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ENHANCEMENT OF SEED GERMINATION AND EARLY SEEDLING GROWTH THROUGH SEED PRIMING AGENTS IN BRINJAL

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Abstract

Two experiments were conducted in the laboratory of Plant Physiology Section of Horticulture Research Centre, Bangladesh Agricultural Institute (BARI) for two consecutive years of 2021 and 2022 for 14 days during 13 February to 26 February to investigate the effect of different priming agents on seed germination, germination parameters, seedling growth and vigour of brinjal (*Solanum melongena* L.). During 2021, the experiment consisted of two brinjal varieties *viz*, BARI Begun-6 and BARI Begun-10 and seven priming agents *viz*., Hydropriming (DH_2O), Gibberellic acid (GA_3) @ 289 µM, Potassium chloride (KCl) @ 134 mM, Urea @ 167 mM, Sodium chloride (NaCl) @ 40 mM, and Diammonium phosphate (DAP) @ 70 mM PEG_{6000} @ 5%) with unprimed control, whereas during 2022 the experiment comprised the same two varieties of brinjal and seven priming agents *viz*., Hydropriming (DH_2O), Gibberellic Acid (GA_3) @ 289 µM, Potassium Nitrate (KNO_3) @ 0.25%, Hydrogen peroxide (H_2O_2) @ 40 mM, Sodium Chloride (NaCl) @ 40 mM, α -triacontanol (TRIA) @ 1 µM and Naphthalene Acetic Acid (NAA) @ 50 ppm. The experiments of both years were laid out in completely randomized design with three replications. In the 1st year, seed germination, germination index, germination rate index, coefficient of velocity of germination, seedling growth (shoot length, root length and seedling dry weight) and seedling vigour (seedling vigour index I and-II) were enhanced significantly in both the varieties with 289 µM of GA_3. In the 2nd year, seeds of the two brinjal varieties treated with 40 mM H_2O_2 showed the maximum germination percentage, germination index, germination value, seedling growth (shoot length, root length and seedling dry weight) and seedling vigour (seedling vigour index I and -II) compared to the other treatments. From the two years' results, it was concluded that either 40 mM H_2O_2 or 0.25% KNO_3 or 289 µM GA_3 can be used as priming agent to enhance the seed germination, growth and seedling vigour of brinjal seed. Prior to sowing or going for breeding work, it was suggested that brinjal seeds should be primed with H_2O_2 or KNO_3 or GA_3 concentrations for 18 hrs to obtain maximum germination and vigourous seedlings.

Keywords: Brinjal, *Solanum melongena*, germination, seedling vigour, germination value, priming, H_2O_2, KNO_3.

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Introduction

Brinjal or eggplant (*Solanum melongena* L) is an important vegetable crop of the family solanaceae. It is one of the most commonly grown vegetable crops which is cultivated both in winter and summer seasons across the country. Brinjal fruit (unripe) is primarily consumed as cooked vegetable in various ways and dried shoots are used as fuel in rural areas. It is low in calories and fats, contains mostly water, some proteins, fiber and carbohydrates. It is a good source of minerals and vitamins and is rich in total water-soluble sugars, free reducing sugars, amide proteins among other nutrients.

Seed germination in field condition is a key factor for crop growth and yield. Low germination percentage, delayed germination and retarded in seedling growth are common problem in brinjal. The germination percentage of brinjal is around 70% under the environment of Bangladesh and India (Agarwal, 1995; Das *et al*., 2020), which is very low compared to that of developed countries. Good seedling establishment under some stress conditions may ensure good crop growth as well as better yield (Nayak and Patra, 2000). It has been reported that due to the lack of quality seedlings, yield of crops decreased by about 15% in Bangladesh (FAO, 2000). Rapid germination and emergence are essential for successful crop establishment, for which seed priming could play an important role. Seed priming is a controlled hydration technique that activates the normal metabolic processes during the early phase of germination (Hussain *et al*., 2016; Silva and Silva, 2016).

Good germination and stand establishment are the maximizing factors in crop production, and their importance is well recognized by farmers and researchers. It has been reported that Gibberellic acid (GA_3), Sodium Chloride (NaCl), Muriate of Potash (KCl), Urea, Diammonium Phosphate (DAP) and Polyethylene glycol (PEG) are used as seed priming materials (Tian *et al*., 2014, Anosheh *et al.*, 2011; Koirala *et al.,* 2019). It is also reported that seeds priming with potassium nitrate (KNO_3), Hydrogen peroxide (H_2O_2), Triacontanol and Naphthalene Acetic Acid (NAA) can improve germination percentage in tomato (Ali *et al*., 2020; Saidi *et al*., 2024). Seed priming, by increasing speed and uniformity of germination, could help to obtain elite seedling along with better crop stand (Ghiyasi *et al.,* 2008; Islam *et al*., 2012). In Bangladesh, farmers are badly in need of appropriate technology for optimizing germination and crop growth of vegetable crops. However, the information on suitable priming technology for potential germination is scanty, especially on the popular vegetables in Bangladesh like brinjal. The investigation was, therefore, conducted to determine appropriate priming agent to increase germination percentage and quality attributes of brinjal seedling.

Materials and Methods

The experiment was conducted at the laboratory of Plant Physiology Section, Horticulture Research Centre, BARI during 2021 and 2022 for 14 days during 13

February to 26 February. The experiment consisted of two factors- Factor A: two varieties, namely 'BARI Begun-6' and 'BARI Begun-10' and Factor B: 8 seed priming treatments *viz*., in 2021, P_1 = control (no priming), P_2 = hydro-priming by distilled water (DH_2O), P_3 = 289.0 µM gibberellic acid (GA_3), P_4 = 134 mM muriate of potash (KCl), P_5 =167.0 mM Urea, P_6 = 40 mM sodium chloride (NaCl), P_7 = 76 mM diammonium phosphate (DAP) and P_8 = 5% polyethylene glycol (PEG_{6000}). During 2022, some treatments were changed, such as: T_1 = Control (No priming), T_2 = Hydropriming by DH_2O, T_3 = 289 µM GA_3, T_4 = 0.25% KNO_3, T_5 = 30 µM H_2O_2, T_6 = 40 mM NACL, T_7 = 1 µM TRIA, T_8= 5 ppm NAA. During 2021, no seeds were germinated when seeds were primed with KCL, Urea and DAP. Therefore, KCL, Urea and DAP were replaced by KNO_3, H_2O_2 and Triacontanol. PEG was also replaced by NAA. BARI Bagun-6 fruit is oval shaped and light green in colour, and this variety has been recommended for cultivation in winter season. Its seed germination is poor and erratic. 'BARI Begun-10' fruit is elongated and bright violet in colour, and this variety has been recommended for cultivation year-round. Its seeds germination is also poor and uneven. Due to two different types of brinjal variety in nature, these two varieties were selected for this experiment. The seeds of these varieties were collected from Olericulture Division, Horticulture Research Centre, Bangladesh Agricultural Research Institute (BARI). Required number of petri dishes each with a diameter of 9 cm were used in the experiment and arranged in a completely randomized design (CRD) moistened with respective treatment in three replications. Three layers of commercial tissue paper were used in each petri dish for retaining required amount of water for imbibition of seeds. Before setting the experiments, seeds were primed with respective solutions for 18 hours. Twenty healthy and equal sized seeds of BARI Bagun-6 and BARI Begun-10 were selected and placed on sterilized petri dish lined with tissue paper.

The seeds were sterilized by soaking in 0.1% mercuric chloride for 5 min and then seeds were washed with distilled water well to remove the mercuric chloride adhered to the seed surface. The priming of seed was done in the dark at 26 ± 2 ℃ for 24 hours. The seeds of control treatment were not primed. The solution was changed after 12 hours to facilitate aeration in seeds. The ratio of seed weight to solution volume (w/v) was 1:5. After 18 hours, the primed seeds were washed with water for 3-4 times and dried in shade at 27 ± 2 ℃ until the moisture content was decreased to initial moisture content. The sterilized and primed seeds were placed on the petri dish lined with filter paper.

The perti dishes with seeds of the selected varieties of brinjal were kept in normal room temperature (27 ± 2 ℃) for germination. Solution of chemicals used in each year was prepared by dissolving calculated amount of lab grade chemicals with distilled water. The respective prime solutions were poured into the petri dish @ 5 ml/petri-dish, separately. In control treatment, 5 ml distilled water was added to the petri dishes. The germination count was taken after 72 hours of placing seeds. The 5 ml of distilled water (control) and 5 ml solution of salinity were added separately in the petri dishes. No nutrient solution was added to the petri dishes. The petri dishes were covered to prevent the loss of moisture by evaporation. Number of seeds germinated was counted daily and data recording were continued up to 14 days. At 14 days, 10 seedlings (shoot + root) were weighed by the electrical balance and this weight was considered as fresh weight of seedling, and these seedlings were kept in an oven at 72^{O}c for 1 week for recording dry weight of seedling. At 14 days, the shoot and the root length of ten randomly selected seedlings from each replicate were measured.

Germination and Germination indices

The number of seeds germinated was recorded daily up to 14 days. Seeds were considered germinated upon emergence of radicles (≥ 2 mm) (Sharma and Sharma, 2010). From these germination counts, several germination attributes were calculated, including final germination percentage (%), germination index, coefficient of velocity of germination (CVG) (Kader and Jutzi, 2004) and germination rate index (GRI) (Kader, 2005), germination value (GV) and mean germination time (MGT) as follows:

Germination Percentage (GP)

Final Germination percentage (FGP) was calculated using the following formulas (Li, 2008 and Mostafavi *et al*., 2011):

Germination percentage (GP) = $\frac{\mathrm{a}}{b} \times 100$

where, a = total number of seeds germinated

b = total number of seeds to germinate

Coefficient of Velocity of Germination and Germination Index

CVG (% day^{-1}) $= \sum Ni / \sum (NiTi) \times 100$,

GRI (%day^{-1}) $= \sum Ni / I$,

where N is the number of seeds germinated on day i, and T_i is the number of days from sowing. The CVG gives an indication of the rapidity of germination: it increases when the number of germinated seeds increases and the time required for germination decreases. The GRI reflects the percentage of germination on each day of the germination period. Higher GRI values indicate higher and faster germination.

Germination Index (GI) = (12 x N1) + (11 x N2) + ...+ (2x N11) + (1 x N12): where N1, N2 .....N13, N14 is the the number of germinated seeds on the first, second and subsequent days until 14th and multipliers (eg., 12, 13..... etc) are weight given to the days of the germination (Kader, 2005).

Mean Germination Time

MGT = ΣDn/Σn, Where, n is the number of seeds which were germinated on day D, and D is the number of days counted from the beginning of germination. GRI = [(G1/1) + (G2/2) + (Gx/X)], Where, G is the germination on each alternate day after placement 1, 2 and x is the corresponding day of germination (Ranal *et al.,* 2009).

Germination Value

GV= (DDGs /N) x GP /10 (Djavanshir and Pourbeik, 1976), where DG is daily germination speed obtained by dividing the cumulative germination percentage by the number of days since sowing. DDGs is total germination obtained by adding DGs value obtained from the daily counts. N is the total number of daily counts, starting from the date of first germination.GP is Germination percentage at the end of the test and 10 as a constant.

Seedling Vigour Index

The seedling vigour index I and II were calculated as per the method prescribed by Abdul-Baki and Anderson (1973) and expressed in whole number. Seedling Vigour index I = Germination (%) × mean seedling length (cm) and Seedling Vigour index II = Germination (%) × dry weight/ seedling (mg) and they were expressed in number.

All data were analyzed through MSTATC software and means were separated with the help of Tukey HSD test at 5% level of probability.

Results and Discussion

Germination percentage

During 2021, brinjal var. BARI Begun-6 showed maximum germination percentage when primed with 289.0 µM GA_3 (66.67% in 2021) followed by 40 mM NaCl (48.90%) and the lowest from control (no priming) (Table 1). During 2021, BARI Begun-10, priming with GA_3 at 289.0 µM gave maximum germination (53.33%) followed by 5% PEG (51.78%) and 40 mM NaCl (47.90%) and the lowest value was recorded from control (22.67%) (Table 1). In both the varieties, during 2021 hydropriming gave higher germination (40% in BARI Begun-10 and 46.67% in BARI Begun-10 than unprimed control (Table 1).

During 2022, both varieties, maximum germination percent was obtained from 40 mM H_2O_2 primed seeds (97.24% in BARI Begun-6 and 100% in BARI Begun-10) followed by 0.25% KNO_3 (86.66% in BARI Begun-6 and 90.85% in BARI Begun-10). The lowest value was observed in unprimed seeds of BARI Begun-6 (42.60%), though in BARI Begun-10, the lowest germination was found from 50 ppm NAA primed seeds of BARI Begun-10 (29.15%) (Table 2). In both the varieties, during 2021 hydropriming gave higher germination (56.05% in BARI Begun-6 and 67.26% in BARI begun-10) than unprimed control (Table 2). Saidi *et al.* (2024) reported that tomato seeds primed with 50 and 100 mM H_2O_2 improved germination in saline solutions. Ali *et al.* (2020) obtained significantly higher germination percentage with 0.25% KNO_3 (87%) than that of control (83%). Parajuli and Bhattaraj (2025) obtained the highest germination (67%) from 100 ppm GA_3 primed brinjal seeds.

