EFFECT OF IRRIGATION AND NITROGEN ON THE GROWTH AND YIELD AND NUTRIENT CONTENT OF ONION

BY

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CERTIFICATE

This is to certify that the thesis entitled, "EFFECT OF IRRIGATION AND NITROGEN ON THE GROWTH AND YIELD AND NUTRIENT CONTENT OF ONION" 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 MD. RIPON MIAH, Registration No. 00939 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.

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DEDICATED TO

MY BELOVED PARENTS

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ABSTRACT

A field experiment was conducted at the Sher-e-Bangla Agricultural University Farm, Dhaka-1207 during the *Rabi* season of 2007-2008 to evaluate the effect of irrigation and nitrogen on the growth and yield of onion. The research was carried out with four levels of nitrogen viz; 0, 50, 100 and 150 kg ha^{-1} and four levels of irrigation viz , I_0 : no irrigation, I_2: two times irrigation, I_4 : four times irrigation, I_8: eight times irrigation in split plot design. Data were recorded on yield and yield components. The experiment was laid out in split plot design with three replications. Single application of N had significant influence on leaf length, vertical length of bulb, dry weight of leaf and dry weight of bulb and yield of bulb. The dose of nitrogen N_{100} (100 kg ha^{-1}) gave the highest plant height, leaf number, leaf length, vertical length of bulb, horizontal length of bulb, dry weight of leaf, dry weight of bulb. The maximum plant height, leaf number, leaf length, vertical length of bulb, horizontal length of bulb, dry weight of leaf, dry weight of bulb were produced by I_4 (four times of irrigation) treatment. The significant combined effect between different number of irrigation and levels of nitrogen in respect Plant height, leaf number, leaf length, vertical length of bulb, horizontal length of bulb, dry weight of leaf, and dry weight of bulb were observed. The highest Plant height, leaf number, leaf length, vertical length of bulb, horizontal length of bulb, dry weight of leaf, and dry weight of bulb were recorded from the treatment combination of I_4N_{100}. The total yield of bulb was significantly varied due to different levels nitrogen doses applied in onion. The highest yield of onion (5.44 kg/plot and 17.94 t/ha) was recorded from N_{100} (100 kg N/ha) treatment. The total yield of bulb was significantly varied due to irrigation in onion. The highest yield of onion (5.04 kg/plot and 17.94 t/ha) was recorded from I_4 four times of irrigation) treatment. The combined effect of irrigation and levels of nitrogen performed significant variation on yield per plot. The highest bulb yield per plot (3.53 kg/plot and 18.6 t/ha) was recorded from the treatment combination of I_4N_{100}, while the lowest yield of bulb (2.217 kg/plot and 15.03 t/ha) was observed from I_0N_0. On overall considerations, 100 kg N/ha and four times of irrigation were considered as optimum dose for the yield of onion under the experimental conditions.

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LIST OF ABBREVIATIONS

AEZ	Agro- ecological zone
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
BRRI	Bangladesh Rice Research Institute
cm	Centimeter
DAS	Days after sowing
DAT	Days after transplanting
cv.	Cultivar (s)
et al.	And others
FAO	Food and Agriculture Organization
g	Gram (s)
Hr	Hour(s)
K	Potassium
K_2O	Potassium oxide
Kg	Kilogram (s)
LSD	Least Significant Difference
m^2	Meter Squares
mm	Millimeter
MOP	Muriate of potash
N	Nitrogen
No.	Number
NS	Non significant
P_2O_5	Phosphorus penta oxide
S	Sulphur
SAU	Sher-e- Bangla Agricultural University
SRDI	Soil Resources and Development Institute
TSP	Triple Superphosphate
var.	Variety
Wt.	Weight
t ha^{-1}	Ton per hectare
^0C	Degree Centigrade

Chapter I

INTRODUCTION

Onion (*Allium cepa* L.) belongs to the family Alliaceae and is one of the major important spice crops in Bangladesh as well as in the world (Jones and Mann, 1963). There are more than 500 species within the genus *Allium*, of these most are bulbous plants. Central Asia is the primary center of its origin and the Mediterranean is the secondary center for large type onion (McCullum, 1976). In world production onion ranks third (46750 thousand Mt) only after tomato (150259 thousand Mt) and cabbage (54503 thousand Mt) in terms of annual world production in the year 2001 (FAO, 2003).

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. It is photo and thermo sensitive crop (Davies And Jones. 1944). Among the spice crops grown in the country, onion ranks second (318000 Acres) next to chilli (349000 Acres) in area and first (894000 Mt) in production during the year 2006-2007 (BBS, 2008). Its cultivation is concentrated in the greater districts of Faridpur, Pabna, Rajshahi, Jessore, Dhaka, Mymensingh, Comilla and Rangpur (BBS, 2006). The average yield of onion in Bangladesh is very low (2.81 Mt/ acre) (BBS, 2008) as compared to the world average yield (17.46 t/ha) (FAO, 2003).

Onion is a thermophotosensitive crop (Davies And Jones. 1944). In Bangladesh, it is mainly produced in winter season. The optimum temperature for onion cultivation is 13-24°C (Rashid, 1983). Usually, it is sown during December to January and harvested mostly in the months from March to April.

Onion being a shallow rooted crop, needs frequent irrigation for growth and yield (Rahman *et al.*, 1992). Farmer in Bangladesh hardly applies irrigation for onion. Under low moisture condition supplemental irrigation is needed for satisfying the crop requirement as well as helps in better utilization of other production inputs and thus ensures higher crop yield.

Onion is very sensitive to change in soil moisture and readily responds to irrigation (Narang and Dastane, 1969). Inadequate water supply is the single most important factor limiting onion productively (Hedge,1986). Onion plants will benefit from frequent watering, especially in the early stage of growth before the plants have developed a good, deep, root system. Wet conditions at a late stage of bulb growth delay maturity and are believed to affect adversely the storage characteristics of the bulbs (Satter, 1979).

The frequency of irrigation and the amount of water required depend on such factors as cultivar, soil type, season, amount of rainfall and diseases; therefore, it is difficult to give definite recommendation. Over irrigation, as well as under irrigation may lower yields (Jones and Mann, 1963). Efficient water management thus plays a vital role in onion production. This can be achieved by adopting improved irrigation practices. Although both timing and the amount of water applied affect irrigation efficiency, timing has greater effect on the yield and quality of a crop. Therefore, a judicious irrigation schedule is needed to avoid over or under irrigation and for profitable onion cultivation.

The deficit situation of onion production in our country can be overcome either by bringing more area under onion cultivation or by increasing the yield through improvement of production technology, such as optimizing the dose of N, P and K fertilizers.

Nitrogen plays an important role for the vegetative growth of the crop which ultimately helps in increasing bulb size and total yield (Steward, 1963). Nitrogen imparts greenness to plants by enhancing chlorophyll synthesis and induces more photosynthetic production per unit photosynthetic area.

Considering the above condition, the present experiment was carried out with the following objectives:

OBJECTIVES:

1. To determine the combined effect of irrigation and nitrogen on the growth and yield of onion.
2. To know optimum levels and times of irrigation on the growth and yield of onion.
3. To know the optimum dose of nitrogen on the growth and yield of onion.

Chapter II

REVIEW OF LITERATURE

2.1 Effect of nitrogen on the growth and yield of onion

Lang (1987) clarified the requirement of N fertilizer to make up the crops at different stages of growth. Flat rate applications of 193 kg N/ha caused considerable losses due to irrigation and the cost of production were higher. Specific application of N at 105 kg/ha was found to reduce N losses and costs and increase yield.

Srinivas and Nail (1987) observed that the bulb yield increased from 16.51 t/ha at zero N to 56.30 t/ha at the highest N rate (200 kg/ha).

Kumar and Shama (1991) conducted an experiment with two onion cultivars N-53 and N-2-4-1, in the *kharif* season and reported that bulb yield increased linearly with increasing N application 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 influenced the diameter of bulb and yield significantly. They also reported that application of nitrogen at 80 kg ha^{-1} resulted in 38% increase in bulb weight over control.

Pandey *et al.* (1991) studied the effect of 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}) on 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, larger umbels and less incidence of thrips than the lower fertilizer rates, 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 6^{th} 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 of bulb to 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 the highest with 150 kg N ha^{-1}, although bulb weight and yield at 100 kg N ha^{-1} were not significantly different. Increasing phosphorus application increased the number of leaves per plant, 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 the best 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 M.R. (1995) worked on sandy loam soil in Mymensingh with onion cv. Taherpuri, planted on 20 December and 20 January and supplied with 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 onions (cv. Pusa Red). The yield and plant nitrogen contents were significantly increased with increased nitrogen application. Combined application of N and S significantly increased its yield.

Anower *et al.* (1998) observed that the 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 on 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) 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 the plant height, leaf number, bulb length, bulb diameter and bulb weight as well as the 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. With increasing N level, plant height increased in both the experimental period. Plant height, bulb girth, number of leaves $plant^{-1}$, bulb weight and highest yield (295.8 q ha^{-1}) were achieved with N and K at 160 and 80 kg/ha, respectively. Based on these results, 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, 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, in which 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. 5, 6 and 7 weeks old onion seedlings were supplied with N at 50, 100 or 150 kg/ ha 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 bulb 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 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 per plot and 7-day intervals irrigation produced higher bulb yield, average bulb weight, and number of large bulbs per plot.

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, 9.2 and 25.48 kg ha^{-1} with 200 kg N ha^{-1}, respectively.

Anonymous (2001) conducted an experiment at Spices Research Centre, BARI, Joydebpur during 2000-2001 with four levels of nitrogen (0, 100, 125 and 150 kg/ha). 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 with the 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.

Dhamendra *et al.* (2001) investigated the effects of N fertilizer application (0, 65 and 130 kg/ha) on onion cv. Pusa Red during 1992-93 and 1993-94 in Uttar Pradesh, India. In both years, the application of 130 kg N/ha 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 with the other application rate.

Yadav *et al.* (2003) 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 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.

Tiwari *et al.* (2002) studied the effects of N (0, 40, 80 and 120 kg/ha) and plant spacing (45 x 30, 60 x 30 and 60 x 45) on the yield of onion (cv. Pusa Red). They stated that plant height, length of flowering stalk, number of umbels per bulb, 1000-seed weight, purple blotch and seed yield increased with increasing rates of N up to 80 kg/ha. Spacing of 60 x 45 gave the highest number of leaves per plant (12.10) and 1000-seed weight (2.88 g), whereas the spacing of 60 x 30 and 45 x 30 gave the highest length of flowering stalk (93.45 cm) and seed yield (9.28 q/ha), respectively. The interaction effects between application of N at 80 or 120 kg/ha, in combination with the closest spacing resulted in the highest yield and cost:benefit ratio.

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.

Naik and Hosamani (2003) conducted a field experiment during 1997-98 and 1998-99 to investigate the effect of spacing (15 x 10, 15 x 15 and 15 x 20 cm) and N level (0, 50, 100 and 150 kg/ha) on the growth and yield of *kharif* onion. Narrow spacing of 15 x 10 cm with application of 150 kg N/ha was found optimum for enhancing yield (169.02 q/ha) and other growth and quality parameters, such as plant height, leaf number per plant, bulb length, bulb diameter and bulb total soluble solid content. The maximum net return and benefit cost ratio were also recorded from this treatment combination.

Qureshi *et al.* (2003) studied the effects of Nitro gold (slow-release, granulated ammonium sulfate), and of standard N sources like urea and ammonium sulfate on the yield and quality of onion in Maharashtra, India. They reported that Urea + SSP were the most effective in the enhancement of the number of leaves. The application of Nitro gold (RR) along with DAP significantly improved bulb polar diameter. The highest yields of grade A and B bulbs were obtained with Nitrogold and urea. On the other hand, the highest total marketable yield was obtained with Nitrogold + SSP. The N fertilizers did not significantly affect plant height, and the neck size and total soluble solid content of bulbs.

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 per plant, 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.

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 highest upon treatment with the highest nitrogen rate (150 kg N ha^{-1}) and with the highest potassium rate (120 kg K ha^{-1}).

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.

Gunjan *et al.* (2005) conducted a field experiment on a sandy loam soil in Jobner, Rajasthan, India during the *rabi* season of 1999-2000 to study the effect of 4 levels of N (25, 50, 75 and 100 kg ha^{-1}) and 2 sources of biofertilizer, i.e. *Azotobacter* (A_1) and *Azospirillum* (A_2) as seedling dipping, seed and soil treatments, on yield and quality of onion bulb (*A. cepa*). The application of N at 100 kg ha^{-1} significantly increased bulb yield and quality attributes. The treatment combination $N_4A_1S_2$ (100 kg N ha^{-1}+*Azotobacter* as seedling dipping) gave the highest bulb yield and fresh weight of bulb, followed at par by $N_3A_1S_2$ (75 Kg N ha^{-1} + *Azotobacter* as seedling dipping). A higher benefit: cost ratio (2.26:1) was recorded with the treatment combination of $N_3A_1S_2$ compared to $N_4A_1S_2$, with a lower benefit:cost ratio (2.24:1) due to additional cost of urea and non significant difference between these 2 treatments regarding yield of bulbs. Thus, the treatment combination $N_3A_1S_2$ was the best.

Qiao-Hong Xia *et al.*(2005) showed that application of 20 kg N, P and K/666.7 m^2 increased the yield of Welsh onions by 3.1-24.4% (34.6-270.9 kg/666.7 m^2), whereas foliar application of organic fertilizer increased the yield of the crop by 14.2-32% (186-425.9 kg/666.7 m^2).

