# BJAR

**Volume 49 Number 4**

# Bangladesh Journal of Agricultural Research

# Bangladesh
# Journal of
# AGRICULTURAL
# RESEARCH

Volume 49 Number 4

## C O N T E N T S

# EFFECT OF SOWING DATES ON YIELD OF MUSTARD IN SYLHET REGION

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## Abstract

The experiment was carried out on a multilocational testing (MLT) site, Hobiganj district to find out suitable sowing dates of rapeseed mustard (*Brassica campestris* and *Brassica napus*). The mustard var. BARI Sarisha-18 was cultivated during *rabi* season of two consecutive years 2022-23 and 2023-24 in randomized complete block (RCB) design with 3 replications. The treatments were five sowing dates *viz.* 15 November, 30 November, 15 December, 30 December and 15 January. The 30th November sowing performed best with seed yield of 2.73 t ha$^{-1}$ by producing 85.71% higher seed yield than 15th January with seed yield of 1.47 t ha$^{-1}$. It was noticed that the sowing time of mustard should be adjusted considering weather change.

Keywords: Sowing dates, rapeseed mustard, seed yield.

## Introduction

Mustards are several plant species under genera *Brassica* and *Sinapis,* play a vital role in the agricultural production of Bangladesh. Among the three species of this genus, *Brassica campestris* and *Brassica napus* are recognized as rape seed and *Brassica juncea* is regarded as mustard. It is a cool season Photo-thermo-sensitive crop (Ghosh and Chatterjee, 1988) providing major edible oil in the country. A total of 3% cultivable land is utilized for oil seed production in the country, where mustard alone holds 60% of the area among the oil crops Anon., 2022). However, there is a potentiality of extending this area to 2.2 million hectares where the land remains fallow in between *Aman* and *Boro* or other crops (*Chowhan et. al*., 2021; *Chowhan et. al., 2019; Chowhan, 2022*).

Rice based rainfed ecosystem is prominent in Sylhet region. The major cropping patterns are Fallow-T. *Aus*-T. *Aman*, Fallow-Fallow- T. *Aman* and Fallow-*Boro*-Fallow, mustard could be inserted in this fallow land for increasing cropping intensity and productivity (Nazrul, 2019). The delayed and or insufficient pre-monsoon downfall makes late transplantation of *Aus* rice, which hampered the cultivation of subsequent *Aman* rice and *Rabi* cops also. As a result, large areas remain fallow shortly after the harvest of T. *Aman* rice due to inadequate information on sowing or planting dates of winter crops under changing climates.

Though agroclimatic conditions of this country are favorable but some reasons are accountable for improper growth and yield of mustard *viz.* sowing time, inadequate

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soil moisture, selection of HYVs and improved management practices. In earlier reports suggested sowing in the late October yields higher than late November (Alam *et al.,* 2014) and on the contrary, delayed sowing of mustard didn't affect the yield and related attributes (Chowhan, *et al.,* 2023). This might be due to weather shift. However, due to delayed harvesting of T. *Aman* rice, mustard sowing become late in the rice-based cropping system at northern-east region of Bangladesh. Late-planted mustard is exposed to high-temperature stress during the reproductive phase enhancing force maturity and increased senescence, shortening the length of the seed filling period, reducing seed size and resulting considerable yield loss (Sharif *et al.,* 2017). Timely sowing permits the crop plants to complete both vegetative and reproductive growth phases with better yield (Sharghi *et al.,* 2011). Furthermore, air temperature gradually rises at the end of winter which is favorable for insect infestation (Das, 2002; Ansary *et al.,* 2007) and late sowing plants also get less time for growth and directly moves to the reproductive stage.

Further due to global climate change and disparities of weather factors, a continuous shifting of winter season is being noticed every year. Being photo-thermosensitive, mustard plants must be adapted to this change. Hence, late sowing results in early flowering and may also cause severe insect pest infestation. Whereas early sowing results in proper vegetative growth and takes more time for floral initiation, consequently affecting seed yield and quality. Now it is climate change that leads demands for fixing areas or region-specific sowing times depending on the weather information for mustard cultivation. The experiment was, therefore, conducted to find out suitable sowing dates of rapeseed mustard (*Brassica campestris* and *Brassica napus*) in Sylhet region.

**Materials and Methods**

*Description of experiment site*

The experimental location was multilocation testing (MLT) site of BARI, Hobiganj (Agro Ecological Zone-20). This location was distinguished by Surma-Kushiyara Floodplain and major land types of medium high-low to low land. Soils were non-calcareous grey ranging from dark grey to brown. Organic matter content is low to medium, whereas dark grey soils have a greater amount. Soils were mostly acidic, with a fertility deficiency (FRG, 2018).

Two years' average climatic data of experimental site and period and ten years back meteorological parameters of same site have been depicted in Figure 1 and Figure 2, respectively. The past and present climatic data of experimental site showed that the minimum and maximum temperature, relative humidity, total rainy days and amount of rainfall were increased with time. From both graphs it was revealed that sporadic precipitation had occurred but ten years before the amount was very small than experimental years. Monsoon started in April and continued until October.
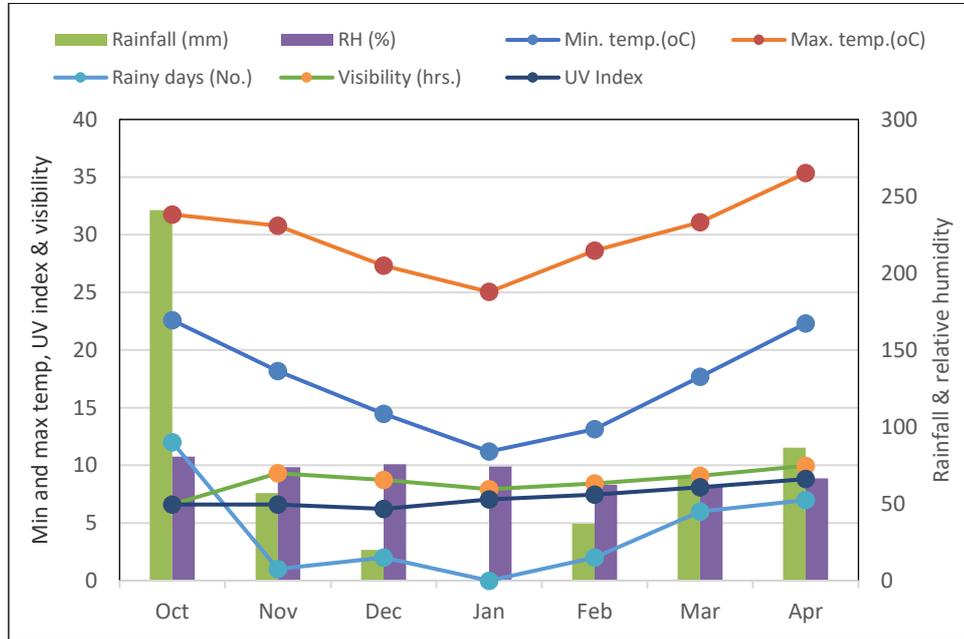
Fig. 1. Average of two years (2022-24) weather information of site during experimentation.
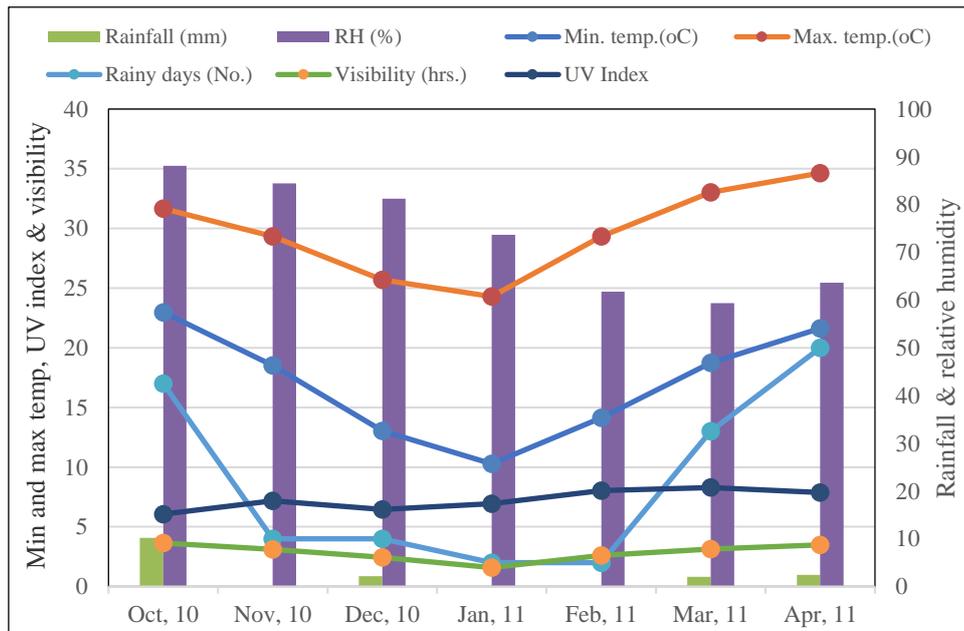


Fig. 2. Weather information of experimental site in Oct.-Dec. 2010 to Jan.-Apr. 2011.

*Crop season and field management*

Consecutive two years (2022-23 and 2023-24) during *rabi* (winter) season was used to carry out the field experiment and the field was prepared by tilling thoroughly to pulverize soil, 2-3 ploughing followed by leveling was done and weeds-plant residue was removed. The recommended fertilizers @115, 36, 45, 27, 2 and 1 kg ha$^{-1}$ of N, P, K, S, Zn and B were used, respectively. The entire P, K, S, Zn, B fertilizers and half of N fertilizer was used as a basal dose, while half of N fertilizer was top-dressed with light irrigation at 20 days after emergence (DAE) of seedlings. The seeds were sown in broadcast method by maintaining seed rate 7 kg ha$^{-1}$ in a unit plot size of 5 m × 4 m. Twenty days after sowing (DAS) weeding and thinning were done to ensure optimum plant density. Mustard was harvested when siliquae reached near 75% maturity with brownish to straw color.

*Experimental design and treatments*

Five different sowing dates were included in the experiment. *viz.* $S_1$: 15$^{th}$ November, $S_2$: 30$^{th}$ November, $S_3$: 15$^{th}$ December, $S_4$: 30$^{th}$ December, $S_5$: 15$^{th}$ January. The experiment was laid out in randomized complete block (RCB) design with three replications, and the var. BARI Sarisha-18 was used in this trial, is one of short duration high yielded new variety of mustard that can be well fitted in cropping pattern or suitable to cultivate in fallow land as single crop.

*Harvesting and data collection*

Ten plants were randomly selected and uprooted from each unit plot to record data on yield-related traits at harvesting time. Harvesting was accomplished at the optimal maturity stage of the crops, and the entire plot area was used for measuring seed yield.

*Statistical analysis*

Data obtained from the parameters were analyzed statistically with ANOVA (analysis of variance) technique by STAR package and the mean differences were adjudged by LSD (Least Significant Difference) test at 5% level of probability.

**Results and Discussion**

*Effect of sowing dates on flower bud, flowering, and crop duration*

Sowing dates greatly influenced the flower bud development. The maximum average days to flower bud development was in $S_1$ (14 days) followed by $S_2$ (13 days) and $S_3$ (12 days). Likewise, seed sown on $S_1$ (15 November) had the longest flowering duration of 41 days and minimum in $S_5$ (30 days). Early sowing ($S_1$, $S_2$) plants took significantly more time for flowering as compared to late sowing $S_4$ and $S_5$. In this situation plants have taken more time to complete various growth-related activities and phenological and developmental stages. Early flowers

appeared in the late sown plants ($S_5$) might be due to little aberrant environmental conditions which triggered the plants earlier to reach and complete reproductive phase. The sowing times have considerable effects on the duration of mustard plants flowering (Rameeh, 2012). The present findings agree with the results of Khan *et al.* (1994), who concluded that delayed sowing led to decrease the flowering duration in canola.

If mustard seeds are sown very late, the plants flowered earlier that depends on the weather factors particularly temperature (vernalization) and day length. Research results revealed that crop (life) duration decreased with the delayed sowing dates of the mustard seeds. Statistically identical and shortest crop durations (82 and 82 days) was observed in $S_4$ (30th December) followed by $S_5$ (15th January), respectively (Table 1a). It might be due to adverse weather factors such as low air temperature (11.2$^{oC}$) during crop vegetative growth, shortened duration of various phases of crop development and elevated air temperature. Delay in sowing shortened time of flowering and maturity of mustard varieties was also reported earlier (Shah *et al.,* 2020).

**Table 1a. Effect of sowing dates on flower bud development, flowering and crop duration of mustard in *rabi* season (pooled of two years)**

| Treatment | Duration (days) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Flower bud development | | | Flowering | | | Crop | | |
| | 2022-23 | 2023-24 | Pooled | 2022-23 | 2023-24 | Pooled | 2022-23 | 2023-24 | Pooled |
| $S_1$ | 14 | 15 | 14 | 41 | 42 | 41 | 94 | 95 | 95 |
| $S_2$ | 13 | 14 | 13 | 39 | 40 | 39 | 92 | 93 | 92 |
| $S_3$ | 11 | 12 | 12 | 34 | 35 | 35 | 87 | 88 | 87 |
| $S_4$ | 11 | 11 | 11 | 31 | 32 | 31 | 80 | 84 | 82 |
| $S_5$ | 11 | 12 | 11 | 30 | 31 | 30 | 79 | 84 | 82 |
| CV (%) | 3.88 | 3.63 | 3.76 | 1.74 | 1.71 | 1.72 | 3.04 | 3.01 | 3.02 |
| LSD $_{(0.05)}$ | 0.76 | 0.87 | 0.81 | 0.96 | 1.14 | 1.05 | 4.63 | 5.03 | 4.83 |

Note: $S_1$: 15th November, $S_2$: 30th November, $S_3$: 15th December, $S_4$: 30th December, $S_5$: 15th January.

### *Plant height (cm)*

All the sowing dates showed significant variation in average plant height ranged from 90.33-110.33 cm, but the maximum plant height (110.33 cm) was recorded in $S_1$ which was statistically similar to $S_2$ at harvesting time. Plant height decreased rapidly and had a decline trend with delayed sowing of mustard seeds. Interestingly, though the sowing time was different in $S_4$ (30th Dec.) and $S_5$ (15th Jan.) but plant height at final stage was almost similar (91.34 and 90.33 cm). It was reported that variations in plant height under various sowing dates with different Indian mustard varieties were also recorded by Singh *et al.* (2017) and Chowhan *et al.* (2023).

### Plant population m⁻²

Optimum sowing time, planting geometry and plant population are the important factors affecting the yield of mustard. Different sowing dates significantly affected plant population $m^{-2}$. The number of plant population decreased with the delayed sowing dates. The highest average number of plant population (43.68 $m^2$) was recorded in $S_2$ (30th Nov.). on the contrary, the last two different sowing dates $S_4$ and $S_5$ gave the lowest and statistically similar plant population in per unit area of experimental plots.

### Number of siliquae plant⁻¹

The effect of the sowing date on siliquae $plant^{-1}$ was found significant, however, two sowing dates $S_4$ (30th Dec.) and $S_5$ (15th Jan.) were found non-significant (Table 1b). The highest mean number of siliqua $plant^{-1}$ (151.09) was obtained from 30th Nov. sowing, which was statistically similar to the 15th of Nov. ($S_1$) sowing, whereas $S_4$ and $S_5$ had the lowest number of siliquae on the plant shoots (112.09 and 112.42, respectively). It happened because late sowing provided unfavorable conditions to plant growth that resulted in the lowest performance on siliquae number. This finding was in conformity with the findings of Mondal *et al.* (1999) who stated that the 30 October planting produced the highest number of siliqua $plant^{-1}$ and reduced in the late sowings. Sakpal *et al.* (2023) also reported the early planting recorded the higher number of siliquae.

**Table 1b. Effect of sowing dates on plant height, plant population and siliquae plant⁻¹ of mustard in *rabi* season (pooled of two years)**

| Treatment | Plant height (cm) | | | Plant populations (m⁻²) | | | Siliquae plant⁻¹ | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2022-23 | 2023-24 | Pooled | 2022-23 | 2023-24 | Pooled | 2022-23 | 2023-24 | Pooled |
| $S_1$ | 109.33 | 111.33 | 110.33 | 41.33 | 42.33 | 41.83 | 150.52 | 150.83 | 150.68 |
| $S_2$ | 106.00 | 108.00 | 107.00 | 43.21 | 44.14 | 43.68 | 150.67 | 151.50 | 151.09 |
| $S_3$ | 100.67 | 103.33 | 102.00 | 41.67 | 42.67 | 42.17 | 146.67 | 147.50 | 147.09 |
| $S_4$ | 86.67 | 96.00 | 91.34 | 37.33 | 38.33 | 37.83 | 111.67 | 112.50 | 112.09 |
| $S_5$ | 85.33 | 95.33 | 90.33 | 35.67 | 36.67 | 36.17 | 112.00 | 112.83 | 112.42 |
| CV (%) | 9.2 | 7.91 | 8.56 | 5.91 | 5.77 | 5.84 | 5.73 | 5.69 | 5.71 |
| LSD $_{(0.05)}$ | 16.91 | NS | 8.46 | 3.95 | 4.43 | 4.19 | 13.23 | 14.36 | 13.79 |

Note: $S_1$: 15th November, $S_2$: 30th November, $S_3$: 15th December, $S_4$: 30th December, $S_5$: 15th January.

### Number of seeds siliqua⁻¹

The number of seeds $siliqua^{-1}$ was found to be significant for different sowing dates (Table 1c). The crops sown in November ($S_1$ and $S_2$) had the most seeds per siliqua (34.93 and 33.96) while crops sown thereafter ($S_3$, $S_4$ and $S_5$) produced seeds per siliqua decreased gradually and 15th January had the least number of seeds per siliqua (30.83). Because of a delay in sowing, and with the earlier starting of the

flowering period, mustard plants entered the pod formation and seed filling stages. As a result, it reduced the number of seeds contained within pod. Earlier sowing showed more seeds indicate that, optimum sowing time had not yet changed over weather conditions. The present results may have similarities to the findings by Mondal *et al.* (1999); Sakpal *et al.* (2023) and Sudeep *et al.* (1996) in canola.

### *Thousand seed weight*

Large and plumpy seed was obtained from seeds sown on 15th November ($S_1$), 30th November ($S_2$), and 15th December ($S_3$), but the plants under late sowing produced the lightest seed weight (Table 1c). Seed weight was not remarkably deviated with the first three sowing dates: but the late sowing ($S_5$) significantly reduced seed weight from 30th December. sowing. This might be changes in short day length and temperature which affected crop maturity; this ultimately led to poor seed filling in siliqua and a decrease in total seed weight (Sowjanya *et al.,* 2021). These findings also supported that 1000-seed weight reduced with the delayed sowing time of mustard (Mondal *et al.,* 1999).

### *Seed yield (t ha$^{-1}$)*

Weather factors had a significant impact on all the yield-attributing characters investigated during the early and late sowing times. Generally, if mustard seeds are sown very late, it flowers in short time; but it depends on the weather factors particularly temperature (vernalization) and day length. Reports are focused on the seed yield increase or reduction of mustard in different sowing dates. The result showed that higher seed yield (2.73 tha$^{-1}$) in $S_2$ sowing; which implies that winter shifted to some extent in later time (Table 1c). Delaying sowing time resulted in a lower seed yield, which could be related to temperature variations in the late-planted crop. Among all the weather attributes, maximum and minimum temperature and sunshine hours are influenced by the mustard yield (Pandey *et al*., 2007). On canola, Bukhtiar *et al.* (1992), Sattar *et al.* (2013) and Bazzaz *et al.* (2020) also reported similar conclusions. The seeds were sown in December ($S_3$ and $S_4$) and January ($S_5$) when the maximum air temperature was low during vegetative, flowering, and pod development phases of mustard compared to November ($S_1$ and $S_2$) sowing. On the contrary, both November sown mustard plants passed their vegetative, flowering, and pod development phases through the favorable weather attributes (Temp. range, RH (%), and visibility) and this might have resulted higher seed yield. It is reported that marginal and large effects on mustard yield and production were noted under slightly and deep change in environmental factors, respectively (Mishra and Chaturvedi, 2019); and UV radiation, especially UV-B, can significantly increase the content of glucosinolates in mustard plants (Michajlovskij, 1968). However, these trials only investigated the effect of different sowing dates on yield of mustard plants; the latter has not yet been studied.

**Table 1c. Effect of sowing dates on some yield attributes and yield of mustard in *rabi* season (pooled of two years)**

| Treatment | Seeds siliqua$^{-1}$ | | | 1000-seed weight (g) | | | Seed yield (tha$^{-1}$) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2022-23 | 2023-24 | Pooled | 2022-23 | 2023-24 | Pooled | 2022-23 | 2023-24 | Pooled |
| $S_1$ | 33.19 | 36.67 | 34.93 | 3.45 | 4.12 | 3.79 | 2.31 | 2.63 | 2.47 |
| $S_2$ | 32.25 | 35.67 | 33.96 | 3.34 | 4.01 | 3.68 | 2.74 | 2.71 | 2.73 |
| $S_3$ | 32.00 | 35.00 | 33.51 | 3.38 | 4.07 | 3.73 | 1.63 | 1.83 | 1.73 |
| $S_4$ | 30.33 | 33.33 | 31.83 | 2.63 | 3.67 | 3.15 | 1.25 | 1.87 | 1.56 |
| $S_5$ | 29.33 | 32.33 | 30.83 | 2.55 | 3.63 | 3.09 | 1.21 | 1.72 | 1.47 |
| CV (%) | 3.92 | 4.27 | 4.09 | 9.58 | 5.37 | 7.48 | 15.4 | 10.98 | 13.11 |
| LSD $_{(0.05)}$ | 2.12 | 2.78 | 2.45 | 0.55 | NS | 0.28 | 0.49 | 0.48 | 0.49 |

Note: $S_1$: 15$^{th}$ November, $S_2$: 30$^{th}$ November, $S_3$: 15$^{th}$ December, $S_4$: 30$^{th}$ December, $S_5$: 15$^{th}$ January.

## Conclusion

From the findings, it is revealed that suitable sowing time of mustard is being shifted towards December. Among the five different sowing dates of mustard, November sowing is found suitable which indicates in future better seed yield might be possible in late sowing i.e., within the third week of November in adverse situation at Habiganj of Sylhet region. It is noted that in Sylhet region, T. *Aman* harvested late condition followed by T. *Aus*, so mustard var. BARI Sarisha-18 could be easily fitted in the existing pattern.