Table 1. Effect of different priming treatments on germination percentage, germination index, germination rate index and coefficient of velocity of germination of two brinjal varieties during 2021

Treat	Germination percentage		Germination index		Germination Rate Index		Coefficient of velocity of germination	
	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2
P_1	35.0d	22.67cd	35.5d	23.5d	3.32e	2.83e	11.29d	11.20e
P_2	40.00c	46.67c	36.5c	45.0c	4.03d	6.27c	11.61c	12.00d
P_3	66.67a	53.33a	51.0a	51.1ab	7.09a	7.10a	14.82a	14.89a
P_4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P_5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P_6	48.90b	47.90bc	44.0b	55.0a	6.62b	6.71b	12.5b	12.3c
P_7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P_8	40.00c	51.78ab	31.5d	47.0bc	4.40c	5.98	11.09d	12.9b
CV (%)	6.01	6.01	5.02	5.02	5.36	5.36	6.45	6.45

Figures in a column, having same letter (s) do not differ significantly at 5% level by Tukey's W test. P_1 = control (no priming), P_2 = hydro-priming by distilled water, P_3 = 289.0 μM GA_3, P_4 = 134.0 mM KCl, P_5 =167.0 mM Urea, P_6 = 40.0 mM NaCl, P_7 = 76.0 mM DAP, P_8 = 5% PEG_{6000}; V_1 = BARI Begun-6 and V_2 = BARI Begun-10

Table 2. Effect of different priming treatments on germination percentage, germination index, germination value and mean germination time of two brinjal varieties during 2022

Treat	Germination percentage		Germination index		Germination value		Mean germination time (days)	
	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2
T_1	42.60g	44.84e	501.81f	524.72e	74.88f	98.72e	8a	11a
T_2	56.05d	67.26d	679.39c	852.05c	110.37c	220.92c	7cd	6e
T_3	65.02c	71.76c	529.17e	576.25d	87.43d	199.17d	8ab	9c
T_4	86.66b	90.85b	920.05b	1109.6b	185.57b	308.08b	8ab	6de
T_5	97.24a	100.00a	1031.4a	1293.8a	266.85a	467.17a	7d	6e
T_6	51.56e	35.87f	560.67d	275.79g	79.83e	28.20h	8bc	6e
T_7	43.61fg	44.85e	443.96g	845.40c	61.24h	77.44f	8b	11a
T_8	44.88f	29.15g	349.79h	358.76f	69.45g	33.90g	7bc	7d
CV (%)	4.31	4.31	3.28	3.28	3.28	3.28	2.57	2.57

Figures in a column, having same letter (s) do not differ significantly at 5% level by Tukey's W test. T_1 = Control, T_2 = Hydropriming, T_3 = 289 µM GA_3, T_4 = 0.25% KNO_3, T_5 = 40 µM H_2O_2, T_6 = 40 mM NACL, T_7 = 1 µM TRIA, T_8= 50 ppm NAA; V_1 = BARI Begun-6 and V_2 = BARI Begun-6

Germination Index, Germination rate index, Coefficient of velocity of germination and Germination value

Germination index (GI), Germination rate index (GRI), Coefficient of velocity of germination (CVG %) and Germination value (GV) indicates the speed of germination. Higher the GI, GRI, CVG and GV faster the germination of seeds. During 2021 var. BARI Begun-6, hormonal priming with 289.0 µM GA_3 (100 ppm) gave maximum values of GI (51.0), GRI (7.09) and CVG (14.82%) which were followed by 40 mM NaCl (GI-44.0, GRI-6.62, CVG-12.5%) and their lowest from control treatment (Table 1). In 2021, var. BARI Begun-10 showed the maximum GI by 40 mM NaCl (55.0) closely followed by 289.0 µM GA_3 (51.1); GRI and CVG were found maximum from 289.0 µM GA_3 (GRI-7.10 and CVG-14.89%) followed by 40 mM NaCl (GI-6.71, CVG-12.5%)

In 2022, in BARI Begun-6, priming with 40 mM H_2O_2 gave maximum values of GI (1031.4) and GV (266.85) which was followed by 0.25% KNO_3 (GI-920.05, GV-266.85) and their lowest values obtained from no priming treatment (Table 2), but in case of coefficient of velocity of germination followed by 5% PEG (12.9) and 40 mM NACL (12.3) (Table 2). During 2022, in BARI Begun-6, seeds primed with 40 mM H_2O_2 recorded the maximum GI value (1031.8) which was followed by 0.25% KNO_3 (920.05), hydropriming (679.39) and 289 µM GA_3 (529.17), and the lowest value of GI from unprimed seeds (501.81); in the same variety of brinjal, GV was also recorded maximum from 40 mM H_2O_2 (266.85) followed by 025%

KNO_3 (185.87) and the lowest GV in 1 µM TRIA (69.45), but in case of coefficient of velocity of germination followed by 5% PEG (12.9) and 40 mM NACL (12.3) (Table 2). In BARI Begun-6, seeds primed with 40 mM H_2O_2 recorded the maximum GI value (1031.8) which was followed by 0.25% KNO_3 (920.05), hydropriming (679.39) and 289 µM GA_3 (529.17), and the lowest value of GI from unprimed seeds (501.81); in the same variety of brinjal, GV was also recorded maximum from 40 mM H_2O_2 (266.85) followed by 025% KNO_3 (185.87) and the lowest GV in 1 µM TRIA (69.45).

The control treatment and 1 µM TRIA took higher germination time (11 and 11 days) in case of BARI Begun-10 but 40 mM H_2O_2 took the lowest germination time (6 days) identical with 40 mM NaCl (6 days) and hydropriming (6 days) for BARI Begun-10 during 2022 (Table 2). In the same year and same variety, the lowest germination time was observed from control (6 days) which was followed by hydropriming 40 mM H_2O_2 and 0.25% KNO_3. During 2022, in BARI Begun-6, unprimed control took maximum time (8 days) closely followed by 289.0 µM GA_3 (8 days) and 0.25% KNO_3 (8 days) and 40 mM H_2O_2 primed seeds took the lowest time (7 days). Ahmed *et al.* (2017) reported that seeds treated with 1 dS/m NaCl gave the maximum germination index in tomato, brinjal and chilli.

Shoot length and root length

In 2021, the results showed that priming agents except urea, KCl and DAP had stimulatory effect on shoot length of brinjal along the growth period (Table 3). During 2021, var. BARI Begun-10 showed the maximum shoot length (5.6 cm) from 289.0 µM GA_3 identical with hydro-priming (49 cm) and no priming (53 cm) and the lowest length in 5% PEG (3.5 cm). In 2021, var. BARI Begun-10 gave maximum shoot length from 289.0 µM GA_3 (4.5 cm) which was statistically similar with 40 mM NaCl (4.4 cm) and hydropriming (4.3 cm) and its minimum value in 5% PEG. BARI Begun-6 enhanced root length significantly higher with GA_3 at 289.0 µM over other treatments (Table 3). At 14 DAS, the maximum root length was 5.0 cm at 289.0 µM GA_3 followed by hydropriming (4.5 cm) whereas the lowest length of roots was observed in control (Table 3). In BARI Begun-10, the priming treatment of 40 mM NaCl gave maximum root length (3.3 cm) which was followed by 289.0 µM GA_3 (2.5 cm). Priming with PEG gave negative effect on root length of both varieties. The unprimed and hydro-primed seeds also gave lower seed length (2.1 cm and 2.2 cm).

In 2022, var. BARI Begun-6 showed the highest shoot length from 40 mM H_2O_2 (5.25 cm) which was identical with 289.0 µM GA_3 (5.24 cm), 0.25% KNO_3 (5.17 cm); whereas priming with 50 ppm NAA gave the lowest shoot length (0.93 cm). In BARI Begun-10 of 2022, maximum shoot length was recorded from 0.25% KNO_3 (4.73 cm) which was statistically similar with no priming (4.64 cm), hydropriming (4.51 cm), 289 µM GA_3 (4.44 cm) and 40 mM H_2O_2 (4.21 cm) and priming with 50 ppm NAA gave the lowest shoot length (0.85 cm) (Table 4). In BARI Begun-6 hydropriming enhanced root length closely followed 40 mM H_2O_2 (Table 4). At 14 DAS, the maximum root length was 1.71 cm at hydropriming treatment statistically similar with 40 mM H_2O_2 (1.65 cm) followed by 1. 35 cm produced by 289.0 µM GA_3. The lowest length of roots was obtained from 1 µM TRIA (0.58 cm) and 50 ppm NAA (0.62 cm). (Table 4). In BARI Begun-10, 2022, the priming treatment of 40 mM NaCl gave maximum root length (1.91 cm) which was closely followed by 40 mM H_2O_2 (1.75 cm) and the lowest length of roots in 50 ppm NAA (0.53 cm) and 1 µM TRIA (0.60 cm). Islam *et al.* (2006) obtained maximum shoot length (5.3 cm) and root length (5.35 cm) from 100 ppm GA_3 primed brinjal seeds after 15 DAS (days after sowing) in petri dish. Ahmed *et al.* (2017) reported that seeds treated with 1 dS/m NaCl gave the maximum shoot and root length in tomato, brinjal and chilli. Parajuli and Bhattarai (2025) obtained the highest shoot length and root length from 100 ppm GA_3 primed brinjal seeds.

Seedling Vigour Index I

In 2021, in var. BARI Begun-6, hormonal priming with 289.0 µM GA_3 recorded maximum Seedling Vigour Index I (706.7) which was closely followed by halo-priming with 40 mM NaCl (420.5), and hydropriming (392.0) whereas priming of seed with 5% PEG gave the lowest result (240.0) (Table 3). In 2021, var. BARI Begun-10 showed similar result. Hormonal priming with 289.0 µM GA_3 recorded maximum Seedling Vigour Index I (373.3) which was closely followed by halo-priming with 40 mM NaCl (368.8) and hydro-priming (303.4) and 5% PEG (243.4), and no priming gave the lowest result (138.3).

Table 3. Effect of different priming treatments for 18 hrs on shoot length, root length and seedling vigour index I of two brinjal varieties during 2021

Treat	Shoot length (cm)		Root length (cm)		Seedling vigour Index I	
	V_1	V_2	V_1	V_2	V_1	V_2
P_1	4.9a	4.0b	4.0cd	2.1c	311.5c	138.3d
P_2	5.3a	4.3ab	4.5b	2.2c	392.0c	303.4b
P_3	5.6a	4.5a	5.0a	2.5b	706.7a	373.3a
P_4	0.0	0.0	0.0	0.0	0.0	0.0
P_5	0.0	0.0	0.0	0.0	0.0	0.0
P_6	4.5c	4.4a	4.1c	3.3a	420.5b	368.8a
P_7	0.0	0.0	0.0	0.0	0.0	0.0
P_8	3.5d	2.5c	2.5d	2.0c	240.0 d	243.4c
CV (%)	2.10	2.10	2.35	2.35	3.56	3.56

Figures in a column, having same letter (s) do not differ significantly at 5% level by Tukey's W test. P_1 = control (no priming), P_2 = hydro-priming by distilled water, P_3 = 289.0 µM GA_3, P_4 = 134.0 mM KCl, P_5 =167.0 mM Urea, P_6 = 40.0 mM NaCl, P_7 = 76.0 mM DAP, P_8 = 5% PEG-6000, V_1 = BARI Begun-6 and V_2 = BARI Begun-10.

During 2022, in BARI Begun-6, maximum seedling vigour index I was observed in 40 mM H_2O_2 (670.96) which was followed by 0.25% KNO_3 (526.95) and 289.0 µM GA_3 (428.33) and minimum was obtained when seeds were primed with 50 ppm NAA (69.29). In 2022, in BARI Begun-10, maximum seedling vigour index I was recorded from 40 mM H_2O_2 (596.20) which was followed by 0.25% KNO_3 (504.16), hydropriming (424.44) and its minimal value was found in 50 ppm NAA (40.28). Hemalatha *et al.* (2017) obtained maximum seed vigour from the seeds primed with 0.25% H_2O_2 in rice. Ahmed *et al.* (2017) reported that seeds treated with 1 dS/m NaCl gave the maximum vigour in tomato, brinjal and chilli.