Yadav *et al.* (2005) studied the effects of N fertilizer (50, 75 or 100% of the recommended N rate of 100 kg/ha) with or without inoculation of *Azospirillum* in Durgapura, Jaipur, Rajasthan, India during the *rabi* of 1999-2000, 2000-01 and 2001-02. N was applied in 3 equal splits at 30-day intervals starting at 20 days after transplanting. Before sowing, seeds were treated with *Azospirillum* at 500 g/ha. Seedlings were dipped for 15 minutes in *Azospirillum* slurry (1 kg *Azospirillum* dissolved in 50 liters of water/ha). Before transplanting, *Azospirillum* (2 kg/ha) was mixed with farmyard manure and incorporated into the soil. Pooled data showed that bulb yields were the highest with N at 75 (328.4 quintal/ha) and 100 kg/ha (336.5 quintal/ha); under these treatments, bulb yields increased by 11.4 and 14.1%, respectively over the control. The inoculation of *Azospirillum* resulted in a higher bulb yield (323.7 quintal/ha) over the control (310.9 quintal/ha). The available N in the soil slightly increased with the increase in the N rate. A significant increase in available N was observed during the first sampling of the second year and during the second sampling of the second and third years. *Azospirillum* inoculation increased the available N during the second sampling of the third year and during the third sampling of the first year. The highest net profits were obtained with *Azospirillum* combined with N at 100 (32792 rupees/ha) or 75 kg/ha (31 288 rupees/ha). [1 quintal=100 kg]

Yamasaki and Tanaka (2005) investigated the role of N in the flower initiation of Welsh onion (A. 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.

Kumar *et al.* (2006) carried out a field experiment to determine the effects of N and K levels (0, 50, 100 and 150 kg ha^{-1} each) 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 by Islam *et al.* (2006) 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}).

Anonymous (2007) conducted an experiment 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. Among the fertilizer treatments, $N_{100}P_{40}K_{100}S_{30}$ gave the highest yield (22.33 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 per plant, percentage bolters, crop growth rate and individual bulb weight. Nitrogen at the rate of 150 $kgha^{-1}$ gave the best results though statistically at par with 100 kg N

ha^{-1}. P 17.5 kg ha^{-1} gave statistically similar results as 35 kg P ha^{-1} and the optimum combination 100 kg N ha^{-1} and 17.5 kg P 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 per plant, bulb diameter and bulb yield in comparison to its lower levels, i.e. 50 and 100 kg N ha^{-1}.

2.2 Effect of irrigation on the growth and yield of onion

Rumasz *et al.* (2001) carried out a field experiment in 1998-99 on a sandy soil of a good-rye-complex. The influence of water of various salinity on the yield of onion and cabbage was tested. The highest onion yield was obtained when the plants had been watered with tap water, whereas cabbage yielded best when diluted saline water had been used. The yield increases were: onion by 24.7%, cabbage by 30.5%. Productivity of 1 mm water depended both on the plant species and water salinity.

Orta and Ener (2001) studied in the response of onion (*Allium cepa*) to different irrigation schedules in Trakya, Turkey during 1997 and 1998. Onion crop was subjected to four irrigation treatments according to available soil water depletion fractions (0.30, 0.50, 0.70, and no irrigation). Irrigation thresholds (amount of soil water at 0.40 m depth) were used as criteria to initiate drip irrigations. For each differential water treatment, the parameters of bulb morphology (diameter and height), solids soluble in bulbs, bulb weight, and total yield were analysed. Yield and yield components except solids soluble in bulbs were affected by irrigation and soil water depletion fractions. The highest yield was obtained from the plots to which irrigation water was applied at a soil water fraction level of 0.30. The maintenance of soil moisture depletion level at 0.30 required 339.4 mm (in 14 applications) and 227.2 mm (in 13 applications) of irrigation water in 1997 and 1998, respectively. The seasonal evapotranspiration of onion was 420.0 mm in 1997 and 351.2 mm in 1998.

Adame *et al.* (2003) conducted an experiment to generate information about when and how much water is needed to irrigate onion crop (*Allium cepa*) through a furrow irrigation system using waste water to improve crop production and to make water application more efficient. A complete random block design with five treatments and four replicates was used. The Contessa variety was used, which was transplanted 45 days after sowing, the fertilizer treatment 140-60-00 (N-P_2O_5-K_2O) was applied. The moisture tensions of irrigation time were: 15, 5.6, 2.4, 1.2 and 0.6 atmospheres. The experimental unit was 6x2.5 m and 0.5 m among rows. Transplanting density was 200 000 plants/ha. The highest yields of 73.047 and 70.370 kg/ha were obtained with a high moisture tension of 0.6 and 1.2 atmospheres, respectively. It can be concluded that to achieve the highest yield of onions in the south of the state of Morelos, Mexico, 9 irrigations during crop cycle are recommended: 93.3 mm initially and 57.4 mm in the following applications.

Bhonde *et al.* (2003) conducted a field trial with onion cultivars Agrifound Light Red and Agrifound White during 2001-02 in Nasik, Maharashtra, India, to investigate the effect of drip irrigation, in comparison to flood irrigation through channels for raised beds and flood irrigation in flat beds (control). Transplanting in the field was carried out on 27 November 2001 and harvesting was carried out on 8 April 2002. In Agrifound White, drip irrigation gave a 96.46% plant stand compared to 96.13% for flood irrigation with the raised bed method and 95.79% for flood irrigation in flat beds. The 20-bulb weight was higher by 23.53% for drip irrigation and by 5.88% for flood irrigation with raised bed planting over flood irrigation on flat beds. The bulb yield increased by 13.76% for drip irrigation and by 1.59% in flood irrigation with raised beds over flood irrigation in flat beds. The bulb development in Agrifound Light Red was similar to that of Agrifound White. The plant stand was higher by 23.97% in drip irrigation and by 16.67% in flood irrigation with raised beds over flood irrigation in flat beds. The 20-bulb weight was higher by 21.05% in drip irrigation and by 15.79% in flood irrigation with raised beds compared with flood irrigation in flat beds. The bulb yield was higher by 26.88% in drip irrigation and by 8.16% in flood irrigation with the raised bed method compared with flood irrigation in flat beds.

Lal *et al.* (2002) conducted a field experiment in Haryana, India during 1992-94 and reported that plant height, number of leaves per plant, bulb size and bulb yield increased with increasing rates of farmyard manure and irrigation. The interaction effects between FYM and irrigation were significant only for bulb size and yield.

Wadatkar *et al.* (2002) conducted a field experiment in Akola, Maharashtra, India, with onion cv. Malav-21 on a sandy clay loam soil, involving basin (control), trickle, drip inline and microsprinkler irrigation treatments. The irrigation for trickle, drip inline and microsprinkler was scheduled equal to previous day crop evapotranspiration, and for the basin treatment irrigation was scheduled at 64 mm

CPE with IW/CPE ratio equal to 0.7. The net irrigation requirement of onion was found to be 83.00 and 60.35 ha-cm in the control basin and micro-irrigation treatments, respectively. The water saving in micro-irrigation treatments over the control basin was 27.3%. In the micro-irrigation treatments, the moisture content was found closer to field capacity with even distribution of moisture in the root zone depth of the crop. It was observed that application efficiency ranged from 69.23 (in the control) to 96.6% (in the microsprinkler treatment). Distribution efficiency was in the range of 89.61 (in the control) to 95.04% (in the trickle treatment). Irrigation water use efficiency was maximum in the microsprinkler irrigation (4.20 q/ha-cm) followed by the trickle (4.07 q/ha-cm). The total onion bulb production and bulb of consumer acceptance were maximum in the microsprinkler treatment (253.52 q/ha) followed by the trickle (245.58 q/ha) and drip inline (238.04 q/ha). The lowest yield (192.25 q/ha) was recorded in the control.

Kanton *et al.* (2003) conducted Field experiments at Bugri and Binduri in northern Ghana during the 1996-97 and 1997-98 onion growing seasons to determine the optimum irrigation regime for onion: morning and evening daily, morning daily, evening daily, morning and evening alternate days, and morning or evening alternate days on bulb yield and yield components of onion cv. Bawku Red. Bulb yield and yield components were significantly ($P<0.05$) influenced by irrigation interval. Mean height of onion plants that received irrigation morning and evening, or morning or evening daily were about 39 cm while plants in other treatments were only 34 cm in height. Mean foliage weight when onion was irrigated morning and evening daily was 1.7 kg/plot compared to 1.4 kg/plot when onion was irrigated every other day. The highest bulb yields of 39.8 Mt/ha were obtained when transplants received irrigation during the morning and evening. Onion bulb yield and yield components generally decreased with increasing irrigation regime. Irrigation regime did not have any significant ($P<0.05$) effect on the total sugar percentage in onion bulb. Over 50% of the farmers in the trial preferred irrigating their onion once daily in the morning, thereby confirming the agronomic results obtained in the study.

Crop coefficients (Kc) of onion cv. N-53 as affected by irrigation (0.6, 0.8, 1.0 or 1.2 irrigation water/cumulative pan evaporation or IW/CPE ratio) were studied in Rajendranagar, Hyderabad, Andhra Pradesh, India during the *rabi* seasons of 1993/94 and 1994/95 by Neeraja and Reddy (2003). Irrigation at 1.2 IW/CPE ratio resulted in significantly higher Kc value at all stages of crop growth compared with other treatments. The variation in Kc value was a function of evapotranspiration deficit at different crop growth periods and leaf area of the crop. The crop coefficient curve for irrigation at 1.2 IW/CPE showed that the Kc value was low (0.713) at the vegetative period (15-60 days after transplanting), increased linearly, reaching peak value of 0.940 at bulb initiation and development period (61-105 DAT), and later decreased to a low value of 0.475 during bulb maturity to harvest stage (106 DAT-harvest). The crop coefficient curve facilitates the prediction of crop evapotranspiration before planting the crop at a new site from the estimates of reference crop evaporation. This study revealed that the net (417.18 mm) and gross irrigation requirements, both at field inlet and head work, were 5863 and 10249 m^3, respectively, for onion.

Olalla *et al.* (2005) carried out an experiment on an onion crop cultivated under controlled deficit irrigation (CDI) conditions in a semi-arid climate. Eight treatments were used in which different water doses were applied according to the water requirements at each stage of the crop cycle. The effect of water deficit was studied at three vegetative stages (development, bulbification and ripening). Although, the dry matter yield was not affected by the total volume of water intake (with volumes ranging from 603.1 to 772.0 mm), the statistical analyses made have shown that there is some interaction between the volumes of water received by the crop at the bulbification and ripening stages, which means that inducing a shortage in both stages at the same time does lead to significant differences in the yield obtained. As to bulb sizes, the treatments which received the greatest volumes of water during the development and ripening stages yielded harvests with higher percentages of large-size bulbs, whereas the water shortages induced during the growth and bulbification stages led to higher percentages of small-size bulbs.

Kumar *et al.* (2006) conducted field experiments in Indian Punjab, India, in 2002 and 2003 to study the effect of variable irrigation and fertigation on storage behaviour of onion. Based on the irrigation water applied (IW) and cumulative pan evaporation (CPE) ratio, the crop was subjected to 4 levels of irrigation where IW/CPE ratio varied from 0.60 to 1.20 at a 0.20 interval. In each irrigation, 10.80 mm water was applied. By varying the cumulative pan evaporation, the desired irrigation level was maintained. Three fertigation options of NPK, i.e. F_1 (100:50:50 kg/ha), F_2 (75:37:5:37.5 kg/ha) and F_3 (50:25:25 kg/ha), were studied.

The field cured onion bulbs were stored in 2 conditions, i.e. on a cemented floor (loose) and on a wooden stack above the ground in gunny bags. Irrigation and fertigation levels significantly influenced physiological loss in weight and sprouting percentage. Bulbs grown under low soil moisture regime resulted in higher physiological loss in weight and sprouting. The maximum sprouting percentage (25.49%) was recorded under an irrigation regime of I_4 when bulbs stored on cemented floor, whereas sprouting was highest (12.76%) under the irrigation regime of I_1 when bulbs were stored in gunny bags. The higher sprouting and physiological loss in weight was found under the fertigation level F1, in which maximum nutrients were applied in all fertigation treatments.

2.3 Combined effect of irrigation and nitrogen on the growth and yield of onion.

Bhonde *et. al.* (2001) reported that the effects of varying irrigation frequencies and N fertilizer levels on onion cv. Agrifound Dark Red seed production were investigated during *rabi* 1998/99 and 1999/2000 at Nasik, Maharashtra, India. The irrigation frequencies tested were: (I_1) irrigation at 15-day-intervals up to day 60, 12-day-intervals from day 60 to 100, and 8-day-intervals from day 100 until maturity; (I_2) irrigation at 12-day-intervals up to day 60 and 8-day-intervals thereafter; and (I_3) irrigation at 10-day-intervals throughout the cropping period. The N fertilizer treatments included: (N_1) 80 kg N/ha applied in 2 splits, 50% at planting and 50% at 45 days after planting (DAP); (N_2) 100 kg N/ha applied in 2 splits, 50% at planting and 50% at 45 DAP; and (N_3) 120 kg N/ha applied in 3 splits, 33% at planting, 33% at 45 DAP and 33% at 60 DAP. Data were recorded for plant height, number of umbels per plant, size of umbels, 1000-seed weight, seed germination, and seed yield. Based on these traits and on the resistance to purple blotch [*Alternaria porri*] and thrips, the best crop performance was obtained under I_2 and I_3. No significant differences in any of these traits were observed as a result of varying N levels, while the interaction effects were only significant for seed germination.

