ISSN 0258-7122 (Print), 2408-8293 (Online)
Bangladesh J. Agril. Res. 49(4): 325-348, December 2024

USG AND PRILLED UREA BASED FERTILIZER PERFORMANCE: A COMPARATIVE STUDY FOR BROCCOLI PRODUCTION

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Abstract

The experiments were conducted at the Horticulture Research Centre (HRC), Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur and RARS, Akbarpur, Moulvibazar during 2013-14 and 2014-15 to evaluate the comparative performance of different Urea Super Granule (USG) and prilled urea (PU) doses on broccoli and to select the suitable fertilizer package(s) for broccoli production. The experiment was laid out in a Randomized Complete Block Design with three replications. Eight treatments of different fertilizer doses were considered as: T_1= $N_{150}P_{50}K_{80}S_{30}Zn_5B_2Mo_1$ kg ha^{-1} (N as PU); T_2= $N_{150}P_{50}K_{80}S_{30}Zn_5B_2Mo_1$ kg ha^{-1} (N as USG); T_3= $N_{180}P_{53}K_{83}S_{20}Zn_2B_1Mo_{0.8}$ kg ha^{-1} (N as PU); T_4= $N_{146}P_{22}K_{62}S_{20}Zn_2B_1M_{0.8}$ kg ha^{-1} + 3 t ha^{-1} PM (Poultry manure) (N as PU); T_5= $N_{126}P_{22}K_{62}S_{20}Zn_2B_1M_{0.8}$ kg ha^{-1} + 3 ton PM (N as USG); T_6= $N_{138}P_{46}K_{58}S_{20}Zn_2B_1M_{0.8}$ kg ha^{-1} + 5 t ha^{-1} CD (Cowdung) (N as USG); T_7= $N_{116}P_{22}K_{20}S_{10}Zn_{1.6}B_1Mo_{0.8}$ kg ha^{-1} for Joydebpur, Gazipur ((N as PU) (Soil test based) and $N_{110}P_{33}K_{23}S_{15}Zn_{1.6}B_1Mo_{0.8}$ kg ha^{-1} for Akbarpur, Moulvibazar (N as PU) (Soil test based) and T_8= Control (native nutrient). Among the treatments, T_5 showed the highest marketable yield (15.91-15.93 t ha^{-1} and 12.64-15.25 t ha^{-1} for Joydebpur and Akbarpur, respectively) followed by T_3 (13.63-15.04 t ha^{-1} and 10.35-14.55 t ha^{-1} for Joydebpur and Akbarpur, respectively). The treatment T_5 gave the maximum benefit-cost ratio (BCR) (4.40-4.25 and 3.50-4.02) followed by T_3 (BCR 3.91- 4.12 and 2.97-3.93 for Joydebpur and Akbarpur, respectively). Among the treatments, 126-22-62-20-2-1-0.8 kg ha^{-1} of N-P-K-S-Zn-B-Mo along with 3 t ha^{-1} PM (N as USG) and 180-53-83-20-2-1-0.8 kg ha^{-1} of N-P-K-S-Zn-B-Mo without organic manure (N as PU) were found effective fertilizer packages for sustainable broccoli production for these areas.

Keywords: Broccoli, Urea Super Granule, Prilled Urea, Yield, BCR.

Introduction

Broccoli (*Brassica oleracea* L. var. *italica*) is one of the most important members of cole crops belonging to the family Brassicaceae and is mainly grown as cool season vegetable crop. Broccoli is an attractive and important vitamin rich winter vegetable. It is fairly rich in carotene and ascorbic acid and contains appreciable quantities of thiamin, riboflavin, niacin and iron (Manríquez-Zúñiga *et al.*, 2023). It is well known for its excellent health benefits and is a source of diverse nutrients (e.g., vitamins, minerals, and dietary fiber) and phytochemicals (e.g., glucosinolates and phenolic compounds) (Montaner *et al.*, 2023). It contains a

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higher rate of antioxidant Sulforaphane that prevents bacteria *Helicobacter pylori* which is responsible for stomach cancer (Dos Reis *et al.*, 2015). In the recent years, broccoli have gained extra attention for its bioactive compounds and their derivative products (Montaner *et al.*, 2023).

Farmers in Bangladesh are very much interested in cultivating broccoli for its high value. Application of balanced fertilizers is essential to produce high-quality vegetables, including broccoli, and for achieving maximum returns (Ahirwar and Nath, 2020). Winter climate and soil of Bangladesh are suitable for the luxuriant growth of broccoli. However, the yield of broccoli in Bangladesh is poor compared to other countries (Hossain and Islam, 2024). Most farmers in Bangladesh are not much aware of the benefits of balanced fertilizers, and they produce different vegetables without application of proper doses of fertilizers. For higher yields, generally, farmers use only chemical fertilizers indiscriminately without organic manure. The irresponsible use of fertilizers can lead to deterioration of soil health and reduce yield, product quality and shelf life (Mal *et al.*, 2014). Only chemical fertilizers may accelerate the crop yield initially, but they eventually have adverse effects (Gupta *et al.*, 2019). Organic manure and chemical fertilizer can meet up the demand for plant nutrients in maintaining quality attributes and improving the physical, chemical and biological properties of soil (Hammad *et al.*, 2019). The mineral fertilizers (N, P and K) increases vegetative growth, yield, and quality of broccoli (Hussain *et al.*, 2017). The use of chemical fertilizers affects soil structure. Organic manures can be an alternative to synthetic fertilizers (Hossain *et al.*, 2020). Locally produced manures like cow dung and poultry manure for vegetable production can increase crop yields with less amount of chemical fertilizer. Consumers who demand higher quality and safe foods are highly interested in organic products.

Although broccoli is cultivated in a limited area, its popularity is increasing day by day. High yielding and high-quality broccoli production require careful nutrient management. Broccoli is highly dependent on N fertilization to achieve a good yield (Hussain *et al.*, 2020). The total yield of broccoli is greatly influenced by different doses of nitrogenous fertilizer (Belec *et al.*, 2001). Urea super granule (USG) has some advantages to check the different losses of N by using judicious application methods and farmers are already applying it profitably in different upland vegetables and fruit crops such as brinjal, cabbage, cauliflower, banana etc. (Hussain *et al.*, 2021). Besides this, organic manure plays an important role in quality production of broccoli. It has already been developed some data base both in inorganic and IPNS based fertilizer recommendations and nutrient management packages on the yield and quality of broccoli in Bangladesh. The study regarding organic manure along with USG and Prilled Urea (PU) on broccoli has not been reported. The present investigation was, therefore, initiated to evaluate the comparative performance of different fertilizer management packages where N used as USG and PU on broccoli production and to find out the suitable fertilizer package for broccoli production.

Materials and Methods

An experiment was conducted with different doses of Urea Super Granule (USG) and Prilled Urea (PU) at Horticulture Research Centre (HRC), Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur and Regional Agricultural Research Station, BARI, Akbarpur, Moulvibazar, Bangladesh, during *rabi* season of 2013-2014 and 2014-2015. The experiment was laid out in a randomized complete block design with three replications. Eight different fertilizer packages were: T_1= $N_{150}P_{50}K_{80}S_{30}Zn_5B_2Mo_1$ (N as PU) as a check (Fertilizer recommendation developed and practiced by vegetable division, HRC, BARI); T_2= $N_{150}P_{50}K_{80}S_{30}Zn_5B_2Mo_1$ kg ha^{-1} (N as USG); T_3= $N_{180}P_{53}K_{83}S_{20}Zn_2B_1Mo_{0.8}$ kg ha^{-1} (N as PU); T_4= $N_{146}P_{22}K_{62}S_{20}Zn_2B_1M_{0.8}$ kg ha^{-1} + 3 t ha^{-1} PM (N as PU); T_5= $N_{126}P_{22}K_{62}S_{20}Zn_2B_1M_{0.8}$ kg ha^{-1} + 3 t ha^{-1} PM (N as USG); T_6= $N_{138}P_{46}K_{58}S_{20}Zn_2B_1M_{0.8}$ kg ha^{-1} + 5 t ha^{-1} CD (N as USG); T_7= N..P..K..S..Zn..B..Mo.. (N as PU) (Soil test-based fertilizer recommendation according to FRG' 2012) and T_8= Control (native nutrient). Soil test based fertilizer recommendation according to FRG'2012 (BARC, 2012) was calculated as $N_{116}P_{22}K_{20}S_{10}Zn_{1.6}B_1Mo_{0.8}$ kg ha^{-1} for Joydebpur, Gazipur and $N_{110}P_{33}K_{23}S_{15}Zn_{1.6}B_1Mo_{0.8}$ kg ha^{-1} for Akbarpur, Moulvibazar. The initial soil sample of the experimental field was collected and analyzed following standard laboratory methods. The soil of the experimental field of Joydebpur was Silty Clay Loam (sand, silt and clay 19.7, 42.4 and 37.9%, respectively) having a bulk density of 1.34 g cm^{-3} and the Akhbarpur soil was Sandy Clay Loam (sand, silt and clay 48.23, 18.3 and 33.47%, respectively) having a bulk density of 1.32 g cm^{-3}. The soil of the RARS, Akbarpur is acidic as it is categorized as tea soil with specific limitations for nutrient deficiency for crop growth and performance (Duncan *et al.*, 1991). The initial soil properties of the experimental plot and nutrient content of cowdung and poultry manure are presented in Table 1 and 2.