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# 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); $T_5= N_{126}P_{22}K_{62}S_{20}Zn_2B_1Mo_{0.8}$ kg ha$^{-1}$ + 3 t ha$^{-1}$ PM (N as USG); $T_6= N_{138}P_{46}K_{58}S_{20}Zn_2B_1Mo_{0.8}$ 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) $\times$ 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≤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 1$^{st}$ 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$_5$B$_2$Mo$_1$ kg ha$^{-1}$ (N as PU); T$_2$= N$_{150}$P$_{50}$K$_{80}$S$_{30}$Zn$_5$B$_2$Mo$_1$ kg ha$^{-1}$ (N as USG); T$_3$= N$_{180}$P$_{53}$K$_{83}$S$_{20}$Zn$_2$B$_1$Mo$_{0.8}$ kg ha$^{-1}$ (N as PU); T$_4$= N$_{146}$P$_{22}$K$_{62}$S$_{20}$Zn$_2$B$_1$M$_{0.8}$ kg ha$^{-1}$ +3 t ha$^{-1}$ PM (Poultry manure) (N as PU); T$_5$= N$_{126}$P$_{22}$K$_{62}$S$_{20}$Zn$_2$B$_1$M$_{0.8}$ + 3 ton PM (N as USG); T$_6$= N$_{138}$P$_{46}$K$_{58}$S$_{20}$Zn$_2$B$_1$M$_{0.8}$+ 5 t ha$^{-1}$ CD (Cowdung) (N as USG); T$_7$= N$_{116}$P$_{22}$K$_{20}$S$_{10}$Zn$_{1.6}$B$_1$Mo$_{0.8}$ 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$_1$Mo$_{0.8}$ 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); $T_4$= $N_{146}P_{22}K_{62}S_{20}Zn_2B_1Mo_{0.8}$ kg ha$^{-1}$ +3 t ha$^{-1}$ PM (Poultry manure) (N as PU); $T_5$= $N_{126}P_{22}K_{62}S_{20}Zn_2B_1Mo_{0.8}$ + 3 ton PM (N as USG); $T_6$= $N_{138}P_{46}K_{58}S_{20}Zn_2B_1Mo_{0.8}$+ 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) Joydebpur | | Total yield (t ha⁻¹) (Marketable head +Lateral head) Joydebpur | | Head length (cm) Joydebpur | | Head length (cm) 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); $T_4$= $N_{146}P_{22}K_{62}S_{20}Zn_2B_1Mo_{0.8}$ 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); $T_4$= $N_{146}P_{22}K_{62}S_{20}Zn_2B_1Mo_{0.8}$ kg ha$^{-1}$ +3 t ha$^{-1}$ PM (Poultry manure) (N as PU); $T_5$= $N_{126}P_{22}K_{62}S_{20}Zn_2B_1Mo_{0.8}$ + 3 ton PM (N as USG); $T_6$= $N_{138}P_{46}K_{58}S_{20}Zn_2B_1Mo_{0.8}$+ 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); $T_4= N_{146}P_{22}K_{62}S_{20}Zn_2B_1Mo_{0.8}$ kg ha$^{-1}$ +3 t ha$^{-1}$ PM (Poultry manure) (N as PU); $T_5= N_{126}P_{22}K_{62}S_{20}Zn_2B_1Mo_{0.8}$ + 3 ton PM (N as USG); $T_6= N_{138}P_{46}K_{58}S_{20}Zn_2B_1Mo_{0.8}$+ 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); $T_4 = N_{146}P_{22}K_{62}S_{20}Zn_2B_1Mo_{0.8}$ kg ha$^{-1}$ +3 t ha$^{-1}$ PM (Poultry manure) (N as PU); $T_5 = N_{126}P_{22}K_{62}S_{20}Zn_2B_1Mo_{0.8}$ + 3 ton PM (N as USG); $T_6 = N_{138}P_{46}K_{58}S_{20}Zn_2B_1Mo_{0.8}$+ 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); $T_4$= $N_{146}P_{22}K_{62}S_{20}Zn_2B_1Mo_{0.8}$ kg ha$^{-1}$ +3 t ha$^{-1}$ PM (Poultry manure) (N as PU); $T_5$= $N_{126}P_{22}K_{62}S_{20}Zn_2B_1Mo_{0.8}$ + 3 ton PM (N as USG); $T_6$= $N_{138}P_{46}K_{58}S_{20}Zn_2B_1Mo_{0.8}$+ 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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# EFFECT OF PLANT GROWTH REGULATORS ON THE PERFORMANCE OF LADY'S FINGER (*Abelmoschus esculentus* L.)

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## Abstract

Field experiments were conducted at the Plant Physiology Field of Horticulture Research Centre (HRC) of Bangladesh Agricultural Research Institute (BARI), Gazipur during the summer seasons of 2022 and 2023 to study the effect of plant growth regulators (PGRs) on the growth and yield of lady's finger. Two okra varieties, namely BARI Dheros-2 and OK-1820 were sprayed with seven PGRs treatments *viz.*, two levels (100 and 200 ppm) of naphthalene acetic acid (NAA), two levels (100 and 200 ppm) gibberellic acid (GA$_3$) and two levels (200 and 400 ppm) of chlorocholine chloride (CCC) concentrations at 4 weeks after seed sowing, first flowering and 3 weeks after first flowering stages. The control plots were treated with tap water. The experiment was conducted in a split-plot design with three replications allocating varieties in main plot and PGR treatments in sub plots. The plant height, leaf area index (LAI), dry weight/plant, fruit length, fruit diameter, individual fruit weight, number of fruits/plant and weight of fruits/plant were the maximum for 100 ppm GA$_3$ followed by 200 ppm GA$_3$ in both BARI Dheros-2 and OK-1820 in two years. The highest fruit yield per hectare (21.10 t in BARI Dheros-2 and 21.74 t in OK-1820 during 2022, and 29.11 t/ha in BARI Dheros-2 and 29.22 t/ha in OK-1820 during 2023) was recorded with the application of 100 ppm GA$_3$ which was followed by 200 ppm GA$_3$ (19.88 t/ha in BARI Dheros-2 and 20.87 t/ha in OK-1820 during 2022, and 28.37 t/ha in BARI Dheros-2 and 28.75 t/ha during 2023) and 400 ppm CCC (27.03 t/ha in BARI Dheros-2 and 26.88 t/ha in OK-1820 during 2023). The BARI Dheros-2, recorded the maximum average fruit yield for 100 ppm GA$_3$ (25.11 t/ha) followed by 200 ppm GA$_3$ (24.13 t/ha) and 400 ppm CCC (21.34 t/ha) while in OK-1820, 25.48, 24.81 and 23.25 t/ha average fruit yield were found in 100 ppm GA$_3$, 200 ppm GA$_3$ and 400 ppm CCC, respectively. Both the varieties provided with the maximum gross margin while treated with GA$_3$ @ 100 ppm (Tk. 4, 52,237/ha from BARI Dheros-2 and Tk. 4, 61,612/ha from OK-1820). The highest BCR (3.94) was recorded for CCC @400 ppm in OK-1820 and BCR 3.62, 3.67 and 3.58 were for 400 ppm CCC, 200 ppm CCC and 100 ppm GA$_3$ from BARI Dheros-2, respectively. It might be recommended that spraying of 400 ppm CCC or 100 ppm GA$_3$ singly in 3 equal sprays at 4 weeks after sowing, at flowering and 3 weeks after first flowering would be optimum for maximum fruit yield and highest return of lady's finger.

Keywords: Lady's finger, *Abelmoschus esculentus*, GA$_3$, NAA, CCC, Yield, BCR

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**Introduction**

Okra [*Abelmoschus esculantus* (L.) Moench] is a very popular summer vegetable crop widely cultivated all over Bangladesh. It is locally known as "Dheros" which belongs to the family Malvacae and can be grown under a high temperature range of 24-27°C. However, it is extremely sensitive to frost and temperature below 12°C and seeds germinate poorly at ground temperature of 20 °C or less (Anon., 2012). Okra pod contains good amount of potassium, calcium, magnesium, phosphorus, vitamin 'A' and 'C'. One hundred gram of fresh pod of okra has around; 1.9 g of protein, 0.2 g fat, 6.4 g carbohydrate, 0.7 g minerals and 1.2 g fiber (Tiwari *et al.*, 1998). In the year 2022-23, the total production of okra was 96 thousand tons from 12.56 thousand hectares of land with an average yield of 7.64 t ha$^{-1}$ (BBS, 2024).

The average yield of okra in our country is very low compared to the other okra growing countries such as India (12.18 t/ha), Pakistan (11.19 t/ha), Egypt (13.84 t/ha) and Ghana (21.35 t/ha) (Anon., 2022; Vanitha *et al.*, 2013). Plant growth regulators (PGRs) can profoundly influence the growth and differentiation of various parts of plant. The activities of PGs depend on their concentration and environmental factors affecting their absorption and plant's physiological state. PGRs have the ability to effect cell division, cell structure, cell expansion, cell function, and mediate environmental stress even at low concentrations (Shagufta *et al.*, 2019). Its use in crop promotes growth along the longitudinal area, increase number of branches, early flower initiation, fruit set, fruit quality and subsequently contributes towards higher production when applied at various concentrations (Maity *et al.*, 2016). Among the several growth substances, gibberellic acid (GA$_3$) naphthalene acetic acid (NAA) and chlorocholine chloride (CCC) are found very promising and these are being used in Okra (Gadade *et al.*, 2017; Meena *et al.,* 2017; Bhagure and Tambe, 2013; Maity *et al.*, 2016; Pateliya *et al.*, 2014; Mondal *et al.*, 2012). The role of GA$_3$ in cell elongation in plant has been well established which resulted in increasing the plant height. Contrary to GA$_3$ and NAA, CCC has been found to retard plant growth by reducing internodes length (Moulana *et al.*, 2020) who observed 17% decrease in internode length at 90 days after sowing (DAS). However, there is little information available on the effect of growth regulators on the growth and yield of okra in Bangladesh. In view of the above facts, the present experiment was conducted to find out a suitable dose of GA$_3$, NAA and CCC on the growth, yield and quality of okra with economic return.

**Materials and Methods**

The experiment was conducted at the research field of plant physiology section of HRC (23°59′33″ N latitude and 90°24′37.95″ E longitude) during the summer season of 2022 and 2023. The experiment was laid out in a split plot design with three replications. The experiment consisted of 7 PGRs treatments *viz.,* T$_1$ = tap water as control, T$_2$ = 100 ppm naphthalene acetic acid (NAA), T$_3$ = 200 ppm

NAA, $T_4$ = 100 ppm gibberellic acid (GA$_3$), $T_5$ = 200 ppm GA$_3$, $T_6$ = 200 ppm chlorocholine chloride (CCC) and $T_7$ = 400 ppm CCC and two varieties *viz.,* $V_1$ = BARI Dheros-2 and $V_2$ = Ok-1820 (Ispahani). The treatment 200 ppm GA$_3$ was selected as one of the treatments after reviewing the literature cited in different journals according to Shahid *et al.* (2013), Gadade *et al* (2017) and Baraskar *et al*. (2018) who all selected 200 ppm GA$_3$ as one of the treatments for their experiments on okra.  The unit plot size was 2.00 m x 2.00 m (4.0 m$^2$) having 16 plants. Manures and fertilizers were applied to the soil @ 5000 kg Cowdung, 200 kg N, 150 kg P, 150 kg K, and 20 kg S per hectare. The source of N, P, K and S were Urea, TSP, MoP and gypsum. The total amount of cowdung, TSP, gypsum and one-fourth quantity of urea and MoP were applied prior to planting seeds and the remaining three- fourth quantity of Urea and MoP was top dressed into three equal installments 30, 45 and 60 days after transplanting. Seeds of two okra varieties were dibbled at the rate of 2 seeds/hill on 12 April 2022 and 16 April 2023 maintaining 50 x 50 cm plant spacing. Prior to planting, seeds were soaked in tap water for 24 hours for uniform and better germination. After germination the seedlings were thinned out to one seedling in each hole. The harvesting of green fruits was done every alternate day. The experiments were completed on 22 July 2022 and 26 July 2023. The control plants were sprayed with tap water, whereas aqueous solutions of NAA, CCC and GA$_3$ were sprayed thrice on the plants i.e. at 4 weeks after sowing, 1$^{st}$ flowering and three weeks after 1$^{st}$ flowering. Trix was added to the solutions as a surfactant for the uniform spread of chemicals and moisture on leaves. In the first year, both varieties were attacked by Jassids 35 days after sowing (DAS) and by red mite 55 DAS. To control Jassids Admire (ai: Imidacloprid 70% WG) was sprayed @ 1.0 ml/L of water thrice at 10 days interval starting from the infestation; whereas, to control red mite Vertimec 1.8 EC (ai: Abamectin) was sprayed two times at an interval of 15 days starting from the infestation. In the 2$^{nd}$ year no infestation of insect and mites was seen because admire and omite (ai: Propargite 57% EC) were sprayed to the crops thrice at 15 days interval starting from 30 DAS. The data were recorded on plant height at the last harvest, leaf area index, dry weight/plant, fruit length, fruit diameter, individual fruit weight, number of fruits/plants, weight of fruits/plant, and fruit yield/ha. Plot yield was converted to per hectare yield.  The following equation was used to calculate the leaf area (LA) of each leaf: $LA\ (m^2) = L \times W \times k$ (1) Where, L = leaf length (m) W = leaf width (m). k= 0.62 for okra (Musa and Usman, 2016). To obtain the total leaf area per plant, the specific leaf area LA was multiplied by the number of leaves counted. The LAI was then determined by dividing the leaf area by the ground area of the plant.

 Recorded data were statistically analyzed by MSTAT-C and mean separation was done by Tukey W test at 5% level of probability. Cost-return analysis was also done considering the average yield of 2022 and 2023 for each variety.

## Results and Discussion

### Growth characters

Plant height, Leaf Area Index (LAI) and dry weight/plant were significantly influenced by different plant growth regulator treatments (Table 1). In 2022 the maximum plant height at last harvest was obtained from 100 ppm $GA_3$ (159.20 cm in BARI Dheros-2 and 142.87 cm in OK-1820 whereas, during 2023, 178.21 cm in BARI Dheros-2 and 168.17 cm in OK-1820. In 2023, in the case of BARI Dheros-2, plant height at 100 ppm $GA_3$ was identical with that of 200 ppm. The lowest plant height was recorded from 400 ppm CCC in both varieties in both 2022 and 2023 because a spray of 400 ppm CCC produced an inhibitory effect on plant height that produced shorter plant compared to control treatment. Kuswaha *et al.* (2020) reported that highest plant height at 90 DAS (96.17 cm) and maximum number of leaves (23.79/Plant) from 100 ppm $GA_3$.

In BARI Dheros-2, during 2022, maximum leaf area index was noticed in 100 ppm $GA_3$ (6.19) which was statistically similar to 200 ppm $GA_3$ (6.03) and the lowest from control 400 ppm CCC (4.70). In OK-1820, during 2022 maximum leaf area index was recorded from 100 ppm $GA_3$ (5.71) followed by 200 ppm $GA_3$ (5.15) and the lowest from 400 ppm CCC. But during 2023, in OK-1820 the highest LAI was observed from 100 ppm $GA_3$ (8.43 and 7.18, respectively) followed by 200 ppm $GA_3$ (7.47 and 6.05, respectively) and the lowest LAI from control treatment. Konyeha and Alatise (2013) obtained leaf area index (LAI) of 3.19 to 4.40 for lady's finger at 7 WAP (weeks after planting) at irrigated condition using 60 cm x 30 cm spacing in Nigeria. Baraskar *et. al.* (2018) reported that plant height, number of branches per plant, number of leaves per plant, leaf area, fresh weight per plant.

In both the varieties during 2022 and 2023, maximum dry weight/plant was observed from 100 ppm $GA_3$ (213.10g and 165.3 g in BARI Dheros-2 and 274.31 g and 237.39 g in OK-1820) and the lowest from 400 ppm CCC in BARI Dheros-2 and OK-1820 during 2022, whereas the lowest dry weight/plant was found in 400 ppm CCC treatment in both the varieties during 2023. The increase of growth characters like plant height, LAI and dry weight/plant might be due to that $GA_3$ could be involved in many aspects of plant growth and development, such as cell enlargement, internodes elongation, stimulated RNA and protein synthesis and thereby leading to enhanced growth and development (Yamaguchi and Kamiya, 2000). The results of better performance of okra under growth regulator treatments might be due to the consequence of growth regulators on cell elongation, stimulated RNA and protein synthesis, and better diversion of food material towards flowering and fruiting. The positive influence of plant growth regulators on growth and yield of okra was in agreement with Kokare *et al.* (2006) and Nawalkar *et al.* (2007). Rajappa *et al.* (2020) obtained highest plant height (102.38 cm), leaf area/plant (1124.87 $cm^2$) from 150 ppm sprayed 30 days after sowing when 150 ppm $GA_3$, 150 ppm NAA and 100 ppm IAA were used. Chowdhury *et al.* (2014) reported that application of $GA_3$ @ 100 ppm produced maximum plant height, number of leaves/plant, number of internodes, fresh weight and dry

weight/plant. Kuswaha *et al*. (2020) reported that highest plant height at 90 DAS (96.17 cm) and maximum number of leaves (23.79/Plant) from 100 ppm $GA_3$.

**Fruit yield and yield components**

During 2022 maximum fruit length was obtained from 100 ppm $GA_3$ (13.07 cm in BARI Dheros-2 and 13.40 cm in 2OK-1820) which was closely followed by 200 ppm $GA_3$ only in BARI Dheros-2 (13.04 cm) (Table 2). The lowest fruit length of BARI Dheros-2 was noted in control treatment. In 2023, the maximum fruit length was recorded from 200 ppm $GA_3$ (16.40 cm in BARI Dheros-2 and 16.38 cm in OK-1820) which was closely followed by 100 ppm $GA_3$ (16.07 cm in BARI Dheros-2 and 16.29 cm in OK-1820), 100 ppm NAA (15.83 cm in BARI Dheros-2 and 15.85 cm in OK-1820) and 400 ppm CCC (15.81 cm in BARI Dheros-2 and 15.45 cm in OK-1820) and the lowest from control (Table 2). Application of 400 ppm CCC gave the maximum fruit diameter (15.77 and 15.23 cm in BARI Dheros-2 and OK-1820, respectively during 2022; 15.40 and 15.99 cm in BARI Dheros-2 and OK-1820, respectively during 2023). During 2022 spraying of 100 ppm $GA_3$ also gave similar fruit diameter (15.15 cm) as 400 ppm CCC recorded (15.23 cm) in OK-1820. In 2023, 100 ppm $GA_3$ registered fruit diameter (14.96 cm in BARI Dheros-2 and 15.91 cm in Ok-1820, which were identical with 400 ppm CCC and the lowest from control in both varieties during both years. In BARI Dheros-2, during 2022 maximum individual fruit weight was recorded from 100 ppm $GA_3$ (20.33 g) which was identical to 200 ppm $GA_3$ (19.93g) and followed by 200 ppm NAA and 400 ppm CCC and the lowest from control, whereas in OK-1820 the highest individual fruit weight was obtained from 100 ppm $GA_3$ (21.13 g) which was followed by 200 ppm $GA_3$ (19.73g), 100 ppm NAA (19.60g) and 200 ppm NAA (19.53g) and the lowest from control in BARI Dheros-2.

In 2022 the maximum number of green fruits/plants was harvested with the application of 100 ppm $GA_3$ (37.90 in BARI Dheros-2 and 45.70 in OK-1820), which was followed by 200 ppm $GA_3$ (35.70 in BARI Dheros-2 and 42.30 in OK-1820) and 100 ppm NAA in OK-1820, while minimum number of fruits/plants was recorded in control in both varieties (Table 2). In 2023, the highest number of green fruits/plant was obtained from 100 ppm $GA_3$ (65.30 in BARI Dheros-2 and 66.06 in OK-1820) which was statistically similar to 200 ppm $GA_3$ only in OK-1820 (63.66/plant) and the lowest number of green fruits was recorded from control in both the varieties. Maximum weight of fruits/plant was recorded from 100 ppm $GA_3$ (546.0 g in BARI Dheros-2 and 739.5 g in OK-1820 during 2022; 1116.7 g in BARI Dheros-2 and 1146.7 g in OK-1820) which was followed by 200 ppm $GA_3$ (515.0 g in BARI Dheros-2 and 689.0 g in OK-1820 during 2022; 1050.0 g in BARI Dheros-2 and 1120.0 g in OK-1820 during 2023) and 200 ppm NAA (709.0 g in OK-1820) and 100 ppm NAA (688.0 g) and the minimum weight of fruits/plant from control in both varieties during both years. Maity *et al.* (2016) obtained the highest fruit length and maximum fruit number/plant from the application of 150 ppm $GA_3$. Bhagure and Tambe (2013) and Singh and Singh (2020) obtained maximum number of fruits/plant (12.29) from 100 ppm $GA_3$.

**Table 1. Effect of Plant growth regulators on growth characters of two varieties of okra during 2022 and 2023**

| Treatment | Plant height at last harvest (cm) | | | | Leaf Area Index (LAI) | | | | Dry weight/plant (g) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2022 | | 2023 | | 2022 | | 2023 | | 2022 | | 2023 | |
| | $V_1$ | $V_2$ | $V_1$ | $V_2$ | $V_1$ | $V_2$ | $V_1$ | $V_2$ | $V_1$ | $V_2$ | $V_1$ | $V_2$ |
| $T_1$ | 145.47c | 124.87de | 137.30d | 143.23e | 4.89c | 4.64c | 4.23e | 4.39e | 140.0d | 136.0de | 176.49f | 130.20f |
| $T_2$ | 149.63b | 126.52cd | 156.33c | 154.77d | 5.59b | 4.53c | 5.23d | 4.78de | 147.2c | 139.6c | 229.89c | 175.44de |
| $T_3$ | 142.67d | 127.79c | 146.27d | 137.20f | 4.49d | 3.94de | 4.52e | 4.31 e | 136.0e | 138.1cd | 213.35de | 162.88e |
| $T_4$ | 159.20a | 142.87a | 178.21a | 168.17a | 6.19a | 5.71a | 8.43a | 7.18a | 213.1a | 163.5a | 274.31a | 237.39a |
| $T_5$ | 150.36b | 136.34b | 173.10a | 162.93b | 6.03a | 5.15b | 7.47b | 6.05 b | 179.8b | 148.9b | 243.2 b | 221.64b |
| $T_6$ | 145.73c | 122.34e | 168.88ab | 158.20c | 4.52d | 4.15d | 5.94c | 5.43c | 140.9d | 138.9c | 206.63e | 181.90cd |
| $T_7$ | 136.01e | 115.68f | 162.07bc | 154.78d | 4.70cd | 3.90e | 5.77cd | 5.00cd | 129.5f | 135.5e | 217.70d | 195.93c |
| CV (%) | 4.37 | 4.37 | 6.21 | 6.21 | 4.13 | 4.13 | 5.45 | 5.45 | 2.16 | 2.46 | 6.58 | 6.58 |

Means within a column, having similar letter (s) are not significantly different by Tukey W test at 5% probability level;

$T_1$ = control (Tap $H_2O$ spray), $T_2$ = 100 ppm NAA, $T_3$ = 200 ppm NAA, $T_4$ = 100 ppm $GA_3$, $T_5$ = 200 ppm $GA_3$, $T_6$ = 200 ppm CCC and $T_7$ = 400 ppm CCC; $V_1$ = BARI Dheros-2, $V_2$ = OK-1820 (Ispahani)

**Table 2. Effect of plant growth regulators on yield attributes and yield of two varieties of okra during 2022 and 2023**

| Treatment | Fruit length (cm) | | | | Fruit Diameter (mm) | | | | Individual Fruit weight (g) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2022 | | 2023 | | 2022 | | 2023 | | 2022 | | 2023 | |
| | $V_1$ | $V_2$ | $V_1$ | $V_2$ | $V_1$ | $V_2$ | $V_1$ | $V_2$ | $V_1$ | $V_2$ | $V_1$ | $V_2$ |
| $T_1$ | 12.25c | 12.44e | 14.42c | 13.50d | 13.52f | 13.63d | 14.01cd | 14.31d | 18.35e | 18.69c | 15.25d | 15.27c |
| $T_2$ | 12.63bc | 13.10bc | 15.83ab | 15.85ab | 13.75e | 14.19c | 15.06ab | 14.90c | 19.03d | 19.60 b | 17.55c | 16.88ab |
| $T_3$ | 12.37c | 12.90d | 14.62c | 14.35cd | 13.52f | 14.05c | 13.96d | 14.75c | 19.73b | 19.53b | 15.97d | 16.53b |
| $T_4$ | 13.07a | 13.40a | 16.07a | 16.29a | 15.44b | 15.15a | 14.96abc | 15.91a | 20.33a | 21.13a | 18.80a | 17.04ab |
| $T_5$ | 13.04a | 13.20b | 16.40a | 16.38a | 14.98c | 14.44b | 14.11 bcd | 15.16b | 19.93ab | 19.93b | 18.48ab | 16.90ab |
| $T_6$ | 12.30c | 12.93cd | 14.68c | 14.78 bc | 14.27d | 13.61d | 14.19bcd | 14.29d | 19.13c | 18.30c | 16.97c | 16.86ab |
| $T_7$ | 12.65bc | 13.12bc | 15.81abc | 15.45abc | 15.77a | 15.23a | 15.40a | 15.99a | 19.53bc | 18.23c | 17.69bc | 17.38a |
| CV (%) | 2.37 | 2.37 | 5.27 | 5.27 | 2.31 | 2.31 | 3.37 | 3.37 | 2.16 | 2.16 | 4.16 | 4.16 |

*Table 2. continued.*

| Treatment | Fruits/plant (no.) | | | | Weight of fruits/plant (g) | | | | Fruit yield (t/ha) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2022 | | 2023 | | 2022 | | 2023 | | 2022 | | 2023 | | Average of two years | |
| | $V_1$ | $V_2$ | $V_1$ | $V_2$ | $V_1$ | $V_2$ | $V_1$ | $V_2$ | $V_1$ | $V_2$ | $V_1$ | $V_2$ | $V_1$ | $V_2$ |
| $T_1$ | 25.61f | 30.03e | 35.50f | 34.86e | 334.3f | 451.1e | 464.75g | 459.23 f | 10.70d | 14.42d | 16.12e | 16.17e | 13.41f | 15.30e |
| $T_2$ | 33.50c | 41.50b | 38.86e | 47.76d | 488.5c | 688.0b | 698.93f | 752.18e | 15.29d | 19.99c | 18.96d | 20.62d | 17.13e | 20.31d |
| $T_3$ | 32.30d | 40.50c | 45.13d | 47.92d | 477.5cd | 709.0b | 736.75e | 761.16e | 16.77d | 19.63c | 19.4d | 19.65d | 18.09d | 19.64d |
| $T_4$ | 37.90a | 45.70a | 65.30a | 66.06a | 546.0a | 739.5a | 1116.7a | 1146.7a | 21.10a | 21.74a | 29.11a | 29.22a | 25.11a | 25.48a |
| $T_5$ | 35.70b | 42.30b | 61.43b | 63.66a | 515.0b | 689.0b | 1050.0b | 1120.0b | 19.88b | 20.87b | 28.37b | 28.75a | 24.13b | 24.81 |
| $T_6$ | 28.60e | 38.90d | 56.11c | 55.97c | 464.0d | 576.5d | 950.0d | 926.7d | 15.85c | 17.78d | 25.67c | 25.54c | 20.76c | 21.66c |
| $T_7$ | 27.90e | 38.80d | 61.13b | 61.32b | 421.0e | 591.5cd | 990.0c | 966.7c | 15.64c | 19.6c2 | 27.03b | 26.88b | 21.34c | 23.75b |
| CV (%) | 2.23 | 2.23 | 4.33 | 4.33 | 3.63 | 3.63 | 5.43 | 5.43 | 5.46 | 5.46 | 6.16 | 6.16 | 7.12 | 6.97 |

Means within a column, having similar letter (s) are not significantly different by Tukey W test at 5% probability level ;

$T_1$ = control (Tap $H_2O$ spray), $T_2$ = 100 ppm NAA, $T_3$ = 200 ppm NAA, $T_4$ = 100 ppm $GA_3$, $T_5$ = 200 ppm $GA_3$, $T_6$ = 200 ppm CCC and $T_7$ = 400 ppm CCC; $V_1$ = BARI Dheros-2, $V_2$ = OK-1820 (Ispahani).