Nandi *et al.* (2002) conducted a field experiment in West Bengal, India, during 1995-96 and 1996-97 to study the response of onion cv. Sukhsagar to N:K:S rates of 0:0:0, 100:120:40 and 150:180:60 kg/ha and irrigation at different levels (no irrigation, farmers' practice, and at 0.55 and 0.80 atmospheric (atm.) tension). Growth and yield of onion were significantly affected by irrigation, but post-harvest storage life was not. The highest yields (198.75 and 201.25 in the first and second years, respectively) were obtained with irrigation at 0.55 atm. tension and 150:180:60 kg/ha. Water use and water use efficiency was highest at 0.55 atm. tension.

Halvorson *et al.* (2002) conducted experiment in furrow irrigated onion (*Allium cepa*) production, with high N fertilizer application rates that may be contributing NO_3-N to ground water in southeastern Colorado, USA. This study determined the growth and N uptake patterns of onion grown on a silty clay soil, N fertilizer use efficiency (NFUE) of onion, and recovery of residual N fertilizer by maize (*Zea mays*) following onion in rotation. Onion was sampled biweekly from 18 May to 15 September 1998 from plots receiving 0 and 224 kg N ha^{-1}. Non-labelled N and labelled 15N fertilizer were band-applied near the onion row in split applications of 112 kg N ha^{-1} each on 18 May and 25 June. Onion dry matter accumulation was slow from planting to about late May, followed by a rapid increase in biomass production and N uptake. Because residual soil NO_3-N was high, N fertilizer application resulted in only a small increase in bulb yield. Greatest demand for N by onion occurred during bulb development. Fertilizer N recovery by onion was 11 and 19% for May and June N applications (average 15%), respectively. Much of the fertilizer N remained in the upper 60-cm soil profile at harvest and had moved toward the onion bed centre. Fertilizer 15N detected at 180-cm soil depth indicated leaching losses from the root zone. The unfertilized 1999 maize crop recovered 24% of fertilizer N applied to onion for a total fertilizer N uptake by the two crops of 39%. Delaying N fertilizer application until onion bulbing begins may improve NFUE. Planting maize directly on the previous onion bed may result in greater N fertilizer recovery by maize.

Serra and Olive (1999) examined in field experiments conducted in 1992 [location not given]. Plants were grown at various densities (20, 40, 80 and 160 plants/m^2) and light levels (natural light condition and black neutral shade). It was found that the upper temperature limit for flower induction was ~17 degrees C and that low irradiance impairs flower production. To control bolting while maintaining yield requires high levels of soil N availability during growth and a leaf area index less than 3.5. Plants started to bulb earlier at higher densities (80 and 160 plants/m^2) compared with those plants at lower densities (20 and 40 plants/m^2). Maturity was achieved first by plants at a density of 160 plants/m^2 under natural light conditions.

The effects of nitrogen (100, 125 and 150 kg/ha) and irrigation (irrigation at 7-, 14- and 21-day intervals) on the growth and yield of onion cv. BARI Piaz-1 were determined in a field experiment conducted in Bangladesh during the *rabi* season of 2000-01 by Haque *et al.* (2004). Plant height, number of leaves per plant, bulb length, bulb diameter, neck thickness, single bulb weight and crop yield increased with increasing rates of N up to 125 kg/ha and decreased thereafter. The values of the parameters measured were highest with irrigation at 7-day intervals except for number of leaves per plant and single bulb weight which were highest with the irrigation at 14-day intervals. Interaction effects between N rates and irrigation were significant for all the parameters measured except for bulb diameter.

Chapter III

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, and cultural operations, collection of soil and plant samples etc. and analytical methods used for the experiment. The details of 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 irrigation and nitrogen were conducted on the Farm of Sher-e-Bangla Agricultural University, Dhaka 1207 during *Robi* season of 2007-2008. The specific location of experimental site is presented in Appendix 1.

3.1.2 Soil

The soil of the experimental field belongs to the Tejgaon series of AEZ No. 28, Madhupur tract and has been classified as deep red brown terrace soils in Bangladesh soil classification system. The soil is characterized by heavy clays within 50 cm from the surface and is 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 Appendix II.

3.2 Soil of the experimental field

Initial soil samples from 0-15 cm depth were collected from experimental field. The collected samples were analyzed at Soil Resources Development Institute (SRDI), Dhaka, Bangladesh. The physico-chemical properties of the soil are presented in Appendix I (a). The soil of the experimental plots belonged to the agro ecological zone of Madhupur Tract (AEZ-28) as shown in Appendix I .

3.3 Climate of the experimental area

The experimental area is under the subtropical climate. Usually the rainfall is heavy during *Kharif* season and scanty in *Rabi* season. The weather conditions during experimentation such as monthly mean rainfall (mm), mean temperature (^{0}C), sunshine hours and humidity (%) are presented in Appendix II.

3.4 Planting material

One onion cultivar namely Taherpuri was used for the experiment. The seeds of this variety were collected from a seed dealer of Siddique Bazar, Gulistan, Dhaka.

3.5 Raising of seedlings.

High, well drained and sunny place was selected for seedbed preparation. The land was ploughed finely and dried for 10 to 15 days. Weeds were removed finely and finally. The soil was made into friable, loose and brought into fine tillth, other stubbles were removed. Onion seedlings were raised in two seedbeds situated on a relatively high land adjacent to the Horticultural Farm Office of SAU. The size of each seedbed was 3 m × 1 m with height of about 10 cm. Seeds were soaked in water for one night and then kept in a piece of cloth for spouting. After spouting the seeds were sown in the seedbed at a depth of about 0.5 cm on November 13, 2007. Curator @ 6 kg/ha was dusted over the seedbed to protect the germinating seeds from ants. The germination was completed within 7 days after sowing. Light irrigation with a watering can was given whenever necessary. Weeding was done as and when required.

3.6 Treatments of the experiment

The study comprised the following treatments:

A. Irrigation level (main plot):

1. I_0 : no irrigation
2. I_2: two times irrigation (30 days interval of after establishment of seedling)
3. I_4 : four times irrigation (15 days interval of after establishment of seedling)
4. I_8: eight times irrigation (7 days interval of after establishment of seedling)

B. Nitrogen levels (subplots):

1. N_0: no fertilizer
2. N_{50}: 50 kg N /ha
3. N_{100}: 100 kg N /ha
4. N_{150}: 150 kg N/ha

There are 16 treatment combinations of irrigation levels and nitrogen doses used in the experiment as following:

T_1= I_0 N_0

T_2= I_0 N_{50}

T_3= I_0 N_{100}

T_4 = I_0 N_{150}

T_5= I_2 N_0

T_6= I_2 N50

T_7= I_2 N_{100}

T_8= I_2 N_{150}

T_9= I_4 N_0

T_{10}= I_4 N_{50}

T_{11}= I_4 N_{100}

T_{12}= I_4 N_{150}

T_{13}= I_8 N_0

T_{14}= I_8 N_{50}

T_{15}= I_8 N_{100}

T_{16}= I_8 N_{150}

3.7 Design and layout of the experiment

The experiment consisted of 16 treatment combinations and was laid out in split plot with 3 replications. An area of 144 m^2 was divided into four main plots and irrigation treatments were placed in the main plots. Each main plot was divided into 12 subplots which received N treatments with 3 replications. The size of subplots was 2m × 1.5m ($3m^2$). The distance maintained between two subplots was 100 cm and between blocks was 150 cm. The layout of the experiment is presented in Appendix IV.

3.8 Cultivation of winter onion

3.8.1 Preparation of the field

The plot selected for the experiment was opened by a tractor on the 2nd December, 2007, afterwards 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 main and subplots in accordance with the experimental design mentioned in the section (3.7). Irrigation and drainage channels were prepared around the plots.

3.8.2 Rates of manures and fertilizers

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

Manures/ fertilizers	Dose/ ha
Farmyard manure	10 tons
Urea	As per treatment
TSP	220 kg
MOP	200 kg
Gypsum	180 Kg

3.8.3 Application of manures and fertilizers

The farmyard manure (FYM) was applied after opening the land. The whole required amounts of Triple Super Phosphate (TSP) and gypsum were applied at the time of final land preparation. Muriate of Potash (MOP) was applied in two equal installments one at the time of final land preparation and the remaining at 40 days after transplanting. Urea was used as top dressed in three equal splits at 35, 55, and 75 days after transplanting.

3.8.4 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 line to line spacing of 20 cm and plant to plant 10 cm in the afternoon on 25 December, 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 as border crop to be used for gap fillings.

3.8.5 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.

3.8.5. 1) Gap fillings

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

3.8.5. 2) Weeding and mulching

Weeding was done three times after transplanting to harvest 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.

3.8.5. 3) Irrigation and drainage

Irrigations were given as per treatments. Irrigation was provided by a watering can and or hose pump when needed. At this time care was taken so that irrigated water could not pass from one plot to another. During each irrigation the soil was made saturated with water. After rainfall, excess water was drained when necessary.

3.8.5. 4) Protection of plants

Preventive measure was taken against the soil borne insect. 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.

3.9 Harvesting

The crop was harvested on 15 April, 2008 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.

3.10 Collection of data

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

a. Plant height
b. No of leaves per plant
c. Leaf length
d. Dry weight of leaf
e. Dry weight of bulb
f. Horizontal diameter of bulb
g. Vertical diameter of bulb
h. Bulb yield (ton/ha)

3.10.1 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.

3.10.2 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 was recorded.

3.10.3 Number of leaves per plant

Number of leaves per plant was counted after harvesting. Five plants were selected randomly from each plot and averaged.

3.10.4 Horizontal length of bulb (cm)

At harvest the horizontal length of bulbs were measured at the middle portion of bulb from five randomly selected plants with a slide calipers and averaged.

3.10.5 Vertical Length of bulb (cm)

Vertical 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.

3.10.6 Dry matter weight of leaf

Ten pseudostems with leaves were collected randomly from each unit plot and weights of dry matter of leaf were measured in gram after heating in an oven at 70° C for drying. It took 72 hrs to reach the constant weight.

3.10.7 Dry matter weight of bulb

Ten bulbs collected from ten plants randomly in each unit plot were sliced finely dried first in the sun and then in an oven at 70° C. It took 72 hrs to reach the constant weight.

3.10.8 Yield of bulb per plot (kg)

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

3.10.9 Yield of bulb per hectare (t)

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

3.11 Collection of samples

3.11.1 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 also collected from each plot at 0-15 cm depth on 8^{th} may 2007. The samples were air-dried, ground and sieved through a 2 mm (10 meshes) sieve and kept for analysis.

3.11.2 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 for recording data. After recording data bulbs and leaves were separated and then samples were dried in the electric 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.

3.12 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:

3.12.1 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.

3.12.2 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).

3.12.3 Organic carbon

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

3.12.4 Organic matter

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

3.12.5 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 a 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).

3.12.6 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.

3.12.7 Exchangeable potassium

Exchangeable potassium in the soil sample was extracted with 1N neutral ammonium acetate (NH_4OAC) and the potassium content was determined by flame photometer (Black, 1965).

3.13 Chemical analysis of plant sample

3.13.1 Digestion of plant samples with nitric-perchloric acid mixture

An amount of 0.5g 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, 6ml 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.

3.13.2 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).

3.13.3 Potassium

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

3.13.4 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).

3.14 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 significance of the differences among the pairs of treatment means was estimated by the Duncan Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984) for the interpretation of results.

Chapter IV

RESULTS AND DISCUSSION

The results obtained on the effect of irrigation and nitrogen supplied from urea, on different yield attributes; yield and nutrient concentrations in the plants of onion are presented and discussed in this chapter.

4.1 Effect of nitrogen and irrigation on the growth, yield of onion.

4.1.1 Plant height

The effect of nitrogen on the plant height of onion is presented in Fig 1. A significant variation was not observed on the plant height of onion when the field was incorporated with nitrogen (Appendix V). However, the highest plant height (38.58 cm) was observed in T_{100} treatment (100 kg N/ha). On the contrary, the lowest plant height (31.38 cm) was observed in the T_1 (control) treatment receiving no inorganic fertilizer. Haque *et al.* (2004) stated that plant height of onion increased with increasing rates of N up to 125 kg/ha and decreased thereafter. Plant height of onion showed increasing trends up to the highest nitrogen rate (Singh *et al.*, 2004).

Plant height varied significantly due to the application of different levels of irrigation (Fig. 2 & Appendix V). The tallest plant (37.42 cm) was produced by I_4 (4 times irrigation) and the shortest plant (31.73 cm) was recorded from no irrigation. Palled *et al.* (1988) reported that irrigation had significant influence on plant height of onion.