As the experimental soils of Akbarpur, Moulvibazar was highly acidic in nature it was treated with Dolomite lime @1.0 t ha^{-1} at 15 days earlier transplanting to bring the pH at an optimum level. Twenty five-day old healthy broccoli (cv. *Premium crop*) seedlings were transplanted in the experimental plot on 15 and 25 November 2013 in Joydebpur, Gazipur and Akbarpur, Moulvibazar, repectively in the year 2013-14 and on 20 and 24 November 2014 Joydebpur and Akbarpur, respectively in the year 2014-15. The unit plot size was 2.7 m × 2.4 m and spacing was 60 cm × 45 cm.

The entire amount of cow dung and poultry manure was applied in the soil one week prior to transplanting. All other fertilizers with 50% MoP except PU and USG were applied as broadcast and incorporated into soil during final land preparation. PU was top-dressed in two equal splits at 15 and 35 days after transplanting (DAT) as ring method around the plant base properly mixing with the soil. USG was placed at 7 cm below the surface, 10 cm apart from plant base and the rest 50% MoP was top-dressed at 15 DAT followed by irrigation.

Table 1. Initial soil nutrient status of the experimental sites

Location	pH	OM %	Ca	Mg	K	Total N%	P	S	Zn	B	Fe	Mn	Cu
			meq 100 g^{-1}				µg g^{-1}						
Moulvibazar													
Nutrient status	5.1	0.60	2.3	2.6	0.16	0.08	6.5	12	1.8	0.23	87	8.3	4.54
Critical level	-	-	2.0	0.50	0.12	0.12	7	10	0.6	0.20	4.0	1.0	0.2
Interpretation			L	VH	L	VL	L	L	Opt	L	VH	VH	VH
Joydebpur													
Nutrient status	6.2	0.99	2.57	2.6	0.18	0.06	13	17.67	1.7	0.22	79.7	10.7	4.30
Critical level	-	-	2.0	0.50	0.12	0.12	7	10	0.6	0.20	4.0	1.0	0.2
Interpretation			Opt	VH	L	VL	Med	Med	Med	L	VH	VH	VH

L = low, VL = very low, Opt = optimum, VH = very high, Med = medium

Table 2. Nutrient contents of cowdung (CD) and poultry manure (PM)

Materials	Moisture %	pH	OM %	N	P	K	Ca	Mg	S	Mn	Zn	B
				%						µg g^{-1}		
CD	40.65	6.85	8.32	0.95	0.86	0.65	0.95	0.33	0.30	0.89	0.58	0.013
PM	52.79	7.42	20.1	1.47	1.61	1.06	7.1	2.13	0.67	0.92	0.34	0.011

Hosepipe irrigations were applied till plant establishment and then ridge and furrow irrigation was given in every 7 days interval. Intercultural operations such as weeding, earthing-up etc were done as and when necessary. The crop was first harvested on 13th and 27th January 2014 at Joydebpur, and Akbarpur, respectively for 1st year and on 27th January and 2nd February 2015 for Joydebpur and Akbarpur, respectively for 2nd year. The crop harvesting was continued upto 10 days. Data on yield and yield contributing characters *viz*. plant height, no. of leaves per plant, head length and diameter, compactness coefficient, SPAD value, marketable yield (terminal head) and lateral head yield were recorded. The nutrient uptake from the soil was also measured using the following formula:

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

Here,

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

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

$$\text{Nutrient uptake (kg ha}^{-1}) = \frac{\text{Nutrient (ppm)} \times Y\ (\text{kg ha}^{-1})}{100 \times 10000}$$

Here,

Nutrient (ppm) = Average nutrient content (ppm or μg g^{-1}) of plant or head biomass

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

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. According to Craswell and Godwin (1984) the uptake efficiency of applied fertilizer N may be quantified with the following equation:

Nitrogen uptake efficiency (NUE) = ((N uptake F – N uptake C)/Fertilizer N applied) × 100

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

Dry matter partitioning, nutrient uptake and nutrient uptake efficiency were calculated only for the location Joydebpur.

Statistical analysis

The ANOVA was performed on yield attributes, yield and nutrient uptake data. When F was significant at the $p \leq 0.05$ level, the means were compared by DMRT at 5% level.

Results and discussion

The yield attributes were significantly influenced by the treatment for both the locations and years.

Plant height and number of leaves per plant

In 2013-14, the highest plant height (72.6 and 62.5 cm for Joydebpur and Akbarpur, respectively) was found in T_3 and T_5 for Joydebpur and Akbarpur, respectively, which were identical to all except the control. In 2014-15, the highest plant height (70.3 and 60.2 cm for Joydebpur and Akbarpur, respectively) was found in T_2 and T_5, respectively. The lowest plant height (44.6 cm) was noted in the control at Akbarpur (Table 3.1). The number of leaves was significantly influenced by the treatment (Table 3.1). In 2013-14, the maximum leaves (12.7) were found in T_5, which was identical to T_2 and T_3 but higher than the other treatments. In 2014-15, T_5 also showed the maximum leaves (15.7) followed by T_3 and T_4. The minimum leaves (8.53) were observed in the control both the years (Table 3.1). Plant height and number of the leaves are major indicator for plant growth and vigour. The better vegetative growth and vigor tends to higher yield and productivity (Hussain *et al.*, 2020; Hossain and Islam, 2024). Hence, the variable response was observed for these traits with the application of the treatment packages for N sources. This may be due to the availability of nutrients to the plants mainly N to be up taken readily and also enhancement of the soils moisture holding capacity with the application of organic and inorganic sources of N (Roe and Cornforth, 2000).

Days to 1st and 50% head initiation

In 2013-14, days to first head initiation was significantly influenced by the different fertilizer packages. The maximum days required to first head initiation was recorded in T_8 followed by T_2 and T_6 in Joydebpur and T_3 and T_6 at Akbarpur, respectively. It might be due to insufficient vegetative growth in the control plot (Table 3.2). In 2014-15, days to first head initiation showed the same trend. The maximum days required to first head initiation (45.33 days) was recorded in T_8 followed by T_3 at Joydebpur and it was also highest in T_8 at Akbarpur. It might be due to insufficient vegetative growth caused by nutritional deficiency in the control plot while higher vegetative growth in T_2 and T_3 treatments associated with sufficient nutrient supply (Table 3.2). In 2013-14, the control showed the highest 52.3 days at Joydebpur while T_3 and T_8 (control) showed the maximum days (46.5 days) to 50% head initiation at Akbarpur. The similar trend was followed in the second year (Table 3.2).

