SEED YIELD AND QUALITY OF ONION AS AFFECTED BY PLANTING TIME AND NUTRIENTS

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This is to certify that the thesis entitled **"SEED YIELD AND QUALITY OF ONION AS AFFECTED BY PLANTING TIME AND NUTRIENTS"** submitted to the **INSTITUTE OF SEED TECHNOLOGY**, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTERS OF SCIENCE (M.S.C.)** in **SEED TECHNOLOGY**, embodies the result of a piece of bona fide research work carried out by **MD. REZAUL HASAN**, Registration No. 14-05911 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that any help or source of information, received during the course of this investigation has been duly acknowledged.

June, 2021

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Dedicated to
My
Beloved Parents

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The Author

SEED YIELD AND QUALITY OF ONION AS AFFECTED BY PLANTING TIME AND NUTRIENTS[1]

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ABSTRACT

The experiment was conducted at central farm of Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from November 2019 to April 2020 to evaluate the seed yield and quality of onion as affected by planting time and nutrients. The treatment consisted of two factors *viz*. Factor A: three planting time; (i) T_1 (1 November) (ii) T_2 (10 November) and (iii) T_3 (20 November) and Factor B: four levels of nutrients; (i) N_0 (NPKS; standard dose), (ii) N_1 (50% NPKS + 50% vermicompost), (iii) N_2 (50% NPKS + 50% mushroom spent compost) and (iv) N_3 (50% vermicompost + 50% mushroom spent compost). The experiment was conducted in randomized complete block design (RCBD) with three replications. A significant variation among the treatments was found while different planting time and different levels of nutrients applied in different combinations. The highest number of umbel per plant (3.25), number of seeds per umbel (606.40), 1000 seed weight (3.50 g), seed yield per plant (3.47 g), seed yield per plot (138.70 g) as well as seed yield per ha (770.60 kg) was recorded from T_2N_1 (10 November with 50% NPKS + 50% Vermicompost) whereas the lowest was from T_3N_3 (20 November with 50% Vermicompost + 50% Spent mushroom compost). Considering seed quality, all the parameters were significantly affected by combined effect of different planting time and different levels of nutrients. T_2N_1 gave the highest seed germination (86.33%), shoot length (9.67 cm), root length (4.56 cm) and seed vigor index (1228.00) whereas T_3N_3 (20 November with 50% vermicompost + 50% spent mushroom compost) showed the lowest results. Considering results of the experiment, planting time at 10 November along with 50% NPKS + 50% Vermicompost are the best for producing better yield and higher quality of onion seed.

keywords: quality seed, production, nutrients, vermicompost, mushroom spent compost.

CONTENTS

LIST OF CONTENTS (Cont'd)

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

ABBREVIATIONS AND ACRONYMS

AEZ	=	Agro-Ecological Zone
BBS	=	Bangladesh Bureau of Statistics
BCSRI	=	Bangladesh Council of Scientific Research Institute
cm	=	Centimeter
CV %	=	Percent Coefficient of Variation
DAS	=	Days After Sowing
DMRT	=	Duncan’s Multiple Range Test
et al.,	=	And others
e.g.	=	exempli gratia (L), for example
etc.	=	Etcetera
FAO	=	Food and Agriculture Organization
g	=	Gram (s)
i.e.	=	id est (L), that is
Kg	=	Kilogram (s)
LSD	=	Least Significant Difference
m^2	=	Meter squares
ml	=	MiliLitre
M.S.	=	Master of Science
No.	=	Number
SAU	=	Sher-e-Bangla Agricultural University
var.	=	Variety
^oC	=	Degree Celceous
%	=	Percentage
NaOH	=	Sodium hydroxide
GM	=	Geometric mean
mg	=	Miligram
P	=	Phosphorus
K	=	Potassium
Ca	=	Calcium
L	=	Litre
µg	=	Microgram
WHO	=	World Health Organization

CHAPTER I

INTRODUCTION

Onion (*Allium cepa* L.) is a bulb crop, belonging to the family *Alliaceae* which central Asia is regarded as a center of domestication. It is a cross-pollinated and biennial short type vegetable and most of the important spice as well as vegetable crops throughout the world (Brewster, 1994). It is used in the preparation of almost all food of our daily diet. The crop is primarily consumed for their unique flavor or for their ability to enhance the flavor of other foods (Randle, 2000). It is called the queen of the kitchen (Selvaraj, 1976). Recently it is known that onion reduces the blood sugar by 25 percent as a diabetic drug in Arabian Folk medicine (Vohra *et al*., 1974; Mossa, 1985; Yawalkar, 1985). Onion is rich in protein, calcium, phosphorus and carbohydrates (Bhattacharjee *et al*., 2013).

In Bangladesh two types of onion variety such as winter and summer are cultivated and produced annually 18.03 lakh metric tonnes from the total area of 4.3 lakh acres against its demand of 28 lakh metric tonnes and its bulb yield is very low, being 9.71 t/ha (BBS, 2020) as compared to Indian onion yield, being 16.10 t/ha (Ratan *et al*., 2017) against the world's productivity, being (17.45 t ha^{-1}) (FAO, 2015). The total production of onion seed in Bangladesh is about 150 tons/year but the requirement is more than 900 tons (BBS, 2019). With the gradual increase of population, the demand of onion in Bangladesh is increasing day by day.

Onion production sometimes hampers due to scarcity of seed. A lot of research work has been conducted on onion bulb production but a little information is available on onion seed production (Anisuzzaman *et al*., 2009). Onion bulb and seed yield and quality are influenced by many factors like cultivar, soil, climate, season, production method, bulb size, time of planting, nutrient management and plant density. Among them, time of plantation and nutrient are the most important factors. The determination of the best combination of these can be used to improve onion seed production and quality (Asaduzzaman *et al*., 2012).

Planting time is one of the most important factors that greatly influence the growth and yield of onion (Ahmad and Munshi, 1995; Badaruddin and Haque, 1977). Also, planting time is important factor affects onion seeds production and quality especially with current climate changes that affect the productivity of various agricultural crops (Mondal, 1980; El-Helaly and Karam, 2012). Mondal (1980) considered last week of October as the best planting time for the highest yield and best quality onion seeds. UD-Deen (2008) considered October 30th as best planting times on onion seed production in Bangladesh. Similarly, November 15th was identified as the best planting time for onion seed production in the Borga region of Bangladesh (Mollah *et al*., 2015).

Farmers in Bangladesh are not harnessing the desired production potential of onion. The potent reason for lesser productivity of onion seed could be attributed to poor nutrient management. It is well documented that growth and yield of plants are greatly influenced by a wide range of nutrients. An approach involving chemical fertilizers and organic manures to bridge this gap between nutrient demand and supply for giving a boost to crop production is only the solution. Application of N, P, K and S fertilizers as well as organic manure are important for production of onion seed. Nitrogen (N) application increases umbels/bulb, flowering stalk length and 1000- seed weight of onion (Tiwari *et al*., 2002). The application of different doses of nitrogen increased plant growth and yield of onion (Kumar *et al*., 2017). Phosphorus (P) is an essential plant nutrient. It plays an important role in formation of nucleic acid and phospholipids, enzyme activation, production of ADP and ATP (Thompson and Torch, 1978). Similarly, phosphorus has its beneficial effect on early root development, plant growth, yield and quality of crop production (Kumar *et al*., 2017). Potassium (K) application increases the uptake of nitrogen by onion plants (Sing and Verma, 2001; Vigidal *et al*., 2002). Potassium also plays important role in crop productivity by functioning as an activator of numerous enzymes like pyruvic kinase, cytoplasmic enzymes and therefore, cause pervasive effect on metabolic events (Kumar *et al*., 2017). Sulphur (S) also carries out many important functions for plant growth. Sulphur fertilizer increases the seed yield and bulb pungency in onion (Paterson, 1979). Application of different doses of sulphur improves plant height, number of leaves, bulb diameter, bulb weight and yield of onion (Kumar *et al*., 2017). The application of organic manures like vermicompost, FYM and poultry manure etc. alone and in combination with NPKS have been reported to decrease the bulk density, improve the soil porosity and increase water holding capacity resulted higher bulb and seed yield of onion (Yadav, 2015).

The unavailability of good quality onion seeds is partly responsible for low yield in Bangladesh (Bokshi *et al*., 1989). Due to limitation of land and climate, introduction and cultivation of high yielding exotic varieties is not possible in Bangladesh. The only possible way to increase the per hectare yield of onion is through manipulating existing method of cultivation such as optimum planting time, planting geometry, fertilization, irrigation and other cultural management practices. Quality seed yield of onion depends on genotype, locality, season and method of seed production (Brewster, 1994). Keeping all these above facts in view, the present study was undertaken with the following objective:

1. To study the effect of planting time on the growth, seed yield and quality of onion.
2. To observe the effect of nutrients for ensuring maximum growth, seed yield and quality of onion.
3. To identify the combined effect of planting time and nutrients for maximum growth, seed yield and quality of onion.

CHAPTER II

REVIEW OF LITERATURE

Onion is an herbaceous, biennial and monocot crop. It takes two seasons for seed production, and during the first season bulbs are formed while flower stalks and seeds are developed in the second season (Brewster, 2008). Onion is grown mainly for its bulb. The present study was undertaken aimed to onion seed yield and quality as affected by planting time and nutrients application. The effect of planting time and nutrient management on onion seed production and its significant effects on both productivity and quality was studied and reported by several scholars in different parts of the world.

2.1 The bulb crop onion

The onion bulb consists of the swollen bases (sheaths) of bladed leaves surrounding swollen bladeless leaves. Each leaf consists of a blade and sheath; the blade may or may not be distinctive. The sheath develops to encircle the growing point and forms a tube that encloses younger leaves and the shoot apex. Collectively, the grouping of these sheaths comprises the pseudo stem. Leaves arise from the short, compressed, disc like stem which continues to increase in diameter with maturation and resembles an inverted cone (Bosekeng, 2012). The onion skin is formed from the dry paper like outermost leaf scales that lose their freshness during bulbing. Major bulb quality features are uniformity of shape, size and skin colour, pungency and dry matter (Rubatzky and Yamaguchi, 1997).

The test and odor characteristics of the alliums are their major attribute. Other features are the umbel inflorescence, flower with nectars, a three-chambered ovary and a basic chromosome number of eight for the cultivated species. The major flavor of alliums results from the activity of the enzymes, alliinase, acting on certain sulfur-containing compounds (S. alkyl cysteine sulfoxides) when tissues are broken or crushed. Onion roots are shallow, most occur within 15-20 cm of the surface, and seldom extends horizontally beyond 50 cm. Onion roots are short lived, being continuously produced. Roots rarely have branch and rarely increase in diameter (Brewster, 1994). The terminal inflorescences develop from the ring like apical meristem scapes and generally elongate well above the leaves and ranges in height from 30 to more than 100 cm. The scape is the stem internodes between the spathe and the last foliage leaf. At first, the scape is solid but, by differential growth, becomes thin walled and hollow. The number of scapes that develop depends on the number of sprouted lateral buds. A spherical umbel is borne in each scape and can range from 2 to 15 cm in diameter. The umbel is an aggregate of many flowers at various stages of development; usually there are 200-600 small individual flowers. The flowering periods may last four or more weeks. Flowers are perfect, having six white petals, six stamens and a three carpel pistil. Flowers have nectars, an attractant to pollinating insects, usually honey bees. Alliums have perfect flowers but, cannot self-pollinate because the male anthers shed pollen before the female stigma is receptive. Therefore, they cross-pollinate via insects (flies and bees) or by manually pollinating (hand-pollinating) the flowers in a controlled environment. Seed producers must keep in mind that varieties of the same species will cross-pollinate with other varieties of the same species (Currah and Proctor, 1990).

After pollination, fertilization of ovules starts within 12 h and is complete in 3-4 days. Pollination itself stimulates the initial development of ovules and ovaries. In fertilized ovules, the endosperm nuclei start to divide and cell division and expansion by the embryo occurs 5-6 days later. The embryo reaches its full development when the seed attains maximum dry weight. Initially the endosperm is liquid, and this is termed as the ‘milk stage’ (Jilani, 2004).

But at about seventeen days after pollination, cell walls develop within the endosperm and it progresses to the pasty ‘dough stage’. At this point, the seed coat starts to turn black. Later on seed attains its maximum fresh weight at about 30 days after flowering. Up to this point, seed dry weight growth is near exponential and seed dry weight is then about half its maximum. The endosperm then becomes solid and the seed reaches its maximum dry weight. After flowering, life completed and on maximum maturity day, the flower turns to give seed. The seeds may be up to 300 per gram (Currah and Proctor, 1990).

Onion seed matures about 45 days after anthesis. Seed are black, irregular shaped, and relatively small and about 200 seeds weigh one gram. Seeds lose viability rapidly unless stored under optimal condition of 0^{o}C and low RH. Under high temperature and humidity of tropical conditions, its viability may be less than a year in the tropics (Brewester, 2008).

2.2 Seed production potential of onion

Bolting (inflorescence production), can occur in all the *Alliums* vegetables. The inflorescence develops from the shoot apical meristem under appropriate environmental conditions. Underneath the spathe on the broad top of the stem numerous membranous bracts develop each covering several young florets arising on kidney-shaped regions of dividing cells (Tindall, 1983). Looking from the outside towards the center of each floret there develop three members in each of five whorls of floral organs: the outer perianth, the inner perianth, outer stamens, inner stamens and the carpels. These develop as glucose projections, with the outer whorls developing first. The carpels develop as three U-shaped up-swellings on the surface within the inner stamens. These up-swellings grow towards the center and their interned edges meet, fold within themselves and form the ovules, two of which occur in each carpel (Rabinowitch and Currah, 2002). In onion there are commonly 200 to 600 flowers per umbel, depending on cultivar, growing conditions and whether the umbel is formed from the main growing point or an axillary shoot. Similar umbels containing large numbers of flowers are produced by leeks and Japanese bunching onions. Chives typically have about 30 flowers per umbel, rakkyo six to 30 flowers and Chinese chives have approximately 40 white, star shaped, and fragrant flowers in a flat-topped umbel (Brewester, 2008).

Alliums have perfect flowers but, cannot self-pollinate because the male anthers shed pollen before the female stigma is receptive. Therefore, they cross-pollinate via insects (flies and bees) or by manually pollinating (hand-pollinating) the flowers in a controlled environment. Seed producers must keep in mind that varieties of the same species will cross-pollinate with other varieties of the same species (Currah and Proctor, 1990). After pollination, fertilization of ovules starts within 12 h and is complete in 3-4 days. Pollination itself stimulates the initial development of ovules and ovaries. In fertilized ovules, the endosperm nuclei start to divide and cell division and expansion by the embryo occurs 5-6 days later. The embryo reaches its full development when the seed attains maximum dry weight. Initially the endosperm is liquid, and this is termed as the ‘milk stage’ (Jilani, 2004). But at about 17 days after pollination, cell walls develop within the endosperm and it progresses to the pasty ‘dough stage’. At this point, the seed coat starts to turn black. Later on seed attains its maximum fresh weight at about 30 days after flowering. Up to this point, seed dry weight growth is near exponential and seed dry weight is then about half its maximum. The endosperm then becomes solid and the seed reaches its maximum dry weight. After flowering, life completed and on maximum maturity day, the flower turns to give seed. The seeds may be up to 300 per gram.

