BULB YIELD OF SUMMER ONION (BARI PIAZ-5) AS INFLUENCED BY THE APPLICATION OF NITROGEN AND POTASSIUM

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Dedicated to

My

"Beloved Parents and Family"

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CERTIFICATE

This is to certify that the thesis titled, " ***BULB YIELD OF SUMMER ONION (BARI PIAZ 5) AS INFLUENCED BY THE APPLICATION OF NITROGEN AND POTASSIUM"*** *submitted to the* ***Department of Soil Science, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka*** *in partial fulfilment of the requirements for the degree of* ***MASTER OF SCIENCE (M.S.)*** *in* ***SOIL SCIENCE*** *embodies the result of a piece of bona fide research work carried out by* ***ETI CHAKRABORTY****,* ***REGISTRATION NO. 15-06502*** *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 by the Author.

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Place: Dhaka, Bangladesh

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ABSTRACT

Lower average yield of onion bulb is the main bottleneck for getting self-sufficiency on onion in Bangladesh. Application of nitrogen and potassium nutrients may improve the yield contributing traits of onion. From the perspective, the experiment was carried out in the research field of Sher-e-Bangla Agricultural University (SAU), Dhaka-1207 during the period from June to September, 2021. The variety, BARI Piaj 5 (**S**ummer variety) was used as test crop under present study. The experiment consisted of two factors *viz*., factor-A (Nitrogen levels-4): N_0= 0 kg ha^{-1}, N_1= 50 kg ha^{-1}, N_2= 75 kg ha^{-1} and N_3= 100 kg ha^{-1} and factor-B (Potassium levels-3): K_0= 0 kg ha^{-1}, K_1= 50 kg ha^{-1} and K_2= 100 kg ha^{-1}. The experiment was conducted by following factorial RCBD (Randomized Complete Block Design) design with three (3) replications. Result revealed that, a gradual increasing trend was found with the increasing of nitrogen (N) levels for most of the parameters studied except non-marketable yield (t ha^{-1}) and small size bulb (< 30 mm) of onion. Similar trend was also found in case of potassium (K) application. The application of N at the rate of 100 kg ha^{-1} exhibited the best one dose for yield and yield contributing traits of summer onion which was statistically similar to 75 kg ha^{-1}. When the onion crop is treated with 100 kg K ha^{-1} showed the best performance for most of the parameters studied. The highest yield and marketable yield of onion bulb (17.876 t ha^{-1} and 16.616 t ha^{-1}, respectively) was found from N_3K_2 treatment combination which was statistically similar to N_2K_2 (17.369 t ha^{-1} and 16.134 t ha^{-1}, respectively) treatment combination while the lowest (9.352 t ha^{-1} and 5.885 t ha^{-1}, respectively) was found in N_0K_0 treatment combination. In case of post-harvest soil properties, the highest total nitrogen and exchangeable potassium were found from N_3K_2 (0.083 % and 0.491 meq/100 g soil, respectively) treatment combination over control. Different yield contributing traits of summer onion and also the soil properties were strongly correlated with each other. Application of nitrogen at the rate of 75 and 100 kg ha^{-1} along with potassium at the rate of 100 kg ha^{-1} gave the better bulb yield merit (182.55 % and 174.16 %, respectively) over control. Finally, on the basis of monetary advantages it may be concluded that application of nitrogen @ 75 kg ha^{-1} along with potassium @ 100 kg ha^{-1} is best for summer onion production.

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LIST OF ACCRONYMS AND ABBREVIATIONS

AEZ	Agro-Ecological Zone
%	Percentage
@	At the rate of
Agric.	Agriculture
Agril.	Agricultural
Appl.	Applied
BADC	Bangladesh Agricultural Development Corporation
BARI	Bangladesh Agricultural Research Institute
Biol.	Biology
Chem.	Chemistry
cm	Centi-meter
CV	Coefficient of Variance
DAT	Days After Transplanting
Ecol.	Ecology
Environ.	Environmental
et al	et alii, And Others
Exptl.	Experimental
g	Gram
i.e.	*id est* (L), that is
J.	Journal
kg	Kilogram
N and K	Nitrogen and potassium
LSD	Least Significant Difference
M.S.	Master of Science
m^2	Meter squares
Nutr.	Nutrition
Physiol.	Physiological
Res.	Research
RDF	Recommended Dose of Fertilizer
SAU	Sher-e-Bangla Agricultural University
Sci.	Science
Soc.	Society
Tk.	Taka
t ha^{-1}	Ton per hectare
viz	*videlicet* (L.), Namely

CHAPTER I

INTRODUCTION

Onion (*Allium cepa* L.) is valued primarily for its ability to infuse flavor into the diet. The crop onion is a popular vegetable and its bulb is used as raw, sliced for seasoning salads and cooked with other vegetables, fish and meat. Onion bulbs are essential ingredients in many African sauces and relishes. China is the largest onion producing country in the world (26-28%) and then India covers 21% of world production followed by USA, Iran, Egypt, Turkey, Russia, Pakistan, Netherlands and Brazil while Bangladesh produces only 2-4% of world production (Quaiyum, 2020). Bangladesh is now ranked 3rd in the world in onion production but it was earlier on 10th position (Alam, 2022). The average bulb yield of onion in Bangladesh is 11.67 t ha^{-1} (FAOSTAT, 2021) which is far below from others major onion growing countries where the world average yield is 19.32 t ha^{-1}.

In 2020, the ministry of agriculture in Bangladesh has reported that the annual demand for onion in the country is 2.8 million metric tons, but the total production is 2.0 million metric tons exhibiting an increasing demand for consumption (Mahmud, 2020) but in 2022, Alam (2022) said that now the annual demand of onion in our country is about 35-36 lakh metric tons and last year we produced 32 lakh metric tons of onion here. So, from these observations we can get an idea that the consumption and production of onion are increasing in our county but each year we are compensating the total demand by importing from the neighboring countries especially India. As a result India is dominating our import market. The main reason behind this is relying only on the winter production of onion in Bangladesh. Farmers usually start sowing onion seeds in October and transplant the seedlings in November. So when April comes, the crop is ready and for a short period there’s an abundance of onion in the market. This means during this time, the price of onions is low. As a result, it's more difficult for farmers’ to gain a good income from selling onions. Moreover, due to the poor storage facilities these onion bulbs cannot keeping long time by maintain their original quality resulted in storage damage, rotting and very lower market price. Therefore, a huge gap of onion supply is facing in national market during August to March and then we have to import onion from other countries to meet up our demands. However, before and after this time, the price of onions is 2 or 3 times higher. The transplanting of seedlings developed from the seeds of onion in early June to December for the production of green leaves and bulb is known as off-season onion. Therefore, the offseason onion production will be the best alternative to substitute the imports and reduce the higher demand of onion bulb during the lean period of production (Farha *et al*., 2020). So, we have to give our keen observation on the year round onion production. The Bangladesh Agricultural Research Institute (BARI) already has developed some summer onion varieties to compensate our national demand without relying on import. Since the cultivable land area is limited in Bangladesh, it is not possible to extent the land coverage under onion cultivation.

In the context of Bangladesh, the information about winter onion production is more enriched to get much yield but, in case of summer onion very few information is on our hands (Islam *et al*., 2008). On the other hand, fertility status of Bangladesh soils has been declining. So, more emphasis must be given to increase the productivity of this crop on yield aspect, which can be made possible with the judicious use of plant nutrients to achieve higher and sustainable bulb yields of onion in Bangladesh (Hossain *et al*., 2019). Nutrients also play a significant role in improving productivity and quality of vegetable crops. Onions are the most susceptible crop plants in extracting nutrients, especially the immobile types, because of their shallow and unbranched root system; hence they require and often respond well to addition of fertilizers. Therefore, judicial fertilizer application and cultivation of suitable varieties with appropriate agronomic practices in specific environment are necessary for obtaining good yield of onion (Kandil *et al*., 2013). Although bulbing is primarily a photoperiodic response, but can also be influenced by other environmental factors including, temperature, light intensity and quality, nitrogen (N) and potassium (K) nutrition and irrigation regime (Robles and Garcia, 2013). Mineral nutrition is main that affects yield and quality of onion. Nitrogen, phosphorus and potassium are often referred to as the primary macronutrients because of the probability of plants being deficient in these nutrients and because of the large quantities taken up by plants from the soil relative to other essential nutrients (Bekele *et al*., 2018). Nitrogen comprises 7% of total dry matter of plants and is a constituent of many fundamental cell components. It is one of the most complexes in behavior, occurring in soil, air and water in organic and inorganic forms. Nitrogen (N) is the most important nutrient for onions production. It is reported that nitrogen promotes the vegetative growth of onion which actually helps in increasing bulb size as well as total production. Excess application of N induces exuberant vegetative growth by increased protein synthesis and plant water content, and decreases plant resistance to diseases and bulb quality (Robles and Garcia, 2013). Uptake levels of nutrients by onion crops may vary from less than 50 kg to more than 300 kg N ha^{-1}, depending on cultivar, climate, plant density and other fertilization. Supplying an optimum nitrogen level was proved to be very essential for plant growth and higher yield (Tekeste *et al*., 2018). Tekalign *et al*. (2012) said that increasing of nitrogen application rates significantly enhances plant height, number of green leaves $plant^{-1}$ and weight of bulb and marketable yield. Potassium is one of the most important primary macronutrients, which is required by the plants in large amount and is available to the plants in cationic form (K^+). K is required for photosynthesis, fruit formation, osmotic regulations, disease resistance, promotion of enzymes activity, translocation of assimilates and maintaining agronomic productivity and sustainability. Hence, it is required to apply potassium at optimum dose for successful crop cultivation (Rani and Jha, 2018). Onion is also known to be a potash loving crop for its high response to potash. Generally, a heavy dose of potassium is recommended for onion cultivation. Potassium is considered to be one of the most important elements due to its role in the translocation of photosynthates, and the improvement of bulb size and yield and storage quality (Resende and Costa, 2014). The application of K at the range of 60-80 kg ha^{-1} to onion resulted better bulb growth, fresh matter of bulb, bulb yield and quality (Fanai *et al*., 2021). Behairy *et al*. (2015) noticed that significantly a higher bulb yield of onion and fresh weight of bulbs was found with the application of 100 kg K_2O ha^{-1} over lower doses of potassium. Abou El-Nasr and Ibrahim (2011) also said that the application of potassium fertilizer at the rate of 75 kg K_2O fed^{-1} gave the tallest shoot, highest fresh weight of shoots and the highest yield. Saud *et al*. (2013) found that the maximum average weight of bulb (64.89 g) and yield (22.91 t ha^{-1}) were observed in onion with the application of highest level of potassium (120 kg K_2O ha^{-1}). Onion yield depends on the number of bulbs harvested per unit area and the average bulb weight. Nitrogen has a much stronger effect on bulb size and weight than on plant density in the field (Tekeste *et al*., 2018). In contrast, N availability has a strong effect on bulb size, with increasing N application rates resulting in larger bulbs (Piri and Naserin, 2020). With larger bulbs, the marketable yield is increased by reducing the number of small, non-marketable bulbs. As a result larger onion bulbs command a premium market price over smaller ones.

In Bangladesh the research findings on summer onion production with nitrogen and potassium fertilizer is not well investigated to us that is needed to develop a production package and thereby may increase the returns to the producers. In the light of above aspects, the present research was conducted to fulfill the following objectives:-

1. To observe the influence of nitrogen and potassium on yield attributes and yield of summer onion bulb,
2. To investigate the interaction of nitrogen and potassium on bulb yield of summer onion and
3. To find out the suitable doses of N and K for maximum yield of summer onion.

CHAPTER II
REVIEW OF LITERATURE

In aspect of Bangladesh the research work is not very frequent on the summer onion production especially for nutritional management. So, from this perspective the present experiment aimed to impart a better thinking on nutritional management for improving the yield of onion under the prevailing climatic condition of Bangladesh. In this chapter some important research works have been reviewed those are related for onion production.

2.1 General back ground

The common bulbing onion (*Allium cepa* L.) has been cultivated in many parts of the world since 5000 years ago. The genus *Allium* is widely distributed over temperate zones in the northern hemisphere, and onion appears to have originated from a region of the world that is considered present day Turkey and Afghanistan (Farha *et al.*, 2020). This geographical area marks the primary center of diversity among the genus, responsible for nearly 200 of the 500 species of *Allium* that have been documented. Another center of diversity is located in western North America, where high concentrations of species are generally confined to mountainous areas.

2.2 Botany of onion

Common bulb onions belong to the class Monocotyloneae, superorder Liliiflorae, order Asparagales, family Alliaceae, tribe Allieae, genus Allium, species cepa, variety cepa. Like most Allium, onion has a chromosome number of 16 and is diploid (Robles and Garcia, 2013). Onion is biennial, and must usually undergo vernalization to flower in their second season of growth. If exposed to cool temperatures for an adequate duration during their first season of growth, plants will produce a seed stalk and an inflorescence in a process called bolting. Bolting can be reversed if onions are suddenly exposed to higher temperatures. If this occurs, the seed stalk will return to vegetative growth and bulbing will continue. The onions are grouped into short-days (day length of 11.5 hours) and long-days (day length of 14 hours or more) depending on the day length requirements. Onions are an outcrossing species, and are typically pollinated by bees or flies in commercial fields (Robles and Garcia, 2013). The primary organ of interest of the onion is the bulb, which is an aggregate of swollen leaf bases and the vegetative stem axis (Farha *et al*., 2020). The onion develops distinct bulbs depending on the varieties. These bulbs are varying in size (small, medium and large).