Table 3.1. Effect of fertilizer on yield attributes and yield of broccoli at Joydebpur and Akbarpur

Treatment	Plant height (cm)				Leaves plant^{-1} (No.)			
	Joydebpur		Akbarpur		Joydebpur		Akbarpur	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
T_1	70.9 a	66.3a	56.7 bc	56.9ab	11.8	12.47	11.27 c	13.57bc
T_2	69.7 a	70.3a	55.8bc	56.08b	11.9	12.80	12.07 ac	13.67bc
T_3	72.6 a	67.1a	54.3 c	54.63b	12.2	13.53	12.53 ab	15.67a
T_4	69.7 a	68.1a	60.1ab	57.63ab	11.5	12.53	11.73 bc	15.33ab
T_5	72.1 a	68.3a	62.5 a	60.18a	12.4	13.80	12.73 a	15.67a
T_6	70.5 a	65.7a	55.2 bc	55.80b	11.7	12.53	11.70 bc	13.33c
T_7	67.4 a	65.7a	59.67 ab	57.52ab	11.27	12.33	11.47 c	13.67bc
T_8	52.53 b	57.33b	46.67 d	44.65c	11.60	12.07	8.533 d	10.30d
LSD (0.05)	5.145	5.93	4.873	3.47	ns	ns	0.9116	6.92
CV (%)	4.31	6.867	4.94	3.364	8.99	1.296	4.52	1.683

Means followed by common letters are not significantly different by DMRT at 5% level of significance

T_1= $N_{150}P_{50}K_{80}S_{30}Zn_5B_2Mo_1$ kg ha^{-1} (N as PU); T_2= $N_{150}P_{50}K_{80}S_{30}Zn_5B_2Mo_1$ kg ha^{-1} (N as USG); T_3= $N_{180}P_{53}K_{83}S_{20}Zn_2B_1Mo_{0.8}$ kg ha^{-1} (N as PU); T_4= $N_{146}P_{22}K_{62}S_{20}Zn_2B_1M_{0.8}$ kg ha^{-1} +3 t ha^{-1} PM (Poultry manure) (N as PU); T_5= $N_{126}P_{22}K_{62}S_{20}Zn_2B_1M_{0.8}$ + 3 ton PM (N as USG); T_6= $N_{138}P_{46}K_{58}S_{20}Zn_2B_1M_{0.8}$+ 5 t ha^{-1} CD (Cowdung) (N as USG); T_7= $N_{116}P_{22}K_{20}S_{10}Zn_{1.6}B_1Mo_{0.8}$ kg ha^{-1} for Joydebpur, Gazipur ((N as PU) (Soil test based) and $N_{110}P_{33}K_{23}S_{15}Zn_{1.6}B_1Mo_{0.8}$ kg ha^{-1} for Akbarpur, Moulvibazar (N as PU) (Soil test based) and T_8= Control (native nutrient).

Table 3.2. Effect of fertilizer on yield and yield attributes of broccoli at Joydebpur and Akbarpur

Treatment	Days to 1st head initiation				Days to 50% head initiation			
	Joydebpur		Akbarpur		Joydebpur		Akbarpur	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
T_1	45.0 bc	43.7	39.2 ab	37.3bd	49.0 ac	47.3	44.7 a	43.3bd
T_2	47.0 ab	44.3	35.7 c	40.3ab	51.0 ab	48.0	40.7 b	45.0ab
T_3	43.7 bc	44.3	41.7 a	39.7ac	47.7 bc	48.3	46.5 a	44.7ac
T_4	43.0 c	44.3	37.0 bc	36.3d	47.0 c	47.7	44.0 a	40.7d
T_5	45.0 bc	44.0	39.7 ab	37.3cd	49.3 ac	47.7	43.7 a	41.7cd
T_6	46.7 ac	43.0	39.9 ab	37.7bd	51.0 ab	47.7	45.7 a	42.0bd
T_7	44.7 bc	43.7	38.7 ac	36.7cd	49.0 bc	47.3	44.0 a	41.7cd
T_8	49.0 a	45.3	41.3 a	41.0a	52.3 a	49.0	46.5 a	46.7a
LSD (0.05)	3.479	ns	3.026	3.89	3.030	ns	2.897	3.96
CV (%)	4.37	1.981	4.41	1.321	3.49	2.026	3.72	2.994

Means followed by common letters are not significantly different by DMRT at 5% level of significance

T_1= $N_{150}P_{50}K_{80}S_{30}Zn_5B_2Mo_1$ kg ha^{-1} (N as PU); T_2= $N_{150}P_{50}K_{80}S_{30}Zn_5B_2Mo_1$ kg ha^{-1} (N as USG); T_3= $N_{180}P_{53}K_{83}S_{20}Zn_2B_1Mo_{0.8}$ kg ha^{-1} (N as PU); T_4= $N_{146}P_{22}K_{62}S_{20}Zn_2B_1M_{0.8}$ kg ha^{-1} +3 t ha^{-1} PM (Poultry manure) (N as PU); T_5= $N_{126}P_{22}K_{62}S_{20}Zn_2B_1M_{0.8}$ + 3 ton PM (N as USG); T_6= $N_{138}P_{46}K_{58}S_{20}Zn_2B_1M_{0.8}$+ 5 t ha^{-1} CD (Cowdung) (N as USG); T_7= $N_{116}P_{22}K_{20}S_{10}Zn_{1.6}B_1Mo_{0.8}$ kg ha^{-1} for Joydebpur, Gazipur ((N as PU) (Soil test based) and $N_{110}P_{33}K_{23}S_{15}Zn_{1.6}B_1Mo_{0.8}$ kg ha^{-1} for Akbarpur, Moulvibazar (N as PU) (Soil test based) and T_8= Control (native nutrient).

Again, the days to first head initiation and the days to 50% head initiation also showed distinct response according to the applied treatments for both of the location and both of the years. Application of inorganic N fertilizers encourages vegetative growth and resulted in delayed head initiation in Broccoli. But combination of different sources of N (T_5) gave better responses due to the interactions of the nutrients and their sources of origin (Hussain *et al.*, 2021; Hossain and Islam, 2024).

Head yield

In 2013-14, the head weight was significantly influenced by the different fertilizer packages (Table 3.3). The highest head weight (429.7 and 341.3 g plant^{-1} for Joydebpur and Akbarpur, respectively) was found in T_5 followed by T_3 (368.0 and 279.3 g plant^{-1} for Joydebpur and Akbarpur, respectively) (Table 3.3). The minimum head weight (123.2 and 89.3 g plant^{-1} for Joydebpur and Akbarpur, respectively) was noted in the control (Table 3.3). Marketable head yield was also significantly varied among the treatments (Table 3.3). In Joydebpur, T_5 showed the highest marketable head yield (15.91 and 15.94 t ha^{-1} for 2013-14 and 2014-15, respectively) followed by T_3 (13.63 and 15.04 t ha^{-1} for 2013-14 and 2014-15, respectively). The lowest head yield (4.56 and 6.07 t ha^{-1} for 2013-14 and 2014-15, respectively) was recorded in the control (Table 3.3). Similar trend was followed in Akbarpur (Table 3.3).

Lateral head yield was studied only in Joydebpur and it was significantly influenced by the different fertilizer packages (Table 3.4). The highest lateral head weight (4.86 and 7.42 g plant^{-1} for the year 2013-14 and 2014-15, respectively) was found in T_5 followed by T_4 (4.58 and 6.87 g plant^{-1}) for the year 2013-14 and 2014-15, respectively) (Table 3.4). Considering lateral head yield total yield of broccoli was found highest in T_5 (20.77 t ha^{-1}) followed by T_3 (17.85 t ha^{-1}) for the year 2013-14 and similarly in T_5 (23.36 t ha^{-1}) followed by T_3 (21.66 t ha^{-1}) for the year 2014-15 and it was significantly higher than all other treatments. This higher yield in T_5 and T_3 might be due to continuous and prolonged supply of nutrients integrating with USG and poultry manure. More precisely for the yield trait, head yield and marketable head yield was revealed a remarkable treatment response and T_5 gave the highest yield followed by T_3 for both the locations and for both of the years (Table 3.3 and 3.4). If the plants get adequate nutrients in available forms, it enhances plant physiological activity and finally gives higher yield. Higher curd diameter and weight of curd in broccoli have strong relationships with the application of optimum doses organic and inorganic N (Varsha *et al.*, 2022). Hossain and Islam (2024) reported that application of cowdung at the rate 5.0 tha^{-1} and NPK (50 % of the recommendation) showed the optimum yield of broccoli, which are in agreement with the findings of our study.

