium cepa*) under onion-maize (*Zea mays*) cropping sequence. *Ind. J. Agric. Sci.*, 78: 659-62.
- Rajas, R. N.; Ghulaxe, S. N. and Tayde, S.R. (1993).** Effect of varying levels of sulphur and spacing compared with frequencies of irrigation on yield of onion grown in Vidarbha. *Journal of Soils and Crops.* 3(1): 37-40.
- Randle, W. M. (1992a).** Sulfur nutrition affects non-structural water-soluble carbohydrates in onion germplasm. *Hort. Science.* 27:52- 54.

- Randle, W.M. (1995).** Preplant calcium affects onion bulb quality and shelf life. *Hort science* 20:768. (Abstr.).
- Randle, W.M. and Bussard, M.L. (1993).** Pungency and Sugars of Short-day Onions as affected by Sulfur Nutrition. *J. Amer. Soc. Hort. Sci.* 118(6):766-770.
- Ranganna, S. (2007).** Handbook of analysis and quality control for fruit and vegetable products. Tata McGraw Hill Publishing Co. New Delhi.
- Rastegar, J. and Ganjehie, M. G. (2009).** Effects of sulphur and number of foliar application with complete micronutrient fertilizer on yield and quality of two onion cultivars. *Seed and Plant Production Journal.* 25-2(1): 1-13.
- Resende, G. M. and de Costa, N. D. (2008).** Nitrogen and potassium levels on the onion yield and storage with different planting times. *Pesquisa Agropecuaria Brasileira* 43(2): 221-226.
- Resurreccion, A.P.; Makino, A.; Bennett, J. and Mae, T. (2002).** Effect of light intensity on the growth and photosynthesis of rice under different sulfur concentrations. *Soil Science and Plant Nutrition.* 48(1): 71-77.
- Rizk, F. A.; Shaheen, A. M. and El-Habbasha, K. M. (1996).** Flowering and seed yield of onion (*Allium cepa* L.) plants as affected by dates of planting and some growth regulators. *Egyptian Journal of Horticulture;* 23(1): 113-127.
- Rubatzky, V.E. and Yamaguchi, M. (1997).** World vegetables, principles, production, and Nutritive Values: *Second ed. Chapman and Hall.* New York, NY.
- Sawant, S. V.; Ingavale, M. T.; Mangave, K. K.; Wath, B. K. and Bhat, N. R. (2002).** Effect of date of planting on growth, yield and quality of onion (*Allium cepa* L.). *Vegetable Science.* 29(2): 164-166.
- Scherer, H.W. (2009).** Sulfur in soils. *J Plant Nutr Soil Sci.* 172: 326-335.
- Schwimmer, S. and Weston, W. J. (1961).** Enzymatic development of pyruvic acid in onion as a measure of pungency. *J. Agric. Food Chem.* 9:301-304.
- Shalaby, G. I.; El-Muraba, A. I.; Kandeel, N. M. and Gamie, A. A. (1991).** Effect of some cultural practices on onion bulb production grown from sets. III - Planting dates, direction of ridges and cultivars. *Assiut Journal Agricultural Sciences.* 22(5): 103-121.
- Sharma, D.K.; Kushwaha, S.S.; Nema, P.K. and Rathore, S.S. (2011).** Effect of Sulphur on Yield and Quality of Potato (*Solanum tuberosum* L.). *International J. of Agricultural Research.* 6(2): 143-148.

