RESPONSE OF SUMMER ONION TO INTEGRATED NITROGEN MANAGEMENT

By

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CERTIFICATE

This is to certify that the thesis entitled, "**RESPONSE OF SUMMER ONION TO INTEGRATED NITROGEN MANAGEMENT**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in SOIL SCIENCE**, embodies the result of a piece of *bona fide* research work carried out by **SAIMA SULTANA** Registration No. **00989** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated:
Place: Dhaka, Bangladesh

Prof. Dr. Alok Kumar Paul
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Dedicated to

My

Beloved parents and sister

who laid the foundation of

my success

LIST OF ABBREVIATIONS

ABBREVIATION	ELABORATION
AEZ	Agro-Ecological Zone
@	At the rate
BARI	Bangladesh Agricultural Research Institute
cm	Centimeter
conc.	Concentrated
$CuSO_4 5H2O$	Green vitriol
cv.	Cultivar(s)
e.g.	example
et al	and others
FYM	Farm Yard Manure
G	Granular
g	Gram
ha	Hectare
H_3BO_3	Boric acid
$HClO_4$	Perchloric acid
HNO_3	Nitric acid
H_2O_2	Hydrogen per oxide
H_2SO_4	Sulfuric acid
i.e.	that is
K	Potassium
kg	Kilogram
kg ha^{-1}	Kg per hectare
K_2SO_4	Potassium Sulfate
m	Meter
meq	Milliequivalent
MP	Muriate of Potash
MT	Ton (Metric 1000 kg)
N	Nitrogen
NaOH	Sodium Hydroxide
NPK	Nitrogen, Phosphorus and Potassium
NS	Non Significant
P	Phosphorus
pH	Hydrogen ion concentration
q	Quintal
S	Sulphur
$SnCl_2$	Staneum chloride
TSP	Triple Super Phosphate
t ha^{-1}	Ton per hectare
WP	Wetable Powder
^0C	Degree Celsius
%	Percent

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RESPONSE OF SUMMER ONION TO INTEGRATED NITROGEN MANAGEMENT

ABSTRACT

Response of summer onion (*Allium cepa* var. BARI Piaz-2) to integrated nitrogen management was assessed in a field experiment carried out on a Silty Clay Loam soil having pH 6.0 in Sher-e-Bangla Agricultural University Farm, Dhaka during the *kharif* season of 2007. Urea, cowdung (CD) and vermicompost (VC) were combined in a way to supply N at 120 kg ha^{-1} from the sources such no urea, CD and VC; 120 kg from urea, CD and VC; 100 kg from urea with 20 kg from CD or VC, 80 kg from urea with 40 kg from CD or VC, 60 kg from urea with 60 kg from CD or VC, 40 kg from urea with 80 kg from CD or VC arranged in a RCBD design with three replications and twelve treatments. The results indicated that maximum bulb yield (12.16 t ha^{-1}) and stover yield (5.46 t ha^{-1}) of summer onion were obtained in treatment receiving 80 kg N ha^{-1} from urea with 40 kg N ha^{-1} substituted by CD (T_5), followed by the treatment receiving 80 kg N ha^{-1} from urea with 40 kg N ha^{-1} substituted by VC (T_6). Comparing with other fertilizer treatments, the yields were significantly lower in treatments where N from urea source was below 50%. The highest N, P, K and S content in bulb (2.30%, 0.185%, 1.71% and 0.96%, respectively) and in leaf (2.91%, 0.183%, 2.45% and 0.98%, respectively) was recorded in treatment T_5 followed by T_6. Similarly, the N, P, K and S uptake (72.78, 5.53, 55.88 and 28.93 kg ha^{-1}, respectively) by onion plants at harvest stage was also significantly ($P<0.01$) greater in treatments receiving 80 kg N ha^{-1} from urea with 40 kg from CD (T_5) followed by treatment T_6. Thus the data suggest that integrated use of N 80 kg from urea with 40 kg from CD or 80 kg from urea with 40 kg from VC has produced maximum yields and is therefore recommended for advantageous onion production.

Chapter 1
Introduction

INTRODUCTION

Onion (*Allium cepa* L.) belongs to the family Alliaceae and is one of the major important bulb and spice crop in Bangladesh as well as in the world (Jones and Mann, 1963). Central Asia is the primary centre of its origin and the Mediterranean area is the second centre for larger type of onion (McCollum, 1976). It is thought to have been first domesticated in the mountainous region of Turkmenia, Uzbekistan, Tajikistan, North Iran, Afganistan and Pakistan (Brewster, 1994). According to the United Nation's Food and Agriculture Organization (FAO, 2005), onions are grown in at least 175 countries. Of those countries, the leading producers are China, India, United States, Turkey, Pakistan, Russia, South Korea, Japan, Egypt and Spain. In Bangladesh, it is commercially cultivated in the greater districts of Faridpur, Rajshahi, Manikgonj, Comilla, Mymensingh, Jessore, Rangpur and Pabna (BBS, 2004).

Onion is used as delicious vegetables in many countries including Bangladesh, and in the tropics. It is the second important crop among the vegetables after tomato (Pathak, 1994) and its use is very common in almost all food preparations (Hossain and Islam, 1994). It is also used as condiments for flavoring foods. People consume onion daily as salad and pickle, as boiled, fried and baked condition as well as in curries (Pandita, 1994). Edible onion bulb of 100 g contains 1.4 g protein, 11.2 g carbohydrates, 12 mg ascorbic acid, 32 mg calcium and 49 calories energy (MacGillivray, 1961). The presence of the chemical "Allyl Propyl Disulphide ($C_6H_{12}S_2$)" gives pungency taste of onion (Rashid, 1983). Onion contains high medicinal properties having adequate vitamin B, vitamin C, iron and calcium (Vohora *et al.*, 1974). It reduces the blood sugar by 25 percent as diabetic drugs in Arabic folk medicine (Mossa, 1985 and

Yawalkar, 1985). In homeopathy, *Allium cepa* is used for rhinorrhea and hay fever (Morrsion, 1993).

Onion is a thermo and photosensetive crop, and optimum temperature for its cultivation is 13-24° C (Rashid, 1983). In Bangladesh, onion is mainly cultivated in winter season. Right now it is also cultivated in summer season which was not previously possible due to adverse weather condition along with absence of summer tolerant varieties and proper cultural practices. Introducing hot and summer tolerant onion variety might help solving shortage of onion production in the country. For this purpose, BARI has released three summer onion varieties viz. BARI Piaz-2, 3 and 5 for growing in *kharif* season as its genetic potentiality already proved to be suitable for summer season.

Bangladesh produced only 153 thousand metric tons (MT) of onion as against the total requirement of 450 thousand MT per year on an area of 38 thousand hectares of land (BBS, 2004). The average yield of onion in Bangladesh is 4 t ha^{-1} (BBS, 2004) which is far below than the world average yield of 17.45 t ha^{-1} (FAO, 2003). The area and production of onion in Bangladesh is increasing gradually. In 2005-06, onion covers 116 thousand hectares area with total production of 1899 thousand MT. In 2006-07, it increased 129 thousand hectares area with total production of 2208 thousand MT (BBS, 2008).

There is a significant response of onion to organic and inorganic fertilizers (Nasreen and Hossain, 2000; Ullah, 2003). The importance of N, P, K, S, Zn and B for the growth and yield of vegetable crops is well established. Among the nutrients, N plays a pivotal role in synthesizing amino acid and metabolic activities to increase vegetative growth of onion which ultimately helps in increasing bulb size and total yield (Singh and Kumar, 1969; Rai, 1981). So, the effect of nitrogen has a great potential on the growth of onion. High rates of nitrogen to onion maximize marketable yields and the percentage of large-sized onion bulbs (Brown, 2000; Brown, 1997; Drost *et al.*, 1997; Painter, 1980; Stevens, 1997; Thornton *et al.*, 1997). Sammis (1997) also reported the need for high rates of nitrogen on onion to optimize yield. N can influence onion bulb development, flavor, and bulb quality (Brewster and Butler, 1989; Randle, 2000). Nitrogen also increases the vegetative growth, produces good quality foliage and promotes carbohydrate synthesis (Rai, 1981).

Soil is the key factor for increased production of any crop. Soil nutrient management is, therefore, a vital area of research. But, the nutrient supplying capacity of soil is gradually declining due to intensive cropping with high yielding varieties. For increasing agricultural productivity we have to focus on using available nutrient resources more efficiently, effectively and sustainably. Integrated nutrient management (INM) is an approach that seeks to both increase agricultural production and safeguard the environment for future generations. Incorporation of both organic and inorganic plant nutrients to attain higher productivity improves enzymatic activity and CO_2 production, prevent soil degradation, and thereby help meet future food supply needs. Organic fertilizer enhances soil porosity by increasing regular and irregular pores and causes a priming effect of native soil organic matter (Marinari *et al.*, 2000). A large variety of organic wastes are available in the country that can be used as potential manure to improve soil organic matter as well as crop productivity (BARI Annual Report, 2007). It includes the excreta (cowdung and urine) of the domestic animals, crop residues, household and farmyard wastes, vermicompost, municipal sewage sludge and other organic wastes. Cowdung is basically the digested residue of herbivorous matter which is acted upon by symbiotic bacteria residing within the animal's rumen that improves soil organic matter. Vermicompost is the outcome of earthworm activities which is important in maintaining and enhancing the quality of environment and conserving resources for sustainable agriculture (Simanaviciene *et al.*, 2001). So, integrated applications of both chemical and organic fertilizers need to be applied for the improvement of soil physical properties and increased yield of onion.

With a view to generate information on this aspect, a field experiment was carried out at Sher-e-Bangla Agricultural University Farm to determine the response of summer onion to the integrated use of nitrogen supplied from urea (as inorganic fertilizer), cowdung and vermicompost (as organic fertilizer). Considering the above conditions the present trial was carried out with the following objectives:

The objectives were to-

1. study the effect of integrated use of manures (vermicompost and cowdung) and fertilizer (urea) on the yield of summer onion
2. find out the appropriate combination of nitrogen from different organic and inorganic sources for high yield of summer onion
3. compare the effect of fertilizer and manure on the growth and yield of summer onion.

Chapter 2
Review of Literature

REVIEW OF LITERATURE

Research reports regarding integrated nitrogen management for summer onion production under varying soil and climatic conditions of Bangladesh is very spartan. But a number of studies on integrated management of nitrogen from urea, cowdung and vermicompost on the performance of various crops in many areas of the world have been done. Vermicompost and cowdung is one of the splendid components in the organic farming and also play an important role on the growth and yield of summer onion. Optimization of manure and fertilizer is very important for maintenance of soil fertility and for maximum production of summer onion. However, some of the published reports relevant to the research topic from various sources have been reviewed here under the following headings with the hope that this may contribute useful information to the present study.

2.1 Effect of nitrogen on the growth and yield of onion

Ahmed *et al.* (1988) studied the effect of different levels of nitrogen (0, 60 and 120 kg ha^{-1}) and sulphur (0, 12, 24 and 36 kg ha^{-1}) on local onion cv. Faridpur Bhati. Both nitrogen and sulphur significantly increased the yield. However, a combined application of nitrogen and sulphur produced higher yield than nitrogen or sulphur alone. Nitrogen at 60 kg ha^{-1} together with sulphur at 36 kg ha^{-1} produced maximum yield (10.44 t ha^{-1}).

Palled *et al.* (1988) studied a field experiment with N fertilizer on irrigation water. They showed that application of 100 kg N ha^{-1} gave 12.2 and 26.4% higher yields than 75 and 50 kg N ha^{-1}, respectively.

Hedge (1988) carried out an experiment with cv. Pusa Red onion and noticed that application of N fertilizer increased bulb yield but not quality. He also showed that the dry matter production in bulb increased due to the uptake of more N, P, K, Ca and Mg nutrients.

Nehra *et al.* (1988) conducted an experiment with various levels of N and reported that the application of 40 and 80 kg N ha^{-1} significantly increased plant height and number of leaves compared with the control. The differences in effect between 40 and 80 kg N were not significant except that 80 kg N increased the number of leaves per plant over 40 kg N.

A field trial was conducted by Soto (1988) with critical level for P, K and S and response to N. The rate was 100 kg ha^{-1} for each of P_2O_5 and K_2O and 50 kg S ha^{-1}. The applied nitrogen @ 0, 55, 100 and 150 kg ha^{-1} and observed that 50 kg N ha^{-1} was the best for yield response.

Singh and Dhankhar (1988) stated that higher level of N reduced bolting and increased plant growth, ascorbic acid content and yield. Potassium also reduced bolting and neck thickness and increased plant growth, yield, ascorbic acid content, dry matter, sugar and S content of the bulbs.

Duque *et al.* (1989) studied the growth and nitrogen, phosphorus, potassium uptake of onion. The results indicated that the plant demand for N and K was higher during early growth stages, whereas demand for P was continuous throughout the development. Uptake levels were 38.8, 38.6 and 71.3 kg N, P_2O_5 and K_2O, respectively, for the yield of 2.5 t ha^{-1}.

Singh *et al.* (1989) conducted two types of experiment on onion production. They set up two types of land; one without previously green manuring and another was cropped with green manuring by *Sesbania aculata*. A combination of 120 kg N and 50 kg K_2O gave the tallest plants and the greatest number of leaves per plant, maximum bulb weight and bulb diameter and higher bulb yield in the first experiment. Green manuring also greatly enhanced plant growth and bulb yield.

Jayabharathi (1989) reported that the higher yield of onion was be obtained by using the highest dose of NPK (75 kg of each nutrient). It was 55-75% greater than the control. With the application of higher dose of fertilizer, bigger size bulbs were produced.

Maier *et al.* (1990) stated that in onion crop fresh weight (FW) increase was correlated with the increase in N level and the largest bulbs were 25-30 mm in diameter. Nitrogen rates in the ranges 299-358 kg ha^{-1} gave 95% of maximum yield. Dry matter of bulbs was not affected by N. Bulb size increased as the rate of applied N increased.

Pandey *et al.* (1990) conducted an experiment with various levels of N and reported the highest yield of marketable bulbs (34.97 t ha^{-1})) by transplanting on 1st January and applying 100 kg N ha^{-1}. Transplanting on 15 February and applying 50 kg N ha^{-1} gave the lowest marketable yield (10.38 t ha^{-1}).

Baloch *et al.* (1991) obtained maximum bulb yield (22.66 t ha^{-1}) with the application of 125 kg N + 75 kg K_2O ha^{-1}. The highest plant height (38.5 cm), number of leaves plant^{-1} (7.0), single bulb weight (82 g), vertical bulb diameter (4.80 cm) and horizontal bulb diameter (5.78) were obtained with 125 kg N + 100 kg K_2O ha^{-1}.

Bhorrdwaj *et al.* (1991) stated that plant height was increased significantly with increasing levels of nitrogen. The main yield containing components were the number of scalps per plant, size of umbel, but the yield increase beyond 80 kg N ha^{-1} was not significant.

Gaushal *et al.* (1991) stated that increasing N levels increased the bulb yield. The highest yield was recorded at 150 kg N ha^{-1} which was significantly superior to rest of the nitrogen levels. The yield at 100 kg N ha^{-1} was also significantly more than 50 kg N ha^{-1} and the control.

Kumar and Shama (1991) conducted an experiment of two onion cultivars designated N-53 and N-2-4-1, grown in the *kharif* season, bulb yield increased linearly as N application was increased up to 75 kg ha^{-1}. The mean increase in the bulb and plant weight ratio was 1: 2.22 with 25 kg N, compared with 1: 1.95 for untreated controls; higher N rates reduced this ratio.

Jitendra *et al.* (1991) in their trial of onion CVs. applied N @ 80, 120 and 160 kg ha^{-1}, K_2O @ 100 and $ZnSO_4$ @ 2.5 kg ha^{-1}. Higher N levels increased plant growth and yield. K alone and with Zn also increased plant growth, yield and dry matter contents. The highest yield (32.68 t ha^{-1}) was obtained with the higher rate of N along with K and Zn.

Singh and Sharma (1991) stated that soil moisture regimes and nitrogen application to onion crop affected the diameter of bulb and yield significantly. They also reported that application of nitrogen at 80 kg ha^{-1} caused 38% increase in bulb weight over control.

Pandey *et al.* (1991) studied four levels of nitrogen (0, 50, 100, 150 kg ha^{-1}), three levels of phosphorus (0, 40 or 80 kg ha^{-1}) and two levels of potash (0 and 50 kg ha^{-1}) to determine the yield and quality of *kharif* onion. They found that the maximum yield and net return were achieved with N: P: K at 150: 40: 50 kg ha^{-1}.

Pandey *et al.* (1992) conducted an experiment to find out the effect of nitrogen and spacing on *kharif* onion cv. Agrifound Dark Red at Jaipur, Rajasthan, India. They found that both 80 and 120 kg N ha^{-1} gave significantly higher yields than the lower fertilizer rates, but the higher N rates resulted in significantly larger umbels and less incidence of thrips. The incidence of purple blotch was unaffected by N application.

Rahim *et al.* (1992) conducted an experiment on the scope for increasing the total yield and fulfilling the demand of onions during the period of shortage in Bangladesh through the bulb-to-bulb (set) method of production. In a fertilizer trial, onion sets were planted on 6th November at a spacing of 25 × 15 cm and supplied with 0-160 kg K ha^{-1} and 0-100 kg N ha^{-1}, half before planting and half 36 days after planting. The combination of the highest application rates of N and K resulted the yield of 11.11 t ha^{-1} compared with 4.5 t ha^{-1} from unfertilized control plots.