2.3 Uses of onion and its product

Onion is a popular vegetable and spices everywhere and its bulb is used as vegetable mixture and flavoring agent during cooking in different dishes. Many Asian are like onion for its pungency. The leaves, whole immature plants (called 'salad onion' or spring onion'), or leafy sprouts from germinating bulbs are used in the same way (Behairy *et al*., 2015). The extracted distillate from onion commonly referred as "Onion oil" is extensively used in the food industry as seasoning and flavoring agent for savory products. It also has a long history of medicinal use. Evidences suggest that onions may be effective for anti-carcinogenic properties, antiplatelet activity, antithrombotic activity, asthmatic and antibiotic effects. In homeopathic medicine, *Allium cepa* is used for rhinorrhea and hay fever (Messele, 2016).

2.4 Reason behind the attention on summer onion production

As a spices crop, the production of onion is mostly belonged in *rabi* season in Bangladesh but, the production is not up to the mark to meet up the local demand. As a result, we are importing more and more amount of onion from neighboring countries like India, Egypt etc. However, we have another two important cropping season (*kharif-I* and *kharif-II*) but we cannot be able to produce onion in these season due to climatic fluctuation and lack of judicious nutritional managements. Recently, Bangladesh Agricultural Research Institute (BARI) released some onion varieties for summer season of Bangladesh but, there is some yield gap between research field and existing farmers' field. So, cultivating onion both in winter and summer season may increase the supply of onion in market during the months of high demands.

2.5 Response of onion to nitrogen and potassium nutrient

Onion, compared with most crops, is usually the weakest crop plant in terms of extracting nutrients, especially the immobile types, because of their shallow and unbranched root system. Thus, the crop is a heavy feeder, requiring ample supplies of N; hence it requires and often responds well to addition of fertilizers.

Singh *et al*. (2021) experimented to study the effect of nitrogen and potassium on the productivity of onion. In the experiment three levels of nitrogen *i.e*., (0, 75, 100 kg ha^{-1} as N_0, N_1 and N_2, respectively) and two levels of potassium (0, 80 kg ha^{-1} as K_0 and K_1, respectively). They reported that the combined application of highest dose of nitrogen and potassium *i.e*., 100:80 kg ha^{-1} was significantly better in the comparison to the other treatments for satisfactory improvement of growth parameters *i.e*., fresh weight of bulb (55.33 g), dry weight of bulb (47.53 g), polar diameter of bulb (4.70 cm), physical parameters *i.e*., volume of bulb (45.19 ml) and yield (1.34 kg $plot^{-1}$) of onion crop over control.

Gererufael *et al*. (2020) reported that excess application of nitrogen causes excessive vegetative growth, delayed maturity, increase susceptibility to diseases, reduces dry matter contents and storability and ultimately reduces yield and quality of bulbs.

The onion bulb size increased significantly with the application of different doses of nitrogen. Application of higher nitrogen of 120 kg ha^{-1} recorded the maximum bulb size while the minimum bulb size was recorded in control (Blanco-Vargas *et al*., 2020).

Lajurkar *et al*. (2020) conducted an experiment to study the role of nitrogen and potassium on quality of onion seed. Two different factors were considered, in which first factor (N) nitrogen with levels (0, 100, 150 kg ha^{-1}) and (K) potassium with levels (0, 50, 75 kg ha^{-1}). The results showed that, the quality of seed of onion in respect to test weight (g), germination per cent (%) and graded seed yield were significantly influenced by different treatment combination. The quality of onion seed increased with increased levels (*i.e.*, NK at 150: 75 kg ha^{-1}) of different treatment combinations. Whereas, the seed yield ha^{-1} was increased with combine application of nitrogen at 150 kg ha^{-1} and potassium at 50kg/ha.

Rani *et al*. (2020) carried out an on-farm trial to assess the effect of application of potash and spray of N: P: K (18:18:18) on yield, quality and bolting of onion. By application of MOP @ 100 kg ha^{-1} along with DAP @ 110 kg ha^{-1} and urea 80 kg ha^{-1} gives higher yield and better quality bulb as compared to produce that are getting in control.

Majeedano *et al*. (2019) conducted an experiment to investigate the effect of potassium application rates on growth and seed quality. Applied potassium fertilizer (SoP) was @ K_1: 0, K_2: 25, K_3 50, K_4: 75, K_5 100 and K_6 125 kg K_2O ha^{-1}. It was observed that the potassium applied @ 100 kg K_2O ha^{-1} (K_5) remained more positively effective for seed quality traits including days to 50% bolting, flowering and maturity, flower stalk height, number of seeds $umbel^{-1}$, seed index and seed yield ha^{-1}.

Nitrogen fertilization increased the bulb yield of onion and yield components. Increasing nitrogen levels from 0 to 120 kg ha^{-1} resulted in progressive increase in bulb yield. Application of 120 kg N ha^{-1} increased the number of leaves per plant and plant height over the control as well as lower levels of nitrogen. There was an increase in diameter and weight of bulbs due to application of nitrogen up to 120 kg N ha^{-1} and thereafter decreased (Khokhar, 2019).

(Gebretsadik and Dechassa, 2018) also stated that with increase in dose of nitrogen up to120 kg N ha^{-1} the marketable and total bulb yield was increased, but below this level the total yield t ha^{-1} began to decrease.

Nigatu *et al*. (2018) reported that increasing the rate of N fertilization from 0 to 138 kg ha^{-1} increased total bulb yield from 19.26 t ha-1 to 32.24 t ha^{-1}. Similarly, increasing the rate of nitrogen application from 0 to 138 kg ha^{-1} significantly increased marketable bulb yield from 18.82 t ha^{-1} to 31.90 t ha^{-1} which was 69.5% higher than the control.

Nitrogen significantly affected yields of various onion bulb size categories. Onion fertilized with different N levels decreased the yield of small sized bulbs, but increased the yield of large sized bulbs. Small sized bulbs decreased by 61.8% when N application was increased from 0 to 138 kg ha^{-1}. On the hand, when N fertilization increased from 0 to 138 kg ha^{-1} the increment of large size bulbs increased from 12.58 t ha^{-1} to 25.67 t ha^{-1}, respectively, resulting in 104% increment (Nigatu *et al*., 2018).

Kumara *et al*. (2018) observed that the increase in K fertilizer nutrient application significantly increased the dry weight of tops and bulbs, bulb diameter, 100-bulb weight and bulb yield up to 40 kg K ha^{-1}. They also conducted another experiment to evaluate the effect of potassium levels, sources and time of application on the yield parameters of onion. Potassium levels at 200 percent of RDF (recommendation dose of fertilizer) significantly influenced the polar and equatorial diameter of bulb (53.80 and 60.63 mm, respectively), weight of single bulb (105.18 g), bulb yield (20.54 kg $plot^{-1}$ and 48.91 t ha^{-1}) and were at par with 150 and 175 percent RDF. They suggested a recommendation to apply potassium as split dose for getting higher yield of onion.

Ozkan *et al*. (2018) conducted a research study to compare the effects of polyhalite, potassium sulphate (SOP), and potassium chloride (MOP) fertilizers on the onion bulb yield, nutrient uptake and bulb quality properties. An equal dose of 70 kg K_2O ha^{-1} was applied as MOP, SOP and polyhalite and these were compared against a control in which only nitrogen (N) and phosphorus (P) fertilizers was applied. They found superior growth, yield and quality of onion from this rate of potassium application over control.

Bekele *et al*. (2018) carried out a research to know the effect of nitrogen (N) and potassium (K) fertilizer on the yield of irrigated onion. The treatments consisted of factorial combinations of four levels of nitrogen (0, 50, 100 and 150 kg N ha^{-1}) and four levels of potassium (0, 40, 80, and 120 kg K_2O ha^{-1}). Results revealed that; N and K had shown a highly significant effect on yield parameters like average weight of bulb (g), dry matter content of bulb (%) and harvest index (%). The higher total bulb yield (18.78 t ha^{-1}) was recorded with combined application of 150:120 kg of N-K ha^{-1} which was statistically similar with 150:80 kg of N-K ha^{-1} and performed superior over the other treatments. According to the partial budget analysis; the highest economic benefit was obtained at 150:80 kg of N-K ha^{-1} whereas the lowest net benefit was obtained from the control treatment.

Marrocos *et al*. (2018) carried a field trial to evaluate the effects of doses of potassium on onion yields. The treatments corresponded to the potassium doses (0, 36, 72, 108, 144 and 180 kg ha^{-1} of K_2O). Potassium fertilization promoted an increase in the content of K in the leaf, commercial and total yield, with the maximum obtained in the dose of 180 kg ha^{-1} of K_2O. The maximum overall and commercial yields were respectively 54.69 and 54.12 t ha^{-1} in the experiment.

Haque *et al*. (2018) conducted an experiment to find out the performance of nitrogen and potassium level on bulb to bulb onion production. Two different factors were considered, factor: (A) Nitrogen level (0, 50, 100, 150) kg ha^{-1}, (B) Potassium level (0, 30, 60, 90 kg ha^{-1}). The yield of onion increased with increased levels of different treatment combination. Synergistic effects of nitrogen and potassium at different days after sowing that 150 kg N with 90 kg K ha^{-1}gave the highest individual bulb weight (26.93g), bulb length (6.30 cm) as well as bulb diameter (4.33cm) of the onion among varying dose level either applied in combined or separate manners. The highest bulb yield 18.43 t ha^{-1} found in N150 K90 treatment. The treatment with 150 kg N with 90 kg K ha^{-1} is most suitable a preferable dose for maximum production of the bulb to bulb onion.

Naher *et al*. (2017) conducted a field experiment to find out the response of summer onion (var. BARI Piaj-3) to different levels and sources of potassium application. Potassium fertilizer combinations were comprised of four levels (0, 60, 120 and 180 kg ha^{-1}) and two potassium sources *viz*., potassium chloride (KCl) and potassium sulphate (K_2SO_4). The results indicated that the maximum diameter of bulb, average bulb weight, number of bulb m^{-2} and yield of bulbs were obtained from sulphate of potash (SOP) at the rate of 120 kg K ha^{-1}. Among the treatments the highest bulb yield (14.33 t ha^{-1}) was obtained with 120 kg K ha^{-1} and the lowest (6.92 t ha^{-1}) from the control. Application of 120 kg K ha^{-1} from K_2SO_4 along with other recommended fertilizers appeared to be the optimum dose for maximizing the bulb yield of summer onion.

Ahmed *et al*. (2017) conducted an experiment to evaluate different nitrogen levels and the cost-effective planting technique for onion production. Four nitrogen levels, 1: recommended dose (RD) of N (90 kg ha^{-1}), 2: 75 % N of RD (67.5 kg ha^{-1}), 3: 125 % N of RD (112.5 kg ha^{-1}) and 4: 150 % N of RD (135 kg ha^{-1}) were used. Results stated that maximum onion yield and yield attributes were recorded with nitrogen application at rate of 150 & 125 of RD in ridge planting.

El-Damarany *et al*. (2016) carried out an experiment to investigate the effect of nitrogen and potassium fertilization on onion seed production. Three nitrogen rates (50, 100 and 150 kg $feddan^{-1}$) and three potassium rates (40, 80 and 120 kg $feddan^{-1}$) were used in this study. Moreover, potassium fertilizer rates significantly affected on seed yield parameters, except umbel diameter. The maximum seed yield was obtained by the high nitrogen rates and the medium potassium rates.

Behairy *et al*. (2015) carried out a field experiment to study the effect of different rates of potassium fertilization (0, 60 and 120 kg K_2O ha^{-1}) on production of onion cv. "Giza 20". Results showed that the highest potassium fertilization rate (120 kg K_2O ha^{-1}) gave the highest number of bulb m^{-2} and the highest fresh weight of bulbs as well as the highest total bulb yield. Also, the reported that the bulb measurements expressed as (bulb length, bulb diameter, average bulb weight, bulb chemical composition (N, P, K and protein) were increased with increasing potassium fertilization rate.

Tekle (2015) carried out a field experiment to assess the influence of intra-row spacing (2.5, 5, 7.5, 10 and 12.5 cm) and nitrogen rate (0, 41, 82 and 123 kg N ha^{-1}) on growth, bulb yield, and quality of onion. Results stated that the total bulb yield and marketable bulb yields increased markedly across the increasing rate of nitrogen and intra-row spacing up to 82 kg N ha^{-1} and 5.0 cm. Increasing the N rate across the increasing intra-row spacing also increased the yields of over-sized bulbs and medium-sized bulbs whereas decreasing the yields of small-sized bulb yield. The highest yield of medium sized and large sized bulb was obtained both at 82 kg N ha^{-1} and plant spacing of 5.0 cm and 7.5 cm, respectively.

Saud *et al*. (2013) conducted an experiment to know the effect of potassium and row spacing on yield of onion. The experiment comprised of four potassium levels (0, 40, 80 and 120 kg ha^{-1}) were applied to main plot while row spacing (15, 20 and 25 cm) were kept in sub plot. The maximum bulb diameter (5.93), average bulb weight (64.89 g) and yield (22.91 t ha^{-1}) were observed with the application of 120 kg K_2O ha^{-1}. The highest yield was observed with the application of 120 kg K_2O ha^{-1} along with 20 cm row spacing. Finally they recommended that 20 cm row spacing with 120 kg K_2O ha^{-1} should be used for the best yield of onion.

Deshpande *et al*. (2013) carried out a field experiment to study the effect of increasing rates of potassium (K) fertilizer application on yield, quality and nutrient uptake of onion. All treatments significantly increased bulb yield compared to the control. Application of 100 kg K_2O ha^{-1} recorded statistically superior bulb yield of (52 t ha^{-1}); but further improvement on yield was not detected with the two higher rates of up to 150 kg K_2O ha^{-1}. The yield contributing characters *viz*., polar diameter and equatorial diameter were significantly increased by 100 kg K_2O ha^{-1}. This beneficial influence of K most probably largely relates to its stimulating effect on photosynthesis and the translocation of photosynthetic products to the bulbs.

