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Effect of Different Levels of Urea Super Granule and Prilled Urea on the Crop Quality, Nutrient Uptake and Soil Nutrient Status of Broccoli

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Abstract

A field experiment was conducted at Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur during the period 2010-2011 to assess the effect of urea super granule (USG) and prilled urea (PU) on the quality attributes (Compactness coefficient, Vitamin C, β-carotene and chlorophyll contents) of broccoli, to assess the comparative performance of USG and PU on nutrient uptake and uptake efficiency of broccoli plant, to assess the effect of different forms and levels of urea N on the post harvest soil nutrient status of broccoli field and to select the better doses of USG and PU for quality broccoli production in Shallow Red-Brown Terrace Soil under Madhupur Tract (AEZ-28). The experiment was laid out in a randomized complete block design with three replications having 17 treatments constituted with different levels of urea super granule (USG) and prilled urea (PU) as- T_1: N-control, T_2: PU-N_{80}, T_3: PU-N_{100}, T_4: PU-N_{120}, T_5: PU-N_{140}, T_6: PU-N_{160}, T_7: PU-N_{180}, T_8: PU-N_{200}, T_9: PU-N_{220}, T_{10}: USG-N_{80}, T_{11}: USG-N_{100}, T_{12}: USG-N_{120}, T_{13}: USG-N_{140}, T_{14}: USG-N_{160}, T_{15}: USG-N_{180}, T_{16}: USG-N_{200}, T_{17} and USG-N_{220} kg ha^{-1}. Results revealed that the comparative performance of USG in relation to head quality (compactness coefficient, ascorbic acid, β-carotene and chlorophyll content), nutrient (NPKS) uptake and N uptake efficiency was found better as compared to PU. The compactness coefficient, β-carotene and chlorophyll contents were increased with increasing rate of N as well as USG and PU, but ascorbic acid content was slightly decreased with increasing rate of USG and PU. The maximum compactness coefficient (18.61) was found from the treatment USG-N_{180} that was followed by USG-N_{160} (18.24) and the highest β-carotene content (0.401 mg/100gFW) was found from USG-N_{160} followed by PU-N_{180} (0.40 mg/100gFW). Similarly the highest chlorophyll-a content (0.818 mg/100gFW) was found from USG-N_{180} followed by USG-N_{160} (0.814 mg/100gFW) and the highest chlorophyll-b content (1.141mg/100g FW) was recorded from USG-N_{180}. The higher nutrient uptake and N uptake efficiency (108.531%) was obtained from USG treated plots over that of the PU. But N uptake efficiency was decreased with increasing rates of N fertilizer. But post harvest soil nitrogen status did not show any systematic trend although it was found higher in USG over PU. Similarly no remarkable changes were observed in post harvest soil P, K, S and B status for the crop. However, USG @ 160 kg N ha^{-1} (USG-N_{160}) followed by USG-N_{140} and PU @ 180 kg N ha^{-1} (PU-N_{180}) with other recommended doses of fertilizer could be suggested as USG and PU based fertilizer recommendation for a good quality broccoli production in terms of yield and quality in Silty Clay Loam Soil of Madhupur Tract.

Keywords: Broccoli, Urea super granule, Head quality, Nutrient uptake, Soil nutrient status.

1. Introduction

Broccoli is the more nutritious vegetable and contains substantial quantities of protein, carbohydrates, Ca, P, Fe, thiamine, riboflavin, and niacin with very high levels of carotene (vitamin A) and ascorbic acid (vitamin C) as reported by Kays (1914). Nutrient uptake and crop quality of broccoli is influenced by the application of different levels of N. Yoldas *et al.* (2008) reported that application of N increased N, P, K and Fe concentrations in broccoli head and the highest amount of the total N and K in broccoli heads was measured at 450 kg ha^{-1} N application. Nitrogen management strategies should be adopted to minimize the different losses of nitrogen from soil to the environment as it is the most limiting factor for crop growth. However, excess application of nitrogen fertilizer may have a negative effect on the environment and human health (Neeteson and Carton 2001). The response to N depends on the availability of water, and on the supply of other nutrients. The apparent N recovery has been found to decrease with increasing fertilizer N application for several vegetable crops (Greenwood and Draycott, 1988). Bakker *et al.* (2009) reported that floret NO_3^- N concentration increased and vitamin C concentration decreased at high nitrogen rates. Averaarts and de Willigen (1999) found that band placement of N positively influenced N uptake. The increase of the N fertilizer dose induces increase of nitrate content in plant tissue of broccoli (Zebarth *et al.,* 1995). Fatemeh and Ahmad (2012) reported that the N, P, K, Fe, and Zn concentrations in broccoli head were positively affected by N treatments and the maximum N concentration (7.18%) in the heads was determined at 400 kg N ha^{-1} applied and K, P and Fe concentrations (0.78%, 2.41% and 177.0 mg kg^{-1}, respectively) were reached maximum at 300 kg N ha^{-1} dose. Utilization of fertilizer P is generally enhanced by the application of N (William, 1958).

Murcia *et al.* (2000) studied chlorophylls *a* and *b* quantitatively determined in raw, frozen and canned florets and stems of broccoli and reported that the chlorophyll *a* and *b* contents were 0.11 and 0.043 g kg^{-1} fresh weight respectively in raw florets and 0.036 and 0.018 g kg^{-1}, respectively in stems that was influenced by the N application. Nitrogen nutrition has a significant impact not only on the amount of harvested broccoli, but also on the content of β-carotene, vitamin C and E_1. Lisiewska and Kmiecik (1996) determined that an increase in nitrogen rates from 80 to 120 kg ha^{-1} results in a 44 and 33% reduction in vitamin C levels in broccoli and cauliflower, respectively. The concentration of ß-carotene increases with increasing nitrogen rates. Ljiljana *et al*. (2012) reported that the increase in nitrogen fertilizer rate from 60 to 120 kg N ha^{-1} led to a reduction in vitamin C content and an increase in ß-carotene. Hocmuth *et al.* (1999) used nitrogen rates of 0 to 220 kg ha^{-1} and obtained the highest content of ß-carotene (55 mg kg^{-1}) with 160 kg ha^{-1}. Similarly, the effect of different forms and levels of urea N on the post harvest soil status of broccoli field was observed by different scientists. Averaarts and de Willigen (1999) reported that the amount of mineral N in the soil at harvest generally increased with increasing amounts of N applied. So, the assessment of crop quality and plant nutrient uptake as well as post harvest soil nutrient status as affected by the N levels is important for quality broccoli production. Therefore, the experiment was undertaken (i) to assess the effect of urea super granule (USG) and prilled urea (PU) on the quality attributes (Compactness coefficient, Vitamin C, β-carotene and chlorophyll contents) of broccoli; (ii) to assess the comparative performance of USG and PU on nutrient uptake and uptake efficiency of broccoli plant; (iii) to assess the effect of different forms and levels of urea N on the post harvest soil nutrient status of broccoli field and (iv) to select the better doses of USG and PU for quality broccoli production.