Table 3.3. Effect of fertilizer on yield and yield attributes of broccoli at Joydebpur and Akbarpur

Treatment	Head weight (g plant^{-1})				Marketable head yield (t ha^{-1})			
	Joydebpur		Akbarpur		Joydebpur		Akbarpur	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
T_1	297.3 b	312.7c	240.3 b	299.9d	11.01 b	11.58c	8.90 b	11.00d
T_2	336.0 b	367.0b	254.3 b	302.1d	12.44 b	13.59b	9.42 b	13.88d
T_3	368.0 ab	406.0a	279.3 ab	388.8b	13.63 ab	15.04a	10.35 ab	14.40b
T_4	321.3 b	351.0bc	275.7 ab	393.0ab	12.52 b	13.00bc	10.21 ab	14.36ab
T_5	429.7 a	430.3a	341.3 a	411.7a	15.91 a	15.94a	12.64 a	15.25a
T_6	338.0 b	330.0bc	251.7 b	374.9c	11.90 b	12.22bc	9.32 b	11.33c
T_7	302.9 b	325.3c	211.3 b	305.9d	11.22 b	12.05c	7.83 b	11,18d
T_8	123.2 c	163.7d	89.3 c	100.0e	4.56 c	6.07d	3.31 c	5.71e
LSD (0.05)	70.37	37.95	67.38	18.37	2.606	1.406	2.496	0.676
CV (%)	12.77	6.22	15.84	2.98	12.77	6.22	15.84	2.96

Means followed by common letters are not significantly different by DMRT at 5% level of significance

T_1= $N_{150}P_{50}K_{80}S_{30}Zn_5B_2Mo_1$ kg ha^{-1} (N as PU); T_2= $N_{150}P_{50}K_{80}S_{30}Zn_5B_2Mo_1$ kg ha^{-1} (N as USG); T_3= $N_{180}P_{53}K_{83}S_{20}Zn_2B_1Mo_{0.8}$ kg ha^{-1} (N as PU); T_4= $N_{146}P_{22}K_{62}S_{20}Zn_2B_1M_{0.8}$ kg ha^{-1} +3 t ha^{-1} PM (Poultry manure) (N as PU); T_5= $N_{126}P_{22}K_{62}S_{20}Zn_2B_1M_{0.8}$ + 3 ton PM (N as USG); T_6= $N_{138}P_{46}K_{58}S_{20}Zn_2B_1M_{0.8}$+ 5 t ha^{-1} CD (Cowdung) (N as USG); T_7= $N_{116}P_{22}K_{20}S_{10}Zn_{1.6}B_1Mo_{0.8}$ kg ha^{-1} for Joydebpur, Gazipur ((N as PU) (Soil test based) and $N_{110}P_{33}K_{23}S_{15}Zn_{1.6}B_1Mo_{0.8}$ kg ha^{-1} for Akbarpur, Moulvibazar (N as PU) (Soil test based) and T_8= Control (native nutrient)

Table 3.4. Effect of fertilizer on yield and yield attributes of broccoli at Joydebpur and Akbarpur

Treatment	Lateral head yield (t ha^{-1})		Total yield (t ha^{-1}) (Marketable head +Lateral head)		Head length (cm)			
	Joydebpur		Joydebpur		Joydebpur		Akbarpur	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
T_1	2.51 d	3.93 d	13.52 d	15.51d	12.86	12.87	13.47 a	13.10b
T_2	3.16 bd	4.96 c	15.60 bd	18.55c	11.29	12.93	11.93 a	13.17b
T_3	4.22 ac	6.62 ab	17.85 b	21.66b	14.19	13.93	14.60 a	15.23a
T_4	4.58 ab	6.87 ab	17.10 bc	19.87c	13.30	13.47	14.13 a	14.23ab
T_5	4.86 a	7.42 a	20.77 a	23.36a	12.07	13.13	12.40 a	15.00a
T_6	4.12 ad	6.35 b	16.02 bd	18.57c	12.52	12.93	12.27 a	13.83ab
T_7	2.86 cd	4.48 cd	14.08 cd	16.53c	13.87	13.67	13.00 a	14.27ab
T_8	0.33 e	0.53 e	4.89 e	6.60e	13.16	12.50	10.13 b	11.40c
LSD (0.05)	1.492	0.961	2.781	1.342	ns	ns	2.398	1.403
CV (%)	25.59	10.67	10.60	4.46	9.32	7.91	10.85	5.82

Means followed by common letters are not significantly different by DMRT at 5% level of significance

T_1= $N_{150}P_{50}K_{80}S_{30}Zn_5B_2Mo_1$ kg ha^{-1} (N as PU); T_2= $N_{150}P_{50}K_{80}S_{30}Zn_5B_2Mo_1$ kg ha^{-1} (N as USG); T_3= $N_{180}P_{53}K_{83}S_{20}Zn_2B_1Mo_{0.8}$ kg ha^{-1} (N as PU); T_4= $N_{146}P_{22}K_{62}S_{20}Zn_2B_1M_{0.8}$ kg ha^{-1} +3 t ha^{-1} PM (Poultry manure) (N as PU); T_5= $N_{126}P_{22}K_{62}S_{20}Zn_2B_1M_{0.8}$ + 3 ton PM (N as USG); T_6= $N_{138}P_{46}K_{58}S_{20}Zn_2B_1M_{0.8}$+ 5 t ha^{-1} CD (Cowdung) (N as USG); T_7= $N_{116}P_{22}K_{20}S_{10}Zn_{1.6}B_1Mo_{0.8}$ kg ha^{-1} for Joydebpur, Gazipur ((N as PU) (Soil test based) and $N_{110}P_{33}K_{23}S_{15}Zn_{1.6}B_1Mo_{0.8}$ kg ha^{-1} for Akbarpur, Moulvibazar (N as PU) (Soil test based) and T_8= Control (native nutrient).

Table 3.5. Effect of fertilizer on yield and yield attributes of broccoli at Joydebpur and Akbarpur

Treatment	Head diameter (cm)				Compactness coefficient (CC)			
	Joydebpur		Akbarpur		Joydebpur		Akbarpur	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
T_1	13.79 a	13.60bc	13.27 a	13.93c	21.88 b	22.99cd	18.63 bc	21.53c
T_2	13.11 a	14.67ab	14.40 a	14.17c	23.05 b	25.09bc	17.66 c	21.32c
T_3	14.91 a	15.07a	12.67 a	14.43bc	25.27 ab	26.94ab	18.86 bc	26.94ab
T_4	14.09 a	13.93ac	14.73 a	14.60bc	25.05 ab	25.20bc	21.86 ab	26.92ab
T_5	14.65 a	14.73ab	14.93 a	15.87a	31.45 a	29.21a	22.91 a	27.68a
T_6	13.72 a	14.00ac	13.87 a	15.50ab	23.28 b	23.57c	18.30 bc	24.19b
T_7	13.37 a	14.67ab	12.73 a	14.50bc	22.77 b	22.17c	16.49 c	21.10c
T_8	9.31 b	10.13c	8.07 b	9.90d	13.23 c	16.16d	11.07 d	10.10d
LSD (0.05)	2.346	1.071	3.125	1.015	6.991	2.925	3.497	1.936
CV (%)	9.93	4.30	13.64	4.04	17.48	6.84	10.97	4.55

Means followed by common letters are not significantly different by DMRT at 5% level of significance