Sultana *et al*. (2012) carried out a field experiment to show the effect of integrated use of nitrogen on yield and nutrient uptake of summer onion (BARI Piaz-2). Urea, cowdung (CD) and vermicompost (VC) were combined in a way to supply N at 120 kg ha^{-1} from the sources. Results indicated that maximum bulb yield (12.16 t ha^{-1}) and stover yield (5.46 t ha^{-1}) of summer onion were obtained in treatment receiving 80 kg N ha^{-1} from urea with 40 kg N ha^{-1} substituted by CD, followed by the treatment receiving 80 kg N ha^{-1} from urea with 40 kg N ha^{-1} substituted by VC. Since the integrated use of 80 kg N from urea with 40 kg N from CD and VC has produced maximum bulb yields therefore it is recommended for advantageous onion production.

Soleymani and Shahrajabian (2012) showed that the highest and the lowest marketable bulb yield of onion were obtained in to the application of 150 kg N ha^{-1} and 0 kg N ha^{-1}, respectively.

A report of Morsy *et al*. (2012) pointed out that 120 kg N ha^{-1} appeared higher values of plant height, number of leaves per plant, bulb diameter, bulb weight and days to maturity as compared to 90 kg ha^{-1}. They also indicated that increasing the level of N fertilizer to 80 kg N ha^{-1} resulted in about 38.5% increase in the bulb yield as compared to the level of 40 kg N ha^{-1}.

Singh *et al*. (2010) trialed a field experiment to study the effect of nitrogen and potassium application raised from onion sets on growth, yield and quality characters. In this trial different levels of nitrogen and potassium significantly affected the growth characters of onion, but yield characters was found non-significantly except total yield. The application of nitrogen significantly increased total yield of onion. Application of 150 kg N + 80 kg K_2O ha^{-1} was most appropriate combination of nutrients with respect to growth and yield of the onion crops raised from seedlings.

Al-Fraihat (2009) stated that with increasing application of nitrogen fertilizer from 100 kg N ha^{-1} to 200 kg N ha^{-1}, the bulb yield value was increased from 13.75% to 14.70% and 13.90% to 15.07% for two varieties, respectively.

Siddiquee *et al*. (2008) conducted an experiment to study the effect of applied potassium fertilizer on growth and yield of two varieties of summer onion. Potash was applied @ 0, 50, 75 and 100 kg ha^{-1}. The positive effect of applied K was noted on both the varieties of onion. Maximum yield of 9.05 t ha^{-1} was obtained when K was applied to N 53 variety. The lowest yield of 6.33 t ha^{-1} was observed in no K fertilizer treatment in BARI Piaz-2. It was observed that the application of K @ 75 kg ha^{-1} significantly increased the yield of both the varieties of onion.

Aliyu *et al*. (2007) conducted a field experiment to study the effect of nitrogen (N) and phosphorus (P) on the growth and yield of irrigated onion. The experiment comprised four levels of nitrogen (0, 50, 100 and 150 kg N ha^{-1}) and three levels of phosphorus (0, 17.5 and 35 kg P ha^{-1}). Nitrogen was allocated to the main plots while phosphorus was assigned to the sub-plots under split-plot design. Results revealed that N and P as well as their interaction, significantly affected crop growth rate and individual bulb weigh. However, interaction was not significant on the bulb yield. Nitrogen at the rate of 150 kg N ha^{-1} gave the best results which was statistically at par with 100 kg N ha^{-1}. The application of phosphorus @ 17.5 kg ha^{-1} gave statistically similar results as 35 kg ha^{-1}. The optimum combination from the results of this investigation was 100 kg N ha^{-1} and 17.5 kg P ha^{-1}.

Khan *et al*. (2007) carried out a field trial to study the growth and yield onion against different levels of nitrogen and zinc. Nitrogen levels under trail were 0, 100 and 200 kg ha^{-1}, while zinc levels were 0, 5, 10 and 15 kg ha^{-1}. The statistical analysis revealed that both nitrogen and zinc significantly affected all the growth and yield parameters studied. The maximum bulb weight (136.5 g) and bulb yield (22,280 kg ha^{-1}) were recorded in plots fertilized with 100 kg nitrogen ha^{-1} and zinc 10 kg ha^{-1}.

Boyhan *et al*. (2007) stated that, potassium fertilizer rates from 0 to 177 kg ha^{-1} had a quadratic effect on the total yield, with the highest yield of 52,361 kg ha^{-1} with 84 kg ha^{-1} K fertilizer rate.

Ali *et al*. (2007) conducted an experiment to study the effect of nitrogen and potassium levels on yield and quality seed production of onion considering two different factors *viz*., nitrogen level (0, 50, 100, 150) kg ha^{-1} and potassium level (0, 40, 80, 120) kg ha^{-1}. The yield of seed increased with the increasing of different treatment combination. The treatment combination at a level NK (150 and 120 kg ha^{-1}) produced the highest yield of seed (515.42 kg ha^{-1}) followed by 100 kg N ha^{-1} with 120 kg K ha^{-1}, 150 kg N ha^{-1} with 40 and 80 kg K ha^{-1}, respectively over control. Finally they suggested that nitrogen @ 150 kg ha^{-1} with potassium @ 80-120 kg ha^{-1} produced more effective flowering stalks and showed better performance on seed yield and quality of onion.

Islam (2006) trialed a field research to study the effect of potash application on the growth parameters and yield of summer onion. Six different levels of potash *viz*., 0, 30, 60, 90, 120 and 150 kg ha^{-1} and three application methods *viz*., basal, ½ basal + ½ at 20 DAT and basal + at 20 DAT + at 40 DAT were followed. Among the methods, highest bulb yield (11.85 t ha^{-1}) was obtained from three split application of potassium and the lowest (11.49 t ha^{-1}) was obtained from one application of basal doses of potassium. Application of potassium at 120 kg ha^{-1} produced highest bulb yield (14.76 t ha^{-1}) and the further increase in the dose of potassium did not show any more increase in yield of summer onion. The lowest bulb yield (7.94 t ha^{-1}) was obtained from control (0 kg ha^{-1}). Finally, he suggested that three split application of 120 kg ha^{-1} potassium may be considered as optimum dose for getting higher yield of summer onion.

By reviewing the different findings of the previous researchers it was found that the application of nitrogen and potassium has the capacity to vary different traits of onion. So, different levels of nitrogen and potassium nutrients were taken for the present study to investigate their effects on yield contributing traits and yield of summer onion.

CHAPTER III
MATERIALS AND METHODS

In this chapter, a brief description about research location, edaphic condition, crop traits, treatments, experimental design and layout, crop husbandry, different intercultural operations, data recording and statistical analysis were described. The details of experimental materials and methods are described below:

3.1 Experimental period and site

The experiment was conducted in the research field of Sher-e-Bangla Agricultural University (SAU), Dhaka-1207 during the period from June to September, 2021. The experimental area was belonged to $23^{o}7'$N latitude and 93^{o}E' longitude at an altitude of 8.6 meter above the sea level (Anon., 2004) and research area was also belonged to agro-ecological zone of "Madhupur Tract", AEZ-28 and Tejgaon soil series. The experimental site has shown in the map of AEZ of Bangladesh in (Appendix-I).

3.2 Climate and soil

The experimental site is characterized by summer season with significant rainy days during the experimental (*Kharif-II* season). During the study period, the weather data of experimental site *viz*., maximum and minimum temperature, total rainfall and relative humidity are shown in (Appendix-II). The surface soil was characterized by silty clay with slight sandy loam in texture, olive-slight grayish white with common fine to medium distinct dark whitish brown-light brown mottles was seen on the top soil. The topography of land was medium high with proper irrigation and drainage system. The detailed physical and chemical properties of soil were presented in Table-1.

Table 1. Analytical results of the chemical properties of initial soil

Characteristics	Value	Methods
pH	6.3	Glass electrode pH meter
Organic Carbon (%)	0.71	Wet Oxidation method
Total N (%)	0.004	Micro-Kjeldahl method
Exchangeable K (me/100 g soil)	0.11	Ammonium Acetate extraction method

3.3 Test Crop

The variety, BARI Piaj-5 **(S**ummer variety) was selected for the experiment. Though it can be grown round the year, it is recommended for summer season. The shape of bulb is nearly round and reddish in color. Average plant height and bulb weight are 45-55 cm and 55-70gm, respectively. Life span is approx. 95-115 days. The yield is 18-20 t ha^{-1} (Azad *et al.*, 2019).

3.4 Experimental treatments and design: The experiment comprised two factors:-

Factor-1 (Nitrogen level-4)	Factor-2 (Potassium level-3)
N_0 =0 kg ha^{-1}	K_0 =0 kg ha^{-1}
N_1 =50 kg ha^{-1}	K_1 =50 kg ha^{-1}
N_2 =75 kg ha^{-1}	K_2 =100 kg ha^{-1}
N_3 =100 kg ha^{-1}	

The experiment was conducted by following factorial RCBD (Randomized Complete Block Design) design with three (3) replication. Total number of plot was 36 where the unit plot size was 1.0 m×1.0 m. The layout of the experimental plots was shown in Appendix-III.

3.5 Growing of seedlings

Seeds of onion were sown in nursery seed bed on 01 June and taken care to facilitate good emergence. Finally, healthy and well emerged onion seedlings were used as planting material to the allocated plots. To prevent ant attack the seeds were drenched with Sevin 85 WP and then sown in seed bed.

3.6 Final land preparation

The land of the experimental site was first opened in the second week of July, 2021 with tractor to obtain the desirable tilth and then the land was ploughed and cross-ploughed four times followed by laddering. Weeds and stubbles were removed from the corners of field using spade. In order to avoid water logging from rainfall, drainage channels were made around the land.

3.7 Manures and fertilizers application

The following manures and fertilizers were applied as per the recommendation of Fertilizer Recommendation Guide (FRG) in the experiment plots:

Manures/Fertilizers	Dose
Cow dung	3 t ha^{-1}
N	As per treatments
P	35.0 kg ha^{-1}
K	As per treatments
S	25.0 kg ha^{-1}
Zn	2.0 kg ha^{-1}
B	1.0 kg ha^{-1}

Reference: FRG (2018)

During final field preparation, the whole amount of decomposed cow dung including all fertilizers except nitrogen was incorporated to the soil. Urea was used as a source of nitrogen and applied in three equal divisions. The 2/3 urea was applied during final land preparation, while the rest 1/3 was applied at 25 days after transplanting (DAT) as side dressing.

3.8 Transplanting of seedling

The well emerged and healthy onion seedlings of 45 days were transplanted on 16th July, 2021 according to plant spacing in each plot. Seedlings were transplanted maintaining 15 cm × 15 cm spacing.

3.9 Intercultural operations

3.9.1 Gap filling

After one week of transplanting, gap filling was done when the empty places were found in plots to maintain the desired plant population and damaged seedlings were also replaced with healthy plants from the extra seedlings.

3.9.2 Removal of weed

First weeding was done two weeks after transplanting. Another weeding was done before 1st top dressing of urea. It was also done as and when required to keep the crop free from weeds and to keep the soil loose for proper aeration and development of bulbs.

3.9.3 Watering and drainage

The sprinkler irrigation was provided on plot as per when needed to keep the proper soil moisture. The first irrigation was given just after transplanting of seedlings for easy recovery in main field. Subsequently, other irrigations were given. The top dressing of urea was followed by irrigation for proper utilization of fertilizers. When the crop was faced by rainfall then proper drainage was given in the field.

3.9.4 Earthing up

For well development of onion bulbs soil was raised to the plant base. This operation was done first at 40 DAT and second was at 60 DAT with a rod spade.

3.9.5 Control of insects and diseases

Preventive measure was taken against soil borne insects like Cutworm. So, Furadan 5G@20 kg ha^{-1} was applied during the final land preparation. After few days of transplanting some plants were attacked by purple blotch disease (caused by *Alternaria puri*) and it was controlled by spraying Ruvral 50WP for two times at 10 days of interval.

3.10 Harvesting of bulb

When the maximum leaves have dried out and collapsed at the neck of the onion bulbs then harvesting was done on 25th September, 2021. The bulbs were collected, bagged and tagged separately against each treatment. The collected bulbs were transported to curing room and kept 4 days for curing.

3.11 Recording of data with procedures

Different data were recorded on the basis of the aims of this study. Some data was taken by using digital balance; some of the data was taken by using manual size grader in shed house and soil properties were analyzed in laboratory.

i. Plant height (cm)

The plant height (cm) was taken from the neck of the onion bulb to the tip of the longest leaf. Three plants were randomly selected from each plot and then the means were taken from three replication.

ii. Number of leaves plant^{-1}

The number of leaves was counted one by one from the plant base where three plants were randomly selected from each plot and then the means were taken from three replication.

iii. Total number of bulb plot^{-1}

Total number of bulb of unit plot was counted against each treatment and then the mean values were taken from three replication.

iv. Average weight of bulb (g)

An electronic balance was used to take this data. To calculate the average weight of bulb, the weight of total bulb plot^{-1} was divided by the total number of bulb plot^{-1} and then means were taken from three replication in gram unit.

v. Yield of bulb plot^{-1} (g)

The entire bulb was weighted by using an electronic balance against each unit plot and then the means were taken from three replication in gram unit.