Table 4. Effect of different priming treatments for 18 hrs on shoot length, root length, and seedling vigour index I of two brinjal varieties during 2022

Treat	Shoot length (cm)		Root length (cm)		Seedling Vigour Index I	
	V_1	V_2	V_1	V_2	V_1	V_2
T_1	4.10 c	4.64a	1.35b	0.84c	300.52d	287.13c
T_2	4.67b	4.51a	1.71a	1.80ab	357.48d	424.44b
T_3	5.24a	4.44a	1.35b	1.66b	428.33c	273.95d
T_4	5.17ab	4.73a	0.91c	0.81cd	526.95b	504.16b
T_5	5.25 a	4.21a	1.65ab	1.75a	670.96a	596.0a
T_6	2.93 d	3.37b	0.80cd	1.91a	192.03f	189.21e
T_7	2.46d	2.25c	0.58d	0.60de	132.64g	204.85e
T_8	0.93e	0.85d	0.62d	0.53e	69.29h	40.28f
CV (%)	5.32	5.98	8.94	6.17	4.10	4.27

Figures in a column, having same letter (s) do not differ significantly at 5% level by Tukey's W test. T_1 = Control (No priming), T_2 = Hydropriming, T_3 = 289 µM GA_3, T_4 = 0.25% KNO_3, T_5 = 40 mM H_2O_2, T_6 = 40 mM NACL, T_7 = 1 µM TRIA, T_8= 50 ppm NAA; V_1 = BARI Begun-6 and V_2 = BARI Begun-10.

Seedling dry weight

In 2021, in var. BAR Begun-6, the highest seedling dry weight was recorded from 289.0 µM GA_3 (3.48 mg) which was identical with hydropriming (3.20 mg) and the lowest seedling dry weight in control (Fig. 1). The same trend of seedling dry weight was also found in BARI Begun-10. Priming with 289.0 µM GA_3 gave maximum seedling dry weight (2.11 mg) which was statistically similar to priming with 40 mM NACL (1.99 mg), hydropriming (1.98 mg), priming with 5% PEG (1.98 mg) and the lowest seedling dry weight from unprimed treatment.

In 2022, in BARI Begun-10, hormonal priming also produced the highest seedling dry weight (Fig. 2). In BARI Begun-6, the treatment 0.25% KNO_3 gave the maximum seedling dry weight (4.19 mg) which was identical with 40 mM H_2O_2 (4.00 mg) and the minimal seedling dry weight was found in 1 µM TRIA (Fig. 2). On the other hand, in BARI Begun-10, maximum seedling dry weight was obtained from 0.25% KNO_3 (3.05) which was statistically similar with 40 mM H_2O_2 (2.99 mg), hydropriming (2.91 mg) and the lowest seedling dry weight was noticed in 1 µM TRIA (2.15 mg) closely followed by control (2.55 mg). Ali *et al*. (2020) obtained significantly maximum seedling dry weight (14.7 mg) when seeds were primed with KNO_3 compared to control (11.9 mg) in tomato. Hemalatha *et al.* (2017) obtained maximum seedling dry weight from the seeds primed with 0.25% H_2O_2 in rice.

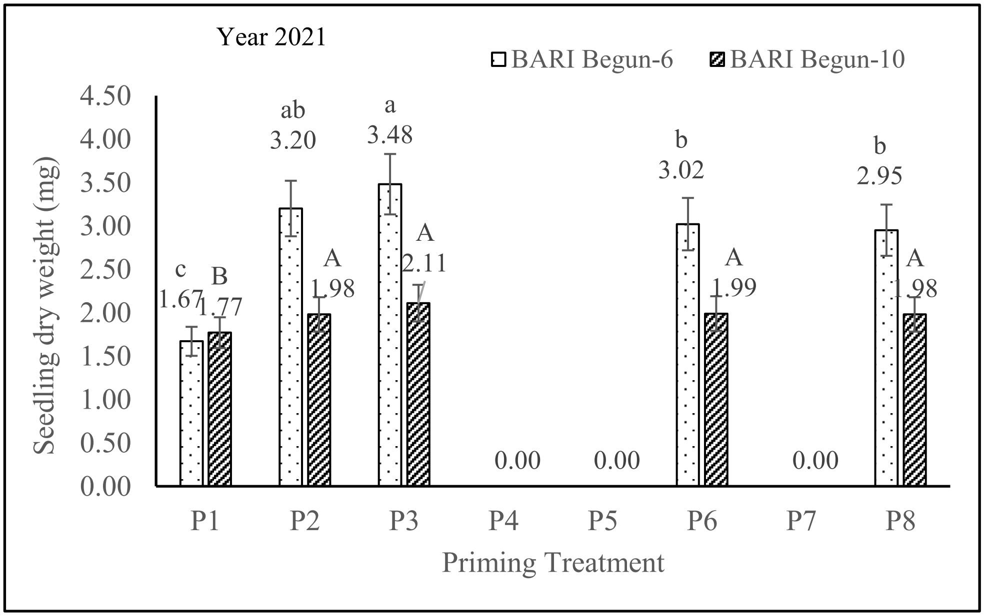

Fig. 1. Effect of seed priming on seedling dry weight in two varieties of brinjal during 2021.

Figures with the same small letter (s) and capital letter (s) for BARI Begun-6 and BARI Begun-10, respectively, are not significantly different ($P \leq 0.05$) by Tukey HSD test. Bars indicate mean SE ± of three replicates. P_1 = control (no priming), P_2 = hydro-priming by distilled water, P_3 = 289.0 µM GA_3, P_4 = 134.0 mM KCl, P_5 =167.0 mM Urea, P_6 = 40.0 mM NaCl, P_7 = 76.0 mM DAP, P_8 = 5% PEG-6000; V_1 = BARI Begun-6 and V_2 = BARI Begun-10.

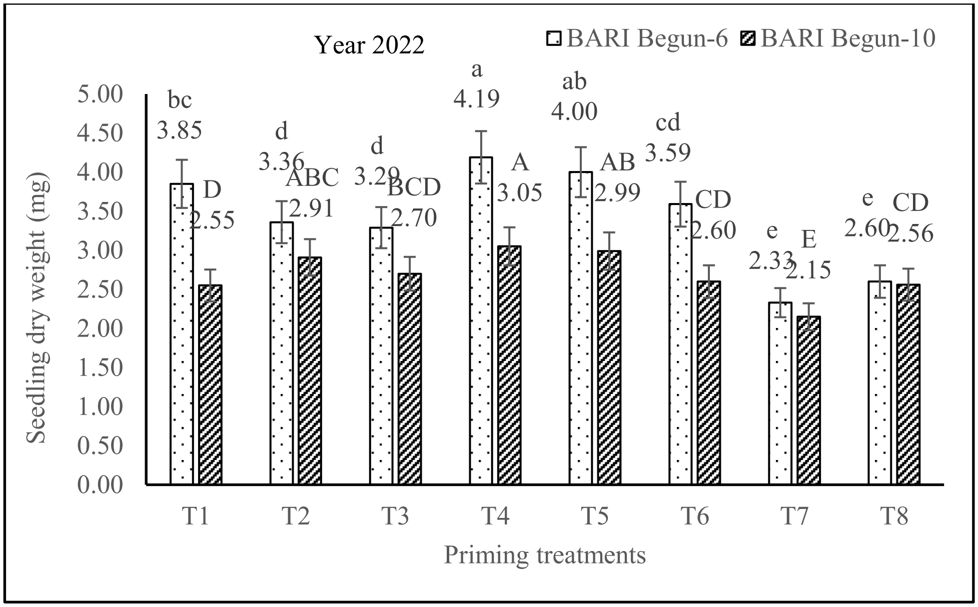

Fig. 2. Effect of seed priming on seedling dry weight in two varieties of brinjal during 2022.

Figures with the same small letter (s) and capital letter (s) for BARI Begun-6 and BARI Begun-10, respectively, are not significantly different ($P \leq 0.05$) by Tukey HSD test. Bars indicate mean ± SE of three replicates. T_1 = Control (No priming), T_2 = Hydropriming, T_3 = 289 µM GA_3, T_4 = 0.25% KNO_3, T_5 = 40 mM H_2O_2, T_6 = 40 mM NACL, T_7 = 1 µM TRIA, T_8= 50 ppm NAA; V_1 = BARI Begun-6 and V_2 = BARI Begun-10.

Seedling Vigor Index II

Seedling Vigour Index II in BARI Begun-10 was found lower than that in BARI Begun-6 (Fig. 3). During 2021, var. BARI Begun-6 showed the maximum Seedling Vigour Index II from the seeds primed with 289 µM GA_3 (232.01) followed by 40 mM (4 dS/m) NaCl (146.70), 5% PEG and its minimum value was recorded from the unprimed seeds (Fig. 3). In BARI Begun-10 the maximum seedling vigour index was also recorded from 289 µM GA_3 (112.53) followed by 5% PEG (102.52), 40 mM (4 dS/m) NACl (95.32), hydropriming (92.41) and the lowest value was observed from the unprimed seeds (40.13).

During 2022, in BARI Begun-6, seeds primed with 40 mM H_2O_2 gave the maximum Seedling Vigour Index (388.96) which was statistically similar with 0.25% KNO_3 (363.11) (Fig. 4). There was no significant difference found among 289 µM GA_3 (213.92), hydropriming (188.33) and 40 mM NACl priming (185.10) in respect of Seedling Vigour Index II. The lowest seedling vigour index was noticed from 5% PEG treatment. In contrast, in BARI Begun-10, the maximum seedling vigour index II was observed from 40 mM H_2O_2 (299.00) closely followed by 0.25% KNO_3 (277.09) and hydro-priming (187.50). During 2022, in var. BARI Begun-10 with 289 µM GA_3 did not perform well compared to hydro-priming with regard to seedling vigour index II and the lowest seedling vigour index was recorded from 5% PEG treatment.

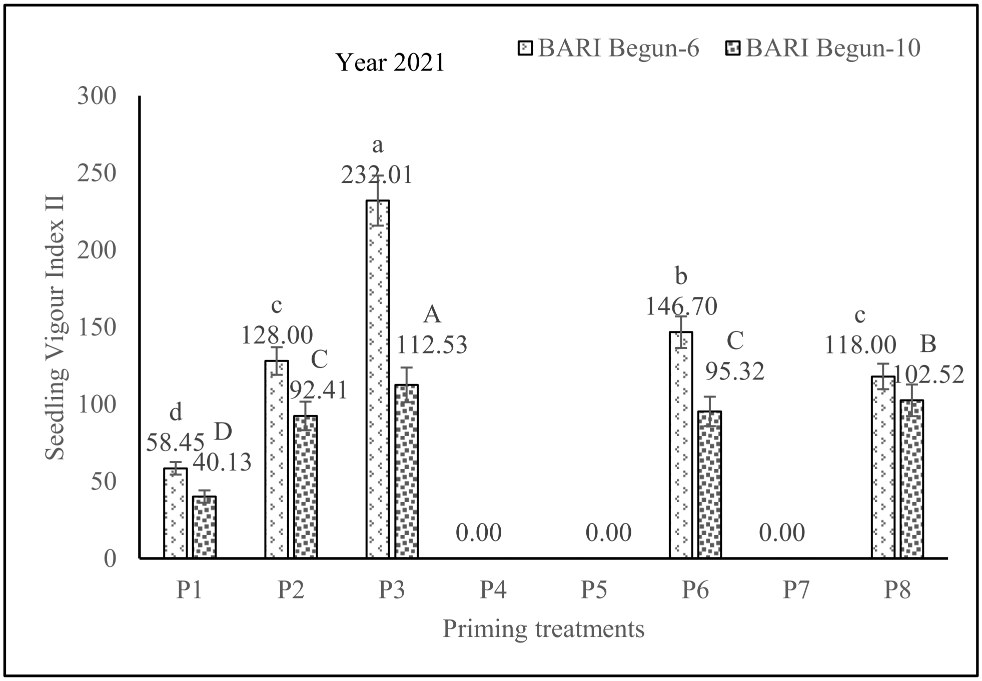

Fig. 3. Effect of seed priming on seedling vigour index II in two varieties of brinjal during 2021.

Figures with the same small letter (s) and capital letter (s) for BARI Begun-6 and BARI Begun-10, respectively, are not significantly different (P≤0.05) by Tukey HSD test. Bars indicate mean SE ± of three replicates. P_1 = control (no priming), P_2 = hydro-priming by distilled water, P_3 = 289.0 µM GA_3, P_4 = 134.0 mM KCl, P_5 =167.0 mM Urea, P_6 = 40.0 mM NaCl, P_7 = 76.0 mM DAP, P_8 = 5% PEG-6000; V_1 = BARI Begun-6 and V_2 = BARI Begun-10.