T_1= $N_{150}P_{50}K_{80}S_{30}Zn_5B_2Mo_1$ kg ha^{-1} (N as PU); T_2= $N_{150}P_{50}K_{80}S_{30}Zn_5B_2Mo_1$ kg ha^{-1} (N as USG); T_3= $N_{180}P_{53}K_{83}S_{20}Zn_2B_1Mo_{0.8}$ kg ha^{-1} (N as PU); T_4= $N_{146}P_{22}K_{62}S_{20}Zn_2B_1M_{0.8}$ kg ha^{-1} +3 t ha^{-1} PM (Poultry manure) (N as PU); T_5= $N_{126}P_{22}K_{62}S_{20}Zn_2B_1M_{0.8}$ + 3 ton PM (N as USG); T_6= $N_{138}P_{46}K_{58}S_{20}Zn_2B_1M_{0.8}$+ 5 t ha^{-1} CD (Cowdung) (N as USG); T_7= $N_{116}P_{22}K_{20}S_{10}Zn_{1.6}B_1Mo_{0.8}$ kg ha^{-1} for Joydebpur, Gazipur ((N as PU) (Soil test based) and $N_{110}P_{33}K_{23}S_{15}Zn_{1.6}B_1Mo_{0.8}$ kg ha^{-1} for Akbarpur, Moulvibazar (N as PU) (Soil test based) and T_8= Control (native nutrient)

Head length

In 2013-14, head length was found insignificant in Joydebpur. Although it was significantly affected by the treatment in Akbarpur but there was no statistical difference among the treatments except control. The highest head length (14.19 cm and 14.60 cm) was recorded in T_3 treatment for both the locations (Table 3.4). In 2014-15, head length was also found insignificant in Joydebpur although the highest head length (13.93 cm) was recorded in T_3 followed by T_4 treatment. But it was significantly affected by the treatment in Akbarpur with the highest length of 15.23 cm recorded from treatment T_3 followed by T_5 (15.00 cm) (Table 3.4).

Head diameter

The head diameter was significantly variable among the treatments (Table 3.5). At Joydebpur, the highest head diameter (14.6 and 14.7 cm for 2013-14 and 2014-15, respectively) was found in T_5 followed by T_3. The minimum head diameter (9.3 and 10.1 cm for 2013-14 and 2014-15, respectively) was recorded in the control (Table 3.5). The similar results were also observed in Akbarpur (Table 3.5). Varsha *et al.* (2022) reported that higher curd diameter and weight of curd in broccoli have strong relationships with the application of optimum doses of organic and inorganic N. Hossain and Islam (2024) also observed that application of cowdung 5.0 t ha^{-1} and NPK (50% of the recommendation) showed the optimum yield of broccoli, which are in agreement with the findings of our results.

Compactness coefficient (CC)

In 2013-14, compactness coefficient (CC=Head weight/Head diameter) of broccoli head was significantly influenced by the different fertilizer packages and the highest CC (31.45) was found in T_5 followed by T_3 (25.27) and T_5 (22.91) followed by T_4 (21.86) for Joydebpur and Akbarpur, respectively. The lowest CC was recorded in control (T_8) treatment for both the location (Table 3.5). In 2014-15, compactness coefficient (CC) was also significantly influenced by the fertilizer packages and the highest CC was found in T_5 (29.21) followed by T_3 (26.94) and T_5 (27.68) followed by T_3 (26.94) for Joydebpur and Akbarpur, respectively. The lowest CC was recorded in control treatment (Table 3.5).

SPAD value

The SPAD values were significantly influenced by the different treatments at head initiation stage (Table 3.6). In 2013-14, the maximum SPAD value was found in T_3 (79.07 and 76.07 for Joydebpur and Akbarpur, respectively) followed by T_5 (75.87 and 74.53 for Joydebpur and Akbarpur, respectively). The lowest SPAD value was recorded in the control (61.0 and 59.0 for locations, respectively). The similar trend was observed in 2014-15. In 2013-14, SPAD values were also significantly variable among the treatments at harvest stage (Table 3.6). T_5 showed the highest SPAD value (77.6 and 76.1 for Joydebpur and Akbarpur, respectively)

followed by T_3 and T_6. The lowest SPAD value was recorded in the control (65.8 and 63.3 for Joydebpur and Akbarpur, respectively). The similar trend was found in 2014-15. This indicated that in head initiation stage N uptake was higher in PU treated plots while it was higher in USG treated plots at harvest stage due to continuous and prolonged supply of nitrogen by the urea super granule as well as poultry manure. It meant that N use efficiency is higher in USG in comparison to PU. SPAD value or leaf greenness is a good indicator for leaf chlorophyll content and plant physiological activities and growth (Alam *et al.*, 2021). The significant response was observed after application of $N_{126}P_{22}K_{62}S_{20}Zn_2B_1M_{0.8}$+ 3 tons PM (N as USG) (Table 3.6). This might be due to proper uptake of N from the soils and higher physiological activities of the plant. T_3 also showed the higher SPAD values with higher level of N as PU.

Partitioning of the growth parameters

These parameters were studied only at Joydebpur location. In 2013-14, total fresh plant weight, shoot fresh weight, fresh head weight, fresh root weight, shoot dry weight, root dry weight and total dry weight of plant were significantly affected by the treatments. Maximum fresh and dry weight for all the parameters was recorded in T_5 treatment and the lowest were recorded from control (Table 3.7). In 2014-15, total fresh plant weight, fresh shoot weight, fresh head weight, fresh root weight, shoot dry weight, root dry weight and total dry weight of plant, were also significantly affected by the treatments and maximum fresh and dry weight were recorded in T_5 treatment and the lowest weight were recorded from control (Table 3.8). It was noticed that the fresh root weight was highest in T_5 followed by T_4 and both of the values were statistically identical (Table 3.7). As the plants get adequate nutrients in available forms under integrated nutrient management packages, it enhances plant physiological activities and finally gives higher yield.

Nitrogen uptake

Nitrogen uptake by the broccoli plant was significantly influenced by the different organic and inorganic sources of N. The highest N uptake (227.84 kg ha^{-1}) was found in T_5 ($N_{126}P_{22}K_{62}S_{20}Zn_2B_1M_{0.8}$+ 3 t ha^{-1} PM) (N as USG) followed by T_3 and T_6. The lowest N uptake (177.28 kg ha^{-1}) was recorded in T_8 (Native nutrient) (Table 3.9). It was observed that N uptake was found higher in USG treated plots along with poultry manure than the PU. It might be due to high availability and continuous supply of N from deep placement of USG in combination with PM. Organic manure act as a slow release N source which can supply N for a long time to the plant as a result plant can uptake more N. This result was supported by the findings of Rickard Mellgren (2008) who reported that N uptake by the plant was strongly influenced by the N application. Tremblay *et al.* (2009) reported that N uptake for an average yield is around 260 kg N ha^{-1} while Eveerarts and de Willigen (1999b) reported a maximum N uptake of 300 kg N ha^{-1}.

Table 3.6. Effect of fertilizer on SPAD value of broccoli at Joydebpur and Akbarpur

Treatment	SPAD value at head initiation stage				SPAD value at harvesting stage			
	Joydebpur		Akbarpur		Joydebpur		Akbarpur	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
T_1	73.72 b	72.73a	71.72 ab	71.02a	73.92 ab	72.67b	73.05 a	74.05a
T_2	75.00 b	74.67a	72.67 ab	73.67a	73.66 b	74.33ab	73.14 a	74.67a
T_3	79.07 a	75.67a	76.07 a	75.33a	76.96 ab	76.67a	75.21 a	75.67a
T_4	75.60 ab	74.33a	72.60 ab	73.33a	75.86 ab	76.67a	74.53 a	75.67a
T_5	75.87 ab	74.67a	74.53 ab	74.33a	77.60 a	76.52ab	76.10 a	75.33a
T_6	74.50 b	71.78a	72.50 ab	73.67a	77.52 a	74.67ab	74.76 a	74.10a
T_7	72.10 b	71.67a	70.10 b	70.67a	74.56 ab	73.33b	72.50 a	73.33a
T_8	61.00 c	61.67b	59.00 c	62.33b	65.80 c	62.87c	63.33 b	62.67b
LSD (0.05)	3.728	3.429	5.089	3.767	3.367	3.071	3.853	3.433
CV (%)	2.90	2.58	4.08	3.338	2.58	2.58	3.02	4.04

Means followed by common letters are not significantly different by DMRT at 5% level of significance