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

The entire bulb was weighted by using an electronic balance against each plot. Then the weight of bulb plot^{-1} was converted to t ha^{-1} and then means were taken from three replication.

vii. Marketable bulb yield (t ha^{-1})

The bulbs, those are >20 g of their weight were considered for marketable bulb yield. Then the bulb was weighted by using an electronic balance against each plot and converted to hectare areas in terms of ton unit (Benti, 2017). Then the means were taken from three replication.

viii. Non-marketable bulb yield (t ha^{-1})

The bulbs, those are <20 g of their weight were considered for non-marketable bulb yield. Then the bulb was weighted by using an electronic balance against each plot and converted to hectare areas in terms of ton unit (Benti, 2017). Then the means were taken from three replication.

ix. Grading of onion bulb (by size)

Grading was done from the total number of bulb plot^{-1}. According to the methods of Fatideh and Asil (2012), the bulb was graded into three sizes on the basis of their diameter.

a. **Small-size bulb (**<30 mm**)**

All bulbs were checked by using manual size grader to get small sized bulb from each plot and then means were taken from three replication.

b. **Medium-size bulb (**31-60 mm**)**

All bulbs were checked by using manual size grader to get medium sized bulb from each plot and then means were taken from three replication.

c. **Large-size bulb (**>60 mm**)**

All bulbs were checked by using manual size grader to get large sized bulb from each plot and then means were taken from three replication.

x. Collection and analysis of post-harvest soils

After harvesting of crop soil samples were collected from each plot at a depth of 0 to 15 cm by using an auger. Soil samples of each plot was bagged separately, air-dried, crushed and passed through a 2 mm (20 meshes) sieve. These soil samples were further analyzed for soil pH, total nitrogen, exchangeable potassium and soil organic carbon and these analyses was done in the laboratory of Department of Soil Science at Sher-e-Bangla Agricultural University, Dhaka.

a. Soil pH

Soil pH was measured with the help of a glass electrode pH meter using soil suspension of 1:2.5 ratio as described by Rahman *et al*. (2012).

b. Organic carbon (%)

Organic carbon in soil was determined by wet oxidation method of Walkley and Black, mentioned by Nemera *et al*. (2018). The underlying principle was to oxidize the organic carbon with an excess of 1N $K_2Cr_2O_7$ in presence of conc. H_2SO_4 and to titrate the residual K_2Cr2O7 solution with 1N $FeSO_4$ solution. The result was expressed in percentage.

c. Total nitrogen (%)

Total nitrogen of soil samples were estimated by Micro-Kjeldahl method where soils were digested with 30% H_2O_2, conc. H_2SO_4 and catalyst mixture (K_2SO_4: $CuSO_4.5H_2O$: Selenium powder in the ratio 100: 10: 1, respectively). Nitrogen in the digests was determined by distillation with 40% NaOH followed by titration of the distillate absorbed H_3BO_3 with 0.01N H_2SO_4 (Rahman *et al*., 2012).

d. Exchangeable potassium (meq/100 g soil)

Available potassium was determined by using 1N-ammonium acetate (pH 7) extraction method. A flame photometer was used to find out the absorbance reading and calibrated with a standard curve (Rahman *et al*., 2012).

3.12 Bulb yield merit (%)

The bulb yield merit means, how much bulb yield was increased for using integrated nitrogen and potassium over control. On the basis of marketable yield, the bulb yield merit was calculated is as follows:

Tuber yield merit (%) = (*Yield obtained from expected treatment–yield obtained from control treatment*) × 100/ *Yield obtained from control treatment*.

3.13 Monetary advantage (From Marketable Yield)

Marketable bulb yield (t ha^{-1}) was taken, then converted to kg ha^{-1} and then multiplied by price kg^{-1} of onion bulb [price kg^{-1} of onion bulb= 50 Tk.]

3.14 Pearson correlation coefficient (r)

Pearson correlation coefficient was calculated between different yield contributing traits and soil properties by using the MS excel spread sheet.

3.15 Statistical Analysis

Collected data on different parameters were analyzed statistically using the analysis of variance (ANOVA) technique with the help of WASP (Web Agri Stat Package: version-1) computer program and means were adjusted by using LSD (Least Significant Difference) at 5 % level of probability (Gomez and Gomez, 1984).

CHAPTER IV
RESULTS AND DISCUSSION

The present study was carried out to investigate the effect of nitrogen and potassium on bulb yield of summer onion. In this chapter; figures, tables and appendices have been used to present, discuss and compare the findings obtained from the studies. The ANOVA (analysis of variance) of analyzed data in aspects of all the visual and measurable characteristics have been presented in Appendix (IV-IV). All possible reveals and interpretations were given under the following headings:

4.1 Growth traits on onion

4.1.1 Plant height (cm)

The plant height was found significant ($p \leq 0.01$) due to nitrogen application (Appendix-IV and Table-2). The tallest plant (36.137 cm) was found in N_3 treatment which was statistically similar to N_2 (35.593 cm) and the smallest plant was found in N_0 (30.873 cm) treatment. A significant ($p \leq 0.01$) effect was found from potassium application on the plant height (Appendix-IV and Table-3). The tallest plant (36.692 cm) was found in K_2 treatment and the smallest plant (32.717 cm) was found in K_1 treatment. Combindely, a significant ($p \leq 0.05$) variation was found among the treatments against plant height on onion (Appendix-IV and Table-4). The tallest plant (40.227 cm) was found in N_3K_2 treatment combination which was statistically similar to N_2K_2 (40.107 cm) while the smallest (30.227 cm) plant was found in N_0K_0 treatment combination. Higher assimilate portioning may be the reason for increasing height of plant in onion plant from the fertilizer application but lower doses of fertilizer or no application may hinder the proper cell enlargement of crop (Gererufael *et al*., 2020). Finding is coinciding with the result of present study.

4.1.2 Number of leaves plant^{-1}

Number of leaves plant^{-1} was found significant ($p \leq 0.01$) due to nitrogen application (Appendix-IV and Table-2). The maximum number of leaves (5.963) was found N_3 treatment which was statistically similar to N_2 (5.796) and the minimum number of leaves was found in N_0 (4.363) treatment. A significant ($p \leq 0.01$) effect was found from potassium application on number of leaves plant^{-1} (Appendix-IV and Table-3). The maximum number of leaves (6.021) was found in K_2 treatment and the minimum number (4.771) was found in K_0 treatment which was statistically similar to K_1 treatment. Combindely, a significant ($p \leq 0.01$) variation was found among the treatments against number of leaves plant^{-1} (Appendix-IV and Table-4). The maximum number of leaves plant^{-1} (7.696) was found in N_3K_2 treatment combination while the minimum number (4.296) was found in N_0K_0 treatment combination. Higher assimilate portioning and higher growth of plant base from fertilizer application increasing number of leaves in onion plant compared to lower or no fertilization (Gererufael *et al.*, 2020). Finding is coinciding with the result of present study.

Table 2. Effect of nitrogen on the growth traits on onion

Nitrogen	Plant height (cm)	Number of leaves plant^{-1}
N_0	30.873 c	4.363 c
N_1	33.793 b	4.863 b
N_2	35.593 ab	5.796 a
N_3	36.137 a	5.963 a
CV (%)	6.40	6.72
LSD $_{(0.05)}$	2.133	0.344
F-test	**	**

Values with common letter (s) within a column do not differ significantly at 5% level of probability
** indicates significant at 1% level of probability
N_0 =0 kg ha^{-1}, N_1 =50 kg ha^{-1}, N_2 =75 kg ha^{-1}, N_3 =100 kg ha^{-1}

Table 3. Effect of potassium on the growth traits on onion

Potassium	Plant height (cm)	Number of leaves $plant^{-1}$
K_0	32.889 b	4.771 b
K_1	32.717 b	4.946 b
K_2	36.692 a	6.021 a
CV (%)	6.40	6.72
LSD $_{(0.05)}$	1.847	0.298
F-test	**	**

Values with common letter (s) within a column do not differ significantly at 5% level of probability
** indicates significant at 1% level of probability
K_0 =0 kg ha^{-1}, K_1 =50 kg ha^{-1}, K_2 =100 kg ha^{-1}

Table 4. Interaction effect of nitrogen and potassium on the growth traits on onion

Combination	Plant height (cm)	Number of leaves $plant^{-1}$
N_0K_0	30.227 c	4.296 e
N_0K_1	31.067 c	4.396 e
N_0K_2	31.327 c	4.396 e
N_1K_0	32.567 bc	4.496 de
N_1K_1	33.707 bc	4.996 cd
N_1K_2	35.107 b	5.096 c
N_2K_0	35.657 b	5.196 c
N_2K_1	32.647 bc	5.296 c
N_2K_2	40.107 a	6.896 b
N_3K_0	33.107 bc	5.096 c
N_3K_1	33.447 bc	5.096 c
N_3K_2	40.227 a	7.696 a
CV (%)	6.40	6.72
LSD $_{(0.05)}$	3.695	0.596
F-test	*	**

Values with common letter (s) within a column do not differ significantly at 5% level of probability
*, ** indicate significant at 5% and 1% level of probability, respectively.
N_0 =0 kg ha^{-1}, N_1 =50 kg ha^{-1}, N_2 =75 kg ha^{-1}, N_3 =100 kg ha^{-1}
K_0 =0 kg ha^{-1}, K_1 =50 kg ha^{-1}, K_2 =100 kg ha^{-1}

4.2 Yield contributing traits and yield on onion

4.2.1 Total number of bulb plot^{-1}

The total number of bulb plot^{-1} was found significant ($p \leq 0.01$) due to nitrogen application (Appendix-V and Table-5). The maximum number of bulb (21.774) was found N_3 treatment which was statistically similar to N_2 (21.667) treatment and the minimum was found in N_0 (18.287) treatment. A significant ($p \leq 0.01$) effect was found from potassium application on the total number of bulb plot^{-1} (Appendix-V and Table-6). The maximum bulb number (21.996) was found in K_2 treatment and the minimum number (19.162) was found in K_1 treatment which was statistically similar to K_0 treatment. Combindely, a significant ($p \leq 0.05$) variation was found among the treatments against total number of bulb plot^{-1} (Appendix-V and Table-7). The maximum bulb number (25.000) was found in N_3K_2 treatment combination which was statistically similar to N_2K_2 (25.000) while the minimum number (17.877) was found in N_0K_0 treatment combination. Higher assimilate portioning may be the reason for increasing number of bulb in onion plant from the fertilizer application but lower doses of fertilizer or no application may hinder the proper growth of crop base resulting in very small bulbing or no (Gererufael *et al.*, 2020). Finding is coinciding with the result of present study.

4.2.2 Average weight of bulb (g)

Remarkable significant ($p \leq 0.01$) effect was found on the average weight of bulb (g) due to nitrogen application (Appendix-V and Table-5). The maximum weight of bulb (61.697 g) was found N_2 treatment which was statistically similar to N_3 (61.417 g) treatment and the minimum was found in in N_0 (51.763 g) treatment. A significant ($p \leq 0.01$) effect was found from potassium application on the average weight of bulb (g) (Appendix-V and Table-6). The maximum weight of bulb (61.842 g) was found in K_2 treatment and the minimum (55.089 g) was found in K_1 treatment which was statistically similar to K_0 treatment. Combindely, a significant ($p \leq 0.05$) variation was found among the treatments against average weight of bulb (g) (Appendix-V and Table-7).

The maximum average weight of bulb (71.227 g) was found in N_3K_2 treatment combination which was statistically similar to N_2K_2 (69.207 g) treatment combination while the minimum weight (51.407 g) was found in N_0K_1 treatment combination. The average bulb weight improvement in response to N application may be attributed to the increase in plant height, number of leaves produced, leaf base diameter and extended physiological maturity in response to the fertilization all might have increased assimilate production and allocation to the bulbs. Similarly, Abdissa *et al*. (2011) reported that significant increase in bulb weight due to increased N application. Morsy *et al*. (2012) mentioned that average bulb weight of onion increased with nitrogen rate. Abdissa *et al*. (2011) also point out that K requirement of onion plants increases with yield and its functions are linked to photosynthesis. Kokobe *et al*. (2013) who reported that interaction effects of N and potassium significantly affected bulb weight of onion. Moreover, integrated use of macro nutrients increased bulb weight by about 8.1–12.2% over control. The increase in mean bulb weight with the supply of K fertilizer nutrients could be due to more luxuriant growth, more foliage and leaf area and higher supply of photosynthates which helped in producing bigger bulb, hence resulting in higher yields (Shedeed *et al*. 2014). Similar results are reported that a significantly higher fresh weight of bulbs (49.53 g) with application of 150 kg of K_2O ha^{-1} over other potassium levels (Bekele, 2018).

4.2.3 Yield of bulb plot^{-1} (g)

In case of yield of bulb plot^{-1} (g) a significant ($p \leq 0.01$) effect was found due to nitrogen application (Appendix-V and Table-5). The highest yield of bulb (1358.6 g) was found from N_3 treatment which was statistically similar to N_2 (1354.5 g) treatment and the lowest was found in N_0 (950.1 g) treatment. A significant ($p \leq 0.01$) effect was found from potassium application on the yield of bulb plot^{-1} (g) (Appendix-V and Table-6). The highest yield of bulb (1391.1 g) was found in K_2 treatment and the lowest (1061.3 g) was found in K_1 treatment which was statistically similar to K_0 treatment. Combindely, a significant ($p \leq 0.05$) variation was found among the treatments against yield of bulb plot^{-1} (g) (Appendix-V and Table-7). The highest yield of bulb (1787.6 g) was found in N_3K_2 treatment combination which was statistically similar to N_2K_2 (1736.9 g) treatment combination while the lowest yield (935.2 g) was found in N_0K_0 treatment. Morsy *et al*. (2012) stated that weight of onion m^{-2} increased with the creasing of nitrogen rate. Similar results are reported that a significantly higher yield of bulb with application of 150 kg of K_2O ha^{-1} over other potassium levels (Bekele, 2018).