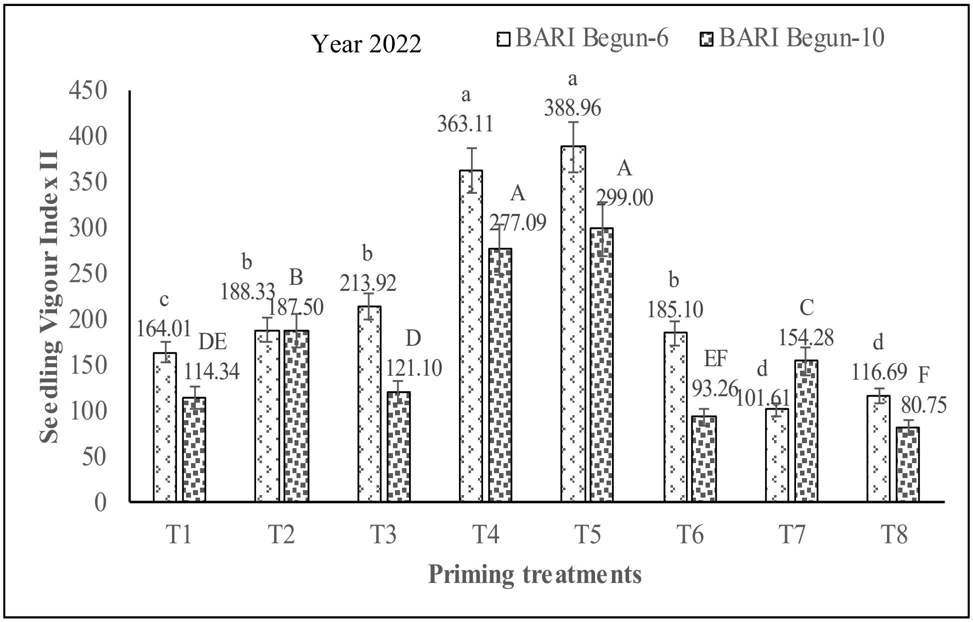

Fig. 4. Effect of seed priming on seedling seedling vigour Index II in two varieties of brinjal during 2022.

Figures with the same small letter (s) and capital letter (s) for BARI Begun-6 and BARI Begun-10, respectively, are not significantly different ($P \leq 0.05$) by Tukey HSD test. Bars indicate mean ± SE of three replicates. T_1 = Control (No priming), T_2 = Hydropriming, T_3 = 289 μM GA_3, T_4 = 0.25% KNO_3, T_5 = 40 mM H_2O_2, T_6 = 40 mM NACL, T_7 = 1 μM TRIA, T_8= 50 ppm NAA; V_1 = BARI Begun-6 and V_2 = BARI Begun-10

Conclusion

From the present study it was found that in 2021 289 μM (100 ppm) GA_3 was the most important priming agent to increase seed germination, germination index, shoot length, root length and seedling vigour of brinjal varieties. However, in the 2^{nd} year, GA_3 did not give encouraging result with regard to germination, germination parameters, seedling growth and vigour. The 2^{nd} year experimental results showed that 40 mM H_2O_2 followed by 0.25% KNO_3 enhanced percent germination, germination index, germination value, shoot length, root length, seedling dry weight and seedling vigour of two brinjal varieties. Seeds primed with 40 mM H_2O_2 took the lowest time to germinate. Therefore, it is suggested that brinjal seeds should be primed with 40 mM H_2O_2 or 0.25% KNO_3 or 289 μM GA_3 for 18 hrs. Priming with either 40 mM H_2O_2 or 0.25% KNO_3 or 289 μM (100 ppm)

GA_3 before sowing or breeding work is very effective for obtaining maximum seed germination and healthy seedlings that can produce higher yield of brinjal.

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References

Abdul-Baki, A. A. and J. D. Anderson. 1973. Vigour determination in soybean seed and by multiple criteria. *J. Crop Sci*. **13**: 630-633.

Agarwal, R.L. 1995. *Seed Tehnology*. Oxford and IBH Publishing Co. Ptv. Ltd. New Delhi. p. 550-552, 689-692.

Ahmed, Z., S. Anwar, A. R. Baloch, S. Ahmed, F. Muhammad, N. A. Alizai, M. Ahmed, S. Khan and S. Faisal.2017. Effect of Halopriming on seed germination and seedling vigor of solanaceous vegetables. *Journal of Natural Sciences Research* **7** (9): 1-9. www.iiste.org.

Ali, M. M., T. Javed, R. P. Mauro, R. Shabbir, I. Afzal and A. F. Yousef. 2020. Effect of Seed Priming with Potassium Nitrate on the Performance of Tomato. MDPI. *Agriculture* **498**: 1-10. [DOI:10.3390/agriculture1011049]

Anosheh, H, P., H. Sadeghi and Y. Emam. 2011. Chemical priming with urea and KNO_3 enhances maize hybrids (*Zea mays* L.) seed viability under abiotic stress. *Journal of Crop Science and Biotechnology* **14:**289–295.

Das, S, S. Behera, R. Bhol, S. Swain, N. Senapati and J. K. Beura.2020. Evaluating relative efficacy of different priming treatments in brinjal (*Solanum melongena* L.). *International Journal of Chemical Studies* **8**(1): 2144-2148. [DOI: https://doi.org/10.22271/chemi.2020.v8.i1af.8587].

Djavanshir,K. and H. Pourbeik. 1976. Germination value: A new formula. *Silvae genetica* **25**: 79-83.

FAO (Food and Agriculture Organization), 2000. Production Yearbook, Rome, Italy, 49: 68.

Ghiyasi M. A. A. Seyahjam, M. Tajbakhs, R. Amrma and S. Hojat.2008 Effect of osmo-priming with polyethylene glycol (8000) on germination and seedling growth of wheat (*Triticum aestivum* L.) seeds under salt stress. *Journal of Biological Science* **3** (10): 1249-1251.

Hemalatha, G., J. Renugadevi1 and T. Eevera. 2017. Studies on seed priming with hydrogen peroxide for mitigating salt stress in rice. *Int. J. Curr. Microbiol. App. Sci*. **6** (6): 691-695. [https://doi.org/10.20546/ijcmas.2017.606.081]

Hussain, S. F., H. A. Khan, L. Hussain and L. Nie 2016. Physiological and biochemical mechanisms of seed priming-induced chilling tolerance in rice cultivars. *Frontiers in Plant Science* **7**(Feb.): 1–14. [https://doi.org/10.3389/fpls.2016.00116].

Islam, M. O., M. S. Islam and A.K.M. Azad-Ud-Doula Prodhan. 2006. Seed germination and seedling growth of brinjal, tomato andchilli treated with GA_3 and GABA. *J. Bangladesh Agril. Univ.* **4** (1): 43-49.

Islam, R. A. Mukherjee and M. Hossin. 2012. Effect of osmo-priming on rice seed germination and seedling growth. *J. Bangladesh Agril. Univ*. **10** (1): 15–20.

Kader, M.A, S. C. Jutzi. 2004. Effects of thermal and salt treatments during imbibition on germination and seedling growth of sorghum at 42/19°C. *J. Agron. Crop Sic.* **190**: 35-38.

Kader, M.A. 2005. A comparison of seed germination calculation formulae and the associated interpretation of resulting data.Journal and Proceeding of the Royal Society of New South Wales. **138**:65-75.

Koirala K.B. 2017.Effect of seed priming on Maize in the western hills of Nepal. *International Journal of Applied Sciences and Biotechnology* **5** (4): 470-478.

Koirala, N. D. Poudel, G. P. Bohara, N. P. Ghimire, A, Raj Devkota. 2019. Effect of seed priming on germination, emergence and seedling growth of spring rice (*Oryza sativa* L.) cv. Hardinath-1. *Azarian J. Agric.* **6** (1): 209-214. [http://dx. doi. org/10. 29252/ azarinj.002].

Li, Y. 2008. Effect of salt stress on seed germination and seedling growth of three salinity plants. *Pakistan J. Biol. Sci.* **11**: 1268-1272.

Mostafavi, K., H. Sadeghi Geive, M. Dadresan and M. Zarabi. 2011. Effects of drought stress on germination indices of corn hybrids (Zea mays L.). *Int. J. Agri l. Sci.* **1**(2): 10-18.

Nayak, B.C. And A. K. Patra.2000. Effect of nursery density on seedling vigour and yield of summer rice (*Otyza sativa*) under varying seedling rates. *Indian J. Agron.* **45** (3): 555-565.

Parajuli, S. and N. Bhattaraj. 2025. Effect of different priming applications on seed germination and seedling growth of brinjal (*Solanum melongena* L.). *Archives of Agriculture and Environmental Science* **10(3):** 490-494. [DOI:10.26832/24566632.2025.1003014].

Ranal, M. A., G. S. Denise, R. F. Wanessa and M. Clesnan. 2009. Calculating germination measurements & organizing spreadsheets. *Brazilian Journal of Botany* **32**: 849-55.

Saidi, W. H. Beltayef, F. Kalleli1, M. Mechri, A. Hashem, M. M. Alenazi, E. F. A. Allah, C. Cruz and M. M. Hamdi. 2024. H_2O_2 seed priming to alleviate the salinity effect in tomato (*Solanum lycopersicon)*. *Pak. J. Bot.* **56** (6): 2059-2066. [DOI: http://dx.doi.org/10.30848/PJB2024-6(24)].

Sharma, R. K.and S. Sharma. 2010. Effect of storage and cold-stratification on seed physiological aspects of *Bunium persicum*: A threatened medicinal herb of Trans-Himalaya. *Int. J. Bot*. **6**(2): 151-156.

Silva V.N. and J. da Silva. 2016. *Rice seed priming. Bioscience Journal* **32**(1): 89–97. [https://doi.org/10.14393/BJ-v32n1a2016-29610].

Tian, Y., B. Guan, D. Zhou, J. Yu, G. Li and Y. Lo. 2014. Responses of seed germination, seedling growth, and seed yield traits to seed Pretreatment in maize (*Zea mays* L.). *The Scientific World Journal* **1-8**, [http://dx.doi.org/10.1155/2014/834630].

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EFFECT OF SOWING DATE AND ROW SPACING ON GREEN POD YIELD OF GARDEN PEA

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M. M. KHAN[4] AND M. M. HOSSAIN[5]

Abstract

Field experiments on garden pea were conducted at the Tuber Crops Research Sub-Centre, Bangladesh Agricultural Research Institute (BARI), Bogura, during the 2015-16 and 2016–17 cropping seasons. The study aimed to evaluate the impact of sowing dates and row spacing on the yield-contributing characteristics and green pod yield of garden pea (cv. BARI Motorshuti-3). The experiment was conducted a split-plot design with three replications, assigning three sowing dates (27 October, 10 November, and 24 November) to the main plots and four row spacings (20 cm, 30 cm, 40 cm, and farmer's practice) to the sub-plots. Results from the 2015–16 season indicated that sowing on 10 November with a 20 cm row spacing achieved the maximum green pod yield (6.80 t ha^{-1}) and green stover yield (5.65 t ha^{-1}). This was statistically similar to the 24 November sowing at the same 20 cm spacing, which produced 6.71 t ha^{-1} green pod; 5.58 t ha^{-1} stover. A similar trend was observed in 2016–17, where the 10 November sowing at 20 cm spacing yielded the highest results (7.08 t ha^{-1} pod; 5.74 t ha^{-1} stover), closely followed by the 24 November sowing at 20 cm spacing (7.01 t ha^{-1} green pod; 5.72 t ha^{-1} stover). Based on these findings, a sowing window between 10 and 24 November combined with a 20 cm row spacing is recommended to optimize green pod yield of garden pea in the Bogura region.

Key words: Garden pea, *Pisum sativum,* sowing date, row spacing, green pod yield and stover yield.

Introduction

Garden pea (*Pisum sativum* L.) is one of the most important winter minor pulse crops in Bangladesh. Peas are full of nutrition because its grain is rich in protein (27.8%), complex carbohydrates (42.65%), vitamins, minerals, dietary fibers and antioxidant compounds (Dahl *et al*., 2012). Pea crop has a great impact in the rice-based cropping system to utilization of fallow land where land remains fallow about 80-90 days between *T. Aman* and *Boro* rice. In the high and medium high

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lands of Bangladesh, *T. Aman* – Fallow - *Boro* cropping pattern is practiced by the farmers. It was found that short duration pea var. BARI Motorshuti-3 can be grown after harvest of short duration *T. Aman* var. Binadhan-7 and BRRI dhan33 in the fallow period of *T. Aman* and Boro cropping pattern. Further, this crop also plays a significant role in soil fertility restoration as a suitable rotation crop that fixes atmospheric nitrogen and also serves as rotational crop that plays great role in controlling disease epidemics and weeds (Hoorman *et al*., 2009). Pea production in Bangladesh is very low due to lack of high yielding modern varieties, lack of proper agronomic management practices such as sowing time and method, row spacing and seed rate as well as nutrient. Pea production in Bangladesh depends on many factors, of which climate is the most important one. The minimum temperature for germination is about 10°C and the optimum about 22°C. It is sensitive to high temperature and drought stress (Baloch, 1994). In plains land peas are sown from October to December; whereas in hilly areas they are planted after mid-March to the end of May. The time of sowing influences the establishment, growth and development of pea crops (Castillo *et al*., 1992). Sowing time can affect the number of days to germination and flowering, the number and weight of green pods plant^{-1} and seed yield (Gill and Ahmad, 1981). Date of sowing determines the amount of radiation and the temperature to be experienced by the crop. Growth and yield of garden peas, greatly influenced by sowing date; plants sown in late November had a higher leaf area index (LAI) and greater yield than earlier sowing in mid-November (Jamil *et al.,* 2006). An early maturing pea variety showed that seed yield, pods plant^{-1}, pod length, seeds pod^{-1} from a November sowing were all superior to October sowing (Randhir *et al*., 1996). So, climate change has been one of the greatest economic, social and environmental threats of pea cultivation. On the other hand, the yield of pea crops normally increases, with increasing plant population, until it reaches an optimum density. Moot and McNeil (1995) showed seed yield of pea doubled from 350 g m^{-2} at 9 plants m^{-2} to 675 g m^{-2} at 400 plants m^{-2} However, once the plant population exceeds the optimum it can lead to a progressive decrease in yield. Sharma (2002) reported that the highest number of pods plant^{-1} in wider row spacing. Therefore, the present study was carried out to determine optimum sowing date and row spacing of garden pea for obtaining its desirable crop characters and yield.