2. Materials and Methods

A field experiment was conducted at Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur during the period 2010-2011 in Shallow Red-Brown Terrace Soil under Madhupur Tract (AEZ-28). The experiment was laid out in a randomized complete block design with three replications having 17 treatment combinations constituted with different levels USG and PU as- T_1: N-control, T_2: PU-N_{80} (80 kg N as PU), T_3: PU-N_{100} (100 kg N as PU), T_4: PU-N_{120} (120 kg N as PU), T_5: PU-N_{140} (140 kg N as PU), T_6: PU-N_{160} (160 kg N as PU), T_7: PU-N_{180} (180 kg N as PU), T_8: PU-N_{200} (200 kg N PU), T_9: PU-N_{220} (220 kg N as PU), T_{10}: USG-N_{80} (80 kg N as USG), T_{11}: USG-N_{100} (100 kg N as USG), T_{12}: USG-N_{120} (120 kg N as USG), T_{13}: USG-N_{140} (140 kg N as USG), T_{14}: USG-N_{160} (160 kg N as USG), T_{15}: USG-N_{180} (180 kg N as USG), T_{16}: USG-N_{200} (200 kg N as USG), T_{17}: USG-N_{220} (220 kg N as USG).

Soil sample of the experimental plot was collected prior to initiation of the experiment and analysis was done accordingly. For each plot 5 samples of 0-15 cm depth were randomly collected, mixed well, air-dried, ground and sieved through a 2 mm (10 mesh) sieve. The soil of the experimental field belongs to Salna series representing the Shallow Red Brown Terrace soil in Bangladesh soil classification system, which falls under order Inceptisols in Soil Taxonomy (Brammer, 1980 and FAO, 1988). But the soil of the study area is silty clay loam in texture with sand, silt and clay 17.8, 45.6 and 36.6%, respectively and having bulk density 1.34 g/cc and particle density 2.61 g/cc, porosity 47.47% and field capacity 28.67%. The initial soil sample of 0-15 cm depth was collected from the experimental unit plots before fertilization. Post-harvest soil samples of 0-15 cm depth were also collected from each plot and the samples were stored in clean plastic bag for physical and chemical analyses. At the same time, undisturbed soil samples from 0-15 cm were collected for determination of soil bulk density. The initial soil sample was analyzed for particle size distribution, particle density, bulk density, pH, organic C, total N, available P, exchangeable K and available S and B. Chemical analysis of soil was done in the BSMRAU laboratory of the Department of Soil Science and the results obtained were presented in Table 1.

Post harvest soil samples were also analyzed for total N, available P, exchangeable K, available S and B. Soil pH was measured with the help of a glass electrode pH meter using soil water suspension of 1: 2.5 as described by Jackson (1962). Organic carbon was determined following the wet oxidation method as described by Page *et al.* (1982) and the organic matter content was calculated by multiplying the % organic carbon with the Van Bemmelen factor 1.73 (Piper, 1950). Cation exchange capacity (CEC) was determined followed by ammonium acetate extraction method using flame-photometer. Total N of soil was estimated following the micro-Kjeldahl method (Jackson *et al.*, 1973).

Table 1. Chemical properties of the initial soil of the experimental plot

Soil properties (0-15 cm soil depth)	Analytical value
Soil pH	5.98
Organic carbon (%)	0.97
Total N (%)	0.11
Available P (µg g-1)	14.17
Exchangeable K (meq/100g soil)	0.32
Available S (µg g-1)	13.81
Available B (µg g-1)	0.20
CEC (meq/100g soil)	12.71

The P was determined colorimetrically through extraction method (Olsen *et al.*, 1954). Exchangeable K of soil was determined from ammonium acetate (1N NH_4OAC) extract as described by Jackson (1973). Available S in soil was determined by extracting the samples with $CaCl_2$ (0.15%) solution using double beam spectrophotometer at 420 nm wave length followed by tubidimetrically with barium sulfate (Page *et al.*, 1982). Total B content was determined followed by digestion with concentrated HNO_3 and $HClO_4$ (Par-chloric acid) method (Hunter, 1980) using double beam spectrophotometer (Model no. 200-20, Hitachi, Japan).

Compactness coefficient (CC) is the ratio of head yield (g plant^{-1}) to head diameter (cm). It was estimated by the following formula:

$$\text{Compactness coefficient (CC)} = \frac{\text{Head yield (g plant}^{-1})}{\text{Head diameter (cm)}} \qquad \text{Eq.1}$$

Ascorbic acid level was determined by the Iodate method of Samotus *et al*. (1982). Ascorbic acid (Vitamin C) content of fresh head sample was determined using centrifuging technique and KIO_3 titration method followed by the formula stated below:

$$\text{Ascorbic acid (mg/100 g FW)} = \frac{(f \times V_1 \times V_2 \times 100)}{(W \times V_3)} \qquad \text{Eq.2}$$

Where,
V_2= Total volume of blended sample (100ml)
V_3= Volume of sample extract taken (5ml)
W= Weight of fresh head sample (20g)
V_1= Titrated volume of KIO_3 (ml)