In 2022, the highest fruit yield was recorded from the application of 100 ppm $GA_3$ (21.10 t/ha in BARI Dheros-2 and 21.74 t/ha in OK-1820) which was followed by 200 ppm $GA_3$ (19.88 t/ha in BARI Dheros-2 and 20.87 t/ha in OK-1820) and the lowest from control in both varieties (Table 2). In 2023, the highest fruit yield was also recorded from 100 ppm $GA_3$ (29.11 t/ha in BARI Dheros-2 and 28.75 t/ha in OK-1820) which was statistically similar to 200 ppm $GA_3$ (28.37 t/ha in BARI Dheros-2 and 28.75 t/ha in OK-1820) and followed by 400 ppm CCC (27.03 t/ha in BARI Dheros-2 and 26.88 t/ha in OK-1820). The lowest yield was observed in control treatment in both varieties during both years. The yield performance of okra in 2023 was much better than that of 2022 because of higher plant height, higher dry weight/plant, higher fruit size and higher number of fruits/plant. Besides, the first year crop was infested by Jassids and red mites resulting in poor growth and ultimately the yield performance was lower than the second year crop which was not attacked by insects as insecticides were sprayed to the plants for precautionary measure.

In respect of average yield of two years, the maximum fruit yield of BARI Dheros-2 was recorded from 100 ppm $GA_3$ (25.11 t/ha) followed by 200 ppm $GA_3$ (24.13 t/ha) and 400 ppm CCC (21.34 t/ha) and the minimum yield obtained from control treatment (13.41 t/ha) in the same variety, while the highest fruit yield of OK-1820 was obtained from 200 ppm $GA_3$ (25.48 t/ha) which was statistically similar to 200 ppm $GA_3$ (24.81 t/ha) and followed by 400 ppm CCC (23.25 t/ha) and the least yield from control treatment (15.30 t/ha) (Table 2). Meena *et al.* (2017) reported that maximum fruit yield/ha in okra was recorded from the application of 20 ppm NAA and 30 ppm $GA_3$ among three concentrations of NAA (10, 20 and 30 ppm) and three concentrations of $GA_3$ (10, 20 and 30 ppm). Bhagure and Tambe (2013) obtained the highest fruit yield/plant grom 100 ppm $GA_3$, whereas Maity *et al.* (2016) obtained the highest number of fruits (18.20/plant) and maximum fruit yield (324.87 g/plant) from 150 ppm $GA_3$ followed by 100 ppm $GA_3$ (17.80/plant; 314.177 g/plant). Pateliya *et al.* (2014) reported that application of 300 ppm CCC produced maximum fruit length, fresh fruit weight, number of fruits/plant and fruit yield both per plant and hectare. Moulana *et al.* (2020) got the highest yield of fruit 13.23 t/ha from 350 ppm CCC application. Kuswaha *et al.* (2020) reported that they got highest number of fruits (22.05/plant), maximum weight of fruits (301.19 g/plant) and fruit yield (16.74 t/ha) from 100 ppm $GA_3$ among 25, 50 and 100 ppm $GA_3$ and higher number of fruits (18.01/plant), maximum weight of fruits (212.04 g/plant) and fruit yield (11.78 t/ha) from 750 ppm CCC among 250, 500 and 750 ppm CCC.

In case of $GA_3$, the increase in fruit yield might be due to greater photosynthesis, higher food accumulation, better plant growth and higher yield attributes. Another probable reason for increasing yield attributes might be due to the increasing growth characters by cell elongation and cell expansion that might have ultimately increased in the fruit yield as a result of $GA_3$ application in this study. CCC application increased fruit diameter and increased fruit length little in 2023. Kumar

*et al.* (2018) reported that 600 ppm CCC gave maximum fruit diameter (16.13 mm) among three concentrations of CCC (200, 400 and 600 ppm). Chowdhury *et al.* (2014) obtained maximum number of pods/plant (33.77), pod length (17.66 cm) and pod diameter (1.77 cm) and yield/ha (16.67 t/ha) from the application of $GA_3$ @ 100 ppm. Kushwaha *et al.* (2000) reported that foliar spray of $GA_3$ was found beneficial for increasing maximum number of fruit (22.05), highest fruit yield plant$^{-1}$ (301.19 g) and fruit yield ha$^{-1}$ (16.74 t) was recorded with 100 ppm $GA_3$.

## Economics

Cost-return analysis of okra production with the application of NAA, $GA_3$ and CCC (average of 2022 and 2023 for BARI Dheros-2 and OK-1820) was presented in Table 3. In BARI Dheros-2, the maximum gross return was recorded at 100 ppm $GA_3$ (Tk 6,27,625/ha) followed by 200 ppm $GA_3$ (Tk 6, 03,125/ha) and 400 ppm CCC (Tk 5,33,375/ha) and the minimum from the control (Table 4). This variety gave the highest gross margin (Tk 4, 52,237/ha) at 100 ppm $GA_3$ followed by 200 ppm $GA_3$ (Tk 3, 87,737/ha) and 400 ppm CCC (Tk. 3, 85,987/ha OK-1820 gave the maximum gross return (Tk 6,37,000/ha) followed by 200 ppm $GA_3$ (Tk 6,20,00/ha) and 400 ppm CCC (Tk. 5,81,250/ha). The maximum gross margin was recorded at 100 ppm $GA_3$ (Tk 4, 61,612/ha) followed by 400 ppm CCC (Tk 4, 33,862/ha) and 200 ppm $GA_3$ (Tk 4, 04,862/ha), and the lowest in control (Tk 2, 46,987/ha). The maximum benefit cost ratio (BCR) was noted at 200 ppm CCC (3.67) closely followed by 400 ppm CCC (3.62) and then followed by 100 ppm $GA_3$ (3.58) in BARI Dheros-2, whereas, in OK-1820 BCR was found maximum at 400 ppm CCC (3.94) followed by 200 ppm CCC (3.83) and 100 ppm $GA_3$ (3.63) and 200 ppm NAA (3.55) and the minimum in control (2.82). Although the higher gross margin was recorded at 100 ppm $GA_3$ and 200 ppm $GA_3$ treatments in both varieties, the maximum BCR was not obtained from $GA_3$ treatments because of the high cost involvement in $GA_3$ treatments.

**Table 3. Cost-return analysis of lady's finger production with the application of NAA, CCC and GA₃ (Average of two years for each variety of BARI Dheros-2 and Ok-1820)**

| Treatment | Mean pod yield (t/ha) | Gross return (Tk/ha) | Cost of treatment Tk/ha) | Total cost of cultivation (Tk/ha) | Gross margin (Tk/ha) | Benefit-cost ratio (BCR) |
|---|---|---|---|---|---|---|
| BARI Dheros-2 | | | | | | |
| $T_1$ | 13.41 | 335250 | 16500 | 135388 | 199862 | 2.48 |
| $T_2$ | 17.13 | 428125 | 18000 | 136888 | 291237 | 3.13 |
| $T_3$ | 18.09 | 452125 | 19500 | 138388 | 313737 | 3.27 |
| $T_4$ | 25.11 | 627625 | 56500 | 175388 | 452237 | 3.58 |
| $T_5$ | 24.13 | 603125 | 96500 | 215388 | 387737 | 2.80 |
| $T_6$ | 20.76 | 519000 | 22500 | 141388 | 377612 | 3.67 |
| $T_7$ | 21.34 | 533375 | 28500 | 147388 | 385987 | 3.62 |

| Treatment | Mean pod yield (t/ha) | Gross return (Tk/ha) | Cost of treatment Tk/ha | Total cost of cultivation (Tk/ha) | Gross margin (Tk/ha) | Benefit-cost ratio (BCR) |
|---|---|---|---|---|---|---|
| OK-1820 | | | | | | |
| $T_1$ | 15.30 | 382375 | 16500 | 135388 | 246987 | 2.82 |
| $T_2$ | 20.31 | 507625 | 18000 | 136888 | 370737 | 3.71 |
| $T_3$ | 19.64 | 491000 | 19500 | 138388 | 352612 | 3.55 |
| $T_4$ | 25.48 | 637000 | 56500 | 175388 | 461612 | 3.63 |
| $T_5$ | 24.81 | 620250 | 96500 | 215388 | 404862 | 2.88 |
| $T_6$ | 21.66 | 541500 | 22500 | 141388 | 400112 | 3.83 |
| $T_7$ | 23.25 | 581250 | 28500 | 147388 | 433862 | 3.94 |

$T_1$ = control (Tap $H_2O$ spray), $T_2$ = 100 ppm NAA, $T_3$ = 200 ppm NAA, $T_4$ = 100 ppm $GA_3$, $T_5$ = 200 ppm $GA_3$, $T_6$ = 200 ppm CCC and $T_7$ = 400 ppm CCC; $V_1$ = BARI Dheros-2, $V_2$ = OK-1820 (Ispahani)

Basic cost of cultivation: Tk. 118888.00;1 kg  produce: Tk 25.00.

Cost of PGRs:

1. Naphthalene Acetic Acid (NAA):Tk 3000.00/100 g

2. Cycocel (CCC): Tk 6000.00/100 g

3. Gibberellic acid: 800.00/g

## Conclusion

The results indicated that application of $GA_3$ @100 ppm yielded 21.10 and 21.74 t/ha in BARI Dheros-2 and OK-1820, respectively while $GA_3$ @ 200 ppm gave the second highest yield 19.88 t/ha of BARI Dheros-1 and 20.87 t/ha of OK- 1820 followed by NAA @ 200 ppm (16.77 t/ha in BARI Dheros-1 and 19.63 t/ha in OK 1820 during 2022. In 2023, spraying of $GA_3$ @ 100 ppm recorded the highest fruit yield 29.11 t/ha in BARI Dheros-2 and 29.22 t/ha in OK-1820, which was identical with 200 ppm $GA_3$ (28.37 t/ha in BARI Dheros-2 and 28.75 t/ha in OK-1820. Application of 200 ppm NAA and 400 ppm CCC also performed well with respect to fruit yield in two varieties.  In Ok-1820, the maximum gross margin was found from 400 ppm CCC followed by 200 ppm CCC and 100 ppm $GA_3$, whereas in BARI Dheros-2, the highest BCR from 200 ppm CCC followed by 400 ppm CCC and 100 ppm $GA_3$ in both BARI Dheros-2 and OK-1820.  Application of 100 ppm $GA_3$ or 200-400 ppm CCC independently in 3 equal sprays at 4 weeks after sowing, first flowering and 3 weeks after first flowering would be optimum for maximum fruit yield and highest return of lady's finger.

## Acknowledgement

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# EFFICACY OF CHEMICAL FUNGICIDES FOR THE MANAGEMENT OF POWDERY MILDEW IN PUMPKIN

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## Abstract

The experiment was conducted to study the efficacy of nine new fungicides in managing powdery mildew disease of pumpkin under field conditions during *rabi* season using the variety 'BARI Mistikumra-2'. The fungicides were K-zeb M-45 WP (Mancozeb 80% WP), Cymozeb 72 WP (Mancozeb 64% + Cymoxanil 8%), Carbostin 50 WDG (Carbendazim 50% WP), Ridhuk 25 SC (Hexaconazole 3%), Lalon 75 WDG (T$_5$Trifloxostrobin 25% + Tebuconazole 50%), Kariwa 28 SC (Azoxystrobin 20% + Cyproconazole 80%), Limotar top 32.5 SC (Azoxystrobin 20% + Difenazole 12.5%), Switch 72 WP (Mancozeb 64% + Cymoxanil 8%) and Bioconazole plus 25 SC (hexaconazole 3% + Tricyclazole 22%). All fungicides enhanced vegetative growth and fruit yield of pumpkin in general. Among the fungicides, Carbostin 50 WDG (@ 2% performed better and reduced the present disease index by 3.17% resulted in a higher fruit yield (19.75 t/ha) of pumpkin. The investigation revealed that the application of Carbostin 50 WDG fungicide would be a potential aspirant for effective management of powdery mildew disease of pumpkins under field conditions.

Keywords: Powdery mildew, Pumpkin, Fungicide, Yield

## Introduction

Pumpkin (*Cucurbita maxima*), a member of the Cucurbitaceae family, is a widely used vegetable in Bangladesh (Lisa *et al.,* 2022). It originated in Central America, domesticated in Mexico and is now widely distributed worldwide (Ahmad and Khan, 2019). It serves as a valuable source of functional components mainly carbohydrates, vitamins A, C, and E and various minerals which act as an antioxidant in human nutrition (Aziz *et al.*, 2023). Pumpkin seeds are a rich source of unsaturated fatty acids and oil (Lisa *et al.,* 2022). Approximately 1.40 lakh hectares in Bangladesh are used for growing this crop, with an average yield of 20-25 metric tons per hectare (Anon., 2021). Nowadays, pumpkin production has decreased dramatically due to the consequence of the occurrence of diseases.

Pumpkins are attacked by many diseases such as bacterial wilt, angular leaf spot, phytophthora blight, downy mildew, powdery mildew, etc. Among the diseases powdery mildew is common. This disease affects all cucurbits (Rhouma *et al.,* 2023). This disease is caused by two fungal species viz. *Podosphaera xanthii* and

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*Erysiphe cichoracearum* (Cohen *et al.,* 2004; Perez-Garcia *et al.,* 2009). In Bangladesh, the fungus *Erysiphe cichoracearum* (Perfect stage-*Oidium* spp.) causes most of the powdery mildew on cucurbits (Yasmin *et al.,* 2008). Powdery mildew appears on leaves, petioles and young stems as a white powdery mass composed of mycelium and numerous spores (Rhouma *et al.*, 2023; Glawe, 2008). Under favourable environmental conditions of this disease, the entire upper surface of the leaf may be covered with the powdery fungus and the whole field may appear to white within a few days (Cohen *et al.*, 2004; Rhouma *et al.*, 2021) and the photosynthesis process is hampered. The resulting decrease in photosynthates may cause significant reductions in the quality and fruit yield and yield loss exceeds 30 to 34 % in the crop (Keinath and DuBose, 2004; Tisserat, 2006).

In the commercial sector, powdery mildew is commonly managed through the use of various synthetic fungicides and/or breeding methods that create cultivars with resistance. Many agricultural experts advised implementing a rotation of fungicides from different classes on a 7-10-day spray schedule once a disease has been detected (Horsfield, 2010). The reason why contact fungicides are effective in controlling powdery mildew is because the majority of plant infections occur on the surface of leaves, requiring thorough coverage for successful treatment. So, fungicide significantly reduces the powdery mildew disease incidence (Maryam *et al*., 2020). Repeated use of systemic chemicals builds up resistance in pathogens against fungicides (Gullino *et al.,* 2000). Mixing of curative and preventive fungicides is the best tactic to get rid of fungicidal resistance (Van den Bosch *et al.,* 2014). Despite the fungicide use is an effective strategy to control plant diseases (Matheron and Porchas, 2008) but continuous use may deteriorate the environment. Limited reports on the chemical control of pumpkin powdery mildew disease are available in Bangladesh. Hence, the present investigation was undertaken to evaluate some new chemical fungicides for the management of powdery mildew disease in pumpkin.

**Materials and Methods**

The experiment was conducted in the research field of the Plant Pathology Division, Bangladesh Agricultural Research Institute (BARl), Gazipur during the *rabi* season of 2017. The texture of the soil was loamy. The experiment was laid out in a Randomized Complete Block Design (RCBD) with ten treatments and each treatment was replicated three times. The following treatments were used in this experiment (Table 1).

The experimental land was well prepared by ploughing and laddering. Each plot size was 4×5 m$^2$ maintaining pits size 50×50×45 cm. The pumpkin variety BARI Mistikumra -2 was used in this experiment. The chemical fertilizers were used as nutrient sources for soil as recommended by BARI. Three seeds of pumpkin were sown in each pit and after germination one healthy seedling was allowed to grow in each plot. Weeding and irrigation was done when required. The insecticide Malathion 57 EC was applied three times at 10-day intervals to control pumpkin

insects. The fungicides were sprayed three times at 9 days interval. The spray was stared with the first appearance of disease. Data were recorded on percentage of disease index, percentage of disease reduction over control, number of fruits per plot, yield per plot (kg). Per plot yield was converted into per hectare yield (ton). Ten leaves per plant in each treatment were considered for measurement of the percentage of disease index.

**Table 1. The name of fungicides with their group name and concentration**

| Treatments & name of fungicides | Group name of fungicides with a.i. | Concentration (%) (g or ml/L) |
|---|---|---|
| $T_1$= K-zeb M-45 WP | Mancozeb 80% WP | 2.00 |
| $T_2$= Cymozeb 72 WP | Mancozeb 64% + Cymoxanil 8% | 2.00 |
| $T_3$= Carbostin 50 WDG | Carbendazim 50% WP | 2.00 |
| $T_4$= Ridhuk 25 SC | Hexaconazole 3% + Tricyclazole 22% | 3.00 |
| $T_5$= Lalon 75 WDG | $T_5$Trifloxostrobin 25% + Tebuconazole 50% | 0.50 |
| $T_6$= Kariwa 28 SC | Azoxystrobin 20% + Cyproconazole 80% | 1.00 |
| $T_7$= Limotar top 32.5 SC | Azoxystrobin 20% + Difenazole 12.5 % | 1.00 |
| $T_8$= Switch 72 WP | Mancozeb 64% + Cymoxanil 8% | 1.00 |
| $T_9$= Bioconazole plus 25 SC | Hexaconazole 3% + Tricyclazole 22% | 1.00 |
| $T_{10}$= Control | Spray water only | |

Data on disease index for Powdery mildew was recorded 7 days after the last spray and converted into percent disease index by using the following formula (Malviya *et al.,* 2022).

$$\text{Percent disease index (PDI)} = \frac{\text{Sum of numerical ratings}}{\text{Number of leaves observed} \times \text{Maximum rating scale}} \times 100$$

The data on diseases severity of Powdery mildew was rated following a 0-4 scale, where 0= healthy or no infection, 1= slight infection, fine coating of powdery growth on upper leaves, stem free from powdery mass, 2= moderately infected, nearly 50% plant is covered powdery mass, the stem also infected, 3= nearly 75% leaves infected, whole plants are covered with powdery mass, the stem also infected and 4= all leaves as well as stem and other parts coated with thick powdery mass, leaf colour changes to greyish and starts drying. The percentage of disease reduction of each treatment over control was calculated. Data on Percent disease index of powdery mildew (%) were transformed according to square root transformation formula before analysis.

Data were analyzed statistically using R software program. The significant differences in the treatment means were compared by Duncan's Multiple Range Test (DMRT) at 1% level. The correlation between vegetative growth of crop and yield parameters with disease index (%) were also computed.

## Results and Discussion

### Disease index (%)

The effect of fungicides on the percent disease index of Powdery mildew of pumpkin was evaluated at 110 days after sowing (DAS). The PDI (percent disease index) ranged from 3.17% to 79.51%, which was found significantly different among the treatments (Table 2). The highest disease index (79.51%) was recorded in the control (only water spray) and the lowest disease index (3.17%) was recorded in the treatment $T_3$ (Carbostin 50 WDG @ 2%). So, the fungicide Carbostin 50 WDG showed highest potential to suppress the powdery mildew disease of pumpkin.

### Disease reduction (%)

The disease reduced by the fungicide treatments ranged from 58.19% to 96.02% (Table 2). The lowest disease reduction was recorded from $T_6$ (Kariwa 28 SC) treatment and the highest disease reduction was obtained from $T_3$ over the control treatment.

### Number of fruits per plot

Regarding the number of fruits per plot, the maximum number of pumpkin fruits per plot (28.60) was observed in $T_3$ and the minimum number of fruits per plot (15.08) was attained from the control (Table 3). Based on the findings, it could be figured out that Carbostin played an imperative role in controlling powdery mildew disease of pumpkin.

**Table 2. Effect of fungicides on the severity (%) and percent reduction of powdery mildew disease of pumpkin under field condition**

| Treatments | Percent disease index of powdery mildew (%) | Disease reduction over control (%) |
|---|---|---|
| $T_1$= K-zeb M-45 WP | 21.78 (4.67) d | 72.61 |
| $T_2$= Cymozeb 72 WP | 15.49 (3.94) e | 80.52 |
| $T_3$= Carbostin 50 WDG | 3.17 (1.78) i | 96.02 |
| $T_4$= Ridhuk 25 SC | 24.95 (4.99) c | 68.62 |
| $T_5$= Lalon 75 WDG | 17.23 (4.15) e | 78.33 |
| $T_6$= Kariwa 28 SC | 12.43 (3.53) f | 84.37 |
| $T_7$= Limotar top 32.5 SC | 33.25 (5.77) b | 58.19 |
| $T_8$= Switch 72 WP | 6.04 (2.76) h | 92.40 |
| $T_9$= Bioconazole plus 25 SC | 8.88 (2.98) g | 88.84 |
| $T_{10}$= Control | 79.51 (8.92) a | - |
| Level of significance | ** | |
| CV (%) | 3.05 | |

Figures in the parenthesis are square root transformed values.

DAS = Days after Sowing, CV=Co-efficient of variations, Here, values in the column having a similar letter (s) are statistically identical (DMRT test at p<0.01). ** = 1% level of significance.