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

Yield (t ha^{-1}) of onion bulb was found significant ($p \leq 0.01$) against nitrogen application (Appendix-V and Table-5). The highest yield of bulb (13.586 t ha^{-1}) was found from N_3 treatment which was statistically similar with N_2 (13.545 t ha^{-1}) treatment and the lowest was found in N_0 (9.501 t ha^{-1}) treatment. In respects of onion bulb yield (t ha^{-1}) a remarkable ($p \leq 0.01$) variation was noted against different levels of potassium application (Appendix-V and Table-6). The highest yield of bulb (13.911 t ha^{-1}) was found in K_2 treatment and the lowest (10.613 t ha^{-1}) was found in K_1 treatment which was statistically similar to K_0 treatment. Combindely, a significant ($p \leq 0.05$) variation was found among the treatment against yield of onion bulb (t ha^{-1}) (Appendix-V and Table-7). The highest yield of bulb (17.876 t ha^{-1}) was found in N_3K_2 treatment combination which was statistically similar to N_2K_2 (17.369 t ha^{-1}) treatment combination while the lowest yield (9.352 t ha^{-1}) was found in N_0K_0 treatment combination. The higher average weight of onion bulb and the highest weight of bulb plot^{-1} might be the main reason for getting highest bulb yield ha^{-1}. Kahsay *et al*., (2014) reported that yield increased with increasing nitrogen levels. Results are supported by the findings related to smaller and larger bulbs, as plots with greater sized bulbs resulted in higher yield. This might be because of an increased photosynthetic rate in response to N-K fertilization had substantially contributed to enhance onion productivity that could be through the production of more assimilates and higher translocation to the growing bulbs. Similarly findings are reported by Bashir and Qureshi (2014). Similarly, Guesh (2015) showed that with increase in dose of nitrogen up to120 kg ha^{-1}, the total bulb yield was increased, but below this rate, the total bulb yield began to decrease. Soleymani and Shahrajabian (2012) also indicated that the control plots achieved lower total yields as compared to the higher nitrogen doses. The addition of more K than the recommended dose, at levels greater than 100 kg K_2O ha^{-1}, resulted in vigorous plant growth and higher bulb yield. This may possibly be due to higher concentrations of K in promoting photosynthesis, enhancing the translocation of assimilates as well as enzyme activity, and protein synthesis (Deshpande *et al.*, 2013). Similar results are reported that a significantly higher yield of bulb with application of 150 kg of K_2O ha^{-1} over other potassium levels (Bekele, 2018).

Table 5. Effect of nitrogen on the yield contributing traits and yield of onion bulb

Nitrogen	**Total number of bulb $plot^{-1}$**	**Average weight of bulb (g)**	**Yield of bulb $plot^{-1}$ (g)**	**Yield of bulb (t ha^{-1})**
N_0	18.287 b	51.763 b	950.1 b	9.501 b
N_1	18.993 b	54.397 b	1037.4 b	10.374 b
N_2	21.667 a	61.697 a	1354.5 a	13.545 a
N_3	21.774 a	61.417 a	1358.6 a	13.586 a
CV (%)	8.14	7.88	16.30	16.30
LSD $_{(0.05)}$	1.605	4.416	187.21	1.872
F-test	**	**	**	**

Values with common letter (s) within a column do not differ significantly at 5% level of probability
** indicates significant at 1% level of probability
N_0 =0 kg ha^{-1}, N_1 =50 kg ha^{-1}, N_2 =75 kg ha^{-1}, N_3 =100 kg ha^{-1}

Table 6. Effect of potassium on the yield contributing traits and yield of onion bulb

Potassium	Total number of bulb plot^{-1}	Average weight of bulb (g)	Yield of bulb plot^{-1} (g)	Yield of bulb (t ha^{-1})
K_0	19.383 b	55.024 b	1073.0 b	10.730 b
K_1	19.162 b	55.089 b	1061.3 b	10.613 b
K_2	21.996 a	61.842 a	1391.1 a	13.911 a
CV (%)	8.14	7.88	16.30	16.30
LSD $_{(0.05)}$	1.389	3.824	162.13	1.621
F-test	**	**	**	**

Values with common letter (s) within a column do not differ significantly at 5% level of probability
** indicates significant at 1% level of probability
K_0 =0 kg ha^{-1}, K_1 =50 kg ha^{-1}, K_2 =100 kg ha^{-1}

Table 7. Interaction effect of nitrogen and potassium on the yield contributing traits and yield of onion bulb

Combination	Total number of bulb plot^{-1}	Average weight of bulb (g)	Yield of bulb plot^{-1} (g)	Yield of bulb (t ha^{-1})
N_0K_0	17.877 c	52.137 b	935.2 b	9.352 b
N_0K_1	18.327 bc	51.407 b	945.8 b	9.458 b
N_0K_2	18.657 bc	51.747 b	969.2 b	9.692 b
N_1K_0	18.657 bc	53.647 b	1004.8 b	10.048 b
N_1K_1	18.997 bc	54.357 b	1036.6 b	10.366 b
N_1K_2	19.327 bc	55.187 b	1070.7 b	10.707 b
N_2K_0	20.000 bc	57.437 b	1153.2 b	11.532 b
N_2K_1	20.000 bc	58.447 b	1173.5 b	11.735 b
N_2K_2	25.000 a	69.207 a	1736.9 a	17.369 a
N_3K_0	20.997 b	56.877 b	1198.9 b	11.989 b
N_3K_1	19.327 bc	56.147 b	1089.4 b	10.894 b
N_3K_2	25.000 a	71.227 a	1787.6 a	17.876 a
CV (%)	8.14	7.88	16.30	16.30
LSD $_{(0.05)}$	2.779	7.648	324.26	3.242
F-test	*	*	*	*

Values with common letter (s) within a column do not differ significantly at 5% level of probability
* indicate significant at 1% level of probability
N_0 =0 kg ha^{-1}, N_1 =50 kg ha^{-1}, N_2 =75 kg ha^{-1}, N_3 =100 kg ha^{-1}
K_0 =0 kg ha^{-1}, K_1 =50 kg ha^{-1}, K_2 =100 kg ha^{-1}

4.2.5 Marketable bulb yield (t ha^{-1})

In case of marketable yield of onion bulb (t ha^{-1}) a significant ($p \leq 0.01$) effect was found against different nitrogen levels (Appendix-VI and Table-8). An increasing trend was found with the increasing of nitrogen levels. The highest marketable yield of bulb (11.895 t ha^{-1}) was found from N_3 treatment which was statistically similar to N_2 (11.555 t ha^{-1}) treatment and the lowest was in N_0 (6.076 t ha^{-1}) treatment. The marketable yield of onion bulb (t ha^{-1}) was found significant ($p \leq 0.01$) against different levels of potassium applications (Appendix-VI and Table-9). The highest marketable yield of onion bulb (11.749 t ha^{-1}) was found in K_2 treatment and the lowest (7.952 t ha^{-1}) was found in K_0 treatment which was statistically similar to K_1 treatment. Combindely, a significant ($p \leq 0.01$) variation was found among the treatments against marketable yield (t ha^{-1}) of onion bulb (Appendix-VI and Table-10). The highest marketable yield of bulb (16.616 t ha^{-1}) was found in N_3K_2 treatment combination which was statistically similar to N_2K_2 (16.134 t ha^{-1}) treatment combination followed by N_3K_0 (10.065 t ha^{-1}) treatment combination while the lowest yield (5.885 t ha^{-1}) was found in N_0K_0 treatment combination. This result was in conformity with the findings of Gererufael *et al*. (2020) who reported that higher levels of inorganic fertilizers resulted in higher bulb yields of onion. So, they told that the increment in marketable bulb yield could be due to the application of N which attributed to the increment in leaves growth and increased production of assimilate leading to increment in bulb diameter and average bulb weight. Soleymani and Shahrajabian (2012) also showed that the higher value of marketable yield was achieved under higher rate of nitrogen fertilization (120 kg ha^{-1}). Similar results are reported that a significantly higher marketable yield of bulb with application of 150 kg of K_2O ha^{-1} over other potassium levels (Bekele, 2018).

4.2.6 Non-marketable bulb yield (t ha^{-1})

A profound significant ($p \leq 0.01$) effect was found from non-marketable yield of onion bulb (t ha^{-1}) due to different nitrogen levels (Appendix-VI and Table-8).

A decreasing trend was found with the increasing of nitrogen levels. The lowest non-marketable yield of bulb (1.640 t ha^{-1}) was found from N_3 treatment followed by N_2 (1.940 t ha^{-1}) treatment and the highest was in N_0 (3.413 t ha^{-1}) treatment. The non-marketable yield of onion bulb (t ha^{-1}) was found significant ($p \leq 0.01$) against different levels of potassium applications (Appendix-VI and Table-9). The lowest non-marketable yield of bulb (2.110 t ha^{-1}) was found in K_2 treatment and the highest (2.755 t ha^{-1}) was found in K_0 treatment. Combindely, a significant ($p \leq 0.01$) variation was found among the treatments against non-marketable yield (t ha^{-1}) of onion bulb (Appendix-VI and Table-10). The lowest non-marketable yield of bulb (1.170 t ha^{-1}) was found in N_2K_2 treatment combination which was statistically similar with N_3K_2 (1.190 t ha^{-1}) treatment combination followed by N_3K_0 (1.880 t ha^{-1}) and N_3K_1 (1.850 t ha^{-1}) treatment combinations while the highest yield (3.500 t ha^{-1}) was found in N_0K_0 treatment combination which was statistically similar to N_0K_1 and N_0K_2 treatment combinations.

Table 8. Effect of nitrogen on the marketable yield and non-marketable yield of onion bulb

Nitrogen	**Marketable yield of bulb (t ha^{-1})**	**Non-marketable yield of bulb (t ha^{-1})**
N_0	6.076 c	3.413 a
N_1	7.459 b	2.876 b
N_2	11.555 a	1.940 c
N_3	11.895 a	1.640 d
CV (%)	6.53	6.52
LSD $_{(0.05)}$	0.590	0.157
F-test	**	**

Values with common letter (s) within a column do not differ significantly at 5% level of probability
** indicates significant at 1% level of probability
N_0 =0 kg ha^{-1}, N_1 =50 kg ha^{-1}, N_2 =75 kg ha^{-1}, N_3 =100 kg ha^{-1}

Table 9. Effect of potassium on the marketable yield and non-marketable yield of onion bulb

Potassium	Marketable yield of bulb ($t\ ha^{-1}$)	Non-marketable yield of bulb ($t\ ha^{-1}$)
K_0	7.952 b	2.755 a
K_1	8.037 b	2.537 b
K_2	11.749 a	2.110 c
CV (%)	6.53	6.52
LSD $_{(0.05)}$	0.511	0.136
F-test	**	**

Values with common letter (s) within a column do not differ significantly at 5% level of probability
** indicates significant at 1% level of probability
K_0 =0 kg ha^{-1}, K_1 =50 kg ha^{-1}, K_2 =100 kg ha^{-1}

Table 10. Interaction effect of nitrogen and potassium on the marketable yield and non-marketable yield of onion bulb

Combination	Marketable yield of bulb ($t\ ha^{-1}$)	Non-marketable yield of bulb ($t\ ha^{-1}$)
N_0K_0	5.885 g	3.500 a
N_0K_1	6.014 fg	3.410 a
N_0K_2	6.329 fg	3.330 a
N_1K_0	7.000 ef	3.010 b
N_1K_1	7.459 e	2.870 bc
N_1K_2	7.916 de	2.750 bc
N_2K_0	8.859 cd	2.630 c
N_2K_1	9.670 bc	2.020 d
N_2K_2	16.134 a	1.170 e
N_3K_0	10.065 b	1.880 d
N_3K_1	9.005 c	1.850 d
N_3K_2	16.616 a	1.190 e
CV (%)	6.53	6.52
LSD $_{(0.05)}$	1.022	0.272
F-test	**	**

Values with common letter (s) within a column do not differ significantly at 5% level of probability
** indicates significant at 1% level of probability
N_0 =0 kg ha^{-1}, N_1 =50 kg ha^{-1}, N_2 =75 kg ha^{-1}, N_3 =100 kg ha^{-1}
K_0 =0 kg ha^{-1}, K_1 =50 kg ha^{-1}, K_2 =100 kg ha^{-1}

4.3 Grading of onion bulb (by size)

4.3.1 Small-size bulb (<30 mm)

The small (<30 mm) size onion bulb was found significant ($p \leq 0.01$) due to nitrogen application (Appendix-VII and Table-11). A decreasing trend was found with the increasing of nitrogen levels. The minimum number of small size bulb (7.330) was found from N_3 treatment followed by N_2 (8.330) treatment and maximum was found in N_0 (12.217) treatment. A significant ($p \leq 0.01$) effect was found from potassium application on the small size (<30 mm) onion bulb (Appendix-VII and Table-12). The minimum number of small size bulb (8.912) was found from K_2 treatment which was statistically similar to K_1 (8.912) treatment and maximum was found in K_0 (10.164) treatment. Combindely, a non-significant (p=NS) variation was found among the treatments against small size (<30 mm) onion bulb (Appendix-VII and Table-13) but, numerically the minimum number of small size bulb (5.997) was found in N_3K_1 treatment combination while the maximum number (12.997) was found in N_0K_0 treatment combination. Negash *et al.* (2009) indicated that small size bulb yield reduction in response to increased N fertilization. The finding is coinciding with the above citation.

4.3.2 Medium-size bulb (31 and 60 mm)

The medium (31 and 60 mm**)** size onion bulb was found significant ($p \leq 0.01$) due to nitrogen application (Appendix-VII and Table-11). An increasing trend was found with the increasing of nitrogen levels. The maximum number of medium size bulb (11.890) was found from N_3 treatment followed by N_2 (10.776) treatment and the minimum was found in N_0 (6.110) treatment. A significant ($p \leq 0.01$) effect was found from potassium application on the medium (31 and 60 mm**)** size onion bulb (Appendix-VII and Table-12). The maximum number of medium size bulb (10.749) was found from K_2 treatment followed by K_1 (9.084) treatment and minimum was found in K_0 (8.079) treatment. Combindely, a significant ($p \leq 0.01$) variation was found among the treatments against medium (31 and 60 mm**)** size onion bulb (Appendix-VII and Table-13). The maximum number of medium size bulb (13.670) was found in N_3K_2 treatment combination which was statistically similar to N_2K_2 (13.327) treatment combination followed by N_3K_1 (11.670) treatment combination while the minimum number (5.000) was found in N_0K_0 treatment combination. Negash *et al.* (2009) reported that highest medium sized bulb yield was recorded at application of higher nitrogen. The finding is coinciding with the above citation.