Chlorophyll a, Chlorophyll b and Beta-carotene were determined followed by acetone-haxen method as stated by Masayasu and Yamashita (1992). This is a simple method for simultaneous determination of pigment in the vegetable. All pigments in sample are extracted with acetone-hexane (4:6) at once. Then optical density of the supernatant at 663 nm, 645 nm, 505 nm and 453 nm are measured by spectrophotometer at the same time. From these values, the contents of Chlorophyll a, Chlorophyll b and Beta-carotene could be estimated using the proposed formula as follows:

$$\text{Chlorophyll a (mg/100 ml)} = 0.999A_{663} - 0.0989A_{645} \qquad \text{Eq.3}$$

$$\text{Chlcrophyll b (mg/100 ml)} = 0.328A_{663} + 1.77A_{645} \qquad \text{Eq.4}$$

$$\text{Beta-carotene (mg/100 ml)} = 0.216A_{663} - 1.22A_{645} - 0.304A_{505} + 0.452A_{453} \qquad \text{Eq.5}$$

*A_{663}, A_{645}, A_{505}, A_{453} are absorbance at 663 nm, 645 nm, 505 nm and 453 nm, respectively.

Total plant biomass was estimated by oven drying the plant samples at 65°- 70° C for 72 hours and weighing. The biomass per plant and biomass per hectare were calculated by the following formulae:

$$\text{Biomass per plant (g)} = \frac{\text{Total above ground biological yield of 10 plants (g)}}{10} \qquad \text{Eq.6}$$

$$\text{Biomass ha}^{-1}\text{(kg)} = \frac{\text{Biomass yield plant}^{-1}\text{(kg)}}{\text{Number of plants ha}^{-1}} \qquad \text{Eq.7}$$

To evaluate the leaf nutrient content leaf samples were collected from three matured leaf of five randomly selected plants from each treatment, which were then oven dried and ground for analysis, at harvesting stage. To estimate the quality of head five randomly selected plants were taken into account from each treatment and head samples were collected from the head of these plants. The collected head samples were divided into two parts and one part is used for immediate analysis of vitamin-C, β-carotene and chlorophyll content. The other part was taken to air and oven dry for nutrient analysis. Leaf, stem and head samples of broccoli were dried in an oven at 65-70^{0}C for 72 hours and then ground by a grinding machine to pass through a 20 mesh sieve and stored in small paper bags and kept into a desiccator. Representative plant samples were also dried and prepared for analysis. The samples were analyzed for N, P, K and S contents.

Nitrogen contents in the leaf stem and head sample were determined following the Micro-Kjeldahl method as described in case of soil analyses. Phosphorus concentration in the leaf, stem and head samples were determined after digestion with HNO_3 and $HClO_4$ mixture in 5:2 ratios. Phosphorus was determined from the digest by adding ammonium molybdate and ammonium vanadate solution and measuring the colour with the help of a double beam spectrophotometer (Model no. 200-20, Hitachi, Japan) at 660 nm wave lengths. Potassium content in leaf, stem and head samples were determined directly with the help of flame photometer after digesting the samples with di-acid mixture. Sulphur content in the digest was determined by adding 6 N HCl to plant extract and then precipitating with $BaCl_2$ and measuring the turbidity calorimetrically at 420 nm wavelength (Black, 1965).

Nutrient uptake assessment

Nutrient uptake from the soil was calculated by using the formula:

$$\text{Nutrient uptake (kg ha}^{-1}) = \frac{\%\ \text{Nutrient} \times \text{Y (kg ha}^{-1})}{100} \qquad \text{Eq. 8}$$

Here,

% Nutrient = Average nutrient content (%) of plant or head biomass

Y ($kgha^{-1}$) = Total dry matter production of plant or head biomass

$$\text{Nutrient uptake (kg ha}^{-1}) = \frac{\text{Nutrient } (\mu g/g) \times \text{Y (kg ha}^{-1})}{10^6} \qquad \text{Eq. 9}$$

Here,

Nutrient ($\mu g\ g^{-1}$) = Average nutrient content ($\mu g\ g^{-1}$) of plant or head biomass

Y ($kg\ ha^{-1}$) = Total dry matter production of plant or head biomass

Nitrogen uptake efficiency

Nitrogen uptake efficiency (NUE) was determined by the ratio of N in the crop at harvest compared to N applied by subtracting the uptake made by the control plot. The efficiency of applied fertilizer N may be quantified by the following equation as stated by Craswell and Godwin (1984):

$$\text{Nitrogen uptake efficiency (NUE)} = \frac{\text{N uptake F} - \text{N uptake C}}{\text{Fertilizer N applied}} \times 100 \qquad \text{Eq. 10}$$

Where,

F and C denote fertilized crop and unfertilized control, respectively.

The collected data were compiled and tabulated in proper form and statistical analysis was done by using the computer package MSTATC. Computation and preparation of graphs were made by the use of Microsoft Excel 2003 program.

3. Results and Discussion

3.1. Effects on the quality attributes of broccoli

3.1.1. Compactness coefficient

A significant effect of different forms and levels of urea on the head compactness coefficient (CC) was found (Table 2). The maximum CC (18.61) was found from the treatment . USG-N_{180} followed by USG-N_{160} (18.24) which was significantly ($P \leq 0.05$) higher than all other treatments (Table 2). The lowest CC (12.56) was found from control where no urea was applied. In each level of N application CC was always higher in USG treated crop. Renata *et al.* (2005) reported that the CC was increased with increasing levels of N, which is in agreement with the present findings. The probable reasons for higher compactness coefficient is might be due to the sufficient supply of plants in nitrogen, leading to sufficient carbon assimilation, resulting in translocation of current photosynthates to the broccoli head which in turns improve head compactness.