T_1= $N_{150}P_{50}K_{80}S_{30}Zn_5B_2Mo_1$ kg ha^{-1} (N as PU); T_2= $N_{150}P_{50}K_{80}S_{30}Zn_5B_2Mo_1$ kg ha^{-1} (N as USG); T_3= $N_{180}P_{53}K_{83}S_{20}Zn_2B_1Mo_{0.8}$ kg ha^{-1} (N as PU); T_4= $N_{146}P_{22}K_{62}S_{20}Zn_2B_1M_{0.8}$ kg ha^{-1} +3 t ha^{-1} PM (Poultry manure) (N as PU); T_5= $N_{126}P_{22}K_{62}S_{20}Zn_2B_1M_{0.8}$ + 3 ton PM (N as USG); T_6= $N_{138}P_{46}K_{58}S_{20}Zn_2B_1M_{0.8}$+ 5 t ha^{-1} CD (Cowdung) (N as USG); T_7= $N_{116}P_{22}K_{20}S_{10}Zn_{1.6}B_1Mo_{0.8}$ kg ha^{-1} for Joydebpur, Gazipur ((N as PU) (Soil test based) and $N_{110}P_{33}K_{23}S_{15}Zn_{1.6}B_1Mo_{0.8}$ kg ha^{-1} for Akbarpur, Moulvibazar (N as PU) (Soil test based) and T_8= Control (native nutrient)

Table 3.7. Effect of fertilizer on the growth parameters and dry matter partitioning of broccoli at Joydebpur

Treatment	Total fresh weight (g plant^{-1})		Fresh shoot weight (g plant^{-1})		Fresh head weight (g plant^{-1})		Fresh root weight (g plant^{-1})	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
T_1	1300 d	1338 d	1205 e	1158 e	350 b	358 b	76.0 e	103.7 ab
T_2	1485 bc	1586 b	1410 bc	1485 ab	323 bc	343 bc	89.7 cd	91.7 cd
T_3	1550 b	1495 bc	1460 ab	1398 bc	350 b	367 b	104.7 ab	101.0 e
T_4	1450 c	1478 c	1335 cd	1377 cd	350 b	440 d	108.3 a	105.3 a
T_5	1650 a	1647 a	1545 a	1574 a	450 a	450 a	114.3 a	116.3 a
T_6	1401 c	1425 c	1300 d	1345 d	240 d	384 b	101.3 ac	98.7 ac
T_7	1200 e	1290 e	1120 e	1211 e	320 c	334 c	80.0 de	83.3 de
T_8	800 f	880 f	705 f	758 f	120 e	142 e	94.7 bc	97.3 bc
LSD (0.05)	83.24	84.41	84.67	86.33	25.65	27.35	12.58	11.58
CV (%)	4.63	3.51	7.01	4.06	8.67	4.68	5.73	7.47

Means followed by common letters are not significantly different by DMRT at 5% level of significance

T_1= $N_{150}P_{50}K_{80}S_{30}Zn_5B_2Mo_1$ kg ha^{-1} (N as PU); T_2= $N_{150}P_{50}K_{80}S_{30}Zn_5B_2Mo_1$ kg ha^{-1} (N as USG); T_3= $N_{180}P_{53}K_{83}S_{20}Zn_2B_1Mo_{0.8}$ kg ha^{-1} (N as PU); T_4= $N_{146}P_{22}K_{62}S_{20}Zn_2B_1M_{0.8}$ kg ha^{-1} +3 t ha^{-1} PM (Poultry manure) (N as PU); T_5= $N_{126}P_{22}K_{62}S_{20}Zn_2B_1M_{0.8}$ + 3 ton PM (N as USG); T_6= $N_{138}P_{46}K_{58}S_{20}Zn_2B_1M_{0.8}$+ 5 t ha^{-1} CD (Cowdung) (N as USG); T_7= $N_{116}P_{22}K_{20}S_{10}Zn_{1.6}B_1Mo_{0.8}$ kg ha^{-1} for Joydebpur, Gazipur ((N as PU) (Soil test based) and $N_{110}P_{33}K_{23}S_{15}Zn_{1.6}B_1Mo_{0.8}$ kg ha^{-1} for Akbarpur, Moulvibazar (N as PU) (Soil test based) and T_8= Control (native nutrient)

Table 3.8. Effect of fertilizer on the growth parameters and dry matter partitioning of broccoli at Joydebpur

Treatment	Total dry weight (g plant^{-1})		Shoot dry weight (g plant^{-1})		Root dry weight (g plant^{-1})	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
T_1	98.2 b	97.1 b	79.5 bc	81.3 bc	18.2 b	19.0 b
T_2	97.6 b	95.8 b	79.1 bc	76.7 bc	18.1 b	17.3 b
T_3	102 b	87.7 c	82.8 b	77.0 cd	19.0 b	16.7 cd
T_4	101 b	113 b	75.0 cd	83.1 b	18.9 b	19.3 b
T_5	112 a	171 a	91.0 a	89.7 a	20.7 a	21.1 a
T_6	88.0 c	102 b	82.3 b	81.3 b	16.0 cd	17.3 b
T_7	87.5 c	88.3 c	70.9 d	72.2 d	16.3 c	15.9 c
T_8	58.8 d	57.7 d	48.2 e	45.9 e	10.6 d	11.8 d
LSD (0.05)	6.98	6.98	4.744	4.744	1.462	1.462
CV (%)	4.67	4.76	4.67	3.53	6.71	4.63

Means followed by common letters are not significantly different by DMRT at 5% level of significance

T_1= $N_{150}P_{50}K_{80}S_{30}Zn_5B_2Mo_1$ kg ha^{-1} (N as PU); T_2= $N_{150}P_{50}K_{80}S_{30}Zn_5B_2Mo_1$ kg ha^{-1} (N as USG); T_3= $N_{180}P_{53}K_{83}S_{20}Zn_2B_1Mo_{0.8}$ kg ha^{-1} (N as PU); T_4= $N_{146}P_{22}K_{62}S_{20}Zn_2B_1M_{0.8}$ kg ha^{-1} +3 t ha^{-1} PM (Poultry manure) (N as PU); T_5= $N_{126}P_{22}K_{62}S_{20}Zn_2B_1M_{0.8}$ + 3 ton PM (N as USG); T_6= $N_{138}P_{46}K_{58}S_{20}Zn_2B_1M_{0.8}$+ 5 t ha^{-1} CD (Cowdung) (N as USG); T_7= $N_{116}P_{22}K_{20}S_{10}Zn_{1.6}B_1Mo_{0.8}$ kg ha^{-1} for Joydebpur, Gazipur ((N as PU) (Soil test based) and $N_{110}P_{33}K_{23}S_{15}Zn_{1.6}B_1Mo_{0.8}$ kg ha^{-1} for Akbarpur, Moulvibazar (N as PU) (Soil test based) and T_8= Control (native nutrient)

Nitrogen uptake efficiency

Nitrogen uptake efficiency was varied among the treatment. It was speculated that N uptake efficiency was decreased with increasing levels of N fertilizer. The highest N uptake efficiency (79.81%) was obtained from T_5 ($N_{126}P_{22}K_{62}S_{20}Zn_2B_1M_{0.8}$+ 3 t ha^{-1} PM, N as USG) followed by 66.96% with T_6 ($N_{138}P_{46}K_{58}S_{20}Zn_2B_1M_{0.8}$+ 5 t ha^{-1} CD, N as USG) and the lowest N uptake efficiency (44.59%) was found from T_1 ($N_{150}P_{50}K_{80}S_{30}Zn_5B_2Mo_1$, N as PU). USG and PU along with 3 tons poultry manure also showed higher N use efficiency (Table 3.9). However, it was higher in USG treated plots as compared to that of PU. It might be due to slow release but long-time supply of N by organic manure as cow dung and poultry manure with continuous N supply and greater fertilizer-N recovery in case of USG could ensure higher N uptake efficiency than that of PU. Most studies have shown that the N uptake efficiency of broccoli decreased with increasing amount of fertilizer (Riley and Vagen, 2003). Khalil *et al.* (2011) 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%). Zebarth *et al*., (1995) stated that apparent fertilizer-N recovery in the aboveground portion of the plant decreased linearly from between 46 and 93% at an N rate of 125 ha^{-1} kg ha^{-1} to between 20 and 44% at an N rate of 625 kg ha^{-1}. These results are corroborated with the findings of present study. The higher use efficiency might be the reflection of USG with deep placement where comparatively lower number of nitrifying bacteria participates to convert a large granule of urea due to its smaller surface area as compared to PU and take a longer time to convert it to available form which is spontaneously uptake by the plants. On the other hand, Mukherjee (1986) explained the phenomenon that the deep placement of USG 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.