4.3.3 Large-size bulb (>60 mm)

The large (>60 mm) size onion bulb was found significant ($p \leq 0.01$) due to nitrogen application (Appendix-VII and Table-11). An increasing trend was found with the increasing of nitrogen levels. The maximum number of large size bulb (2.5567) was found from N_2 treatment which was statistically similar to N_3 (2.5533) treatment followed by N_1 (1.1100) treatment and the minimum was found in N_0 (0.0000, not found) treatment. A significant ($p \leq 0.01$) effect was found from potassium application on the large (>60 mm) size onion bulb (Appendix-VII and Table-12). The maximum number of large size bulb (2.3325) was found from K_2 treatment followed by K_1 (1.1650) and K_0 (1.1675) treatments. Combindely, a significant ($p \leq 0.01$) variation was found among the treatments against large (>60 mm) size onion bulb (Appendix-VII and Table-13). The maximum number of large size bulb (4.000) was found in N_3K_2 treatment combination which was statistically similar to N_3K_2 (4.000) treatment combination while the minimum number (0.000, not found) was in N_0K_0 treatment combination which was statistically similar to N_0K_1 (0.000) and N_0K_2 (0.000) treatment combinations. The achievements of higher yields of large sized bulbs by increasing N level might be due to resource availability and assimilation and less stiff competition among the onion plants (Kahsay *et al.*, 2014). This may lead to increased weights of individual bulbs shifting from small to medium and then to large bulb categories. Kokobe *et al.* (2013) also reported that onion bulb size increased with increasing nitrogen dose.

Table 11. Effect of nitrogen on the grading of onion bulb

Nitrogen	Grading of bulbs (by size)		
	Small	**Medium**	**Large**
N_0	12.217 a	6.110 d	0.0000 c
N_1	9.440 b	8.441 c	1.1100 b
N_2	8.330 c	10.776 b	2.5567 a
N_3	7.330 d	11.890 a	2.5533 a
CV (%)	6.56	6.04	8.29
LSD $_{(0.05)}$	0.598	0.549	0.126
F-test	**	**	**

Values with common letter (s) within a column do not differ significantly at 5% level of probability
** indicates significant at 1% level of probability
N_0 =0 kg ha^{-1}, N_1 =50 kg ha^{-1}, N_2 =75 kg ha^{-1}, N_3 =100 kg ha^{-1}

Table 12. Effect of potassium on the grading of onion bulb

Potassium	Grading of bulbs (by size)		
	Small	**Medium**	**Large**
K_0	10.164 a	8.079 c	1.1675 b
K_1	8.912 b	9.084 b	1.1650 b
K_2	8.912 b	10.749 a	2.3325 a
CV (%)	6.56	6.04	8.29
LSD $_{(0.05)}$	0.518	0.475	0.109
F-test	**	**	**

Values with common letter (s) within a column do not differ significantly at 5% level of probability
** indicates significant at 1% level of probability
K_0 =0 kg ha^{-1}, K_1 =50 kg ha^{-1}, K_2 =100 kg ha^{-1}

Table 13. Interaction effect of nitrogen and potassium on the grading of onion bulb

Combination	Grading of bulbs (by size)		
	Small	**Medium**	**Large**
N_0K_0	12.997	5.000 h	0.000 f
N_0K_1	11.997	6.330 g	0.000 f
N_0K_2	11.657	7.000 fg	0.000 f
N_1K_0	9.997	7.658 f	1.000 e
N_1K_1	9.327	8.667 e	1.000 e
N_1K_2	8.997	8.999 de	1.330 d
N_2K_0	8.997	9.330 de	1.670 c
N_2K_1	8.327	9.670 cd	2.000 b
N_2K_2	7.667	13.327 a	4.000 a
N_3K_0	8.667	10.330 c	2.000 b
N_3K_1	5.997	11.670 b	1.660 c
N_3K_2	7.327	13.670 a	4.000 a
CV (%)	6.56	6.04	8.29
LSD $_{(0.05)}$	-----	0.951	0.218
F-test	**NS**	**	**

Values with common letter (s) within a column do not differ significantly at 5% level of probability
** indicates significant at 1% level of probability; NS indicates non-significant
N_0 =0 kg ha^{-1}, N_1 =50 kg ha^{-1}, N_2 =75 kg ha^{-1}, N_3 =100 kg ha^{-1}
K_0 =0 kg ha^{-1}, K_1 =50 kg ha^{-1}, K_2 =100 kg ha^{-1}

4.4 Post-harvest soil properties

4.4.1 Soil pH

In case of soil pH a non-significant (p=NS) effect was found against different nitrogen levels (Appendix-VIII and Table-14). The soil pH was found non-significant (p=NS) against different levels of potassium application (Appendix-VIII and Table-15). Combindely, a non-significant (p=NS) variation was found among the treatments against soil pH (Appendix-VIII and Table-16). But, numerically the higher soil pH (6.296) was found in N_3K_2 treatment combination which was numerically similar to N_2K_2 (6.296) treatment combination while the lower (6.196) was found in N_0K_0 treatment combination. Ramesh *et al*. (2019) hypothesized that decreased soil pH would lead to a greater accumulation of soil organic matter in soil due to a reduced rate of microbial mineralization. In contrast, Hong *et al*. (2019) stated that, application of fertilizers has changed the soil chemical nature but not fully occupies the changes over potential soil nature.

4.4.2 Soil Organic Carbon (%)

A non-significant (p=NS) effect was found in case of soil organic carbon (%) due to different nitrogen levels (Appendix-VIII and Table-14). The soil organic carbon (%) was found non-significant (p=NS) against different levels of potassium application (Appendix-VIII and Table-15). Combindely, a non-significant (p=NS) effect was found among the treatment againsts soil organic carbon (Appendix-VIII and Table-16). But, numerically, the highest soil organic carbon (0.716 %) was found in N_3K_0 treatment combination which was statistically similar to N_1K_2 and N_0K_1 treatment combinations while the lowest (0.696 %) was found in N_0K_0 treatment combination.

4.4.3 Total soil nitrogen (%)

Total soil nitrogen (%) was found significant ($p \leq 0.01$) due to different nitrogen levels (Appendix-VIII and Table-14). With the increasing of nitrogen levels the soil nitrogen percent was increased in post-harvest soil. The highest soil nitrogen (0.069 %) was found from N_3 treatment which was statistically similar to N_2 (0.069 %) treatment and the lowest was in N_0 (0.050 %) treatment. A remarkable significant ($p \leq 0.01$) variation was noted from total soil nitrogen (%) against different levels of potassium application (Appendix-VIII and Table-15). The highest soil nitrogen (0.068 %) was found in K_2 treatment followed by K_1 (0.059 %) treatment and the lowest (0.056 %) was found in K_0 treatment. Combindely, a significant ($p \leq 0.01$) variation was found among the treatments against soil total nitrogen (%) (Appendix-VIII and Table-16). The highest total soil nitrogen (0.083 %) was found in N_3K_2 treatment combination which was statistically similar to N_2K_2 (0.081 %) treatment combination while the lowest (0.049 %) was found in N_0K_0 treatment combination. Studies also have indicated that the application of inorganic fertilizers can increase the content of total nitrogen of soil (Ge *et al.*, 2018). In the present experiment, soil total nitrogen concentration was increased considerably in the fertilization treatments compared with control.

4.4.4 Exchangeable Potassium (meq/100 g soil)

In case of exchangeable potassium (meq/100 g soil) of post-harvest soil a significant ($p \leq 0.01$) variation was found due to different nitrogen levels (Appendix-VIII and Table-14). With the increasing of nitrogen levels the exchangeable potassium (meq/100 g soil) was increased in post-harvest soil. The highest exchangeable potassium (0.348 meq/100 g soil) of soil was found from N_3 treatment followed by N_2 (0.308 meq/100 g soil) treatment and the lowest was found in N_0 (0.143 meq/100 g soil) treatment. A remarkable significant ($p \leq 0.01$) variation was noted from exchangeable potassium (meq/100 g soil) of post-harvest soil against different levels of potassium application (Appendix-VIII and Table-15). The highest exchangeable potassium (0.323 meq/100 g soil) was found in K_2 treatment followed by K_1 (0.210 meq/100 g soil) treatment and the lowest (0.189 meq/100 g soil) was found in K_0 treatment. Combindely, a profound significant ($p \leq 0.01$) variation was noted among the treatments against exchangeable potassium (meq/100 g soil) of post-harvest soil (Appendix-VIII and Table-16). The highest exchangeable potassium (0.491 meq/100 g soil) of post-harvest soil was found in N_3K_2 treatment combination which was statistically similar to N_2K_2 (0.487 meq/100 g soil) treatment combination while the lowest (0.143 meq/100 g soil) was found in N_0K_0 treatment combination which was statistically similar to N_0K_1 and N_0K_2 treatment combinations. Finding of Cheng *et al.* (2013) exhibited that, at low soil pH, K is more susceptible for leaching loss under coarse texture or sandy soil. In the contrast, at high pH the soil would have greater capacity for supplying higher amount exchangeable potassium for plant growth and the soil used for present experiment was silty clay loam in texture. So, the result of present experiment is coinciding with this agreement.

Table 14. Effect of nitrogen on the post-harvest soil properties

Nitrogen	Soil pH	Organic Carbon (%)	Nitrogen (%)	Exchangeable Potassium (meq/100 g soil)
N_0	6.263	0.706	0.050 c	0.143 d
N_1	6.263	0.710	0.056 b	0.164 c
N_2	6.230	0.706	0.069 a	0.308 b
N_3	6.230	0.710	0.069 a	0.348 a
CV (%)	4.60	5.16	4.73	5.12
LSD $_{(0.05)}$	-----	-----	0.027	0.012
F-test	**NS**	**NS**	**	**

Values with common letter (s) within a column do not differ significantly at 5% level of probability
** indicates significant at 1% level of probability
N_0 =0 kg ha^{-1}, N_1 =50 kg ha^{-1}, N_2 =75 kg ha^{-1}, N_3 =100 kg ha^{-1}

Table 15. Effect of potassium on the post-harvest soil properties

Potassium	Soil pH	Organic carbon (%)	Nitrogen (%)	Exchangeable Potassium (meq/100 g soil)
K_0	6.196	0.706	0.056 c	0.189 c
K_1	6.246	0.709	0.059 b	0.210 b
K_2	6.296	0.709	0.068 a	0.323 a
CV (%)	4.60	5.16	4.73	5.12
LSD $_{(0.05)}$	-----	-----	0.027	0.011
F-test	**NS**	**NS**	**	**

Values with common letter (s) within a column do not differ significantly at 5% level of probability
** indicates significant at 1% level of probability
K_0 =0 kg ha^{-1}, K_1 =50 kg ha^{-1}, K_2 =100 kg ha^{-1}

Table 16. Interaction effect of nitrogen and potassium on the post-harvest soil properties

Combination	Soil pH	Organic carbon (%)	Nitrogen (%)	Exchangeable Potassium (meq/100 g soil)
N_0K_0	6.196	0.696	0.049 g	0.143 h
N_0K_1	6.296	0.706	0.051 fg	0.146 h
N_0K_2	6.296	0.716	0.050 fg	0.142 h
N_1K_0	6.196	0.706	0.054 ef	0.149 gh
N_1K_1	6.296	0.716	0.057 de	0.168 fg
N_1K_2	6.296	0.706	0.059 cd	0.175 f
N_2K_0	6.196	0.706	0.061 bcd	0.201 e
N_2K_1	6.196	0.706	0.065 b	0.239 d
N_2K_2	6.296	0.706	0.081 a	0.487 a
N_3K_0	6.196	0.716	0.062 bcd	0.267 c
N_3K_1	6.196	0.706	0.063 bc	0.288 b
N_3K_2	6.296	0.706	0.083 a	0.491 a
CV (%)	4.60	5.16	4.73	5.12
LSD $_{(0.05)}$	----	----	0.025	0.021
F-test	NS	NS	**	**

Values with common letter (s) within a column do not differ significantly at 5% level of probability
** indicates significant at 1% level of probability; NS, indicate non-significant
N_0 =0 kg ha^{-1}, N_1 =50 kg ha^{-1}, N_2 =75 kg ha^{-1}, N_3 =100 kg ha^{-1}
K_0 =0 kg ha^{-1}, K_1 =50 kg ha^{-1}, K_2 =100 kg ha^{-1}

4.5 Pearson correlation co-efficient (r)

From the correlation study it was exhibited that different yield contributing traits and soil properties are dependent and/or independent each other respective of the interaction effect of nitrogen and potassium. A positive and strong relation (r= 0.981**) was found between total number of bulb plot^{-1} and average weight of onion bulb (g) (Figure-1). In Figure-2, a positive and strong relation (r= 0.995**) was exhibited between total number of bulb plot^{-1} and yield of onion bulb (t ha^{-1}). A positive and strong relation (r= 0.993**) was found between average weight of bulb (g) and marketable yield (t ha^{-1}) of onion bulb (Figure-3). A positive and weak relation (r= 0.3015*) was found between pH and soil organic carbon (%) of post-harvest soil (Figure-4). In Figure-5, a negative and very weak relation (r= -0.0262^{NS}) was noted between total nitrogen (%) and soil organic carbon (%) of post-harvest soil. A negative and very weak relation (r= -0.0599) was found showed between exchangeable potassium (meq $100g^{-1}$ of soil) and organic carbon (%) of post-harvest soil (Figure-6). Research findings of Dai *et al.* (2019) stated that the application of inorganic fertilizer accelerated the crop growth and yield characters and in returns also increased the content of fertilizers elements in post-harvest soil. They also reported that, the soil nitrogen and carbon was strongly correlated but slightly correlated with soil acidity or alkalinity.