3.1.2. Vitamin -C content

The different form and levels of urea N significantly influenced vitamin-C or ascorbic acid content of the broccoli floret and vitamin-C content was gradually decreased with increasing rate of USG and PU (Table 2). The highest vitamin-C content (94.73 mg $100g^{-1}$ FW) was recorded from the treatment USG-N_{80} followed by the treatment PU-N_{120} (94.49 mg $100g^{-1}$ FW), which were statistically identical with the treatment USG-N_{100}. However, Vitamin-C content in USG treated broccoli was found higher at each dose of N application. The lowest ascorbic acid content (55.71 mg $100g^{-1}$ FW) was found from 220 kg PU which was statistically identical with PU-N_{100} treatment. Chao-Jiong *et al*. (2010) reported that the ascorbic acid and glucoraphanine concentrations in broccoli floret and stem were decreased with the increase in higher N application, and significant lower levels of ascorbic acid were detected by N fertilization at range of N 300-400 kg ha^{-1}. Lisiewska and Kmiecik (1996) determined that an increase in nitrogen rates from 80 to 120 kg ha^{-1} results in a 44 and 33% reduction in vitamin C levels in broccoli and cauliflower, respectively. Ljiljana *et al*. (2012) found that the increase in nitrogen fertilizer rate from 60 to 120 kg N ha^{-1} led to a reduction in vitamin C content and an increase in ß-carotene in carrot. Karitonas (2001) studied with N supply (60 to 300 kg ha^{-1}) on the yield and quality of broccoli and found that an increased level of N supply slightly reduced the vitamin C content from 83 to 73 mg/100 g f.m. in broccoli flowers which also correlated our finding at higher N levels. This was might be due to the higher nitrogen doses which reduced dry matter content resulting in less ascorbic acid in broccoli (Roni *et al*., 2014).

3.1.3. Beta-carotene content

The different forms and levels of urea N significantly influenced β-carotene content of broccoli floret (Table 2). The highest β-carotene content (0.401 mg $100g^{-1}$ FW) was found from the treatment USG-N_{160} that was statistically identical with the treatments PU-N_{180} (0.40 mg/100gFW), PU-N_{160}, PU-N_{140}, USG-N_{180} and USG-N_{140}. The significantly lowest β-carotene was recorded from PU-N_{80} (0.187 mg $100g^{-1}$ FW) treatment.

Table 2. Effect different forms and levels of urea N on head quality of broccoli

Treatments	Compactness coefficient (cc)	Vitamin-C (mg/100g FW)	B-carotene (mg/100g FW)	Chlophyll-a (mg/100g FW)	Chlophyll-b (mg/100g FW)
N-control	12.93 hi	87.35 c	0.249 c-e	0.648	0.751 m
PU-N_{80}	14.15 gh	94.49 a	0.187 e	0.693	0.803 k
PU-N_{100}	14.08 gh	82.00 d	0.222 de	0.712	0.839 j
PU-N_{120}	14.71 fg	77.68 e	0.220 de	0.755	1.037 ef
PU-N_{140}	15.85 d-f	70.92 f	0.321 a-c	0.771	1.039 e
PU-N_{160}	15.55 ef	68.16 fg	0.379 a	0.779	1.101 c
PU-N_{180}	16.41 c-e	64.44 hi	0.400 a	0.795	1.114 bc
PU-N_{200}	14.77 fg	56.72 j	0.286 b-d	0.799	1.076 d
PU-N_{220}	15.20 e-g	55.71 j	0.219 de	0.792	1.040 e
USG-N_{80}	15.76 d-f	94.73 a	0.214 de	0.767	0.812 k
USG-N_{100}	16.29 c-e	93.65 ab	0.254 c-e	0.773	0.859 i
USG-N_{120}	16.98 bc	91.07 b	0.289 b-d	0.788	0.970 h
USG-N_{140}	17.33 b-d	79.32 de	0.354 ab	0.797	1.042 e
USG-N_{160}	18.24 a	70.02 fg	0.401 a	0.814	1.122 b
USG-N_{180}	18.61 a	68.40 fg	0.346 ab	0.818	1.141 a
USG-N_{200}	17.73 b	67.12 gh	0.279 b-d	0.807	1.021 fg
USG-N_{220}	16.35 c-e	63.12 i	0.275 b-d	0.803	1.007 g
CV(%)	4.20	2.42	14.45	5.79	2.15
SE (±0.05)	0.3674	1.054	0.026	ns	0.006

Means followed by uncommon letters are statistically different from each other at 5% level of probability by DMRT

Here, it was also observed that comparatively higher β-carotene was contained by the USG treated plots than that of PU. These higher nutritional values obtained by applying USG due to its continuous and balanced N supply to the broccoli head. Anton *et al.* (2014) reported that nitrogen nutrition has a positive effect on increasing the amount of β-carotene in broccoli rosettes. Ljiljana *et al.* (2012) reported that ß-carotene content increased with increasing rates of nitrogen and was found to be statistically significant even at 120 and 180 kg N ha^{-1}, as compared to both the control and 60 kg N ha^{-1}. Hocmuth *et al.* (1999) also obtained the highest content of ß-carotene (55 mg kg^{-1}) with 160 kg N ha^{-1} using N rates of 0 to 220 kg ha^{-1}.

3.1.4. Chlorophyll-a content

Chlorophyll-a content was increased with increasing levels of nitrogenous fertilizer (Table 2). Although there was no significant effect was found among the treatment highest chlorophyll-a (0.818 mg $100g^{-1}$ FW) content was found from USG-N_{180} followed by USG-N_{160} (0.814 mg $100g^{-1}$ FW). However, the higher chlorophyll-a content was resulted in USG treated plots than that of PU. These results are supported by the findings of Karitonas (2001) who reported from their study by investigating the effect of varying N supply (60 to 300 kg ha^{-1}) on the yield and quality of broccoli and found the increased N supply improved chlorophyll contents in florets. Ouda and Mahadeen (2008) reported that chlorophyll content and head diameter were higher when a combination of organic and inorganic fertilizers was added compared to their individual addition. .