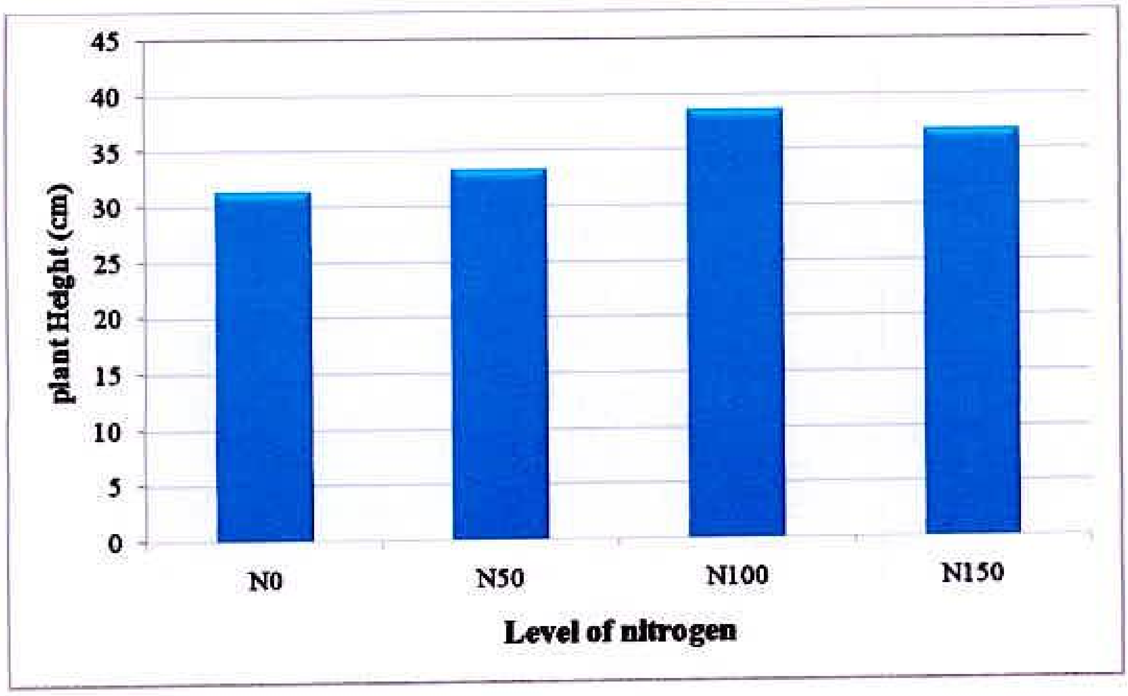

Figure 1 Effects of nitrogen on the plant height of onion

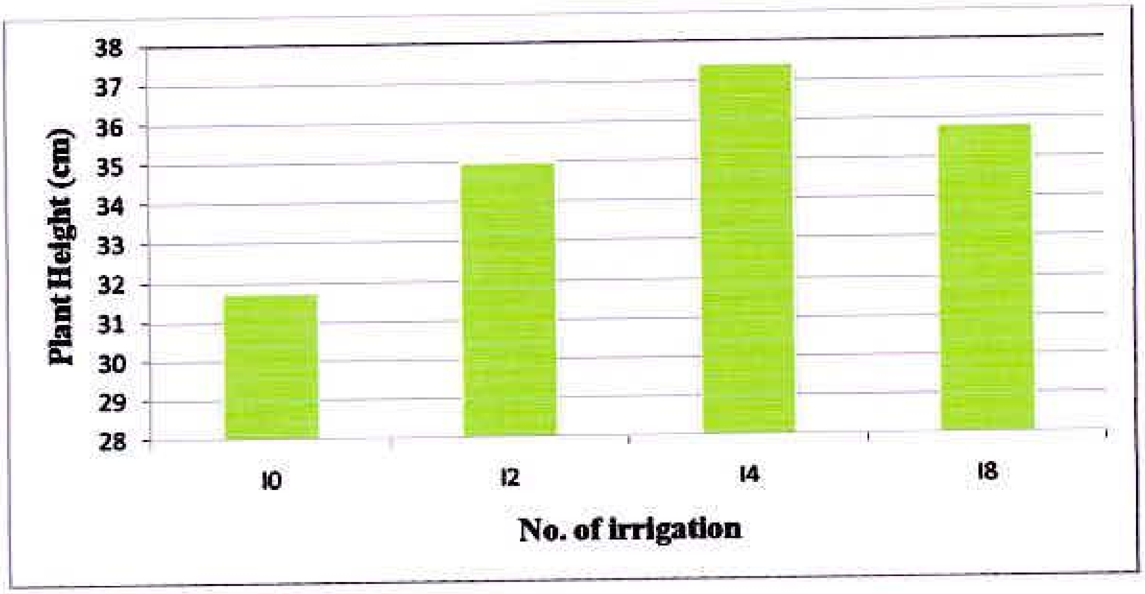

Figure 2 Effects of irrigation on the plant height of onion

The obtained results are in good agreement with several investigations reported where applied irrigation water resulted a significant increase in plant height of onion (Hegde, 1986; Begum *et al.* 1990; Rana and Sharma, 1993).

Different irrigation and nitrogen treatment showed significant interaction on the plant height at the harvest (Table 1 & Appendix V). The highest plant height (41.47 cm) was obtained from I_4N_{100} (four time irrigation and 100 kg N/ha) treatment while the lowest plant height (25.23 cm) was obtained from I_0N_0 (no irrigation and no nitrogen) treatment (Table 1).

4.1.2 Number of leaves per plant

Statistically significant variation was not recorded on number of leaves per plant of onion due to application the effect of nitrogen (Fig 3 & Appendix V). The highest number of leaves $plant^{-1}$ (6.15) was observed in treatment T_{100} (100 kg N/ha). On the other hand, the minimum number of leaves (5.35) 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. Kumar *et al.* (1998) recorded that application of N at 150 kg/ha gave the best results with regard to number of leaves/plant of onion.

Table 1. Combined effect of nitrogen and irrigation management on the growth parameters of onion

Treatment	**Plant height (cm)**	**Number of leaves/plant**	**Length of leaf (cm)**
I_0N_0	25.23h	4.53d	24.43g
I_0N_{50}	33.4def	5.467bcd	32.27bcd
I_0N_{100}	35.87a-e	5.867a-d	35.1b
I_0N_{150}	32.43efg	5.867a-d	27.27fg
I_2N_0	35.67b-f	5.667bcd	33.37bc
I_2N_{50}	27.7gh	4.8cd	31.77cd
I_2N_{100}	39.63abc	5.467bcd	32.93bcd
I_2N_{150}	36.9a-e	5.533bcd	38.47a
I_4N_0	34.37c-f	6abcd	32.23bcd
I_4N_{50}	33.8def	5.267bcd	34.8bc
I_4N_{100}	41.47a	7.53a	39.17a
I_4N_{150}	40.07ab	5.667bcd	33.77bc
I_8N_0	30.23fgh	6.667ab	27.63ef
I_8N_{50}	38.2a-d	6.45abc	30.3de
I_8N_{100}	37.33a-e	6.8ab	38.9a
I_0N_{150}	37.57a-e	4.367d	25.37fg
$LSD_{(0.05)}$	4.889	1.589	2.722
CV(%)	8.27	10.49	4.99

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Application of 80 kg N increased the number of leaves per plant over 40 kg N (Nehra *et al.*, 1988). Kumar *et al.* (2001) found that 130 kg N ha^{-1} resulted in the highest number of green leaves/plant of onion.

Number of leaves was also not significantly influenced due to the application of different irrigation treatments. The maximum number of leaves (6.34) was produced by I_4 (four times of irrigation) and the minimum number of leaves (5.30) was produced by I_0 (no irrigation) (Fig. 4). Similar result was also found by Aujla *et al.* (1992). Mondal (1986) found that leaf per plant increased due to irrigation. Similar results were obtained by Brewster *et al.* (1986) where they found that the production of more leaves per unit area of land had a direct bearing on the yield of onion bulbs.

The combined effects of different irrigation and nitrogen had a significant influence on the number of leaves per plant. The highest number of leaves per plant (7.53) was counted with I_4N_{100} (four times irrigation and 100 kg N/ha) treatment combination, whereas the lowest number of leaves per plant (4.53) was obtained from I_0N_0 (control irrigation and nitrogen) treatment. The number of leaf increased with different combined treatment at different days (Table1).

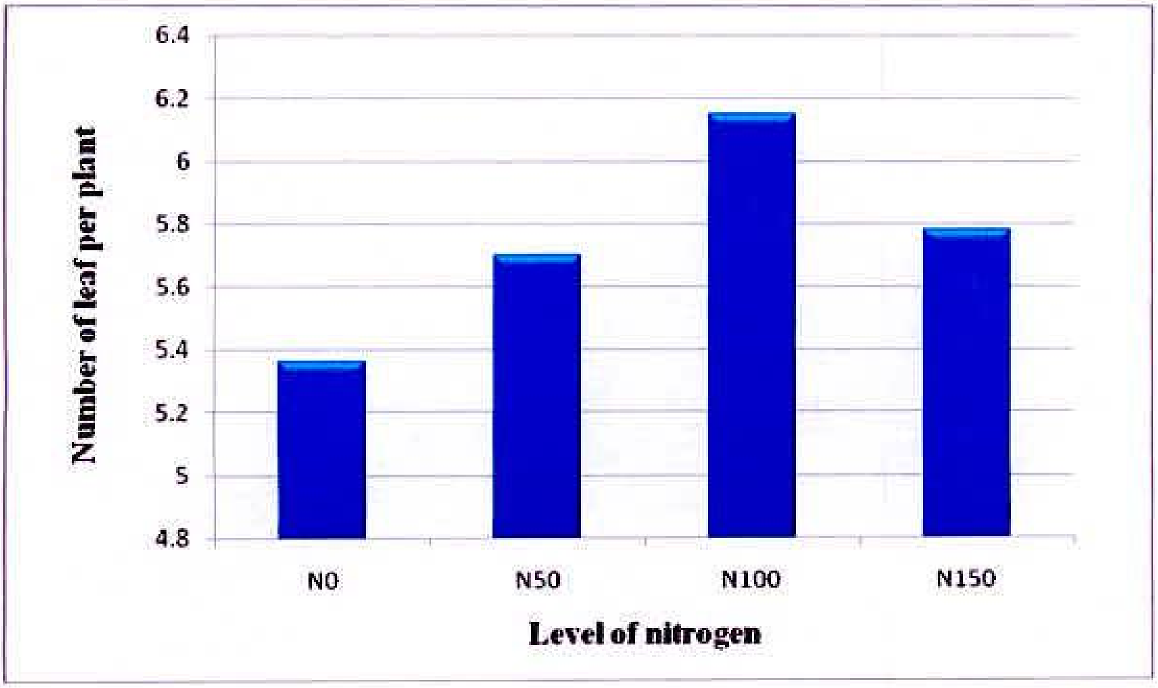

Figure 3 Effects of nitrogen on the number of leaf per plant of onion

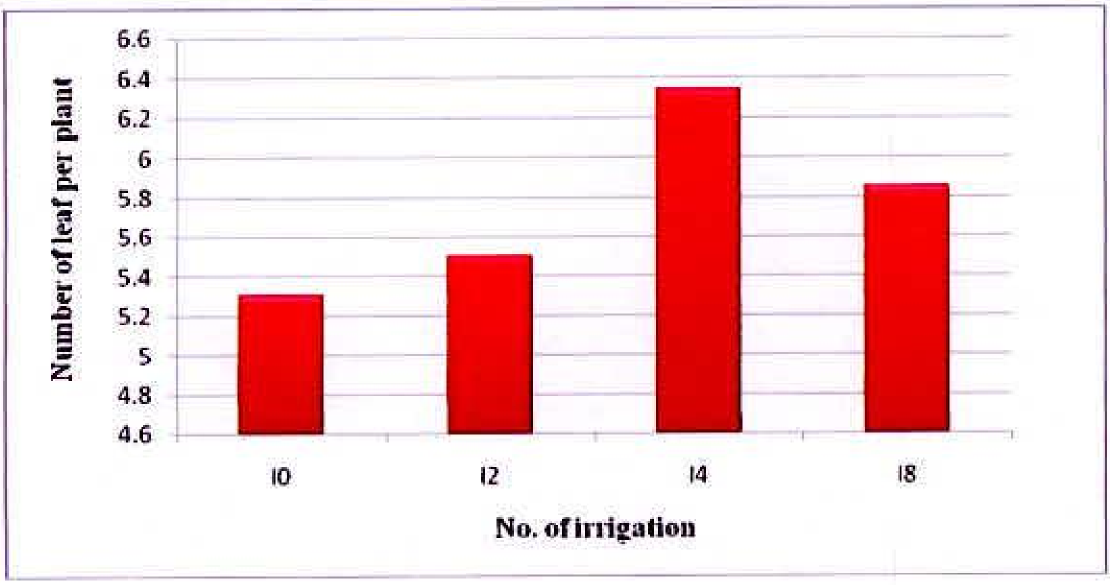

Figure 4 Effects of irrigation on the number of leaf per plant of onion

4.1.3 Length of leaf

A significant variation was found in case of length of leaf due to the application of different levels of nitrogen treatment (Fig. 5 and Appendix V). The longest leaf length (36.53 cm) was observed when the field was incorporated with 100 kg N/ha (N_{100}). The minimum leaf length (29.65 cm) was recorded in the treatment N_0 (control) receiving no nitrogen fertilizer. Kumar *et al.* (1998) also recorded longest leaf of onion with the application of N at 150 kg ha^{-1}. 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 that 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.

Different irrigation practice also influenced the length of onion leaf (Fig. 6 and Appendix V). The maximum length of leaf (34.99 cm) was produced by I_4 (four times of irrigation) and the minimum number of leaves (30 cm) was produced by I_0 (no irrigation).

The combined effects of irrigation and nitrogen significantly influenced the length of leaf (Table 1 and Appendix V). The highest length of leaf (39.17 cm) was counted with I_4N_{100} (four times irrigation and 100 kg N/ha) treatment combination which was statistically similar with I_2N_{150}, I_8N_{100} whereas the lowest length of leaf (24.43 cm) was obtained from I_0N_0 (control irrigation and nitrogen) treatment.