**Table 3. Effect of different chemical fungicides on yield contributing characters of pumpkin combating powdery mildew under field conditions**

| Treatments | No. of fruits per plot | Yield per plot (kg) | Yield (t/ha) |
|---|---|---|---|
| $T_1$= K-zeb M-45 WP | 22.33 d | 32.43 c | 16.29 bc |
| $T_2$= Cymozeb 72 WP | 24.17 cd | 33.52 bc | 16.73 bc |
| $T_3$= Carbostin 50 WDG | 28.60 a | 39.53 a | 19.75 a |
| $T_4$= Ridhuk 25 SC | 22.23 d | 31.82 c | 15.76 c |
| $T_5$= Lalon 75 WDG | 21.60 d | 33.24 bc | 16.65 bc |
| $T_6$= Kariwa 28 SC | 23.34 cd | 34.25 bc | 17.16 b |
| $T_7$= Limotar top 32.5 SC | 24.28 cd | 28.53 d | 14.27 c |
| $T_8$= Switch 72 WP | 27.48 ab | 35.64 b | 17.74 b |
| $T_9$= Bioconazole plus 25 SC | 25.26 c | 34.53 bc | 17.26 b |
| $T_{10}$= Control | 15.08 e | 18.56 e | 9.26 d |
| Level of significance | ** | ** | ** |
| CV (%) | 2.33 | 5.67 | 6.23 |

CV=Co-efficient of variations, Here, values in the column having a similar letter (s) are statistically identical (DMRT test at p<0.01). ** = 1% level of significance.

### Yield per plot (kg)

The fruit yield per plot varied significantly in different treatments (Table 3). The highest fruit yield per plot (39.53 kg) was found in $T_3$ and it was different significantly from the rest treatments. The findings of the study indicated that the pumpkin fruit yield per plot was varied among the treatments in the field conditions and Carbostin 50 WDG demonstrated the best performance in controlling powdery mildew disease and increasing crop yield.

### Yield per hectare (tons)

Notably, significant variations were observed among the fungicide treatments in respect of pumpkin yield per hectare (Table 3). The highest yield per hectare (19.75 tons) was found in $T_3$ which was different significantly from the rest treatments. The lowest yield per hectare (9.26 tons) was recorded in the control.

The results of the investigation showed that there existed a substantial negative correlation between the severity of powdery mildew disease and vegetative growth as well as fruit yield of pumpkin (Figure 1). Significant negative correlations were found to be existed between the powdery mildew disease severity with number of fruits per plant ($y = -0.583x + 28.974$), yield per plot ($y = -0.8791x + 40.555$) and yield per hectare ($y = -0.4385x + 20.252$). The findings validated that the application of chemical fungicides would reduce the severity of powdery mildew disease and thereby, enhanced vegetative growth as well as the fruit yield of pumpkin.
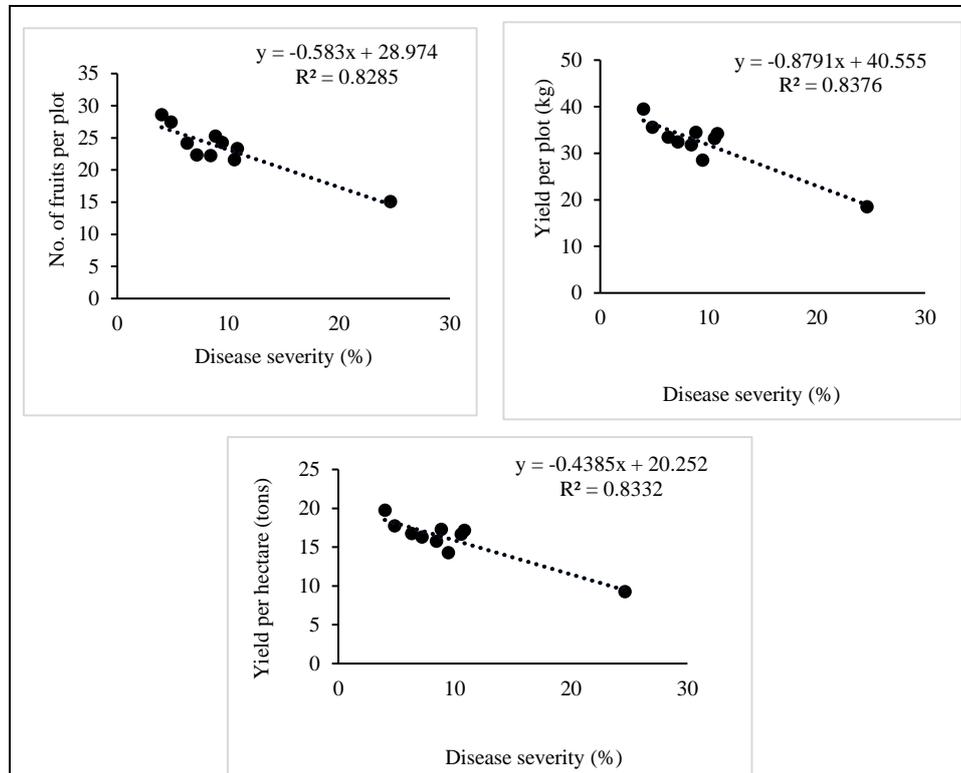
**Fig. 1. Correlation between vegetative growth and yield parameters of pumpkin with powdery mildew disease severity (%) (a-c).**

The impact of various fungicides was imperative on severity of powdery mildew disease, fruit yield, and yield components of pumpkin (Table 2 & 3). The outcomes demonstrated the significant effectiveness of all fungicides, viz. K-zeb M-45 WP, Cymozeb 72, Carbostin 50 WDG, Ridhuk 25 SC, Lalon 75 WDG, Kariwa 28 SC, Limotar top 32.5 SC, Switch 72 WP, and Bioconazole plus 25 SC against powdery mildew disease of pumpkin. Assessment of the percent disease index, percentage of disease reduction, number of fruits per plot, yield per plot (kg), and yield per hectare (tons) in various chemical fungicide treatments revealed compelling results. Due to fungicide treatments the severity of powdery mildew disease of pumpkin was ranged from 3.17 to 79.51%. The findings were aligned with McGrath *et al.* (2015), who reported that chemical fungicides showed a significant reduction in controlling powdery mildew disease of pumpkin. The percent of disease reduction over control ranged from 58.19% to 96.02%. The lowest diseases reduction was recorded from Kariwa 28 SC treatment and the highest disease reduction was obtained from Carbostin 50 WDG over the control treatment. These findings aligned with previous studies

reported by Jones (1978). Matheron and Porchas (2008) found that fungicide treatments used in melon varieties reduced the percentage of diseases of powdery mildew compared to untreated control.

The effect on yield and yield contributing characters of pumpkin under set treatments were enhanced by the application of different fungicides. Moreover, similar findings were reported by Bhaskar *et al.* (2012) in groundnut, Meena *et al.* (2016) in green gram, Abhishek and Sobita (2017) in garden pea, Madhuri and Sagar (2020) in black gram, Jayasekhar and Ebenazar (2016), and Rhouma *et al.* (2023) in melon. The correlation study showed a substantial negative relation between vegetative growth and fruit yield of pumpkin with powdery mildew severity.

## Conclusion

The findings of the experiment revealed that application of Carbostin 50 WDG @ 2% increased the fruit yield of pumpkin and lessened the severity of powdery mildew disease. Therefore, compared to other fungicides, Carbostin 50 WDG, a member of the Carbendazim group, was a better choice for reducing the powdery mildew disease of pumpkin under field conditions.

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# ASSESSMENT OF RAT DAMAGE SURROUNDING THE WATCH TOWER AREAS AND NEST BOX OCCUPATION BY OWL

M. S. ALAM[1] AND A.T.M. HASANUZZAMAN[2]

## Abstract

A study was carried out to assess the rat damage around the watching tower and the effectiveness of nest box for owl occupation at Rajshahi and Gazipur district. Watching towers were set at the field and nest box were installed in different trees above 3.7 – 4.5 m from the ground level in both the locations. Wheat, barley, potato, sweet potato and groundnut crop damaged by rat were assessed at 0-25, 26-50 and 51-75 m apart around the watching tower areas. Nest box occupancy was also recorded for nesting and roosting by owl. Percent rat damage in different growth stages of wheat and barley differed significantly in active burrow count methods and cut uncut methods around the owl watching tower areas. Significantly the lowest number of active burrows (0.6) was recorded in 0-25-m distance around the watching tower followed by 25-50-m distance and the highest number of active burrows was observed in 50-75 m distance from watching tower both in Rajshahi and Gazipur. Rat damaged and number of active burrows were higher as the distance increased from the watching tower areas. In Rajshahi, 55 % nest boxes were occupied by owl whereas 50 % nest boxes were occupied by owl in Gazipur. In Gazipur maximum nest boxes were occupied by spotted owlet (*Athene brama*) and in Rajshahi most of the nest boxes occupied by barn owl (*Tyto alba*).

Keywords: *Tyto alba*, *Athene brama*, watch tower, rat damage, wheat, potato.

## Introduction

Rodents considerably damage agricultural production around the globe. Singleton (2003) estimated losses of 5-10% in annual rice production in Asia. Rats are the serious pest of wheat crop throughout southern Asia causing damage from 3.5 to 12% (Ahmad, 1986). In Bangladesh yield loss caused by rats ranging from 32% to 67%, damage elongation was more severe during ripening stage (Aplin *et al*., 2004) and in another study pre-harvest losses ranging from 5- 17% (Belmain and Shafali, 2008). Higher rodent damage was observed in wheat crop (13.25%) while 6.90% damage was observed in rice. Burrowing rats hoard a considerable amount of rice and wheat grain in their burrow. Rodents reproduce at an alarming rate. One female mouse or rat can produce up to 120 offsprings in a single year. The over-population of rodents can equal devastation to anyone working in the agricultural business. Trapping and the use of poisons are typical remedies for a rodent infestation. But the rodents catch on to the use of traps and poisons are damaging to our eco-systems. Moreover, poison treatments are frequently tardy both because

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rodent population outbreaks are unpredictable and poisons have short-run impacts due to the rapid immigration of rodents from adjacent untreated areas; furthermore, poisons are often considered by farmers to be too costly (Skonhoft *et al*., 2006, Davis *et al*., 2004, Stenseth *et al*., 2003). Risks of mortality by self-poisoning (Eddleston, 2000) and detrimental impacts on non-target animals are additional drawbacks of rodenticides. Crop quality, eco-systems and local wildlife are all adversely affected by the use poisons. Using poisons to management rodent control causes a ripple effect within the eco-system. The poisons can leech into the soil and subsequently get washed in to the watershed through rain water and crop irrigation. For additional wildlife, rodent poisoning can equal death. If a predator ingests a poisoned rodent, they can become extremely ill and die. The cycle continues if that predator is eaten by another animal and so on. Installing barn owl boxes is an effective addition to integrated pest management. They cause no damage to the environment or agricultural crops and pose no threat to additional wildlife.

Barn owls are superior hunters, preying on small nocturnal mammals including mice, rats, voles, and gophers. Install a nest box to encourage barn owls to your property for natural rodent control. Barn owls need open fields or grassy slopes in which to hunt for prey. A single pair of barn owls can consume over 2000 rodents a year. Installing barn owl nesting boxes and watching tower throughout the crop field is a sure way to diminish the number of rodents destructing your crops. And because barn owls are not as territorial as other raptors, numerous boxes and watching tower can be installed throughout crop field to effectively control growing rodent population. Installing owl nest boxes and watching tower to control rodent population is an extremely cost-effective remedy. The cost to purchase and/or install an owl nest box is a one-time investment. Owl boxes from air superiority require little to no maintenance. The population of different owl species are decreasing day by day due loss or destruction of vegetation and large tree which is suitable for owl nesting and increased breeding success. The occupation of nest boxes varied with exposure and orientation. A higher percentage of occupation and more barn owl nestlings per breeding attempt were found in nest boxes located in the shade than in the sun, and in those facing east/north rather than other directions. The temperature in the nest boxes varied, being lowest in those located in the shade and in those facing east. Nest boxes located in crop fields fledged younger per breeding attempt than those located in date plantations (Charter *et al*., 2010) Increasing owl population and conservation installation of nest box is very important. In our crop field there are very little scope for searching and capturing rodent prey from crop field for owl. Therefore, watching tower installation is also important for seating, searching and capturing prey. Very little or no study has been done in these regards. The aim of the study was to assessethe rat damage around the watching tower and the effectiveness of nest box for owl occupation.

**Materials and Methods**

The study was conducted at Bangladesh Agricultural Research Institute, Gazipur experimental field and residential areas, and Regional Wheat Research Centre, Shampur (24.37 N, 88.66E), Rajshahi and Fruit Research Centre, Binodpur, Rajshahi (24$^0$36' N, 88$^0$65'E). Twenty owl watching towers and fifteen



**Fig.1. Owl watch tower      Fig. 2. Owl nest box**

nest boxes were installed in both the location. Watching tower are 3.7 – 4.5 m long pole prepared by bamboo with cross (X) shaped top for seating owl on it and perching and searching rat in crop field (Fig 1). Nest box (87 cm × 89.5 cm × 90.5 cm) is a triangular shaped box staying and breeding for owl safely (Fig 2). Nest boxes were installed in different tree and building above 15 feet apart from the ground level. One nest box was set for every four hectare of crop field. When Nest box was used by owl species for nesting, roosting and breeding was term as owl occupation. Nest box was set in north and east side to avoid excess sunlight and wind.

Wheat, barley, potato, sweet potato and groundnut crops damaged by rat were assessed around the watch tower areas. Rat damage assessment around the owl watching tower was done by two ways. One Number of active burrows count methods and another crop damage assessment method. Active burrow count and crop damage was done three different distance 0-25, 26-50 and 51-75 m apart around the owl watching tower according to some modification of Malhotra and Singla (2018). Data were recorded in three crop stage i.e., booting, grain filling and mature stages of the crop.

**Rat damage estimation by cut and uncut method**

Wheat and barley damage was estimated by this method. The experiment was laid out following randomized complete block design with 10 replications. Ten plots were randomly selected. In each plot ten samples were taken. The data from these ten samples were used for calculation the damage in each plot as a percentage. Very large or very small plots were not selected for sampling data. Ten samples along one of the diagonals were selected in each plot. The distance between samples (between 3 to 5 steps) depends on the length of the diagonal. A sample closer than 3 m (3 large steps) from any edge of the plot was not chosen. Each sample consists of 50 cm square frame in which all tillers, cut and uncut tillers were counted. These figures were put on a record sheet. The sampling frame in

placed without looking, so that taking data would be real. After taking data from one plot next plots were selected randomly and repeated up to ten samples.

Percent wheat and barley damage was calculated with following formula:

$$\text{Percent rat damage} = \frac{\text{Number of cut tillers}}{\text{Total number of tillers}} \times 100$$

Data were taken every 15 days interval up to harvesting of the crop.

Rodent damage of groundnut in the form of per cent pods damaged was recorded at 0-25 m, 26-50 m and 50-75 m distance from the watch tower areas. At each watch tower distance area 2 m x 2 m quadrats were placed. Five plants were uprooted from each quadrat randomly to count the total number of pods and the pods damaged by rodents (those with signs of rodent gnawing) per plant. Average number of pods damaged per plant and average density of plants/4m$^2$ were determined for each field. Percent pods damaged were calculated using the formula given below:

$$\text{Percent pod damaged} = \frac{\text{Damaged pods}}{\text{Total pods}} \times 100$$

Potato and sweet potato damage by rat in the form of percent tuber damaged was also recorded at

0-25 m, 26-50 m and 50-75 m distance from the watch tower areas. Sampling of potato and sweet potato damaged was recorded as same as the groundnut. Percent tuber damaged of potato or sweet potato were calculated using the following formula

$$\text{Percent tuber damaged} = \frac{\text{Damaged tubers}}{\text{Total tubers}} \times 100$$

Collected data were analyzed by one-way analysis of variance by IBM SPSS 26 statistical software and means were separated by Tukey's HSD test. All results are presented as mean ± SE. Graphical data were presented by Sigma plot software.

**Results and Discussion**

**Rat damage Assessment**

Percent rat damage in different growth stage of wheat differed significantly in active burrow count methods and cut uncut methods around the owl watching tower areas (Fig. 3 and 4). Significantly the lowest number of active burrow (0.6) was recorded in 0-25-m distance around the watching tower followed by 25-50 m (1.5) distance and the highest number of active burrows was observed in 50-75 m (7.5) distance from watching tower in Rajshahi. In case of cut and uncut methods follow the same trend as active burrow count methods. (Table 1). Wheat and barley damaged by rat in the form of active burrows and grain damaged at Gazipur also

followed the same trend as Rajshahi. Rat damaged and number of active burrows were higher as increase the distance from the watch tower areas (Fig. 5-8)
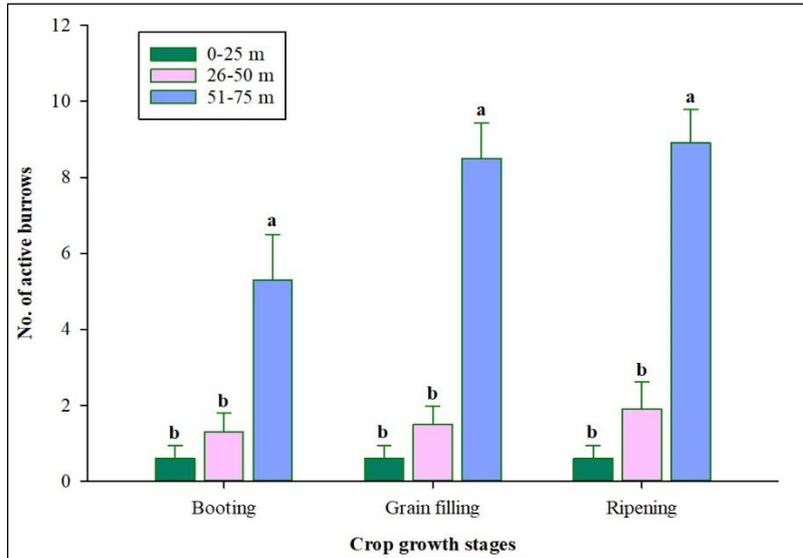


Fig. 3. Extent of rat damage in different growth stage of wheat around the watching tower area at Rajshahi by active burrow count method. Error bars indicate ± SE, Means followed by the same letter (s) are not significantly different at 5% level by Tukey's HSD.
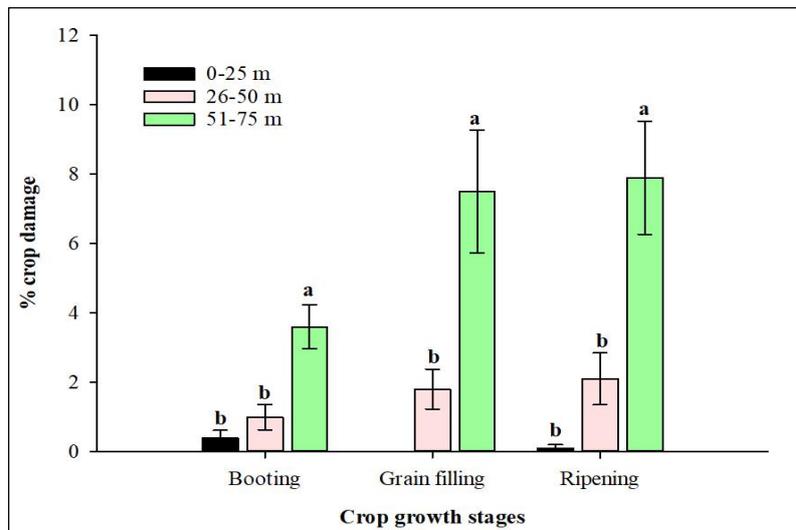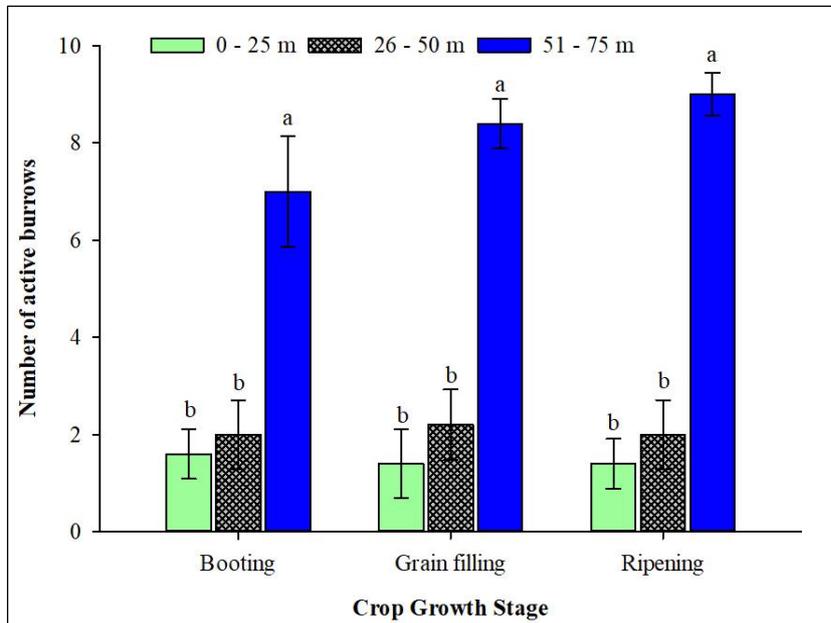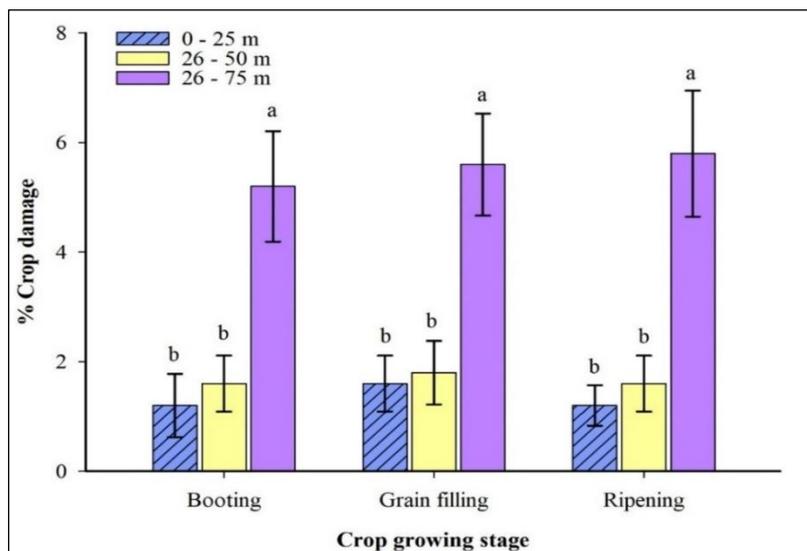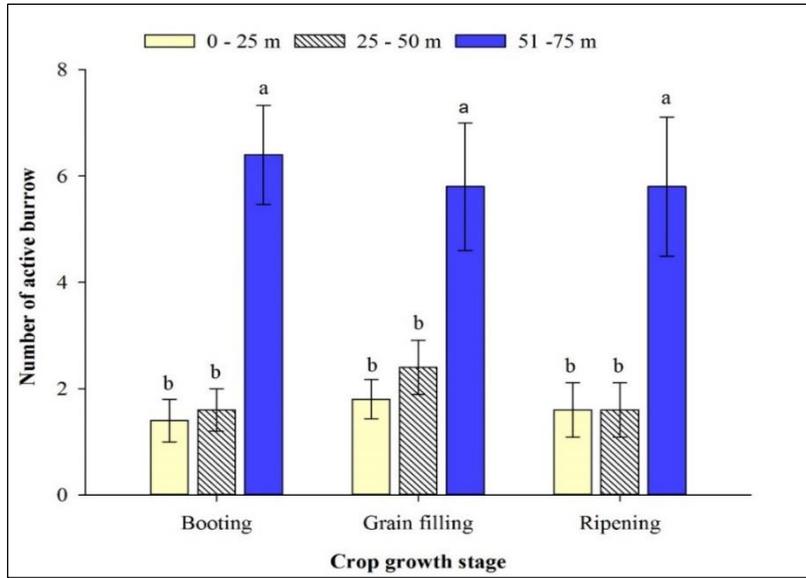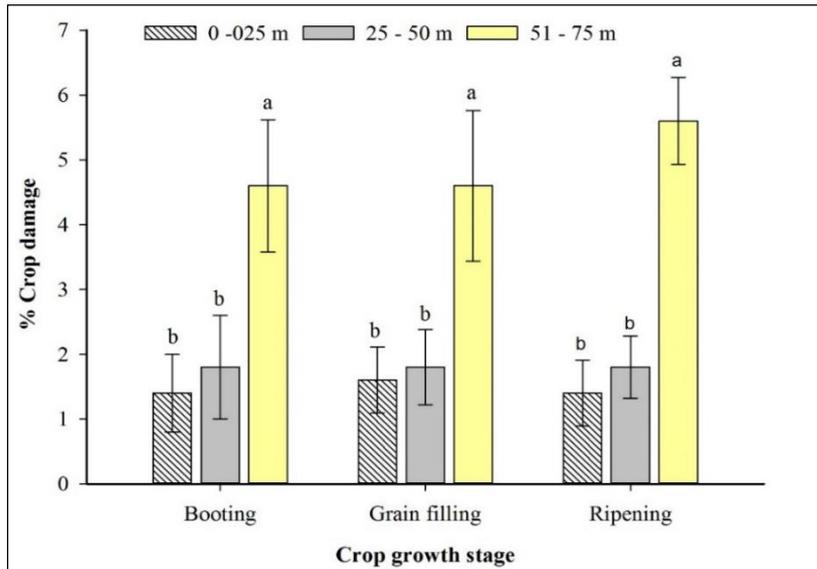


Fig. 4. Extent of crop damage in different growth stage of wheat around the watching tower area at Rajshahi by cut and uncut count method. Error bars indicate ± SE, Means followed by the same letter (s) are not significantly different at 5% level by Tukey's HSD.