Materials and Methods

The experiment was conducted at the Tuber Crops Research Sub-Center, Bangladesh Agricultural Research Institute (BARI), Bogura, Bangladesh during *rabi* season 2015-16 and 2016-17. It was located at 24.51^0 N latitude and 89.18^0 E longitudes which is 17 m above the sea level (UNDP and FAO, 1988) and belongs to the Barind Level Tract "AEZ 25". The experimental site was associated with a medium high land with sandy-loam soil texture and the soil was slightly acidic in reaction. The experimental area is under the sub-tropical climatic zone characterized by relatively scanty rainfall, low humidity and temperature, short day and long clear sunshine period during October to March. The temperature during winter season December to February remains fairly low and goes up during the summer season (March to October). The average (10 years) annual rainfall is 1525 mm, most of which fell during May-September. The warmest and coldest months are April (35^0 C maximum) and January (11.6^0 C minimum), respectively. Bangladesh's overall mean temperature in summer ranges between 25 and 33^0 C, and in winter remains between 11 to 26^0 C (Hossain 2007). The meteorological data of the experimental site during crop period (October-February) are presented in Table 1. The weather data were taken from the Meteorological Department, Khander, Bogura.

Table 1. The meteorological data of the experimental site during crop period (October 2015-February 2017).

Months	Temperature (^{0}C)				Relative Humidity (%)		Rainfall (mm)	
	2015-2016		2016-2017		2015-2016	2016-2017	2015-2016	2016-2017
	Maximum (Mean)	Minimum (Mean)	Maximum (Mean)	Minimum (Mean)				
October	29.15	25.10	28.12	26.56	78	77	40	270
November	26.1	20.22	26.33	24.19	75	75	-	-
December	21.2	15.13	21.88	16.01	77	76	-	-
January	19.29	15.03	19.08	15.32	77	76	-	-
February	22.10	20.11	24.13	20.01	72	68	15	-

The experiment was laid out in a spilt plot design with three replications. The experiment consisted of three sowing dates *viz.*, (i) 27 October (D_1), (ii) 10 November (D_2) and (iii) 24 November (D_3) in the main plots and row spacings *viz.*, (i) 20 cm (S_1), (ii) 30 cm (S_2), (iii) 40 cm (S_3) and (iv) Farmer practice or broadcast (S_4) in the sub-plots. The unit plot size was 3.0 m x 4.0 m. The garden pea var. BARI Motorshuti-3 was used as a test crop. The land was uniformly fertilized with PKSB @ 14-20-20-10-7 kg ha^{-1} PKSB (BARC, 2012) through Urea, Triple Super Phosphate (TSP), Muriate of Potash (MP), Gypsum and Boric Acid, respectively. Total amount of all the fertilizers was applied during the final land preparation. Seeds were sown with recommended seed rate of 200 kg ha^{-1}. The seeds were sown in furrows and in case of farmer practice or broadcast, seeds were scattered in the plot and covered with soil by leveler for the best germination. Finally, approximately 5 cm plant to plant distance along with row was maintained through gap filling and thinning to have uniform population. Different intercultural operations such as weeding, thinning, gap filling, pesticide spray and irrigation were accomplished time to time for better growth and development of the crop. The crop was harvested plot-wise at maturity stages. Five plants were uprooted each time randomly from the sampling area of each plot. Data were recorded on plant population m^{-2}, plant height, number of pods $plant^{-1}$, pod length, weight of 100 fresh pods, green pod yield $plot^{-1}$and green stover yield $plot^{-1}$. The plot yield was then converted into t ha^{-1}. The collected data of different parameters were statistically analyzed with the help of STATISTIX 10 software and differences among the treatment means were adjudged by Duncan's Multiple Range Test (DMRT) at 5% level of profanity.

Results and Discussion

Interaction effect on plant population m^{-2}

Plant population m^{-2} of garden pea was significantly influenced by the combination of sowing date and row spacing. In 2015-16 (Table 2), the maximum plant population m^{-2} (91.66) was recorded from 27 October sowing at 20 cm row spacing followed by 10 November sowing of same row spacing (90.00), while the minimum in 27 October sowing at 40 cm row spacing (58.33). It might be due to more plant population $unit^{-1}$ area. Similar results have been reported by Rops (1997). In 2016-17, the maximum plant population m^{-2} (91.00) was recorded from 10 November sowing at 20 cm row spacing followed by 24 November sowing at 20 cm row spacing (89.33) and 27 October sowing at 20 cm row spacing (81.00), while the minimum in 27 October sowing at 40 cm row spacing (47.33).

Interaction effect on plant height

Sowing date coupled with row spacing had significant effect on plant height in both the years (Table 2). In 2015-2016, the maximum plant height (44.63 cm) was recorded from the crops sown on 10 November at 20 cm row spacing followed by 24 November sown at 20 cm row spacing (42.99 cm), while the lowest plant height was recorded in 27 October sowing at broadcast method (31.90 cm) followed by 27 October sowing at 30 cm row spacing (33.34 cm). It might be due to relatively cool temperature and sufficient time available for the growth and development to these seeds before low temperatures creep in, which could have promoted the growth of the plants. Similar results have been reported by Baloch (1994). The result indicated that closer row spacing (20 cm) enhanced to produce taller plant than other spacing. It might be due to space for plant spread was less and hence plant height increased significantly. It was also reported that the tallest plants from closer row spacing (Sharma 2002). Almost Similar trend was observed in 2016-17. The maximum plant height (45.13 cm) was recorded from the crops sown 10 November at 20 cm row spacing followed by 10 November sown at 20 cm row spacing (43.15 cm) and 24 November sowing at 20 cm row spacing (42.49 cm), while the lowest plant height was obtained in 27 October sowing at 30 cm row spacing (32.83 cm).

Interaction effect on number of pods plant^{-1}

Dates of sowing and row spacing had a significant interaction effect on number of pods plant^{-1} in both the years (Table 2). In 2015-16, the maximum number of pods plant^{-1} (3.94) was found in 24 November sowing at 40 cm row spacing followed by 10 November sowing at 20 cm row spacing (3.55), 10 November sowing at 30 cm row spacing (3.62), 10 November sowing at 40 cm row spacing (3.72), 10 November sowing at broadcast method (3.48), 24 November sowing at 20 cm row spacing (3.35) 24 November sowing at 30 cm row spacing (3.37) and 24 November sowing at broadcast method (3.26), while the minimum was found in 27 October sowing at broadcast method (2.20). Sowing time can affect the number of pods plant^{-1} and seed yield (Gill and Ahmad, 1981). Similar results have been reported by Randhir *et al*. (1996). Increase in number of pods plant^{-1} in wider row spacing (40 cm) might be due to vigorous plants, as in wider space, plant grew vigorously and produce more branches which resulted in high number of pods plant^{-1}. These results are in consonance with the results of Sharma (2002) who reported the highest number of pods plant^{-1} in wider row spacing. With decrease in row spacing, the plant growth was also decreased which resulted in low pods production. Almost similar trend was found in 2016-17. The maximum number of pods plant^{-1} (3.97) was found in 24 November sowing at 40 cm row spacing followed by 10 November sowing at 20 cm row spacing (3.61), 10 November sowing at 30 cm row spacing (3.68), 10 November sowing at 40 cm row spacing (3.76), 10 November sowing at broadcast method (3.54), 24 November sowing at 20 cm row spacing (3.42), 24 November sowing at 30 cm row spacing (3.44) and 24 November sowing at broadcast method (3.33), while the minimum was found in 27 October sowing at broadcast method (1.95).

Interaction effect on pod length

Sowing date and row spacing had significant interaction effect on pod length in both the years (Table 2). In 2015-16, the maximum pod length (6.66 cm) was recorded from 10 November sowing at 30 cm row spacing followed by 10 November sowing at 20 cm row spacing (6.39 cm), 10 November sowing at 40 cm row spacing (6.43 cm), 10 November sowing at broadcast method (6.44 cm), 24 November sowing at 20 cm row spacing (6.23 cm), 24 November sowing at 30 cm row spacing (6.23 cm) 24 November sowing at 40 cm row spacing (6.06 cm) and 24 November sowing at broadcast method (6.29 cm), while the minimum was found in 27 October sowing at 20 cm row spacing (4.67 cm). It might be due to the prevailing of optimum temperature (average 23.16-25.26^0 c) for the plants sown on 10 and 24 November and as such there was best vegetative and reproductive growth, as a result maximum pod length was recorded for this sowing date. During the period of 27 October, temperature (average 27.34^0 c) was high that resulted in small size production of pods. Results showed that pod length from a November sowing was all superior to an October sowing. These results are in agreement with the findings of Randhir *et al.* (1996). Almost the similar result was found in 2016-17. The maximum pod length (6.79 cm) was recorded from 10 November sowing at 30 cm row spacing followed by 10 November sowing at 20 cm row spacing (6.45 cm), 10 November sowing at 40 cm row spacing (6.44 cm), 10 November sowing at broadcast method (6.40 cm), 24 November sowing at 20 cm row spacing (6.25 cm), 24 November sowing at 30 cm row spacing (6.25 cm) 24 November sowing at 40 cm row spacing (6.31 cm) and 24 November sowing at broadcast method (6.08 cm), while the minimum was found in 27 October sowing at 20 cm row spacing (4.79 cm).

Table 2. Effect of interaction of sowing date and row spacingon crop characters, yield attributes and yield of garden pea

Interaction (D×S)	Plant population m^{-2}		Plant height (cm)		Number of Pods $plant^{-1}$		Pod length (cm)	
	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2
D_1 x S_1	91.66a	81.00ab	35.18d	36.68efg	2.41c	2.16b	4.67b	4.79b
D_1 x S_2	75.33c	59.33cd	33.00de	34.50gh	2.53bc	2.28b	4.89b	5.01b
D_1 x S_3	58.33f	47.33d	33.34de	32.83h	2.55bc	2.30b	5.31b	5.21b
D_1 x S_4	65.67f	65.66bc	31.90e	35.40fgh	2.20c	1.95b	5.11b	4.57b
D_2 x S_1	90.00a	91.00a	44.63a	45.13a	3.55a	3.61a	6.39a	6.45a
D_2 x S_2	74.00d	78.00bc	42.05b	43.15ab	3.62a	3.68a	6.66a	6.79a
D_2 x S_3	64.66f	55.53d	40.74b	41.24bcd	3.72a	3.76a	6.43a	6.44a
D_2 x S_4	68.66e	73.00bc	38.06c	38.56def	3.48a	3.54a	6.44a	6.40a
D_3 x S_1	87.33b	89.33a	42.99ab	42.49abc	3.35a	3.42a	6.23a	6.25a
D_3 x S_2	76.66c	77.33bc	39.88bc	41.38bcd	3.37a	3.44a	6.23a	6.25a
D_3 x S_3	65.33f	56.33d	38.29c	39.79cde	3.94a	3.97a	6.06a	6.31a
D_3 x S_4	66.00f	75.00bc	38.11c	39.61cde	3.26ab	3.33a	6.29a	6.08a
CV (%)	7.82	9.20	4.12	3.58	13.61	13.97	6.11	5.62

Table 2. Cont'd

Interaction (DXS)	Weight of 100 fresh pods (g)		Number of seeds pod^{-1}		Green pod yield (t ha^{-1})		Green stover yield (t ha^{-1})	
	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2
D_1 x S_1	273.30h	270.93i	3.54c	3.72cd	5.90b	5.75b	4.95b	4.85b
D_1 x S_2	274.54h	271.20h	3.87bc	3.89cd	4.12ef	3.97g	3.62d	3.51e
D_1 x S_3	310.70c	305.10c	4.36b	4.21c	3.15g	2.95h	2.95f	2.80f
D_1 x S_4	263.92k	266.91k	4.02bc	3.39d	4.35de	4.20f	3.68d	3.72d
D_2 x S_1	276.93f	284.29d	5.63a	5.89ab	6.80a	7.08a	5.65a	5.74a
D_2 x S_2	281.29d	278.8e	5.90a	6.07a	5.21c	5.51c	4.30c	4.55c
D_2 x S_3	349.11a	351.80a	5.82a	6.19a	3.89ef	4.10fg	3.35e	3.50e
D_2 x S_4	269.80i	271.35h	5.72a	5.60ab	5.11c	5.25d	4.54c	4.64c
D_3 x S_1	275.21g	277.2g	5.62a	5.64ab	6.71a	7.01a	5.58a	5.72a
D_3 x S_2	278.32e	278.3f	5.94a	5.90ab	5.14c	5.44c	4.30c	4.55c
D_3 x S_3	346.96b	349.3b	5.54a	5.53ab	3.70fg	3.99g	3.19ef	3.35e
D_3 x S_4	266.80j	268.5j	5.33a	5.28b	4.65cd	4.85e	4.42c	4.57c
CV (%)	3.33	4.80	7.13	6.99	6.93	6.26	3.45	5.32

Mean values in a column having the same letters do not differ significantly while those with dissimilar letters differ significantly as per DMRT ($P \leq 0.05$).