There are two methods of onion seeds production which are seed-to seed method and bulb-to seed. Each of them has advantages and disadvantages, while higher seed yield and good quality are those achieved from bulb -to-seed method. Bulb-to-seed allows the seed producers to select specific bulbs that offer the characteristics, and high-quality genetics they're looking for. In bulb to seed method a bulb crop is raised first and seeds are produced from the planted bulbs. However, seed-to-seed production is much cheaper, because there's no need to store bulbs from one season to the next; nor do any bulbs have to be replanted. It is possible where the crop can overwinter as growing plants. In this method, seeds are planted rather than bulbs, in which growing plants are vernalized and induced to flower and produce seeds without going through a bulb stage and it will result in the selection of easy bolting genotypes (Jones and Mann, 1963).

Onions are sensitive to photoperiod and temperature. Both are known to interact to enhance bulbing. Long day are favorable to onion production as this enhance leaf development and formation which, in turn, is directly related to bulb size. Bulb formation and subsequent growth are influenced by temperature and photoperiod (Lancaster *et al.,* 1996). Bulbing, flowering and seed production of onion are controlled by climatic condition such as temperature and photoperiod and seed production is more demanding than bulb production (Rabinowitch and Brewster, 1990). Temperature greatly influences the flowering of onion. Cool temperature with adequate water supply is most suitable for earlier growth followed by warm, drier condition for maturation. Low temperature (9°C to 17°C) is required for flower stalk development (Singh, 2001).

Length of day affects flowering and bulb formation. Under a 10-hour day, however, the plants remained green for 12 months and formed no bulb and no flower. In seedlings, a minimum time of about 40 days at 9°C to 12°C at 16 hours is required. Photoperiods are required to produce an inflorescence initial and at least another 40 days of cool temperature and long photoperiods are required for the inflorescence to enlarge temperature around 9°C before they start to develop bulbs (Rabinowitch and Brewster, 1990).

Planting season can affect onion seed production. Currah and Proctor, (1990) reported that time of planting was critical in order to achieve a satisfactory seed yield, where a cold requirement was defined in terms of hours below a threshold of 15^0C. The tallest seed stalks were associated with the highest yields and the greatest number of seeds per plant; however, it was also noted that this may not be a cause and effect relationship. Seed stalk height was correlated with days required for flowering. It is possible that the flowers on the taller seed stalks were visited more often by bees than those on shorter seed stalks, or that air circulation was better around the taller stalks. It is also possible that the taller seed stalk provide more photosynthetic to the plant causing the weight of each seed to be greater than the weight of seed from plants with short stalks.

2.3 Effect of planting time on onion seed production

Ashagrie *et al*. (2020) conducted a field experiment to study the influence of planting date and onion bulb size on yield and quality of onion seed. The experiment was laid out in Randomized Complete Block Design with three replications and involved three levels of onion bulb sizes and four levels of planting dates. The results of the study revealed that significant interactions between planting date and mother bulb size on seed yield ton ha^{-1}, germination percentage, seed vigor index I and seed vigor index II. The highest seed yield (2.8 tons ha^{-1}) was recorded from large onion bulbs of a size planted at Kobo early October. Planted onion bulbs early1October increased seed yield (ton ha^{-1} by 21.7%) than planted early-November. The highest (97.3) germination percentage was recorded from large onion bulbs planted at Kobo in early-October. Therefore, for the production of better yield and quality of onion seeds, early1October planting and large onion bulbs (4.1–5 cm) can be recommended in the study areas and other similar agro-ecology areas of the country.

Khan *et al*. (2020) conducted a field experiment at Spices Research Sub-Centre (SRSC), Bangladesh Agricultural Research Institute (BARI), Faridpur, Bangladesh during the winter season of 2018-2019 to investigate the influences of transplanting times of seedlings and the varieties on the yield and quality of onion bulbs. There were six levels of transplanting time such as T_1: November 15, T_2: November 30, T_3: December 15, T_4: December 30, T_5: January 14 and T_6: January 29 under the trial. The varieties used in the study were: BARI Onion-1 and BARI Onion-4. The results revealed that dates of transplanting, varieties and their combined effects had significant effect on the parameters studied with minor exception. The plant height, number of leaves/plant and incidence of bolting were decreased with the passage of transplanting time. The maximum values (54.51 cm, 8.53 and 71.28%) of the aforementioned traits were recorded at early transplanting on November 15, respectively. The reduced percent of bolting (2.22%) was observed at December 30. While no incidence of bolting was found under transplanting on 14-29 January. Bulb diameter, individual bulb weight, yield, total soluble solid content and dry matter content of bulb were increased up to transplanting on December 15. Afterwards the values of aforesaid parameters were gradually decreased. The highest yield (17.65 t/ha) and dry matter content of bulb (15.95%) were obtained from December 15 insignificantly followed by December 30 (16.30 t/ha). The delayed transplanting on 29 January markedly reduced the dry matter content of bulb (11.61%) as well.

Tesfaye *et al*. (2018) conducted an experiment from September 2015 to April 2016 to determine an appropriate planting time for a better plant growth, yield components, seed yield and quality of Adama red onion variety. Treatments were nine planting dates: September 1st, September 16th, October 1st, October 16th, October 31st, November 15th, November 30th, December 15th and December 30th. Data were collected on growth, yield components, seed yield and quality parameters. Plant height, number of leaves per plant, number of scapes per plant, scape diameter, scape height, days to 50% flowering and maturity, umbel diameter, number of seeds per umbel, 1000-seed weight, seed yield and germination percentage were significantly influenced by planting time. The highest seed yield (1032.7 kg/ha) and the highest germination percentage (94.3%) were recorded from bulbs planted early (September 1st). On the other hand, the lowest seed yield (29.7 kg/ha) and germination percentage (15.3%) recorded from bulb planted late (December). The correlation values explain the apparent association of the planting time parameters with each other and clearly indicated the magnitude and directions of the association and relationships.

Prasad *et al*. (2017) conducted a field experiment to find out the effect of different dates of transplanting and mulching on growth, yield and quality of onion (*Allium cepa* L.) cv. Nasik Red. There were 16 treatments comprising 4 dates of transplanting (15th November, 1st, 15th and 30th December) and 3 mulching (saw dust, rice husk and wheat straw) while, without mulching as control. The study clearly revealed that there were significant effects of all treatments on vegetative growth, yield and quality attributes of onion. Plant height (65.34 cm), number of leaves per plant (8.89), length of leaves (56.07 cm), neck thickness (18.75 mm), yield (5.166 kg/plot and 387.46 q/ha) were found maximum at 1st December planting with wheat straw mulching. The best quality bulb in respect of maximum neck thickness (12.35 mm), basal diameter (13.61.mm), diameter of bulb (54.41 mm polar and 64.15 mm equatorial), length of bulb (65.17 mm) and number of scales per bulb (9.24) were also obtained when mulching was done with wheat straw and transplanted on 1st December followed by planted on 1st December and mulching with rice husk. The study clearly concluded that late transplanting on 30th December showed very poor performance irrespective of mulching and transplanting on 1st December and mulching with wheat straw was the best combination.

Mehri (2015) conducted an experiment in order to evaluate the effects of planting date on some morphological characters and seed production of onion cultivars such as Texas Early Grano 502 and Ghermez Iranshahr (Iranian Cultivar) in Iran 2012-2013. The experiment was arranged as split plot based on randomized complete block design in three replications. The four planting dates were assigned to main plots: P_1: 22nd September, P_2: 6th October, P_3: 21st October and P_4: 5th November. Two cultivars were randomizes in sub plots. Results of analysis of variance showed that the number of leaves/plant, plant height, number of flowering stalk/plant, number of capsule/umbel, number of seed/capsule and number of umbels/plant were significantly affected by planting date. The cultivars had significant effects to all the characters. Also the interaction between planting dates and cultivars had significant effect on only for the number of leaves/plant and total seed yield. At this study, the highest seed yield (2166.4 kg/ha) was obtained from Texas Early Grano 502 planted on 22nd September and the lowest seed yield (407.9 kg/ha) was obtained from Ghermez Iranshahr planted on 22nd September. However, highest seed yield for Ghermez Iranshahr (1005.8 kg/ha) obtained on 6th October.

Mollah *et al*. (2015) carried out a field experiment to find out the optimum planting time for maximizing quality true seeds of onion. The experiment was laid out in a randomized complete block design with four replications. The treatments were five planting dates *viz*. 1 October, 15 October, 30 October, 15 November and 30 November to achieve the objective. The research work was done at On-Farm Research Division, BARI, Bogra. The results revealed that the growth parameters, seed yield components, health and quality of harvested seeds were significantly influenced by the different treatments. Results showed that among different planting dates, 15th November was the best for seed and quality.

Teshome *et al.*, (2014) reported significant ($p<0.001$) effect of bulb size and planting time on seed yield per hectare. According to them, the highest seed yield (1.155 t/ha) was obtained from large bulb size planted on 25 October, followed by medium bulb size planted on the same date (0.983 t/ha) while, the least (0.075 t/ha) was obtained from small bulb size planted on 15 November.

Planting date is important for proper temperature and photoperiod both of which influence the flowering and number of seed stalks, ultimately affecting the seed yields. Karim and Ibrahim (2013) reported the impacts of planting time, day length, soil pH and soil moisture on the production of onion.

Planting time for onion is different across the countries due to seasonal variations. EL-Helaly and Karam (2012) conducted a field experiment at Cairo University, Giza Governorate during 2008-2009 and 2009-2010 season, to assess the influence of planting date (November 15, December 15 and January 15) on production of onion cv.Giza 20. Results showed significant effect for most of studied characters. Significantly the highest scape number/plant, scape diameter, main scape length, umbel diameter, seed yield/fed, weight of 1000 seeds and percentage of seed germination were obtained from planting on mid of November.

Khodadadi (2012) conducted a study aimed at determining the planting date and size of the mother bulb effects on some traits which are related to seed on onion Rey variety in Iran during the 2008-2010. The result showed that the planting date significantly affected number of plant emergence plant height and yield per hectare. Significantly the highest seed yield was recorded from the planting date of November 6.

Khodadadi (2009) in Iran compared between two planting dates (mid- September and mid- November), and reported the highest seed yield for GholiGhese onion variety planted on mid- September. Rahim *et al.* (2009) reported significant effect of planting time and mulches on agronomic traits contributing for growth and seed yield of onion cultivar Taherpuri. Ud- Deen (2008) conducted an experiment to study the effect of mother bulb size and planting time on growth, bulb and seed yield of onion. Onion bulbs of different sizes (20 g, 15 g and 10 g) were planted at different dates *viz.*, October 30, October 15 and November 30. The large mother bulb and early planting were favorable for getting higher bulb and seed yields. The treatment combinations of large mother bulb (20 g) and 30 October planting time gave the highest bulb (17.52 t/ha) and seed (0.4 t/ha) yield.

George *et al.* (2009) conducted an experiment to study the effect of sowing date, transplanting date and varieties on production of transplanted short day onion varieties in south eastern Georgia's Vidalia growing region. The propensity of some varieties to form double bulbs can be reduced with later sowing and transplanting dates. Sowing the first week of October rather than the fourth week of September and transplanting in December rather than November can reduce double bulbs in some varieties.

Anisuzzaman *et al.,* (2009) found that planting time significantly affecting onion development and seed production. According to Ibrahim *et al.,* (1996) average number of sprouts, number of scapes and number of umbels/plant were not markedly affected by planting date. The maximum diameter of umbel and longest scape the highest seed yield/plant and best quality seed were obtained from early planting from the planting of (November 25).

Singh *et al.,* (2005) carried out an experiment to study the effect of planting time, bulb size and bulb spacing on plant growth and seed yield attributes of onion cultivar RO-1 at Agricultural Research Station, Durgapur (Jaipur) of Rajasthan Agricultural University (Bikaner). Maximum seed yields (10.95 t/ha) was obtained in October 11 planting, followed by October-1 (10.05 t/ha).

Mohanty *et al.,* (2001) reported that the planting on November 16 gave the tallest plants (50.52) with the highest number of leaves per plant (14.85), bulb diameter (5.93 cm), bulb weight (70.78 g) and bulb yield (0.283 t/ha). Further delay in planting resulted in reduced vegetative growth and yield.

The reduction in seed yield as a result of late planting was may be due to flower abortion and low seed yield per plant (El-Helaly and Karam, 2012).

Malik *et al.,* (1999) reported that the highest yield and quality of onion seed was obtained with early planting (15th October) in India. Mosleh (2008) indicated significant influence of planting date on onion growth and seed yield, and early planting was found favorable for getting higher bulb and seed yield in Bangladesh. El-Aweel and Ghobashi (1999) also reported significant seed yield increase with early planting (10 November), which was mainly attributed to increase in weight of seed and number of umbels per plant and 1000 seed weight.

2.3.1 Effect on germination and emergence

Onions are a cool season crop and tolerant to frost. Onion seed can germinate at temperatures as low as 1.4°C to 3.5°C. However, for a germination and emergence percentage of more than 70%, temperatures between 7.5°C and 30°C are needed (Abu-Rayyan *et al.*, 2012). In Germany, an emergence percentage of 90% and more were obtained with soil temperatures ranging between 10°C to 25°C (Kretschmer, 1994). Ansari (2007) reported that a delayed sowing date accelerated the emergence of onion seedlings in Iran. Onion seedlings from seed sown in January emerge after 22 days experiencing an average temperature of 17.7°C, whereas February sown seed emerge after only 10 days experiencing an average temperature of 24.7°C. Seedlings emerge after only 7 days when onion seed was sown in March when there was much higher average temperature (34.7°C) than the earlier sowing dates. These results indicated that higher temperatures can shorten the number of days from germination to emergence. Onions therefore, can germinate at a wide temperature range with the highest germination percentage and seedling emergence between 15°C to 25°C (Ansari, 2007).

Large bulb size (90.78) and planting on 25 October gave the highest germination percentage (97.56), followed by medium bulb size (83.22) and 5 November planting (86.44). Whereas, small bulb size (80.11) and late planting 15 November gave the lowest germination percentage (70.11). Early planting on 25 October increased germination percentage by 39% than late planting (15 November). EL-Helaly and Karam (2012) significant effect of planting date on seed germination and the highest percentage of seed germination was obtained from early planting.

2.3.2 Seedling and vegetative growth

The seedling phase of onions (from the loop up to the cotyledon senescence stage) is a long and slow period of growth and can be as long as 2 to 3 months (Sullivan *et al.,* 2001). The relative growth rate (RGR) of onion seedlings (1.00) is almost half of that of other cool season crops such as lettuce (1.91) and cabbage (1.96) and is temperature dependent. However, onion seedlings are the fastest growing of most edible alliums (Brewster, 2008).