Fig. 5. Extent of rat damage in different growth stage of wheat around the watching tower area at Gazipur by active burrow count method. Error bars indicate ± SE, Means followed by the same letter (s) are not significantly different at 5% level by Tukey's HSD.



Fig. 6. Extent of crop damage in different growth stage of wheat around the watching tower area at Gazipur by cut and uncut count method. Error bars indicate ± SE, Means followed by the same letter (s) are not significantly different at 5% level by Tukey's HSD.

Fig. 7. Extent of rat damage in different growth stage of Barley around the watching tower area at Gazipur by active burrow count method. Error bars indicate ± SE, Means followed by the same letter (s) are not significantly different at 5% level by Tukey's HSD.



Fig. 8. Extent of crop damage in different growth stage of Barley around the watching tower area at Gazipur by cut and uncut count method. Error bars indicate ± SE, Means followed by the same letter (s) are not significantly different at 5% level by Tukey's HSD.

Potato, sweet potato and groundnut damaged by rat and number of active burrows were differed significantly among different distance (0-25 m and 25-50 m and 51-75 m) from the watch tower. The number of active burrows ranged from 1-1.8, 1.2-1.6 and percent damaged ranged from 0.6-1.0, 0.6-1.8 at 0-25 m and 25-50 m distance from the watch tower in potato and sweet potato respectively compared to 51-75 m distance from the watch tower at Gazipur (Table 1). Number of active burrows and nut damaged in ground nut was also followed the same trend as potato and sweet potato at different distance from the watch tower (Table 1). Because owl can be easily search and detected the prey within 50 m that's why the rat damaged and active rat burrows were lower within the 50 m. Malhotra and Singla (2018) studied the live active burrows count at four different radii such as 0-100 m, 101-500 m, 501-1000 m and 1001-2000 m distance around roosting and nesting sites at Punjab, India and found that numerically lower active burrow within 100 m radius and being highest at 1001-2000 m radius but no significant among four distances. In another study (Johnson and George, 2020) a rigorous estimate of the number of rodents that barn owls remove from the landscape to nest box by using remote nest box cameras at wine grape orchard in California, USA. Results indicate that each barn owl chick received $170.2 \pm 8.92$ rodents before dispersing from the nest box. Combined with the average number of chicks fledged ($3.62 \pm 1.40$), this finding indicates adults deliver on average 616 rodents per nest box, they also estimated a barn owl family could remove 3,466 rodents in a full year (estimates ranged from 1,821 to 7,563). An analysis linking videography to owl telemetry data suggested that 43% of rodents killed were taken from vineyard habitat, which nearly matches the availability of vineyard habitat around the monitored nest boxes (46%). Their results suggest barn owl nest boxes could contribute meaningfully to integrated pest management.

**Table 1. Extent of rat damage of potato, sweet potato and groundnut around the watching tower area at Gazipur in Bangladesh**

| Crop | Watch tower distance (m) | Extend of rat damage | |
|---|---|---|---|
| | | Number of active burrow (Mean $\pm$ SE) | % Tuber/pod damage (Mean $\pm$ SE) |
| Potato | 0 -25 | $1.0 \pm 0.32$ a | $0.60 \pm 0.24$ a |
| | 26 -50 | $0.80 \pm 0.37$ a | $1.00 \pm 0.45$ a |
| | 51 -75 | $3.4 \pm 0.68$ b | $3.0 \pm 0.45$ b |
| Sweet potato | 0 -25 | $1.20 \pm 0.37$ a | $0.60 \pm 0.24$ a |
| | 26 -50 | $1.60 \pm 0.40$ a | $1.80 \pm 0.58$ ab |
| | 51-75 | $3.40 \pm 0.51$ b | $3.20 \pm 0.58$ b |
| Ground nut | 0 -25 | $1.60 \pm 0.51$ a | $1.00 \pm 0.31$ a |
| | 26 -50 | $1.60 \pm 0.51$ a | $1.80 \pm 0.49$ a |
| | 51-75 | $5.20 \pm 1.2$ b | $4.40 \pm 0.24$ b |

Means followed by the same letter are not significantly different at 5% level by Tukey's HSD.

**Nest box occupied by owl**

Nest box occupy mean the number owl enter into the nest box started for living. In Rajshahi 55 % nest boxes were occupied by owl whereas 50 % nest boxes were occupied by owl (Fig. 9). In Gazipur maximum nest box were occupied by spotted owlet (*Athene brama*) and in Rajshahi most of the nest box occupied by barn owl.

Examination of pellets from our and other study revealed that 70-80% of the barn owls diet is composed of rodents from agricultural fields and plantations (Tores *et al.,* 2005; Charter *et al.,* 2007). Browning *et al.* (2016) measured the effect of a population of barn owls on a rodent population in a 40-ha vineyard near Sacramento, California, USA. In First year 11 of 20 (55%) boxes were occupied by breeding pairs, fledging 40 young. In second year, 18 of 24 (75%) owl boxes were occupied, fledging 66 young; and in third year, three of 24 (12.5%) boxes were occupied, fledging nine young. Nocturnal observations revealed the owls hunted the study area heavily. Monthly pocket gopher surveys using the mound-count method indicated that gophers (rat species) declined on the vineyard with barn owl boxes relative to a control vineyard without barn owl boxes. Pellet analysis showed diet was composed mainly of Botta's pocket gophers (70.4%) and California voles (26.2%). Using these figures, and adding conservative estimates of adult consumption over the 165-day breeding season, and adult and fledgling consumption prior to dispersal, the total number of preys taken over the three breeding seasons was 30,020 rodents indicating 30,020 rodents were reduced over three years of 40-hectare vineyard. The presence of barn owls is thus welcomed by farmers in Israel. Since the establishment of the pest control project, many farmers use barn owls as an alternative method of rodent control and thereby drastically reduce the use of rodenticides. The high occupancy of nest boxes by barn owls detailed in this study demonstrates, as also found in other studies throughout the world, that not only were natural nest sites lacking in the area, but also that nest boxes offer barn owls alternative nest sites, that can increase owl numbers in agricultural fields both for conservation and biological pest control aspects. Nest box orientation and habitation also affect the occupation of owl. Charte *et al.* (2010) studied the effect of exposure, orientation, and habitat on nest box occupation and breeding success of barn owls in a semi-arid environment. The occupation of nest boxes varied with exposure and orientation. A higher percentage of occupation and more barn owl nestlings per breeding attempt were found in nest boxes located in the shade than in the sun, and in those facing east/north rather than other directions. The temperature in the nest boxes varied, being lowest in those located in the shade and in those facing east. Nest boxes located in crop fields fledged younger per breeding attempt than those located in date plantations.
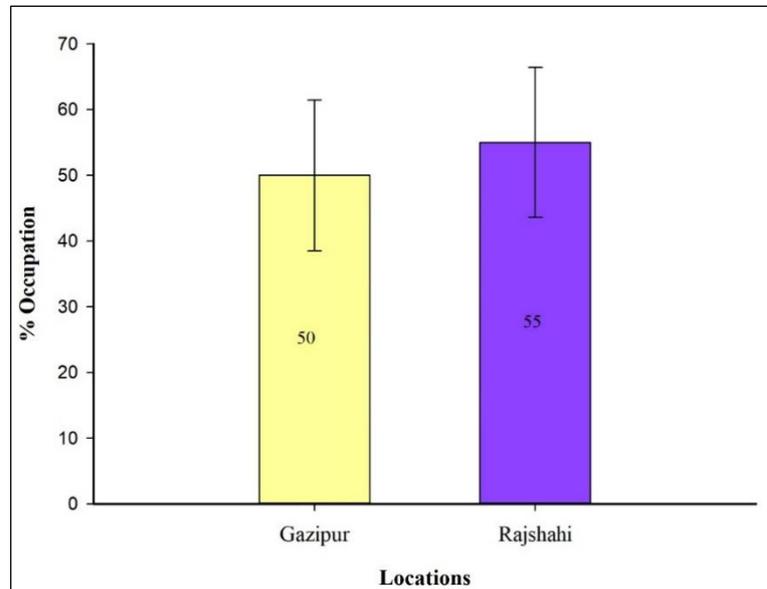
Fig. 9. Nest box occupation by owls as a function of exposure at two locations of Gazipur and Rajshahi.

## Conclusion

Based on above results and discussion it is observed that rat damage and number of active burrows in different crop differed significantly from distance of watch tower. Comparatively lower rat damage and active burrows were recorded shorter distance to the watch tower compared to longer distance of watch tower. The percentages of nest box occupation in Rajshahi 55 % nest boxes were occupied by owl whereas 50 % were occupied by owl in Gazipur. Our results suggest owl nest boxes and watch tower could contribute meaningfully to integrated pest management of rats.

## Acknowledgement

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# LINE X TESTER ANALYSIS OF QUANTITATIVE TRAITS FOR SHORT DURATION AND HIGH YIELDING OF *BRASSICA RAPA* IN BANGLADESH

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AND M. A. L. Akanda[4]

## Abstract

Three lines and nine testers are used for hybridization following Line × Tester mating design to get 27 hybrids. Evaluation of segregating generation was done to study combining ability effect and find out high yielding genotypes. Analysis of variance showed that mean squares due to replications, genotypes, lines, tester and interaction of line and tester were significant for all the studied traits except days to maturity and days to flowering in case of lines. It indicated that a large amount of variation present among the studied materials for these traits. Specific combining ability is considered an important criterion for evaluation of hybrid. From the result, the cross BS-14 × BC-4093 has shown the highest value of SCA in case of yield per plant. On the other hand, the parent BS-14 has the highest GCA effect among three lines in case of yield per plant. Besides, the tester BC-4093 has the highest GCA effect for yield per plant. Other side, considering days to maturity the cross BS-14 × SBC-2193 and the parent BS-17 has been exploited for future breeding by adopting proper strategies for short duration variety development. Besides, considering both traits (short duration and high yielding) the hybrid BS-15 × BS-9 could be selected for future use after large scale evaluation.

Keywords: Line × Tester analysis, Quantitative traits, GCA, SCA, *Brassica rapa.*

## Introduction

The oilseed Brassicas rank third in the world in terms of oil output, and conventional and modern plant breeding techniques have led to a constant increase in their yield (Sabaghnia *et al.*, 2010). The quantitative characteristic of rapeseed seed production is mostly impacted by several environmental factors and it often has poor heritability. Any crop species' ability to use genetic variability is thought to be essential for gaining additional genetic improvements in seed production and other economically significant features (Wang *et al*., 2010). Crosses between and within *Brassica* species are useful methods for creating genetic differences and creating new varieties (Amiri *et al*., 2009). Mustard hybrids are developed through crossbreeding within the Brassicaceae family to improve traits such as yield, disease resistance, adaptability, and other desirable characteristics (Singh *et al*., 2022). Hybridization fosters genetic diversity, resulting in plants that are more

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resilient to pests and diseases, better suited to diverse environmental conditions, and exhibit enhanced vigor. A key objective of mustard hybridization is to increase crop yield (Ahmad *et al*., 2024). The general and specific combining ability effects (GCA and SCA) of rapeseed are significant markers of the inbred lines potential in hybrid combinations in the breeding programme for both hybrid and open pollinated varieties. Knowing how to combine genes is useful to learn about parent selection and the nature of the genes' functions, which can help to incorporate desirable traits and maximize economic outputs. Specific information and research on combining ability can be helpful when choosing breeding techniques and lines for hybrid combinations.

Besides, according to Varshney *et al.* (1986), seed yield in rapeseed is a complicated and highly changeable character that is linked to a variety of component characters. One of the main goals of rapeseed breeding is to increase yield. It is now understood that effective breeding techniques are required for yield improvement in order to introduce favorable genes into current commercial cultivars. For selecting suitable parents and crossings for yield and its related components in the breeding plan, combining ability is one of the effective approaches to distinguish between good and poor combiners (Kumar *et al*., 2022). To choose the best parents for hybridization, it is, therefore, necessary to evaluate interesting strains for their combining potential (Chaudhary *et al*., 2019). As a result, this experiment was conducted for the current Line x Tester analysis research. Here, the focus was on creating a short-lived and high-yielding rapeseed variety that will grow between Transplanted *Aman* and *Boro* rice to achieve sustained food security as well as early sowing variety which would be grown in first week of October.

**Materials and Methods**

Parent materials of the experiment consisted of three lines and nine testers. Here, BS-14, BS-15, and BS-17 were used as lines. Besides, BS-4093, BS-12, BS-9, Din-2, SBC-2193, SBC-6823, SBC-8693, Tori-7 and a wild type were used as testers. All of the lines and testers are short duration varieties and inbred lines, respectively. All the lines and testers were sown and crossed followed by Line $\times$ Tester method during *rabi* season 2021-22. Three lines, nine tester and their resultant $F_1$ crosses (27) were evaluated in a RCB (Randomized complete block) design with three replications during the *rabi* season of 2022-23 at Oilseed Research Centre of Bangladesh Agricultural Research Institute in Gazipur. It is located at a latitude of 23°99′N and a longitude of 90°41′E. Annual precipitation averages around 1,898 and 1,895 mm, indicating a subtropical monsoon climate (Khaldun *et al.,* 2022.). Plot size was 4 rows 3 m long. Row to row distance was 30 cm and plant to plant distance was 5 cm. Fertilizers were applied @ 120: 80: 60: 40: 4: 1 kg/ha of N: P: K: S: Zn and Boron from Urea, TSP, MOP, Gypsum,

Zinc sulphate, and Boric acid, respectively (FRG, 2018). Half of the urea and all other fertilizers were applied during final land preparation. The rest of the urea was applied at the flower initiation stage. All intercultural operations were done timely to raise a good crop. Ten plants were chosen randomly from every plot for recording data on days to flowering, days to maturity, plant height (cm), number of branches per plant, number of siliquae per plant and yield per plant (g). For statistical analysis, mean values were used. The line × tester analysis was done followed by Kempthorne (1957).

**Results and Discussion**

Analysis of variance showed that mean squares due to replications, genotypes, lines, tester and interaction of line and tester were significant for all the studied traits except for days to maturity and days to flowering for lines. It indicated that a large amount of variation is present among the studied materials for these traits (Table 1) (Amiruzaman *et al*., 2008). The mean squares due to lines were of larger magnitude than those of testers for some traits such as the number of branches per plant and yield per plant. On the other hand, the mean squares due to testers were of larger magnitude than those of lines for other traits indicating greater diversity present among the testers. The majority of the studied traits have lower mean squares value of interaction between line and tester than genotypes meaning that greater uniformity or homogeneity is present among the crosses than their parents. The variance component due to lines was higher than testers for the traits number of branches per plant meaning that greater diversity present among this trait. Specific combining ability is considered an important criterion for the evaluation of hybrid (Datta *et al*., 2021). Combining ability is a useful tool for selecting appropriate parental lines for a hybridization programme and for differentiating between good and poor combiners. Additionally, it offers details on particular promising combination to take advantage of heterosis (Kaur *et al*., 2020). From the result we found that, the cross BS-14 × BC-4093 had the highest value (11.08) of SCA followed by BS-15 × BS-9 (9.52) and BS-14 × SBC -6823 (8.38) in case of yield per plant (Table 2). For plant height, the cross BS-15 × SBC-2193 had the highest value (17.40) of SCA followed by BS-17 × Tori-7 (10.68). Besides, the trait number of branches per plant showed the highest value (3.71) from the crosses BS-14 × BS-12 followed by BS-15 × SBC-2193 (2.02). The estimates of the specific combining ability effect for the number of siliquae per plant, the cross BS-14 × SBC-6823 had the highest value (273.84) followed by the cross BS-15 × BS-9 (185.25). In case of days to first flowering, the combination BS-17 × BS-12 showed the highest value (1.81) followed by the cross BS-14 × SBC-6823 (1.54) meaning they need more time to mature than others. The cross BS-14 × Tori-7 had the highest negative value of SCA for days to first flowering. It means the crosses flowered earlier than all others. The maximum (4.07) significant positive SCA effect was found from the combination BS-14 × BS-12 followed by the hybrid BS-

14 × Tori-7 (2.35). The highest negative value (6.19) of SCA was recorded from the combination BS-14 × SBC-2193 followed by BS-14 × Wild for days to maturity meaning that both require less time to mature than others. The mean performance of all crosses for all the studied characters was presented in Table 3. The plant height average value was 97.14 cm and the character number of branches per plant was 7.24 with the average value for number of siliqua per plant was 282.81. The mean value for yield per plant (YPP) was 76.37 g and the average value for days to first flowering of the plant was 35.15 with the days to maturity value was 91.59.

On the other hand, the studied parents with high GCA values (strong GCA effects) could be used to further varietal improvement of the population depending on desirable traits (Datta *et al*., 2021). In case of yield per plant, the parent BS-14 has the highest GCA effect (0.92) and this parent could be used for the development of hybrid. The higher value of SCA and dominance effect indicated that the hybrids may be used for better yield (Ali *et al*., 2014).

**Table 1. Mean squares of analysis of variance and components of variance for parents and crosses**

| SOV | df | PH | NOBP | NOSP | YPP | DF | DM |
|-----|-----|-----|------|------|-----|-----|-----|
| R | 1 | 46.89** | 3.46** | 257.85** | 2.75** | 46.29** | 46.30** |
| G | 26 | 185.88** | 6.22** | 54165.99** | 68.54** | 3.12* | 13.70** |
| L | 2 | 160.62** | 15.84** | 49983.74** | 91.21** | 3.35 ns | 0.68ns |
| T | 8 | 194.47** | 5.77** | 74774.09** | 83.51** | 3.87* | 12.50** |
| L × T | 16 | 184.75** | 5.24** | 44384.72** | 58.22** | 2.72* | 15.93** |
| E | 26 | 3.23 | 0.11** | 32.36 | 0.09 | 1.25 | 1.99 |
| $\sigma^2_L$ | | 0 | 0.59 | 311.05 | 1.83 | 0.03 | 0 |
| $\sigma^2_T$ | | 1.62 | 0.09 | 5064.89 | 4.21 | 0.19 | 0 |
| $\sigma^2_{L \times T}$ | | 90.75 | 2.56 | 22176.17 | 29.07 | 0.73 | 6.97 |
| $h^2_{B\,(\%)}$ | | 99.55 | 99.52 | 99.98 | 99.98 | 40.68 | 96.55 |
| $h^2_{N\,(\%)}$ | | 00 | 10.52 | 12.01 | 54 | 12.26 | 0 |

Legend: '**' significant at 1% level and '*' significant at 0.5% level, SOV: Source of variation, df: degrees of freedom, R; Replication, G: Genotypes, L: Line, T: Tester, E: Error, $\sigma^2_L$: Genotypic variance of line, $\sigma^2_T$: Genotypic variance of tester, $\sigma^2_{L \times T}$: Genotypic variance of line × tester, $h^2_B$: Heritability in broad sense, $h^2_N$: Heritability in narrow sense, PH: Plant height, NOBP: Number of branches per plant, NOSP: number of siliquae per plant, YPP: Yield per plant, DF: Days to first flowering, DM: Days to maturity

**Table 2. General combining ability effects (GCA) of parents and specific combining ability (SCA) effects on crosses**

| LINE and TESTER | PH | NOB | NOSP | YPP | DF | DM |
|---|---|---|---|---|---|---|
| BC-4093 | -0.42 | -0.42 | 1.33 | 1.32 | 1.06 | 00 |
| BS-12 | 0.07 | 0.07 | 0.12 | 0.12 | 8.32 | 00 |
| BS-9 | -0.26 | -0.26 | 1.11 | 1.11 | -2.53 | 00 |
| Din-2 | 0.24 | 0.24 | 0.00 | 0.00 | 1.70 | 00 |
| SBC-2193 | -1.26 | -1.26 | -1.31 | -1.30 | -0.47 | 00 |
| SBC-6823 | 0.07 | 0.07 | 0.03 | 0.03 | -2.53 | 00 |
| SBC-8693 | -0.76 | -0.76 | -0.90 | -0.90 | 2.25 | 00 |
| Tori-7 | 1.24 | 1.24 | 1.32 | 1.32 | 4.40 | 00 |
| Wild | 1.07 | 1.07 | -1.71 | -1.71 | -12.18 | 00 |
| BS-14 | 0.20 | -0.56 | -59.84 | 0.92 | 0.02 | 0.2 |
| BS-15 | -0.02 | 1.08 | 39.49 | -0.3 | -0.09 | -0.02 |
| BS-17 | -0.19 | - 0.52 | 20.35 | -0.62 | 0.06 | -0.19 |
| **Crosses** | | | | | | |
| BS-14× BC-4093 | -0.29 | 0.7 | -126.36 | 11.08** | 0.54 | 1.50 |
| BS-14 × BS-12 | 5.13 | 3.71 | -30.16 | 2.30 | -0.46 | 4.07** |
| BS-14 × BS-9 | 8.31 | -0.24 | -13.23 | -1.49 | 0.37 | 1.07 |
| BS-14 × Din-2 | 2.38 | -0.54 | -96.56 | -5.87 | 0.37 | 1.93 |
| BS-14 × SBC-2193 | -19.25 | -1.54 | -27.43 | -7.25 | 0.37 | -6.19 |
| BS-14 × SBC -6823 | 9.61 | -1.9 | 273.84 | 8.38** | 1.54 | 1.50 |
| BS-14 × SBC -8693 | -1.72 | -0.4 | 113.04 | 3.03 | 0.37 | -0.20 |
| BS-14 × Tori-7 | -4.32 | -0.24 | -114.36 | 6.1 | -2.13 | 2.35 |
| BS-14 × Wild | 0.14 | 0.45 | 21.24 | -1.66 | -0.96 | -4.48 |
| BS-15× BC-4093 | -1.83 | -0.55 | 26.51 | -3.57 | -0.85 | 1.07 |
| BS-15 × BS-12 | -4.59 | -3.11 | -133.49 | -2.27 | -1.35 | -1.91 |
| BS-15 × BS-9 | -4.73 | -0.28 | 185.25 | 9.52** | 0.48 | 0.22 |
| BS-15 × Din-2 | -4.46 | -0.08 | 150.51 | 6.03* | 0.48 | 0.65 |
| BS-15 × SBC-2193 | 17.4 | 2.02 | 44.55 | -2.94 | -0.02 | -0.20 |
| BS-15 × SBC -6823 | 5.27 | 1.55 | -155.79 | -4.08 | -0.35 | -0.20 |
| BS-15 × SBC -8693 | -4.61 | 0.2 | -130.69 | -3.14 | -0.02 | 1.93 |
| BS-15 × Tori-7 | -6.36 | 1.12 | -23.09 | 3.93 | 1.48 | 1.50 |
| BS-15 × Wild | 3.92 | -0.86 | 36.21 | -8.23 | 0.15 | -3.20 |
| BS-17× BC-4093 | 2.12 | -0.15 | 99.85 | 1.64 | 0.31 | -1.06 |
| BS-17 × BS-12 | -0.54 | -0.6 | 163.65 | 0.84 | 1.81 | -3.20 |
| BS-17 × BS-9 | -3.58 | 0.52 | -172.02 | -0.34 | -0.85 | -0.20 |
| BS-17 × Din-2 | 2.08 | 0.62 | -53.95 | -0.13 | -0.85 | 1.08 |
| BS-17 × SBC-2193 | 1.85 | -0.48 | -17.12 | 1.18 | -0.35 | 1.08 |
| BS-17 × SBC -6823 | -14.88 | 0.35 | -118.05 | -4.06 | -1.19 | -0.63 |
| BS-17 × SBC -8693 | 6.33 | 0.2 | 17.65 | -6.12 | -0.35 | -1.06 |
| BS-17× Tori-7 | 10.68 | -0.88 | 137.45 | -0.95 | 0.65 | 1.08 |
| BS-17 × Wild | -4.06 | 0.41 | -57.45 | -1.92 | 0.81 | 1.50 |