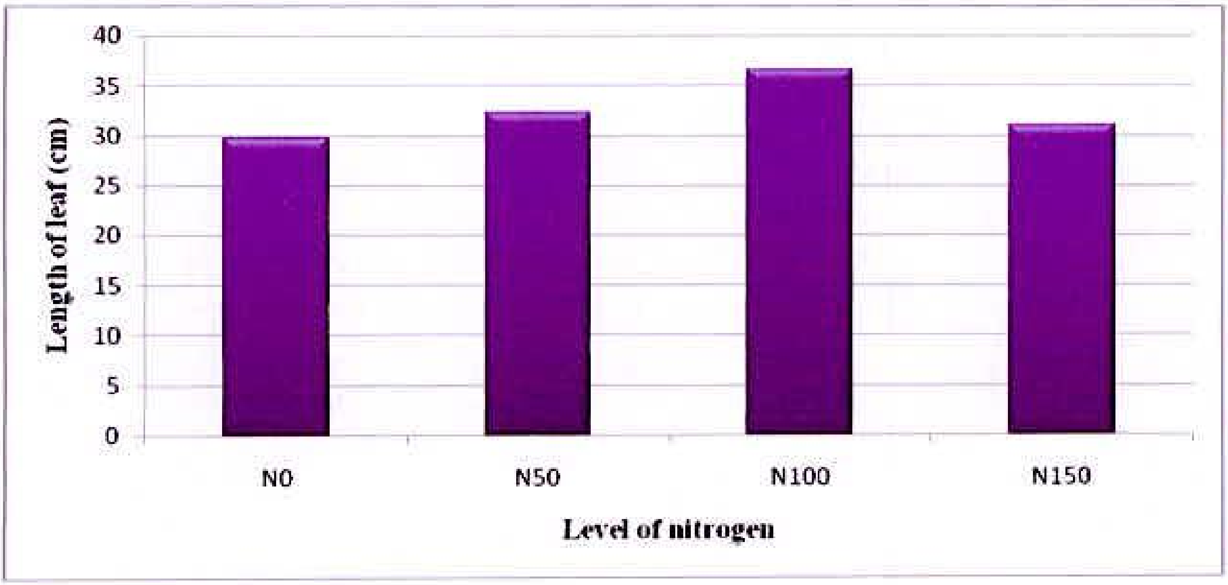

Figure 5 Effects of different level of nitrogen on the length of leaf of onion

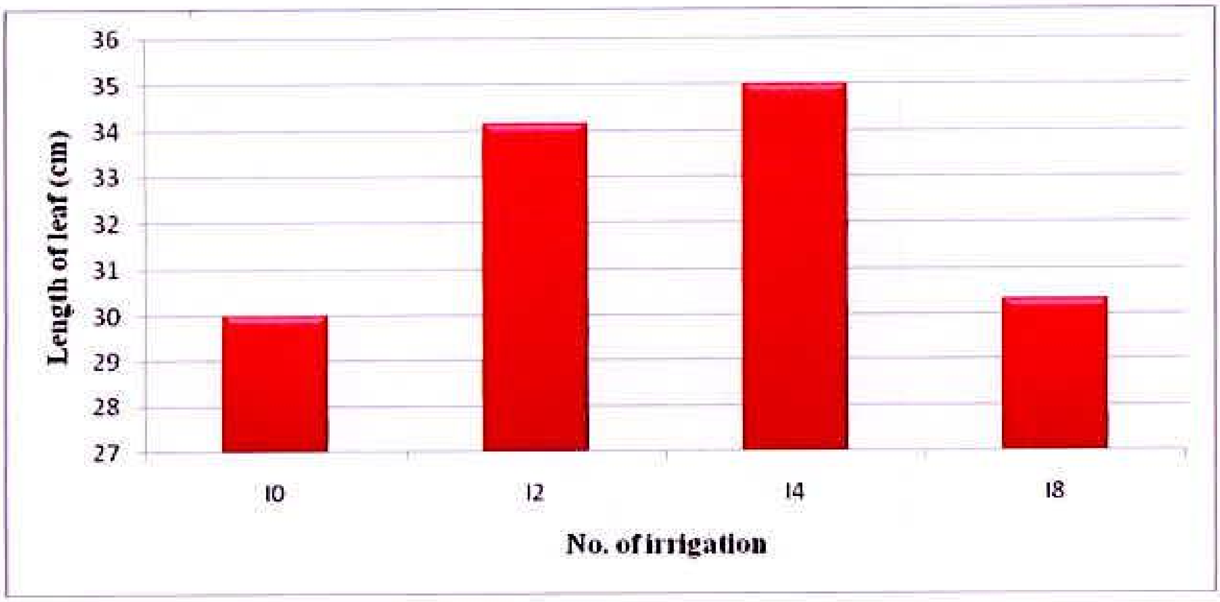

Figure 6 Effects of irrigation on the length of leaf of onion

4.1.4 Vertical length of bulb

It revealed from the study that nitrogen had a positive role on vertical length of bulb of onion (Fig 7 and Appendix V). There was a significant variation of vertical length of bulb. Result showed that treatment N_{100} (100 kg N/ha) gave the highest vertical length of bulb (3.98 cm). Lowest vertical length of bulb (2.93 cm) was obtained under N_1 (control) treatment. It is observed that integrated application of nitrogen from organic and inorganic sources increased vertical length of bulb. 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}.

Irrigation had significant variation in the vertical length of bulb of onion (Fig. 8 and Appendix V). The highest vertical length of bulb (3.71 cm) was recorded by the I_4 (four times of irrigation) and the lowest (3.091 cm) by the control (I_0) treatment. Favorable soil moisture regimes are essential for proper development of onion bulb (Narang and Dastane 1969). Optimum soil moisture conditions ensures proper bulb development not only through providing ample amount of water for satisfying elevated rates of evapotranspiration during Thus bulb diameter observed in the present study as result of frequent irrigation might be considered logical. The present results are in good agreement with those of several investigations reported from home and abroad (Begum *et al.* 1990; Das 1990; Karim *et al.* 1981; Rana and Sharma 1993; Sing and Sharma 1991)

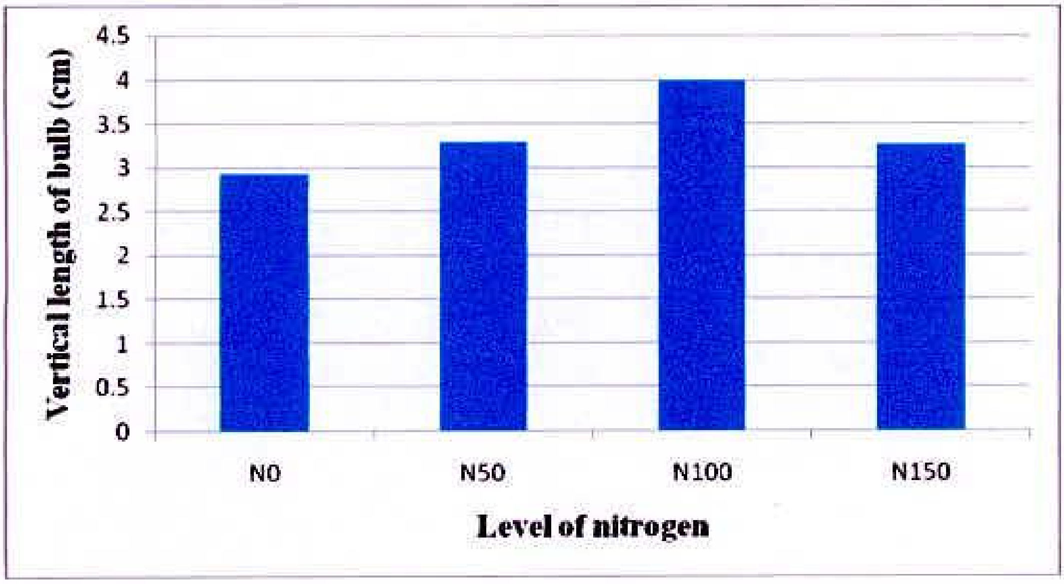

Figure 7 Effects of different level of nitrogen on the vertical length of bulb of onion

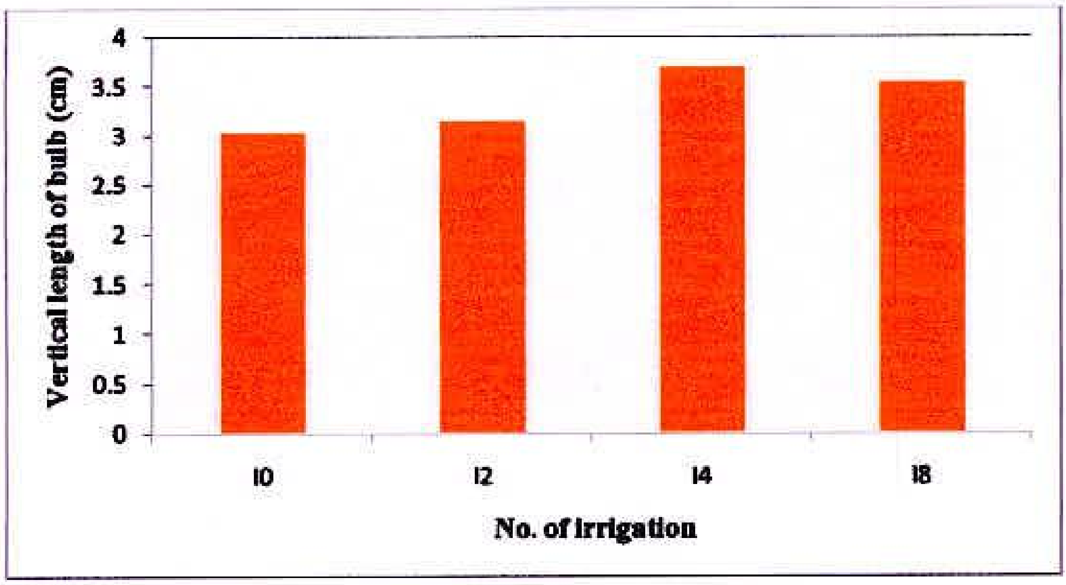

Figure 8 Effects of irrigation on the vertical length of leaf of onion

The significant interaction effect between different irrigation doses and levels of nitrogen in respect of vertical length of bulb was observed (Table 2 and Appendix V). The highest vertical length of bulb (4.27 cm) was recorded from the treatment combination of I_4N_{100} (four times of irrigation and 100 kg N/ha), whereas the lowest vertical length of bulb (2.16 cm) was observed from I_0N_0 (control irrigation and nitrogen) .

4.1.5 Horizontal length of bulb

Application of nitrogen had no significant variations in respect of horizontal length of bulb of onion (Fig.9 & Appendix V). The highest horizontal length of bulb (3.97 cm) was achieved under treatment N_{100} . On the contrary, control treated plot (N_0) gave the lowest bulb length (2.98 cm) of onion. Similar views were reported by Reddy and Reddy (2005). Bulb length of onion increased with increasing rates of N up to 125 kg/ha (Haque *et al.*, 2004).

There was also no significant variation in the horizontal length of bulb of onion due to irrigation (Fig 10 and Appendix V). The highest horizontal length of bulb (3.59 cm) was recorded in the I_4 (four times of irrigation) and the lowest (3.19 cm) in the control (I_0) treatment.

Table 2. Combined effect of nitrogen and irrigation on vertical and horizontal length of onion bulb

Treatment	Vertical length of bulb (cm)	Horizontal length of bulb (cm)
I_0N_0	2.16f	2.48d
I_0N_{50}	2.987de	3.127bcd
I_0N_{100}	4.14ab	3.827abc
I_0N_{150}	2.887de	3.353a-d
I_2N_0	3.033de	3.2bcd
I_2N_{50}	2.813e	3.043bcd
I_2N_{100}	3.507bcde	3.543a-d
I_2N_{150}	3.293cde	3.507a-d
I_4N_0	3.247cde	2.813cd
I_4N_{50}	3.793abc	3.38a-d
I_4N_{100}	4.267a	4.383a
I_4N_{150}	3.53bcd	3.797abc
I_8N_0	3.29cde	3.423a-d
I_8N_{50}	3.587bcd	3.69abc
I_8N_{100}	4.017ab	4.143ab
I_0N_{150}	3.333cde	3.13bcd
$LSD_{(0.05)}$	0.6053	0.9548
CV(%)	8.35	6.5

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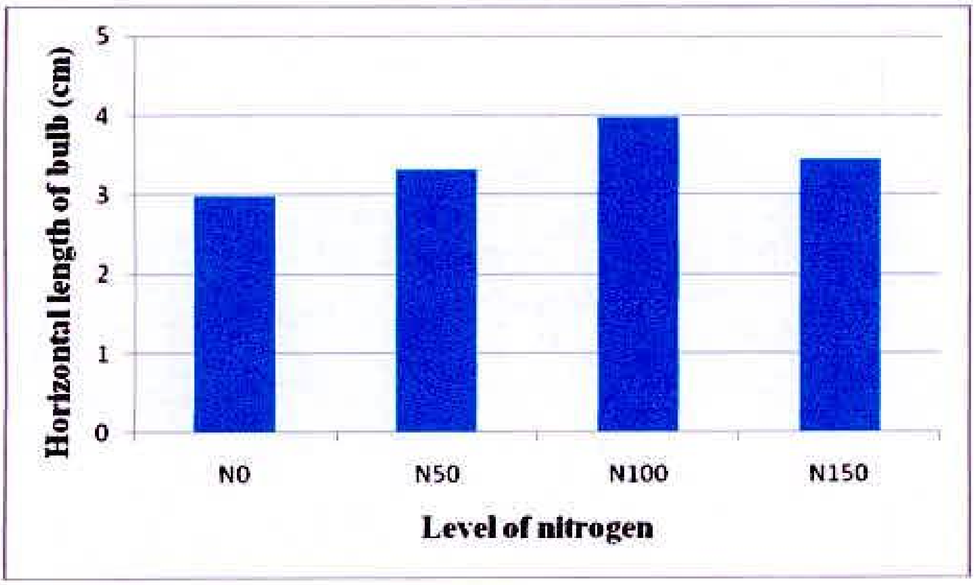

Figure 9 Effects of different level of nitrogen on the horizontal length of bulb of onion

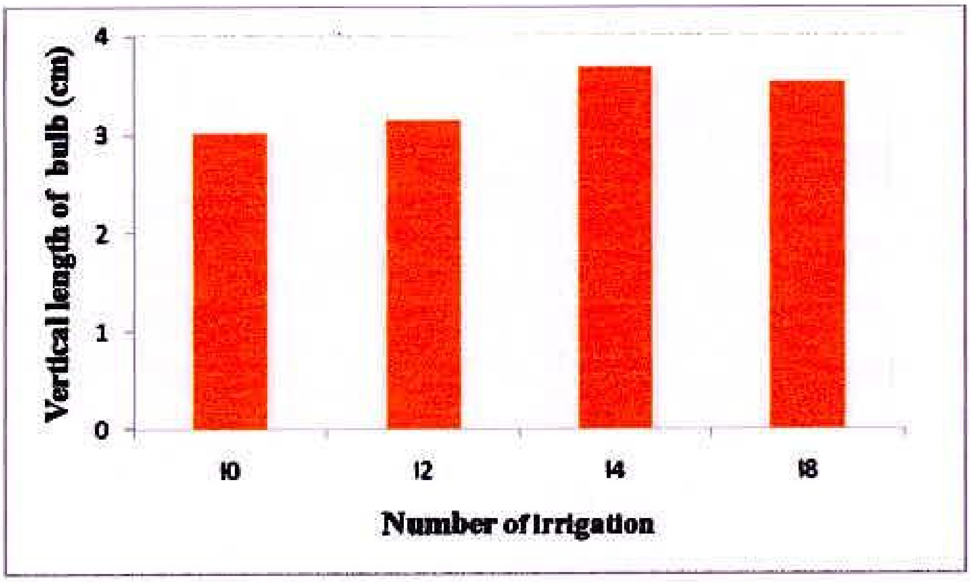

Figure 10 Effects of different irrigation on the horizontal length of bulb of onion

The significant interaction effect between irrigations and levels of nitrogen in respect horizontal length of bulb was observed (Table 2 and Appendix V). The highest vertical length of bulb (4.38 cm) was recorded from the treatment combination of I_4N_{100} (four times of irrigation and 100 kg N/ha), whereas the lowest vertical length of bulb (2.48 cm) was observed from I_0N_0 (control irrigation and nitrogen).