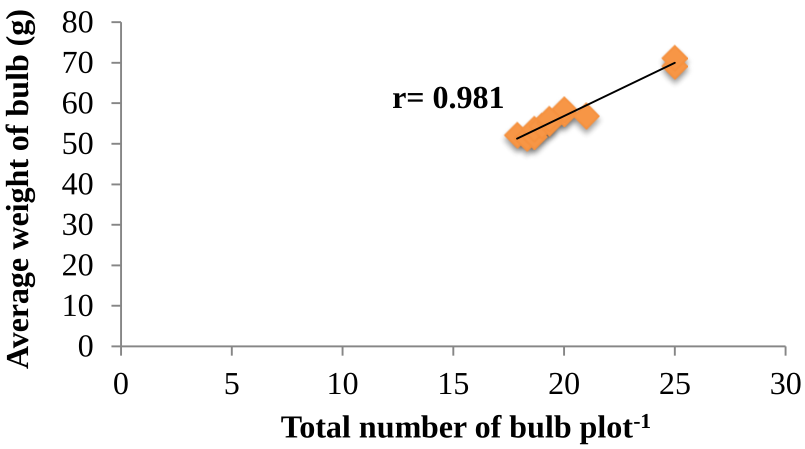

Figure 1. Relationship between total number of bulb $plot^{-1}$ and average weight of bulb (g) of onion

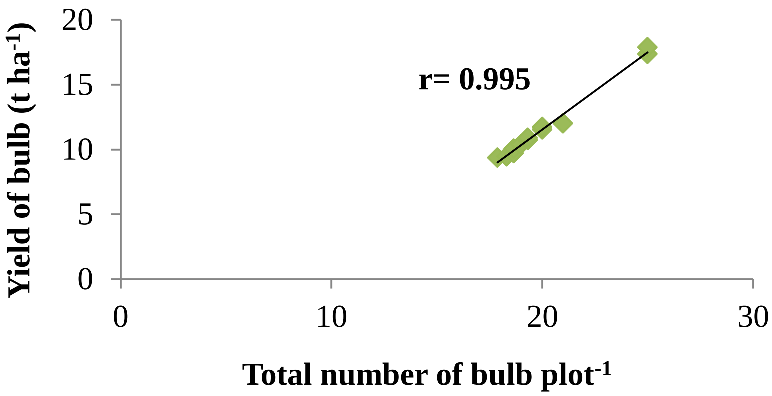

Figure 2. Relationship between total number of bulb $plot^{-1}$ and yield of bulb (t ha^{-1}) of onion

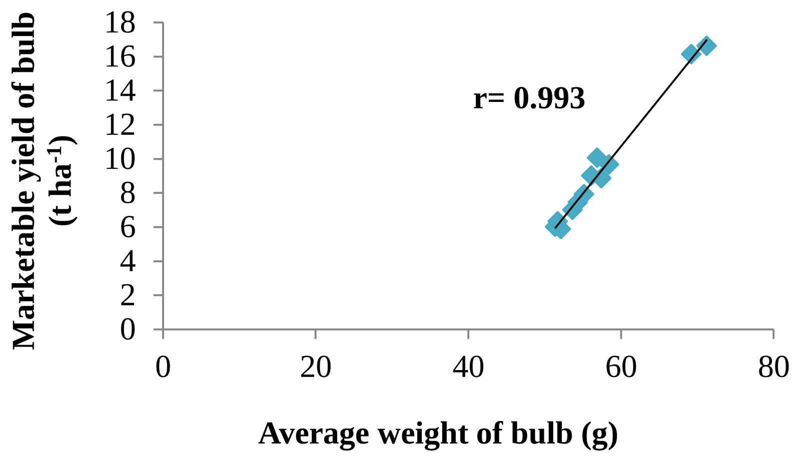

Figure 3. Relationship between average weight of bulb (g) and marketable yield of onion bulb (t ha^{-1})

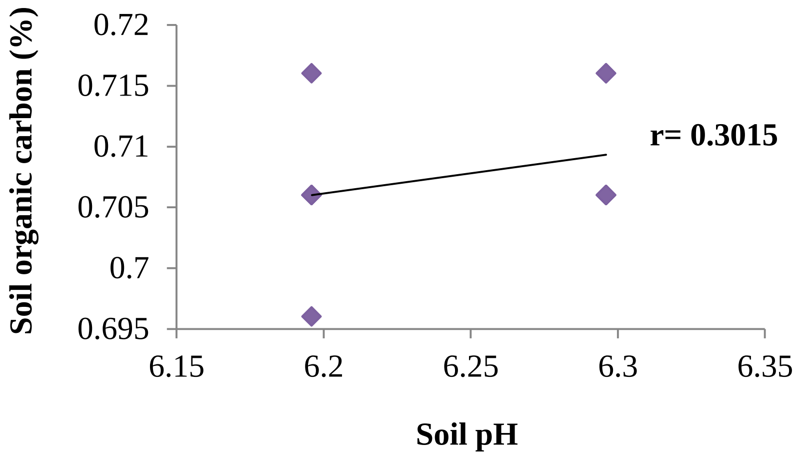

Figure 4. Relationship between soil pH and soil organic carbon (%)

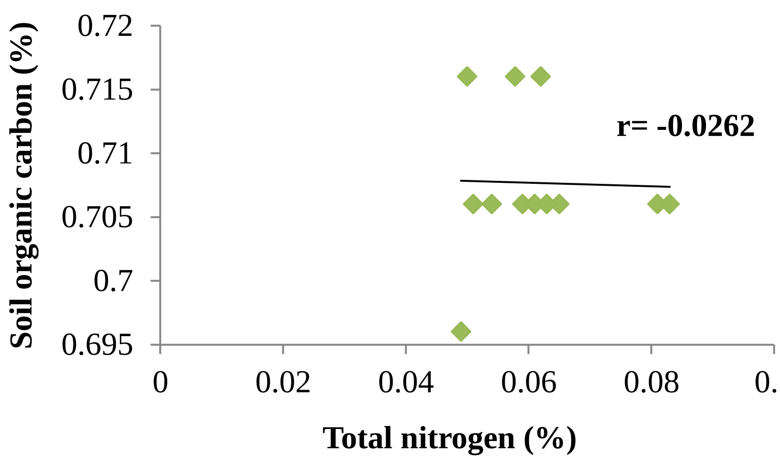

Figure 5. Relationship between total nitrogen (%) and soil organic carbon (%)

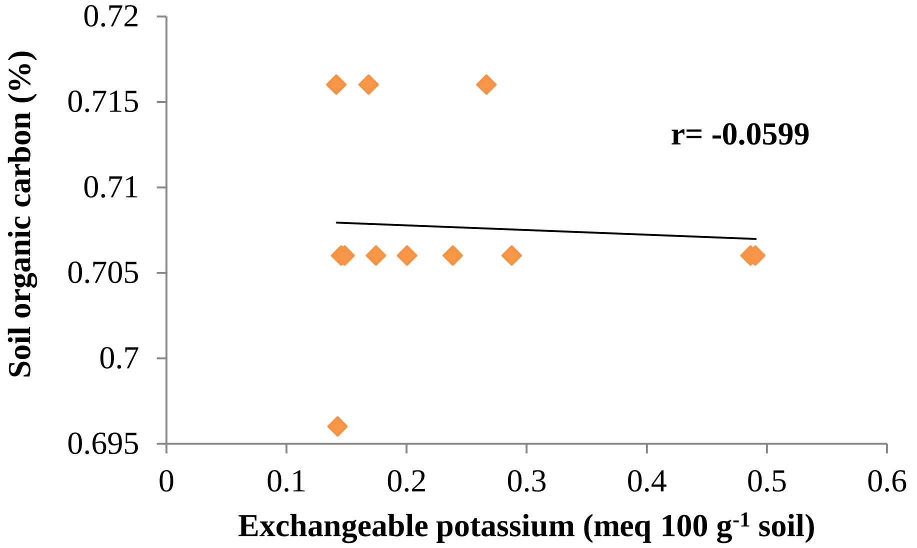

Figure 6. Relationship between exchangeable potassium (meq 100g^{-1} of soil) and soil organic carbon (%)

4.6 Bulb yield merit (%)

A much variation was found after the calculation of bulb yield merit under present study. Apparently, N_3K_2 treatment combination exhibited the highest bulb yield merit (182.35 %) and which was very near to N_2K_2 (174.16 %) treatment combination over N_0K_0 treatment combination.

Treatment combination	Bulb yield merit (%)
N_0K_0	---------
N_0K_1	2.19
N_0K_2	7.55
N_1K_0	18.95
N_1K_1	26.75
N_1K_2	34.52
N_2K_0	50.54
N_2K_1	64.32
N_2K_2	**174.16**
N_3K_0	71.03
N_3K_1	53.02
N_3K_2	**182.35**

N_0 =0 kg ha^{-1}, N_1 =50 kg ha^{-1}, N_2 =75 kg ha^{-1}, N_3 =100 kg ha^{-1}
K_0 =0 kg ha^{-1}, K_1 =50 kg ha^{-1}, K_2 =100 kg ha^{-1}

4.7 Monetary Advantage (Tk./ha)

From the present study it was found that, the uses of nitrogen and potassium have shown much economic returns on onion production. Numerically, N_3K_2 treatment combination gave the maximum monetary return (8,30,800 Tk.) and which was very near to N_2K_2 (8,06,700 Tk.) and N_2K_1 (4,83,500 Tk.) treatment combinations over N_0K_0 (2,94,250 Tk.) treatment combination. The higher bulb yield from the application of nitrogen at higher does may be the reason for higher economic return. Findings of Deshpande *et al*. (2013) stated that the application of K proved a profitable onion production up to the highest level of applied K (150 kg K_2O ha^{-1}) which was not differ with 100 kg K_2O ha^{-1}.

Treatment combination	Monetary Advantage (Tk./ha)
N_0K_0	**2,94,250**
N_0K_1	3,00,700
N_0K_2	3,16,450
N_1K_0	3,50,000
N_1K_1	3,72,950
N_1K_2	3,95,800
N_2K_0	4,42,950
N_2K_1	**4,83,500**
N_2K_2	**8,06,700**
N_3K_0	4,33,250
N_3K_1	4,50,250
N_3K_2	**8,30,800**

N_0 =0 kg ha^{-1}, N_1 =50 kg ha^{-1}, N_2 =75 kg ha^{-1}, N_3 =100 kg ha^{-1}
K_0 =0 kg ha^{-1}, K_1 =50 kg ha^{-1}, K_2 =100 kg ha^{-1}

CHAPTER V
SUMMARY AND CONCLUSION

The experiment was conducted in the research field of Sher-e-Bangla Agricultural University (SAU), Dhaka-1207 during the period from June to September, 2021. The variety, BARI Piaj-5 **(S**ummer variety) was used as test crop under present study. The experiment comprised two factors *viz*., factor-A (Nitrogen levels-4): N_0 =0 kg ha^{-1}, N_1 =50 kg ha^{-1}, N_2 =75 kg ha^{-1} and N_3 =100 kg ha^{-1} and factor-B (Potassium levels-3): K_0 =0 kg ha^{-1}, K_1 =50 kg ha^{-1} and K_2 =100 kg ha^{-1}. The experiment was conducted by following factorial RCBD (Randomized Complete Block Design) design with three (3) replication.

Onion seedlings were properly grown for field transplanting. The crop was fertilized by following the recommendation of BARI except the treatment of this experiment. The well emerged and healthy onion seedlings of 45 days were transplanted in main field. Different intercultural operation were done as per when needed. The well matured onion bulbs were harvested, collected, cured and bagged separately as per treatment of the experiment and the weighted to take the different data of onion bulbs. Under this experiment, the number of bulbs plant^{-1}, average weight of bulb (g), yield of bulb plot^{-1} (g), yield of bulb (t ha^{-1}), marketable bulb yield (t ha^{-1}), non-marketable bulb yield (t ha^{-1}), grading of onion bulbs, different post-harvest soil properties (soil pH, soil organic carbon in percent, total nitrogen in percent and exchangeable potassium in meq/100g of soil) were considered for taking data for statistical analysis. Person’s correlation co-efficient (r) done by using excel spread sheet, bulb yield merit and monetary advantages was calculated for this experiment. Collected data on different parameters were analyzed statistically using the analysis of variance (ANOVA) technique with the help of WASP (Web Agri Stat Package: version-1) computer program and mean were adjusted by using LSD (Least Significant Difference) at 5 % level of probability. Raw data management and graphical representation were done by using Microsoft excel spread sheet. From the present study, it was found that, this summer variety have good performances under different yield and yield contributing parameters of onion. The application of nitrogen has significantly influenced most of the parameters studied under present study and the application of potassium also has shown a good combining ability with nitrogen for better yield response of summer onion. From the correlation studies, it was also found that, different yield contributing traits of summer onion were strongly and positively correlated with each other. A strong correlation was found among the post-harvest soil properties. A significant variation was found among the treatment combinations against total number of bulb plot^{-1}. The maximum bulb number (25.000) was found in N_3K_2 treatment combination which was statistically similar to N_2K_2 (25.000) while the minimum number (17.877) was found in N_0K_0 treatment combination. Combindely, a significant variation was found among the treatment against average weight of bulb (g). The maximum average weight of bulb (71.227 g) was found in N_3K_2 treatment combination which was statistically similar to N_2K_2 (69.207 g) while the minimum weight (51.407 g) was found in N_0K_1 treatment combination.

Yield of onion bulb (t ha^{-1}) was found significant due to different treatment combinations. The highest yield of bulb (17.876 t ha^{-1}) was found in N_3K_2 treatment combination which was statistically similar to N_2K_2 (17.369 t ha^{-1}) while the lowest yield (9.352 t ha^{-1}) was found in N_0K_0 treatment combination. Combindely, a significant variation was found among the treatment against marketable yield (t ha^{-1}) of onion bulb. The highest marketable yield of bulb (16.616 t ha^{-1}) was found in N_3K_2 treatment combination which was statistically similar to N_2K_2 (16.134 t ha^{-1}) followed by N_3K_0 (10.065 t ha^{-1}) while the lowest yield (5.885 t ha^{-1}) was found in N_0K_0 treatment combination. The application of nitrogen and potassium has significantly influenced the size distribution of onion bulb. A significant variation was found among the treatment combinations against medium (31 and 60 mm) size onion bulb. The maximum number of medium size bulb (13.670) was found in N_3K_2 treatment combination which was statistically similar to N_2K_2 (13.327) followed by N_3K_1

(11.670) while the minimum number (5.000) was in N_0K_0 treatment combination. Combindely, a significant variation was found among the treatment against large (>60 mm) size onion bulb. The maximum number of large size bulb (4.000) was found in N_3K_2 treatment combination which was statistically similar to N_3K_2 (4.000) while the minimum number (0.000, not found) was in N_0K_0 treatment combination which was statistically similar to N_0K_1 (0.000) and N_0K_2 (0.000) treatment combinations.