Legend: '**' significant at 1% level and '*' significant at 0.5% level, PH: Plant height, NOBP: Number of branches per plant, NOSP: number of siliquae per plant, YPP: Yield per plant, DF: Days to first flowering, DM: Days to maturity

**Table 3. Mean performance of the crosses for different studied characters**

| Crosses | PH | NOBP | NOSP | YPP | DF | DM |
|---|---|---|---|---|---|---|
| BS-14 X BC-4093 | 13 | 6.2 | 91.6 | 143 | 34 | 92 |
| BS-14 X BS-12 | 118.34 | 10.67 | 41 | 93 | 34 | 95 |
| BS-14 X BS-9 | 11.1 | 6.6 | 330.6 | 80 | 35 | 94 |
| BS-14 X Din-2 | 109.6 | 6 | 187.4 | 50 | 35 | 94 |
| BS-14 X SBC-2193 | 82 | 4.4 | 155.2 | 38 | 35 | 84 |
| BS-14 X SBC-6823 | 110.6 | 3.2 | 614.4 | 123 | 38 | 93 |
| BS-14 X SBC-8693 | 105.5 | 6.75 | 318 | 90 | 34 | 90 |
| BS-14 X Tori-7 | 106.6 | 8.2 | 71.2 | 118 | 35 | 95 |
| BS-14 X Wild | 92.34 | 7.34 | 26.4 | 65 | 35 | 85 |
| BS-15 X SBC-4093 | 110 | 7 | 346 | 63 | 34 | 92 |
| BS-15 X BS-12 | 100 | 5 | 300 | 62 | 34 | 92 |
| BS-15 X BS-9 | 12.6 | 8.2 | 636.2 | 129 | 34 | 92 |
| BS-15 X Din-2 | 107 | 8.2 | 537.6 | 107 | 34 | 92 |
| BS-15 X BC-2193 | 127.4 | 10 | 326.8 | 54 | 34 | 92 |
| BS-15 X SBC-6823 | 113 | 8.6 | 283.8 | 54 | 35 | 93 |
| BS-15 X SBC-8693 | 109.8 | 10 | 177.2 | 53 | 35 | 94 |
| BS-15 X Tori-7 | 108.6 | 11.2 | 263.4 | 100 | 38 | 95 |
| BS-15 X Wild | 100 | 7.5 | 140 | 22 | 35 | 88 |
| BS-17 X SBC-4093 | 110.2 | 5.6 | 397.4 | 88 | 35 | 90 |
| BS-17 X BS-12 | 117.4 | 6.8 | 318 | 78 | 38 | 88 |
| BS-17 X BS-9 | 100.6 | 7.6 | 242.4 | 76 | 35 | 90 |
| BS-17 X Din-2 | 112.4 | 7.4 | 310.4 | 72 | 35 | 94 |
| BS-17 X BC-2193 | 108.6 | 5.8 | 245.2 | 70 | 35 | 94 |
| BS-17 X SBC-6823 | 91 | 6 | 301 | 52 | 35 | 90 |
| BS-17 X SBC-8693 | 118 | 7.8 | 305.6 | 38 | 35 | 90 |
| BS-17 X Tori-7 | 124 | 8 | 409.2 | 74 | 38 | 94 |
| BS-17 X Wild | 103 | 5.4 | 260 | 70 | 35 | 91 |
| Mean | 97.14 | 7.24 | 282.81 | 76.37 | 35.15 | 91.59 |

Legend: '**' significant at 1% level and '*' significant at 0.5% level, PH: Plant height, NOBP: Number of branches per plant, NOSP: number of siliquae per plant, YPP: Yield per plant, DF: Days to first flowering, DM: Days to maturity

## Conclusion

Considering yield potentiality, the cross BS-14 × BC-4093 and the parent BS-14 were selected as the best hybrid and the best parent, respectively. Other side, considering days to maturity the cross BS-14 × SBC-2193 showed the lowest value of SCA among all other crosses and the parent BS-17 has shown the lowest GCA effect among all lines and testers. Besides, considering both traits (short duration and high yielding) the hybrid BS-15 × BS-9 could be selected for future use after a large-scale evaluation.

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# EFFECT OF GA$_3$ AND GROWING CONDITION ON EMERGENCE AND SEEDLING GROWTH OF LETTUCE (*LACTUCA SATIVA* L.)

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## Abstract

Two experiments were conducted in the research field of the Plant Physiology Section, Horticulture Research Centre (HRC), Bangladesh Agricultural Research Institute (BARI) from 05 to 30 December each of 2019 and 2020 to examine the influence of GA$_3$ and find suitable growing conditions for better seed germination of lettuce seeds. The experiment consisted of two levels of GA$_3$ *viz.* T$_1$ = 0.0 ppm (control) and T$_2$ = 10 ppm, and four growing conditions, G$_1$ = Seeding in polythene bag placed under diffused light; G$_2$ = Seeding in polythene bag placed under bright light, G$_3$ = Seeding in seedbed placed under diffused light and G$_4$ = Seeding in seedbed placed under bright light. Soaking of lettuce seeds in 10 ppm GA$_3$ gave higher seed emergence percent, seedling fresh weight, seedling dry weight, seedling length and seedling dry weight and seedling vigour index than that with control treatment and seed growing condition, G$_1$ treatment recorded the maximum seed emergence percent, seedling length and seedling vigour index. The treatment combination T$_2$ x G$_1$ or T$_2$ x G$_3$ showed the maximum seed emergence percent, seedling length and seedling vigour index. Treatment of lettuce seeds with 10 ppm GA$_3$ and grown under diffused light would be good for growing healthy seedlings.

Keywords: Lettuce, *Lactuca sativa*, field emergence, gibberellic acid, diffused light, vigour index.

## Introduction

Lettuce (*Lactuca sativa* L.), an annual plant of Asteraceae family, is an important vegetable. It is normally consumed fresh as salads with tomato, carrot, cucumber or other salad vegetable and often served alone or with dressing. It is a good source of vitamins and is often prescribed to weight-conscious consumers because of its low kilojoules content (Maboko, 2007). The composition of lettuce leaves is approximately 94.3% water, 1.2% protein, 0.2% fat, 2.9% carbohydrate (CHO), 0.7% fiber, and 0.7% ash. It is rich in vitamin A, C, and E and minerals such as calcium, phosphorus, sodium, magnesium, and potassium.

BARI has released two varieties, namely BARI Lettuce-1 and BARI Lettuce-2, but seed germination of these two varieties is low (Quamruzzaman, 2019). Plant growth regulators have been reported to improve germination, seed yield and seed quality (Saimbhi, 1993). It is reported that soaking seeds with GA$_3$ solution could break the dormancy of lettuce seeds. The period of imbibitions is extremely

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sensitive to changes in the environment, and slight or sudden changes appear to profound effect on seedling emergence (Kahn and Goss, 1978). Lettuce seed is positively photoblastic and germinate only after they have been exposed to light. Gibberellins are known to replace the effect of light on seed germination at moderate temperature (Thomas *et al.,* 1977). $GA_3$ promotes germination, reduces many of the environmental requirements for germination and has a role in counteracting the inhibitory effects of ABA. Schuller and Colquhoun (2022) reported that the potential use of plant growth regulators such as gibberellic acid (GA) could enhance early emergence and growth rates. In response, a controlled environment study was conducted to investigate the effects of GA on cabbage, carrot, and onion. At 7 days after seeding carrot emergence was greater (14%) when carrot seeds were treated with 4 ppm GA compared with non-treated seeds and treatment of cabbage seeds with 2 to 4 ppm GA increased cabbage emergence rate compared with non-treated seeds (Schuler and Colquhaon, 2022). With the above facts in mind, the experiment was carried out to examine the influence of $GA_3$ and to find out suitable growing condition for better seed germination of lettuce seeds.

## Materials and Methods

The experiment was carried out in the research field of Plant Physiology Section, Horticulture Research Center, BARI from 05 to 30 December 2019 and 03 to 28 December 2020. The treatment consisted of two levels of $GA_3$ ($T_1 = 0.0$ ppm $GA_3$, control as distilled water and $T_2 = 10$ ppm $GA_3$) and four growing conditions: $G_1$ = Seeding in poly bag placed under diffused light created by bamboo chatai with black polythene, $G_2$=Seeding in poly bag placed under bright light keeping open, $G_3$ = Seeding in seed bed placed under diffused light created by bamboo chatai with black polythene and $G_4$ = Seeding in seed bed placed under bright light keeping open. The experiment was laid out in Split-Plot design. Growth regulator treatments and growing condition treatments were allocated in main plot and subplot, respectively. The field was dived into 24 unit plots [1.0 $m^2$ (1 m x 1 m)]. Poly bags (7 cm x 6 cm) were kept in twelve unit plots. Thirty poly bags were taken for each unit plot. The medium of poly bag was prepared by mixing sandy loam soil and well rotten cowdung in 1:1 ratio. The rest of the 12 plots were prepared like seed bed. Only three kg well rotten cowdung was applied to each unit plot. Required amount of lettuce (BARI Lettuce -1) seeds were divided into two parts; one part was soaked in control (distilled water) for 12 hours and another part was soaked in 10 ppm $GA_3$ solution for 12 hours. After soaking, the seeds were air dried. Then air dried seeds were sown in unit plots on 5 December 2019 and 03 December 2020 maintaining spacing of 20 cm x 5 cm. Twenty seeds were sown in each line. After sowing, twelve plots were covered by bamboo-chatai and black polythene, and the rest 12 plots were kept open. Watering was done to poly bags and seed bed daily by water can with fine meshed nozzle until germination. The experiment was daily surveyed, and some traits were measured. Emergence started

after 6 days of sowing. Data on emergence was recorded at 15 days after sowing (DAS). Data on shoot length, root length, shoot fresh weight, root fresh weight, SPAD value were recorded on 30 December 2019 and 28 December 2020. SPAD value was recorded by SPAD meter ((502 plus, Konika, Minolta, Japan) two days before taking growth related data. The root and shoot fresh sample were collected and were oven dried at 72°C, for 72 hours. For root sampling, the desired plants were well watered and uprooted cautiously and collected roots were cleaned properly. The seedlings selected for calculating the seedling vigour index was oven dried at 72°C for seven days. The oven dry weight of these seedlings was used as seedling dry matter. Seedling vigour index was determined by using the formula given by Abdul-Baki and Anderson (1973) as below:

Seedling Vigour index = Seedling length x germination percentage (%)

The collected data were subjected to analysis of variance using MSTAT-C. Mean separation was performed by LSD at 5% level of probability.

## Results and Discussion

### *Emergence percentage*

Application of GA₃ significantly influenced seed emergence percent in both the years 2019 and 2020 (Fig. 1 A). A higher emergence% was obtained from 10 ppm GA₃ (75.25% in 2019 and 73.61% in 2020) while lower from control (without GA₃) (60.53% in 2019 and 66.71% in 2020). Mohammed (2023) obtained the highest emergence percent (59.08%) of soybean seed using GA₃ while 48.75% emergence from control (without GA₃) in field condition. Abdullah *et al.* (2023) reported that GA₃ treed seeds of barley gave 97-98% germination while the control gave 93% germination in different varieties in field. Seed emergence was also significantly influenced by different growing conditions (Fig. 1 B). The maximum emergence% was recorded from $G_1$ (79.39% in 2019 and 85.28% in 2020) followed by $G_3$ (75.72% in 2019 and 82.21% in 2020) and the lowest from $G_4$ (55.28% in 2019 and 57.56% in 2020). The combination of GA₃ and growing condition had also a significant effect on emergence % (Fig. 2). The highest emergence % was obtained from $T_2$ x $G_1$ combination (86.11% in 2019 and 94.34% in 2020) followed by $T_2$ x $G_3$ combination (78.44% in 2019 and 88.90% in 2020) and its minimum value was recorded from $T_1$ x $G_4$ combination (44.44% in 2019 and 52.22% in 2020). Seed priming with GA₃ caused physiological and biochemical changes before germination that helps to increase germination percentage (Jaskani *et al.,* 2006). It is known that lettuce is a positive photoblastic seed, so poor germination is supposed to occur in the field underneath the soil. In this circumstance, GA₃ could meet the requirement of light. It is reported that the germination of photoblastic lettuce seeds is regulated by phytochrome, which is a red (R) and far-red (FR) light receptor in plants (Butler *et al*., 1959). Red light irradiation induces the germination of lettuce seeds, and FR irradiation given after R cancels the effect of R; hence, phytochrome-induced changes in seeds are

reversibly modulated by different light frequencies. The regulation of lettuce seed germination by phytochrome is thought to be mediated by gibberellin (GA) (Sawada *et al*., 2008).
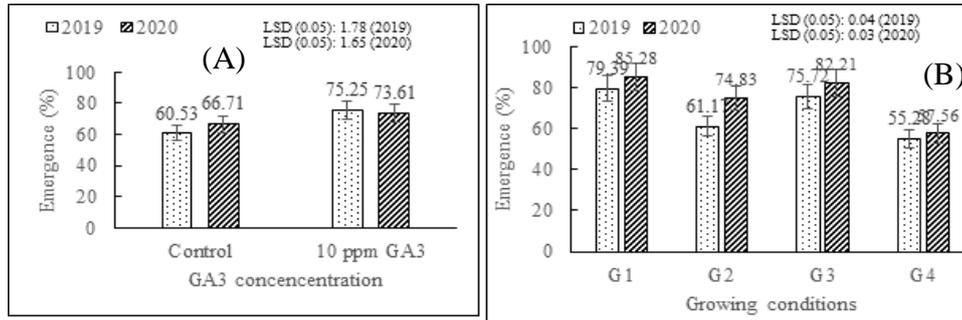


**Fig. 1. Effect of GA₃ (A) and growing conditions (G) on emergence percent of lettuce seed.**

$T_1$= 0.00 ppm $GA_3$ (distilled water), $T_2$ = 10 ppm $GA_3$, $G_1$ = Seeding in polythene bag placed under diffused light created by bamboo chatai with black polythene; $G_2$ = Seeding in polythene bag placed under bright light keeping open; $G_3$ = Seeding in seed bed placed under diffused light created by bamboo chatai with black polythene; $G_4$ = Seeding in seed bed placed under bright light place keeping open; $Y_1$ = 2019, $Y_2$ = 2020.
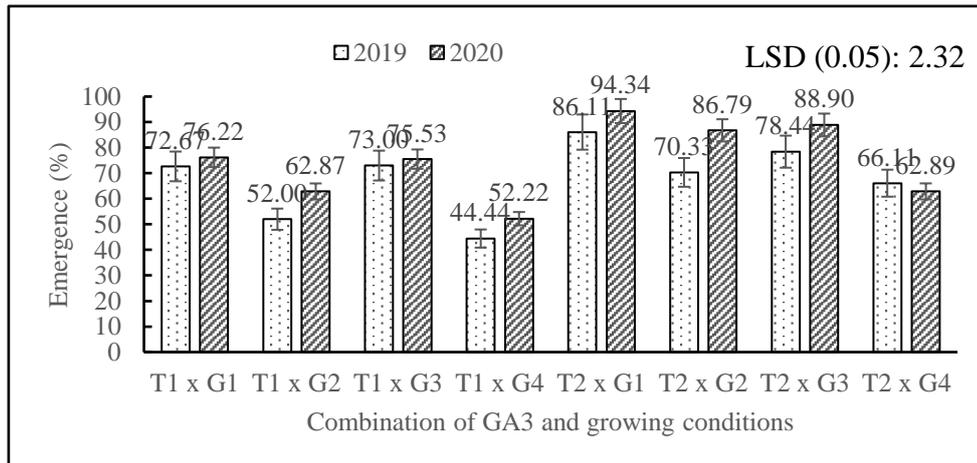


Fig. 2. Combined effect of GA₃ and growing conditions on emergence percent of lettuce seed.

$T_1$= 0.00 ppm $GA_3$ (distilled water), $T_2$ = 10 ppm $GA_3$, $G_1$ = Seeding in polythene bag placed under diffused light created by bamboo chatai with black polythene; $G_2$ = Seeding in polythene bag placed under bright light keeping open; $G_3$ = Seeding in seed bed placed under diffused light created by bamboo chatai with black polythene; $G_4$ = Seeding in seed bed placed under bright light place keeping open; $Y_1$ = 2019, $Y_2$ = 2020.

Lewak and Khan (1977) reported that the seeds of lettuce (*Lactuca sativa* L. cv. Grand Rapids) germinate in darkness at $25^0$ C when treated by gibberellic acid (GA$_3$) @ $10^{-3}$ M GA$_3$ for 1 hour following 2 hours of imbibition. Shade and dark condition created by bamboo chatai and black polythene influenced to synthesize less auxin hormone that also helped balance indigenous phytohormones within seeds and increase germination percentage (Korobova *et al*., 2023). Shaded condition also helped preserve soil moisture and seed germination was increased.

### Shoot fresh weight, root fresh weight and seedling fresh weight

Shoot fresh weight and seedling fresh weight were significantly influenced by single effect of GA$_3$ application (Table 1). Shoot fresh weight (19.11 g in 2019) and seedling fresh weight (20.82 g in 2019 and 24.02 g in 2020) were found maximum from 10 ppm GA$_3$ application. Shoot fresh weight, root fresh weight and seedling fresh weight were also significantly affected by single effect of different growing conditions (Table 1). Maximum shoot fresh weight was found from G$_4$ (23.79 g in 2019 and 25.83 g in 2020) followed by G$_2$ (16.87 g in 2019 and 18.58 g in 2020) and G$_3$ (17.32 g in 2019 and 21.11 g in 2020) and the lowest shoot fresh weight from G$_1$ (14.70 g in 2019 and 18.78 g in 2020). The highest root fresh weight was obtained from G$_1$ (1.80 g in 2019 and 2.55 g in 2020) closely followed by G$_2$ and G$_4$ only in 2019. The growing condition G$_4$ produced maximum seedling fresh weight (25.29 g in 2019 and 27.64 g in 2020) which was followed by G$_3$ treatment (18.82 g in 2019 and 23.13 g in 2020) and the treatment G$_1$ gave the lowest seedling fresh weight (16.50 g in 2019 and 21.33 g in 2020). The combination of GA$_3$ and growing conditions had significant effect on shoot fresh weight, root fresh weight and seedling fresh weight (Table 1). The highest shoot fresh weight was recorded from T$_2$ x G$_4$ combination (25.45 g in 2019 and 26.58 g in 2020) followed by T$_1$ x G$_4$ combination (22.14 g in 2019 and 25.08 g in 2020). The lowest shoot fresh weight was obtained from T$_1$ x G$_1$ combination (14.10 g in 2019 and 18.06 g in 2020). In 2019, the combination T$_2$ x G$_1$ gave the maximum root fresh weight (1.86 g), which was statistically similar to T$_2$ x G$_2$ combination (1.85 g) and the lowest root fresh weight was obtained from T$_1$ x G$_4$ combination. In 2020, the highest root fresh weight was recorded from T$_2$ x G$_1$ combination (2.63 g) and the lowest from T$_1$ x G$_4$ combination (1.75 g).

Higher seedling fresh weight was obtained from 10 ppm GA$_3$ (20.82 g in 2019 and 24.02 g in 2020) while lower from the control (18.79 g in 2019 and 22.39 g in 2020) (without GA$_3$) (Table 1). Maximum seedling fresh weight was recorded from G$_4$ (25.29 g in 2019 and 27.64 g in 2020) followed by G$_3$ treatment (18.82 g in 2019 and 23.13 g in 2020) and the lowest from G$_1$ treatment (16.50 g in 2019 and 21.33 g in 2020). GA$_3$ and growing condition in combination gave the maximum seedling fresh weight (27.06 g in 2019 and 28.45 g in 2020) followed by T$_1$ x G$_4$ combination (23.53 g in 2019 and 26.83 g in 2020). The combination T$_1$ x G$_1$ combination produced the lowest seedling fresh weight (15.84 g in 2019 and 20.54 g in 2020).

**Table 1. Effect of GA₃ and growing condition on seed emergence percentage, shoot fresh weight, root fresh weight, seedling fresh weight and SPAD value of lettuce seed**

| Treatment | Shoot fresh weight (g) | | Root fresh weight (g) | | Seedling fresh weight (g) | | SPAD value | |
|---|---|---|---|---|---|---|---|---|
| | $Y_1$ | $Y_2$ | $Y_1$ | $Y_2$ | $Y_1$ | $Y_2$ | $Y_1$ | $Y_2$ |
| GA₃ (T) | | | | | | | | |
| $T_1$ | 17.23 | 20.33 | 1.56 | 2.06 | 18.79 | 22.39 | 30.59 | 30.89 |
| $T_2$ | 19.11 | 21.82 | 1.71 | 2.20 | 20.82 | 24.02 | 30.42 | 30.72 |
| LSD (0.05) | 1.15 | NS | NS | NS | 0.08 | 0.09 | NS | NS |
| $G_1$ | 14.70 | 18.78 | 1.80 | 2.55 | 16.50 | 21.33 | 28.36 | 28.64 |
| $G_2$ | 16.87 | 18.58 | 1.74 | 2.13 | 18.61 | 20.71 | 31.42 | 31.73 |
| $G_3$ | 17.32 | 21.11 | 1.49 | 2.02 | 18.82 | 23.13 | 28.08 | 28.36 |
| $G_4$ | 23.79 | 25.83 | 1.50 | 1.81 | 25.29 | 27.64 | 34.16 | 34.50 |
| LSD (0.05) | 1.15 | 1.75 | 0.09 | 0.11 | 0.10 | 0.13 | 2.41 | 2.61 |
| CV (%) | 3.70 | 4.31 | 9.20 | 5.76 | 3.98 | 6.76 | 6.81 | 7.09 |
| Combined effect (TxG) | | | | | | | | |
| $T_1$ x $G_1$ | 14.10 | 18.06 | 1.74 | 2.48 | 15.84 | 20.54 | 27.83 | 28.11 |
| $T_1$ x $G_2$ | 15.60 | 17.78 | 1.63 | 2.06 | 17.23 | 19.84 | 32.81 | 33.14 |
| $T_1$ x $G_3$ | 17.10 | 20.40 | 1.46 | 1.94 | 18.56 | 22.34 | 29.51 | 29.80 |

| Treatment | Shoot fresh weight (g) | | Root fresh weight (g) | | Seedling fresh weight (g) | | SPAD value | |
|---|---|---|---|---|---|---|---|---|
| | $Y_1$ | $Y_2$ | $Y_1$ | $Y_2$ | $Y_1$ | $Y_2$ | $Y_1$ | $Y_2$ |
| $T_1 \times G_4$ | 22.14 | 25.08 | 1.39 | 1.75 | 23.53 | 26.83 | 32.71 | 33.04 |
| $T_2 \times G_1$ | 15.30 | 19.50 | 1.86 | 2.63 | 17.16 | 22.13 | 29.89 | 30.19 |
| $T_2 \times G_2$ | 18.15 | 19.38 | 1.85 | 2.20 | 20.00 | 21.58 | 30.53 | 30.84 |
| $T_2 \times G_3$ | 17.55 | 21.82 | 1.52 | 2.10 | 19.07 | 23.92 | 26.65 | 26.92 |
| $T_2 \times G_4$ | 25.45 | 26.58 | 1.61a | 1.87f | 27.06 | 28.45 | 35.61 | 35.97 |
| LSD (0.05) | 2.09 | 2.31 | 0.11 | 0.13 | 0.54 | 1.17 | 3.09 | 3.09 |
| CV (%) | 3.70 | 4.31 | 9.20 | 5.76 | 6.12 | 6.76 | 6.81 | 7.05 |

$T_1$= 0.00 ppm GA$_3$ (distilled water), $T_2$ = 10 ppm GA$_3$, $G_1$ = Seeding in polythene bag placed under diffused light created by bamboo chatai with black polythene; $G_2$ = Seeding in polythene bag placed in bright light keeping open; $G_3$ = Seeding in seed bed placed under diffused light created by bamboo chatai with black polythene; $G_4$ = Seeding in seed bed placed under bright light place keeping open; $Y_1$ = 2019, $Y_2$ = 2020.