Note: D_1 = 27 October, D_2 = 10 November, D_3 = 24 November.

S_1 = Row spacing 20 cm, S_2 = Row spacing 30 cm, S_3 = Row spacing 40 cm, S_4 = Broadcast sowing; Y_1 = 2015-16 and Y_2 = 2016-17

Interaction effect on number of seeds pod^{-1}

Date of sowing in combination with row spacing had a significant effect on number of seeds pod^{-1} in both the years (Table 2). In the first year, the maximum number of seeds pod^{-1} (5.94) was found in 24 November sowing at 30 cm row spacing followed by 10 November sowing at 20 cm row spacing (5.63), 10 November sowing at 30 cm row spacing (5.90), 10 November sowing at 40 cm row spacing (5.82), 10 November sowing at broadcast method (5.72), 24 November sowing at 20 cm row spacing (5.62), 10 November sowing at 40 cm row spacing (5.54) and 24 November sowing at broadcast method (5.33), while the lowest in 27 October sowing at 20 cm row spacing (3.54). These results corroborate the findings of Rai and Gupta (2003). Seed number pod^{-1} is correlated with pod growth in particular with early pod elongation (Jeuffroy and Chabanet, 1994. Almost similar trend was found in 2016-17. The highest number of seeds pod^{-1} (6.19) was found in 10 November sowing at 40 cm row spacing followed by 10 November sowing at 20 cm row spacing (5.89), 10 November sowing at 30 cm row spacing (6.07), 10 November sowing at broadcast method (5.60), 24 November sowing at 20 cm row spacing (5.64), 24 November sowing at 30 cm row spacing (5.90), 24 November sowing at 40 cm row spacing (5.53) and 24 November sowing at broadcast method (5.28), while the lowest in 27 October sowing at broadcast method (3.39).

Interaction effect on weight of 100 fresh pods

Sowing date and row spacing had significant interaction effect on weight of 100 fresh pods in both the years (Table 2). In 2015-16, the highest weight of 100 fresh pods (349.11g) was recorded from 10 November sowing at 40 cm row spacing, while the minimum in 27 October sowing at farmer practices or broadcast method (263.92g). It might be due to prevailing of high temperatures during pod and seed formation in early sowing on 27 October, as a result photosynthates from source to sink were not translocated properly. Similar results have been reported by Duke (1981). Almost similar trend was found in 2016-17. The highest weight of 100 fresh pods (351.80g) was recorded from 10 November sowing at 40 cm row spacing, while the minimum in 27 October sowing at 20 cm row spacing (266.91g).

Interaction effect on greed pod yield

Date of sowing and row spacing had a significant effect on seed yield in both the years (table 2). In 2015-16, the maximum green pod yield (6.80 t ha^{-1}) was obtained from 10 November sowing at 20 cm row spacing followed by 24 November sowing at 20 cm row spacing (6.71 t ha^{-1}), while the lowest in 27 October sowing at 40 cm row spacing (3.15 t ha^{-1}) followed by 24 November sowing at 40 cm row spacing (3.70 t ha^{-1}). It might be due to improvement of yield contributing characters *viz.,* number of pods $plant^{-1}$, pod length and number of seeds pod^{-1}. Similar results have been reported by Jamil *et al.* (2006). In closer row spacing, the number of pods $plant^{-1}$ were less as compared to wider row spacing but the number of plants population $unit^{-1}$ area was more that resulted in higher green pods yield. Similar results have been reported by Sajid *et al.* (2012) and Rops (1997). Almost similar trend was found in 2016-2017. The highest green pod yield (7.08 t ha^{-1}) was obtained from 10 November sowing at 20 cm row spacing followed by 24 November sowing at 20 cm row spacing (7.01 t ha^{-1}), while the lowest in 27 October sowing at 40 cm row spacing (2.95 t ha^{-1}).

Interaction effect on green stover yield

Date of sowing coupled with row spacing had significant effect on green stover yield in both the years (Table 2). In 2015-16, the maximum green stover yield (5.65 t ha^{-1}) was obtained from 10 November sowing at 20 cm row spacing followed by 24 November sowing at 20 cm row spacing (5.58 t ha^{-1}), while the lowest in 27 October sowing at 40 cm row spacing (2.95 t ha^{-1}) followed by 24 November sowing at 40 cm row spacing (3.19 t ha^{-1}). It might be due to improvement of yield contributing characters *viz*., plant height and more plant population $unit^{-1}$ area. These results agree with the findings of by Rops (1997), Rai and Gupta (2003). Almost similar trend was found in 2016-2017. The maximum green stover yield (5.74 t ha^{-1}) was obtained from 10 November sowing at 20 cm row spacing followed by 24 November sowing at 20 cm row spacing (5.72 t ha^{-1}), while the lowest in 27 October sowing at 40 cm row spacing (2.80 t ha^{-1}).

Relationship between plant population and green pod yield

In, 2015-16, the green pod yield showed a linear response with the increasing population per square meter (Fig. 1). The linear relationship as estimated was: y = 0.1016x -2.5286, R^2 = 0.9336, r = 0.97**. The positive relationship indicated that green pod yield (t ha^{-1}) increased with the increasing plant population. The linear equation stated that for every increased population of 1 per square meter, about 101.6 kg green pod yield was increased per hectare of land. The R^2 value indicated that 93% increase in green pod yield was attributed to plant population Almost similar trend was also observed in 2016-17 under correlation (y = 0.0789x-0.4675, R^2 =0.9085, 0.95r= 0.95**) (Fig. 2). In this year, the linear equation stated that for every increased population of 1 per square meter, about 78.9 kg green pod yield was increased per hectare of land. The R^2 value indicated that 90% increase in green pod yield was attributed to plant population.

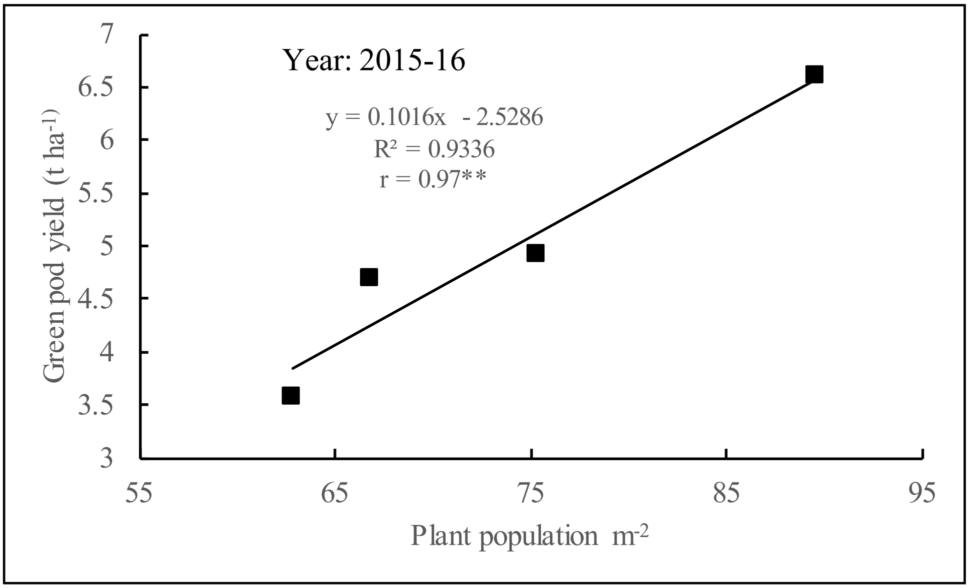

Fig. 1. Relationship between plant population and green pod yield of pea during 2015-16.

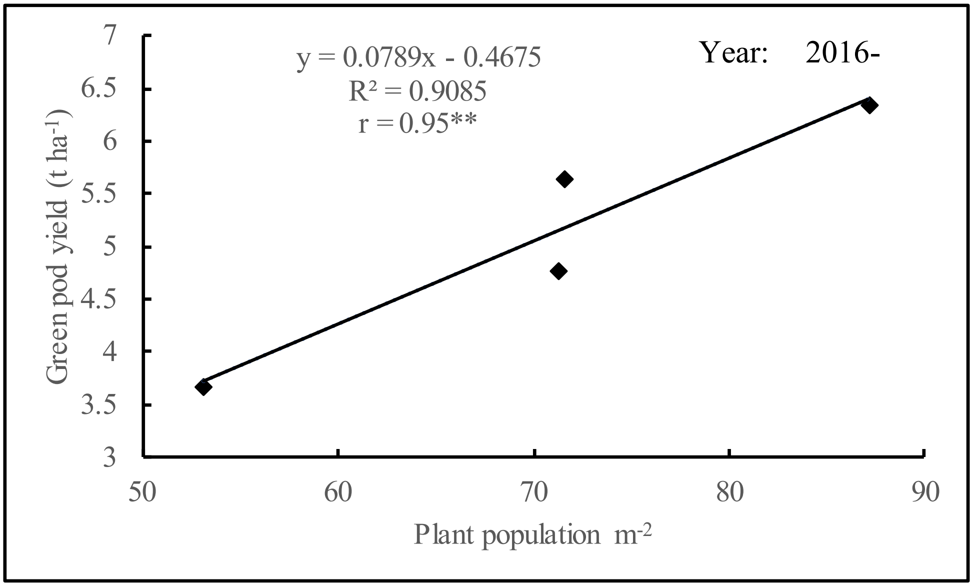

Fig. 2. Relationship between plant population and green pod yield of pea during 2016-17.

Conclusion

Based on this study, the BARI Motorshuti-3 Garden pea variety performs best when sown between November 10 and 24. This sowing time optimizes the number of pods per plant, as well as green pod and stover yields. Furthermore, using a 20 cm row-to-row spacing significantly outperforms broadcasting or farmer practices in all key yield attributes, especially number of pods per plant, green pod yield and stove yield.

Reference

BRAC (Bangladesh Agricultural Research Council) 2012: Fertilizer recommendation Guide, farm gate, Dhaka.

Baloch, A. F. 1994. Vegetable crops. Manure and fertilizers in horticulture. (1st Ed.) M.N. Malik. *National Book Foundation, Islamabad, Pakistan. pp.* 525-526.

Dahl, W. J., L. M. Foster and R.T. Tyler, 2012. Review of the health benefits of peas (*Pisum sativum* L.). *British Journal of Nutrition* **108**: S3-S10.

Duke, J. A. 1981. Handbook of legumes of world economic importance. *Plenum Press.* NewYork.

Gill, I. A. and M. Ahmad, 1981. Effect of different sowing times on the growth and yield characteristics of some promising peas (*Pisum sativum* L.) varieties. *Pakistan Journal of Agricultural Research* **19**: 73-75.

Hoorman, J.J., R. Islam and A. Sundermeier, 2009. Sustainable Crop Rotations with Cover Crops. OSU, *Agriculture and Natural Resources. Fact Sheet*.

Hossain, T. 2007. Impact of inflation on economic growth in Bangladesh. *Journal of the Institute of Bangladesh studies* **30**: 124-130

Jamil, M. K., M. M. Hossain, S. N. Mozumder, K. M. Khalequzzaman, Kumar and M. Singh 2006. Published by: Indian Institute of pulses maturity. *Agronomy Journal* **70**: 74-76.

Moot, D. J. and D. L. McNeil, 1995. Yield components, harvest index and plant type in relation to yield differences in field pea genotypes. *Euphytica* **86**: 31-40.

Rai, O. P. and R. P. Gupta, 2003. Effect of sowing date and population density on yield and rust in dwarf pea. *Indian Journal Pulses Research* **16**: 34-35.

Randhir, S., S. Mohan and J. S. Kanwar, 1996. Effect of date of sowing on growth and seed yield of early maturing pea variety Matar Ageta-6. *Punjab Vegetable Grower* **31**: 35-36.

Rops, A. H. J. 1997. Effect of wider row spacing and date of sowing on the yield of canning peas (Publicatie No. 81A). Proefstation voor de Akkerbouw en de Groenteteelt in de Vollegrond. pp. 215-216. (CAB Abst).