El-Oksh *et al.* (1993) observed that N application had no significant effect on plant height, number of leaves, fresh weight or dry weight, but bulbing ratio (the ratio between bulb and neck diameter) was decreased and total chlorophyll content was increased with increasing N application. High N increased bulb fresh weight at harvest.

Vachhani and Patel (1993) studied the effect of different levels of NPK on the growth and yield of onion. They found that plant height, number of leaves plant^{-1}, bulb weight and yield were highest with 150 kg N ha^{-1}, although bulb weight and yield with 100 kg N ha^{-1} were not significantly different. Increasing phosphorus application increased the number of leaves per plant and weight, size and yield of bulbs. Application of K increased only the number of leaves per plants.

Singh *et al.* (1994) noticed that net plot yield, total marketable yield and total dry weight production were best plots treated with N at 80 kg ha^{-1}. They also stated that plant mortality increased with increasing rates of N.

Katwale and Saraf (1994) reported that the maximum bulb yield was obtained with the application of NPK at the rate of 125: 60: 100 kg ha^{-1}, respectively. This rate also gave the highest economic return.

Perilas and Nicor (1994) stated that the bulb weights of 12.34 and 45.72 t ha^{-1} were found when 180 and 300 kg N ha^{-1} were applied respectively. They also reported that application of 180 to 240 kg N ha^{-1} showed an appreciable increase in diameter of bulbs from 2.85 (control) to 3.70 cm. The largest bulb diameter of 4.13 cm was observed when 300 kg N ha^{-1} was applied.

Amin *et al.* (1995) worked on sandy loam soil in Mymensingh on onion cv. Taherpuri, planted on 20 December and 20 January and gave 0, 25, 50 or 100 kg N/ha. Yields were the highest from the planting of 20 December supplied with 100 kg N ha^{-1}. Individual bulb weight was also greater in this treatment.

Singh *et al.* (1996) carried out a field trial in Agra, India to observe the effects of N (0, 60, 120 or 180 kg ha^{-1}) and S (0, 20, 40 or 80 kg ha^{-1}) on the growth of onion (cv. Pusa Red). The yield and plant nitrogen contents were significantly increased with increased nitrogen application. Combined addition of N and S significantly increased its yield.

Anwar *et al.* (1998) observed that application of nitrogen, phosphorus, potassium, sulphur and zinc increased the number of leaves $plant^{-1}$ along with higher bulb yield of onion with the increasing rates up to 150 kg N, 120 kg P_2O_5, 120 kg K_2O, 20 kg S and 5 kg Zn ha^{-1} at Jessore area.

Harun-or-Rashid (1998) conducted a field trial at Bangladesh Agricultural University, Mymensingh to observe the effect of NPKS on growth and yield of onion at different plant spacing. He stated that the maximum bulb weight (40.50 g) and bulb yield (20.75 t ha^{-1}) were found from the combination of 125-150-150-30 kg N, P_2O_5, K_2O, S ha^{-1}, respectively. Application of NPKS increased plant height, leaf number, bulb length, bulb diameter and bulb weight as well as bulb yield. He recommended 100-150-200-30 kg N, P_2O_5, K_2O, S ha^{-1}, respectively for the cultivation of BARI Piaz-1 at BAU farm conditions.

Singh and Mohanty (1998) studied the effect of NPK on growth and yield of onion in Orissa, India in 1995-96. They found that with the increasing N level, plant height increased. Plant height, bulb girth, number of leaves $plant^{-1}$, bulb weight and the highest yield (295.8 q ha^{-1}) were achieved with N and K at 160 and 80 kg ha^{-1}, respectively. Based on these results, the recommended rates for commercial onion production in and around Bhubaneswar are 160 kg N, 80 kg K_2O and 60 kg P_2O_5 ha^{-1}.

Kumar *et al.* (1998) carried out an experiment in India during 1993/94 and 1994/95 and observed that N at 150 kg ha^{-1} gave the best results with regard to plant height, length and diameter of the longest leaf, diameter of the thickest stem, number of leaves $plant^{-1}$, plant spread, time to bulb maturity, bulb diameter, bulb FW and DW, length of the longest root, and bulb yield.

Rodriguez *et al.* (1999) carried out experiments during 1993-94 and 1994-95 on onion to find out the effect of nitrogen, phosphorus and potassium rates, sources and forms upon onion (*Allium cepa*) bulb yield and quality. Yield, plant height, leaf number and polar and equatorial diameters were measured with different rates, sources and forms of N, P and K. Significant effects of P and K rates (applied up to 98.2 and 200 kg ha^{-1}, respectively) could not be detected, nor significant interactions between N and P.

Ramamoorthy *et al.* (1999) conducted a field experiment at Bhavanisagar, Tamil Nudu, India. Onion cv. CO4 was given 0, 30, 60 or 90 kg N ha^{-1} during the *kharif* and summer seasons of 1994 and 1995. They stated that bulb yield increased as N rate increased.

A field trial was conducted by Singh and Chaure (1999) on a sandy loam soil at Bilaspur, India. Five, 6 and 7 weeks old onion seedlings were supplied with N at 50, 100 or 150 kg ha^{-1} in 1989-90 and with N at 50, 100, 150 or 200 kg ha^{-1} in 1990-91 and 1991-92. The optimum age of seedling and N application rate, in terms of leaf length, number of leaves per plant, bolting percentage, bulb weight and yield were 6 weeks and 150 kg ha^{-1}, respectively. At an extra fertilizer rate of N 200 kg ha^{-1}, the additional yield did not compensate for the cost of extra fertilizer.

Singh *et al.* (2000) conducted an experiment at Rajasthan, India during summer season of 1993-95. Onion cv. N-53 was grown under factorial combinations of 3 levels each of nitrogen (50, 75 and 100 kg N), phosphate (13.2, 22.0 and 30.8 kg P) and potash (41.5, 62.2 and 83.0 kg K). It was concluded that onion productivity could be enhanced considerably by application of 100 kg N, 30.8 kg P and 83.0 kg K ha^{-1}.

Hussaini and Amans (2000) carried out a field experiment during the 1993-94 and 1994-95 dry seasons, at Kadawa in the Sudan Savannah ecological zone of Nigeria. They stated that nitrogen application positively increased the bulb yield, average bulb weight, and number of large bulbs $plot^{-1}$ and 7-day intervals irrigation produced higher bulb yield, average bulb weight, and number of large bulbs $plot^{-1}$.

According to Neeraja *et al.* (2000) increased level of N fertilizer significantly increased the leaf, bulb and whole plant uptake of Ca, Mg and S at different stages of crop growth. The uptake of these nutrients continued until bulb maturity. They also revealed that the total uptake of Ca, Mg and S was 16.66, 9.20 and 25.48 kg ha^{-1}, respectively with 200 kg N ha^{-1}.

An experiment was conducted at Spices Research Centre, BARI, Joydebpur during 2000-2001 with four levels (0, 100, 125 and 150 kg ha^{-1}) of nitrogen (Anonymous, 2001). Influence of different levels of nitrogen was significant on different parameters of onion studied. Although 125 kg ha^{-1} and 150 kg ha^{-1} of nitrogen produced 10.91 t ha^{-1} and 8.70 t ha^{-1} of bulb, respectively while it was 5.74 t ha^{-1} in control.

A field experiment carried out by Kumar *et al.* (2001) to study the effect of N fertilization (0, 65 and 130 kg ha^{-1}) on onion cv. Pusa Red during 1992-93 and 1993-

94 in Uttar Pradesh, India. They stated that application of 130 kg N ha^{-1} resulted in the highest percentage of seedling survival, plant height, number of green leaves and pseudostem diameter, as well as the lowest number of days to maturity. This treatment also resulted in the greatest number of roots, length of the longest root, bulb diameter, bulb fresh weight and bulb yield, compared to other application rates.

According to Mohanty and Das (2001), application of 90 kg N and 60 kg K_2O ha^{-1} was better for obtaining higher yield with larger bulbs, while 30 kg ha^{-1} each of N and K_2O was suggested to realize medium bulbs with moderate yield and better keeping quality in long term storage.

In a field experiment conducted by Tiwari *et al.* (2002) in Patharchatta, Uttar Pradesh, India during the winter seasons of 1995-96, 1996-97 and 1997-98 with three levels of N and its application methods on onion cv. Pusa Red. It was reported that 100 kg N ha^{-1} and foliar spray gave the highest yield.

Tiwari *et al.* (2002) conducted a field trial to investigate the effects of N and plant spacing on the yield of onion cv. Pusa Red and found that plant height, length of flowering stalk, number of umbels $bulb^{-1}$, 1000-seed weight, purple blotch and seed yield increased with increasing rates of N up to 80 kg ha^{-1}.

Yadav *et al.* (2002) carried out an investigation on onion cultivars Puna Red, White Marglobe, Nasik Red and Rasidpura Local which were supplied with 50, 100 and 150 kg N and K ha^{-1} in Jaipur, Rajasthan, India during the *rabi* seasons of 1998-2000. Yield, fresh weight of bulb, total soluble solids and allyl propyl disulphide content increased, whereas ascorbic acid content decreased with the increase in N and K rates.

Rasidpura Local recorded the highest values for the parameters measured except Allyl Propyl Disulphide content which was highest in Nasik Red.

Muoneke *et al.* (2003) conducted a field trial to investigate the effects of four levels of nitrogen and three levels of phosphorus on growth and keeping quality of onions. They found that application of 90 and 135 kg N ha^{-1} increased the growth and yield but reduced the post harvest storage quality. Phosphorus at 60 kg ha^{-1} increased these attributes but did not influence the keeping quality of the bulbs.

Mandira and Khan (2003) carried out an experiment with different levels of nitrogen (0, 100, 150 and 200 kg ha^{-1}) and potassium (0, 75 and 150 kg ha^{-1}) to study their effect on the growth, yield and yield attributes of onion cv. N-53 in Tripura, India during *rabi* season of 2001. Nitrogen at 150 kg ha^{-1}, potassium at 75 kg ha^{-1} and their combination recorded the best performance in terms of yield and growth.

Yadav *et al.* (2003) stated that application of 100 kg ha^{-1} N produced significantly highest bulb yields over 50 kg ha^{-1} but 150 kg N ha^{-1} did not significantly increase the bulb yield. They also reported that 150 kg K_2O ha^{-1} produced significantly higher bulb yield compared to lower rates of potash.

Singh *et al.* (2004) studied the effect of NK on the growth and bulb yield of onion crop. They reported that plant height at harvest (51.43 cm), leaf length (28.22 cm), fresh weight of leaves (25.21 g) and total chlorophyll content at 45 days after transplanting (1.33 mg) and 90 days after transplanting (1.67 mg) were the highest upon treatment with the highest nitrogen rate (150 kg N ha^{-1}) and with the highest potassium rate (120 kg K ha^{-1}).

Haque *et al.* (2004) investigated the effects of nitrogen and irrigation on the growth and yield of onion cv. BARI Piaz-1 during the *rabi* season of 2000-01. Plant height, number of leaves $plant^{-1}$, bulb length, bulb diameter, neck thickness, single bulb weight and crop yield increased with increasing rates of N up to 125 kg ha^{-1} and with irrigation at 7-day intervals and decreased thereafter. Interaction effects between N rates and irrigation were significant for all the parameters measured except for bulb diameter.

Jilani *et al.* (2004) conducted a field trial to study the effect of different levels of nitrogen on three onion cultivars (Faisalabad Early, Phulkara and Shah Alam). They observed that maximum value cost ratio was found in Shah Alam followed by Faisalabad Early and Phulkara and N at 120 kg ha^{-1} proved to be the best for all the parameters studied.

Yamasaki and Tanaka (2005) investigated the role of N in the flower initiation of Welsh onion (*Allium fistulosum*) cv. Kincho. They found that low N rates retarded the growth but promoted leaf sheath bulbing and bolting of Welsh onions. It also reduced the nitrogen and carbon concentration but increased the C: N ratio in the crop.

Islam *et al.* (2006) conducted an experiment at the Horticultural Farm, Bangladesh Agricultural University, Mymensingh during the *rabi* season of 1999-2000 to evaluate the effects of nitrogen and potassium levels on the growth and yield of onion. The results revealed that the highest bulb yield (17.60 t ha^{-1}) was obtained when the plants were grown with nitrogen at 150 kg ha^{-1}, higher levels of N did not show any more increase in yield of onion. Application of potassium at 200 kg K ha^{-1} produced the highest bulb yield (16.69 t ha^{-1}).

Kumar *et al.* (2006) carried out a field experiment to determine the effects of N and K levels each of 0, 50, 100 and 150 kg ha^{-1} on onion bulb yield, quality and nutrient uptake. They observed that the bulb yield was significantly higher with the application of 150 kg N ha^{-1} and 100 kg K ha^{-1}. Similarly, the dry matter yield, protein percentage as well as N, P, K and S contents and uptakes were increased significantly over the control with the application of 150 kg N ha^{-1}.

An experiment was conducted at Spices Research Centre, BARI, Bogra with four levels of nitrogen (0, 50, 100 and 150 kg ha^{-1}), phosphorus (0, 20, 40 and 60 kg ha^{-1}), potassium (0, 50, 100 and 150 kg ha^{-1}) and sulphur (0, 10, 20 and 30 kg ha^{-1}) for *kharif* onion cultivation (Anonymous, 2007). Among the fertilizer treatments, $N_{100}P_{40}K_{100}S_{30}$ kg ha^{-1} gave the highest yield (22.3 t ha^{-1}) and the lowest yield (9.67 t ha^{-1}) was obtained in control.

Aliyu *et al.* (2007) studied the effect of nitrogen (N) and phosphorus (P) on the growth and yield of irrigated onion in the Sudan Sananna of Nigeria during 2003/2004 and 2004/2005 in dry seasons. Results revealed that N and P as well as their interaction, significantly affected plant height, number of leaves $plant^{-1}$, percentage bolters, crop growth rate and individual bulb weight. Nitrogen at the rate of 150 kg ha^{-1} gave the best results, though, statistically at par with 100 kg N ha^{-1}.

Meena *et al.* (2007) conducted an experiment to study the effect nitrogen levels on the growth and yield attributes of onion cv. Nasik Red. The highest N level (150 kg ha^{-1}) gave the maximum plant height, length of the longest leaf, pseudostem diameter, number of leaves $plant^{-1}$, bulb diameter and bulb yield in comparison to its lower levels, i.e. 50 and 100 kg N ha^{-1}.

2. 2 Effect of vermicompost on different crops

A field experiment was conducted by Ranwa and Singh (1999) at Hisar, Haryana, India during the winter seasons of 1994-96 to study the effect of integration of nitrogen with vermicompost on wheat crop. The treatment comprised organic manures, viz. farmyard manure at 10 t ha^{-1}, vermicompost (at 5, 7.5 and 10 t ha^{-1}) and 5 levels of N viz. 0, 50, 100, 150 kg ha^{-1} and recommended fertilizer. They reported that the application of organic manures improved yield attributes and grain, straw and biological yields of wheat. Application of vermicompost at 7.5 or 10 t ha^{-1} resulted in higher yields than 10 t ha^{-1} FYM.

Vasanthi and Kumaraswamy (1999) from an experiment with vermicompost and NPK fertilizers showed that the grain yields of rice were significantly higher in the treatments that received vermicompost from any of the 5 to 10 t ha^{-1} organic materials (sugarcane trash, *Ipomoea*, banana peduncle etc.) with N, P and K at recommended levels than in the treatment that received N, P and K alone. Organic carbon content and fertility status as reflected by the available status of N, P, and K, micronutrients and CEC were higher and bulk density were lower in the treatments that received vermicompost plus N, P and K than in the treatments with N, P and K alone. It was found that vermicompost at 5 t ha^{-1} would be sufficient for rice crop when applied with recommended levels of N, P and K.

Rao *et al.* (2000) from a field experiment carried out at the Indian Agricultural Research Institute, New Delhi, India reported that application of 3 t ha^{-1} vermicompost to chickpea improved dry matter accumulation, grain yield and grain protein content in chickpea, soil N and P and bacterial count, dry fodder yield of succeeding maize, total N and P uptake by the cropping system over no vermicompost.

Vermicompost produced higher yield of tomato than the chemical fertilizer treated and control plots. Same margin of production was obtained in snake gourd, bitter gourd and lady's finger. It was observed that crops grown under chemical fertilizer became yellowish rapidly while crops grown under vermicompost remained green. Germination of different seeds in the vermicomposted plots was higher than the control and chemical fertilizer treated plots (Zahid, 2001).

A study was conducted by Khandal and Nagendra (2002) in India on two wheat cultivars to investigate the effect of chemical fertilizers (NPK fertilizer) and organic manure (vermicompost). Results showed that plant height, dry matter production and grain yield were higher at higher dose of vermicompost. Number of tillers and leaves $plant^{-1}$ were very low at early stages of growth and suddenly increased after adding different concentrations of vermicompost and organic manure.