3.1.5. Chlorophyll-b content

In case of Chlorophyll-b content, a significant difference was observed among the treatments (Table 2). It was observed that chlorophyll-b content was increased with increasing levels of nitrogenous fertilizer. The highest chlorophyll-b content (1.141 mg $100g^{-1}$ FW) was recorded from the treatment USG-N_{180}, which was statistically different from all other treatments. The second highest chlorophyll-b content (1.122 mg $100g^{-1}$ FW) was recorded from USG-N_{160} followed by PU-N_{180} (1.114 mg $100g^{-1}$ FW) which was statistically identical with each other. The lowest chlorophyll-b content (0.751 mg $100g^{-1}$ FW) was obtained from control. It was clearly observed that the higher chlorophyll-b content was found from USG treated plots than that of PU. This result is corroborated with the findings of Karitonas (2001) and Ouda and Mahadeen (2008), who reported that the increased N supply improved florets chlorophyll contents. This is due to a promotion effect of N fertilizer on chlorophyll formation might be attributed to the fact that N is a constituent of chlorophyll molecule. Moreover, nitrogen is the main constituent of all amino acids in proteins and lipids that acting as a structural compounds of the chloroplast (Arisha and Bradisi, 1999).

3.2. Effects on plant nutrient uptake of broccoli

3.2.1. Nitrogen uptake by the crop

The effect of different forms and levels of urea nitrogen on the N uptake and its uptake efficiency is presented in the Fig.1. Nitrogen uptake was increased significantly with increasing levels of N which followed a curvilinear fashion and the highest N uptake (280.2 kg ha^{-1}) was recorded from USG-N_{180} treatment which was statistically identical with USG-N_{200} and USG-N_{160} treatments. The highest N (240.9 kg ha^{-1}) uptake from PU treated plots was recorded from the treatment PU-N_{180}. The overall N uptake performance was higher in USG treated plots than that of PU. This might be due to higher and continuous availability of N and better growth of the crop, higher dry matter weight, N content and minimum volatilization loss of N due to deep placement of USG that have lead to higher N harvest and greater fertilizer-N recovery than that of PU (Khalil *et al.*, 2006). The possible reason for higher uptake is that as USG placed at deeper zone the limited number of nitrifying bacteria present at the premise of the USG and converts a limited portion of urea to NO_3^{-1} and takes more time to convert whole USG as compared to PU which may be utilized by the plant throughout the whole growing period.

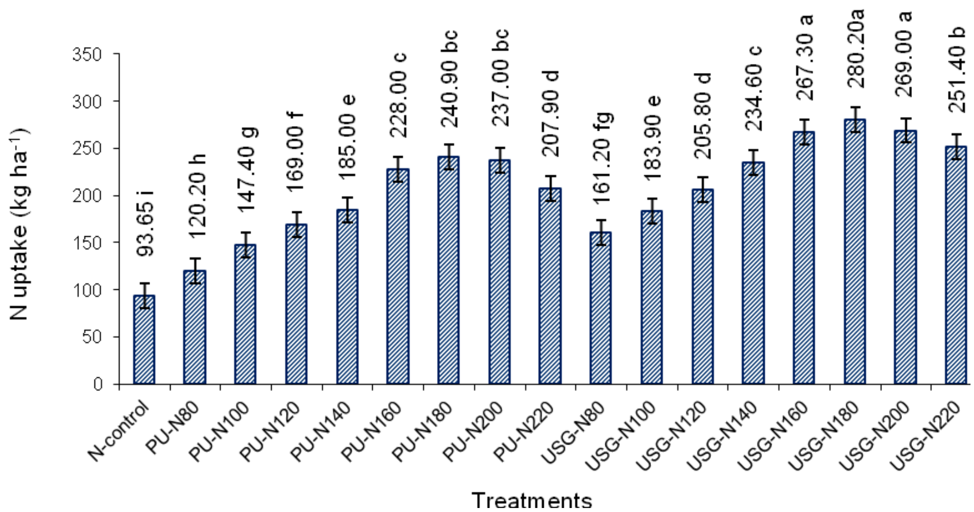

Figure 1. Effect of different levels of USG and PU on N uptake by the broccoli plant. Vertical bars showed standard error.

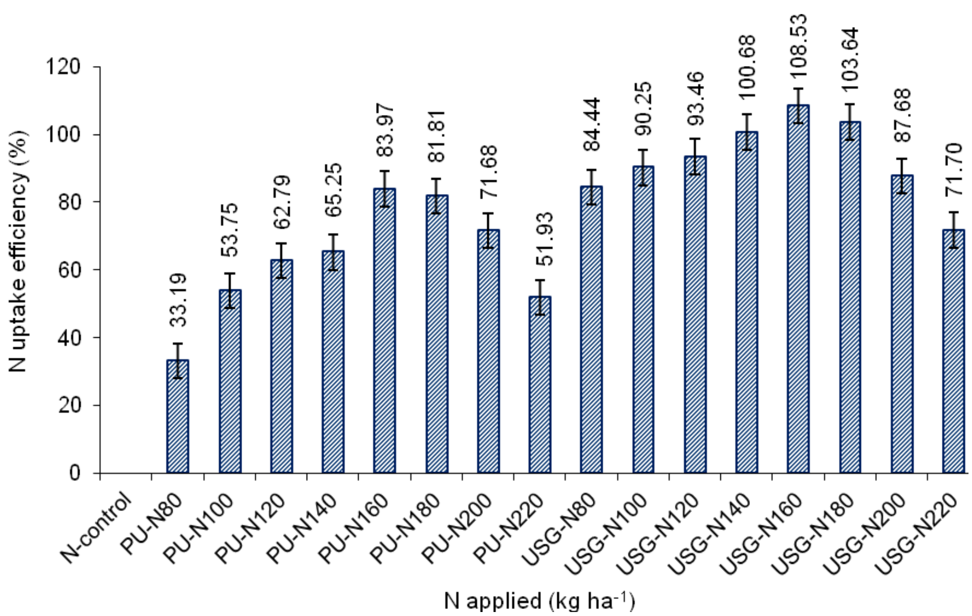

Figure 2. Effect of different levels of USG and PU on N uptake efficiency of broccoli plant. Vertical bars showed standard error.

Mukherjee (1986) explained this phenomenon as the USG with deep placement provided a zone of concentrated urea solution where the denitrifying bacteria cannot enter and therefore N is left at the root zone for uptake by the plants. This result is in agreement with Khalil *et al*. (2011) who reported that deeper placements of USGs (5.0–7.5 cm) resulted in greater fertilizer-N recovery in the crop (70.5–78.0%) compared to the use of prills (56.6%). They strongly suggested that the proper application of USGs can increase yields and fertilizer-N utilization of wheat and simultaneously decrease N losses compared to equivalent use of prills, and therefore presents important agronomic advantages.