The post-harvest soil properties were significantly influenced by the application of nitrogen and potassium. The soil pH and soil organic carbon were found non-significant against the doses of nitrogen and potassium. Combindely, a significant variation was found among the treatment against soil total nitrogen (%). The highest total soil nitrogen (0.083 %) was found in N_3K_2 treatment combination which was statistically similar to N_2K_2 (0.081 %) while the lowest (0.049 %) was found in N_0K_0 treatment combination. The exchangeable potassium (meq/100 g soil) content of post-harvest soil was found significant due to different treatment combinations. The higher exchangeable potassium (0.491 meq/100 g soil) of post-harvest soil was found in N_3K_2 treatment combination which was statistically similar to N_2K_2 (0.487 meq/100 g soil) while the lowest (0.143 meq/100 g soil) was found in N_0K_0 treatment combination which was statistically similar to N_0K_1 and N_0K_2 treatment combinations.

The bulb yield merit (%) was found much profound due to the application of nitrogen and potassium under present study. Apparently, N_3K_2 treatment combination exhibited the highest bulb yield merit (182.35 %) and which was very near to N_2K_2 (174.16 %) over N_0K_0 treatment combination. The uses of nitrogen and potassium have shown much economic returns on onion production. Numerically, N_3K_2 treatment combination gave the maximum monetary return (8,30,800 Tk.) and which was very near to N_2K_2 (8,06,700 Tk.) and N_2K_1 (4,83,500 Tk.) over N_0K_0 (2,94,250 Tk.) treatment combination.

Conclusions

From the experiment, it may be concluded that nitrogen and potassium showed the better performance for yield and yield contributing traits of summer onion. Nitrogen application at the rate of 100 kg ha^{-1} exhibited the best one for yield and yield contributing traits of summer onion which was statistically similar to 75 kg ha^{-1}. Application of potassium @ 100 kg ha^{-1} exhibited the best performance for most of the parameters studied. Combindely, the application of nitrogen @ 75 and 100 kg ha^{-1} along with potassium @ 100 kg ha^{-1} showed statistical similar results over control. So, on the basis of monetary advantages application of nitrogen @ 75 along with potassium @ 100 kg ha^{-1} is best combination.

Recommendations

1. The onion growers Bangladesh may use this variety, BARI Piaj-5 in summer season for getting better yield with the combination of nitrogen and potassium at higher dose than the conventional one.

2. In order to validate these findings, more research programs should be conducted to assess the combined effect of organic sources of nutrient along with other inorganic fertilizers in different major onion growing areas of Bangladesh.

3. Nowadays, potassium fertilization has become an important factor for onion production under Bangladeshi soils. However, farmers are minimizing the uses of it or ignored using it because chemical potassium fertilizer becoming a high expensive fertilizer in Bangladesh. So, in very near future researchers should search the alternative source of potassium for easy and sustainable handling.

4. Besides, the summer varieties can play a big role in making the country self-sufficient in onion. In this connection, Bangladesh Agricultural Development Corporation (BADC) may take initiative to produce and supply adequate seeds of summer onion to the growers.

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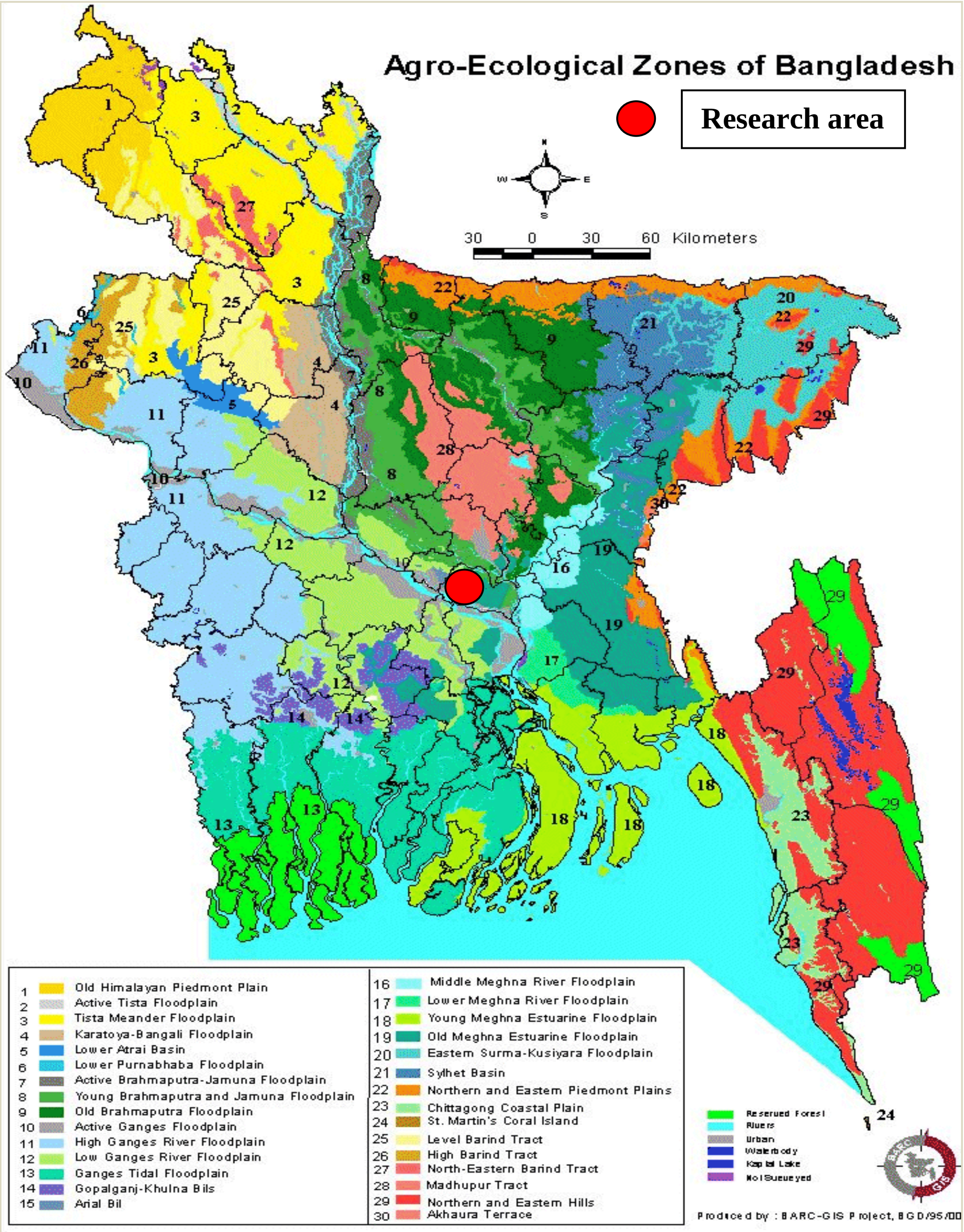
APPENDICES

Appendix I. Map showing the site used for present study



Appendix II. Monthly meteorological information during the period from June to September, 2021

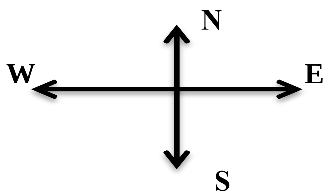
Month	Air temperature (^oC)		Relative Humidity (%)	Total rainfall (mm)
	Maximum	Minimum		
June	26.0	12.0	79.1	340.11
July	28.1	11.1	79.2	373.1
August	25.4	15.0	78.3	316.5
September	25.2	11.2	77.1	300.4

Source: Metrological Centre (Climate Division), Agargaon, Dhaka

Appendix III. Layout of the experiment

N_0K_0	N_3K_2	N_1K_2
N_3K_2	N_1K_0	N_0K_2
N_1K_0	N_3K_1	N_2K_1
N_3K_0	N_0K_1	N_0K_1
N_2K_1	N_2K_0	N_2K_2
N_1K_2	N_2K_2	N_0K_0
N_2K_0	N_3K_0	N_3K_2
N_2K_2	N_1K_1	N_3K_0
N_0K_2	N_0K_2	N_1K_0
N_1K_1	N_2K_1	N_3K_1
N_3K_1	N_1K_2	N_2K_0
N_0K_1	N_0K_0	N_1K_1
R_1	R_2	R_3

Replication to replication distance: 1.0 m, **Plot to plot distance**: 0.5 m
Unit plot size: 1.0 m × 1.0 m (1.0 m^2)



Appendix IV. Mean sum square values for plant height and number of leaves of onion

Source of variation	df	Plant height (cm)	Number of leaves plant^{-1}
Replication (A)	2	0.0001	0.00063
Nitrogen (N)	3	50.6504**	5.23000**
Potassium (P)	2	60.5788**	5.49750**
N×P	6	11.9716*	1.43750**
Error	22	4.7622	0.12418
Total	35		

*, ** indicate significant at 5% and 1% level of probability, respectively.

Appendix V. Mean sum square values for yield contributing traits and yield of onion bulb

Source of variation	df	Total number of bulb per plot	Average weight of bulb (g)	Yield of bulb plot^{-1} (g)	Yield of bulb (t ha^{-1})
Replication (A)	2	0.0116	0.015	323	0.0323
Nitrogen (N)	3	29.2360**	226.081**	406458**	40.6458**
Potassium (P)	2	29.8114**	184.158**	420172**	42.0172**
N×P	6	7.1621*	54.207*	112125*	11.2125*
Error	22	2.6951	20.404	36671	3.6671
Total	35				

*, ** indicate significant at 5% and 1% level of probability, respectively.

Appendix VI. Mean sum square values for marketable and non-marketable yield of onion bulb

Source of variation	df	Marketable bulb yield	Non-marketable bulb yield
Replication (A)	2	0.0039	0.00053
Nitrogen (N)	3	76.7692**	6.07509**
Potassium (P)	2	56.3901**	1.29218**
N×P	6	14.3542**	0.28324**
Error	22	0.3648	0.02586
Total	35		

**, indicates significant at 1% level of probability.

Appendix VII. Mean sum square values for grading of onion bulb

Source of variation	df	Grading of Onion bulb		
		Small	**Medium**	**Large**
Replication (A)	2	0.0005	0.0006	0.0012
Nitrogen (N)	3	40.0348**	59.3967**	13.8481**
Potassium (P)	2	6.2750**	21.8196**	5.4406**
N×P	6	0.8776^{NS}	1.9892**	1.4110**
Error	22	0.3750	0.3155	0.0166
Total	35			

**, indicates significant at 1% level of probability; NS, indicates non-significant

Appendix VIII. Mean sum square values for post-harvest soil properties

Source of variation	df	Soil pH	Organic carbon	Total Nitrogen	Exchangeable potassium
Replication (A)	2	0.00010	0.0390	0.07190	0.05891
Nitrogen (N)	3	0.00333^{NS}	0.04666^{NS}	0.03180**	0.09470**
Potassium (P)	2	0.03000^{NS}	0.04755^{NS}	0.03540**	0.06227**
N×P	6	0.00333^{NS}	0.03841^{NS}	0.03890**	0.01886**
Error	22	0.08250	0.02866	0.05161	0.0384
Total	35				

** indicates significant at 1% level of probability; NS, indicates non-significant

Plate 1. Raising of onion seedling

Plate 2. Collection of initial soil sample

Plate 3. Final land preparation

Plate 4. Application of fertilizer

Plate 5. Transplanting of onion seedlings

Plate 6. Tagging of treatments

Plate 7. Experimental signboard

Plate 8. Removal of weeds

Plate 9. Onion plant at early, mid and later growth stage

Plate 10. Harvesting of onion bulb

Plate 11. Collection of post-harvest soil samples

Plate 12. Yield from best combinations and control

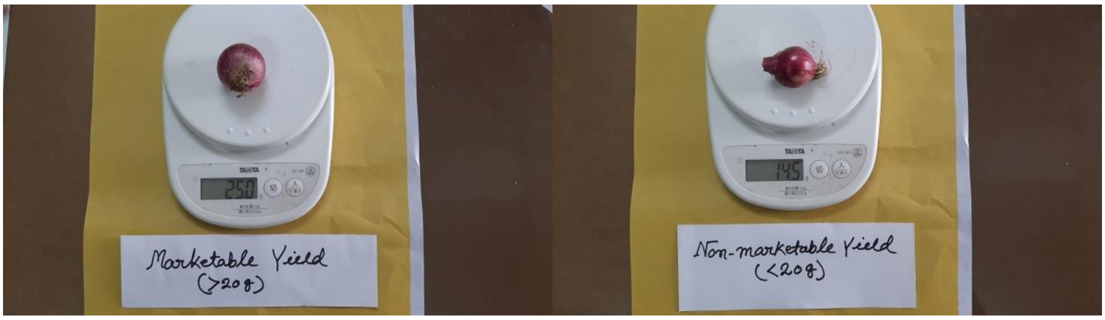


Plate 13. Marketable and non-marketable yield of onion

Plate 14. Grading of onion bulb from best treatments and control

A **B**

C

Plate 15. Total nitrogen determination (A: digestion; B: Distillation and C: titration)

Plate 16. Picture with research supervisor and another teacher

Chapter I

Introduction

Chapter II

Review of literature

Chapter III

Materials and methods

Chapter IV

Results and Discussion

Chapter V

Summary and Conclusion

References

Appendices