Sajid, M., A. Rab, N. Amin, Fazaliwahid, I. Jan, I, Ahmad, I. A. Khan and M. A. Khan, 2012. Effect of herbicides and row spacing on the growth and yield of pea (*Pisum sativum* L.). *Pakistan Journal of Weed Science Research* **18**(1): 1-13.

Sharma, B. R. 2002. Water management in the 21st century: Priority issue. *Journal of Water Management* **10**: 11-17.

UNDP AND FAO (United Nations Development Program and Food and Agriculture Organization) 1988. *Land Resources Appraisal of Bangladesh for Agricultural Development Rep 2.* Agroecological Regions of Bangladesh. BARC/UNDP, New Airport Road, Farmgate, Dhaka-1207. pp. 212-221.

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DEVELOPMENT OF AN ORCHARD WEEDER CUM MINI TILLER

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Abstract

Number of fruit orchards have been increased over the years and also being increasing with a reasonable pace in Bangladesh. But the orchard owners are facing problems in tilling and weeding their lands. Thus, the farmers are, now, searching for suitable power weeder cum mini tillers for both tilling and weeding operations, specifically, for a machine that can be used safely for weeding and cultivating vegetables and spices in orchard lands. Therefore, this research was undertaken to develop a power weeder suitable for both orchard and kitchen yards. On a previous BARI developed weeder, improvement was done by redesigning it during 2020-22. Then the weeder was fabricated with locally available materials and spare parts. The power weeder was operated with a 4.0 hp diesel engine and the weight of the weeder was 140 kg. The effective field capacities of the improved weeder in the orchard and in the kitchen garden as mini tiller were 0.068 and 0.075 ha/h and the field efficiencies were 73.71 and 77.84%, respectively. The operating cost of the orchard weeder cum mini tiller was 1700 Tk/ha. Net profit from the orchard weeder cum mini tiller was 150000 Tk/year. The BCR of the machine was 1.64 and the payback period was 0.33 year. The weeding index in the kitchen garden and in the orchard were 0.88 and 0.80, respectively. The orchard weeder cum mini tiller can be used in high density orchard since the designed width was less than that of the power tiller. Thus, the orchard weeder cum mini tiller could be recommended for the orchard farmers.

Keywords: Orchard, Weeder, Mini Tiller, Capacity, Efficiency, Profit.

Introduction

Weeds have always been problems in the crop cultivation process as they reduce yields and deteriorate the quality of crops. Weeds reduce yields by competing with crops for water, nutrient and sunlight. Weeds may also reduce profits directly by hindering harvest operations and producing chemicals that are harmful to crop plants (allelopathy). The weeds give shelters to insects, compete with the crops for water, light, and plant nutrients, reducing the quality and yield of crops and farmers' income (RNAM, 1993; Frayer, 1970). This competition generally occurs quite early in the life of a crop and thus, the damage causes heavy lossto the farmers (Paul *et al*., 2025; Paul *et al*., 2023; Dilipkumar *et al*., 2020). More than 3,000 weed species have been identified all over the world (Olukunle and Oguntunde,

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2006). The cost of weed management is enormous; however, the opportunity cost of weed management is higher (Kushal *et al*., 2024). Yield reduction (50-70%) is caused by poor weed control (Oni, 1990; Dilipkumar *et al*., 2020). Therefore, timely removal of weeds is essential to achieve increased agricultural production.

Four methods of weed controls such as cultural, mechanical, biological and chemical were identified (Robbins and Craft, 1962; Manuwa *et al*., 2009; Saha *et al*., 2021). The decision on which weed control method is to adopt depends on several factors such as specificity of weed problems, farm size, type of growing crops, availability of working labours and tools used (Mganilwa *et al*., 2003; Zimdahl, 2018). Mechanical weeding is an environmentally friendly method for controlling weeds (Mganilwa *et al*., 2003; Manuwa *et al*., 2009; Islam *et al*., 2024).

Mechanical weeding using improved hand tools or power operated machines appear to be the most practical and efficient method for the country. Agricultural labour is becoming scarce and their wages are also increasing day by day. On the contrary, engine is becoming popular as a source of power and engine operated machines are replacing costly and drudgery manual operations (land preparation, threshing, winnowing, etc). Therefore, Use of power weeder should get high preference to reduce the cost of weeding, maintain timeliness, and to meet-up the scarcity of agricultural labour.

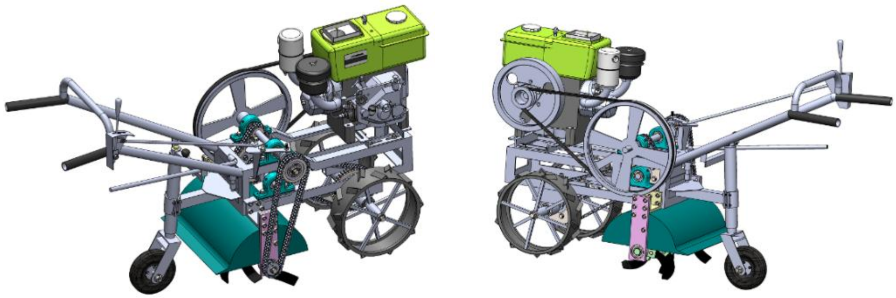
Mechanical weeders range from basic hand tools to sophisticated tractor driven or self-propelled machines. Such weeders include cultivation tools such as hoes, harrows, tined implements, brush weeders, cutting tools like mowers and trimmers, as well as implements like thistle-bars that may do both (Bond and Turner, 2005; Manuwa *et al*., 2009). The term mechanical weed control is restricted to methods implying shallow (0-50 mm) soil tillage (Kurstiens, 2002). If the working depth of cutting tools is adequately shallow and precisely controlled, they may be operated as close as 20-30 mm from plants (Ascard and Mattsson, 1991; Melander and Hartvig, 1997; Northway and Tullberg, 2000; Home *et al*., 2001). So, inter-row weed control is generally not a problem if this strip can be tilled (Kurstiens, 2002). Mechanical weed control not only uproots the weeds between the crop rows but also keeps the soil surface loose, ensuring better soil aeration and water intake capacity (Prasad *et al*., 2019). Manual weeding can give a clean weeding, but it is a slow process (Biswas 1990).

In Bangladesh, though many researchers of BARI and BRRI worked on manual weeder, a good initiation was done on development of power weeder by Hoque *et al.* (2010). The weeder was mainly developed for row crops and tested for weeding in mango orchard. Gulandaz *et al*. (2019) developed a battery-operated weeder for row crops during 2016-19. Recently, a good number of fruit orchards have been grown up and farmers are searching for suitable power weeders to use in those orchards not only to till inter row spaces for weeding but also cultivating vegetables on those spaces. Battery operated weeder was not capable to operate in the orchard.

Hoque *et al.* (2010) also suggested for further detailed study to adopt the power weeder in the orchard. However, this research was undertaken as continuation of the previous study to improve the power weeder suitable for both orchard and kitchen yards.

Materials and Methods

An orchard weeder cum mini tiller was designed and fabricated in Farm Machinery and Postharvest Process Engineering Division of BARI, Gazipur during 2021-22. The design (Fig. 1) was performed with the aid of the software, Solidworks 2022. Orthographic views of the machine with dimensions are shown in Fig. 2.



Left view Right view

Fig. 1. Isometric views of the orchard weeder cum mini tiller.

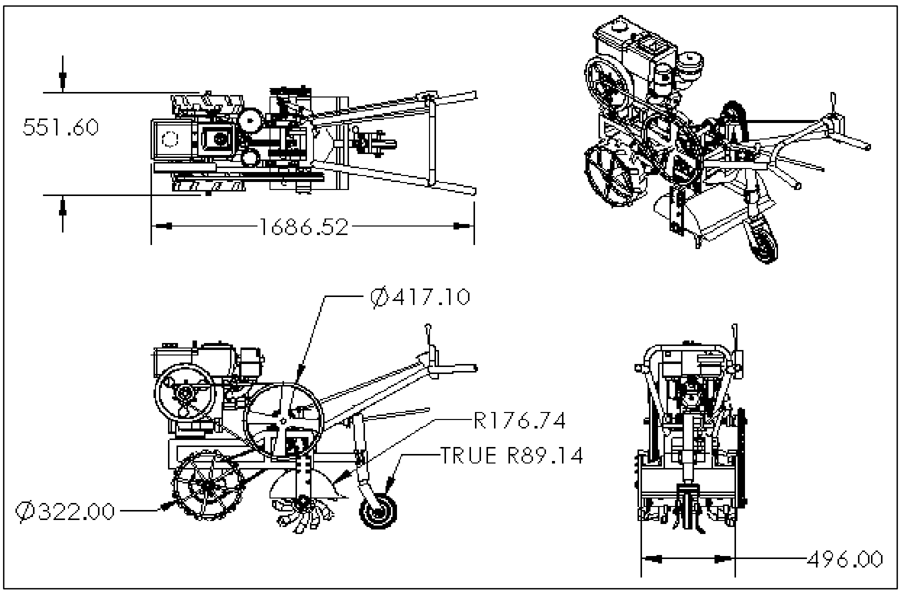


Fig. 2. Orthographic views of the orchard weeder cum mini tiller.

The major functions parts are described briefly as follows.

Engine: A diesel engine (4 hp) was used as the source of power. This engine is China made and available in the market.

Mainframe: The mainframe (Fig. 3) was supported on a wheel shaft by bearings. It was made of 40×40×5 mm MS angle. The engine was hinged on the mainframe with nuts and bolts. The mainframe also supported power transmission shafts, rotary shaft assembly, clutch mechanism, depth control wheel, and handle.

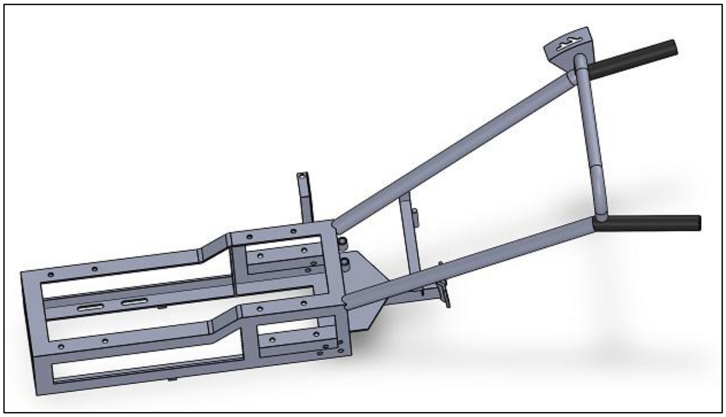


Fig. 3. Mainframe of the weeder.

Drive wheel: The weeder was supported on two drive wheels (Fig. 4) made of 50 mm flat bar. The wheel diameter was 360 mm. Lugs, made of 40x40x5 mm MS angle bar of 16 mm height, were 55 mm apart to provide grip on soil. The wheel to wheel outer distance was 500 mm and space between the wheels was 300 mm which allowed operating between 30 and 60 cm row spacing.

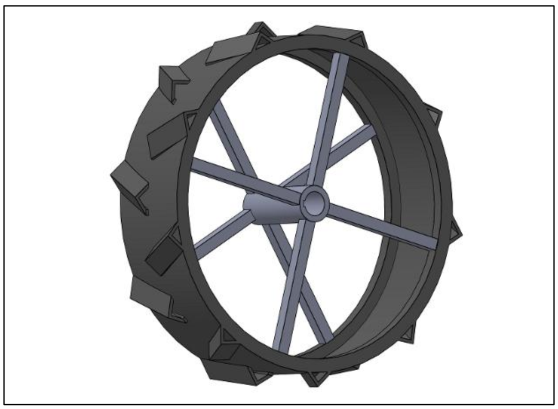


Fig. 4. Drive wheel of the machine.

Depth wheel: Depth wheel of 210 mm diameter and 65 mm width supported rear of the rotary blades by a depth control assembly. The depth of the rotary blade be adjusted by the depth control attachment. The depth wheel also bears some load of the weeder giving the operator comfort and helps maintaining the direction of travel.

Handle: The handle was made of MS pipe and attached to the mainframe (Fig. 3). This part enabled the operator to keep the weeder straight during operation and to make a turn in the headlands by hanging the handle to raise the rotary. The handle was fixed at ergonomic working height (0.90 m) of the operator. Two clutch levers were attached to the handle - one for the rotary shaft (right) and one for the wheel axle (left). An accelerator lever was also attached to the right handle. A main gear lever was provided with the load transmission system set to the wheel axle.

Rotary shaft with blade: The rotary shaft (Fig. 5) was made of MS pipe and MS shaft. Total 14 blades pockets were welded on the rotary shaft with a screw thread pattern. Tip to tip blade tilling width was 468 mm. Individual blade width was 46.95.mm. The blade pocket to blade pocket horizontal space was 8 mm.