3.2.2. Nitrogen uptake efficiency

From Fig. 2, it was found that the N uptake efficiency was increased (up to 83.969% and 108.531%) with increasing levels of N up to the treatment PU-N_{160} and USG-N_{160} and then it was decreased. Rashid *et al. (*1996) reported that USG N was more efficiently used than that of PU and they stated that deep placement of USG is an effective means of increasing N use efficiency of rice as compared to the traditional split application of PU. Zebarth *et al*. (1995) also stated that apparent fertilizer-N recovery in the aboveground portion of the plant decreased linearly from between 46 and 93% at a N rate of 125 kg ha^{-1} N to between 20 and 4% at an N rate of 625 kg ha^{-1}. Moreover, apparent fertilizer-N recovery in the harvested portion of the plant decreased linearly from between 14 and 25% at an N rate of 125 kg ha^{-1} to between 8 and 14% at an N rate of 625 kg ha^{-1}. Most studies have shown that the N use efficiency (NUE) of broccoli decreased with increasing amount of N application (Zebarth *et al.*, 1995; Tremblay and Beaudet, 2006 and Khalil *et al.* 2011).

3.2.3. Phosphorus uptake by the crop

Phosphorus uptake (24.678 kg and 28.255 kg P ha^{-1}) was increased significantly with increasing levels of urea N up to the treatment PU-N_{180} and USG-N_{180} and then decreased with a curviliniar fashion (Fig. 3). Overall, higher P uptake was found from USG treated plots as compare to that of PU. This is due to continuous supply, higher P use efficiency and greater fertilizer-P recovery in case of USG than that of PU. Fatemeh and Ahmad (2012) reported that the P, K, and concentrations in broccoli head were significantly increased by N treatments and reached maximum at 300 kg N ha-1 dose which is in agreement with this study. As the N conversion to nitrate in soil and nitrate absorption by roots makes negative charge in root cells and the plants for equilibrium charge in cells proceed to the cation absorption. Therefore, absorption of K and P is increased by the plant (Uygur and Rimmer, 2000 and Moniruzzaman *et al*., 2007). The results were similar to Yoldas *et al.* (2008) in broccoli and Abdelrazzag (2002) and Magnusson (2002) on several vegetable crops. Edson *et al*. (2012) also reported that P-TSP recovery by corn increased with N increasing rates.

3.2.4. K uptake by the crop

Potassium uptake (214.4 kg and 227.40 kg K ha^{-1}) was increased significantly with increasing levels of N up to 180 kg both for PU and USG and then it decreased in a curvilinear fashion (Fig. 4). The higher uptake was found from USG treated plots than that of PU. This is might be due to the synergistic effect of K with N which might help continuous supply, higher K uptake efficiency and greater fertilizer-K recovery in case of USG than that of PU. Yoldas *et al.* (2008) reported that application of N increased N, P, K and Fe concentrations in broccoli head. They revealed the highest concentrations of N and K in broccoli head under the application of N at 450 kg ha^{-1}. Abdelrazzag (2002) and Magnusson (2002) obtained similar results on several vegetable crops. The similar reason as stated earlier in P uptake is applicable for absorption of more K by the plant according to Uygur and Rimmer (2000) and Moniruzzaman *et al*. (2007).

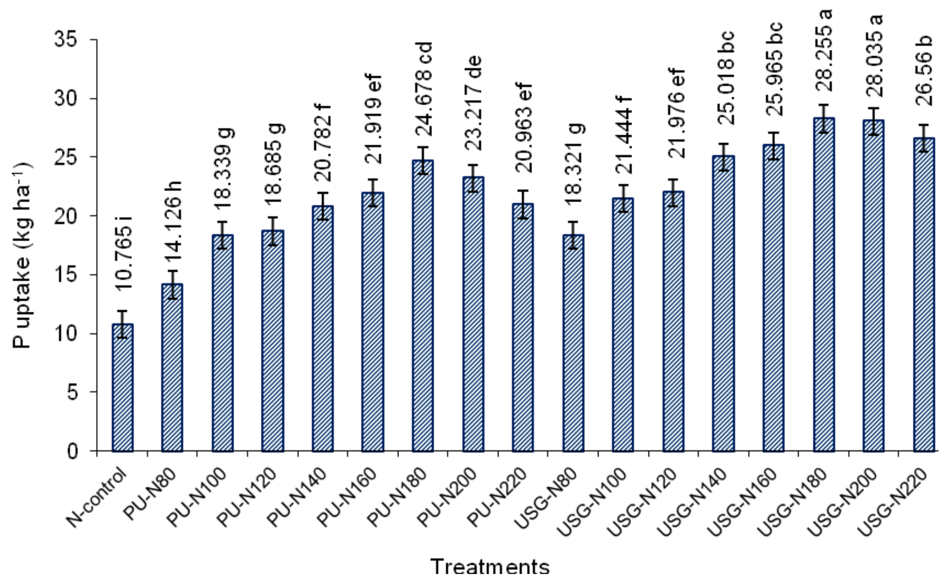

Figure 3. Effect of different levels of USG and PU on the P uptake of broccoli. Vertical bars showed standard error.