- Sharma, M. P.; Singh, A. and Gupta, J.P. (2002).** Sulphur status and response of onion *Allium cepa* to applied sulphur in soils of Jammu districts. *Indian Journal of Agricultural Sciences*. 72(1): 26-28.
- Sharma, P. K.;Yadav, G. L. and Kumar, S. (2003).** Effects of methods and dates of planting of onion sets on the bulb yield of kharif onion. *News Letter - National Horticultural Research and Development Foundation*. 23(4): 1-3.
- Singh, A. K.; Singh, V. and Nainwal, K. (2002).** Effects of size, distance and date of planting of mother sets on the quality of *kharif* onion (*Allium cepa* L.).*Progressive Horticulture*; 34(1): 109-112.
- Singh, B.; Singh, B. and Tomar, B. S. (2005).** Effect of dates of planting, bulb size and bulb spacing on growth and seed yield of onion (*Allium cepa* L.).*Seed Research*. 33(1): 78-81.
- Singh, D. and Pandey, R.N. (1995).**Effect of applied sulphur on dry matter yield and sulphur uptake by onion in different soil series of Delhi. *Annals of Agricultural Research* 16(3): 348-350.
- Singh, H.; Singh, S. and Singh, V. (1996).**Response of onion (*Allium cepa* L.) to nitrogen and sulphur. *Annals of Agricultural Research*. 17(4): 441-444.
- Singh, L.;Chauhan, K. P. S. and Singh, J. B. (1991).**Response of different onion varieties for delayed planting under Karnal conditions. *Associated Agricultural Development Foundation* 11(4): 1- 9.
- Singh, N.; Thamburaj, S. and Pal, N. (2001).**Vegetables, Tuber crops and spices. Directorate of information and publication of agriculture, I.C.A.R., New Dehli.
- Singh, S. (2008).** Effect of sulphur on yields and S uptake by onion and garlic grown in acid alfisol of Ranchi. *Agricultural Science Digest*. 28(3): 189-191.
- Singh, V.; Singh, A. and Mehta, V.S.(1995).** Effect of sulphur sources and levels on yield and uptake of nutrients by garlic. *Fertiliser News*. 40(8): 47-49.
- Skwierawska, M. and Zawartka.(2009).** Effect of different rates and forms of sulphur on content of available phosphorus in soil. *Journal of Elementology*. 14(4): 795-803.
- Skwierawska, M.;Zawartka, L. and Zawadzki, B. (2008).** The effect of different rates and forms of applied sulphur on nutrient composition of planted crops Plant. *Soil Environ*. 54 (5): 179–189.
- Smirnoff, N. and Pallanca, J.E. (1996).** Ascorbate metabolism in relation to oxidative stress. *Biochemical Society Transactions*. 24: 472–478.

- Soro, S.; Doumbia, M.; Yeboue, N. L.; Dao, D. and Tano, Y. (2011).**Influence of onion planting date on *Helicoverpa armigera* (Hubner) larvae population in Northern Burkiana Faso. *Journal of Applied Biosciences*. 46:3113-3119.
- Steer, B.R. (1982).** The effect of growth temperature on dry weight and carbohydrate content of onion (*Allium cepa*L. cv. Creamgold) bulbs. *Aust. J. Agr. Res.* 33:559-563.
- Stone, I. (1972).** The natural history of ascorbic acid in the evolution of the mammals and primates and its significance for present day man. *J. Orthomolecular Psychiatry*, 1(2-3): 82-89.
- Subbiah, B.V. and Asija, G.L.(1956).**A rapid procedure for the determination of available nitrogen in soil, *Curr. Sci.*,25:259-260.
- SumantraKarTiwari, R. S. (1997).** Effect of sulphur on growth and yield of onion (*Allium cepa* L.) cv. Pusa Red. *Recent Horticulture*. 4: 138-139.
- Tandon, H. L. S. (1993).** Methods for Analysis of soils, plant, water and fertilizers. Fertilizers Development and Consultation Organization, New Delhi, India.
- Thakur, B.S. and Parmar, Y. S. (2011).** Effect of planting date, nitrogen and phosphorus levels on marketable bulb yield in garlic (*Allium sativum* L.) under mid hill conditions of Himachal Pradesh. 2(1):42-46.
- Thippeswamy, H.J. (1993).** Leaf sampling guide and nutrient norms for yield and quality in relation to applied sulphur to onion. M.Sc. (Ag.) Thesis, University of Agricultural Sciences, Bangalore.
- Thomas, L.; Leung, S.; Cumming, M.; Shaw, M.; Albert, N.; McCallum, J. and McManus, M. T. (2011).**Genotypic variation in sulphur assimilation and metabolism of onion (*Allium cepa* L.). II: Characterisation of ATP sulphurylase activity. *Phytochemistry*; 72(9): 888-896.
- Ud-Deen,Md. M. (2008).** Effect of mother bulb size and planting time on growth, bulb and seed yield of onion. *Bangladesh J. Agril. Res.* 33(3): 531-537.
- Ullah, M.H.; Huq, S.M.I.;Alam, M.D.U. and Rahman, M.A. (2008).**Impacts of Sulphur Levels on Yield, Storability and Economic Return of Onion. *Bangladesh J. Agril. Res.* 33(3): 539-548.
- Valenzuela, H.; Shimabuku, R.;Kratky, B. and Hamasaki, R. (1999).** Onions in Hawaii and around the world. *In:* R. Hamasaki, H. Valenzuela & R. Shimabuka (eds.). Bulb production in Hawaii.College of Tropical Agriculture and Human Resources. Manoa, Hawaii.