A field experiment was conducted in Orissa, India during the *kharif* season of 1999 to determine the effect of integrated application of vermicompost and chemical fertilizer on rice cv. Lalat (Das *et al*., 2002). Yield components were increased by integrated application of vermicompost and chemical fertilizers compared to the other treatments. The highest results in terms of straw and crop yields were obtained with 50% vermicompost + 50% chemical fertilizers.

The combined application of organic and inorganic N sustained the productivity. Soil available nutrients like N, P and K increased significantly with the application of various organic sources of nutrients in combination with fertilizers over the fertilizer alone. The highest grain yields of *rabi* sorghum and chickpea were obtained with 50 percent N through green manure plus 50 percent fertilizer N (Tolanur and Badanur, 2003).

2.3 Nutrient status of vermicompost

Vermicomposting is the managed bioconversion of organic materials through earthworm consumption. Vermiculture and vercomposting experiments have been set up in many countries like England, France, Germany, Italy, Israel, USA, Japan, The Philippines, India and other parts of South-East Asia, Australia, Cuba, The Bahamas and many countries in Africa and South America (Edwards and Bohlen, 1996).

Harris *et al.* (1990) reported that earthworm excreta is the excellent soil conditioning material with higher water holding capacity and required less time for releasing nitrogen into the soil. The nutrient level of the vermicompost was about two times greater than natural compost and the use of vermicompost is important for the farmers to get better quality crop yields.

Vermicasts have a high base exchange capacity and are generally rich in total organic matter, total exchangeable bases, phosphorous, exchangeable potassium, manganese and total exchangeable calcium. Vermicompost helps to improve and protect fertility of topsoil and also helps to boost up productivity by 40% with 20 to 60% lower nutrient inputs. It also enhances the quality of end products and thereby creating significant impact on flexibility in marketing as well as increases the storage time.

Vermicompost contain 30 to 50% humic substances which help in the stimulation of plant growth, particularly that of roots, drilling mud and emulsifiers (Dusserre, 1992).

Robinson *et al*. (1992) reported that the nutrients present in vermicompost are readily available and the increase in earthworm populations on application of vermicompost and mulching leads to the easy transfer of nutrient to plants thus providing synchrony in ecosystems.

Saerah *et al*. (1996) conducted an experiment on the effect of compost in optimizing the physical condition of sandy soil. Compost at the rates of 0.0, 16.5, 33.0, 49.5 and 66.0 t ha^{-1} was incorporated into the soil and then wheat was grown. The results indicated that the various application rates were significantly correlated with improvement in physical properties of soil as well as straw and grain yields of wheat.

The organic wastes could be efficiently converted into vermicompost with a recovery of 75 - 87% in a composting period of 3 months. Earthworm biomass was doubled irrespective of organic waste used in a period of 2 months. Major nutrients (NPK) and micronutrient (Cu, Zn, Fe and Mn) contents were slightly higher in all the vermicompost samples than in normal compost. Vermicompost had lower C: N ratio and pH than normal compost irrespective of the source of organic waste. Microbial population was considerably higher in vermicompost than in normal compost (Chowdappa *et al*., 1999).

Earthworms influence the changes in various chemical parameters governing the compost maturity of local grass, mango leaves and farm wastes. There was a decrease in C: N ratio, while humic acid, cation exchange capacity and water soluble carbohydrates increased up to 150 days of composting. Compost maturation was achieved up to a period of 120 and 150 days in farm wastes and mango leaves, respectively, while more than 150 days would be required to reach the maturity in case of local grass. Inoculation of earthworms reduced the composting by 13 days (Talashilkar *et al.*, 1999).

Vermicomposting of sugarcane trash individually and in combination with pressmud using earthworm *Perionyx excavatus* increased significantly N by 34%, P by 87%, K by 40%, Ca by 64%, Mg by 39% and Mn by 11% over the control compost along with a reduction in C: N (15: 1) and C: P (6: 1) ratio due to mineralization and combined action of earthworms and microbes (Ramalingam, 1999).

Vermicompost contains 2.29 folds more organic carbon, 1.76 times total nitrogen, 3.02 folds phosphorous and 1.60 times potassium than normal compost. Earthworms decrease the C: N ratio from 14.21 to 10.11 and an average 56.03% of organic waste can be converted into vermicompost by the activities of earthworms in short time (Sohrab and Sarwar, 2001).

Vermicompost contain more organic matter, N, P, S, Ca and Mg than normal compost. It was shown that worm-worked composts have better texture and soil enhancing properties, hold typically higher percentages of N, P and K (Zahid, 2001).

Kumari and Kumari (2002) from an experiment stated that vermicompost is a potential source of organic manure due to the presence of readily available plant nutrients, growth enhancing substances and number of beneficial microorganisms like N fixing, P solubilising and cellulose decomposing organisms.

2.4 Effect of integrated use of chemical and organic fertilizers on onion

A field experiment was carried out by Singh *et al.* (1997) during winter 1993-94, 1994-95 and 1995-96, the effects of different organic manures and inorganic fertilizers on the yield and quality of *rabi* onion cv. Agrifound Light Red were investigated in Nasik, India. They used green manure, farmyard manure, vermicompost and inorganic fertilizer. Combination of 100 kg N + 25 kg P + 25 kg K ha^{-1} and farmyard manure, yields were increased to 323.1 and 313.6 q ha^{-1}, respectively and the highest net return (32 651 Rs ha^{-1}) was obtained.

Dixit (1997) carried out a field experiment with onion during the summer of 1994 at Lari, Himachal Pradesh, India. He used five rates of nitrogen (0, 40, 80, 120 and 160 kg ha^{-1}) and two rates of farmyard manure (10 and 20 t ha^{-1}) and reported that increasing nitrogen application rates increased bulb yields up to 120 kg N ha^{-1}. Higher yields were also obtained with the higher rate of farmyard manure used. Application of 120 kg N ha^{-1} with 20 t ha^{-1} farmyard manure increased yields by 42.8% compared to the control.

Willumsen and Kristensen (2001) carried out two years experiment to explore the effect of green manure crops of legumes and non-legumes and compared with bare soil for their ability to supply nitrogen to two organically grown onion cv. Hysam and white cabbage cv. Cantor and Koobenhavns Torve 4 Koto. They found that green manure crops of legumes facilitated a substantial biological nitrogen fixation which increased the amount of mineral N (Nmin) available for the subsequent vegetable crops and reduce the amount of leachable N by between 50 and 85%.

A field experiment was conducted by Singh *et al.* (2001) in Rajasthan, India during *kharif* season to study the response of onion (*Allium cepa*) cv. N53 to integrated application of N (0, 60, 90, 120 and 150 kg ha^{-1}) and farmyard manure, FYM (0, 5, 10 and 15 t ha^{-1}). They found that the average weight $bulb^{-1}$ and bulb yield increased significantly up to 120 kg N ha^{-1} and FYM at 10 t ha^{-1}. Maximum net returns were recorded with N at 150 kg ha^{-1} and FYM at 10 t ha^{-1}. A combination of 149 kg N + 9.13 t FYM ha^{-1} gave the highest bulb yield.

Jayathilake *et al.* (2003) studied the effects of integrated nutrient management using farmyard manure (FYM) and vermicompost (VC), alone or in combination with 2 biofertilizers (*Azotobacter chroococcum* and *Azospirillum brasilense*) and chemical fertilizers. The growth of onion in terms of plant height, number of leaves $plant^{-1}$, dry matter accumulation in bulb, yield and yield components such as bulb diameter, weight and quality significantly increased with the application of biofertilizers in combination with 50% N applied through organic manure (VC or FYM) while the other 50% of recommended N and 100% PK were supplied through chemical fertilizers. This treatment was significantly superior to the application of 50% of recommended N through organic manure with other 50% N and 100% PK supplied through chemical fertilizer as well as application of chemical fertilizer alone or application of organic manure alone.

A study was carried out by Abbey and Kanton (2004) to investigate the response of onion (cv. Bawku Red) to the application of farmyard manure (FYM), inorganic fertilizer (IF) or combination of manure and inorganic fertilizer (FYM + IF). Onion bulb yield due to the FYM + IF treatment was 34.1% higher than that for FYM, and 4.6% higher than that for the IF treatment. Application of FYM either alone or in combination with IF significantly ($P < 0.05$) reduced bulb rot and use of both FYM + IF at half their recommended rates increased onion bulb yield and reduced field defects.

Reddy and Reddy (2005) conducted a study in Andhra Pradesh, India during 1996-98 with different levels of vermicompost and nitrogen fertilizer on the growth and yield of onion (cv. N-53) and their residual effect on succeeding radish in an onion-radish (cv. Sel-7) cropping system. They noticed that the plant height, number of leaves $plant^{-1}$, leaf area, bulb length, diameter and weight and yield of onion increased significantly with increasing levels of vermicompost and nitrogen fertilizer. The highest plant height and number of leaves $plant^{-1}$ was recorded with vermicompost at 30 t ha^{-1} + 200 kg N ha^{-1} and the highest bulb length, bulb weight and onion yield was recorded with vermicompost at 30 t ha^{-1} + 150 kg N ha^{-1}.

Chadha *et al.* (2006) studied the most viable and sustainable nutrient management system in summer onion at Lari in Himachal Pradesh, India. The results indicated that 100% NPK (N: P_2O_5: K_2O at 120: 75: 60 kg ha^{-1}) + farmyard manure (100 t ha^{-1}) + mulch (8 t ha^{-1}) and 100% NPK + farmyard manure resulted in significantly higher plant height, bulb weight, polar diameter, net return and benefit: cost (B: C) ratio. 50-75% NPK + farmyard manure resulted in significantly higher bulb yield and net returns over the 100% NPK treatment without farmyard manure.

Mehla *et al.* (2006) conducted an experiment to find out the suitable organic source of nitrogen to partially replace (50%) inorganic fertilizer. The highest bulb yield (141 q ha^{-1}) was obtained when inorganic fertilizer was supplemented with vermicompost, followed by that with FYM and dung cake ash. All these three sources also proved significantly better than inorganic fertilizer alone.

Singh *et al.* (2006) carried out an experiment to develop an appropriate integrated nutrient management (INM) for sustainable production of onion and to study the status of available nutrients in an alluvial soil. They suggested that the combined use of FYM, fertilizers and biofertilizers (75% NPK + 10 tones FYM ha^{-1} + *Azotobacter*) would be the optimum integrated nutrient management practices for higher yield, nutrient uptake and fertility status of soil.

From these reviews, it is clear that nitrogen plays a significant role in summer onion production. Integrated management of nitrogen improves both soil properties and yield of onion. Sole application of organic manure or chemical fertilizers gave inferior results to their integrated use. The practice of summer onion is not popular in our country but onion is growing successfully in India during summer season. Bangladesh is adjacent to India and there is close relation in weather conditions. So, there are great possibilities to grow onion in Bangladesh during summer season and it will be help to meet the demand of consumers. From the above mentioned literature it can be concluded that high dose of nitrogen and integrated use of chemical and organic fertilizer could give better yield as compared to lower doses and sole submission of nutrients.

Chapter 3
Materials and Methods

MATERIALS AND METHODS

This chapter arranges the materials and methods used in the experiment including a brief description of the experimental site, onion variety, soil, climate, land preparation, experimental design, treatments, cultural operations, collection of soil and plant samples etc. and analytical methods used for the experiment. Details of the research procedure are described here.

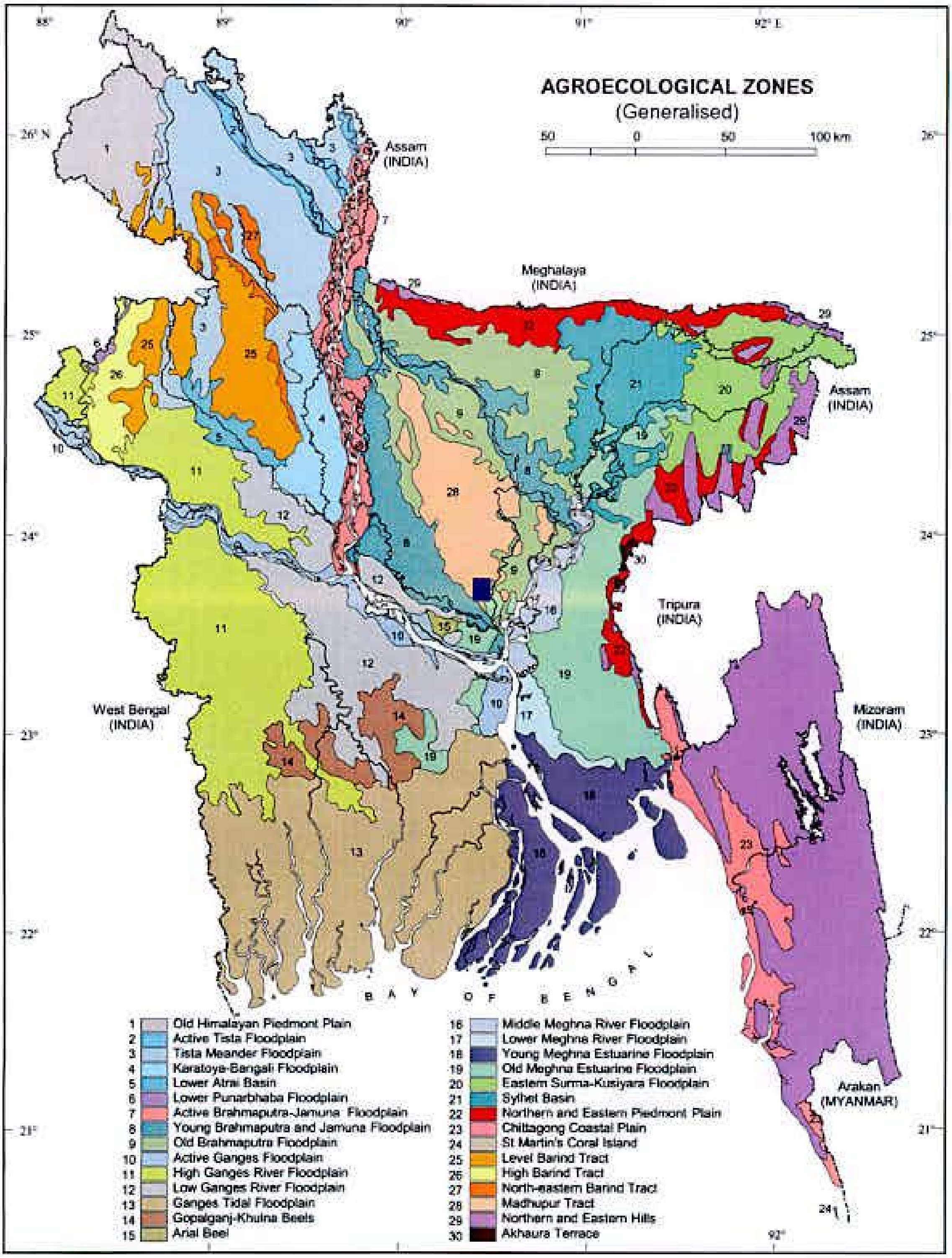
3.1 Description of the experimental site

3.1.1 Location

The research work relating to the study of the response of summer onion to integrated effect of nitrogen was conducted on the Farm division of Sher-e-Bangla Agricultural University, Dhaka 1207 during the *kharif* season of 2007. The specific location of experimental site is presented in Figure 1.

3.1.2 Soil

The soil of the experimental field belongs to the Tejgaon series of AEZ No. 28, Madhupur Tract, classified as Shallow Red Brown Terrace Soils in Bangladesh soil classification system. The soil is characterized by heavy clays within 50 cm from the surface and acidic in nature. A composite sample was made by collecting soil from several spots of the field at a depth of 0-15 cm before the initiation of the experiment. The collected soil was air-dried, ground and passed through 2 mm sieve and analyzed for some important physical and chemical parameters. Some initial physical and chemical characteristics of the soil are presented in Table 1.



■ **Location of the experimental site**

Figure 1. Map showing the experimental site under study

Table 1. Physical and chemical properties of the initial soil

Soil properties	Analytical result
A. Physical properties	
1. Sand (%)	24.5
2. Silt (%)	43.1
3. Clay (%)	32.4
4. Textural class	Silty Clay Loam
B. Chemical properties	
1. Soil pH	6.00
2. Organic matter (%)	0.83
3. Total N (%)	0.076
4. Available phosphorus (ppm)	19.72
5. Exchangeable potassium (meq/100 g soil)	0.17
6. Available sulphur (ppm)	20.51

3.1.3 Climate

The climate of the experimental area is characterized by sub-tropical accompanied by heavy rainfall, high humidity, high temperature, relatively long day during the *kharif* season and scanty rainfall, low humidity, moderately low temperature and short day period during the rest period of the year. The monthly temperature, total rainfall, average relative humidity and sunshine data during the cropping period are shown in figure 2-5 and Appendix Table 1.