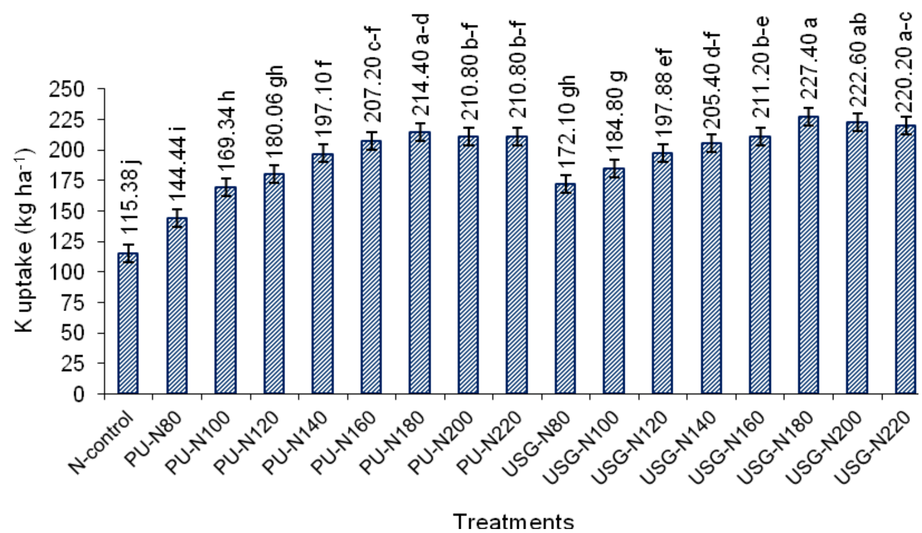

Figure 4. Effect of different levels of USG and PU on the K uptake of broccoli. Vertical bars showed standard error.

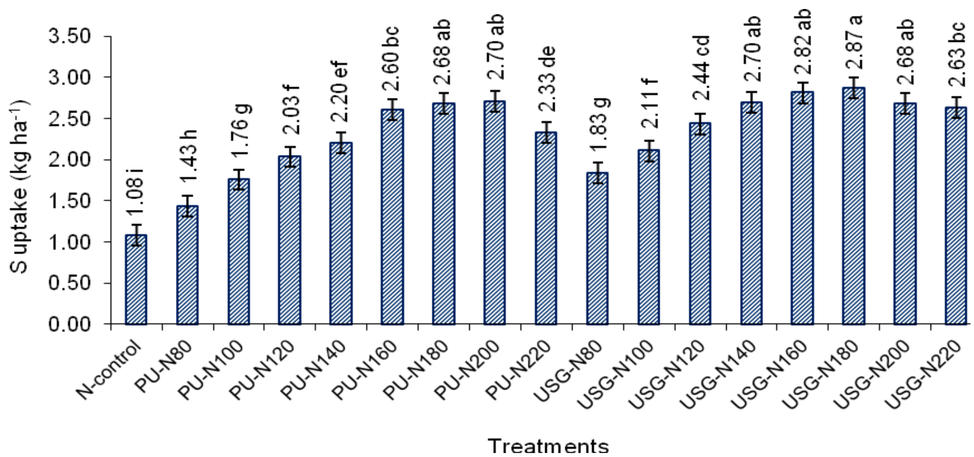

Figure 5. Effect of different levels of USG and PU on the S uptake of broccoli. Vertical bars showed standard error.

3.2.5. S uptake by the crop

Sulphur uptake was increased significantly with increasing levels of N up to 180 kg both for PU (2.684 kg S ha^{-1}) and USG (2.871 kg S ha^{-1}) and then it decreased in a curvilinear fashion (Fig. 5). The higher uptake was found from USG treated plots as compared to that of PU. This is due to continuous supply of N, which induces higher growth which in turns the plant taken up more S as well as higher S use efficiency and greater fertilizer-S recovery in case of USG than that of PU. Abd el-All and EL-Shabrawy (2013) reported that increasing levels of nitrogen application significantly increased total N, P and S contents in broccoli and the highest values were obtained by fertilization broccoli plant with 80kg N/fed. Aires *et al*. (2007) found that N fertilization significantly influenced the uptake of N, S, K, Ca, Mg, Na, Cl and silicon of broccoli sprouts which is in agreement with the present study.

3.3. Effects on post-harvest soil nutrient status

3.3.1. Total soil N content

Total N content of post-harvest soil showed a significant variation among the treatments (Table 3). The highest total N (0.107 %) was obtained from USG-N$_{220}$ followed by USG-N$_{200}$ which was statistically identical with USG-N$_{100}$, USG-N$_{120}$, USG-N$_{140}$, USG-N$_{160}$, USG-N$_{180}$, PU-N$_{180}$ and the control. The lowest N content was found from PU-N$_{200}$ and PU-N$_{220}$. These lower soil N contents might be due to the consequence of higher uptake rate of N by the crop as the supply was not adequate according to demand. However, deep placement of USG limits the volatilization loss, which results higher residual soil N content where N supply was also sufficient for crop requirement. Averaarts and de Willigen (1999) reported that the amount of mineral N in the soil at harvest generally increased with increasing amounts of N applied.

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3.3.2. Available soil P content

Post harvest soil P was significantly influenced by different treatments (Table 3) and the highest available soil P (17.38 µg g^{-1}) was recorded from control followed by 80 kg N for both PU and USG (17.25 µg g^{-1}) which was statistically identical with PU-N$_{100}$ and USG-N$_{100}$. It was observed that residual soil P content was decreased with increasing rate of N application and the minimum P content (13.89 µg g^{-1}) was found from PU-N$_{200}$ followed by USG-N$_{180}$ (13.93 µg g^{-1}). Yoldas *et al*. (2008) reported that application of nitrogen increased N, P, K and Fe concentrations in broccoli head. Utilization of fertilizer P is generally enhanced by the application of N (William, 1958). Therefore, reduction of P in soil in higher N levels might be due to the consequence of higher P uptake with higher crop growth induced by higher rate of N application. Aydin *et al*. (2008) reported that increasing levels of N negatively correlated with plant P and positively correlated with Ca, Fe, and Zn which is somehow differ from our result. In support in my results root architecture plays an important role in maximizing P acquisition because root systems with higher surface area are able to explore a given volume of soil more effectively (Lynch, 1995). Root architecture that distributes more roots to the place where P resources are located plays an important role in efficiently exploiting these P resources (Jianbo *et al*., 2011). Localized application of phosphates plus ammonium significantly enhances P uptake and crop growth through stimulating root proliferation and rhizosphere acidification in a calcareous soil (Jing *et al*., 2010). The chemical and biological processes in the rhizosphere not only determine mobilization and acquisition of soil nutrients as well as microbial dynamics, but also control nutrient-use efficiency of crops, and thus profoundly influence crop productivity (Richardson *et al*., 2009 and Zhang *et al*., 2010). Soluble P in the rhizosphere soil solution should be replaced 20 to 50 times per day by P delivery from bulk soil to the rhizosphere to meet plant demand (Marschner, 1995). Therefore, P dynamics in the rhizosphere are mainly controlled by plant root growth and function, and also highly related to physical and chemical properties of soil (Neumann and Römheld, 2002).