4.1.6 Dry matter weight of leaf

There was a significant influence of different doses of nitrogen on the dry matter weight of onion leaf (Fig.11 and Appendix V). The maximum dry matter weight of leaf (1.03 gm) was obtained at N_{100} (100 kg N/ha), while the minimum (0.59 gm) dry matter weight of leaf was obtained from control treatment.

A significant variation in the dry weight of onion leaf was found due to different treatments of irrigation. The highest dry weight of onion leaf (1.11gm) was recorded in the I_4 (four times of irrigation) and the lowest (0.89 gm) in the control (I_0) treatment (Fig .12).

Significant interaction between different irrigation treatments and levels of nitrogen in respect dry weight of onion leaf was observed (Table 3 and Appendix V). The highest dry weight of leaf (1.47 gm) was recorded from the treatment combination of I_4N_{100} (four times of irrigation and 100 kg N/ha), whereas the lowest dry weight of leaf (0.50 gm) was observed in I_0N_0 (control irrigation and nitrogen).

Table 3. Combined effect of nitrogen and irrigation on dry weight of bulb and leaf of onion

Treatment	Dry weight of bulb (g)	Dry Weight of Leaf (g)
I_0N_0	3.407d	0.5g
I_0N_{50}	4.027bcd	0.84f
I_0N_{100}	4.23abc	1.18bcd
I_0N_{150}	3.893bcd	1.05de
I_2N_0	3.733cd	0.566g
$2N_{50}$	3.96bcd	0.933ef
I_2N_{100}	4.8a	1.333ab
I_2N_{150}	4.033bcd	1.15cd
I_4N_0	3.793cd	0.6333g
I_4N_{50}	3.953bcd	1.127cd
I_4N_{100}	4.45ab	1.467a
I_4N_{150}	4.1bc	1.233bc
I_8N_0	3.9bcd	0.667g
I_8N_{50}	3.9bcd	0.903ef
I_8N_{100}	4.8a	1.233bc
I_0N_{150}	4.163bc	1.02de
$LSD_{(0.05)}$	0.554	0.1599
CV(%)	8.08	9.67

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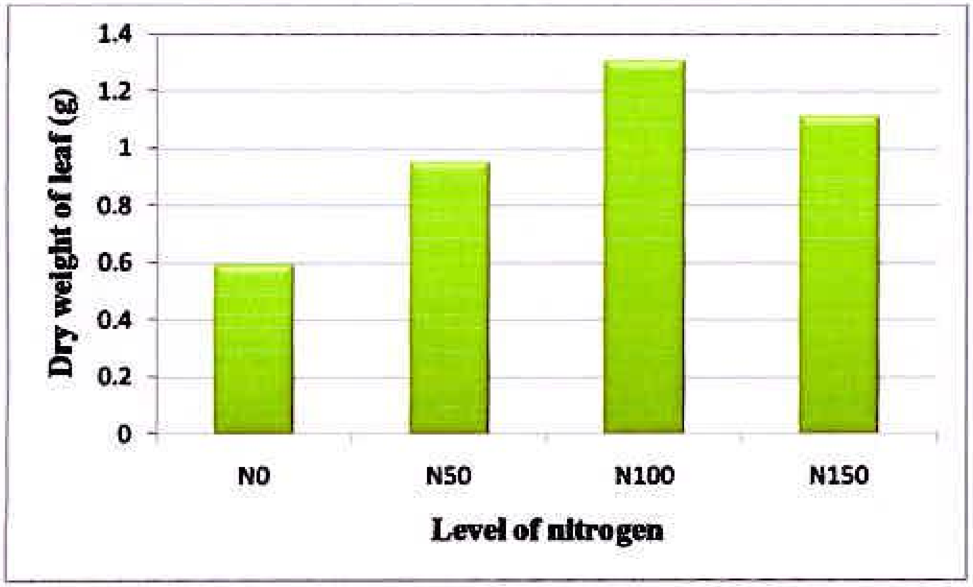

Figure 11. Effects of different level of nitrogen on dry weight of leaf of onion

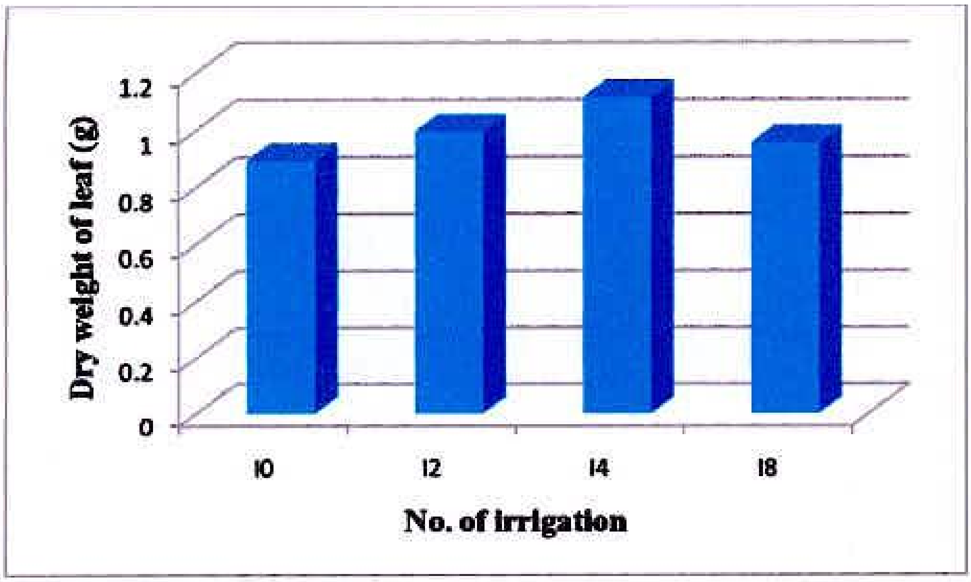

Figure 12. Effects of irrigation on the dry weight of leaf of onion

4.1.7 Dry weight of bulb

The dry matter content of bulb varied significantly with the different doses of nitrogen (Fig. 13 & Appendix V). The maximum (4.57) dry weight of onion bulb per plant was found from N_{100} (100 kg N/ha), while the minimum (3.71) dry weight of bulb per plant was noted in control treatment. 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 onion bulb. 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}.

The dry weight of onion bulb did not vary significantly due to different irrigation treatments (Fig 14 and Appendix V). The highest dry weight of bulb (4.19) was recorded by the I_4 (four times of irrigation) and the lowest (3.96) in the control (I_0) treatment.

The significant interaction between different irrigation treatments and levels of nitrogen in respect dry weight of onion bulb was observed (Table 3 and Appendix V). The highest dry weight of bulb (4.8) was recorded from the treatment combination of I_4N_{100} (four times of irrigation and 100 kg N/ha), whereas the lowest dry weight of bulb (3.4) was observed from I_0N_0 (control irrigation and nitrogen).

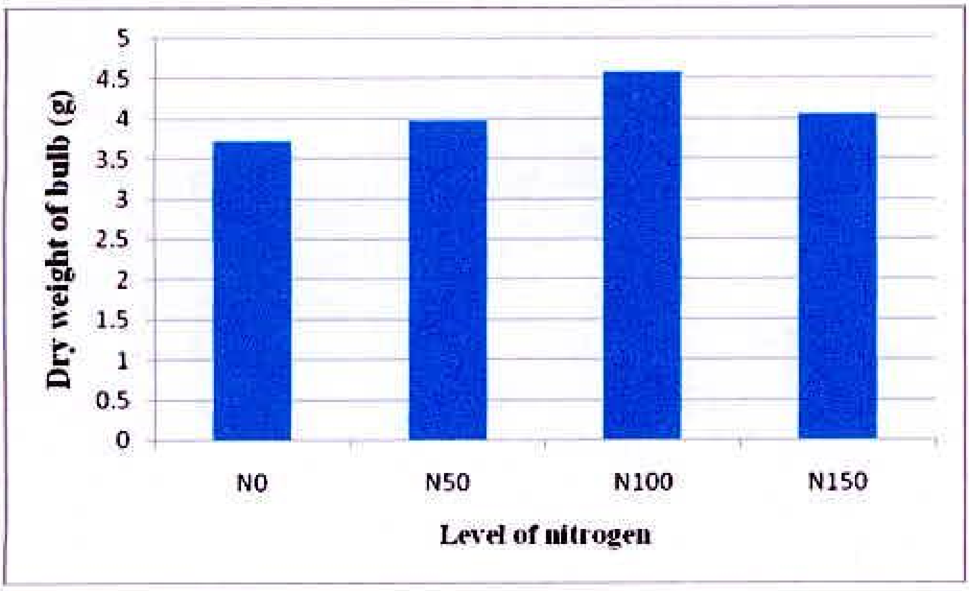

Figure 13. Effects of different level of nitrogen on dry weight of bulb of onion

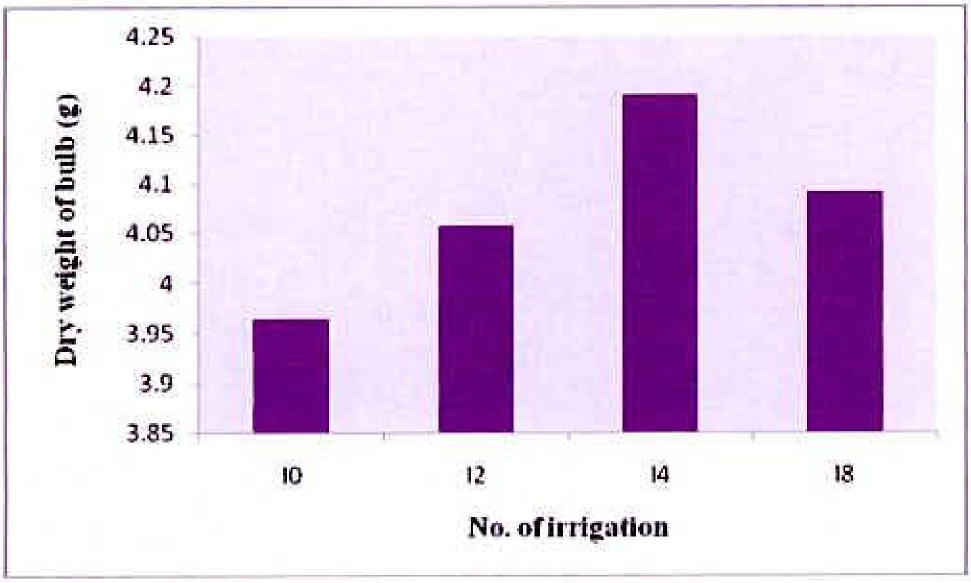

Figure 14. Effects of different irrigation on dry weight of bulb of onion

4.1.8 Yield of bulbs

The total yield of onion bulb varied significantly due to different levels of nitrogen doses applied in onion (Table 4 and Appendix V). The highest yield of onion (5.44 kg/plot and 17.94 t/ha) was recorded from N_{100} (100 kg N/ha) treatment while the control treatment (N_0) produced the lowest yield (4.21 kg/plot and 13.89 t/ha). It was clearly observed that the yield increased with increasing levels of nitrogen (N) (Table 4). Different doses of nitrogen produced significantly different yields. The present results was also supported the findings of Ramamoorthy *et al.* (1999). Pandey *et al.* (1992) observed that both 80 and 120 kg N ha^{-1} ha gave significantly higher yields of summer onion than the lower fertilizer rates.

The total yield of bulb significantly varied due to different irrigation treatments in onion (Table 5). The highest yield of onion (5.04 kg/plot and 16.61 t/ha) was recorded from I_4 (four times of irrigation) treatment while the control treatment (I_0) produced the lowest yield (4.19 kg/plot and 13.84 t/ha). Significant yield response of onion to supplemental irrigations have also been reported from many investigations carried out under varying agroclimatic situations (Begum *et al.* 1991; Das, 1990; Karim *et al.* 1981; Rana and Sharma 1991) which supported the present findings.