The application of sole organic fertilizers may be less efficient for promoting broccoli growth and yield because of slower release of nutrients from organic sources but at the same time organic fertilizers increase organic matter content of the soil which ultimately improve soil structure and ensure adequate soil aeration for enhanced root growth and nutrient uptake (Mehedi *et al.*, 2018). Organic sources of nutrients increase the availability of N and P and ensure better uptake and utilization of nutrients for vigorous growth of plant. Again, chemical fertilizers increase the vegetative growth and yield of broccoli to a certain limit but after that limit yield is decreased and it also renders a detrimental impact on soil health and nutrient dynamics in the long run (Yoldas *et al.*, 2008). So, the combination of organic and inorganic sources of nutrients is a sustainable way for quality and higher production of broccoli (Hussain *et al.*, 2020; Hossain and Islam, 2024). In our present study 3 tons poultry manure for the treatment T_5 was more effective for enhanced growth, yield and quality of broccoli and it was also found to be more economic in comparison to other packages and more precisely to the control with native soil fertility. This phenomenon was due to the more effectiveness of the

poultry manure in comparison to other manures to release the available nutrients for better growth and accumulation of photosynthates in broccoli. These findings were also confirmed by other researchers in previous studies (Kayesh *et al.*, 2019; Hussain *et al.*, 2020).

Table 3.9. Effect of fertilizer on N uptake and uptake efficiency of broccoli plant

Treatments	N uptake (Kg ha^{-1})	N uptake efficiency (%) over control
T_1= $N_{150}P_{50}K_{80}S_{30}Zn_5B_2Mo_1$ (N as PU)	194.16 bc	44.59
T_2= $N_{150}P_{50}K_{80}S_{30}Zn_5B_2Mo_1$ (N as USG)	202.32 ac	50.03
T_3= $N_{180}P_{53}K_{83}S_{20}Zn_2B_1Mo_{0.8}$ (N as PU)	220.48 ab	51.78
T_4= $N_{146}P_{22}K_{62}S_{20}Zn_2B_1M_{0.8}$+ 3 ton PM (N as PU)	214.32 ab	59.62
T_5= $N_{126}P_{22}K_{62}S_{20}Zn_2B_1M_{0.8}$+ 3 ton PM (N as USG)	227.84 a	79.81
T_6= $N_{138}P_{46}K_{58}S_{20}Zn_2B_1M_{0.8}$+ 5 ton CD (N as USG)	219.68 ab	66.96
T_7=$N_{116}P_{22}K_{20}S_{10}Zn_{1.6}B_1Mo_{0.8}$ (N as PU) (STB, FRG, 2012)	196.64 bc	59.79
T_8= Native fertility	127.28 c	-
LSD (0.05)	27.488	-
CV (%)	6.08	-

Means followed by common letters are not significantly different by DMRT at 5% level of significance

Cost and Return

The data pertaining to economic comparison is presented in Table 3.10 to 3.13. In 2013-14, the highest gross return (Tk. 477300) and benefit-cost ratio (BCR) (4.40) were found in T_5 at Joydebpur, which was closely followed by T_3 (3.91) and the lowest benefit-cost ratio (1.59) was noted in T_8 treatment. At Akbarpur, the highest gross return (Tk. 379200) and BCR (3.50) were also observed in T_5 followed by T_3. Similarly in 2014-15, the highest gross return (Tk. 477300) and benefit-cost ratio (4.25) were found in T_5 at Joydebpur, which was closely followed by T_3 (4.12) and the lowest benefit-cost ratio (2.01) were calculated in T_8 treatment. At Akbarpur, the highest gross return (Tk. 457350) and BCR (4.02) were also observed in T_5 followed by T_3. These two treatment packages (T_5 and T_3) were found superior compare to other treatment packages in terms of economic profitability for both of the locations. Considering all these aspects treatment T_5 followed by T_3 could be the most economically viable fertilizer packages for quality broccoli production. Similar results were also reported by other studies for broccoli (Srichandan *et al.*, 2015; Kayesh *et al.*, 2019; Hussain *et al.*, 2020; Aouass and Kenny, 2023).

Table-3.10. Economic profitability of broccoli production under different fertilizer packages at Joydebpur, 2013-14

Treatments	Marketable Yield (t ha^{-1})	Price of broccoli (Tk ton^{-1})	Gross return (Tk ha^{-1})	TVS (Tk ha^{-1})	Gross Margin (Tk ha^{-1})	BCR
T_1	11.01	30000	330300	105609	224691	3.13
T_2	12.44	30000	373200	106911	266289	3.49
T_3	13.63	30000	408900	104602	304298	3.91
T_4	11.90	30000	357000	107126	249874	3.33
T_5	15.91	30000	477300	108471	368829	4.40
T_6	12.52	30000	375600	110252	265348	3.41
T_7	11.22	30000	336600	97367	239233	3.45
T_8	4.563	30000	136890	86342	50548	1.59

Broccoli price = Tk. 30/kg, Urea= 16 Tk./kg, USG= 20 Tk/kg, TSP= 24 Tk./kg, MoP= 15 Tk./kg, Gypsum= 15 Tk./kg, Boric Acid = 195 Tk./kg, Zinc Oxide= 135 Tk./kg, Seed: Tk. 30000/kg, Poultry liter: 3 Tk/kg, Cowdung: 1.5 Tk/kg.

T_1= $N_{150}P_{50}K_{80}S_{30}Zn_5B_2Mo_1$ kg ha^{-1} (N as PU); T_2= $N_{150}P_{50}K_{80}S_{30}Zn_5B_2Mo_1$ kg ha^{-1} (N as USG); T_3= $N_{180}P_{53}K_{83}S_{20}Zn_2B_1Mo_{0.8}$ kg ha^{-1} (N as PU); T_4= $N_{146}P_{22}K_{62}S_{20}Zn_2B_1M_{0.8}$ kg ha^{-1} +3 t ha^{-1} PM (Poultry manure) (N as PU); T_5= $N_{126}P_{22}K_{62}S_{20}Zn_2B_1M_{0.8}$ + 3 ton PM (N as USG); T_6= $N_{138}P_{46}K_{58}S_{20}Zn_2B_1M_{0.8}$+ 5 t ha^{-1} CD (Cowdung) (N as USG); T_7= $N_{116}P_{22}K_{20}S_{10}Zn_{1.6}B_1Mo_{0.8}$ kg ha^{-1} for Joydebpur, Gazipur ((N as PU) (Soil test based) and T_8= Control (native nutrient)

Table-3.11. Economic profitability of broccoli production under different fertilizer packages at Akbarpur, 2013-14

Treatments	Marketable Yield (t ha^{-1})	Price of broccoli (Tk ton^{-1})	Gross return (Tk ha^{-1})	TVS (Tk ha^{-1})	Gross Margin (Tk ha^{-1})	BCR
T_1	8.901	30000	267030	105609	161421	2.52
T_2	9.420	30000	282600	106911	175689	2.64
T_3	10.35	30000	310500	104602	205898	2.97
T_4	10.21	30000	306300	107126	199174	2.86
T_5	12.64	30000	379200	108471	270729	3.50
T_6	9.321	30000	279630	110252	169378	2.54
T_7	7.827	30000	234810	97948	136862	2.40
T_8	3.308	30000	99240	86342	12898	1.15

Broccoli price = Tk. 30/kg, Urea= 16 Tk./kg, USG= 20 Tk/kg, TSP= 24 Tk./kg, MoP= 15 Tk./kg, Gypsum= 15 Tk./kg, Boric Acid = 195 Tk./kg, Zinc Oxide= 135 Tk./kg, Seed: Tk. 30000/kg, Poultry liter: 3 Tk/kg, Cowdung: 1.5 Tk/kg.