$GA_3$ application @ 10 ppm helped increase vegetative growth that is why maximum fresh weight was recorded from this treatment. Numerically root fresh weight was increased due to $GA_3$ application. As a result of increased shoot and fresh weight, seedling fresh weight was increased owing to $GA_3$ application. Under $G_4$ (Seeding in seed bed and placed in bright light place) treatment emergence percent was low that decreased the number of seedlings in unit area and hence the seedling got opportunity to have enough natural resources (light, nutrient, moisture, air etc.) and this treatment was able to give maximum shoot fresh weight. Conversely $G_1$ (shaded by bamboo chatai with black polythene) treatment helped increase root fresh weight because under this treatment, dark was created that increased root fresh weight. Ultimately seedling fresh weight was increased due to maximum shoot fresh weight that might be happened for higher chlorophyll synthesis and photosynthates.

### SPAD value

$GA_3$ application singly did not influence SPAD value, but growing condition independently significantly influenced SPAD value (Table 1). Maximum SPAD value was recorded from $G_4$ (31.16 in 2019 and 34.50 in 2020) closely followed by $G_2$ (31.42 in 2019 and 31.73 in 2020) and its minimum value obtained from $G_1$ treatment (28.36 in 2019 and 28.64 in 2020). $GA_3$ and growing condition in combination had significant effect on SPAD value (Table 1). The highest SPAD value was obtained from $T_2$ x $G_4$ combination (35.61 in 2019 and 35.97 in 2020) closely followed by $T_1$ x $G_4$ (32.71 in 2019 and 33.04 in 2020), $T_1$ x $G_2$ (32.81 in 2019 and 33.14 in 2020) and $T_2$ x $G_3$ combination gave the lowest SPAD value (26.65 in 2019 and 26.92 in 2020) which was identical with $T_2$ x $G_1$, $T_1$ x $G_3$ and $T_1$ x $G_1$ combinations. Light helps in chlorophyll formation.  Fan *et al*. (2023) reported that the concentration of photosynthetic pigments and chlorophyll biosynthesis precursors were higher under red and blue light, and this light condition was beneficial to pigment accumulation. For this reason, the seedlings grown in open condition had higher level of SPAD value than those grown in bamboo-chatai and black polythene covered condition that reduces light to create dark condition.

### Shoot length and root length

Application of $GA_3$ irrespective of growing conditions had significant effect on shoot and root length of lettuce seedling (Table 2). $GA_3$ @ 10 ppm produced higher shoot length (7.86 cm in 2019 and 5.58 cm in 2020) and root length (8.82 cm in 2019 and 11.89 cm in 2020) than control treatment. Abdullah *et al*. (2023) reported that $GA_3$ treated seeds of barley gave higher shoot length than without $GA_3$. Growing condition singly influenced shoot and root length significantly (Table 2). Maximum shoot length was recorded from $G_4$ (8.56 g in 2019 and 5.70 g in 2020) followed by $G_1$ (7.53 cm in 2019), $G_3$ (7.43 cm in 2019) and $G_2$ (5.36 cm in 2020). In 2019, the highest root length was obtained from $G_1$ (9.65 cm) which was

statistically similar to G$_2$ (9.54 cm) and growing condition G$_3$ and G$_4$ produced identical root length. In 2020, G$_1$ treatment produced maximum root length (14.48 cm) followed by G$_2$ (13.00 cm). GA$_3$ and growing condition in combination had significant effect on shoot and root length (Table 2). Maximum shoot length was recorded from T$_2$ x G$_4$ combination (9.38 cm in 2019 and 6.00 cm in 2020) followed by T$_2$ x G$_3$ combination (7.95 cm in 2019 and 5.28 cm in 2020). In 2020, there was no significant difference among T$_1$ x G$_4$, T$_2$ x G$_1$, T$_2$ x G$_2$ and T$_2$ x G$_3$ combinations. In the first year, the highest root length was obtained from T$_2$ x G$_2$ combination (10.78 cm) followed by T$_1$ x G$_1$ (9.70 cm) and T$_2$ x G$_1$ (9.60 cm) combination and the lowest from T$_2$ x G$_4$ combination. In 2020, the combination T$_2$ x G$_2$ combination gave the highest root length (14.95 cm) which was followed by T$_1$ x G$_1$ and T$_1$ x G$_1$ combinations and the lowest from T$_1$ x G$_3$ combination. GA$_3$ acts as a growth promoter and hence shoot length was increased (Noor *et al*., 2017) who obtained higher plant height than control treatment. Under bright light place (open condition), chlorophyll was synthesized more and greater photo-assimilates was produced (Fan *et al*., 2023) that helped increase shoot. Dark condition was also helpful to preserve soil moisture and keep the soil loose that assists in increasing root.

### *Seedling length*

Application of GA$_3$ significantly influenced seedling length (Table 2). Higher seedling length was obtained from 10 ppm GA$_3$ (16.68 cm in 2019 and 17.47 cm in 2020) while lower from the control (without GA$_3$) (15.27 cm in 2019 and 15.53 cm in 2020). Noor *et al*. (2017) obtained higher plant height using GA$_3$ than control treatment. Seedling length was significantly influenced by different growing conditions (Table 2). Maximum seedling length was recorded from G$_1$ (17.17 cm in 2019 and 19.65 cm in 2020) followed by G$_4$ (15.89 cm in 2019) and by G$_2$ (18.36 cm in 2020) and G$_2$ (15.86 cm in 2019) and the lowest from G$_3$ (14.98 cm in 2019), but from G$_4$ (11.98 cm) in 2020. The combination of GA$_3$ and growing condition had a significant effect on seedling length (Table 2). The highest seedling length was obtained from T$_2$ x G$_2$ combination (17.58 cm in 2019 and 19.01 cm in 2020) closely followed by T$_1$ x G$_1$ combination (17.38 cm) in 2019 and its minimum value was recorded from T$_1$ x G$_3$ combination (13.50 cm) in 2019. But in 2020, the combination T$_2$ x G$_1$ recorded maximum seedling length (20.37 cm) which was followed by T$_2$ x G$_2$ combination (19.01 cm) and T$_1$ x G$_1$ combination (18.93 cm). Application of gibberellic acid increased shoot length as well as root length that resulted in seedling length. Low light condition created in G$_1$ and G$_2$ treatments which made such environment for the seedlings that helped increase seedling length. Ultimately, GA$_3$ application in combination with low light condition increased seedling length.

**Table. 2. Effect of GA₃ and growing condition on shoot length, root length and seedling length of lettuce**

| Treatment | Shoot length (cm) | | Root length (cm) | | Seedling length (cm) | |
|---|---|---|---|---|---|---|
| | $Y_1$ | $Y_2$ | $Y_1$ | $Y_2$ | $Y_1$ | $Y_2$ |
| GA₃ (T) | | | | | | |
| $T_1$ | 7.06 | 5.06 | 8.21 | 10.47 | 15.27 | 15.53 |
| $T_2$ | 7.86 | 5.58 | 8.82 | 11.89 | 16.68 | 17.47 |
| LSD (0.05) | 0.35 | 0.33 | 0.47 | 0.45 | 0.39 | 0.54 |
| Growing condition (G) | | | | | | |
| $G_1$ | 7.53 | 5.17 | 9.65 | 14.48 | 17.17 | 19.65 |
| $G_2$ | 6.31 | 5.36 | 9.54 | 13.00 | 15.86 | 18.36 |
| $G_3$ | 7.43 | 5.04 | 7.55 | 9.35 | 14.98 | 14.39 |
| $G_4$ | 8.56 | 5.70 | 7.33 | 6.28 | 15.89 | 11.98 |
| LSD (0.05) | 0.32 | 0.31 | 0.37 | 0.37 | 0.38 | 0.51 |
| CV (%) | 3.93 | 4.05 | 3.49 | 5.43 | 3.10 | 4.87 |
| Interaction (TxG) | | | | | | |
| $T_1$ x $G_1$ | 7.68 | 4.93 | 9.70 | 14.00 | 17.38 | 18.93 |
| $T_1$ x $G_2$ | 5.82 | 5.10 | 8.30 | 12.60 | 14.12 | 17.70 |
| $T_1$ x $G_3$ | 6.90 | 4.80 | 6.60 | 9.13 | 13.50 | 13.93 |
| $T_1$ x $G_4$ | 7.82 | 5.41 | 8.25 | 6.13 | 16.07 | 11.54 |
| $T_2$ x $G_1$ | 7.37 | 5.42 | 9.60 | 14.95 | 16.97 | 20.37 |
| $T_2$ x $G_2$ | 6.80 | 5.61 | 10.78 | 13.40 | 17.58 | 19.01 |
| $T_2$ x $G_3$ | 7.95 | 5.28 | 8.50 | 9.57 | 16.45 | 14.85 |
| $T_2$ x $G_4$ | 9.38 | 6.00 | 6.40 | 6.43 | 15.70 | 12.43 |
| LSD (0.05) | 0.45 | 0.41 | 0.53 | 0.51 | 0.54 | 0.53 |
| CV (%) | 3.93 | 4.05 | 3.49 | 5.43 | 3.10 | 4.87 |

$T_1$= 0.00 ppm GA₃ (distilled water), $T_2$ = 10 ppm GA₃, $G_1$ = Seeding in polythene bag placed under diffused light created by bamboo chatai with black polythene; $G_2$ = Seeding in polythene bag placed in bright light keeping open; $G_3$ = Seeding in seed bed placed under diffused light created by bamboo chatai with black polythene; $G_4$ = Seeding in seed bed placed under bright light place keeping open; $Y_1$ = 2019, $Y_2$ = 2020

*Shoot dry weight*

Application of GA₃ significantly influenced shoot dry weight (Table 3). Higher shoot dry weight was obtained from 10 ppm GA₃ (1.67 g in 2019 and 1.56 g in 2020) while lower from the control (without GA₃) (1.58 g in 2019 and 1.49 g in 2020). Shoot dry weight was significantly influenced by different growing conditions (Table 3). Maximum shoot dry weight was recorded from $G_4$ (2.04 g in 2019 and 1.65 g in 2020) followed by $G_2$ and $G_3$ in 2019, but by $G_3$ in 2020 and the lowest from $G_1$. The combination of GA₃ and growing condition had a significant effect on shoot dry weight (Table 3). Maximum shoot dry weight was obtained from $T_2$ x $G_4$ combination (2.24 g in 2019 and 1.86 g in 2020) followed

by $T_1$ x $G_4$ combination (1.84 g in 2019 g and 1.76 g in 2024) and its minimum value was recorded from $T_1$ x $G_2$ combination (1.49 g in 2019 and 1.26 g in 2020). Seedling dry weight was increased due to higher chlorophyll synthesis and net photosynthates under bright light condition and GA₃ application which helps in growth of seedlings. Under bright light place (open condition), chlorophyll was synthesized more and greater photo-assimilates was produced (Fan *et al*., 2023).

**Table 3. Effect of GA₃ and growing condition on shoot dry weight, root dry weight, total dry weight and seedling vigour index of lettuce seedling**

| Treatment | Shoot dry weight (g) | | Root dry weight (g) | | Seedling dry weight (g) | |
|---|---|---|---|---|---|---|
| | $Y_1$ | $Y_2$ | $Y_1$ | $Y_2$ | $Y_1$ | $Y_2$ |
| GA₃ (T) | | | | | | |
| $T_1$ | 1.58 | 1.49 | 0.27 | 0.31 | 1.85b | 1.80b |
| $T_2$ | 1.67 | 1.56 | 0.30 | 0.33 | 1.97a | 1.90a |
| LSD (0.05) | 0.06 | 0.04 | NS | NS | 0.10 | 0.09 |
| Growing condition (G) | | | | | | |
| $G_1$ | 1.43 | 1.33 | 0.29 | 0. 39 | 1.72 | 1.72 |
| $G_2$ | 1.53 | 1.48 | 0.27 | 0.32 | 1.80 | 1.80 |
| $G_3$ | 1.51 | 1.54 | 0.22 | 0.31 | 1.73 | 1.79 |
| $G_4$ | 2.04 | 1.65 | 0.36 | 0.27 | 2.40 | 2.08 |
| LSD (0.05) | 0.04 | 0.03 | 0.04 | 0.02 | 0.07 | 0.08 |
| CV (%) | 4.64 | 4.67 | 12.11 | 6.76 | 3.99 | 5.43 |
| Combined effect (TxG) | | | | | | |
| $T_1$ x $G_1$ | 1.49 | 1.26 | 0.31 | 0.38 | 1.79 | 1.64 |
| $T_1$ x $G_2$ | 1.41 | 1.53 | 0.25 | 0.30 | 1.66 | 1.83 |
| $T_1$ x $G_3$ | 1.58 | 1.42 | 0.21 | 0.30 | 1.79 | 1.72 |
| $T_1$ x $G_4$ | 1.84 | 1.76 | 0.33 | 0.27 | 2.17 | 2.03 |
| $T_2$ x $G_1$ | 1.37 | 1.39 | 0.28 | 0.40 | 1.64 | 1.79 |
| $T_2$ x $G_2$ | 1.66 | 1.43 | 0.29 | 0.34 | 1.95 | 1.77 |
| $T_2$ x $G_3$ | 1.43 | 1.65 | 0.22 | 0.32 | 1.66 | 1.87 |
| $T_2$ x $G_4$ | 2.24 | 1.86 | 0.39 | 0.27 | 2.63 | 2.13 |
| LSD (0.05) | 0.06 | 0.07 | 0.03 | 0.05 | 0.13 | 0.10 |
| CV (%) | 4.64 | 4.67 | 12.11 | 6.76 | 3.99 | 5.43 |

$T_1$= 0.00 ppm GA₃ (distilled water), $T_2$ = 10 ppm GA₃, $G_1$ = Seeding in polythene bag placed under diffused light created by bamboo chatai with black polythene; $G_2$ = Seeding in polythene bag placed in bright light keeping open; $G_3$ = Seeding in seed bed placed under diffused light created by bamboo chatai with black polythene; $G_4$ = Seeding in seed bed placed under bright light place keeping open; $Y_1$ = 2019, $Y_2$ = 2020

***Root dry weight***

Root dry weight was not significantly influenced by GA₃ application and growing condition (Table 3). Numerically higher root fresh weight was obtained from GA₃

application. Root dry weight was significantly influenced by different growing conditions (Table 3). In 2019, maximum root dry weight was recorded from $G_4$ treatment (0.36 g) followed by $G_1$ and $G_2$ conditions, but in 2020, maximum root dry weight was recorded from $G_1$ condition (0.39 g) followed by $G_2$ condition. $GA_3$ application and growing conditions in combination significantly influenced root dry weight (Table 3). In 2019, maximum root dry weight was recorded from $T_2$ x $G_4$ combination (0.39 g) closely followed by $T_1$ x $G_4$ (0.33 g) and $T_1$ x $G_1$ (0.31 g) combinations. While, in 2020, maximum root dry weight was obtained from $T_2$ x $G_1$ condition (0.40 g) which was closely followed by $T_1$ x $G_1$ combination (0.38 g) and followed by $T_2$ x $G_2$ combination (0.34 g).

It is observed that there was a different result from two years in respect root dry weight. Dark condition (low light condition) helped more to increase root fresh weight in 2020, but in 2019, the bright sun light. There was also influence of $GA_3$ for increasing root dry weight.

### Seedling dry weight

The application of $GA_3$ significantly influenced seedling dry weight (Table 3). Higher seedling dry weight was obtained from 10 ppm $GA_3$ (1.97 g in 2019 and 1.90 g in 2020), while lower from the control (without $GA_3$) (1.85 g in 2019 and 1.80 g in 2020). Abdullah *et al*. (2023) reported that $GA_3$ treed seeds of barley gave higher seedling dry weight than without $GA_3$. Seedling dry weight was significantly influenced by different growing conditions (Table 3). Maximum seedling dry weight was recorded from $G_4$ (2.40 g in 2019 and 2.08 g in 2020) followed by $G_2$ (1.80 in both 2019 and 2020) and the lowest from $G_1$ (1.72 g in both years). The combination of $GA_3$ and growing condition had a significant effect on seedling dry weight (Table 3). The highest seedling dry weight was obtained from $T_2$ x $G_4$ combination (2.63 g in 2019 and 2.13 g in 2020) followed by $T_1$ x $G_4$ combination (2.17 g in 2019 and 2.03 g in 2020) and its minimum value was recorded from $T_2$ x $G_1$ combination (1.64 g) in 2019, but from $T_1$ x $G_1$ combination in 2024. Seedling dry weight was increased due to maximum shoot fresh weight that might be happened for higher chlorophyll synthesis and photosynthates under bright sun light and due to the positive influence of $GA_3$.

### Seedling vigour index

Application of $GA_3$ significantly influenced seedling vigour index (SVI) (Fig. 3A). Higher SVI was obtained from 10 ppm $GA_3$ (1256.7 in 2019 and 1285.97 in 2020) while lower from control (without $GA_3$) (924.14 in 2019 and 1036.01 in 2020). SVI was significantly influenced by different growing conditions (Fig 3 B). Maximum SVI was recorded from $G_1$ (1362.0 in 2019 and 1675.75 in 2020) and the lowest from $G_4$ (876.10 in 2019 and 689.57 in 2020). The combination of $GA_3$ and growing condition had a significant effect on SVI (Fig. 4). The highest SVI was obtained from $T_2$ x $G_1$ combination (1461.0 in 2019 and 1921.71 in 2020)

followed by $T_2$ x $G_3$ combination (1290.0) in 2019 and $T_2$ x $G_2$ combination (1669.88) in 2020 and its minimum value was recorded from $T_1$ x $G_4$ combination (714.30 in 2019 and 602.60 in 2020). The seedling vigour index was calculated by multiplying the seed emergence percent and seedling length. A higher emergence percentage was recorded from GA₃ application and by the influence of low light condition. GA₃ helps break seed dormancy that gave higher emergence percentage. On the other hand, low light condition preserved soil moister and maintained the soil in loose condition that resulted in higher emergence percentage. Both GA₃ and low light condition gave the higher seedling length and ultimately maximum seedling vigour index was obtained. Abdullah *et al.* (2023) reported that GA₃ treated seeds of barley recorded maximum seedling vigour.
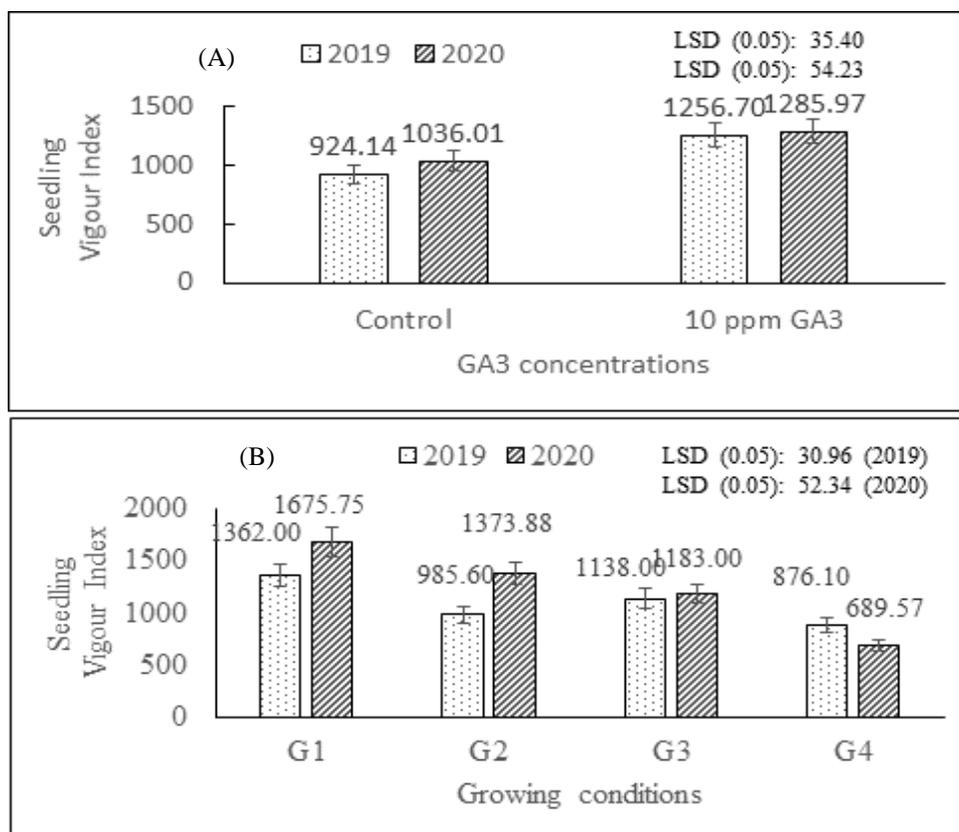


Fig. 3. Effect of GA₃ (A) and growing conditions (B) on seedling vigour index of lettuce seeds.

$T_1$= 0.00 ppm GA₃ (distilled water), $T_2$ = 10 ppm GA₃, $G_1$ = Seeding in polythene bag placed under diffused light created by bamboo chatai with black polythene; $G_2$ = Seeding in polythene bag placed in bright light keeping open; $G_3$ = Seeding in seed bed placed under diffused light created by bamboo chatai with black polythene; $G_4$ = Seeding in seed bed placed under bright light place keeping open; $Y_1$ = 2019, $Y_2$ = 2020.
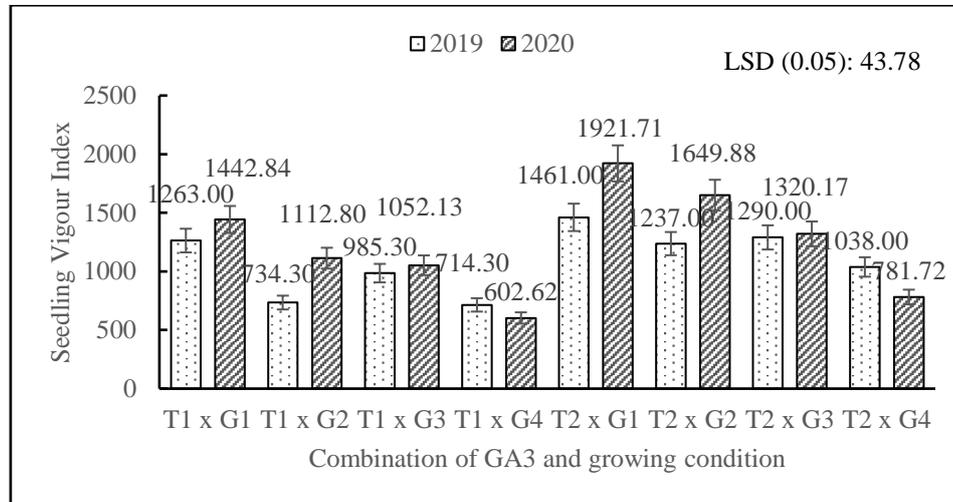
**Fig. 4. Combined effect of GA$_3$ and growing conditions on seedling vigour Index of lettuce seeds**

T$_1$= 0.00 ppm GA$_3$ (distilled water), T$_2$ = 10 ppm GA$_3$, G$_1$ = Seeding in polythene bag placed under diffused light created by bamboo chatai with black polythene; G$_2$ = Seeding in polythene bag placed in bright light keeping open; G$_3$ = Seeding in seed bed placed under diffused light created by bamboo chatai with black polythene; G$_4$ = Seeding in seed bed placed under bright light place keeping open; Y$_1$ = 2019, Y$_2$ = 2020, Y$_2$ = 2020

## Conclusion

The experimental results revealed that application of 10 ppm GA$_3$ (T$_2$) positively influenced seed emergence percent, seedling fresh weight, seedling dry weight, seedling length and seedling dry weight and seedling vigour index. Seed growing condition (G$_1$) (Seeding in polybag placed under diffused created by bamboo-chatai and black polythene) or G$_3$ (Seeding in seed bed placed under diffused light created by bamboo chatai with black polythene) recorded maximum seed emergence per cent, seedling length and seedling vigour index. Thus, the T$_2$ x G$_1$ or T$_2$ x G$_3$ combinations gave maximum seed emergence percent, seedling length and seedling vigour index. It is concluded that, for raising good and healthy lettuce seedlings diffused light condition created by bamboo chatai with black polythene cover in combination with 10 ppm GA$_3$ might be suggested.