- Vashisht, R.; Pandey, U. C. and Verma, B. S. (2008).** Nutrient uptake by groundnut as influenced by weed control measures, phosphorus and sulphur application. *Res. on Crops*.9 (3): 578-579.
- Vavrina, C.S. and Smittle, D.A. (1993).**Evaluating sweet onion cultivars for sugar concentrations and pungency. *Hort-Science*. 28:804-806.
- Venkatesh, M. S. and Satyanarayana, T. (2000).** Transformation of sulphur in soils of North Karnataka as influenced by sources and levels of sulphur. *Madras Agricultural Journal*.86(7/9): 414-418.
- Verma, K. S.; Kushwah, S. S. and Ukey, V. (2011).**Seed production of onion and post harvest nutrients status of soil as influenced with planting time and nutrient levels. *Asian Journal of Horticulture*. 6(1): 231-235.
- Virendersardana; Atwal, A. K. and Sangha, M.K. (2008).**Effect of foliar application of sulphur on yield, quality and economics of Indian mustard, *Brassica juncea* (L.) Czern&Coss *Res. on Crops* 9 (3): 728-730.
- Walkley, A. and Black, I. A. (1934).** An Examination of Degtjareff Method for Determining Soil Organic Matter and a Proposed Modification of the Chromic Acid Titration Method. *Soil Sci*. 37:29-37.
- Wani, M. A. (2005).** Effect of different sources and levels of sulphur on yield and nutrient uptake by garlic (*Allium sativum*). *Advances in Plant Sciences*. 18(1): 273-275.
- Wani, M. A. and Chattoo, M. A. (2005).** Effect of different sources and doses of sulphur on the performance of garlic (*Allium sativum*). *Horticultural Journal*. 18(2): 114-116.
- Wiles, G.C.(1989).** The effect of light and temperature on bulb initiation and development in tropical cultivars of onion (*Allium cepa*L.).Ph.D. thesis, Wye College University of London, London.
- Woziullah, M.; Hossain, M. M.; Alam, M. K.; Hoque, A. M. M. M. and Waliullah, A. K. M. (2008).**Onion seed production as influenced by cultivars and planting date. *Journal of Subtropical Agricultural Research and Development*. 6(3): 512-517.
- Yadav, V. K.; Singh, B. and Srivastava, J. P. (2002).** Study on the effects of planting geometry, bulb size and planting dates on the growth and seed yield of onion (*Allium cepa* L.). *Progressive Agriculture*. 2(2): 148-150.
- Yamaguchi; Paulson, M. K. N.; Kinsella, M. N. and Bernhard, R. A. (1975).** Effects of soil temperature on growth and quality of onion bulbs (*Allium cepa*L.) used for dehydration. *J. Amer. Soc. Hort. Sci*. 100:415-419

**Yasmin, N.; Blair, G. and Till, R. (2007).** Effect of elemental sulfur, gypsum and elemental sulfur coated fertilizers on the availability of sulfur to rice. *Journal of Plant Nutrition*. 30(1-3): 79-91.