Leaf growth and leaf canopy development during the vegetative growth phase from the cotyledon senescence up to the fall of the first leaf stage are temperature related. For leaf growth and leaf canopy development a minimum or base temperature of 6°C is required and at temperatures below 6°C leaf growth will cease. The relative leaf growth rate (RLGR) increase linearly with an increase in temperature from 6°C to 20°C (Brewster, 2008). With a further increase in temperature, growth rate will start to slow down and at temperatures above 26°C it will cease.

2.3.3 Bolting (development of seed stalk)

Bolting is the development of a seed stalk, important for onion seed production but not bulb production (Voss *et al.,* 1999). Bolting will also reduce the marketable yield of onion bulbs. Un-timely bolting occurs when the onion plant is exposed to low temperatures (8°C to 13°C) when plants are ready to start forming bulbs (start of bulbing phase). The sensitivity to low temperatures increases with an increase in plant age (Cramer, 2003). The number of leaves has been used to determine a critical plant size at which bolting will be induced under low temperature conditions.

According to Khokhar *et al*., (2007) sensitive plant size is when 7 to 10 leaves are formed (i.e., at the end of the first leaf fall and the beginning of bulbing stage). When sowing is done too early in the season, the onion plant will reach the minimum plant size for bulbing when temperatures are still low and will bolt instead of forming bulbs. Sowing date therefore needs to be at a time to prevent plants receiving a cold spell when reaching a minimum plant size resulting in bolting instead of bulbing. However, with late sowing the occurrence of bolting is lower, but plants are still small when bulb formation starts resulting in small bulbs of a poor quality (Cramer, 2003).

Therefore, sowing date is one of the important production factors that need to be taken in to consideration for bolting to occur. Agic *et al.,* (2007) reported enhanced bolting due to early sowing in the Republic of Macedonia. Late sown onions (1st of September) had the lowest bolting percentage (13.12%) compared to plants sown earlier on 10 and 25 August (34.81 and 27.00%, respectively). Al- Moshileh (2007) reported that early planted onions under central Saudi Arabian conditions resulted in a higher percentage of bolting than late plantings.

2.3.4 Flower development and seed formation

Inflorescence development in onion has three definite successive phases: floral initiation due to low temperature “Thermo phase”, growth and development of differentiated inflorescence “competition phase” and the actual flowering and seed production stage “completion phase” that is favored by high temperature and long days (Rabinowitch and Brewster, 1990; Brewster,1994). The progress of flower opening on the umbels is somewhat irregular. Hence, both closed buds and the open flowers at all stages of development are present all over the head at peak flowering in varying proportion in different regions of the umbel (Currah and Ockendon, 1978).

Teshome *et al.,* (2014), in Kobo, found early flowering (69 days) from the large bulbs planted on 25 October, while the longest days to attain 50 %

flowering were recorded from small bulb size planted on 15 November (82.67). This might be because there was low temperature during early planting which might have contributed for the enhancement bolting and flower stalk development and subsequent flower development, while at late planting the temperature increased which, in turn, 'might have delayed bolting and subsequent flowering and maturity. Large bulbs contributed to the plants by giving enough amount of reserved food. Anisuzzaman *et al.,* (2009) reported that planting time had marked influence on the number of days required for emergence of 50% flowering and sometimes early maturing is good, as it can escape from bad weather and diseases. Vinney *et al.,* (2011) also reported that low temperatures favor bolting.

2.3.5 Components of seed yield

The most important components for onion seed production are umbel size, flower stalk height, number of flower stalks per plant and per plot and flower stalk diameter, which are closely related with the size of mother bulb and cultivars (Prats *et al.,* 1996). The number of flower stalks per plant varied from1 to 15 per plant at Melkassa and the terminal number of 50-200 flowers produced per umbel on "Adama Red" depending on the number of shoots axis (Lemma, 1998). Seed yield per plant was positively and significantly correlated with the number of seed stalk per plant and seed yield per umbel (Lemma, 1998).

Umbel diameter was the most important index for seed yield (Prats *et al.,* 1996). This character was influenced strongly by base flower stalk diameter. While cause and effect relationship between seed weight and the evaluated components in the inflorescence, it was found that umbel diameter was determining seed yield. This indicated that this character could be a good index for seed yield estimation in onion. According to Teshome *et al.,* (2014), the maximum umbel diameter was recorded from large bulb size (5.8 cm) but was on par with the one obtained from medium sized bulbs (5.58 cm). The lowest umbel diameter (5.02 cm) was obtained from small bulbs. The maximum umbel diameter (6.01 cm) was also obtained from those planted on 25 October, followed by 5 November (5.57 cm) and 15 November (4.82 cm). This might be due to higher supply of food materials to the umbel by larger bulb size and early planting also created favorable environmental conditions for earliest flowering and subsequently large umbel size.

Number of seed per umbel was recorded the maximum (515.33) and the least (256.56) number of seeds per umbel were recorded from planted on 25 October and 15 November, respectively. Early planting (25 October) increased seed number per umbel by 100% than the last planting (15 November). Regarding mother bulb size, large bulbs increased seed number per umbel by 26.23% than the small bulbs. In addition to bulb size and planting time, the variation in number of seeds per umbel might be due to flower abortion caused by high temperature, lack of efficient pollinators of all the flowers in the umbel, shortage of nutrition which caused high competition and death of the weak florets in the umbel. Delayed planting resulted in poor plant growth and delayed bolting, moreover, high temperature at scape forming stages might have reduced the number of seed per umbel (Teshome *et al.*, 2014).

2.4 Effect of integrated plant nutrients

The yield of onion seed depends mainly on cultural practices like nutrition, irrigation, plant protection measures besides the congenial climatic factors. Nutrition is one of the most important factors which govern the onion seed production. There is need of supplementing the use of chemical fertilizers with organic manures. Organic matter provides many additional benefits such as supply of micronutrients, preventing erosion improving drainage and food microorganisms as well as increase in Base Exchange capacity (Lakshmi and Sekhar, 2018). The nutrient management paradigm acknowledges the need for both inorganic and organic inputs to sustain soil health and crop production due to positive interactions and complementarities between them (Sanchez and Jama, 2001; Vanlauwe *et al*., 2002). It is a strategy that incorporates both inorganic and organic inputs plant nutrients to attain higher crop productivity, prevent soil degradation, and thereby helps meet future food supply needs (Vanlauwe *et al*., 2002; Place *et al*., 2003). This is due to practical reasons as fertilizer or organic resources alone may not provide sufficient amounts or may be unsuitable for alleviating specific constraints to crop production. Especially, vermicompost with inorganic fertilizers is one of the promising techniques for improving soil fertility and increasing vegetables production (Kachapur *et al*., 2001; Linus and Irungu, 2004).

Vaghela *et al*. (2019) conducted an investigation in Rabi season to study the effect of organic, inorganic and biofertilizer on growth and yield of onion (*Allium cepa* L.) cv. GJRO-11. The soil application of 50% RDF (50: 37.5: 37.5 NPK kg/ha) + 25% N from vermicompost + 5 ml Bio-NPK consortium was most effective treatment and which was recorded significantly maximum parameters *viz*., plant height (70.11 and 86.70 cm at 45 and 90 DAT respectively), minimum bolting percent (4.38), neck thickness (1.11 cm) and TSS (13.47 oBrix). While number of leaves per plant was non-significant.

Asgele *et al*. (2018) conducted a field experiment to study the effect of inorganic NP fertilizers and vermicompost on growth, seed yield and yield components of red onion (*Allium cepa* L.) variety. The treatments consisted of five NP fertilizer rates 0, 25, 50, 75 and 100% of recommended NP rates (69 kg N and 92 kg P_2O_5 ha^{-1}) and four rates of vermicompost (0, 2.5, 5.0 and 7.5 t ha^{-1}). Results of the analysis revealed that the interaction effects on inorganic NP fertilizer and vermicompost significantly affected plant height. Days to bolting, days to 50% flowering, flower stalk diameter and days to maturity were significantly affected by the main effect of NP fertilizer rates and vermicompost. Similarly, numbers of umbels per plant, umbel diameter, number of seeds per umbel and seed weight per umbel were significantly affected by the main effect of NP fertilizer rates and vermicompost. The highest seed yield per hectare (1462.5 kg ha^{-1}) was obtained from the plants grown at 75% of RDF with vermicompost at 2.5 t ha^{-1} which was about 263% higher than seed yield from unfertilized control plot. It can, thus, be concluded that the combined application of 75% of RDF with vermicompost at 2.5 t ha^{-1} can improve growth, seed yield and yield components of Bombay red onion variety in the study area.

Yadav *et al*., (2018) reported that the practice of integrated nutrient management helped in obtaining maximum growth and yield parameters in onion var. Agrifound Red. In another experiment by Keniseto Chuda Kanaujia *et al*. (2009) recorded highest plant height, number of leaves per plant, neck thickness, bulb size, bulb yield and dry matter with the application of 50% NPK + 50% FYM. Abbey and Kanton (2003) also reported maximum plant height, bulb weight, bulb diameter and bulb yield with the application of FYM coupled with fertilizers.

Hossain *et al*., (2017) carried out an experiment with a view to observe the effect of micronutrients (Zn, B and Mn) with different levels of macronutrients (NPKS fertilizers) on onion (*Allium cepa* L.) seed yield. The experiment was conducted with four levels of micronutrients *viz*. M_1= $Zn_0B_0Mn_0$ kg/ha, M_2= $Zn_4B_1Mn_2$ kg/ha, M_3= $Zn_6B_2Mn_3$ kg/ha and M_4= $Zn_8B_3Mn_4$ kg/ha and three doses of macronutrients *viz*. F_1= $N_{57}P_{21}K_{39}S_9$ kg/ha, F_2= $N_{114}P_{42}K_{78}S_{18}$ kg/ha and F_3 =$N_{171}P_{63}K_{117}S_{27}$ kg/ha. All doses of micro and macronutrients are applied to the soil. Application of micronutrients and different doses of macronutrients increased number of umbels/plot, number of seeds per umbel, weight of seeds per umbel, seed yield per plant. The highest seed yield (879.9 kg/ha) were recorded from M_3 treatment and the lowest seed yield (787.4 kg/ha). The positive effects of micronutrients were found in order of M_3> M_4> M_2> M_1. The F_2 treatment produced the highest seed yield (957.6 kg/ha) and F_1 treatment produced lowest (776.6 kg/ha). The positive effects were found in order of $F_2 > F_3 > F_1$. Amongst the treatment combinations, M_3F_2 produced the highest seed yield (1027.0 kg/ha) and M_1F_1 produced the lowest yield (734.4 kg/ha).

Santhosh *et al*., (2017) conducted an experiment to study the effect of INM on growth and yield attributes of kharif onion at Horticulture Farm, SKN College of Agriculture, Jobner and revealed that the application of FYM @ 5 t/ha + vermicompost @ 2.5 t/ha + biofertilizers (Azospirillum + PSB) or application of N, P, K, S, Zn @ 100:50:100:20:10 kg/ha are worth recommended as both fetched comparable bulb yield and net returns.

Sekhon *et al*., (2016) conducted a study with integrated nutrient management interventions and evaluated their effect on yield of rabi onion. Three farmyard manure (FYM) rates (0, 25 and 50 t ha^{-1}), three nitrogen (N) rates (75,100 and 125 kg N ha^{-1}), three P rates (30, 50 and 70 kg P_2O_5 ha^{-1}) and three K rates (30, 50 and 70 kg K_2O ha^{-1}) were tested. A control plot was kept with each rate of FYM application. The treatments were replicated over three artificially created fertility strips. Fertilizer N was the most limiting element. Higher FYM rates though can be used to reduce N, P, and K fertilizer rates, but doubling FYM rate from 25 to 50 t ha^{-1} did not benefit in general. Growth and yield of bulb data indicated that 25 t ha^{-1} FYM, 100 kg N ha^{-1}, 50 kg of P and K ha^{-1}gave the best results. The results hold significance in view of higher FYM rate recommendation (50 t ha^{-1}) in certain states.

Mandal *et al*., (2015) carried out a trial at Horticulture Farm, Institute of Agriculture, Sriniketan, West Bengal and reported that the treatment combination of 20t FYM/ha + State Recommended NPK (125:100:100 kg/ha) resulted in maximum growth parameters in onion.

Bhagwat (2014) documented that highest plant height, number of leaves and neck thickness, polar diameter, equatorial diameter, average weight of bulb and total bulb yield were recorded in the treatment comprising 110:40:60:40 kg NPKS + 7.5t FYM + 2.5t poultry manure + 2.5t vermicompost per hectare.

Shinde *et al*., (2013), the treatment receiving 110:40:60:40 kg NPKS + 7.5t FYM + 2.5t vermicompost + biofertilizer (5 kg each of Azospirillum + phosphobacteria) per hectare recorded the highest bulb yield indicating that the use of biofertilizers in combination with inorganic fertilizers and organic manures offers a great opportunity to increase the production in onion. In another trial conducted by Jawadagi *et al*., (2012) recorded maximum leaf length and number of leaves in onion with the application of RDF (125:50:125: N:P:K kg/ha) + FYM @ 30 t/ha.

Yoldas *et al*., (2011) conducted this experiment to find the influence of both organic and mineral fertilizer on the quality and yield of onion (*Allium cepa* L.) and also on the macro and micro element contents of onion bulb. Cattle manure was applied at 0, 20, 40 and 60 t/ha. N: P: K was applied at the recommended dose of 120:100:150 with half of the recommended rate of NPK. Yield, yield components and macro-micro element contents were measured. In the first year, bulb width and number of storage leaf were influenced significantly by the treatments. In the second year, applications affected onion yield significantly but bulb number, fleshy thickness, bulb weight, bulb height, number of storage leaf, number of shoot tip and number of dried leaves were not influenced statistically. In the first year, treatments influenced K content, but did not influence N, P, Ca, Na, Mg, Fe, Zn, Cu and Mn contents of the onion bulb. In the second year, the treatments influenced Na content, but did not influence the others.

Khandelwal (2010) reported that maximum number of leaves and plant height was observed with per hectare application of NPKS @ 110:40:60:40 kg along with 7.5t FYM + 2.5t poultry manure + 2.5t vermicompost + biofertilizer in onion crop.

Thangasamy *et al*., (2010) revealed that in onion and garlic combined application of fertilizers along with organic manures and biofertilizers enhanced crop productivity, quality and soil health.

Patil *et al.*, (2007) conducted a field experiment entitled, "Effect of integrated nutrient management on growth and yield of onion seed production" with variety of N-2-4-1. The experiment was laid out in randomized block design with nine treatments and three replications. Significantly higher values of all growth attribute parameters were recorded with the treatment (T_2) fertilizer combination of 120 : 60 : 60 N : P_2O_5 : K_2O kg ha^{-1} + 20 t FYM ha^{-1} over all treatments but was closely followed by application of RDF as per soil test. The treatment (T_3) 75 % RDF + 5 t FYM ha^{-1} recorded the lowest values of growth attributes. Treatment (T_2) 120 : 60 : 60 NPK + 20 t FYM ha^{-1} recorded highest number of umbels/plant, number of seeds/umbel, weight of seeds/umbel and 1000 seed weight (g). The use of 100 per cent RDF (T_2) through inorganic source with 20 t FYM ha^{-1} was capable to gain the highest residual N, P and K. The results obtained in the present investigation indicated that the treatment (T_2) combination of 100 % RDF of NPK (120 : 60 : 60 kg ha^{-1}) with FYM (20 t ha^{-1}) gave the highest seed yield. So it can be advocated for cv. N-2-4-1 in rabi season under irrigated conditions.