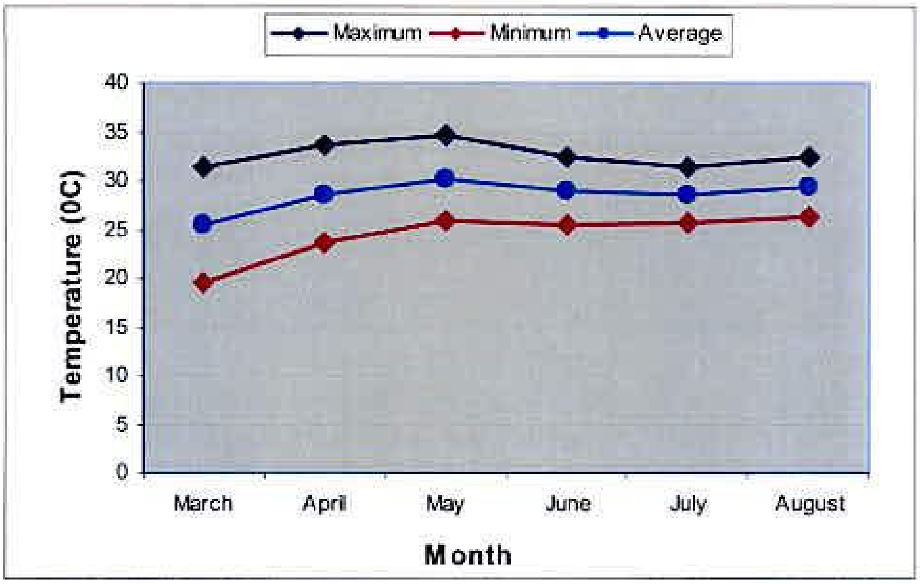


Figure 2. Monthly average, maximum and minimum air temperature (^{o}C) of the experimental site, Dhaka during the growing time (March to August' 2007) (Anon., 2007)

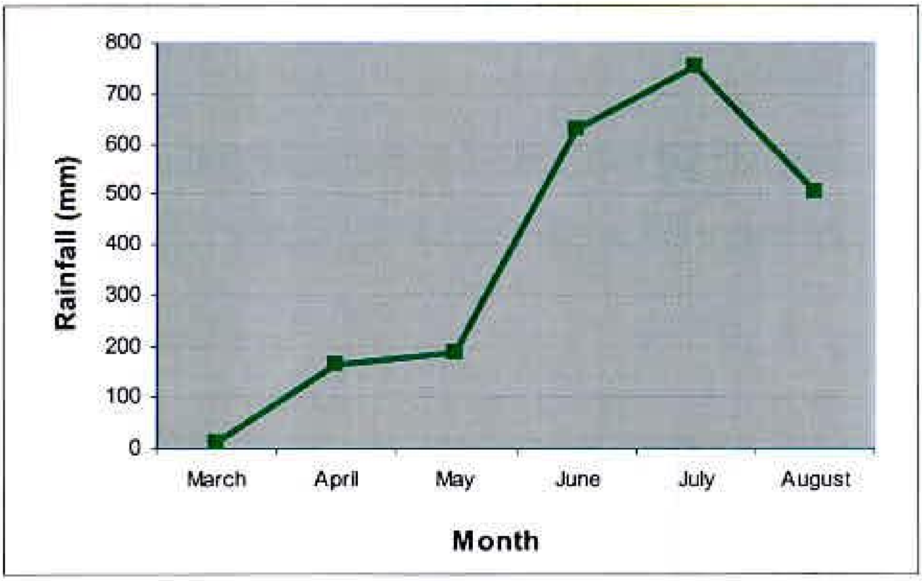


Figure 3. Monthly total rainfall (mm) of the experimental site, Dhaka during the growing period (March to August' 2007) (Anon., 2007)

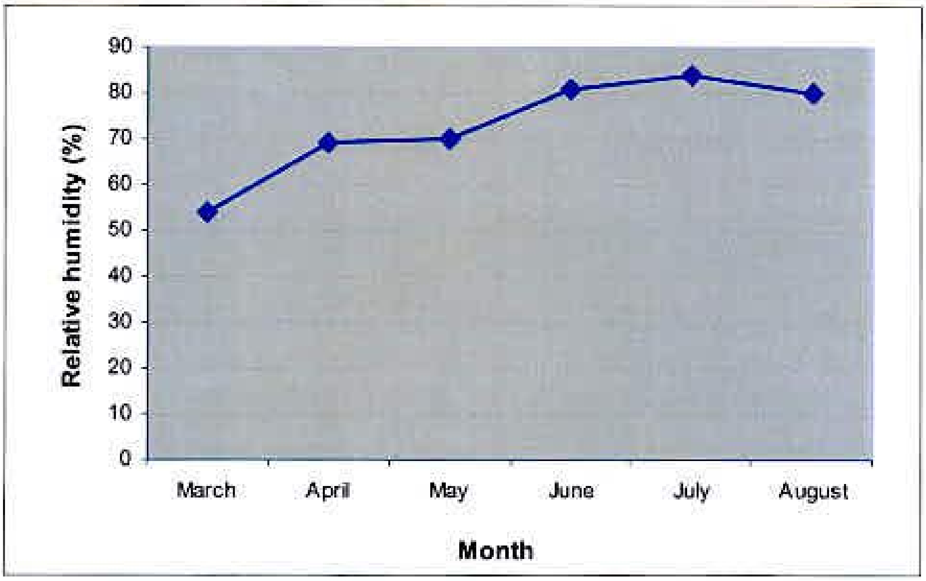


Figure 4. Monthly average relative humidity (%) of the experimental site, Dhaka during the growing period (March to August' 2007) (Anon., 2007)

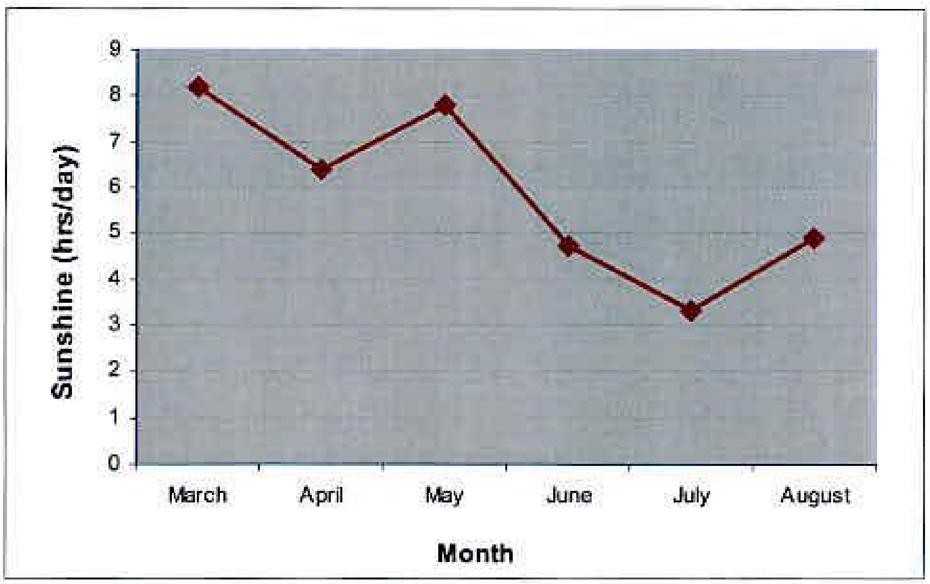


Figure 5. Monthly average sunshine (hrs/day) of the experimental site, Dhaka during the growing period (March to August' 2007) (Anon., 2007)

3.2 Description of the summer onion variety

BARI Piaz-2, a high yielding variety of summer onion was selected for this experiment. This variety was released by the Bangladesh Agricultural Research Institute (BARI), Joyddebpur, Gazipur in 2000. The bulbs are highly pungent with pinkish red skin. Nearly 50-60% bulbs are of single type mature within 90-120 days and yield of bulb is about 10 to 12 t ha^{-1} (Anonymous, 2000). The germination percentage of the seed was 85.

3.3 Raising of seedlings

The land selected for raising seedlings was light in texture and well drained. The land was ploughed well and left for drying for 10 days. Bigger clods were broken into pieces and finally the soil was made loose and friable. All weeds and stubbles were removed and then the soil of seedbeds were mixed with well-decomposed cow dung @ 10 t ha^{-1}; applying Furadan 3 G @ 20 kg ha^{-1} were covered by polyethylene for two days. The seedbeds were 3 m × 1 m in size with height of about 20 cm. Onion seeds were soaked over night (12 hours) in water and allowed to burgeon in a piece of moist cloth keeping in the sunshade for one day. Then seeds were sown directly in the raised seedbed on 30 March 2007 for raising seedlings. Irrigation was provided regularly and seedbeds were always kept free from weeds. The young seedlings were exposed to dew by night and mild sunshine in the morning and evening. To retain the soil moisture and to save the seedlings from direct sunlight and rain, shades were given over the seedbeds. Seedlings were not attacked by any kinds of insects and diseases.

3.4 Treatments of the experiment

The experiment consists of 12 treatments where 120 kg ha^{-1} N supplied from urea, cowdung (CD) and vermicompost (VC) as follows:

T_1 - No fertilizer

T_2 - 120 kg N ha^{-1} supplied from urea

T_3 - 100 kg N ha^{-1} supplied from urea + 20 kg N ha^{-1} substituted by CD

T_4 -100 kg N ha^{-1} supplied from urea + 20 kg N ha^{-1} substituted by VC

T_5 - 80 kg N ha^{-1} supplied from urea + 40 kg N ha^{-1} substituted by CD

T_6 - 80 kg N ha^{-1} supplied from urea + 40 kg N ha^{-1} substituted by VC

T_7 - 60 kg N ha^{-1} supplied from urea + 60 kg N ha^{-1} substituted by CD

T_8 - 60 kg N ha^{-1} supplied from urea + 60 kg N ha^{-1} substituted by VC

T_9 - 40 kg N ha^{-1} supplied from urea + 80 kg N ha^{-1} substituted by CD

T_{10} - 40 kg N ha^{-1} supplied from urea + 80 kg N ha^{-1} substituted by VC

T_{11} - 120 kg N ha^{-1} supplied from CD

T_{12} - 120 kg N ha^{-1} supplied from VC

3.5 Design and layout of the experiment

The experiment consisted of 12 treatment combinations and was laid out in Randomized Complete Block Design (RCBD) with 3 replications. An area of 380 m^2 was divided into three equal blocks, representing the replications, each containing 12 plots. Thus, the total numbers of micro plots were 36, each measuring 2 m × 2 m (4 m^2). The distance between two plots was 1 m and between blocks was 1.5 m. The layout of the experiment is presented in Figure 2.

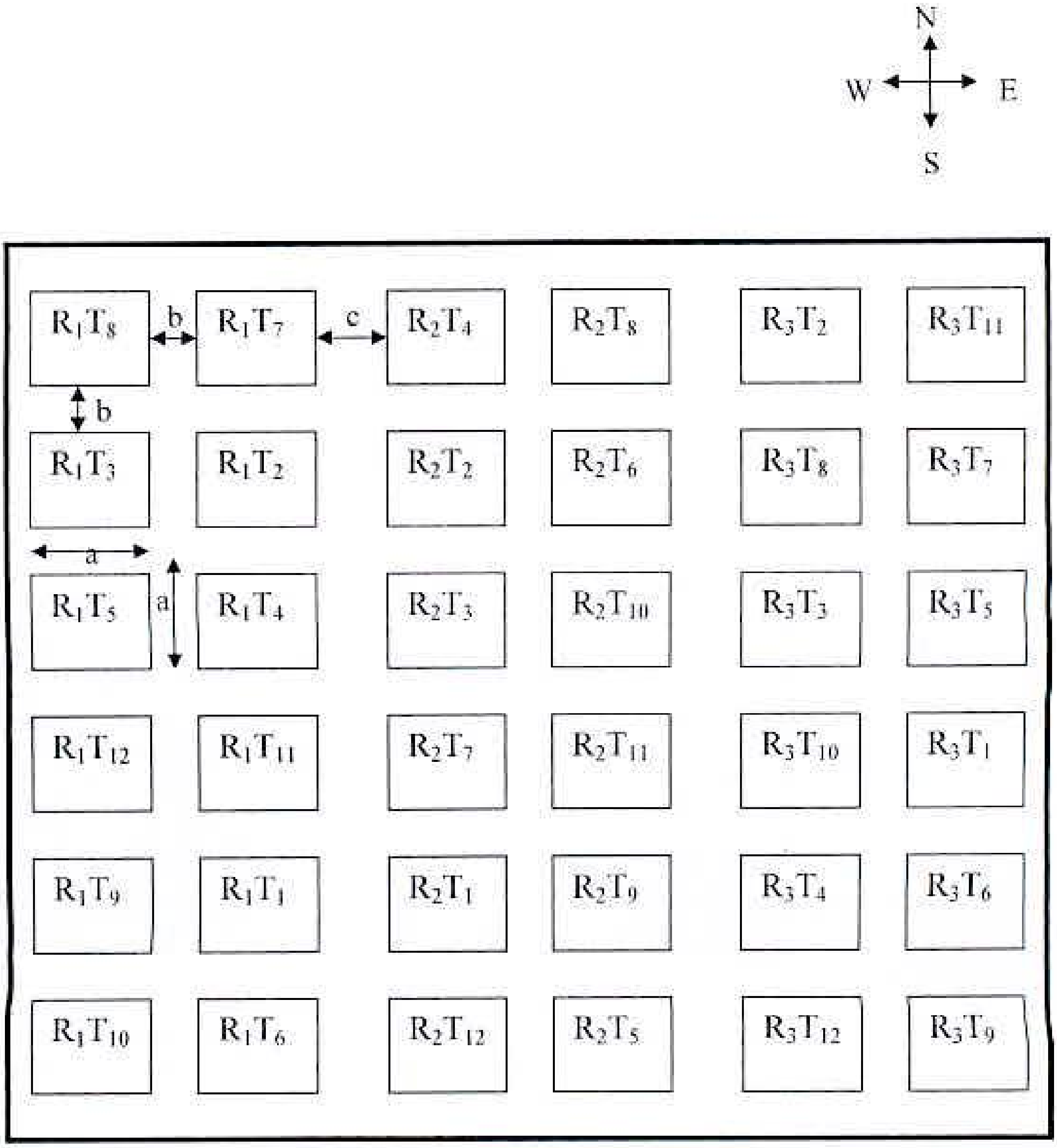


Figure 2. Layout of the experimental field

a) Plot size: 2 m x 2 m (4 m^2)

b) Plot to plot distance: 1 m

c) Block to block distance: 1.5 m

3.6 Cultivation of summer onion

3.6.1 Preparation of the field

The experimental plot was opened by a tractor on the 07 May 2007 then the land was ploughed and cross-ploughed several times with the help of a power tiller followed by laddering to obtain a good tilth. Weeds and stubbles were removed, and the large clods were broken into smaller pieces to obtain a desirable tilth of friable soil for transplanting of seedlings. Finally, the land was leveled and the experimental plot was partitioned into the unit plots in accordance with the experimental design mentioned in the previous section (3.5). Irrigation and drainage channels were prepared around the plots.

3.6.2 Rate of manures and fertilizers

In this experiment manures and fertilizers were used according to the recommendation of BARI as follows:

Manures/ fertilizers	Dose (kg ha^{-1})	Dose (g $plot^{-1}$)
Urea	260	
TSP	220	88
MP	200	80
Gypsum	180	72

Recommended 260 kg urea contains 120 kg N ha^{-1}. Urea contains 46% N, cowdung contain 0.5% N and vermicompost contain 0.64% N. Treatment wise per hectare requirement of urea, cowdung and vermicompost are described below:

T_1 - No fertilizer

T_2 - Urea 260 kg ha^{-1}

T_3 - Urea 215 kg ha^{-1} + cowdung 4 t ha^{-1}

T_4 - Urea 215 kg ha^{-1} + vermicompost 3.0 t ha^{-1}

T_5 - Urea 174 kg ha^{-1} + cowdung 8 t ha^{-1}

T_6 - Urea 174 kg ha^{-1} + vermicompost 6.25 t ha^{-1}

T_7 - Urea 130 kg ha^{-1} + cowdung 12 t ha^{-1}

T_8 - Urea 130 kg ha^{-1} + vermicompost 9.5 t ha^{-1}

T_9 - Urea 87 kg ha^{-1} + cowdung 16 t ha^{-1}

T_{10} - Urea 87 kg ha^{-1} + vermicompost 12.5 t ha^{-1}

T_{11} - Cowdung 24 t ha^{-1}

T_{12} - Vermicompost 18.75 t ha^{-1}

3.6.3 Application of manures and fertilizers

The entire amount of recommended fertilizers and well decomposed cowdung except urea and vermicompost were added to the soil at the time of final land preparation. Urea was applied in four equal splits and vermicompost was applied in three splits where 50% in first split and remaining 50% in two equal splits. The first split of urea and vermicompost were applied during final land preparation, the second split after 18 days of transplanting, the third split after 36 days of transplanting and the fourth split of urea was applied after 54 days of transplanting. The added manures and fertilizer were mixed with the soil consistently.

3.6.4 Transplanting of seedlings

Healthy and disease free uniform sized 45 days old seedlings were uprooted from the seedbeds and transplanted in the main field with the spacing of line to line 25 cm and plant to plant 10 cm in the afternoon on 13 May 2007. The seedbed was watered before uprooting the seedlings so as to minimize the damage of roots. The seedlings were watered immediately after transplanting. Some seedlings were also transplanted contiguous to the experimental field to be used for gap fillings.

3.6.5 Intercultural operation

After transplanting the seedlings, intercultural operations were done whenever required for getting better growth and development of the plants. So, the plants were always kept under careful observation.

3.6.5. a) Gap fillings

Damaged seedlings were replaced by healthy plants from the excess plants within one week.