Table 3. Effect of different levels of USG and PU on the post harvest soil nutrient status of broccoli plot

Treatment	Soil total N (%)	Available soil P (μg g^{-1})	Exchangeable soil K (me/100g)	Soil available S (μg g^{-1})	Soil available B (μg g^{-1})
N-control	0.092 a-c	17.38 a	0.379 a	19.85 a	0.332 a
PU-N_{80}	0.086 bc	17.25 a	0.352 bc	17.02 b	0.311 a
PU-N_{100}	0.101 ab	16.91 ab	0.358 bc	16.07 c	0.311 a
PU-N_{120}	0.103 ab	16.12 c	0.347 c	15.29 d	0.291 ab
PU-N_{140}	0.092 a-c	16.00 c	0.347 c	14.34 e	0.291 ab
PU-N_{160}	0.098 a-c	14.98 d	0.326 d	14.34 e	0.252 bc
PU-N_{180}	0.098 a-c	14.19 ef	0.326 d	12.29 f	0.249 b-d
PU-N_{200}	0.081 c	13.89 f	0.316 d	10.40 h	0.249 b-d
PU-N_{220}	0.081 c	14.41 d-f	0.358 bc	12.29 f	0.226 cd
USG-N_{80}	0.084 bc	17.25 a	0.384 a	14.18 e	0.260 bc
USG-N_{100}	0.089 a-c	16.97 a	0.368 ab	11.34 g	0.260 bc
USG-N_{120}	0.089 a-c	16.29 bc	0.347 c	10.40 h	0.256 bc
USG-N_{140}	0.092 a-c	15.69 c	0.347 c	9.45 i	0.249 b-d
USG-N_{160}	0.092 a-c	14.63 de	0.326 d	8.77 j	0.249 b-d
USG-N_{180}	0.104 ab	13.93 ef	0.326 d	8.35 j	0.249 b-d
USG-N_{200}	0.106 a	13.96 ef	0.358 bc	8.77 j	0.209 cd
USG-N_{220}	0.107 a	14.64 de	0.358 bc	8.77 j	0.197 d
CV(%)	5.01	1.42	2.65	2.12	8.64
SE (±0.05)	0.00577	0.22033	0.00577	0.20016	0.01534

Means followed by uncommon letters are statistically different from each other at 5% level of probability by DMRT

3.3.3. Exchangeable soil K content

The different forms and levels of N fertilizer significantly influenced the exchangeable soil K of post harvest soil (Table 3). The highest exchangeable soil K (0.384 me/100g soil) was found from the treatment USG-N_{80} which was statistically identical with control (0.379 me/100g soil) and USG-N_{100} treatment. The lowest K content (0.316 (me/100g soil) was recorded from the treatment PU-N_{200} that might be due to higher K uptake with higher crop growth as induced by higher rate of N application. Crops respond to higher K levels when N is sufficient, and greater yield response to N fertilizer occurs when K is sufficient (http://www.ipni.net/publication/bettercrops, 1998). So, at higher N levels crop growth will be higher and K uptake also higher as result lower soil K content was reflected.

3.3.4. Soil available S content

In case of post harvest soil a significant variation was observed among the treatments (Table 3). Accordingly, the highest S content (19.85 µg g^{-1}) was recorded from control, which was statistically higher than all other treatment combinations. A decreasing trend was observed in S content with the increasing rates of N application and lower S content was found in USG treated plots as compared to that of PU. It might be due to higher S uptake by the plant with higher crop growth favored by sufficient supply of N. The minimum S content (8.35 µg g^{-1}) was estimated from the treatment USG-N_{180}, which was statistically similar to USG-N_{160}, USG-N_{200} and USG-N_{220} treatments. This indicated that higher N rate induced higher crop growth and consequently higher S uptake which reduced the soil S content as well.

3.3.5. Soil B content

The post harvest soil B content showed a significant difference among the treatments. (Table 3). It was observed that post harvest soil B content was decreased with increasing rate of N. The maximum soil B content (0.332 µg g^{-1}) was found in control, which was statically identical with PU-N_{80}, PU-N_{100}, PU-N_{120}, and PU-N_{140} and the lowest (0.197 µg g^{-1}) was found from USG-N_{220} treated plot. As B is an intermediate mobile element and it was applied in the soil it's uptake was also restricted. Its uptake is defends on the crop growth and higher uptake will be for higher crop growth accelerated by the higher rate of N. Consequently, B content was higher in the soil where lower doses of N used.

4. Conclusions

According to the experimental outcome generated from the above mentioned experiment it was concluded that compactness coefficient, beta-carotene, Chlorophyll-a and Chlorophyll-b content were significantly increased with increasing levels of nitrogenous fertilizer, and USG performed better than that of PU for all the quality attributes but ascorbic acid content was slightly decreased with increasing rate of USG and PU. The USG showed better compactness coefficient (18.24 to 18.61), β-carotene (0.401 mg $100g^{-1}$ FW) and chlorophyll contents (chlorophyll-a: 0.814 to 0.818 mg $100g^{-1}$ FW and chlorophyll-b: 1.122 to 1.141 mg $100g^{-1}$ FW). Plant nutrient status was also higher in higher doses of N as well as USG and it was higher than PU but N uptake efficiency was decreased with increasing rates of N fertilizer. The higher nutrient (NPKS) uptake and N uptake efficiency (maximum 108.53 %) was found in USG treated plots over PU. Post harvest soil nutrient status was increased with increasing rates of N as well as USG which was also higher than PU. From this study it was found that the treatment USG-N_{160} followed by USG-N_{140} and USG-N_{180} and the treatment PU-N_{180} with other recommended doses of fertilizer performed better those could be suggested as a good treatment combinations for broccoli production in terms of yield, quality and nutrient status in Shallow Red-Brown Terrace Soil under Madhupur Tract (AEZ-28).

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