CHAPTER III

MATERIALS AND METHODS

A field experiment was conducted at the research field of Sher-e-Bangla Agricultural University. This chapter provided a brief description on location, climate, soil, crop, fertilizer, experimental design, cultural operations, collection of plant samples, materials used in the experiment and the methods followed and statistical analyses.

3.1 Experimental site

The research work was conducted at the Agronomy Farm of Sher-e-Bangla Agricultural University, Dhaka-1207 to find out the onion seed yield and quality as affected by planting time and nutrients during the period from October 2019 to April 2020. Experimental field was located at 90°22$^{/}$E longitude and 23°41$^{/}$N latitude and altitude of 8.2 m above the sea level. The experimental site is presented in Appendix I.

3.2 Climate

Experimental area belongs to subtropical climatic zone which is characterized by heavy rainfall, high temperature and relatively long day period during "Kharif-1" season (April-September) and scarce rainfall, low humidity, low temperature and short day period during "Rabi" season (October-March). This climate is also characterized by distinct season, *viz*. the monsoon extending from May to October, the winter or dry season from November to February and per-monsoon period or hot season from March to April (Edris *et al.*, 1979). The meteorological data in respect of temperature, rainfall, relative humidity, average sunshine and soil temperature for the entire experimental period have been shown in Appendix II.

3.3 Characteristics of soil

The soil of the experimental area belongs to the Modhupur Tract in Agroecological Zone (AEZ)-28 (UNDP, 1988). It was medium high land and the soil series was Tejgaon (FAO, 1988). The soil was having a texture of sandy loam with pH and CEC were 5.6 and 2.64 meq/100 g soil, respectively. The characteristics of the soil under the experimental plot were analyzed in the Soil Testing laboratory, SRDI, Khamarbari, Dhaka and details of the recorded soil characteristics were presented in Appendix III.

3.4 Planting materials

The materials used in the study was onion bulbs (cv. Taherpuri). The average weight of bulb is 10-12 g.

3.5 Experimental Treatment

The following treatments were included in the experiment:

Factor A: Planting time – three levels

1. T_1 = 1 November
2. T_2 = 10 November
3. T_3 = 20 November

Factor B: Nutrients (Four levels)

1. N_0 = NPKS (Standard dose) + 5 t cowdung/ha
2. N_1 = 50% NPKS + 50% Vermicompost
3. N_2 = 50% NPKS + 50% Mushroom spent compost
4. N_3 = 50% Vermicompost + 50% Mushroom spent compost

There were 12 (3×4) treatment combinations given below:

T_1N_0, T_1N_1, T_1N_2, T_1N_3, T_2N_0, T_2N_1, T_2N_2, T_2N_3, T_3N_0, T_3N_1, T_3N_2 and T_3N_3.

3.6 Land preparation

The land was first ploughed by a tractor drawn disc plough and subsequently cross ploughed four times with power tiller and ladder on 15 October, 2019. The corners of the land were spaded. It was then harrowed to bring the soil in a good tilth condition. The land was then thoroughly leveled by a ladder. Weeds and stubbles were removed from the field. All the clods were broken into small pieces. The unit plots were also prepared smoothly with spade before sowing.

3.7 Fertilizer application

According to Fertilizer recommendation Guide 2016, standard manure and fertilizer doses as follows:

Name of fertilizer and manure	Doses ha^{-1}	Nutrients			
		N (kg)	P (kg)	K (kg)	S (kg)
Cow dung	5 t	28	24	35	-
Vermicompost (50%)	3.2 t	96	64	64	-
Mushroom spent compost (50%)	4.8 t	96	10	60	-
Urea	360 kg	165	-	-	-
TSP	480 kg	-	95	-	-
MoP	160 kg	-	-	80	-
Gypsum	100 kg	-	-	-	18

The manures and fertilizers were applied as basal dose at final land preparation but urea was applied in three equal installments. All manures and fertilizers were applied by broadcasting and mixed thoroughly with soil.

The nutrient composition of cow dung, vermicompost and mushroom spent compost were as follows:

Manure	N (%)	P (%)	K (%)
Cow dung	0.57	0.47	0.69
Vermicompost	3.00	2.00	2.00
Mushroom spent compost	2.00	0.20	1.30

3.8 Experimental design and layout

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. There were 12 treatment combinations. In total of 36 unit plots and the size of each unit plot was 1.5 m × 1.2 m. The distance maintained between two replications and two plots were 1 m and 0.5 m, respectively. The layout of the experiment is shown in Figure 1.

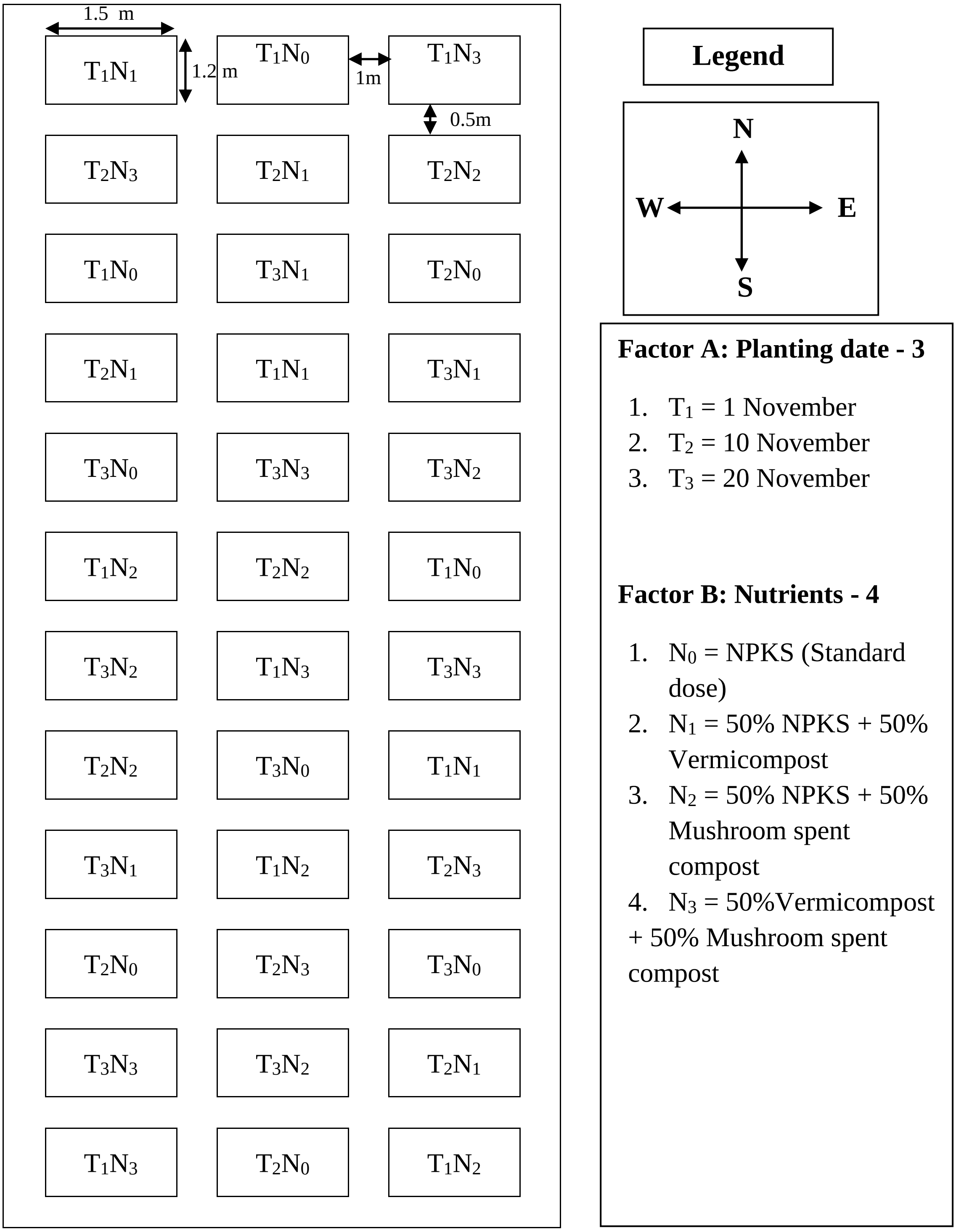


Fig. 1. Layout of the experimental plot

3.9 Planting of bulbs

The bulb of onion were planted in the research field on 1, 10 and 20 November 2019. The distances between row to row was 30 cm and bulb to bulb was 15 cm. One mature bulb was placed in each point at 2–3 cm depth from the soil surface.

3.10 Intercultural operation

3.10.1 Weed control

The crop was found to be infested with weeds during the early stage of crop establishment. Two hand weddings were done; first weeding was given at 15 days after sowing followed by second weeding at 15 days after first weeding.

3.10.2 Irrigation

The young plants were irrigated by a watering can and at later stage irrigation was done by flooding of each plot whenever necessary.

3.10.3 Stalking

Stalking operation was done to protect morphological damage of plants as and when necessary.

3.10.4 Plant protection

Insects: Preventive measure was taken against soil borne insects. For the prevention of cutworm, Furadan 3 G @ 20 kg ha^{-1} was applied. No insect pest infestation was found in the field after pesticide application.

Disease: Few days after transplanting some plants were attacked by purple blotch disease caused by *Alternaria puri*. It was controlled by spraying Ruvral 50 WP four times at 10 days interval after transplanting.

3.11 Harvesting and sampling

The matured umbels were harvested in 30^h March, 9 and 19 April 2020 when the fruit had black seed exposed. Umbels were harvested with a small portion of flowering stalk in the morning to prevent shattering of seeds. The harvesting continued upto to 19 April, 2020.

3.12 Threshing, cleaning, drying and storage

Harvested onion umbels were dried on the cemented floor of under sunlight. Umbels were ready for threshing when the capsules and small stems were brittle and broke quickly while rubbed between the hands. The seeds were threshed by beating the umbels with small stick. Seeds were then cleaned by winnowing manually and dried by spreading in the open sunlight on brown paper until they reached safe moisture content (6-9%). After putting the seeds in airtight polythene bags, these were kept in dry and cool place at room temperature for storing. The seeds thus collected were dried in the sun for reducing the moisture in the seeds to a constant level. The dried seeds and straw were cleaned and weighed.

3.13 Seed quality

Seeds obtained from the field experiment were taken separately. These seeds were used for taking quality determination experiments in the laboratory. For this purpose standard germination test was conducted and other different quality attributes data were taken.

3.14 Collection of data

The data were recorded on the following parameters:

3.14.1 Growth parameters

1. Plant height
2. Number of leaves plant^{-1}

3.14.2 Yield contributing parameters

1. Number of umbel plant^{-1}
2. Umbel diameter
3. Number of seeds umbel^{-1}

4. Length of flowering stalk
5. 1000 seed weight

3.14.3 Yield parameters

1. Seed yield plant^{-1}
2. Seed yield plot^{-1}
3. Seed yield ha^{-1}

3.14.4 Seed quality parameters

1. Germination (%)
2. Shoot length
3. Root length
4. Seed vigor index

3.15 Procedure of data

Data on the following characters were collected from experimental plots and selected plants.

3. 15.1 Plant height

The height of the 10 randomly selected plant was measured from the ground level to the tip of the largest leaf at 30, 60, 90 DAP and at harvest. Mean highest was calculated expressed in centimeter.

3. 15.2 Number of leaves plant^{-1}

Total number of leaves was counted from the 10 randomly selected plants at 30, 60, 90 DAP and at harvest and the mean of total number of leaves was then taken.

3. 15.3 Number of umbels plant^{-1}

Number of umbel plant^{-1} was counted from the 10 randomly selected plant samples and then the average umbel number was calculated.

3. 15.4 Umbel diameter

Umbel diameter was measured by slide callipers from 10 randomly selected umbels of plants and then the average umbel diameter was calculated.

3. 15.5 Number of seeds umbel^{-1}

Number of seeds per umbel was counted from 10 randomly selected umbels of plants and then the average seed number was calculated.

3. 15.6 Length of flowering stalk

At the time of harvest the length of flowering stalk was measured with a meter scale from the base to the bottom of the flowering stalk from ten randomly selected plants from each plot and their average was taken.

3. 15.7 Weight of 1000 seeds

1000 seeds were counted, which were taken from the seeds sample of each plot separately, then weighed in an electrical balance and data were recorded in gram (g).

3. 15.8 Seed yield plant^{-1}

The 10 plants selected at random from the inner rows of each plot which were harvested to take seed yield per plant. The seed were threshed, cleaned, dried, weighed and then averaged in gram (g).

3. 15.9 Seed yield plot^{-1}

All plots were harvested individually and the average yield of seeds plot^{-1} was recorded.

3. 15.10 Grain yield ha^{-1}

The yield of seed in g per plot was adjusted at 12% moisture content of seed and then it was converted to kg per hectare.

3. 15.11 Seed viability test

3. 15.11.1 Percent (%) seed germination

After collection of harvested seeds, percent seedling emergence was tested in the Laboratory. Sample seeds from each replication collected from the experiment field were tested for percent seed germination. Germination was calculated as the number of seeds which was germinated within 15 days as a proportion of number of seeds set for germination test in each treatment.

$$\text{Germination percentage (\%)} = \frac{\text{Number of germinated seeds}}{\text{Total number of seeds set for germination}} \times 100$$

3.15.11.2 Root length

The Root length of ten seedlings from each sample was recorded finally at 12 days of germination test. Measurement was done using a meter scale and unit was expressed in centimeter (cm).

3.15.11.3 Shoot length

The shoot length of ten seedlings from each sample was measured finally at 12 days of germination test. Measurement was done using the unit centimeter (cm) by a meter scale.

3.15.11.4 Seed vigor index

The vigor index (VI) of the seedlings can be estimated as suggested by Abdul-Baki and Anderson (1973):

$$VI = RL+SL\times GP,$$

Where

RL = root length (cm),

SL = shoot length (cm) and

GP = germination percentage.

3.16 Statistical analysis

The collected data were compiled and tabulated. Statistical analysis was done on various plant characters to find out the significance of variance resulting from the experimental treatments. Data were analyzed using analysis of variance (ANOVA) technique with the help of computer package programme MSTAT-C (software) and the mean differences were adjudged by least significant difference test (LSD) as laid out by Gomez and Gomez (1984).