3.6.5. b) Weeding and mulching

Weeding was done three times after transplanting to keep the crop free from weeds and mulching was done by breaking the crust of the soil for easy aeration and to conserve soil moisture when needed, especially after irrigation.

3.6.5. c) Irrigation and drainage

The young seedlings in the field were irrigated just after transplanting. Irrigation was provided by a watering can and or hose pipe when needed throughout the growing time mainly after top dressing and after weeding. At this time care was taken so that irrigated water could not pass from one plot to another. At the time of irrigation the soil was made saturated with water. After rainfall, excess water was drained when necessary.

3.6.5. d) Protection of plants

Preventive measure was taken against the soil borne insects. For the prevention of Cutworm (*Agrotis ipsilon*), soil treatment was done with Furadan 3 G @ 20 kg ha^{-1}. Few days after transplanting, some plants were attacked by purple blotch disease caused by *Alternaria porri*. It was controlled by spraying Rovral 50 WP two times at 15 days interval after transplanting.

3.7 Harvesting

The crop was harvested on 07 August 2007 according to their attainment of maturity showing the sign of drying out of most of the leaves and collapsing at the neck of the bulbs.

3.8 Collection of data

Data collection were done from the sample plants on the following parameters at the time of experiment –

1. Plant height (cm)
2. Leaf length (cm)
3. Number of leaves $plant^{-1}$
4. Diameter of bulb (cm)
5. Length of bulb (cm)
6. Weight of single bulb (g)
7. Yield of bulb (t ha^{-1})
8. Stover yield (t ha^{-1})
9. Dry matter yield (t ha^{-1})

3.8.1 Plant height (cm)

The height of the randomly selected five plants in each plot was measured after harvesting. The height was measured in centimeter (cm) from the bottom of the bulb to the tip of the longest leaf and average height of the selected five plants was taken to observe the rate of growth.

3.8.2 Leaf length (cm)

The length of leaf was measured in centimeter (cm) from pseudostem to the tip of the leaf from five randomly selected plants after harvesting and their average length was recorded.

3.8.3 Number of leaves plant^{-1}

Number of leaves plant^{-1} was counted after harvesting. Five plants were selected randomly from each plot and averaged.

3.8.4 Diameter of bulb (cm)

After harvesting the diameter of bulbs were measured at the middle portion of bulb from five randomly selected plants with a slide calipers and averaged.

3.8.5 Length of bulb (cm)

Length of harvested bulbs was measured with a slide calipers from the neck to the bottom of the bulb from five randomly selected plants and their average was taken.

3.8.6 Weight of individual bulb (g)

After harvesting five plants were randomly selected from each unit plot. By cutting off the pseudostem of each plant the top was removed and keeping only 1.5 cm with the bulb. Five bulbs were weighed in an electronic balance and their average was considered as the single bulb weight and expressed in gram (g).

3.8.7 Yield of bulb (kg $plot^{-1}$)

Pseudostem and all the leaves were removed from the plants remaining only 1.5 cm neck. Then with a simple balance bulbs weight were taken in kilogram (kg) from each unit plot separately.

3.8.8 Yield of bulb (t ha^{-1})

Yield obtained from each unit plot was converted to get yield in tones ha^{-1}

3.8.9 Dry matter yield (t ha^{-1})

For determination of dry matter yield, sliced fresh onion bulbs and leaves from selected five plants were kept in an oven at 70^{0}C temperature for drying. It took 48 hours to reach the constant weight. Three replications were used for the determination of dry matter content and their average was taken and calculated to find out the dry matter yield.

3.9 Collection of samples

3.9.1 Soil Sample

The initial soil sample was collected randomly from different spots of the field selected for the experiment at 0-15 cm depth before the land preparation and mixed thoroughly to make a composite sample for analysis. Post harvest soil samples were collected from each plot at 0-15 cm depth on 8 August 2007. The samples were air-dried, ground and sieved through a 2 mm (10 meshes) sieve and kept for analysis.

3.9.2 Plant sample

Plant samples were collected from every individual plot for laboratory analysis at the harvesting stage of the crop. Five plants were randomly selected from each plot to record data. After recording data bulbs and leaves were separated and then samples were dried in the electronic oven at 70^0 C for 48 hours. After that the samples were ground in an electric grinding machine and stored for chemical analysis. The plant samples were collected by avoiding the border effect for the highest precision. For this the outer two rows and the outer plants of the middle rows were avoided.

3.10 Soil sample analysis

The initial and post harvest soil samples were analyzed for both physical and chemical properties. The properties studied included texture, pH, organic matter, total N, available P, exchangeable K and available S. The soil was analyzed by the following standard methods:

3.10.1 Particle size analysis

Particle size analysis of soil sample was done by hydrometer method as outlined by Day (1965) and the textural class was ascertained using USDA textural triangle.

3.10.2 Soil pH

Soil pH was determined by glass electrode pH meter in soil- water suspension having soil: water ratio of 1: 2.5 as outlined by Jackson (1958).

3.10.3 Organic carbon

Soil organic carbon was determined by wet oxidation method described by Walkley and Black (1935).

3.10.4 Organic matter

The organic matter content was determined by multiplying the percent organic carbon with Van Bemmelen factor 1.73 (Piper, 1950).

3.10.5 Total nitrogen

Total nitrogen of soil samples were estimated by Micro-Kjeldahl method where soils were digested with 30% H_2O_2, conc. H_2SO_4 and catalyst mixture (K_2SO_4: $CuSO_4$. $5H_2O$: Selenium powder in the ratio of 100: 10: 1, respectively). Nitrogen in the digest was determined by distillation with 40% NaOH followed by titration of the distillate absorbed in H_3BO_3 with 0.01 N H_2SO_4 (Bremner and Mulvaney, 1982).

3.10.6 Available phosphorous

Available phosphorous was extracted from the soil by shaking with 0.5 M $NaHCO_3$ solution of pH 8.5 (Olsen *et al.*, 1954). The phosphorous in the extract was then determined by developing blue color using $SnCl_2$ reduction of phosphomolybdate complex. The absorbance of the molybdophosphate blue color was measured at 660 nm wave length by spectrophotometer and available P was calculated with the help of a standard curve.

3.10.7 Exchangeable potassium

Exchangeable potassium in the soil sample was extracted with 1N neutral ammonium acetate (NH_4OAc) and the potassium content was determined at 766 nm wave length by flame photometer (Black, 1965).

3.10.8 Available sulphur

Available sulphur was extracted from the soil with Ca $(H_2PO_4)_2.H_2O$ (Fox *et al.*, 1964). Sulphur in the extract was determined by the turbidimetric method as described by Hunt (1980) using a Spectrophotometer at 420 nm wave length (LKB Novaspec, 4049).

3.11 Chemical analysis of plant sample

3.11.1 Digestion of plant samples with nitric-perchloric acid mixture

An amount of 0.5 g of sub-sample was taken into a dry clean 100 ml Kjeldahl flask. 10 ml of di-acid mixture (HNO_3, $HClO_4$ in the ratio of 2:1) was added and kept for few minutes. Then, the flask was heated at a temperature rising slowly to 200°C. Heating was instantly stopped as soon as the dense white fumes of $HClO_4$ occurred and after cooling, 6 ml of 6N HCl were added to it. The content of the flask was boiled until they became clear and colorless. This digest was used for determining P, K and S.

3.11.2 Phosphorous

Phosphorous in the digest was determined by ascorbic acid blue color method (Murphy and Riley, 1962) with the help of a Spectrophotometer (LKB Novaspec, 4049).

3.11.3 Potassium

Potassium content in the digested plant sample was determined by flame photometer.

3.11.4 Sulphur

Sulphur content in the digest was determined by turbidimetric method as described by Hunt (1980) using a Spectrophotometer (LKB Novaspec, 4049).

3.11.5 Nitrogen

Plant samples were digested with 30% H_2O_2, conc. H_2SO_4 and a catalyst mixture (K_2SO_4: $CuSO_4.5H_2O$: Selenium powder in the ratio of 100: 10: 1, respectively) for the determination of total nitrogen by Micro-Kjeldahl method. Nitrogen in the digest was determined by distillation with 40% NaOH followed by titration of the distillate absorbed in H_3BO_3 with 0.01 N H_2SO_4 (Bremner and Mulvaney, 1982).

3.12 Chemical analysis of vermicompost sample

Vermicompost was analyzed for organic matter, total N, available P, K and S contents following the methods used for plant and soil analysis. Vermicompost contained 11.06% organic matter, 0.64% total N, 0.0225% available P, 0.0783% available K and 0.0313% available S.

3.13 Statistical analysis

The data obtained from the experiment were analyzed statistically using MSTAT computer package program to find out the significance of the difference among the treatments. The mean values of all the treatment were calculated and analysis of variances for all the characters was performed by the 'F' (variance ratio) test. The significance of the differences among the pairs of treatment means was estimated by the Duncan Multiple Range Test (DMRT) at 1% and 5% level of probability (Gomez and Gomez, 1984) for the interpretation of results.

Chapter 4
Results and Discussion

RESULTS AND DISCUSSION

The results obtained on the effect of integrated use of nitrogen supplied from urea, cowdung and vermicompost on different yield attributes, yield and nutrient concentrations in the plants of summer onion are presented and discussed in this chapter.

4.1 Growth parameter of summer onion as influenced by integrated use of nitrogen supplied from urea, cowdung and vermicompost

4.1.1 Plant height

The effect of integrated use of nitrogen supplied from urea, cowdung and vermicompost on plant height of summer onion are presented in Table 2. A significant variation was observed on plant height of summer onion when the field was incorporated with nitrogen. Application of N influenced plant height positively. Among the treatments, urea with cowdung treated plots gave higher plant height compared to urea with vermicompost treated plots. The highest plant height (39.25 cm) was observed in T_5 where 80 kg N supplied from urea and 40 kg N substituted by CD followed by T_6 (80 kg N supplied from urea + 40 kg N substituted by VC) with the value of 37.82 cm and the difference was statistically significant. On the contrary, the lowest plant height (24.25 cm) was observed in the T_1 (control) treated plot receiving no organic or inorganic fertilizer. Treatment receiving full dose of N from urea (T_2), cowdung (T_{11}) and vermicompost (T_{12}) alone had significantly lower plant height compared to those receiving N from urea with cowdung and urea with vermicompost that is the plots received N from the integrated use of organic and inorganic sources. Moderately similar result was found by Reddy and Reddy (2005).

They observed that plant height of onion increased significantly with increasing levels of vermicompost (from 10 to 30 t ha^{-1}) and nitrogen fertilizer (from 50 to 200 kg ha^{-1}). Haque *et al.* (2004) stated that plant height of onion increased with increasing rates of N up to 125 kg ha^{-1} and decreased thereafter. Plant height of onion showed increasing trends up to the highest nitrogen rate (Singh *et al.*, 2004). Jayathilake *et al.* (2003) found that the plant height of summer onion was significantly increased with the application of biofertilizers in combination with 50% N applied through organic manure (vermicompost or farmyard manure) while the other 50% of recommended N and 100% PK were supplied through chemical fertilizer which was significantly superior to the application of chemical fertilizer alone or application of organic manure alone.

4.1.2 Number of leaves $plant^{-1}$

Statistically significant variation was not recorded on number of leaves $plant^{-1}$ of summer onion when the effect of integrated use of nitrogen from urea, cowdung and vermicompost were compared (Table 2). Among the twelve treatments number of leaves per plant ranges from 4.98 to 6.00. The highest number of leaves $plant^{-1}$ (6.00) was observed in treatment T_2 (120 kg N supplied from urea) followed by T_3, T_{11} and T_{12} with the value of 5.67. On the other hand, the minimum number of leaves (4.98) per plant was found in T_1 treated plots, where no fertilizer was applied. This result is in agreement with the findings of El-Oksh *et al.* (1993). They observed that N application had no significant effect on number of leaves of onion. Singh *et al.* (1989) stated that a combination of 120 kg N with green manure gave the tallest plants and the maximum number of leaves per plant. Reddy and Reddy (2005) also observed that highest number of leaves per plant in onion was recorded with 30 t ha^{-1} vermicompost with 200 kg N ha^{-1}. Kumar *et al.* (1998) recorded that submission of N at 150 kg ha^{-1} gave the best results with regard to number of leaves $plant^{-1}$ of onion. Application of 80 kg N increased the number of leaves per plant over 40 kg N ha^{-1} (Nehra *et al.*, 1988). Kumar *et al.* (2001) found that 130 kg N ha^{-1} resulted in the highest number of green leaves $plant^{-1}$ of onion.

4.1.3 Leaf length

Twelve different treatments were taken to evaluate the effect of integrated use of nitrogen supplied from urea, cowdung and vermicompost on the leaf length of summer onion (Table 2). It revealed that the performances of the most of the treatment differed significantly from each other. The longest leaf length (34.35 cm) was observed when the field was incorporated with 80 kg N from urea and 40 kg N from cowdung (T_5) followed by treatment T_6 (80 kg N supplied from urea and 40 kg N substituted by vermicompost) with the value of 32.16 cm. The minimum leaf length (21.20 cm) was recorded in the treatment T_1 (control) receiving no organic or inorganic fertilizer. Leaf length decreased due to the sole application of urea, cowdung and vermicompost compared to their integrated use. Kumar *et al.* (1998) also recorded longest leaf of onion with the application of N at 150 kg ha^{-1}. Singh *et al.* (1997) found that combination of different sources of organic manures viz. cowdung, farmyard manure, vermicompost and inorganic fertilizer increased the leaf length of onion compared with their sole application and control treatment. Singh *et al.* (2004) found that application of the highest nitrogen rate (150 kg ha^{-1}) gave the highest leaf length (28.22 cm) of onion. Meena *et al.* (2007) stated the highest N level (150 kg ha^{-1}) gave the maximum length of the longest leaf in comparison to its lower levels, i.e. 50 and 100 kg N ha^{-1}.

Table 2. Effect of integrated use of nitrogen supplied from urea, cowdung and vermicompost on the growth parameter of summer onion

Treatments	Plant height (cm)	Number of Leaves per plant	Leaf length (cm)
T_1	24.25 h	4.98	21.20 h
T_2	32.57 de	6.00	26.94 c-g
T_3	37.18 abc	5.67	30.97 abc
T_4	35.56 bcd	5.00	30.16 a-d
T_5	39.25 a	5.00	34.35 a
T_6	37.82 ab	5.00	32.16 ab
T_7	35.15 bcd	5.33	29.05 b-e
T_8	34.18 cd	5.33	27.83 b-f
T_9	30.88 ef	5.33	25.91 d-h
T_{10}	29.10 fg	5.00	25.15 e-h
T_{11}	28.35 fg	5.67	23.33 fgh
T_{12}	26.70 gh	5.67	22.67 gh
Level of significance	0.01	NS	0.01

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT

T_1 - No fertilizer
T_2 - 120 kg N supplied from urea
T_3 - 100 kg N supplied from urea + 20 kg N substituted by CD
T_4 - 100 kg N supplied from urea + 20 kg N substituted by VC
T_5 - 80 kg N supplied from urea + 40 kg N substituted by CD
T_6 - 80 kg N supplied from urea + 40 kg N substituted by VC
T_7 - 60 kg N supplied from urea + 60 kg N substituted by CD
T_8 - 60 kg N supplied from urea + 60 kg N substituted by VC
T_9 - 40 kg N supplied from urea + 80 kg N substituted by CD
T_{10} - 40 kg N supplied from urea + 80 kg N substituted by VC
T_{11} - 120 kg N supplied from CD
T_{12} - 120 kg N supplied from VC

4.2 Yield and yield attributing characters of summer onion as influenced by integrated use of nitrogen supplied from urea, cowdung and vermicompost

4.2.1 Bulb diameter

Bulb diameter of summer onion as influenced by the integrated use of nitrogen supplied from urea, cowdung and vermicompost is presented in Table 3. It revealed from the study that nitrogen had a positive role on bulb diameter of summer onion. There was a significant variation of bulb diameter among the 12 different treatments. Result showed that treatment T_5 (80 kg N supplied from urea + 40 kg N substituted by CD) gave the highest bulb diameter (3.79 cm) followed by the treatment T_6 (80 kg N supplied from urea + 40 kg N substituted by VC) and treatment T_3 (100 kg N supplied from urea + 20 kg N substituted by CD). Treatments T_6 and T_3 are statistically alike. Lowest bulb diameter (2.44 cm) was obtained under T_1 (control) treatment. It is observed that integrated application of nitrogen from organic and inorganic sources increased bulb diameter. Treatment receiving 120 kg N ha^{-1} only from cowdung or vermicompost was better only when compared to control. Similar result was obtained by Singh *et al.* (1997). They stated that the maximum bulb diameter was found when farmyard manure was applied in combination with 100 kg N + 25 kg P + 25 kg K ha^{-1}. Again, Jayathilake *et al.* (2003) observed that the bulb diameter of summer onion significantly increased with the application of biofertilizers in combination with 50% N applied through vermicompost or farmyard manure while the rest 50% of recommended N was supplied through chemical fertilizer. Singh *et al.* (1989) found that a combination of 120 kg N with green manure gave the maximum bulb diameter of summer onion. Pande and Mundra (1971) stated that application of nitrogen significantly increased the diameter of bulbs compared with the control treatments.