**Zeinani, A. M.;Zarbakhsh, A. and Khodadadi, M. (2010).** Effect of sulfur on the yield, quality and storability of two onion (*Allium cepa* L.) cultivars. *Seed and Plant Production Journal*. 26(2): 153-168.

# Appendices

## APPENDIX-1

### ANOVA TABLE

Source of variance	D.F.	S.S.	M.S.	F – cal	F - tab
Replication	r-1	RSS	RMS		
Factor A	a-1	ASS	AMS	AMS/EMS	
Factor B	b-1	BSS	BMS	BMS/EMS	
Interaction A × B	(a-1)(b-1)	ABSS	ABMS	ABMS/EMS	
Error	(r-1) (ab-1)	ESS	EMS		
Total	rab-1	TSS			

b) The standard error ( $SE_{m\pm}$ ) for the difference of treatment means were computed as follows:

$$SE_{m\pm} = \sqrt{EMSS/V}$$

Where,

EMSS is error mean sum of squares

c) Critical Difference (CD) was calculated as:

$$CD = t\sqrt{2EMSS/r}$$

$t_{(5\%)}$  = value from ( $\pm$ ) table for error degrees of freedom at 5% level of Probability.

RSS	:	replication sum of squares
ASS	:	Factor “A” sum of squares
BSS	:	Factor “B” sum of squares
ABSS	:	Interaction sum of squares
ESS	:	Error sum of squares
TSS	:	Total sum of squares
RMS	:	Replication mean sum of squares

AMS : Factor "A" mean sum of squares  
BMS : Factor "B" mean sum of squares  
ABMS : Interaction mean sum of squares

## APPENDIX -2

### Cost of onion cultivation per hectare (Rs.)

S. No.	Description	Per ha			
		Quantity	Unit	Rate (Rs.)	Total (Rs.)
<b>A. Fixed cost</b>					
<b>1.</b>	<b>Field preparation</b>				
	a) Ploughing by Rotavator	3	No.	1500/ha	4,500.00
	b) Planking	2	No.	700/ha	1400.00
<b>2.</b>	<b>Seed cost</b>	12	Kg/ha	1500	18,000.00
<b>3.</b>	<b>Sowing cost</b>	2	Labour days	200	400.00
<b>4.</b>	<b>Layout &amp; Transplanting</b>	100	Labour days	200	20,000.00
<b>5.</b>	<b>Irrigation(7times)</b>	84	hours	150/hr	12,600.00
	a) Irrigation hours				
	b) Lad. for Irrigation	8	Labour days	200	1600.00
<b>6.</b>	<b>Intercultural operations</b>				
a)	Five Weeding	40	Labour days	200	8,000.00
b)	Four Hoeing	40	Labour days	200	8,000.00
<b>7.</b>	<b>Plant protection</b>				
a)	Capton in nursery raising	150	g	400/g	300.00
b)	3 spray of Dithane m-45	2	lit	973/lit	1,946.00
c)	Spraying cost	4	Labour days	200	800.00

<b>8.</b>	<b>Harvesting</b>				
a)	Harvesting and packing	40	Labour days	200	8,000.00
b)	Transportation charges		Per hectare		20,000.00
<b>9.</b>	Rental value of a land	6	month	40000/ha/yr	20,000.00
<b>10.</b>	<b>Miscellaneous</b>				
a)	Charges @ 5% of 11,60,46				58,023.00
				<b>Total Rs.</b>	<b>1,75,569.00</b>
<b>B. Variable cost</b>					
S. No.	Description	Per ha			
		Quantity	Unit	Rate (Rs.)	Total (Rs.)
11.	100 Kg N through urea	217	Kg/ha	10/Kg	2,170.00
12.	60 Kg phosphorus through SSP	375	Kg/ha	8/Kg	3,000.00
13.	60 Kg K through MOP	100	Kg/ha	9/Kg	900.00
14.	FYM	20	t/ha	200/t	6000.00
15.	Gypsum	60	Kg/ha	7/Kg	420.00
16.	Elemental sulphur	60	Kg/ha	40/Kg	2,400.00