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# BIO-RATIONAL MANAGEMENT FOR ROOT-KNOT DISEASE OF TOMATO CAUSED BY *MELOIDOGYNE INCOGNITA*

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## Abstract

The experiments were conducted during two consecutive cropping seasons of 2017-19 to develop bio-rational based eco-friendly integrated management of root-knot diseases of tomato caused by *Meloidogyne incognita*. The root knot nematode (RKN) infested soils were treated with a different combination of *Trichoderma* based Tricho-compost and neem oil cake with or without low dose of chemical nematicide Furadan 5G. All the treatments gave appreciable reduction of gall development in roots, increased plant growth parameters such as shoot and root growth and fruit yield of tomato. Among the treatments, integration of Tricho-composts with Furadan 5G or neem oil cake integrated with Furadan 5G proved better. However, Trichoderma based bio-fungicides Tricho-composts alone produced promising results but integration of Tricho-composts with Furadan 5G or neem oil cake integrated with Furadan 5G could be the best for management of root knot nematode.

Keywords: Tomato, root-knot nematode**,** *Meloidogyne incognita*, Tricho-compost, neem oil cake, Furadan 5G.

## Introduction

Tomato *(Lycopersicon esculentum* L.) is one of the most popular high value vegetable crops grown throughout the world including Bangladesh. The average yield of tomato in Bangladesh is 14.93 t/ha (BBS 2022) which is quite low as compared to that of other tomato producing countries in the World (Anonymous, 1998). Various factors such as lack of good quality seed and incidence of diseases and pests have been identified for low yield of tomato in Bangladesh. Among the diseases, nematodes are important economical pests of horticultural crops including tomato (Afroz *et al*., 2008; Aktar *et al*., 2008; Tipu *et al*., 2021; Akhter *et al*., 2019). Severe infestation of nematodes can lead to yield losses of over 30% in highly susceptible vegetable crops (Sikora and Fernandez, 2005). The average losses due to root-knot nematode infestation are 20.6% in tomato (Sasser, 1989) and go up to 40% (Singh and Kumar, 2015). Root-knot nematode has been considered as a major limiting factor in the production of tomato throughout Bangladesh (Mian, 1986).

Various strategies for controlling root-knot nematodes, application of nematicides (Hossain *et al.,* 1989), organic soil amendments (Faruk *et al.,* 2001*;* Bari *et al.,*

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2004), cultural, physical measures and biological measures (*Trichoderma* spp, *Pacecilomyces lilacinus, Pasturia penetrans* and *Pseudomonas aeruginosa*) (Rao *et al*., 1997; Reddy *et al.,* 1998 and Siddiqui *et al*., 1999) are practicing. Use of resistant cultivar would be an effective control measure against the disease but none of the tomato varieties cultivated in the country is resistant against the disease. The indiscriminate use of chemicals insisted the appearance of resistant micro-organisms leading to the occurrence of emerging soil borne diseases and also degrading to the environment, other beneficial soil microbes and human health (Akinpelu, 2001; Wachira *et al*., 2009). Therefore, an alternative management option of root-knot nematode disease management is urgently needed. Most effective alternative management option of root-knot nematode is biological control. In the facts mentioned above, the present study was undertaken to develop an eco-friendly management option against root-knot nematode disease of tomato.

**Materials and Methods**

The experiment was conducted during two consecutive cropping seasons of 2017-2019 in the field of Plant Pathology Division of BARI, Joydebpur, Gazipur with 7 treatment combinations. The treatments were (i) Furadan 5G @ 45 kgha$^{-1}$, (ii) Tricho-compost-1@ 3 tha$^{-1}$, (iii) Tricho-compost-2@ 3 tha$^{-1}$, (iv) Tricho-compost-1@ 3 tha$^{-1}$+ Furadan 5G @ 25 kgha$^{-1}$, (v) Tricho-compost-1@ 3 tha$^{-1}$+ Furadan 5G @ 25 kgha$^{-1}$, (vi) Neem oil cake @ 500 kgha$^{-1}$+ Furadan 5G @ 25 kgha$^{-1}$, and vii) Untreated control. The experiment was laid out in a randomized complete block design (RCBD) with three replications. The unit plot size was 3m x 3m. The tomato seedlings were transplanted keeping plant to plant distance 50 cm and line-to-line distance 60 cm. The field soil was inoculated with @ 1 gm of *Melodogyne incognita* infected galled chopped roots of Indian spinach per plant at the time of seedling transplanting. Trichoderma inoculum (bioderma) collected from the Ispahani Agro Tech. Bangladesh, was mass-multiplied in vermi-compost and it was designated as Tricho-compost-1. The *T. harzianum* isolates collected from Plant Pathology Division was multiplied in the mixture of grass pea and wheat bran with mustard oilcake substrates. Mass multiplication of the formulated *Trichoderma* was made in vermi-compost and it was designated as Tricho-compost-2. Tricho-composts were added @ 3 tha$^{-1}$ at 5 days before seedling transplanting, mixed properly with soil and kept for Trichoderma establishment in soil. Neem oilcake was applied at 21 days before seedling transplanting and was properly mixed with the soil and kept moist for proper decomposition. Furadan 5G was added before seedling transplanting. Twenty-five days old tomato seedlings of tomato var. BARI Tomato-15, grown on sterilized soils, were transplanted in the field. Fertilizers, weeding, and irrigation were applied as per recommendation of the crop.

**Data collection and analysis:** Data on different parameters viz. shoot height, shoot weight, root length, root weight, fruit number per plant and yield of tomato were taken. During the growing period bacterial wilt incidence was recorded from

seedling to maturity stage. The severity of root-knot nematode disease was recorded as gall index following 0-10 scale (Zeck, 1971). Data were analyzed statistically by using the MSTATC program and treatments were compared by least significant different (LSD) test at P=0.05 level.

**Results and Discussion**

**Reduction of root-knot nematode (RKN) disease severity:** The severity of root-knot nematode disease of tomato was reduced significantly over control due to soil treatment with Tricho-composts alone or combination with lower dose of Furadan 5G as well as integration of neem oil cake (NOC) with Furadan 5G (Table 1). In the first year, the maximum average gall index 6.13 was recorded in the untreated control plot. The root gall index was reduced from 2.00 to 2.47 due to soil treatments with Tricho-composts, and also integration of Tricho-compost and NOC with Furadan 5G. The lowest RKN disease severity of tomato was recorded from the treatments with NOC @ 500 kg/ha + Furadan 5G @ 25 kgha$^{-1}$ and Tricho-compost-2 @ 3 tha$^{-1}$ + Furadan 5G @ 25 kgha$^{-1}$, which was followed by Tricho-compost-1 @ 3 tha$^{-1}$ + Furadan 5G @ 25 kgha$^{-1}$, Tricho-compost-2 @ 3 tha$^{-1}$ and Tricho-compost-1 @ 3 tha$^{-1}$. Furadan 5G @ 45 kgha$^{-1}$ alone gave higher root gall index (Table 1). Integration of Furadan 5G with NOC and Tricho-compost-2 gave the highest reduction 67.37% of RKN disease severity followed by Tricho-compost-1 + Furadan 5G (65.25%) (Table 1). Besides, the highest gall index value of 5.08 was found in control plot and the values were reduced from 1.08 to 1.92 due to application of different treatments during the second-year experiment. The reduction in disease severity was significant compared to control treatment. The maximum reduction of RKN disease 78.74% was obtained with NOC @ 500 kg/ha + Furadan 5G @ 25 kgha$^{-1}$ followed by Tricho-compost-1 @ 3 tha$^{-1}$ + Furadan 5G @ 25 kgha$^{-1}$, Tricho-compost-2 @ 3 tha$^{-1}$ + Furadan 5G @ 25 kgha$^{-1}$ with the reduction of 74.61% and 73.82%, respectively compared to control. Individually Tricho-compost-2 @ 3 tha$^{-1}$, Furadan 5G @ 45 kgha$^{-1}$, and Tricho-compost-1 @ 3 tha$^{-1}$ reduced 72.04%, 72.04% and 62.20%, respectively root knot nematode disease compared to control (Table 1).

**Shoot growth:** Average shoot length of tomato under control treatment was 55.20 cm plant$^{-1}$ in first year and 64.63 cm plant$^{-1}$ in second year (Table 2). Treatment of soil with Tricho-compost-1 and Tricho-compost-2 alone or integration of Tricho-compost and NOC with Furadan 5G increased the parameter from 77.93 to 83.00 cm plant$^{-1}$ and 79.90 to 98.70 cm plant$^{-1}$t of first and second year respectively. . In the first year, higher shoot length was obtained by NOC + Furadan 5G [1], Tricho-compost-1 + Furadan 5G [1], Tricho-compost-2 + Furadan 5G followed by Tricho-compost-1, Tricho-compost-2 and Furadan 5G. Similar trend was observed in the second year followed by Tricho-compost-2. The least effective treatment was Furadan 5G @ 45 kgha$^{-1}$ followed by Tricho-compost-1 @ 3 tha$^{-1}$.

**Table 1.  Effect of two Tricho-composts, organic amendment and nematicide on the severity of root -knot disease *(Meloidogyne incognita)* of tomato**

| Treatments | Gall index at harvest (0-10 scale) | | Gall index reduction over control (%) | |
|---|---|---|---|---|
| | 1st year | 2nd year | 1st year | 2nd year |
| Furadan 5G @ 45 kgha-1 | 2.93 b | 1.42 bc | 52.20 | 72.04 |
| Tricho-compost-1 @ 3tha-1 | 2.47 c | 1.92 b | 59.71 | 62.20 |
| Tricho-compost-2 @ 3tha-1 | 2.33 cd | 1.42 bc | 61.99 | 72.04 |
| Tricho-compost-1 @ 3tha-1+ Furadan 5G@ 25 kgha-1 | 2.13 cd | 1.29 bc | 65.25 | 74.61 |
| Tricho-compost-2 @3tha-1+ Furadan 5G@ 25 kgha-1 | 2.00 d | 1.33 bc | 67.37 | 73.82 |
| Neem oil cake @ 500 kgha-1+ Furadan 5G @ 25 kgha-1 | 2.00 d | 1.08 c | 67.37 | 78.74 |
| Control | 6.13 a | 5.08 a | - | - |
| LSD (P=0.05) | 0.373 | 0.832 | - | - |

Values within the same column with a common letter do not differ significantly (P=0.05).

**Table 2. Effect of Tricho-composts, neem oilcake and nematicide on shoot growth of tomato in soil inoculated with *Meloidogyne incognita.***

| Treatments | Shoot growth (cm/plant) | | Shoot weight (gm/plant) | |
|---|---|---|---|---|
| | 1st year | 2nd year | 1st year | 2nd year |
| Furadan 5G @ 45 kgha-1 | 77.93 b | 79.90 c | 280.00 d | 226.4 bc |
| Tricho-compost-1 @ 3tha-1 | 78.20 b | 87.10 bc | 290.60 d | 253.0 ab |
| Tricho-compost-2 @ 3tha-1 | 79.47 b | 93.03 ab | 312.40 c | 267.9 a |
| Tricho-compost-1 @ 3tha-1 + Furadan 5G@ 25 kgha-1 | 82.20 a | 98.23 a | 357.70 b | 275.4 a |
| Tricho-compost-2 @3tha-1 + Furadan 5G@ 25 kgha-1 | 83.00 a | 96.67 a | 373.10 a | 283.9 a |
| Neem oil cake @ 500 kgha-1 + Furadan 5G @ 25 kgha-1 | 82.60 a | 98.70 a | 382.40 a | 282.8 a |
| Control | 55.20 c | 64.63 d | 208.90 e | 191.7 c |
| LSD (P=0.05) | 4.883 | 9.018 | 12.86 | 39.24 |

**Root growth:** Soil amendment with Tricho-compost and NOC either singly or in combination with low dose of Furadan 5G showed positive effects on root growth of tomato as compared to untreated control (Table 3). In the first year, minimum root length of 16.07 cm plant-1 was recorded under control treatment. The highest root length of 20.67 cm was achieved from NOC @ 500 kg/ha + Furadan5G @ 25 kg/ha and Tricho-compost-2 @ 3 t/ha + Furadan5G @ 25 kg/ha. Besides, the Tricho-compost-1 @ 3 t/ha + Furadan5G @ 25 kg/ha, Tricho-compost-2 @ 3 t/ha and Tricho-compost-1 @ 3 t/ha gave root length per plant 20.13 cm, 19.73 cm, and

19.13 cm, respectively. Application of Furadan 5G alone increased the root length over control in both the year. In first year, root weight was as low as 18.97 g/plant under control. The maximum root weight of 27.70 g/plant was recorded from Tricho-compost-2 @ 3 t/ha + Furadan5G @ 25 kg/ha treatment followed by NOC @ 500 kg/ha + Furadan5G @ 25 kg/ha treatment of root weight (25.89 g/plant). The root weights ranging from 21.91 to 24.70 g/plant was observed other treatment. However, in second year, the root weight was increased to some extent over control (29.60 g/plant) and it ranged from 31.20 to 34.37 g/plant in plots treated with Tricho-compost and integration of Tricho-composts and NOC with lower dose of Furadan 5G (Table 3).

**Table 3. Effect of Tricho-composts, organic amendments and nematicide on root growth of tomato in soil inoculated with *Meloidogyne incognita***

| Treatments | Root length (cm/plant) | | Root weight (gm/plant) | |
|---|---|---|---|---|
| | 1st year | 2nd year | 1st year | 2nd year |
| Furadan 5G @ 45 kgha$^{-1}$ | 20.13 ab | 19.93 bc | 24.70 bc | 32.73 |
| Tricho-compost-1 @ 3tha$^{-1}$ | 18.47 b | 23.10 ab | 22.09 d | 31.20 |
| Tricho-compost-2 @ 3tha$^{-1}$ | 20.67 a | 24.07 ab | 23.50 cd | 32.23 |
| Tricho-compost-1 @ 3tha$^{-1}$ + Furadan 5G@ 25 kgha$^{-1}$ | 19.13 ab | 25.90 a | 21.91 d | 33.10 |
| Tricho-compost-2 @ 3tha$^{-1}$ + Furadan 5G@ 25 kgha$^{-1}$ | 20.67 a | 27.70 a | 27.70 a | 32.83 |
| Neem oil cake @ 500 kgha$^{-1}$ + Furadan 5G @ 25 kgha$^{-1}$ | 19.73 ab | 26.07 a | 25.89 b | 34.37 |
| Control | 16.07 c | 17.40 c | 18.97 e | 29.60 |
| LSD (P=0.05) | 1.057 | 5.13 | 1.723 | NS |

Values within the same column with a common letter do not differ significantly (P=0.05).

**Crop yield:** Soil amendment with Tricho-compost or in combination of Tricho-compost and NOC with low dose of Furadan 5G gave appreciable increase in fruit number per plant and fruit yield per hectare in both the years (Table 4 and 5). Under control, the average fruit number per plant was 22.67 in 1st year and 28.00 in 2nd year. Fruit number per plant was increased from 31.33 to 38.67 in 1st and 35.33 to 41.33 in 2nd year due to different treatments (Table 4). In 1st year, integration of Tricho-compost-2 with Furadan 5G gave 41.38% higher number of fruits per plant over control followed by integration of NOC with Furadan 5G and Tricho-compost-1 with Furadan 5G treatments where number of fruits per plant was increased 41.00% and 40.33%, respectively compared to control. In 2nd year, all treatments with Tricho-compost, NOC and Furadan 5G caused significant increase in fruit number per plant over control. Integration of NOC with Furadan 5G and Tricho-compost-2 with Furadan 5G gave 32.25% and 31.71%, respectively higher fruit number per plant compared to control.

Integration of Tricho-compost-1 with Furadan 5G, Tricho-compost-2 and Tricho-compost-1 treatments gave comparatively lower fruit number per plant (Table 4). All these treatments were statistically similar where the least effective treatment was Furadan 5G.

**Table 4. Efficacy of Tricho-composts, neem oil cake and Furadan 5G on the fruit number per plant of tomato in soil inoculated with *Meloidogyne incognita***

| Treatments | Number of fruits plant[-1] | | Number of fruits increased over control (%) | |
|---|---|---|---|---|
| | 1st year | 2nd year | 1st year | 2nd year |
| Furadan 5G @ 45 kgha[-1] | 31.33 c | 35.33 b | 29.88 | 20.75 |
| Tricho-compost-1 @ 3tha[-1] | 32.33 bc | 38.33 ab | 26.79 | 26.95 |
| Tricho-compost-2 @ 3tha[-1] | 32.67 bc | 39.67 ab | 30.61 | 30.57 |
| Tricho-compost-1 @ 3tha[-1]+ Furadan 5G@ 25 kgha[-1] | 37.00 ab | 40.33 ab | 38.73 | 29.42 |
| Tricho-compost-2 @3tha[-1]+ Furadan 5G@ 25 kgha[-1] | 38.67 a | 41.00 a | 41.38 | 31.71 |
| Neem oil cake @ 500 kgha[-1]+ Furadan 5G @ 25 kgha[-1] | 36.67 ab | 41.33 a | 38.18 | 32.25 |
| Control | 22.67 d | 28.00 c | - | - |
| LSD (P=0.05) | 3.512 | 5.02 | - | - |

Values within the same column with a common letter do not differ significantly (P=0.05).

The lowest fruit yield of 40.0 t/ha was recorded from the control treatment during 1st year trial (Table 5). The yield ranged from 51.11 to 60.55 t/ha due to application of different treatments. The maximum fruit yield was obtained by integration of NOC with Furadan 5G, Tricho-compost-2 with Furadan 5G and Tricho-compost-1 with Furadan 5G where the fruit yield was 60.55, 60.55 and 57.78 t/ha, respectively. Integration of NOC, Tricho-compost-2 and Tricho-compost-1 with Furadan 5G gave 32.61, 30.34 and 30.07%, respectively higher yield compared to control. Efficacy of these three treatments for increasing fruit yield was statistically similar. Differences in fruit yield harvested from Furadan 5G treated plot and plots treated with Tricho-compost-1 and Tricho-compost-2 was not significant. In 2nd year, the average fruit yield was 49.60 t/ha under control and it ranged from 61.33 to 73.60 t/ha under other treated plots. The tomato yield was 32.61% higher compared to control due to application of Tricho-compost-2 with Furadan 5G. The yield was 30.34, 30.07, 28.74 and 27.91% higher due to integrated application of NOC with Furadan 5G, Tricho-compost-1 with Furadan 5G as well as singly application of Tricho-compost-2 and Tricho-compost-1, respectively compared to control. Furadan 5G alone was less effective to increase yield of tomato.

**Table 5. Effect of soil treatment with Tricho-composts, organic amendment and nematicide on fruit yield of tomato in soil inoculated with *Meloidogyne incognita*.**

| Treatments | Fruit yield (t/ha) | | Yield increase over control (%) | |
|---|---|---|---|---|
| | 1st year | 2nd year | 1st year | 2nd year |
| Furadan 5G @ 45 kgha$^{-1}$ | 51.11 b | 61.33 b | 21.74 | 19.19 |
| Tricho-compost-1 @ 3tha$^{-1}$ | 52.22 b | 68.80 a | 23.40 | 27.91 |
| Tricho-compost-2 @ 3tha$^{-1}$ | 53.33 b | 69.60 a | 24.99 | 28.74 |
| Tricho-compost-1 @ 3tha$^{-1}$+ Furadan 5G@ 25 kgha$^{-1}$ | 57.78 a | 70.93 a | 30.77 | 30.07 |
| Tricho-compost-2 @3tha$^{-1}$+ Furadan 5G@ 25 kgha$^{-1}$ | 60.55 a | 73.60 a | 33.94 | 32.61 |
| Neem oil cake @ 500 kgha$^{-1}$+ Furadan 5G @ 25 kgha$^{-1}$ | 60.55 a | 71.20 a | 33.94 | 30.34 |
| Control | 40.00 c | 49.60 c | - | - |
| LSD (P=0.05) | 4.01 | 7.324 | - | - |

Values within the same column with a common letter do not differ significantly (P=0.05).

The present study revealed that integrated soil amending with Tricho-composts with Furadan 5G, neem oil cake and Furadan 5G drastically suppressed the root gall index value caused by root-knot nematode *M. incognita* and thereby improving plant growth parameters such as shoot length, shoot weight, root length, root weight and fruit yield of tomato compared to untreated control plot. Although soil amendment with Tricho-compost and Furadan 5G alone also reduced gall index values and improved plant growth to some extent, it was inferior in general. In the present study application of Trichoderma based bio-fungicide Tricho-compost @ 3 tha$^{-1}$ or NOC @ 500 kg/ha with low dose of Furadan 5G @ 25 kgha$^{-1}$ observed to be effective for reducing RKN disease of tomato. *Trichoderma* spp. can improve plant defense against diverse plant pathogens, including fungi, bacteria, viruses, and nematodes (Yaru *et al*., 2021; Akhter *et al*. 2021). The findings of the study are in agreement with the findings of (Singh 2013).. The study were also supported by the findings of (Singh and Mahanta 2013). The findings of the study are also in agreement with the findings of Kumar and Khanna (2006) who reported that combination of bio-control agents, chemical and vermi-compost (*T. harzianum* + *G. fasciculatum* +Carbosulfan ST + vermi-compost gave maximum reduction of nematode population of tomato in field. Kumari *et al*. (2020), Mukhtar (2018) and Devi *et al*. (2002) also supported the present findings that the soil application of fungal bio-control agents *T. viride, T. harzianum* and *T. asperellum* improving plant growth of tomato and significantly reduced reproduction of root-knot nematode in tomato. Many other researchers also confirmed previous findings, on the use of isolates of *Trichoderma* spp. for the management of root-knot nematodes of vegetable crops (Dababat *et al*., 2007; Sahebani and Hadavi, 2008; Affokpon *et al*., 2011; Faruk, 2022). Several studies

reported that oil cake applications reduced the *Meloidogyne* spp. population and thereby increasing plant growth and yield of different crops (Yadav *et al*., 2005; Nirosha *et al.,* 2018; Faruk, 2020). Similar findings had also been reported by many other researchers that bio-control agents *Trichoderma* spp. and different oil cakes were effective in controlling root-knot nematode as well as increasing plant growth and yield of different crops (Yadav *et al.,* 2005; Javed, *et. al.*, 2008; Sahebani and Hadavi, 2008; Singh *et al*., 2011; Lidia *et al*., 2014 and Nirosha *et al*., 2018).

## Conclusion

From the present study it could be concluded that soil treated with either integration of Trichoderma based bio-fungicide Tricho-compost or neem oil cake with lower dose of Furadan 5G might be effective for reducing root-knot nematode disease, as well as increasing plant growth and fruit yield of tomato.

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