Haque *et al.* (2004) affirmed that bulb diameter increased with the application of N up to 125 kg ha^{-1}.

4.2.2 Bulb length

Integrated application of nitrogen supplied from urea, cowdung and vermicompost showed significant variations in respect of bulb length of summer onion (Table 3.) Bulb length increased due to the integration of inorganic and organic fertilizer compared to their sole submission. Among the different treatments, the highest bulb length (2.79 cm) was achieved under treatment T_5 where 80 kg N supplied from urea and 40 kg N substituted by cowdung which was statistically identical with the treatment T_6 (80 kg N supplied from urea + 40 kg N substituted by VC) with a value of 2.74 cm. On the contrary, control treated plot (T_1) gave the lowest bulb length (2.40 cm) of summer onion. The treatment receiving 120 kg nitrogen ha^{-1} from only urea (T_2) was better than the treatment receiving 120 kg N from only cowdung (T_{11}) or 120 kg N only from vermicompost (T_{12}). Treatments T_{11} and T_{12} showed statistically similar result. Probably integration of organic and inorganic sources of N supplied the necessary requirements for the proper vegetative growth of plant that helps in obtaining the highest bulb length. Hussain *et al.* (1988) reported that organic manures increased the efficiency of chemical fertilizers. Similar views were reported by Reddy and Reddy (2005). They observed that combination of 30 t ha^{-1} vermicompost and 150 kg N ha^{-1} gave the highest bulb length of onion. Pande and Mundra (1971) also stated that the bulb length of summer onion significantly increased by the application of nitrogen. Bulb length of onion increased with increasing rates of N up to 125 kg ha^{-1} (Haque *et al.*, 2004).

Table 3. Effect of integrated use of nitrogen supplied from urea, cowdung and vermicompost on the yield and yield attributing characters of summer onion

Treatments	Diameter of bulb (cm)	Length of bulb (cm)	Bulb weight (gm)	Bulb yield ($t\ ha^{-1}$)	Stover yield ($t\ ha^{-1}$)
T_1	2.44 h	2.40 g	14.90 i	5.96 h	2.61 g
T_2	2.87 ef	2.54 def	24.10 def	9.64 cde	3.67 d
T_3	3.44 b	2.69 abc	28.25 abc	11.30 ab	5.11 ab
T_4	3.19 c	2.65 bcd	27.10 a-d	10.84 abc	4.82 b
T_5	3.79 a	2.79 a	30.40 a	12.16 a	5.46 a
T_6	3.56 b	2.74 ab	29.10 ab	11.64 a	5.38 a
T_7	3.14 cd	2.63 bcd	26.80 b-e	10.72 a-d	4.41 c
T_8	2.98 de	2.59 cde	25.25 c-f	10.10 b-e	4.11 c
T_9	2.79 efg	2.50 efg	23.45 efg	9.38 def	3.57 de
T_{10}	2.71 fg	2.48 efg	21.90 fgh	8.76 efg	3.29 ef
T_{11}	2.65 g	2.46 fg	20.38 gh	8.15 fg	3.06 f
T_{12}	2.63 gh	2.43 fg	18.55 h	7.42 g	2.96 f
Level of significance	0.01	0.01	0.01	0.01	0.01

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT

T_1 - No fertilizer
T_2 - 120 kg N supplied from urea
T_3 - 100 kg N supplied from urea + 20 kg N substituted by CD
T_4 - 100 kg N supplied from urea + 20 kg N substituted by VC
T_5 - 80 kg N supplied from urea + 40 kg N substituted by CD
T_6 - 80 kg N supplied from urea + 40 kg N substituted by VC
T_7 - 60 kg N supplied from urea + 60 kg N substituted by CD
T_8 - 60 kg N supplied from urea + 60 kg N substituted by VC
T_9 - 40 kg N supplied from urea + 80 kg N substituted by CD
T_{10} - 40 kg N supplied from urea + 80 kg N substituted by VC
T_{11} - 120 kg N supplied from CD
T_{12} - 120 kg N supplied from VC

4.2.3 Bulb weight

Onion plants showed a significant variation in respect of bulb weight (g) when nitrogen was applied combinedly from different organic and inorganic sources (urea, cowdung and vermicompost) is presented in Table 3. There was a remarkable variation in bulb weight of summer onion among the twelve different treatments. The variation of bulb weight was recorded due to the application of nitrogen from different sources of organic and inorganic fertilizers. Result revealed that treatment T_5 where 80 kg N supplied from urea and 40 kg N substituted by cowdung gave the highest (30.40 g) bulb weight followed (29.10 g) closely by treatment T_6 (80 kg N supplied from urea and 40 kg N substituted by VC) which was statistically identical with treatment T_6. Treatment T_3 and T_4 also showed statistically similar performance with treatment T_5. In contrast, the lowest bulb weight (14.90 g) was obtained from T_1 (control) treatment. Like bulb diameter and bulb length, bulb weight was increased by the integrated use of nitrogen compared to sole use of nitrogen as urea. However, treatment T_9 (40 kg ha^{-1} N supplied from urea and 80 kg substituted by CD) and T_{10} (40 kg ha^{-1} N supplied from urea and 80 kg substituted by VC) gave inferior results compared to treatment T_2 where 120 kg ha^{-1} N supplied only from urea. Singh *et al.* (2001) also observed partially related results in *kharif* onion (*Allium cepa*) cv. N53. They found that the average bulb weight increased significantly up to 120 kg N ha^{-1} and FYM at 10 t ha^{-1}. Haque *et al.* (2004) stated that application of 125 kg N ha^{-1} increased bulb weight. Singh *et al.* (2004) recorded the highest fresh weight of bulb (47.48 g) with 150 kg N ha^{-1}. Hussaini and Amans (2000) suggested that nitrogen application positively increased the average bulb weight and number of large bulbs per plot.

4.2.4 Bulb yield

The effect of integrated use of nitrogen from different sources such as urea, cowdung and vermicompost showed statistically significant variations (Table 3) in respect of bulb yield. The highest bulb yield of 12.16 t ha^{-1} was recorded in treatment T_5 receiving 80 kg N from urea and 40 kg N substituted by cowdung followed by the treatments T_6, T_3, T_4 and T_7 which were statistically identical. Treatments receiving 120 kg N from urea (T_2), 40 kg N from urea and rest of the 80 kg N substituted by CD or VC (T_9 and T_{10}) produced comparable yields but were significantly lower than the treatments T_5 and T_6. Treatments receiving N solely from CD and VC (T_{11} and T_{12}) produced lower bulb yield compared with the other fertilizer treatments. The lowest bulb yield (5.96 t ha^{-1}) was obtained from T_1 (control) treatment. Cowdung showed better performance compared to vermicompost may be due to the slower mineralization of vermicompost. Similar results were achieved by Abbey and Kanton (2004). They stated that onion bulb yield due to the FYM with IF (inorganic fertilizer) treatment was 34.1% higher than that for FYM, and 4.6% higher than that for the IF treatment. Application of FYM either alone or in combination with IF significantly ($P < 0.05$) reduced bulb rot and use of both FYM with IF at half their recommended rates increased onion bulb yield and reduced field defects. Singh *et al.* (1997) found that the combination of green manure, farmyard manure (25 t ha^{-1}), vermicompost (2 t ha^{-1}) and 100 kg N ha^{-1}, yields were increased to 323.1 q ha^{-1}. Pandey *et al.* (1992) observed that both 80 and 120 kg N ha^{-1} gave significantly higher yields of summer onion than the lower fertilizer rates. Gupta *et al.* (1983) found that combination of 50% N from farmyard manure and 50% N from urea gave 30% higher grain yield of pearl millet. Reddy and Reddy (2005) noticed that yield of onion increased significantly with increasing levels of vermicompost and nitrogen fertilizer and the highest yield was recorded with vermicompost at 30 t ha^{-1} with 150 kg N ha^{-1}. Singh *et al.* (2001) stated that integrated application of 150 kg N with 9 t FYM ha^{-1} gave the highest bulb yield. Dixit (1997) reported that increasing nitrogen application rates increased bulb yields of summer onion up to 120 kg N ha^{-1}. Higher yields were also obtained with the higher rate of farmyard manure used. Application of 120 kg N ha^{-1} with 20 t ha^{-1} farmyard manure increased yields by 42.79% compared to the control.

4.2.5 Stover yield

Like bulb yield, the stover yield of summer onion was also significantly influenced by the integrated use of nitrogen from urea, cowdung and vermicompost (Table 3). Highest stover yield (5.46 t ha^{-1}) was found in the treatment T_5 followed by the treatment T_6 (5.38 t ha^{-1}) which are statistically similar. Treatment receiving 100% N from cowdung (T_{11}) and vermicompost (T_{12}) was only better than the control (T_1) with respect to stover yield. These results indicated that in the given experimental conditions, combined application of cowdung with urea and vermicompost with urea significantly improved stover yield of summer onion only when the N contribution from urea was 50% or more. Cowdung and vermicompost alone did not prove as effective as urea alone. Urea is a quick and more potent source of nitrogen for increasing the vegetative growth as compared to manure but the combination of the two sources was found more effective up to a certain limit. Das *et al.* (2002) found that the highest results in terms of straw and crop yields were obtained from 50% vermicompost with 50% chemical fertilizers. Bangar *et al.* (1990) reported that compost increased starw yield significantly.

4.2.6 Dry matter yield of bulb

Onion plants showed significant variations in respect of dry matter yield of bulb (t/ha) when nitrogen was applied from different organic and inorganic fertilizers (urea, cowdung and vermicompost) are presented in Figure 6 and Appendix Table 2. The performances of the most of the treatment differ significantly from each other. Treatment T_5 (80 kg N supplied from urea + 40 kg N substituted by cowdung) showed the highest (2.38 t ha^{-1}) dry matter yield of bulb which was statistically similar with the treatment T_6 (80 kg N supplied from urea + 40 kg N substituted by vermicompost) having a value of 2.22 t ha^{-1}. In contrast, the treatment T_1 (control) gave the lowest (0.89 t ha^{-1}) dry matter yield of bulb. The highest dry matter yield of bulb might be due to the favorable uptake of nutrient by integrated application of urea with cowdung and urea with vermicompost that reduced the moisture content of bulb and improved dry matter content. Hedge (1988) stated that dry matter production in bulbs was increased due to the more uptakes of N, P, K, Ca and Mg nutrients. Singh *et al.* (1994) found that total dry matter production were better for plots treated with N at 80 kg/ha. Kumar *et al.* (1998) recorded that N at 150 kg ha^{-1} gave the best bulb fresh weight and dry weight of onion. Singh *et al.* (1997) found that combination of farmyard manure (25 t ha^{-1}) with 100 kg N + 25 kg P + 25 kg K ha^{-1} increased the dry matter production of bulb. Dry matter accumulation in bulb and bulb quality significantly increased by the application of 50% N through organic manure (vermicompost or FYM) while the other 50% of recommended N and 100% PK were supplied through chemical fertilizers in association with biofertilizers (Jayathilake *et al.*, 2003). Kumar *et al.* (2006) found that the dry matter yield of bulb was increased significantly over the control with the application of 150 kg N ha^{-1}.

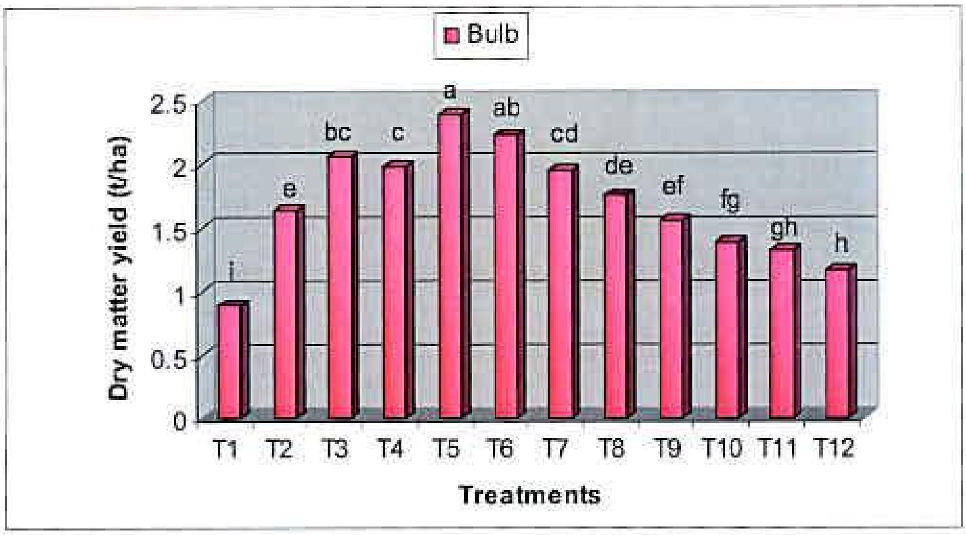


Figure 6. Effect of integrated use of nitrogen supplied from urea, cowdung and vermicompost on the dry matter yield of bulb

4.2.7 Dry matter yield of leaf

A statistically significant variation was observed in the dry matter yield of leaves of summer onion when different combinations of nitrogen were applied from different organic or inorganic sources (Figure 7 and Appendix Table 2). Similar to bulb, the maximum (0.62 t ha^{-1}) dry matter yield of leaves were found in treatment T_5 (80 kg N supplied from urea + 40 kg N substituted by cowdung) followed (0.60 t ha^{-1}) by the treatment T_6 (80 kg N supplied from urea + 40 kg N substituted by vermicompost). Treatment T_3, T_4, T_6 and T_7 also gave statistically identical performance with treatment T_5. Conversely, the lowest (0.19 t ha^{-1}) dry matter yield was found in control (T_1) treatment where no fertilizer was applied.

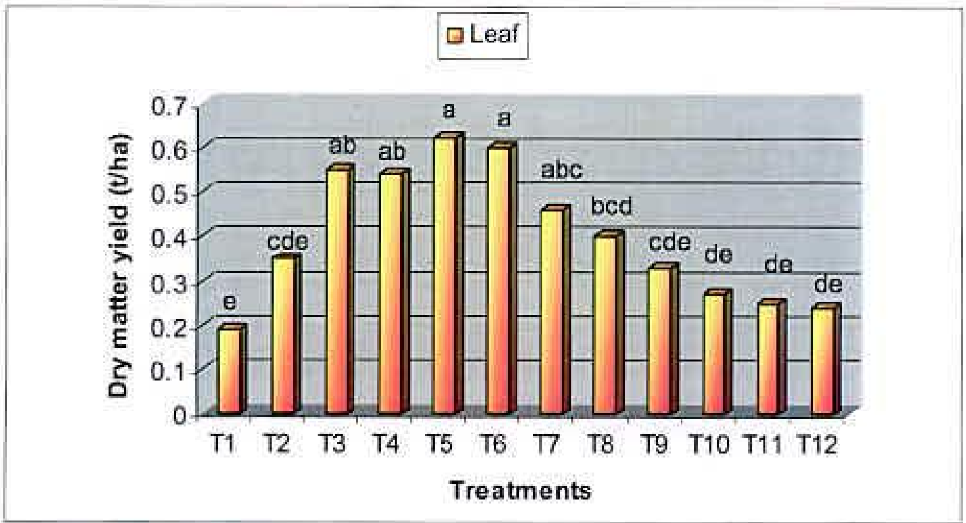


Figure 7. Effect of integrated use of nitrogen supplied from urea, cowdung and vermicompost on the dry matter yield of leaf

4.3 Nutrient concentrations in the bulb of summer onion as influenced by integrated use of nitrogen supplied from urea, cowdung and vermicompost

4.3.1 Nitrogen content

Table 4 presents the effect of integrated use of nitrogen supplied from urea, cowdung and vermicompost in response to nitrogen content in bulb at the harvest of summer onion. There was a significant variation in the nitrogen content of bulb among the different treatments. The highest nitrogen concentration (2.30%) was recorded in the treatment T_5 (80 kg N supplied from urea + 40 kg N substituted by CD) which was statistically identical with treatment T_6 (80 kg N supplied from urea + 40 kg N substituted by VC). On the other hand, significantly lowest nitrogen concentration

(1.41%) was found in treatment T_1 (control). These observations are in accordance with those of Metwally and Khamis (1998) who reported that combination of organic and inorganic N resulted in greater values of apparent net N release than those obtained when each was applied singly. They also observed that the best mixture ratio between organic and inorganic N sources was 1: 1, which partially agree with the present findings. Hedge (1988) stated that nitrogen fertilization increased the N, Ca and Mg concentrations in the bulb of onion. Maximum nitrogen content by the bulb of summer onion was observed when organic nitrogen was applied with inorganic nitrogen up to a certain limit.

4.3.2 Phosphorus content

The phosphorus content of bulb as improved by different combinations of nitrogen from urea, cowdung and vermicompost showed a statistically significant variation is presented in Table 4. With the twelve different treatments, the highest phosphorous concentration in bulb (0.185%) was recorded under the treatment T_5 (80 kg N supplied from urea + 40 kg N substituted by CD). Statistically identical performance was observed in treatment T_6 (80 kg N supplied from urea + 40 kg N substituted by VC) and treatment T_3 (100 kg N supplied from urea + 20 kg N substituted by VC). On the contrary, the lowest phosphorous concentration (0.055%) was found in control treated plot (T_1). Hedge (1988) also reported that P and K concentrations decreased with nitrogen fertilization. Kumar *et al*. (2006) found that the phosphorus content of bulb was increased significantly over the control with the application of 150 kg N/ha.