Table 4. Effect of nitrogen on yield of onion

Treatment	Yield of bulb per plot (kg)	Yield of Bulb (t/ha)
N_0	4.212c	13.89c
N_{50}	4.71b	15.5b
N_{100}	5.44a	17.94a
N_{150}	4.686b	15.57b
$LSD_{(0.05)}$	0.3438	1.355
CV(%)	3.20	3.32

Table 5. effect of irrigation management of yield of onion

Treatment	Yield of bulb per plot (kg)	Yield of Bulb (t/ha)
I_0	4.198b	13.84b
I_2	4.893a	16.13a
I_4	5.04a	16.61a
I_8	4.917a	16.32a
$LSD_{(0.05)}$	0.4109	1.694
CV (%)	3.20	3.32

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Table 6. Combined effect of nitrogen and irrigation management on yield of onion

Treatment	Yield of bulb per plot (kg)	Yield of bulb (t/ha)
I_0N_0	3.333g	11.01i
I_0N_{50}	4.31f	14.21gh
I_0N_{100}	4.943de	16.3de
I_0N_{150}	4.203f	13.85h
I_2N_0	4.733e	15.6ef
I_2N_{50}	4.217f	13.9h
I_2N_{100}	5.54ab	18.26a
I_2N_{150}	5.083cd	16.76cd
I_4N_0	4.45f	14.67gh
I_4N_{50}	4.983de	16.43de
I_4N_{100}	5.637a	18.6a
I_4N_{150}	5.09cd	16.76cd
I_8N_0	4.33f	14.27gh
I_8N_{50}	5.33bc	17.48bc
I_8N_{100}	5.64ab	18.59a
I_0N_{150}	4.367f	14.92fg
LSD(0.05)	0.2556	0.8789
CV(%)	3.20	3.32

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

The combined effect of irrigation and different levels of nitrogen showed a significant variation in the onion yield per plot (Table 6). The highest bulb yield per plot (5.637 kg/plot and 18.6 t/ha) was recorded from the treatment combination of I_4N_{100} (four times of irrigation and 100 kg N/ha), while the lowest yield of bulb (3.33 kg/plot and 11.01 t/ha) was observed from I_0N_0 (control irrigation and nitrogen).

4.2 Nutrient concentrations in the onion bulb

4.2.1 Nitrogen content

N concentration of onion bulb was not significantly influenced by the levels of nitrogen application (Table 7). The highest nitrogen concentration in onion bulb (2.11 %) was recorded in N_2 (100 kg/ha) treatment. On the other hand, the lowest nitrogen concentration in onion bulb (1.98 %) was recorded in N_0 treatment where no nitrogen was applied. Hegde (1988) stated that nitrogen fertilization increased the N, Ca and Mg concentrations in the bulb of onion.

The N concentration of onion bulb was not significantly varied due to irrigations in onion (Table 8). The highest N concentration of bulb (2.129 %) was recorded from I_4 (four times of irrigation) treatment while the control treatment (I_0) showed the lowest (1.834%) content of nitrogen.

The combined effect of irrigation and different levels of nitrogen showed significant variation in N concentration of onion bulb (Table 9). The highest N concentration of bulb (2.327%) was recorded from the treatment combination of

Table 7. Effect of nitrogen supplied on the nutrient concentrations in the bulb of onion

Treatment	Concentration		
	Nitrogen	Phosphorus	Potassium
N_0	1.981	2.642	0.9792
N_{50}	2.077	2.708	1.108
N_{100}	2.11	2.775	1.226
N_{150}	1.967	2.683	1.058
$LSD_{(0.05)}$	NS	NS	NS
CV(%)	8.73	10.83	5.70

Table 8. Effect of irrigation on the nutrient concentrations in the bulb of onion

Treatment	Concentration		
	Nitrogen	Phosphorus	Potassium
I_0	1.837	0.9783	2.675
I_2	2.067	1.093	2.708
I_4	2.129	1.211	2.733
I_8	2.102	1.089	2.692
$LSD_{(0.05)}$	NS	NS	NS
CV(%)	8.73	5.70	10.83

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

Table 9. Combined effect of nitrogen and irrigation on the nutrient concentrations in the bulb of onion

Treatment	Concentration (%)		
	Nitrogen	Phosphorus	Potassium
I_0N_0	1.573c	2.5b	0.8d
I_0N_{50}	1.833bc	2.7ab	0.9733cd
I_0N_{100}	1.943abc	2.8ab	1.133bc
I_0N_{150}	2ab	2.7ab	1.007bcd
I_2N_0	1.95abc	2.8ab	1.213b
I_2N_{50}	2.18ab	2.633ab	1.12bc
I_2N_{100}	2.003ab	2.733ab	1.047bc
I_2N_{150}	2.06ab	2.767ab	0.9933bcd
I_4N_0	2.22ab	2.633ab	0.9667cd
I_4N_{50}	2.11ab	2.767ab	1.127bc
I_4N_{100}	2.327a	2.867a	1.587a
I_4N_{150}	1.933abc	2.567ab	1.163bc
I_8N_0	2.18ab	2.633ab	0.9367cd
I_8N_{50}	2.183ab	2.733ab	1.213b
I_8N_{100}	2.167ab	2.7ab	1.137bc
I_0N_{150}	1.877bc	2.7ab	1.07bc
$LSD_{(0.05)}$	0.3575	0.2611	0.1994
CV(%)	8.73	5.70	10.83

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

I_4N_{100} (four times of irrigation and 100 kg N/ha), while the lowest N concentration of bulb (1.573%) was observed from I_0N_0 (control irrigation and nitrogen).

4.2.2 Phosphorus content

P concentration of onion bulb was not significantly influenced by application of different levels of nitrogen (Table 7). The highest phosphorus concentration in onion bulb (2.775 %) was recorded in N_2 (100 kg/ha). On the other hand, the lowest phosphorus concentration in onion bulb (2.642 %) was recorded in N_0 treatment. Hegde (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.

The P concentration of onion bulb did not vary significantly due to different irrigation treatments in onion (Table 8). The highest P concentration of bulb (1.211 %) was recorded from I_4 (four times of irrigation) treatment while the control treatment (I_0) showed the lowest (0.9783%) content of phosphorus.

The combined effect of irrigation and different levels of nitrogen performed significant variation on P concentration of onion bulb (Table 9). The highest P concentration of bulb (2.867%) was recorded from the treatment combination of I_4N_{100} (four times of irrigation and 100 kg N/ha), while the lowest P concentration of bulb (2.50%) was observed from I_0N_0 (control irrigation and nitrogen).

4.2.3 Potassium content

K concentration of onion bulb was not significantly influenced by application of different levels of nitrogen (Table 7). The highest potassium concentration in onion bulb (1.226 %) was recorded in N_{100} (100 kgN/ha). On the other hand, the lowest potassium concentration in onion bulb (0.979 %) was recorded in N_0 treatment where no nitrogen was applied.

The K concentration of onion bulb was not significantly varied due to different irrigation levels in onion (Table 8). The highest K concentration of bulb (2.733 %) was recorded from I_4 (four times of irrigation) treatment while the control treatment (I_0) was produced the lowest (2.675%) in this respect.

The combined effect of irrigation and different levels of nitrogen performed significant variation on K concentration of onion bulb (Table 9). The highest K concentration of bulb (1.587%) was recorded from the treatment combination of I_4N_{100} (four times of irrigation and 100 kg N/ha), while the lowest K concentration of bulb (0.80%) was observed from I_0N_0 (control irrigation and nitrogen).

4.3 Nutrient concentrations in the post harvest soils field

4.3.1 Nitrogen content of soil

The nitrogen content of soil after harvest of onion was not influenced significantly by different doses of nitrogen applied (Table 10). The highest N content (0.1192%) of soil was observed in case of treatment N_{100} (100 kg N/ha). In contrast, the lowest N content (0.07583%) was obtained in the N_0 treatment where no fertilizer was applied. This may be due to the fact that highest yield was obtained by uptake of more amount of nitrogen from soil by plant. Similar trend was pointed out by Zahir and Mian (2006) in case of wheat. Chellamuthu *et al.* (1988) found that application of farm yard manure as well as ammonium sulphate significantly increased the total nitrogen content of soil.

The N concentration of postharvest soil was not significantly varied due to different irrigation treatments in onion (Table 11). The highest N concentration of soil (0.1225 %) was recorded from I_0 (no irrigation) treatment while the I_8 treatment (8 times of irrigation) showed the lowest (0.0658%) nitrogen content.

The combined effect of irrigation and different levels of nitrogen performed significant variation on N concentration of postharvest soil. The highest N concentration of soil (0.26%) was recorded from the treatment combination of I_0N_{100} (No irrigation and 100 kg N/ha), while the lowest N concentration of soil (0.05%) was observed from I_8N_{100} (eight times of irrigation and 100 kg N/ha) treatment (Table 12).

Table 10. Effect of nitrogen on the nutrient concentrations in the post harvest soil

	Concentration (%)		
Treatment	Nitrogen	Phosphorus	Potassium
N_0	0.07583	0.1167	0.2225
N_{50}	0.1017	0.1175	0.2525
N_{100}	0.1192	0.1175	0.2817
N_{150}	0.07583	0.1483	0.2558
$LSD_{(0.05)}$	NS	NS	NS
CV (%)	11.5	8.9	12.3

Table 11. Effect of irrigation on the nutrient concentrations in the post harvest soil

	Concentration (%)		
Treatment	Nitrogen	Phosphorus	Potassium
I_0	0.1225	0.1133b	0.2342
I_2	0.115	0.1508a	0.3042
I_4	0.06917	0.12b	0.265
I_8	0.06583	0.1158b	0.2092
$LSD_{(0.05)}$	NS	0.02598	NS
CV (%)	11.5	8.9	12.3

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

Table 12. Combined effect of nitrogen and irrigation on the nutrient concentrations in the post harvest soil

Treatment	Concentration		
	Nitrogen	Phosphorus	Potassium
I_0N_0	0.1ab	0.11cde	0.1633c
I_0N_{50}	0.0567b	0.09de	0.2867abc
I_0N_{100}	0.26a	0.1633abc	0.233bc
I_0N_{150}	0.0733b	0.09de	0.253abc
I_2N_0	0.07b	0.15bcd	0.3167abc
I_2N_{50}	0.227ab	0.16abc	0.227bc
I_2N_{100}	0.09ab	0.08e	0.22bc
I_2N_{150}	0.07333b	0.2133a	0.2567abc
I_4N_0	0.06b	0.12cde	0.367ab
I_4N_{50}	0.067b	0.133bcde	0.303abc
I_4N_{100}	0.077b	0.123cde	0.417a
I_4N_{150}	0.073b	0.103cde	0.17c
I_8N_0	0.073b	0.08667e	0.177c
I_8N_{50}	0.0567b	0.0867e	0.193bc
I_8N_{100}	0.05b	0.103cde	0.257abc
I_0N_{150}	0.083ab	0.187ab	0.21bc
$LSD_{(0.05)}$	0.1599	0.05329	0.1507
CV (%)	11.5	8.9	12.3

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

4.3.2 Phosphorous content of soil

The phosphorous content of soil after harvest of onion was not influenced significantly by different doses of nitrogen applied (Table 10). The highest P content (0.118%) of soil was observed in case of treatment N_{100} (100 kg N/ha) In contrast, the lowest N content (0.1167%) was obtained in the N_0 treatment where no fertilizer was applied.

The P concentration of postharvest soil significantly varied due to different irrigation treatments in onion (Table 11). The highest P concentration of soil (0.1508 %) was recorded from I_2 (two times of irrigation) treatment while the control treatment (I_0) produced the lowest (0.1133%) P content.

The combined effect of irrigations and different levels of nitrogen performed significant variation on P concentration of postharvest soil (Table 12). The highest P concentration of soil (0.2133%) was recorded from the treatment combination of I_2N_{150} (two times of irrigation and 150 kg N/ha), while the lowest P concentration of soil (0.0867%) was observed from I_8N_0 (eight times of irrigation and no nitrogen) (Table 12).

4.3.3 Potassium content of soil

The effect of different doses of nitrogen fertilizer showed a statistically insignificant variation in the potassium concentration in post harvest soil (Table10). The total K content of the post harvest soil varied from 0.2225 % to 0.2817 %. The highest total K content (0.2817 %) was observed in N_{100} (100 kg/ha) treatment and the lowest value of 0.2225 % under control (N_0) treatment.

The K concentration of postharvest soil did not significantly varied due to different irrigation treatments in onion (Table 11). The highest K concentration of soil (0.3042 %) was recorded from I_2 (two times of irrigation) treatment while the eight times of treatment (I_8) produced the lowest (0.2092%) K content.

The combined effect of irrigation and different levels of nitrogen showed significant variation in K concentration of soil (Table 12). The highest K concentration of soil (0.417%) was recorded from the treatment combination of I_4N_{100} (four times of irrigation and 100 kg N/ha), while the lowest K concentration of soil (0.1633%) was observed from I_0N_0 (eight times of irrigation and no nitrogen) (Table 12).

Chapter V

SUMMARY AND CONCLUSION

The experiment was carried out at the Sher-e-Bangla Agricultural University Farm, Dhaka-1207 during *Robi* season of 2007-2008 to evaluate the effect of irrigation and nitrogen on the growth and yield of onion. The soil was silty clay loam in texture having pH 5.80, and organic matter content 1.21 %. The experiment comprised of two factors such as (A) four levels of irrigation viz , I_0 : no irrigation, I_2: two times irrigation (30 days interval of after establishment of seedling), I_4 : four times irrigation (15 days interval of after establishment of seedling), I_8: eight times irrigation (7 days interval of after establishment of seedling) and (B) four levels of nitrogen viz; 0, 50, 100 and 150 kg ha^{-1}. The experiment was laid out in split plot design with three replications. The size of each unit plot was 2 m × 1.5 m (3 m^2). The irrigation treatments were assigned in main plots and N treatment in subplots with 3 replications. The distance maintained between two subplots was 100 cm and between main plots was 150 cm. Bulb yield per hectare was estimated on the basis of yield per plot.