T_1= $N_{150}P_{50}K_{80}S_{30}Zn_5B_2Mo_1$ kg ha^{-1} (N as PU); T_2= $N_{150}P_{50}K_{80}S_{30}Zn_5B_2Mo_1$ kg ha^{-1} (N as USG); T_3= $N_{180}P_{53}K_{83}S_{20}Zn_2B_1Mo_{0.8}$ kg ha^{-1} (N as PU); T_4= $N_{146}P_{22}K_{62}S_{20}Zn_2B_1M_{0.8}$ kg ha^{-1} +3 t ha^{-1} PM (Poultry manure) (N as PU); T_5= $N_{126}P_{22}K_{62}S_{20}Zn_2B_1M_{0.8}$ + 3 ton PM (N as USG); T_6= $N_{138}P_{46}K_{58}S_{20}Zn_2B_1M_{0.8}$+ 5 t ha^{-1} CD (Cowdung) (N as USG); T_7= $N_{116}P_{22}K_{20}S_{10}Zn_{1.6}B_1Mo_{0.8}$ kg ha^{-1} for Joydebpur, Gazipur ((N as PU) (Soil test based) and $N_{110}P_{33}K_{23}S_{15}Zn_{1.6}B_1Mo_{0.8}$ kg ha^{-1} for Akbarpur, Moulvibazar (N as PU) (Soil test based) and T_8= Control (native nutrient)

Table-3.12. Economic profitability of broccoli production under different fertilizer packages at Joydebpur, 2014-15

Treatments	Marketable Yield (t ha^{-1})	Price of broccoli (Tk ton^{-1})	Gross return (Tk ha^{-1})	TVC (Tk ha^{-1})	Gross Margin (Tk ha^{-1})	BCR
T_1	11.580	30000	347400	110889	236511	3.13
T_2	13.592	30000	407760	112256	295504	3.63
T_3	15.037	30000	451110	109832	341278	4.12
T_4	13.000	30000	390000	113894	276106	3.42
T_5	15.939	30000	478170	112482	365688	4.25
T_6	12.222	30000	366660	115764	250896	3.17
T_7	12.049	30000	361470	102235	259235	3.54
T_8	6.071	30000	182130	90659	91471	2.01

Broccoli price = Tk. 30 kg^{-1}, Urea= 16 Tk kg^{-1}, USG= 20 Tk kg^{-1}, TSP= 24 Tk kg^{-1}, MoP= 15 Tk kg^{-1}, Gypsum= 15 Tk kg^{-1}, Boric Acid = 195 Tk kg^{-1}, Zinc Oxide= 135 Tk kg^{-1}, Seed: Tk. 30000 kg^{-1}, Poultry liter: 3 Tk kg^{-1}, Cowdung: 1.5 Tk kg^{-1}.

T_1= $N_{150}P_{50}K_{80}S_{30}Zn_5B_2Mo_1$ kg ha^{-1} (N as PU); T_2= $N_{150}P_{50}K_{80}S_{30}Zn_5B_2Mo_1$ kg ha^{-1} (N as USG); T_3= $N_{180}P_{53}K_{83}S_{20}Zn_2B_1Mo_{0.8}$ kg ha^{-1} (N as PU); T_4= $N_{146}P_{22}K_{62}S_{20}Zn_2B_1M_{0.8}$ kg ha^{-1} +3 t ha^{-1} PM (Poultry manure) (N as PU); T_5= $N_{126}P_{22}K_{62}S_{20}Zn_2B_1M_{0.8}$ + 3 ton PM (N as USG); T_6= $N_{138}P_{46}K_{58}S_{20}Zn_2B_1M_{0.8}$+ 5 t ha^{-1} CD (Cowdung) (N as USG); T_7= $N_{116}P_{22}K_{20}S_{10}Zn_{1.6}B_1Mo_{0.8}$ kg ha^{-1} for Joydebpur, Gazipur ((N as PU) (Soil test based) and $N_{110}P_{33}K_{23}S_{15}Zn_{1.6}B_1Mo_{0.8}$ kg ha^{-1} for Akbarpur, Moulvibazar (N as PU) (Soil test based) and T_8= Control (native nutrient)

Table-3.13. Economic profitability of broccoli production under different fertilizer packages at Akbarpur, 2014-15

Treatments	Marketable Yield (t ha^{-1})	Price of broccoli (Tk ton^{-1})	Gross return (Tk ha^{-1})	TVS (Tk ha^{-1})	Gross Margin (Tk ha^{-1})	BCR
T_1	11.001	30000	330030	110889	219141	2.98
T_2	13.882	30000	416460	112256	304204	3.71
T_3	14.399	30000	431970	109832	323038	3.93
T_4	14.357	30000	430710	112482	318228	3.83
T_5	15.245	30000	457350	113894	343456	4.02
T_6	11.331	30000	339930	115764	224166	2.94
T_7	11,182	30000	335460	102845	232615	3.26
T_8	5.711	30000	171330	90659	80671	1.89

Broccoli price = Tk. 30 kg^{-1}, Urea= 16 Tk kg^{-1}, USG= 20 Tk kg^{-1}, TSP= 24 Tk kg^{-1}, MoP= 15 Tk kg^{-1}, Gypsum= 15 Tk kg^{-1}, Boric Acid = 195 Tk kg^{-1}, Zinc Oxide= 135 Tk kg^{-1}, Seed: Tk. 30000 kg^{-1}, Poultry liter: 3 Tk kg^{-1}, Cowdung: 1.5 Tk kg^{-1}.

T_1= $N_{150}P_{50}K_{80}S_{30}Zn_5B_2Mo_1$ kg ha^{-1} (N as PU); T_2= $N_{150}P_{50}K_{80}S_{30}Zn_5B_2Mo_1$ kg ha^{-1} (N as USG); T_3= $N_{180}P_{53}K_{83}S_{20}Zn_2B_1Mo_{0.8}$ kg ha^{-1} (N as PU); T_4= $N_{146}P_{22}K_{62}S_{20}Zn_2B_1M_{0.8}$ kg ha^{-1} +3 t ha^{-1} PM (Poultry manure) (N as PU); T_5= $N_{126}P_{22}K_{62}S_{20}Zn_2B_1M_{0.8}$ + 3 ton PM (N as USG); T_6= $N_{138}P_{46}K_{58}S_{20}Zn_2B_1M_{0.8}$+ 5 t ha^{-1} CD (Cowdung) (N as USG); T_7= $N_{116}P_{22}K_{20}S_{10}Zn_{1.6}B_1Mo_{0.8}$ kg ha^{-1} for Joydebpur, Gazipur ((N as PU) (Soil test based) and $N_{110}P_{33}K_{23}S_{15}Zn_{1.6}B_1Mo_{0.8}$ kg ha^{-1} for Akbarpur, Moulvibazar (N as PU) (Soil test based) and T_8= Control (native nutrient).

Conclusion

Application of organic manure in combination with urea super granule (USG) or prilled urea (PU) along with other fertilizers showed positive effect on the yield parameters and yield of broccoli. The yield attributes, marketable head yield, benefit cost ratio (BCR) and nitrogen use efficiency were found maximum in T_5 ($N_{126}P_{22}K_{62}S_{20}Zn_2B_1M_{0.8}$ kg/ha + 3 tons PM ha^{-1}) (N as USG) followed by T_3 ($N_{180}P_{53}K_{83}S_{20}Zn_2B_1Mo_{0.8}$ kg ha^{-1}) (N as PU) in both Joydebpur and Akhbarpur locations. Therefore, 126-22-62-20-2-1-0.8 kg ha^{-1} of N-P-K-S-Zn-B-Mo along with 3 t ha^{-1} PM (N as USG) or 180-53-83-20-2-1-0.8 kg ha^{-1} of N-P-K-S-Zn-B-Mo without organic manure (N as PU) fertilizer package can be recommended for sustainable broccoli production in Bangladesh.

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