CHAPTER IV

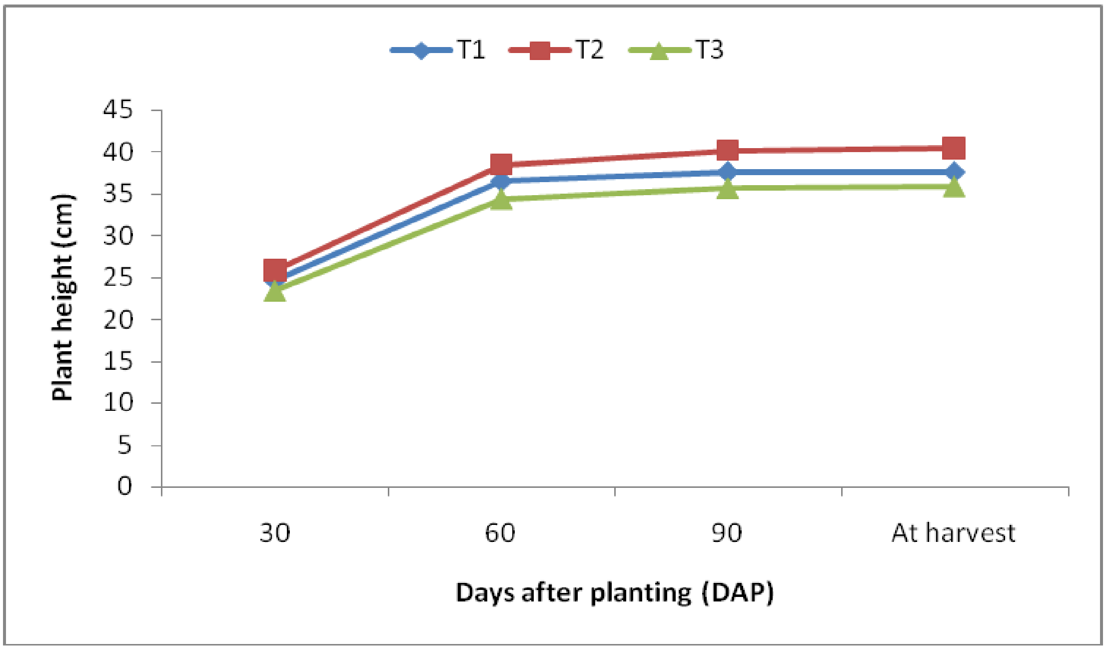
RESULTS AND DISCUSSION

Results obtained from the present study regarding the time of bulb plantation and nutrient management effect on growth, seed yield and yield attributes are presented and discussed in this chapter. After observing the field performance, further investigation was also observed on the aspect of seed quality of the obtained study. The results have been presented in tables and figures. Different parameters of the onion cultivars have been presented and discussed under separate heads and sub–heads as follows:

4.1 Growth parameters

4.1.1 Plant height

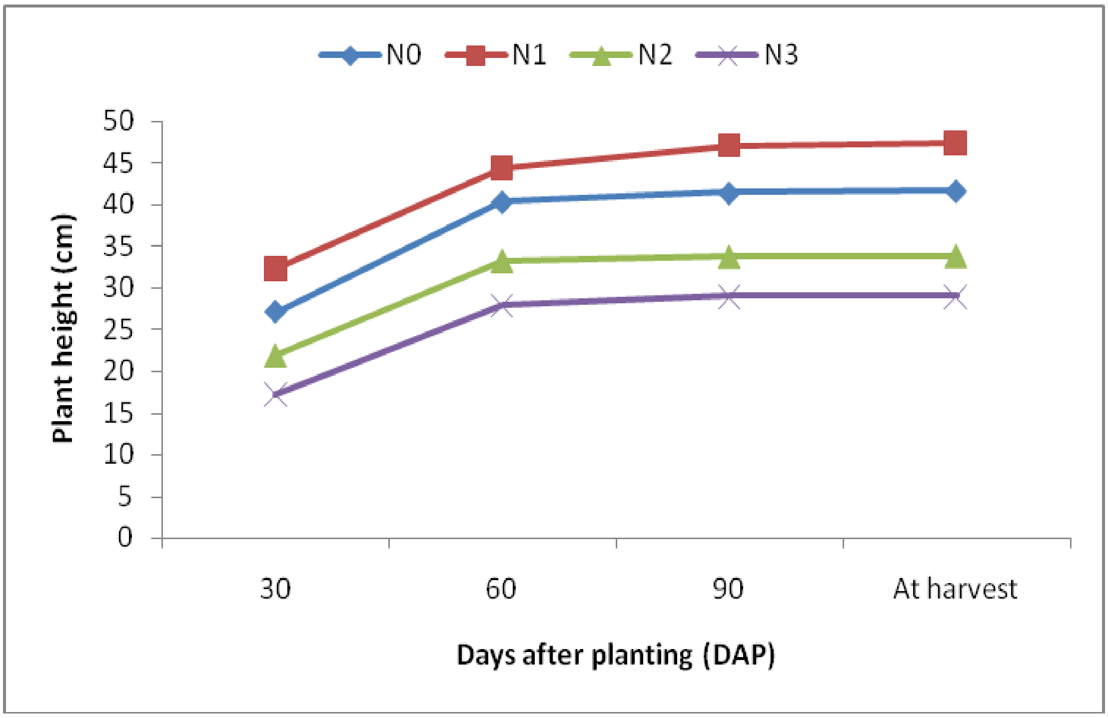
Plant height onion at different growth stages was significantly influenced by different planting time. During the study, plant height was taken at 30, 60, 90 DAP and at harvest. Results revealed that at 30 DAP, the highest plant height (25.78 cm) was recorded from T_2 (10 November) treatment which was significantly same with T_1 (1 November) whereas the lowest plant height (23.44 cm) was recorded from T_3 (20 November) treatment (Figure 2 and Appendix IV). At 60 DAP, the highest plant height (38.49 cm) was recorded from T_2 (10 November) treatment that was significantly different from others followed by T_1 (1 November) whereas the lowest plant height (34.44 cm) was recorded from T_3 (20 November) treatment. Similarly, at 90 DAP, T_2 (10 November) treatment gave the highest plant height (40.15 cm) that was significantly different from other planting time followed by T_1 (1 November) and T_3 (20 November) treatment showed the lowest plant height (35.73 cm). At the time of harvest, the highest plant height (40.47 cm) was given by T_2 (10 November) treatment whereas the lowest plant height (35.96 cm) was given by T_3 (20 November) which was significantly same with T_1 (1 November) treatment. This result suggested that early plantation of onion showed higher plant height than the late plantation. Khan *et al*. (2020) reported that plant height, was decreased with the passage of transplanting time. Tesfaye *et al*. (2018) reported that plant height was significantly influenced by planting time.



T_1 = 1 November, T_2 = 10 November, T_3 = 20 November

Fig. 2. Effect of planting time on plant height at different days after planting of onion at 5% level of significance

Significant influence was found on plant height of onion at different growth stages as affected by different levels of plant nutrients. Data were recorded at 30, 60, 90 DAP and at harvest. Accordingly, at harvest, the highest plant height (47.48 cm) was recorded from N_1 (50% NPKS + 50% vermicompost) which was significantly different from other treatments followed by N_0 (NPKS; standard dose) whereas the lowest plant height (29.01 cm) was found from N_3 (50% vermicompost + 50% mushroom spent compost) nutrients (Figure 3 and Appendix IV). The result obtained from the present study revealed that different combination of plant nutrient affects significantly the plant height of onion. Similar result was also observed by Vaghela *et al*., (2019). Asgele *et al*., (2018), Yadav *et al*., (2018) and Abbey and Kanton (2003) also found similar result with the present study.



N_0 = NPKS (Standard dose), N_1 = 50% NPKS + 50% Vermicompost, N_2 = 50% NPKS + 50% Mushroom spent compost, N_3 = 50% Vermicompost + 50% Mushroom spent compost

Fig. 3. Effect of nutrients on plant height at different days after planting of onion at 5% level of significance

Recorded data on plant height of onion at 30, 60, 90 DAP and at harvest varied significantly due to combined effect of planting time and nutrients. At harvest, the highest plant height (50.37 cm) was identified from T_2N_1 (10 November with 50% NPKS + 50% vermicompost) treatment combination and the lowest plant height (27.87 cm) was produced from T_3N_3 (20 November with 50% vermicompost + 50% mushroom spent compost) treatment combination which was statistically similar to T_1N_3 (1 November with 50% vermicompost + 50% spent mushroom compost) treatment combination (Table 1 and Appendix IV).

Table 1. Combined effect of planting time and nutrients on plant height at different days after planting of onion

Treatment combinations	Plant height (cm)			
	30 DAP	60 DAP	90 DAP	At harvest
T_1N_0	27.40 c	40.83 cd	41.40 de	41.50 d
T_1N_1	32.23 ab	44.53 ab	47.03 ab	47.23 b
T_1N_2	21.67 e	32.33 f	32.87 g	32.93 f
T_1N_3	17.53 fg	28.17 gh	28.83 h	28.43 gh
T_2N_0	27.53 c	41.27 c	42.93 cd	43.10 cd
T_2N_1	33.91 a	45.90 a	49.70 a	50.37 a
T_2N_2	24.50 d	37.23 e	37.53 f	37.67 e
T_2N_3	17.20 g	29.57 g	30.43 gh	30.73 fg
T_3N_0	26.35 cd	38.90 de	39.87 ef	40.40 de
T_3N_1	30.91 b	42.80 bc	44.67 bc	44.83 bc
T_3N_2	19.70 ef	30.07 g	30.67 gh	30.75 fg
T_3N_3	16.81 g	26.00 h	27.73 h	27.87 h
$LSD_{0.05}$	2.230	2.178	2.982	2.747
CV(%)	6.48	9.22	7.21	12.09

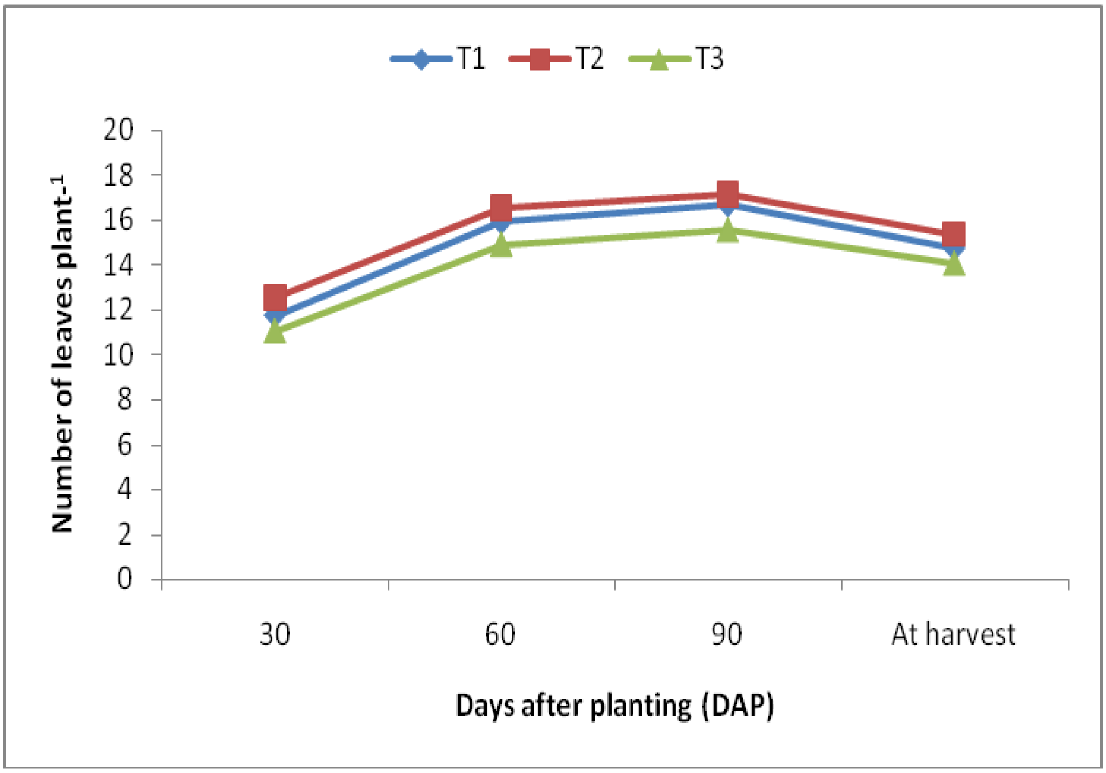
In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

T_1 = 1 November, T_2 = 10 November, T_3 = 20 November

N_0 = NPKS (Standard dose), N_1 = 50% NPKS + 50% Vermicompost, N_2 = 50% NPKS + 50% Mushroom spent compost, N_3 = 50% Vermicompost + 50% Mushroom spent compost

4.1.2 Number of leaves per plant

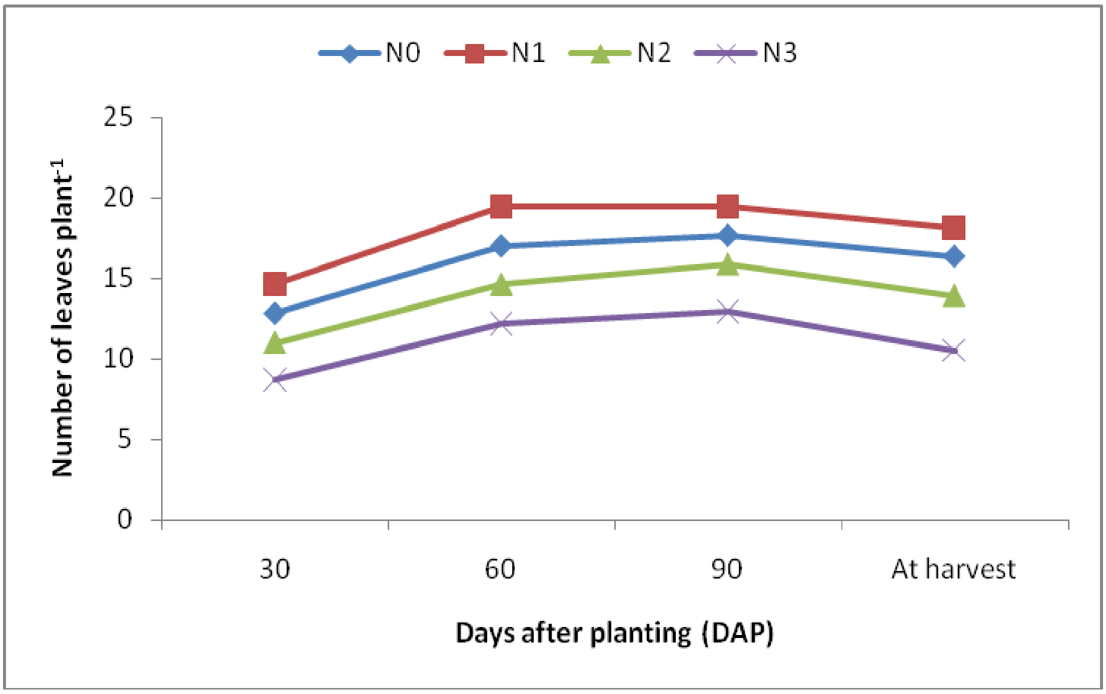
At different growth stages number of leaves per plant of onion was significantly varied due to different planting time. During the study, data on number of leaves plant^{-1} was taken at 30, 60, 90 DAP and at harvest. At the time of harvest, the highest number of leaves per plant (15.38) was produced from T_2 (10 November) treatment followed by T_1 (1 November) whereas the lowest number of leaves per plant (14.09) was given by T_3 (20 November) treatment (Figure 4 and Appendix V). Prasad *et al*., (2017) and Tesfaye *et al*., (2018) found similar result with the present study and reported that number of leaves per plant was significantly influenced by planting time. Khan *et al*. (2020) found that number of leaves plant^{-1} was decreased with the passage of transplanting time.