Data were recorded on bulb yield and yield components namely plant height, leaf number, leaf length, vertical length of bulb, horizontal length of bulb, dry weight of leaf, dry weight of bulb, bulb yield per plot and hectare. The collected data were analyzed and the differences between the means were evaluated by Duncan's Multiple Range Test. The experimental results are summarized as follows.

The result of the experiment revealed that the application of nitrogen had a statistically significant effect on leaf length, vertical length of bulb, dry weight of bulb, dry weight of leaf, yield of bulb per plot and yield of bulb per hectare. The highest leaf length (36.53 cm), vertical length of bulb (3.98 cm), dry weight of bulb (4.57), dry weight leaf (1.03), yield of bulb per plot (5.44 kg) and yield of bulb per hectare (17.94 t) was obtained with N_{100} (100 kg N ha^{-1}).

Application of irrigation at different intervals showed a statistically significant variation in plant height, leaf length, and dry weight of leaf, yield of bulb per plot and yield of bulb per hectare. Irrigation of onion plots four times in the cropping period with 15 days interval produced the maximum plant height (37.42 cm), leaf length (34.99 cm), dry weight of leaf (1.11), yield of bulb per plot (5.04 kg) and yield of bulb per hectare (17.94 t) was obtained with N_{100} (100 kg N ha^{-1}).

Interaction effect of irrigation and N levels was statistically significant for plant height, leaf number, leaf length, vertical length of bulb, horizontal length of bulb, dry weight of leaf, dry weight of bulb, bulb yield per plot and hectare. The treatment combination I_4N_{100} (4 irrigation and 100 kg N ha^{-1}) gave the highest values of all these parameters. Irrigation and N levels had not significant effect on NPK concentration in bulb and post harvest soil except the effect of irrigation on P content of post harvest soil. However their interaction effects were significant for NPK concentration in bulb and post harvest soil.

From the above discussion it may be concluded that irrigation and nitrogen influenced the growth, yield and yield components of onion. Among the irrigation levels four irrigations gave the best results. Among the nitrogen treatments, 100 kg N/ha gave the best result. The interaction effects of four irrigations and 100 kg N/ha were found most effective in respect of onion yield. However the results are required to substantiate further with different varieties and soil management practices.

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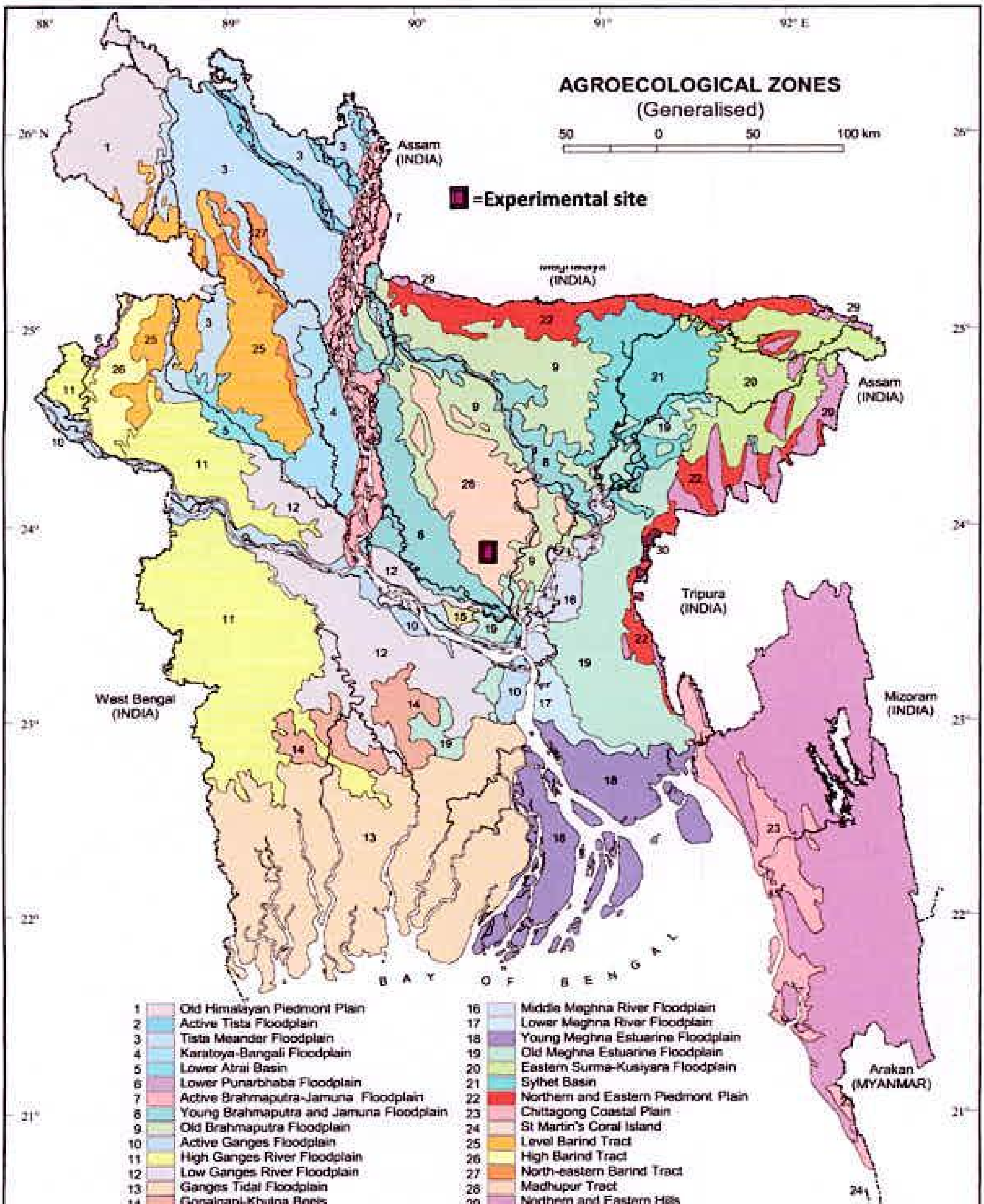
APPENDICES

Appendix I. Experimental location on the map of Agro-ecological Zones of Bangladesh



Appendix II. Results of Physical and chemical properties of soil of the experimental plot.

Physical properties (a)

Constituents	Percent
Sand,	32.45
Silt,	61.35
Clay,	6.10
Textural class	Sandy loam

Chemical analysis (b)

Soil properties	Amount
Soil pH	5.6
Organic carbon (%)	1.21
Total nitrogen (%)	0.075
Available P (ppm)	19.5
Exchangeable K (%)	0.2

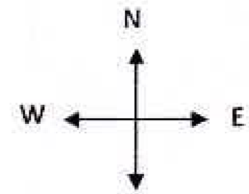
Appendix III. Monthly Average Air Temperature, Total Rainfall, Relative Humidity and Sunshine Hours of the experimental site during the period from November 2007 to April 2008

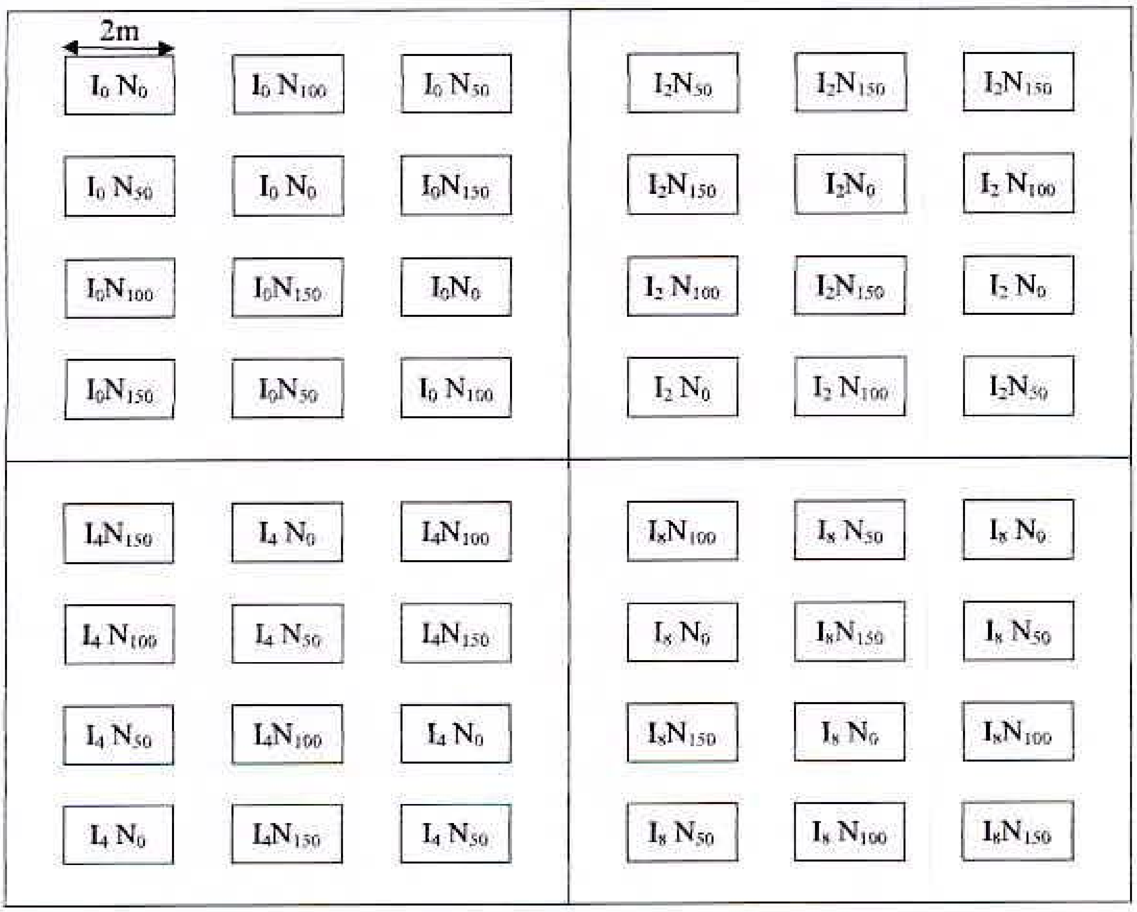
Year	Month	Average Air temperature (^0C)			Total rainfall (mm)	Average RH (%)	Total Sun shine hours
		Maximum	Minimum	Mean			
2007	November	29.7	20.1	24.9	5	65	192.20
	December	26.9	15.8	21.35	0	68	217.03
2008	January	24.6	12.5	18.7	0	66	171.01
	February	27.1	15.8	21.05	09	66	168.60
	March	30.2	18.4	24.3	12	68	165.02
	April	38.3	23.2	30.75	25	72	166.8

Source: Dhaka Metrological Centre (Climate Division)

Appendix IV. Field layout of two factors experiment in the Split Plot Design (SPD)

Layout of the experiment:





A. Irrigation level (main plot):
1. I_0 : no irrigation
2. I_2: two times irrigation
3. I_4 : four times irrigation
4. I_8: eight times irrigation

B. Nitrogen levels (subplots):
1. N_0: no fertilizer
2. N_{50}: 50 kg N /ha
3. N_{100}: 100 kg N /ha
4. N_{150}: 150 kg N/ha

Appendix V. Analysis of variance of the data on the growth and yield components of onion as influenced by irrigation and level of nitrogen

Source	Degrees of Freedom	Sum square								
		Plant height	Number of leaf	Length of leaf	Horizontal length of bulb	vertical length of bulb	Dry weight of bulb	Dry Weight of Leaf	Yield of Bulb per plot	Yield of Bulb(t/ha)
Replication		30.504	30.939	36.583	26.379	51.939	4.682	0.115	0.107	0.013
Factor A	3	68.986*	2.5NS	79.261*	1.2NS	0.481NS	0.104NS	0.105*	1.748*	19.394*
Error	6	6.187	0.561	3.962	0.642	0.117	0.345	0.018	0.025	0.425
Factor B	3	127.72NS	1.268NS	106.37*	2.336NS	2.056*	1.574*	1.096*	3.084*	33.353*
AB	9	33.905*	2.237*	40.729*	0.282*	0.311*	0.1*	0.011*	0.407*	3.821*
Error	24	8.416	0.889	2.609	0.129	0.321	0.108	0.009	0.023	0.272
Total	47									

*Significant at 5% level of probability

NS Non Significant

Appendix IV. Analysis of variance of the data on the nutrient concentrationof bulb and postharvest soil of onion as influenced by irrigation and level of nitrogen

Source	Degrees of Freedom	Sum square					
		Bulb			Soil		
		Nitrogen	Phosphorus	Potassium	Nitrogen	Phosphorus	Potassium
Replication	2	0.033	0.003	0.015	0.008	0	0.003
Factor A (Irrigation)	3	0.213 NS	0.007 NS	0.108 NS	0.011NS	0.004*	0.008 NS
Error	6	0.218	0.007	0.011	0.011	0	0.003
Factor B (Nitrogen)	3	0.059 NS	0.037 NS	0.128 NS	0.005 NS	0.003 NS	0.003 NS
AB	9	0.08*	0.028*	0.069*	0.013*	0.006*	0.007*
Error	24	0.045	0.024	0.014	0.009	0.001	0.008
Total	47						

*Significant at 5% level of probability

NS Non Significant