Table 4. Effect of integrated use of nitrogen supplied from urea, cowdung and vermicompost on the nutrient concentrations in the bulb of summer onion

Treatments	Concentration (%)			
	Nitrogen	Phosphorus	Potassium	Sulphur
T_1	1.41 j	0.055 h	0.89 h	0.66 f
T_2	1.85 ef	0.103 def	1.36 c-f	0.77 c-f
T_3	2.19 ab	0.166 ab	1.56 abc	0.88 abc
T_4	2.10 bc	0.147 bc	1.50 a-d	0.85 a-d
T_5	2.30 a	0.185 a	1.71 a	0.96 a
T_6	2.24 a	0.173 ab	1.62 ab	0.91 ab
T_7	2.01 cd	0.126 cd	1.48 a-d	0.81 b-e
T_8	1.93 de	0.112 de	1.42 b-e	0.79 b-f
T_9	1.78 fg	0.093 efg	1.28 d-g	0.75 c-f
T_{10}	1.69 gh	0.085 efg	1.21 efg	0.73 def
T_{11}	1.61 hi	0.078 fg	1.15 fg	0.71 def
T_{12}	1.55 i	0.069 gh	1.10 gh	0.70 ef
Level of significance	0.01	0.01	0.01	0.01

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT

T_1 - No fertilizer
T_2 - 120 kg N supplied from urea
T_3 - 100 kg N supplied from urea + 20 kg N substituted by CD
T_4 - 100 kg N supplied from urea + 20 kg N substituted by VC
T_5 - 80 kg N supplied from urea + 40 kg N substituted by CD
T_6 - 80 kg N supplied from urea + 40 kg N substituted by VC
T_7 - 60 kg N supplied from urea + 60 kg N substituted by CD
T_8 - 60 kg N supplied from urea + 60 kg N substituted by VC
T_9 - 40 kg N supplied from urea + 80 kg N substituted by CD
T_{10} - 40 kg N supplied from urea + 80 kg N substituted by VC
T_{11} - 120 kg N supplied from CD
T_{12} - 120 kg N supplied from VC

4.3.3 Potassium content

Statistically significant variation was recorded regarding potassium concentration in the bulb after harvest of summer onion when different doses of nitrogen applied from urea, cowdung and vermicompost (Table 4). It was revealed from the Table 4 that the performances of the most of the treatment differ significantly from each other. The highest potassium concentration (1.71%) was recorded in treatment T_5 (80 kg N supplied from urea + 40 kg N substituted by CD), which was closely followed (1.62%) by treatment T_6 (80 kg N supplied from urea + 40 kg N substituted by VC). The next highest potassium concentration was achieved in T_3 and T_4 treatment which were also statistically similar with the treatment T_5. Controlled treated plot (T_1) showed significantly lowest potassium concentration (0.89%). It was observed that the combined application of nitrogen increased potassium content of bulb compared to other treatment.

4.3.4 Sulphur content

Effect of integrated use of nitrogen supplied from urea, cowdung and vermicompost on sulphur concentration in the bulb of summer onion is presented in Table 4. There was a statistically remarkable variation in respect of sulphur content in the bulbs after harvest among the 12 different treatments. The highest sulphur concentration (0.96%) was observed in the treatment T_5 (80 kg N supplied from urea + 40 kg N substituted by CD) which was statistically similar with treatment T_6 (80 kg N supplied from urea + 40 kg N substituted by VC) with a value of 0.91%. In contrast, the lowest sulphur concentration (0.66%) was found in treatment T_1 (control). This might be due to the fact that, the combined effect of nitrogen from organic and inorganic sources played positive effect on sulphur accumulation in the bulb of summer onion up to a certain limit.

4.4 Nutrient concentrations in the leaves of summer onion as influenced by integrated use of nitrogen supplied from urea, cowdung and vermicompost

4.4.1 Nitrogen content

Integrated application of nitrogen supplied from urea, cowdung and vermicompost showed significant variations in respect of nitrogen content in the leaves of summer onion after harvest are presented in Table 5. The effect of integrated use of nitrogen revealed that the treatment T_5 (80 kg N supplied from urea + 40 kg N substituted by CD) showed the highest nitrogen concentration (2.91%) in the leaf of summer onion. Statistically identical performance was observed in the treatment T_6 where 80 kg N supplied from urea with 40 kg N substituted by vermicompost. The next highest N content was obtained in treatment T_3 and T_4. On the contrary, significantly lowest nitrogen concentration (2.15%) was recorded in the treatment T_1 where none of the fertilizers was applied. Similar results were found by Metwally and Khamis (1998). They reported that combination of organic and inorganic N resulted in greater values of apparent net N release than those obtained when each was applied singly. Again, Hedge (1988) noticed that the N, Ca and Mg concentrations in the leaf of onion was also increased by the nitrogen fertilization. Probably, maximum nitrogen concentration in the leaf of summer onion was observed when organic nitrogen was applied with inorganic nitrogen up to a certain limit, after that sole application performed better. Kumar *et al*. (2006) also found that the application of 150 kg N ha^{-1} significantly increased the N content in the leaves of onion over the control.

4.4.2 Phosphorus content

The phosphorus content of leaves of summer onion at harvest as influenced by different doses of nitrogen applied from urea, cowdung and vermicompost showed a statistically significant variation (Table 5). The highest phosphorous concentration in leaves (0.183%) was recorded in the treatment T_5 where 80 kg N supplied from urea with 40 kg N substituted by cowdung. On the other hand, the lowest phosphorous concentration (0.053%) was found in treatment T_1 receiving no organic or inorganic fertilizers. The highest content of the nutrient in the plant might be due to application of most favorable rate of organic or inorganic fertilizers in treatment T_5. The application of 150 kg N ha^{-1} significantly increased the phosphorous concentration in the leaves of onion (Kumar *et al.*, 2006).

4.4.3 Potassium content

The leaf of summer onion showed significant variations in respect of potassium concentration after harvest when nitrogen was applied from different organic and inorganic sources (urea, cowdung and vermicompost) are presented in Table 5. Among the different treatments, application of 80 kg N from urea with 40 kg N substituted by cowdung (T_5) showed the highest (2.45%) potassium concentration which was closely followed (2.41%) by treatment T_6 (80 kg N supplied from urea + 40 kg N substituted by VC). The next highest potassium concentration was achieved in T_3 and T_4 treatment. Controlled treated plot (T_1) showed significantly lowest potassium concentration (1.71%). It is observed that all the treatment combination showed statistically similar values of potassium concentration except T_1 and T_{12} treatment.

Table 5. Effect of integrated use of nitrogen supplied from urea, cowdung and vermicompost on the nutrient concentrations in the leaf of summer onion

Treatments	Concentration (%)			
	Nitrogen	Phosphorus	Potassium	Sulphur
T_1	2.15 i	0.053 k	1.71 b	0.63 f
T_2	2.51 efg	0.086 fg	2.22 a	0.76 c-f
T_3	2.75 bc	0.153 c	2.38 a	0.89 abc
T_4	2.69 cd	0.133 d	2.34 a	0.87 a-d
T_5	2.91 a	0.183 a	2.45 a	0.98 a
T_6	2.83 ab	0.166 b	2.41 a	0.94 ab
T_7	2.61 de	0.107 e	2.31 a	0.84 a-e
T_8	2.55 ef	0.093 f	2.27 a	0.79 b-f
T_9	2.46 fgh	0.080 gh	2.19 a	0.74 c-f
T_{10}	2.41 gh	0.073 hi	2.15 a	0.71 def
T_{11}	2.40 gh	0.067 ij	2.11 a	0.69 ef
T_{12}	2.39 h	0.060 jk	2.05 ab	0.68 ef
Level of significance	0.01	0.01	0.01	0.01

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT

T_1 = No fertilizer
T_2 = 120 kg N supplied from urea
T_3 = 100 kg N supplied from urea + 20 kg N substituted by CD
T_4 = 100 kg N supplied from urea + 20 kg N substituted by VC
T_5 = 80 kg N supplied from urea + 40 kg N substituted by CD
T_6 = 80 kg N supplied from urea + 40 kg N substituted by VC
T_7 = 60 kg N supplied from urea + 60 kg N substituted by CD
T_8 = 60 kg N supplied from urea + 60 kg N substituted by VC
T_9 = 40 kg N supplied from urea + 80 kg N substituted by CD
T_{10} = 40 kg N supplied from urea + 80 kg N substituted by VC
T_{11} = 120 kg N supplied from CD
T_{12} = 120 kg N supplied from VC

4.4.4 Sulphur content

Sulphur concentration in the leaves of summer onion after harvest also showed variable response to different doses of nitrogen fertilizer treatments (Table 5). The performances of the most of the treatment differ significantly from each other. The highest sulphur concentration in the leaves (0.98%) was observed in the treatment T_5 (80 kg N supplied from urea + 40 kg N substituted by CD) which was statistically similar with treatment T_6 (80 kg N supplied from urea + 40 kg N substituted by VC) with a value of 0.94%. Treatment T_3, T_4, T_6 also showed statistically identical performance. On the contrary, the lowest sulphur concentration (0.63%) was found in treatment T_1 where any type of fertilizer was not applied. This might be due to the integrated effect of nitrogen from organic and inorganic sources played positive effect on sulphur concentration in the leaves of summer onion up to a certain limit.

4.5 Nutrient uptake by the summer onion plant as influenced by integrated use of nitrogen supplied from urea, cowdung and vermicompost

4.5.1 Nitrogen uptake

Table 6 represents the effect of integrated use of nitrogen from urea, cowdung and vermicompost regarding nitrogen uptake by the summer onion plants at harvest stage. Nitrogen uptake by onion bulb and leaf followed similar pattern in response to various combinations of fertilizer treatments. The results showed that N uptake by onion plant were significantly greater in N fertilized than in the control treatment. The maximum N uptake of 72.78 kg ha^{-1} by onion plant was obtained in treatment T_5 receiving 80 kg N from urea with 40 kg N from cowdung followed by the treatment T_6 where 80 kg N supplied from urea with 40 kg N substituted by vermicompost with a value of 66.71 kg ha^{-1}. Significantly lowest N uptake was obtained in treatment T_{11} and T_{12} receiving full amount of N from cowdung and vermicompost respectively, comparing with the other fertilizer treatments. The minimum N uptake by onion plant (16.64 kg ha^{-1}) was recorded with control treatment (T_1) receiving no fertilizer or manure. These observations are in accordance with those of Zahir and Mian (2006) in case of wheat who reported that combination of organic and inorganic N resulted in superior values of net N release than their single application. Their observation that the best mixture ratio between inorganic and organic N sources was 3: 1, partially agreed with the present study. Hedge (1988) observed that uptake of N, P, K, Ca and Mg in leaves and bulbs generally increased due to higher dry matter production. Kumar *et al.* (2006) also found that the N, P, K and S uptakes were increased significantly over the control with the application of 150 kg N ha^{-1}. Halvorson *et al.* (2002) stated that nitrogen fertilization influenced N uptake of onion. Total leaf-plus-bulb N uptake at final harvest was 80 and 60.5 kg ha^{-1} with nitrogen fertilization and without nitrogen fertilization, respectively.

These results suggested that integrated use of urea with cowdung and urea with vermicompost performed better than the use of urea, cowdung or vermicompost alone in terms of improving N uptake by the summer onion plants even with the fact that the level of applied N was same that is 120 kg N ha^{-1} either alone from urea, cowdung and vermicompost or combinations. The combined application of N 80 kg from urea with 40 kg N from cowdung closely followed by N 80 kg from urea with 40 kg N from vermicompost based on net N contribution produced excellent results.

Table 6. Effect of integrated use of nitrogen supplied from urea, cowdung and vermicompost on the N uptake by summer onion plant

Treatments	N uptake (kg ha^{-1})		
	Bulb	Leaf	Total
T_1	12.55 l	4.09 k	16.64 l
T_2	30.15 g	8.79 g	38.94 g
T_3	45.11 c	15.13 c	60.24 c
T_4	41.58 d	14.53 d	56.11 d
T_5	54.74 a	18.04 a	72.78 a
T_6	49.73 b	16.98 b	66.71 b
T_7	38.99 e	12.01 e	51.00 e
T_8	33.78 f	10.20 f	43.98 f
T_9	27.59 h	8.12 h	35.71 h
T_{10}	23.32 i	6.51 i	29.83 i
T_{11}	21.25 g	6.00 ij	27.25 j
T_{12}	17.98 k	5.74 j	23.72 k
Level of significance	0.01	0.01	0.01

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT

T_1 - No fertilizer
T_2 - 120 kg N supplied from urea
T_3 - 100 kg N supplied from urea + 20 kg N substituted by CD
T_4 - 100 kg N supplied from urea + 20 kg N substituted by VC
T_5 - 80 kg N supplied from urea + 40 kg N substituted by CD
T_6 - 80 kg N supplied from urea + 40 kg N substituted by VC
T_7 - 60 kg N supplied from urea + 60 kg N substituted by CD
T_8 - 60 kg N supplied from urea + 60 kg N substituted by VC
T_9 - 40 kg N supplied from urea + 80 kg N substituted by CD
T_{10} - 40 kg N supplied from urea + 80 kg N substituted by VC
T_{11} - 120 kg N supplied from CD
T_{12} - 120 kg N supplied from VC

4.5.2 Phosphorus uptake

Phosphorus uptake by summer onion plants was significantly influenced due to the addition of different combinations of nitrogen from urea, cowdung and vermicompost (Table 7). Application of 80 kg ha^{-1} N from urea with 40 kg from cowdung (T_5) showed the highest phosphorus uptake by onion plant (5.53 kg ha^{-1}) followed by the treatment T_6 (80 kg N supplied from urea + 40 kg N substituted by VC) with a value of 4.84 kg ha^{-1}. On the contrary, the lowest phosphorus uptake (0.59 kg ha^{-1}) was recorded in treatment T_1 (control). Jat and Ahlawat (2004) reported that application of vermicompost to chickpea improved N and P uptake by the cropping system over no vermicompost treatment.

4.5.3 Potassium uptake

Effect of integrated use of nitrogen from urea, cowdung and vermicompost showed significant difference with respect to potassium uptake by summer onion plant is presented in Table 8. K uptake by the bulb and leaf of summer onion showed similar performance in different treatment combinations. The result revealed that potassium uptake by summer onion plant was maximum (55.88 kg ha^{-1}) in the treatment T_5 where 80 kg N supplied from urea with 40 kg N substituted by cowdung. The next higher (50.42 kg ha^{-1}) potassium uptake was obtained in treatment T_6 (80 kg N supplied from urea and 40 kg N substituted by VC). In contrast, control treated plot (T_1) showed lowest (11.17 kg ha^{-1}) potassium uptake by summer onion plant. It might be, due to the fact that integrated application of nitrogen showed positive effect compared to their sole effect on potassium uptake by onion plant. Singh *et al.* (2005) also point out that the maximum potassium uptake was recorded with the application of 60 kg N ha^{-1} plus Azolla treatment.