T_1 = 1 November, T_2 = 10 November, T_3 = 20 November

Figure 4. Effect of planting time on number of leaves plant^{-1} at different days after planting of onion at 5% level of significance

Different levels of nutrients applied to onion showed significant variation on number of leaves per plant at different growth stages. Data were recorded at 30, 60, 90 DAP and at harvest. The highest number of leaves per plant at harvest (18.10) was recorded from N_1 (50% NPKS + 50% vermicompost) which was significantly different to other treatments followed by N_0 (NPKS; standard dose) whereas the lowest number of leaves per plant (10.53) was found from N_3 (50% vermicompost + 50% mushroom spent compost) nutrients (Figure 5 and Appendix V). This result indicated that application of nutrients at different composition showed considerable influence on leaf number of onion which was supported by the findings of Yadav *et al*., (2018), Bhagwat (2014) and Jawadagi *et al*., (2012).



N_0 = NPKS (Standard dose), N_1 = 50% NPKS + 50% Vermicompost, N_2 = 50% NPKS + 50% Mushroom spent compost, N_3 = 50% Vermicompost + 50% Mushroom spent compost

Figure 5. Effect of nutrients on number of leaves plant^{-1} at different days after planting of onion at 5% level of significance

Recorded data on number of leaves plant^{-1} of onion at 30, 60, 90 DAP and at harvest was influenced significantly due to combined effect of planting time and nutrients. At the maximum number of leaves 50% NPKS + 50% vermicompost (18.50) was given from T_2N_1 (10 November with 50% NPKS + 50% vermicompost) treatment combination which was statistically identical to T_1N_1 (1 November with 50% NPKS + 50% vermicompost) treatment combination and similar to T_3N_1 (20 November with 50% NPKS + 50% vermicompost) treatment combination and the minimum number of leaves per plant (9.83) was produced from T_3N_3 (20 November with 50% vermicompost + 50% mushroom spent compost) treatment combination and similar to T_1N_3 (1 November with 50% vermicompost + 50% mushroom spent compost) treatment combination (Table 2 and Appendix V).

Table 2. Combined effect of planting time and nutrients on number of leaves plant^{-1} at different days after planting of onion

Treatment combinations	Number of leaves per plant			
	30 DAP	60 DAP	90 DAP	At harvest
T_1N_0	12.73 d	17.17 c	17.73 cd	16.37 cd
T_1N_1	14.50 b	19.47 ab	19.57 a	18.17 a
T_1N_2	10.97 f	14.83 e	16.27 e	13.97 ef
T_1N_3	8.80 h	12.23 g	13.23 g	10.43 gh
T_2N_0	13.53 c	17.67 c	18.20 bc	17.07 bc
T_2N_1	15.37 a	20.00 a	20.13 a	18.50 a
T_2N_2	11.70 e	15.37 de	16.67 e	14.63 e
T_2N_3	9.57 g	13.23 f	13.77 g	11.33 g
T_3N_0	12.27 de	16.20 d	17.03 de	15.67 d
T_3N_1	13.97 bc	18.73 b	18.63 b	17.63 ab
T_3N_2	10.33 f	13.70 f	14.73 f	13.23 f
T_3N_3	7.67 i	11.13 h	11.97 h	9.83 h
$LSD_{0.05}$	0.636	0.937	0.896	0.901
CV(%)	10.09	7.06	10.71	9.96

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

T_1 = 1 November, T_2 = 10 November, T_3 = 20 November

N_0 = NPKS (Standard dose), N_1 = 50% NPKS + 50% Vermicompost, N_2 = 50% NPKS + 50% Mushroom spent compost, N_3 = 50% Vermicompost + 50% Mushroom spent compost

4.2 Yield contributing parameters

4.2.1 Number of umbel per plant

Number of umbels per plant was significantly influenced by different planting time. It was observed that the highest number of umbels per plant (2.72) was recorded from T_2 (10 November) planting time that was significantly different to other planting time followed by T_1 (1 November) whereas the lowest number of umbels per plant (2.44) was recorded from T_3 (20 November) planting time (Table 3 and Appendix VI). This result suggested that number of umbels per plant reduced at late plantation compared to early plantation of onion. Mehri (2015) reported that number of umbels per plant was significantly affected by planting time. Anisuzzaman *et al*,. (2009) also found similar result with the present study.

Significant variation was remarked on number of umbels per plant as influenced by different levels of nutrients. Results exhibited that the highest number of umbels per plant (3.13) was recorded from N_1 (50% NPKS + 50% vermicompost) which was statistically identical to N_0 (NPKS; standard dose) treatment whereas the lowest number of umbels per plant (1.94) was found from N_3 (50% vermicompost + 50% mushroom spent compost) nutrients (Table 3 and Appendix VI). Supported result was also observed by Asgele *et al.*, (2018) who found different levels of nutrient application had significant effect on number of umbel plant^{-1}.

Combined effect of planting time and nutrient levels showed significant influence on number of umbels per plant. Results showed that the highest number of umbels per plant (3.25) was recorded from T_2N_1 (20 November with 50% NPKS + 50% vermicompost) treatment combination which was significantly different from other treatment combinations. Again, the lowest number of umbels per plant (1.85) was recorded from T_3N_3 (20 November with 50% vermicompost + 50% mushroom spent compost) treatment combination which was statistically identical with T_1N_3 (1 November with 50% vermicompost + 50% spent mushroom compost) treatment combination (Table 3 and Appendix VI).

Table 3. Yield contributing parameters of onion as influenced by different planting time and nutrients

Treatment	Yield contributing parameters				
	Number of umbels per plant	Umbel diameter (cm)	Number of seeds per umbel	Flower stalk length (cm)	1000 seed weight (g)
Effect of planting time					
T_1	2.55 b	3.97 b	536.70 b	68.48 b	3.42
T_2	2.72 a	4.12 a	552.50 a	71.07 a	3.44
T_3	2.44 c	3.85 b	520.90 c	66.67 c	3.40
$LSD_{0.05}$	0.061	0.139	5.136	1.503	NS
CV(%)	6.63	8.23	10.81	11.49	5.71
Effect of nutrients					
N_0	2.84 b	4.49 a	560.60 b	79.69 a	3.44
N_1	3.13 a	4.16 a	589.60 a	72.30 b	3.47
N_2	2.37 c	3.80 b	515.50 c	65.66 c	3.40
N_3	1.94 d	3.47 b	481.10 d	57.30 d	3.39
$LSD_{0.05}$	0.207	0.339	6.362	1.968	NS
CV(%)	6.63	8.23	10.81	11.49	5.71
Combined effect of planting time and nutrients					
T_1N_0	2.79 c	4.49 ab	557.90 d	79.81 a	3.42
T_1N_1	3.14 b	4.11 c	591.30 b	70.93 c	3.47
T_1N_2	2.37 f	3.78 e	515.90 g	66.23 de	3.38
T_1N_3	1.92 i	3.48 g	481.80 i	56.93 g	3.41
T_2N_0	3.05 b	4.58 a	583.10 b	81.97 a	3.47
T_2N_1	3.25 a	4.39 b	606.40 a	75.73 b	3.50
T_2N_2	2.52 e	3.88 de	528.90 f	66.67 d	3.40
T_2N_3	2.06 h	3.62 fg	491.50 hi	59.90 f	3.40
T_3N_0	2.69 d	4.39 b	540.80 e	77.30 b	3.42
T_3N_1	3.00 b	3.96 cd	571.10 c	70.23 c	3.45
T_3N_2	2.22 g	3.73 ef	501.80 h	64.07 e	3.38
T_3N_3	1.85 i	3.31 h	470.00 j	55.07 g	3.37
$LSD_{0.05}$	0.091	0.152	11.78	2.426	NS
CV(%)	6.63	8.23	10.81	11.49	5.71

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

T_1 = 1 November, T_2 = 10 November, T_3 = 20 November

N_0 = NPKS (Standard dose), N_1 = 50% NPKS + 50% Vermicompost, N_2 = 50% NPKS + 50% Mushroom spent compost, N_3 = 50% Vermicompost + 50% Mushroom spent compost

4.2.2 Umbel diameter

The recorded data on umbel diameter was affected significantly by different planting time (Table 3 and Appendix VI). Results revealed that the planting time T_2 (10 November) gave the highest umbel diameter (4.12 cm) whereas the planting time T_3 (20 November) showed the lowest umbel diameter (3.85 cm) which was significantly identical with T_1 (1 November) treatment. Tesfaye *et al.*, (2018) reported similar result with the present study and found that umbel diameter was significantly influenced by planting time. Mehri (2015), EL-Helaly and Karam (2012) and Anisuzzaman *et al.*, (2009) also found similar result with the present study.

Different levels of nutrient showed significant variation on umbel diameter of onion (Table 3 and Appendix VI). Results indicated that the treatment N_0 (NPKS; standard dose) registered the highest umbel diameter (4.49 cm) which was statistically identical with N_1 (50% NPKS + 50% vermicompost) treatment whereas the treatment N_3 (50% vermicompost + 50% spent mushroom compost) treatment recorded the lowest umbel diameter (3.47 cm) that was statistically identical to N_2 (50% NPKS + 50% mushroom spent compost). Asgele *et al.*, (2018) also found similar result with the present study.

Significant influence was observed on umbel diameter of onion as influenced by combined effect of different planting time and nutrients (Table 3 and Appendix VI). Results revealed that the treatment combination T_2N_0 (10 November with NPKS; standard dose) verified the highest umbel diameter (4.58 cm) that was statistically similar to T_1N_0 (1 November with NPKS; standard dose). On the other hand, the treatment combination of T_3N_3 (20 November with 50% vermicompost + 50% mushroom spent compost) gave the lowest umbel diameter (3.31 cm) that was significantly different from other treatment combinations.

4.2.3 Number of seeds per umbel

Different planting time of onion showed significant influence on number of seeds per umbel (Table 3 and Appendix VI). Results showed that the highest number of seeds per umbel (552.50) was recorded from T_2 (10 November) treatment which was followed by T_1 (1 November) treatment whereas the T_3 (20 November) treatment showed the lowest number of seeds per umbel (520.90). Similar result was also observed by the findings of Tesfaye *et al*., (2018) and Mehri (2015) who reported significant influence of planting time on number of seeds per umbel.

Number of seeds per umbel of onion was significantly varied due to different levels of nutrient (Table 3 and Appendix VI). It was observed that the treatment N_1 (50% NPKS + 50% vermicompost) gave the highest number of seeds per umbel (589.60) whereas the lowest number of seeds per umbel (481.10) was found from N_3 (50% vermicompost + 50% mushroom spent compost) treatment. Asgele *et al*., (2018) and Hossain *et al*. (2017) also reported results on number of seeds umbel^{-1} varied with different nutrients level which supported the present study.

Combined effect of different planting time and nutrients gave statistically significant variation on number of seeds per umbel of onion (Table 3 and Appendix VI). Results revealed that the treatment combination T_2N_1 (10 November with 50% NPKS + 50% vermicompost) produced the highest number of seeds per umbel (606.40) which was significantly different to other treatment combinations followed by T_1N_1 and T_2N_0. On the other hand, the lowest number of seeds per umbel (470.00) was recorded from the treatment combination of T_3N_3 (20 November with 50% vermicompost + 50% mushroom spent compost) that was significantly different from other treatment combinations.

4.2.4 Flower stalk length

The recorded data on flower stalk length was affected significantly by different planting time (Table 3 and Appendix VI). Results indicated that the highest flower stalk length (71.07 cm) was given by T_2 (10 November) treatment whereas T_3 (20 November) treatment resulted the lowest flower stalk length (66.67 cm). Rabinowitch and Brewster (1990) reported that length of day affects flowering and bulb formation which influence flower stalk length. Planting time represents day length which affects flower stalk length.

Different levels of nutrient showed significant variation on flower stalk length of onion (Table 3 and Appendix VI). Regarding better performance, the highest flower stalk length (79.69 cm) was recorded from the treatment N_0 (NPKS; standard dose) whereas N_3 (50% vermicompost + 50% spent mushroom compost) treatment gave the lowest flower stalk length (57.30 cm).

Combined effect of different planting time and nutrients significantly influenced the flower stalk length of onion (Table 3 and Appendix VI). The treatment combination of T_2N_0 (10 November with NPKS; standard dose) obtained the highest flower stalk length (81.97 cm) which was statistically identical with the treatment combination of T_1N_0 (1 November with NPKS; standard dose). Reversely, the treatment combination of T_3N_3 (20 November with 50% vermicompost + 50% mushroom spent compost) showed the lowest flower stalk length (55.07 cm) that was significantly same to T_1N_3 (1 November with 50% vermicompost + 50% mushroom spent compost).

4.2.5 Weight of 1000 seeds

Non-significant variation was found on 1000 seed weight of onion as influenced by different planting time. However, the highest 1000 seed weight (3.44 g) was recorded from the planting time T_2 (10 November) whereas the lowest 1000 seed weight (3.40 g) was recorded from the planting time T_3 (20 November) (Table 3 and Appendix VI). Similar result was also observed by Tesfaye *et al*., (2018) and EL-Helaly and Karam (2012).

Different levels of nutrient showed non-significant variation on 1000 seed weight of onion. However, the treatment N_1 (50% NPKS + 50% vermicompost) gave the highest 1000 seed weight (3.47 g) whereas the treatment N_3 (50% vermicompost + 50% mushroom spent compost) showed the lowest 1000 seed weight (3.39 g) (Table 3 and Appendix VI).

Significant influence was not found on 1000 seed weight of onion as influenced by combined effect of different planting time and nutrients. However, the highest 1000 seed weight (3.50 g) was recorded from the treatment combination of T_2N_1 (10 November with 50% NPKS + 50% vermicompost) whereas the lowest 1000 seed weight (3.37 g) was recorded from the treatment combination of T_3N_3 (20 November with 50% vermicompost + 50% mushroom spent compost) (Table 3 and Appendix VI).

4.3 Yield parameters

4.3.1 Seed yield per plant

Onion seed yield per plant was influenced significantly by different planting time. Results showed that the highest seed yield per plant (3.16 g) was recorded from the T_2 (10 November) treatment whereas the lowest seed yield per plant (2.97 g) was recorded from the T_3 (20 November) treatment which was statistically identical with T_1 (1 November) (Table 4 and Appendix VII). This result revealed that planting time influence seed yield of onion which was supported by the findings of Khan *et al*., (2020), Tesfaye *et al*., (2018), Vaghela *et al*., (2019), Asgele *et al*., (2018) and Prasad *et al*., (2017) and they reported early plantation is better than late plantation for higher seed yield of onion.

Different levels of nutrient showed significant variation on seed yield per plant of onion. It was observed that the highest seed yield per plant (3.38 g) was recorded from the treatment N_1 (50% NPKS + 50% vermicompost) which was statistically identical with N_0 (NPKS; standard dose) whereas the lowest seed yield per plant (2.67 g) was found from the treatment N_3 (50% vermicompost + 50% mushroom spent compost) (Table 4 and Appendix VII). Similar result was also observed by Hossain *et al*., (2017) and found that seed yield per plant of onion affected significantly due to variation in nutrients application.

Significant influence was found on seed yield per plant of onion as influenced by combined effect of different planting time and nutrients. The highest seed yield per plant (3.47 g) was recorded from the treatment combination of T_2N_1 (10 November with 50% NPKS + 50% vermicompost) that was significantly different from other treatment combinations followed by T_1N_1, T_2N_0 and T_3N_1 whereas the lowest seed yield per plant (2.55 g) was recorded from the treatment combination of T_3N_3 (20 November with 50% vermicompost + 50% mushroom spent compost) which was statistically identical to T_1N_3 (1 November with 50% vermicompost + 50% mushroom spent compost) (Table 4 and Appendix VII).

Table 4. Yield parameters of onion as influenced by different planting time and nutrients

Treatment	Yield parameters		
	Seed yield plant^{-1} (g)	Seed yield plot^{-1} (g)	Seed yield ha^{-1} (kg)
Effect of planting time			
T_1	3.03 b	121.16 b	673.10 b
T_2	3.16 a	126.57 a	703.20 a
T_3	2.97 b	118.70 c	659.50 c
$LSD_{0.05}$	0.101	2.117	6.714
CV(%)	8.27	12.36	10.52
Effect of nutrients			
N_0	3.23 b	129.28 b	718.20 b
N_1	3.38 a	135.00 a	750.00 a
N_2	2.94 c	117.60 c	653.20 c
N_3	2.67 d	106.70 d	593.00 d
$LSD_{0.05}$	0.137	2.652	8.316
CV(%)	8.27	12.36	10.52
Combined effect of planting time and nutrients			
T_1N_0	3.23 bc	129.30 bc	718.30 c
T_1N_1	3.35 b	134.10 b	744.90 b
T_1N_2	2.93 de	117.30 de	651.60 f
T_1N_3	2.60 f	104.00 f	577.70 h
T_2N_0	3.33 b	133.10 b	739.50 b
T_2N_1	3.47 a	138.70 a	770.60 a
T_2N_2	3.01 d	120.30 d	668.40 e
T_2N_3	2.85 e	114.20 e	634.20 g
T_3N_0	3.14 c	125.40 c	696.90 d
T_3N_1	3.31 b	132.20 b	734.60 b
T_3N_2	2.88 e	115.10 e	639.50 fg
T_3N_3	2.55 f	102.10 f	567.00 h
$LSD_{0.05}$	0.118	4.098	14.137
CV(%)	8.27	12.36	10.52

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

T_1 = 1 November, T_2 = 10 November, T_3 = 20 November

N_0 = NPKS (Standard dose), N_1 = 50% NPKS + 50% Vermicompost, N_2 = 50% NPKS + 50% Mushroom spent compost, N_3 = 50% Vermicompost + 50% Mushroom spent compost

4.3.2 Seed yield per plot

The recorded data on seed yield per plot was affected significantly by different planting time. Results indicated that the highest seed yield per plot (126.57 g) was given by the T_2 (10 November) planting time followed by T_1 (1 November) whereas the T_3 (20 November) planting time resulted the lowest seed yield per plot (118.70 g) (Table 4 and Appendix VII). Similar result was observed by Tesfaye *et al*., (2018) and Prasad *et al*., (2017).

Different levels of nutrient showed significant variation on seed yield per plot of onion. The highest seed yield per plot (135.00 g) was recorded from the N_1 (50% NPKS + 50% vermicompost) treatment followed by N_0 (NPKS; standard dose) treatment whereas N_3 (50% vermicompost + 50% spent mushroom compost) treatment gave the lowest seed per plot (106.70 g) (Table 4 and Appendix VII). Hossain *et al*., (2017) also found similar result with the present study.

Significant influence was observed seed yield per plot of onion as influenced by combined effect of different planting time and nutrients. The treatment combination of T_2N_1 (10 November with 50% NPKS + 50% vermicompost) produced the highest seed yield per plot (138.70 g) which was significantly different from other treatment combinations followed by T_1N_1, T_2N_0 and T_3N_1 (Table 4 and Appendix VII). Reversely, the treatment combination of T_3N_3 (20 November with 50% vermicompost + 50% spent mushroom compost) showed the lowest seed yield per plot (102.10 g) that was statistically identical to T_1N_3.

4.3.3 Seed yield ha^{-1}

The recorded data on seed yield per ha was affected significantly by different planting time. Results indicated that the highest seed yield per ha (703.20 kg) was produced from the T_2 (10 November) treatment followed by T_1 (1 November) treatment whereas the T_3 (20 November) treatment showed the lowest seed yield per ha (659.50 kg) (Table 4 and Appendix VII). The result obtained from the present study was similar with the findings of Khan *et al*., (2020), Tesfaye *et al*., (2018) and Asgele *et al*., (2018) who reported early plantation of onion gave higher seed yield of onion than delay plantation.

Different levels of nutrient showed significant variation on seed yield per ha of onion. The highest seed yield per ha (750.00 kg) was recorded from N_1 (50% NPKS + 50% vermicompost) treatment followed by N_0 (NPKS; standard dose) treatment whereas N_3 (50% vermicompost + 50% mushroom spent compost) treatment gave the lowest seed yield per ha (593.00 kg) (Table 4 and Appendix VII). Similar result was also observed by the findings of Asgele *et al*., (2018), Hossain *et al*., (2017), Sekhon *et al*., (2016) and Shinde *et al*., (2013).

Significant influence was observed on seed yield per ha of onion as influenced by combined effect of different planting time and nutrients. The treatment combination of T_2N_1 (10 November with 50% NPKS + 50% vermicompost) gave the highest seed yield per ha (770.60 kg) which was significantly different with other treatment combinations followed by T_1N_1, T_2N_0 and T_2N_1. Reversely, the T_3N_3 (20 November with 50% vermicompost + 50% mushroom spent compost) treatment combination showed the lowest seed yield per ha (567.00 kg) that was statistically identical to T_1N_3 (1 November with 50% vermicompost + 50% mushroom spent compost) treatment combination (Table 4 and Appendix VII).

4.4 Seed quality parameters

After completion of field experiment, produced seeds were tested for quality. Regarding quality test, seed germination, shoot and root length of seedlings and seed vigour index were tested.

4.4.1 Germination (%)

Significant variation was observed on seed germination as influenced by different planting time (Table 5 and Appendix VIII). Results indicated that the highest seed germination (81.08%) was given from the seeds obtained from T_2 (10 November) planting time which was statistically identical to seeds obtained from T_1 (1 November) treatment. On the other hand, the lowest seed germination (79.33%) was found from seeds which was obtained from T_3 (20 November) planting time. Ashagrie *et al*., (2019) also found similar result with the present study and they observed early planted onion showed higher percentage of seed germination.

Seeds of onion obtained from different nutrient levels showed significant variation on seed germination. The highest seed germination (83.44%) was recorded from the seeds obtained from N_1 (50% NPKS + 50% vermicompost) treatment followed by N_0 (NPKS; standard dose) and N_2 (50% NPKS + 50% mushroom spent compost) treatment whereas seeds obtained from N_3 (50% vermicompost + 50% mushroom spent compost) treatment gave the lowest seed germination (76.67%) (Table 5 and Appendix VIII). Tesfaye *et al*., (2018) recorded significant variation on percent seed germination that seeds were obtained from different nutrient treatments which supported the present study.

Onion seeds obtained from the combination of different planting time and nutrient treatments showed significant variation on seed germination. Seeds obtained from T_2N_1 (10 November with 50% NPKS + 50% vermicompost) treatment combination showed highest seed germination (86.33%) followed by T_1N_0, T_1N_1, T_1N_2, T_2N_0, T_3N_1 and T_3N_2 (Table 5 and Appendix VIII). Reversely, seeds obtained from the treatment combination of T_3N_3 (20 November with 50% vermicompost + 50% spent mushroom compost) showed the lowest seed germination (76.00%) that was significantly similar to T_1N_3 and T_2N_3.

Table 5. Seed quality parameters of onion as influenced by different planting date and nutrients

Treatment	Seed quality parameters			
	Germination (%)	Shoot length (cm)	Root length (cm)	Seed vigour index
Effect of planting time				
T_1	80.67 a	8.55	4.05	1017.00 b
T_2	81.08 a	8.82	4.16	1055.00 a
T_3	79.33 b	8.40	3.94	980.40 c
$LSD_{0.05}$	1.507	NS	NS	11.36
CV(%)	8.24	9.12	6.74	10.84
Effect of nutrients				
N_0	81.00 b	9.11 b	4.29 a	1086.00 b
N_1	83.44 a	9.48 a	4.44 a	1160.00 a
N_2	80.33 b	8.23 c	3.88 b	972.30 c
N_3	76.67 c	7.52 d	3.59 b	851.90 d
$LSD_{0.05}$	1.804	0.116	0.321	10.863
CV(%)	8.24	9.12	6.74	10.84
Combined effect of planting time and nutrients				
T_1N_0	81.67 b	9.11 c	4.31 bc	1096.00 c
T_1N_1	82.33 b	9.43 b	4.40 b	1138.00 b
T_1N_2	81.67 b	8.18 f	3.90 e	986.10 e
T_1N_3	76.67 de	7.46 h	3.60 fg	848.20 h
T_2N_0	81.67 b	9.41 b	4.38 b	1126.00 b
T_2N_1	86.33 a	9.67 a	4.56 a	1228.00 a
T_2N_2	79.00 bcd	8.49 e	3.99 e	985.40 e
T_2N_3	77.33 cde	7.70 g	3.70 f	881.30 g
T_3N_0	79.67 bc	8.81 d	4.19 d	1036.00 d
T_3N_1	81.33 b	9.35 b	4.35 b	1114.00 bc
T_3N_2	80.33 b	8.03 f	3.74 f	945.50 f
T_3N_3	76.00 e	7.39 h	3.48 g	826.10 h
$LSD_{0.05}$	3.012	0.203	0.145	23.783
CV(%)	8.24	9.12	6.74	10.84

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

T_1 = 1 November, T_2 = 10 November, T_3 = 20 November

N_0 = NPKS (Standard dose), N_1 = 50% NPKS + 50% Vermicompost, N_2 = 50% NPKS + 50% Mushroom spent compost, N_3 = 50% Vermicompost + 50% Mushroom spent compost

4.4.2 Shoot length

Shoot length obtained from seeds of different planting time showed non-significant variation. However, the highest shoot length (8.82 cm) was recorded from seeds of T_2 (10 November) treatment whereas the seeds of T_3 (20 November) treatment showed the lowest shoot length (8.40 cm) (Table 5 and Appendix VIII).

Shoot length obtained from seeds of different treatments of nutrients showed significant variation. Seeds obtained from N_1 (50% NPKS + 50% vermicompost) treatment gave the highest shoot length (9.48 cm) followed by N_0 (NPKS; standard dose) treatment whereas seeds of N_3 (50% vermicompost + 50% mushroom spent compost) treatment gave the lowest shoot length (7.52 cm) (Table 5 and Appendix VIII).

Shoot length achieved from seeds of different treatment combinations of planting time and nutrients showed significant variation. Seeds obtained from the T_2N_1 (20 November with 50% NPKS + 50% vermicompost) treatment combination gave the highest shoot length (9.67 cm) which was significantly different from other treatment combinations (Table 5 and Appendix VIII). On the other hand, seeds obtained from the treatment combination of T_3N_3 (20 November with 50% vermicompost + 50% mushroom spent compost) gave the lowest shoot length (7.39 cm).

4.4.3 Root length

Root length obtained from seeds of different planting time showed non-significant variation. However, the highest root length (4.16 cm) was recorded from seeds of T_2 (10 November) planting time whereas the seeds of T_3 (20 November) planting time showed the lowest root length (3.94 cm) (Table 5 and Appendix VIII).

Root length obtained from seeds of different treatments of nutrients showed significant variation. Seeds obtained from N_1 (50% NPKS + 50%

vermicompost) treatment gave the highest root length (4.44 cm) that was statistically identical to N_0 (NPKS; standard dose) whereas seeds of N_3 (50% vermicompost + 50% mushroom spent compost) treatment gave the lowest root length (3.59 cm) that was statistically identical to N_2 (50% NPKS + 50% mushroom spent compost) (Table 5 and Appendix VIII).

Root length achieved from seeds of different treatment combinations of planting time and nutrients showed significant variation. Seeds obtained from the treatment combination of T_2N_1 (10 November with 50% NPKS + 50% vermicompost) gave the highest root length (4.56 cm) which was significantly different from other treatment combinations. On the other hand, seeds obtained from the treatment combination of T_3N_3 (20 November with 50% vermicompost + 50% mushroom spent compost) spent gave the lowest root length (3.48 cm) which was statistically similar to T_1N_3 (Table 5 and Appendix VIII).

4.4.4 Seed vigour index

The recorded data on seed vigour index was affected significantly by different planting time. Results indicated that the highest seed vigour index (1055) was given by T_2 (10 November) planting time followed by T_1 (1 November) whereas the T_3 (20 November) planting time resulted the lowest seed vigour index (980.40) (Table 5 and Appendix VIII). Similar result was observed by Ashagrie *et al.*, (2021); they found seeds obtained from early planted onion showed higher percentage of seed vigor index than late planted onion.

Different levels of nutrient showed significant variation on seed vigour index. The highest seed vigour index (1160) was recorded from the treatment N_1 (50% NPKS + 50% vermicompost) followed by N_0 (NPKS; standard dose) whereas N_3 (50% vermicompost + 50% spent mushroom compost) gave the lowest seed vigour index (851.90) (Table 5 and Appendix VIII). Similar result was also observed by Ashagrie *et al.*, (2019).

Significant influence was observed on seed vigour index as influenced by combined effect of different planting time and nutrients. The T_2N_1 (10 November with 50% NPKS + 50% vermicompost) treatment combination registered the highest seed vigour index (1228) followed by T_1N_1 and T_2N_0. Reversely, the treatment combination of T_3N_3 (20 November with 50% vermicompost + 50% mushroom spent compost) showed the lowest seed vigour index (826.10) (Table 5 and Appendix VIII).