Table 7. Effect of integrated use of nitrogen supplied from urea, cowdung and vermicompost on the P uptake by summer onion plant

Treatments	P uptake (kg ha^{-1})		
	Bulb	Leaf	Total
T_1	0.49 j	0.10 g	0.59 j
T_2	1.68 fg	0.30 ef	1.98 g
T_3	3.42 bc	0.84 bc	4.26 c
T_4	2.91 cd	0.72 c	3.63 d
T_5	4.40 a	1.13 a	5.53 a
T_6	3.84 b	1.00 ab	4.84 b
T_7	2.44 de	0.49 d	2.93 e
T_8	1.96 ef	0.37 de	2.33 f
T_9	1.44 fgh	0.26 efg	1.70 g
T_{10}	1.17 ghi	0.20 efg	1.37 h
T_{11}	1.03 hij	0.17 fg	1.20 hi
T_{12}	0.80 ij	0.14 fg	0.95 i
Level of significance	0.01	0.01	0.01

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT

T_1 - No fertilizer
T_2 - 120 kg N supplied from urea
T_3 - 100 kg N supplied from urea + 20 kg N substituted by CD
T_4 - 100 kg N supplied from urea + 20 kg N substituted by VC
T_5 - 80 kg N supplied from urea + 40 kg N substituted by CD
T_6 - 80 kg N supplied from urea + 40 kg N substituted by VC
T_7 - 60 kg N supplied from urea + 60 kg N substituted by CD
T_8 - 60 kg N supplied from urea + 60 kg N substituted by VC
T_9 - 40 kg N supplied from urea + 80 kg N substituted by CD
T_{10} - 40 kg N supplied from urea + 80 kg N substituted by VC
T_{11} - 120 kg N supplied from CD
T_{12} - 120 kg N supplied from VC

Table 8. Effect of integrated use of nitrogen supplied from urea, cowdung and vermicompost on the K uptake by summer onion plant

Treatments	K uptake (kg ha^{-1})		
	Bulb	Leaf	Total
T_1	7.92 l	3.25 l	11.17 l
T_2	22.17 g	7.77 g	29.94 g
T_3	32.14 c	13.09 c	45.23 c
T_4	29.70 d	12.64 d	42.34 d
T_5	40.69 a	15.19 a	55.88 a
T_6	35.96 b	14.46 b	50.42 b
T_7	28.71 e	10.63 e	39.34 e
T_8	24.85 f	9.08 f	33.93 f
T_9	19.84 h	7.23 h	27.07 h
T_{10}	16.70 i	5.81 i	22.51 i
T_{11}	15.18 j	5.28 j	20.46 j
T_{12}	12.76 k	4.92 k	17.68 k
Level of significance	0.01	0.01	0.01

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT

T_1 - No fertilizer
T_2 - 120 kg N supplied from urea
T_3 - 100 kg N supplied from urea + 20 kg N substituted by CD
T_4 - 100 kg N supplied from urea + 20 kg N substituted by VC
T_5 - 80 kg N supplied from urea + 40 kg N substituted by CD
T_6 - 80 kg N supplied from urea + 40 kg N substituted by VC
T_7 - 60 kg N supplied from urea + 60 kg N substituted by CD
T_8 - 60 kg N supplied from urea + 60 kg N substituted by VC
T_9 - 40 kg N supplied from urea + 80 kg N substituted by CD
T_{10} - 40 kg N supplied from urea + 80 kg N substituted by VC
T_{11} - 120 kg N supplied from CD
T_{12} - 120 kg N supplied from VC

Table 9. Effect of integrated use of nitrogen supplied from urea, cowdung and vermicompost on the S uptake by summer onion plant

Treatments	S uptake (kg ha^{-1})		
	Bulb	Leaf	Total
T_1	5.87 l	1.20 h	7.07 l
T_2	12.55 g	2.66 f	15.21 g
T_3	18.13 c	4.90 c	23.03 c
T_4	16.83 d	4.70 c	21.53 d
T_5	22.85 a	6.08 a	28.93 a
T_6	20.20 b	5.64 b	25.84 b
T_7	15.71 e	3.86 d	19.57 e
T_8	13.83 f	3.16 e	16.99 f
T_9	11.63 h	2.44 f	14.07 h
T_{10}	10.07 i	1.92 g	11.99 i
T_{11}	9.37 j	1.73 g	11.10 j
T_{12}	8.12 k	1.63 g	9.75 k
Level of significance	0.01	0.01	0.01

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT

T_1 - No fertilizer
T_2 - 120 kg N supplied from urea
T_3 - 100 kg N supplied from urea + 20 kg N substituted by CD
T_4 - 100 kg N supplied from urea + 20 kg N substituted by VC
T_5 - 80 kg N supplied from urea + 40 kg N substituted by CD
T_6 - 80 kg N supplied from urea + 40 kg N substituted by VC
T_7 - 60 kg N supplied from urea + 60 kg N substituted by CD
T_8 - 60 kg N supplied from urea + 60 kg N substituted by VC
T_9 - 40 kg N supplied from urea + 80 kg N substituted by CD
T_{10} - 40 kg N supplied from urea + 80 kg N substituted by VC
T_{11} - 120 kg N supplied from CD
T_{12} - 120 kg N supplied from VC

4.5.4 Sulphur uptake

The amount of sulphur taken up by onion bulb and leaf with different combinations of nitrogen from urea, cowdung and vermicompost resulted (Table 9) significantly higher value over the control. Like other nutrient uptake by summer onion plant the highest (28.93 kg ha^{-1}) sulphur uptake was recorded in the treatment T_5 receiving 80 kg N from urea and 40 kg N from cowdung and the next higher (25.84 kg ha^{-1}) quantity of sulphur uptake was achieved by treatment T_6 (80 kg N supplied from urea + 40 kg N substituted by VC). The lowest sulphur uptake (7.07 kg ha^{-1}) was obtained in treatment T_1 receiving no organic or organic fertilizer. Neeraja *et al.* (2000) stated that increased level of N fertilizer significantly increased the leaf, bulb and whole plant uptake of Ca, Mg and S at different stages of crop growth. The uptake of these nutrients continued until bulb maturity. They also revealed that the total uptake of Ca, Mg and S was 16.66, 9.2 and 25.48 kg ha^{-1} with 200 kg N ha^{-1}, respectively.

4.6 Nutrient status of soil at harvest of summer onion as influenced by integrated use of nitrogen supplied from urea, cowdung and vermicompost

4.6.1 Nitrogen content of soil

The nitrogen content of soil after harvest of summer onion was influenced significantly by different doses of nitrogen applied from urea, cowdung and vermicompost (Table 10). The highest N content (0.103%) of soil was observed in case of treatment T_{12} (120 kg N ha^{-1} supplied from vermicompost) and it was statistically identical (0.100%) with the treatment T_{11} (120 kg N ha^{-1} supplied from cowdung). The next higher N concentration was obtained from the treatment T_{10}

where 40 kg N supplied from urea with 80 kg N substituted by vermicompost. In contrast, the lowest N content (0.08%) was obtained in the T_1 treatment where no fertilizer was applied. This may be due to the fact that highest yield was obtained by uptake more amount of nitrogen from soil by plant. Yield was comparatively low in treatment T_{12}, thus the status of N concentration in soil is high. In addition, vermicompost added N in soil, reduced the loss of nitrogen and conserved nitrogen in soil. Similar trend was pointed out by Zahir and Mian (2006) in case of wheat. They found that total N content of soil was the highest with application of 100% N from FYM or 75% from FYM and 25% from urea. Bangar *et al.* (1990) found that compost enriched the total N content of soil. Badiyala *et al.* (1990) found that the total soil nitrogen increased with time and this increase was higher due to combined application of farm yard manure and biofertilizer. Chellamuthu *et al.* (1988) found that application of farm yard manure as well as ammonium sulphate significantly increased the total nitrogen content of soil.

4.6.2 Phosphorous content of soil

Different combinations of nitrogen from urea, cowdung and vermicompost on the phosphorous content of soil after harvest of summer onion showed a statistically significant variation is presented in Table 10. It revealed from the study that the performances of the most of the treatment differed significantly from each other. Among the different treatments, T_{12} where 120 kg N ha^{-1} added only from vermicompost showed the highest phosphorus content (27.16 ppm) in soil after the harvest of crop. On the other hand, the lowest phosphorus content (12.12 ppm) was observed in the treatment T_1 receiving no fertilizer. Guan (1989) reported that the application of compost increased the availability of P in comparison with the control.

Table 10. Effect of integrated use of nitrogen supplied from urea, cowdung and vermicompost on the total N, available P, K and S contents in the soil after harvest of summer onion

Treatments	Total N (%)	Available P (ppm)	Available K (meq/100 g soil)	Available S (ppm)
T_1	0.080 e	12.12 k	0.110 b	17.16 k
T_2	0.097 abc	22.56 e	0.210 a	25.19 e
T_3	0.090 cd	19.74 h	0.181 ab	21.35 h
T_4	0.092 bcd	20.87 g	0.187 ab	22.18 g
T_5	0.086 de	17.43 j	0.171 ab	19.26 j
T_6	0.088 de	18.13 i	0.179 ab	20.63 i
T_7	0.093 bcd	21.63 f	0.197 a	23.44 f
T_8	0.095 abc	22.12 ef	0.203 a	24.56 e
T_9	0.096 abc	23.25 d	0.217 a	26.16 d
T_{10}	0.097 abc	25.17 c	0.223 a	28.52 c
T_{11}	0.100 ab	25.91 b	0.236 a	29.49 b
T_{12}	0.103 a	27.16 a	0.240 a	30.30 a
Level of significance	0.01	0.01	0.05	0.01

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT

T_1 - No fertilizer
T_2 - 120 kg N supplied from urea
T_3 - 100 kg N supplied from urea + 20 kg N substituted by CD
T_4 - 100 kg N supplied from urea + 20 kg N substituted by VC
T_5 - 80 kg N supplied from urea + 40 kg N substituted by CD
T_6 - 80 kg N supplied from urea + 40 kg N substituted by VC
T_7 - 60 kg N supplied from urea + 60 kg N substituted by CD
T_8 - 60 kg N supplied from urea + 60 kg N substituted by VC
T_9 - 40 kg N supplied from urea + 80 kg N substituted by CD
T_{10} - 40 kg N supplied from urea + 80 kg N substituted by VC
T_{11} - 120 kg N supplied from CD
T_{12} - 120 kg N supplied from VC

4.6.3 Potassium content of soil

The effect of integrated use of nitrogen from urea, cowdung and vermicompost showed significant differences in respect of K content of soil after harvest of summer onion (Table 10). There was slight disparity in available K content of soil by different treatments but most of treatment showed statistically identical performance. However, the lowest K content of crop-harvested soil (0.11 meq/100 g soil) was recorded in the treatment T_1 (control) and the highest K content (0.24 meq/100 g soil) was recorded with treatment T_{12} (120 kg N added from vermicompost) followed closely by 0.236 meq/100 g soil in treatment receiving 120 kg N ha^{-1} from cowdung (T_{11}). Probably, highest amount of application of vermicompost and cowdung and lowest uptake of K by the plant improved the K status of soil in treatment T_{12}.

4.6.4 Sulphur content of soil

Statistically significant difference in the S content of soil after harvest was obtained when different combinations of nitrogen were applied (Table 10). Application of 120 kg ha^{-1} N from vermicompost (T_{12}) showed the highest sulphur content (30.30 ppm) in soil. The next higher sulphur content (29.49 ppm) was found in treatment T_{11} receiving 120 kg ha^{-1} N from cowdung. On the contrary, the lowest sulphur content (17.16 ppm) was observed in the T_1 treatment where no fertilizer was applied. This might be due to the application of higher rates of vermicompost.

Chapter 5
Summary and Conclusion

SUMMARY AND CONCLUSION

A field experiment was carried out at Sher-e-Bangla Agricultural University Farm (Tejgaon series under AEZ No. 28), Dhaka 1207 during the *Kharif* season of 2007 to study the response of summer onion to integrated nitrogen management. The soil was Silty Clay Loam in texture having pH 6.0 and organic matter 0.83%. The research was accomplished in a Randomized Complete Block Design (RCBD) with twelve treatments and three replications having unit plot size of 2m x 2m ($4m^2$). The treatments were T_1 (No fertilizer), T_2 (120 kg N supplied from urea), T_3 (100 kg N supplied from urea + 20 kg N substituted by cowdung), T_4 (100 kg N supplied from urea + 20 kg N substituted by vermicompost), T_5 (80 kg N supplied from urea + 40 kg N substituted by cowdung), T_6 (80 kg N supplied from urea + 40 kg N substituted by vermicompost), T_7 (60 kg N supplied from urea + 60 kg N substituted by cowdung), T_8 (60 kg N supplied from urea + 60 kg N substituted by vermicompost), T_9 (40 kg N supplied from urea + 80 kg N substituted by cowdung), T_{10} (40 kg N supplied from urea + 80 kg N substituted by vermicompost), T_{11} (120 kg N supplied from cowdung) and T_{12} (120 kg N supplied from vermicompost). TSP- 220 kg ha^{-1}, MP- 200 kg ha^{-1} and Gypsum- 180 kg ha^{-1} were used as blanket dose. The entire amount of recommended fertilizers and well decomposed cowdung, except urea and vermicompost were added to the soil at the time of final land preparation. Urea was top dressed in four equal splits and vermicompost in three splits where 50% in first split and remaining 50% in two equal splits. The first split of urea and vermicompost were applied during final land preparation, the second, third and the fourth split of urea was applied after 18, 36 and 54 days of transplanting, respectively. Forty five days old onion seedlings of cv. BARI Piaz - 2 were transplanted on 13 May 2007 and the crop was harvested on 07 August 2007. Intercultural operations were done when required. The data were collected plot wise for plant height, leaf length, number of leaves per plant, diameter of bulb, length of bulb, weight of single bulb, bulb yield, stover yield and dry matter content of bulb. The post harvest soil samples were analyzed for total N, available P, K and S contents. The collected data on different parameters were statistically analyzed by F-test and the mean comparison was made by DMRT at 5% and 1% level. The salient results of the experiment are stated below.

The results of the experiment revealed that the effect of integrated use of nitrogen from urea, cowdung and vermicompost significantly influenced the plant height of summer onion. The shortest plant (24.25 cm) was found in the treatment T_1 (control) and the tallest plant (39.25 cm) in treatment T_5 where 80 kg N supplied from urea and 40 kg N substituted by cowdung. This plant height was not significantly different from the plant height (37.82 cm) recorded in T_6 (80 kg N supplied from urea + 40 kg N substituted by vermicompost). Like plant height, the longest leaf length (34.35 cm) was observed when the field was incorporated with 80 kg N from urea with 40 kg N from cowdung (T_5) and the shortest leaf length (21.20 cm) was recorded in the T_1 treatment receiving no organic or inorganic fertilizer. Statistically significant variation was not recorded on number of leaves per plant of summer onion.

Diameter of bulb, length of bulb, bulb weight and bulb yield of summer onion responded significantly to the integrated use of nitrogen. Treatment receiving 80 kg N from urea and 40 kg N substituted by cowdung (T_5) gave the highest bulb diameter (3.79 cm), bulb length (2.79 cm), bulb weight (30.40 g) as well as highest bulb yield (12.16 t ha^{-1}). Statistically identical performance in bulb yield (11.64 t ha^{-1}) was obtained from treatment T_6 (80 kg N from urea + 40 kg N substituted by vermicompost). The result exposed that when urea was applied with cowdung and vermicompost, the performance was better than their single application. Like bulb yield, the highest stover yield (5.46 t ha^{-1}) of summer onion was recorded in treatment T_5 (80 kg N supplied from urea with 40 kg N substituted by cowdung) and the lowest (2.61 t ha^{-1}) was found in control treatment (T_1).

Integrated management of nitrogen from urea, cowdung and vermicompost significantly influenced the dry matter yield of bulb and leaf of summer onion. Treatment T_5 (80 kg N supplied from urea with 40 kg N substituted by cowdung) gave the highest (2.38 t ha^{-1}) and treatment T_1 (control) gave the lowest (0.89 t ha^{-1}) dry matter yield of bulb. Similar trend was observed incase of leaf.

The N, P, K and S contents in bulb and leaf of summer onion and uptake of these nutrients by onion plants were influenced significantly by the integrated application of nitrogen from urea, cowdung and vermicompost. The highest N, P, K and S content in bulb (2.30%, 0.185%, 1.71% and 0.96%, respectively) and in leaf (2.91%, 0.183%, 2.45% and 0.98%, respectively) was recorded in T_5 (80 kg N supplied from urea + 40 kg N substituted by cowdung) treatment. The lowest 1.41% N, 0.055% P, 0.89% K, 0.66% S in bulb and 2.15% N, 0.053% P, 1.71% K and 0.63% S in leaf were obtained with T_1 control (No fertilizer) treatment. The highest uptake of 72.78, 5.53, 55.88 and 28.93 kg ha^{-1} and the lowest uptake of 16.64, 0.59, 11.17 and 7.07 kg ha^{-1} of N, P, K and S by onion plants at harvest stage were found in treatment T_5 receiving 80 kg N from urea with 40 kg N from cowdung and treatment T_1 receiving no fertilizer or manure, respectively.

The soil properties such as total nitrogen, available phosphorus, available potassium and available sulphur were increased after the harvest of crop compared to the nutrient status of the initial soil.

Results suggested that the integrated use of urea, cowdung and vermicompost performed better than the use of urea, cowdung or vermicompost alone in terms of improving crop yields of summer onion despite the level of applied N was same that is 120 kg N ha^{-1}. Results also suggested that the effect of sole application of urea is better compared to the sole application of cowdung or vermicompost. The combination of N 80 kg ha^{-1} from urea with 40 kg ha^{-1} from cowdung and N 80 kg ha^{-1} from urea with 40 kg ha^{-1} from vermicompost based on net N contribution produced excellent results and is therefore recommended for optimum summer onion production. However, more studies are required to optimize N doses from organic and inorganic sources in different soil under different management systems.

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Appendices

APPENDICES

Appendix Table 1: Monthly temperature, total rainfall, average humidity and sunshine data during March to August' 2007 of experiment site (Dhaka)

Month	Air temperature (^oC)			Total rainfall (mm)	Average Relative humidity (%)	Average sunshine (Hrs/day)
	Maximum	Minimum	Average			
March	31.4	19.6	25.50	11	54	8.2
April	33.6	23.6	28.60	163	69	6.4
May	34.7	25.9	30.30	185	70	7.8
June	32.4	25.5	28.95	628	81	4.7
July	31.4	25.7	28.55	753	84	3.3
August	32.5	26.4	29.45	505	80	4.9

Appendix Table 2. Effect of integrated use of nitrogen supplied from urea, cowdung and vermicompost on the dry matter yield of summer onion

Treatments	Dry matter yield (t ha^{-1})	
	Bulb	Leaf
T_1	0.89 i	0.19 e
T_2	1.63 e	0.35 cde
T_3	2.06 bc	0.55 ab
T_4	1.98 c	0.54 ab
T_5	2.38 a	0.62 a
T_6	2.22 ab	0.60 a
T_7	1.94 cd	0.46 abc
T_8	1.75 de	0.40 bcd
T_9	1.55 ef	0.33 cde
T_{10}	1.38 fg	0.27 de
T_{11}	1.32 gh	0.25 de
T_{12}	1.16 h	0.24 de
Level of significance	0.01	0.01