CHAPTER V

SUMMARY AND CONCLUSION

This experiment was conducted at the experimental field of Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka-1207 during the period from November 2019 to April 2020 to study onion seed yield and quality as affected by planting time and nutrients. The whole experiment was conducted in two different phases *viz*. growth and yield performance at field level and after that collected seeds from the experiment field was tested in Laboratory for seed quality. Two factor experiment was conducted; Factor A: 3 planting time *viz*. T_1 = 1 November, T_2 = 10 November and T_3 = 20 November and Factor B: 4 nutrient levels *viz*. N_0 = NPKS (Standard dose), N_1 = 50% NPKS + 50% Vermicompost, N_2 = 50% NPKS + 50% Mushroom spent compost and N_3 = 50% Vermicompost + 50% Mushroom pent compost. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The data on different crop characters, yield and seed quality attributes were recorded. Collected data were analyzed using a computer software MSTAT-C. The significance of difference among the treatments means was estimated by the least significant difference (LSD) at 5% level of probability.

Different planting time showed significant variation on different growth, yield contributing parameters and yield of onion seeds and also quality parameters but 100 seed weight was not affected significantly due to planting time. Considering growth parameters, at 30, 60, 90 DAP and at harvest T_2 (10 November) gave the highest plant height (25.78, 38.49, 40.15 and 40.47 cm, respectively) and number of leaves plant^{-1} (12.54, 16.57, 17.19 and 15.38, respectively) whereas the lowest plant height (23.44, 34.44, 35.73 and 35.96 cm, respectively) and number of leaves plant^{-1} (11.06, 14.94, 15.59 and 14.09, respectively) was recorded from plantation time of T_3 (20 November). Regarding yield contributing parameters and yield of onion seed, planting time of T_2 (10 November) gave better performance and showed highest number of umbel per plant (2.72), umbel diameter (4.12 cm), number of seeds per umbel (552.50), flower stalk length (71.07 cm), 1000 seed weight (3.44 g), seed yield per plant (3.16 g), seed yield per plot (126.57 g) and seed yield per ha (703.20 kg) while the lowest number of umbel per plant (2.44), umbel diameter (3.85 cm), number of seeds umbel^{-1} (520.90), flower stalk length (66.67 cm), 1000 seed weight (3.40 g), seed yield per plant (2.97 g), seed yield per plot (118.7 g) and seed yield per ha (659.50 kg) were found from the planting time T_3 (20 November).

Different nutrient treatment showed significant variation on most of the studied parameters except 1000 seed weight. In case of growth parameters, at 30, 60, 90 DAP and at harvest, treatment N_1 (50% NPKS + 50% vermicompost) gave the highest plant height (32.35, 44.41, 47.13 and 47.48 cm, respectively) and number of leaves plant^{-1} (14.61, 19.40, 19.44 and 18.10, respectively) whereas the lowest plant height (17.18, 27.91, 29.00 and 29.01 cm, respectively) and number of leaves plant^{-1} (8.68, 12.20, 12.99 and 10.53, respectively) was recorded from N_3 (50% vermicompost + 50% mushroom spent compost) treatment. Regarding yield contributing parameters and yield of onion seed, treatment N_1 (50% NPKS + 50% vermicompost) gave the highest number of umbel per plant (3.13), number of seeds per umbel (589.60), 1000 seed weight (3.47 g), seed yield per plant (3.38 g), seed yield per plot (135.00 g) and seed yield per ha (750.00 kg) but the highest umbel diameter (4.49 cm) and flower stalk length (79.69 cm) were recorded from the control treatment N_0 (NPKS; standard dose). Again, the treatment N_3 (50% vermicompost + 50% mushroom spent compost) showed the lowest number of umbel per plant (1.94), umbel diameter (3.47 cm), number of seeds per umbel (481.10), flower stalk length (57.30 cm), 1000 seed weight (3.39 g), seed yield per plant (2.67 g), seed yield per plot (106.70 g) and seed yield ha^{-1} (593.00 kg).

In terms of combined effect of planting time and nutrients, all the studied parameters regarding growth, seed yield and quality were affected significantly except 1000 seed weight. Considering growth parameters, at 30, 60, 90 DAP and at harvest, the highest plant height (333.91, 45.90, 49.70 and 50.37 cm, respectively) and number of leaves plant^{-1} (15.37, 20.00, 20.13 and 18.50, respectively) was achieved from the treatment combination of T_2N_1 whereas the lowest plant height (16.81, 26.00, 27.73 and 27.87 cm, respectively) and number of leaves plant^{-1} (7.67, 11.13, 11.97 and 9.83, respectively) was recorded from T_3N_3. Similarly, in case of yield contributing parameters and seed yield of onion, T_2N_1 showed highest number of umbel per plant (3.25), number of seeds per umbel (606.40), 1000 seed weight (3.50 g), seed yield per plant (3.47 g), seed yield per plot (138.70 g) and seed yield ha^{-1} (770.60 kg) while T_2N_0 gave the highest umbel diameter (4.58 cm) and flower stalk length (81.97 cm) whereas the treatment combination T_3N_3 produced the lowest number of umbel per plant (1.85), umbel diameter (3.31 cm), number of seeds per umbel (470.00), flower stalk length (55.07 cm), 1000 seed weight (3.37 g), seed yield per plant (2.55 g), seed yield per plot (102.10 g) and seed yield per ha (567.00 kg)

In consideration of seed quality parameters, the seeds were tested in the laboratory after obtaining of seeds due to different treatment of planting time and nutrient management regarding the parameters of germination, shoot length, root length and seed vigour index at the duration of 12 days. Different planning time showed significant variation on germination percentage and seed vigour index but shoot and root length were not affected significantly. However, seeds of T_2 (10 November) planting time showed highest germination (81.08%), shoot length (8.82 cm), root length (4.16 cm) and seed vigour index (1055) whereas the lowest performance regarding germination (79.33%), shoot length (8.40 cm), root length (3.94 cm) and seed vigour index (980.40) was recorded from seeds of T_3 (20 November) planting time. Similarly, seeds obtained from different nutrient treatments, seed quality parameters affected significantly and N_1 (50% NPKS + 50% vermicompost) treated seeds showed the highest germination (83.44%), shoot length (9.48 cm), root length (4.44 cm) and seed vigour index (1160) whereas the lowest (76.67%, 7.52 cm, 3.59 cm and 851.90, respectively) obtained from seed of N_3 (50% vermicompost + 50% mushroom spent compost) treatment. Again, seeds obtained from different combination of planning time and nutrient treatments, seed quality parameters showed significant variation and T_2N_1 (10 November with 50% NPKS + 50% vermicompost) gave the highest seed germination (86.33%), shoot length (9.67 cm), root length (4.56 cm) and seed vigour index (1228.00) whereas seeds of T_3N_3 (20 November with 50% vermicompost + 50% mushroom spent compost) treatment combination showed the lowest result (76.00%, 7.39 cm, 3.48 cm and 826.10, respectively).

Conclusion

From the above results, it can be concluded that the combination of T_2N_1 (10 November with 50% NPKS + 50% Vermicompost) is very much promising for higher yield and better quality of onion seed compared to other treatment combinations whereas the T_3N_3 (20 November with 50% Vermicompost + 50% mushroom spent compost) treatment combination showed lowest performance. So, T_2N_1 (10 November with 50% NPKS + 50% Vermicompost) treatment combination was the best under the present study compared to other treatment combinations.

Recommendation

The present research work was carried out at the Sher-e-Bangla Agricultural University in one season only. Further trial of this work in different locations of the country is needed to justify the present results.

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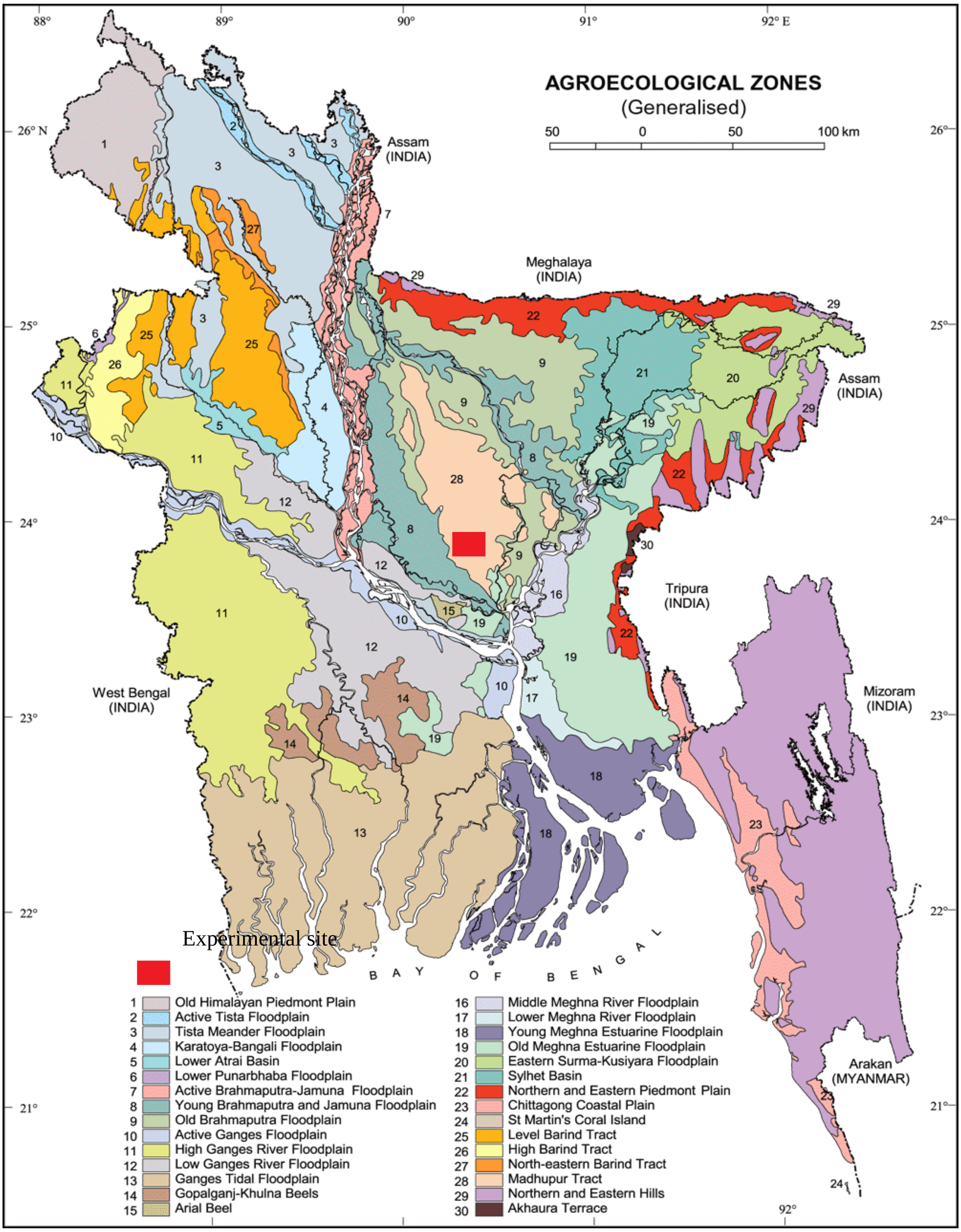
APPENDICES

Appendix I. Agro-Ecological Zone of Bangladesh showing the experimental location



Appendix II. Monthly records of air temperature, relative humidity and rainfall during the period from November 2019 to April 2020.

Year	Month	Air temperature (°C)			Relative humidity (%)	Rainfall (mm)
		Max	*Min*	*Mean*		
2019	November	28.60	8.52	18.56	56.75	14.40
2019	December	25.50	6.70	16.10	54.80	0.0
2020	January	23.80	11.70	17.75	46.20	0.0
2020	February	22.75	14.26	18.51	37.90	0.0
2020	March	35.20	21.00	28.10	52.44	20.4
2020	April	34.70	24.60	29.65	65.40	165.0

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1212.

Appendix III. Characteristics of experimental soil analyzed at Soil Resources Development Institute (SRDI), Farmgate, Dhaka.

A. Morphological characteristics of the experimental field

Morphological features	**Characteristics**
Location	Agronomy Farm, SAU, Dhaka
AEZ	Modhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained

Source: Soil Resource Development Institute (SRDI)

B. Physical and chemical properties of the initial soil

Characteristics	**Value**
Partical size analysis % Sand	27
%Silt	43
% Clay	30
Textural class	Silty Clay Loam (ISSS)
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20
Exchangeable K (me/100 g soil)	0.1
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI)

Appendix IV. Mean square of plant height of onion at different growth stages

Sources of variation	Degrees of freedom	Mean square of plant height			
		30 DAP	60 DAP	90 DAP	At harvest
Replication	2	0.035	0.168	0.320	0.295
Factor A (Planting time)	2	16.474*	49.208*	59.188*	62.765*
Factor B (Nutrients)	3	384.93*	485.58*	583.23*	605.55*
AB	6	3.132**	4.246*	3.701**	3.428**
Error	22	1.735	1.654	3.101	2.631

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix V. Mean square of number of leaves plant^{-1} of onion at different growth stages

Sources of variation	Degrees of freedom	Mean square of number of leaves plant^{-1}			
		30 DAP	60 DAP	90 DAP	At harvest
Replication	2	0.280	0.041	0.010	0.192
Factor A	2	6.611**	8.039*	8.060*	5.005**
Factor B	3	58.14*	86.24*	68.11*	96.79*
AB	6	0.088**	0.109**	0.128**	0.073**
Error	22	0.141	0.306	0.280	0.283

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix VI. Mean square of yield contributing parameters of onion

Sources of variation	Degrees of freedom	Mean square of yield contributing parameters				
		Number of umbel plant^{-1}	Umbel diameter	Number of seeds umbel^{-1}	Length of flowering stalk	1000 seed weight
Replication	2	0.002	0.001	7.250	1.264	0.002
Factor A	2	0.218**	0.216**	2992.23*	58.735*	0.005^{NS}
Factor B	3	2.465**	1.746**	21156.1*	819.11*	0.015^{NS}
AB	6	0.006**	0.014**	81.192*	2.736**	0.001^{NS}
Error	22	0.003	0.008	47.986	2.053	0.001

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix VII. Mean square of yield parameters of onion

Sources of variation	Degrees of freedom	Mean square of yield parameters		
		Seed yield $plant^{-1}$	Seed yield $plot^{-1}$	Seed yield ha^{-1}
Replication	2	0.014	22.775	702.802
Factor A	2	0.104**	168.344**	5196.721*
Factor B	3	0.878*	1402.33*	43285.42*
AB	6	0.009**	13.713**	423.019*
Error	22	0.005	7.768	69.595

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix VIII. Mean square of seed quality parameters of onion

Sources of variation	Degrees of freedom	Mean square of seed quality parameters			
		Percent germination	Shoot length	Root length	Seed vigour index
Replication	2	0.194	0.001	0.001	16.013
Factor A	2	13.52*	0.538^{NS}	0.133^{NS}	17105.21*
Factor B	3	86.44*	7.179*	1.356**	176791.5*
AB	6	5.750**	0.017**	0.001**	919.832*
Error	22	3.073	0.014	0.007	181.956

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Plate 1. Sample field view at pre flowering stage of onion

Plate 2. Sample field view of onion at flowering stage