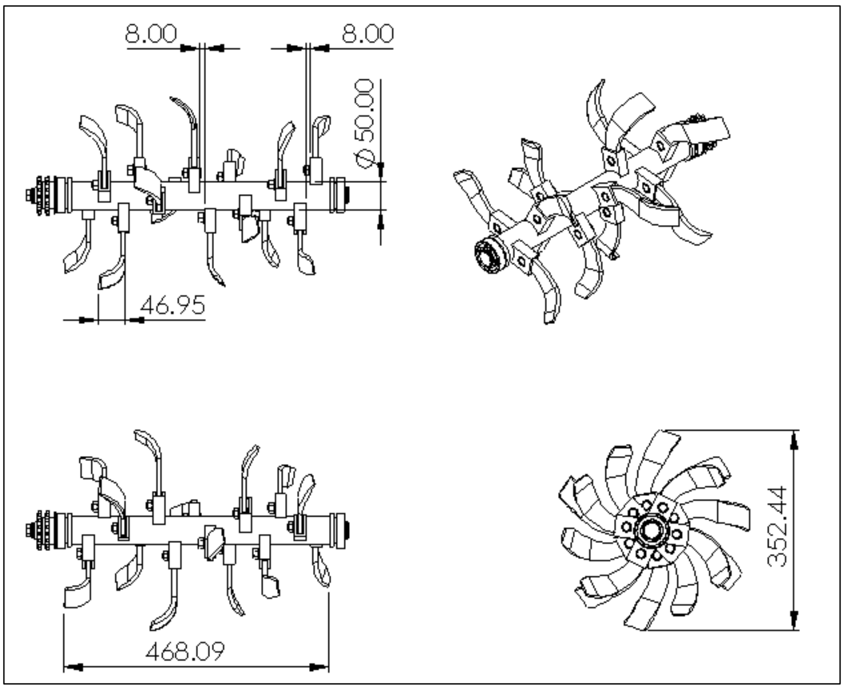


Fig. 5. The blade shaft with tilling blades.

Power transmission: The power transmission system is shown in Fig. 6. The engine speed was stepped down from 2000 to 370 rpm through belt pulley. The main pulley, where power was reduced, was directly coupled with main shaft. From the main shaft, power was divided into two ways. The rotary blade was powered from the main shaft through double gut chain and sprocket (Fig. 8). The rotational speed of the blades on the rotary shaft was maintained at 450-540 rpm. Power transmission to the blade was controlled by a dog-clutch to turn the power on and off. Power to the wheel shaft was transferred though an auxiliary shaft. There was a dog clutch in the auxiliary shaft to engage/disengage power from the wheel. The wheel speed was 35-42 rpm to obtain a laboratory speed of 2.0-2.3 km/h. The depth was adjustable by depth control wheel.

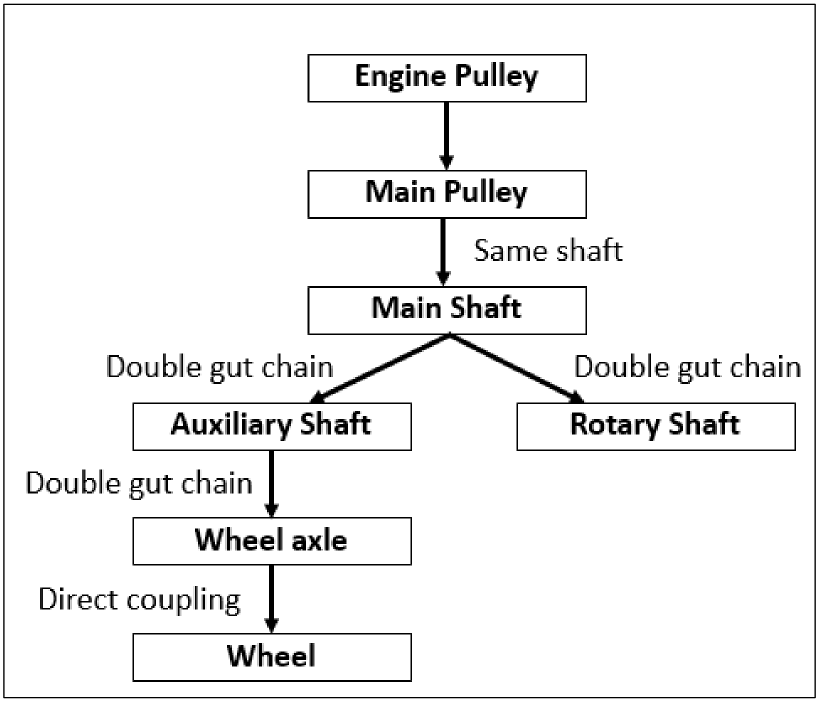


Fig. 6. Power transmission system of power weeder.

The machine was fabricated with locally available materials (Fig. 7) during 2020-21. The orchard weeder cum mini tiller was modified (Fig. 8) during 2021-22. The main components of the improved orchard weeder cum mini tiller comprised of drive wheel, depth wheel, mainframe, handle, power transmission system and engine. The materials of the machine were MS sheet, MS angle bar, steel rod, belt, pulley, chain and sprocket, nut and bolts. The fabricated machine (Fig. 9) removed the big gear box with typical power transmission system. Comparative specifications of both previous, and modified models during 2021-22 are shown in Table 1. The specifications of both the models are shown in Table 2.

Fig. 7. Previous model.

Fig. 8. Modified model.

(a) Right side view (b) Left side view

Fig. 9. Different views of the orchard weeder cum mini tiller.

Table 1. Comparative specifications and costs of both previous and improved weeder models

Sl.No.	Items	Previous in 2020-21	Modified in 2021-22
1	Power	4 hp	4 hp
2	Drive wheel type	Mild steel	Mild steel
3	Drive wheel diameter	330 mm	360 mm
4	Drive wheel lugs height	10 mm	15 mm
5	Depth wheel diameter	150 mm	210 mm
6	Power transmission	V belt; chain sprocket	V belt; double gut chainchain sprocket
7	Rotary shaft width	380 mm	380 mm
8	Weight	100 kg	140 kg

Table 2. Specification of the orchard weeder cum mini tiller

SL. No.	Parameters	Observation/value
01	Overall dimension (LxBxH), mm	1650 x 540 x 1200
02	Power, hp	04
03	Fuel type	Diesel
04	Fuel consumption, l/h	0.5
05	Power supply control	Dog Clutch
06	Main power transmission	Belt Pully
07	Other power transmission	Double chain
08	Tilling mechanism	Rotary tiller
09	Rotary blade speed, rpm	650
10	Number of blades, No.	12
11	Blade size, mm	80
12	Tilling width, mm	410
13	Soil tilling depth, mm	40-60
14	Rotary depth controller	Tail wheel with easy adjusting
15	Number of drive wheel	02
16	Drive wheel type	Metallic case wheel
17	Drive wheel size, mm (dia. x width)	360 x 100
18	Depth wheel size, mm (dia. x width)	210 x 65
19	Weight, kg	140

Performance test and evaluation

To ascertain various design parameter of the weeder, laboratory test was carried out to determine the engine speed, rotary speed and fuel consumption. Fuel consumption was determined from operating the power weeder at field speed in tilled soil and measuring the time and volume of fuel required.

The field experiment was conducted at a kitchen garden (Fig. 10) and a malta orchard (Fig. 11) at Bangladesh Agricultural Research Institute (BARI), Gazipur during 2021-22.

Fig. 10. Field performance evaluation of the weeder in a kitchen garden.

Fig. 11. Field performance evaluation of orchard weeder in a malta orchard.

The engine was started and clutch of rotary shaft was engaged. The depth was measured with a steel rule and set at 35-60 mm by adjusting rear wheel, depending on soil moisture, weed rooting, and soil condition (hard or soft). The wheel clutch was engaged and the machine traveled forward cutting the weeds and soil. Time to cover the length of the field was recorded. Seven-to-ten-centimeter margins on both sides of plants were left to protect the plant from injury. The effective width and depth of weeding were randomly measured by a steel tape. Lost time due to adjustments and interruptions were recorded. The weed count before weeding (WI) was done for the strip between crop rows and then tilled it by the power weeder. The weeder was also tested in the kitchen garden to till the soil in small plot at BARI campus. Three quadrants of 50×75 cm were previously marked on the soil and the weed species and number were recorded. Weed counts (uncut) were done in these three quadrates after one pass of the weeder. Weeds not uprooted or cut partially were counted as uncut, as it could survive. Effective field capacity (EFC) was calculated from the record of the total time required to cover unit plot. It included turning time and time required for break downs or adjustments. Theoretical field capacity (TFC) was calculated from the mean values of working width and speed. Field efficiency was calculated from the ratio of EFC and TFC. Average forward speed was calculated for each plot from the record of time required to travel one line (6 m).

Theoretical field capacity (TFC), effective field capacity (EFC), field efficiency (η), weeding index (e) were calculated using the following equations 1-4 (Dauda et al., 2013; Hoque *et al*., 2010).

$$TFC = \frac{W \times S}{10} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(1)}$$

$$EFC = \frac{A}{t} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2)}$$

$$\eta = \frac{EFC}{TFC} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3)}$$

$$e = \frac{W_1\text{-}W_2}{W_1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(4)}$$

Here, TFC= theoretical field capacity (ha h^{-1}), W = machine cutting width (m), S = speed of operation (km h^{-1}), EFC= effective field capacity (ha h^{-1}), A = working area (ha), t = working time (h), and η = field efficiency (%), W_1= weed count before weeding, W_2= weed count after weeding by mini tiller and e = weeding index (%).

Financial analysis

An economic analysis of the orchard weeder cum mini tiller was performed. The cost analysis included the operating costs of the machine. The operating costs of the machine included fixed costs and variable costs. The fixed costs of the machine included capital consumption and housing. Variable costs included labour, diesel, repair, and maintenance, lubrication cost. Labour was required to operate the machine.

Fixed cost

Fixed cost of the machine included annual depreciation, interest on investment, and shelter. Capital consumption included depreciation and interest as shown in equation (5-9) (Hunt, 2008).

i) Capital consumption (CC)

$$CC = (P\text{-}S)\ CRF + S \times I \qquad (5)$$

Where, P = purchase price, Tk; S = salvage value (10%P), Tk; CRF= capital recovery factor

$$CRF = \frac{i(1+i)^L}{(1+i)^L - 1} \qquad (6)$$

Where, i = rate of interest, L = life of machine, yr

ii) Shelter, T = 3.0% of purchase price of the machine, Tk (Hunt, 2008).

Total fixed cost per year, FC= CC+T (7)

Variable Cost

In calculation of variable cost, the following relations were assumed (Hunt, 2008).

i) Labour cost per hour, L_b=Tk man-h^{-1}

ii) Diesel cost per hour, D=Lh^{-1}

iii) Repair and maintenance (R&M) cost per year =3.5% of purchase price of the machine

iv) Lubrication cost per year, L= 3% of the diesel cost

Total variable cost, VC=L_b+D+R&M+L (8)

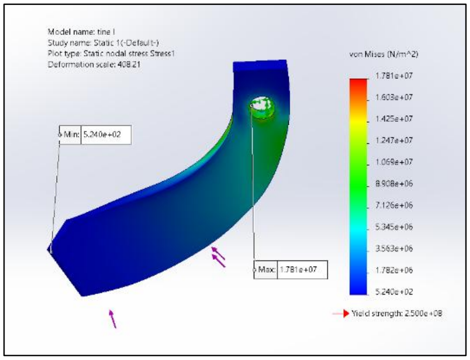
Annual cost/operating cost, AC= FC+VC (9)

Results and Discussion

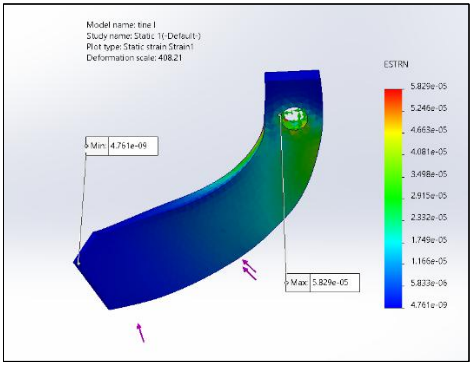
The design analysis of tilling blade of orchard weeder cum mini tiller was done. The results of the analysis are shown in Fig. 13. The highest, medium, and lowest scales are represented by the colors- red, green, and blue in the figures, respectively. The design analyses were studied based on the load enforced on the tilling blade. To perform this, 100 N force was considered for the blade. The minimum factor of safety value of tilling blades was 14. This illustrated that the material would start to yield if much higher force is applied. The results also presented that the tine yield strength was 2.5×10^{8} Nm^{2}, proposing that the tine or tilling blade of the orchard weeder cum mini tiller will start to bend in the other direction when the magnitude of the strength is greater than this amount (Fig. 12). It was noticed that the maximum and minimum von Mises stress 1.78×10^{7} Nm^{2} and 5.24×10^{2} Nm^{2}. The highest displacement and strain of the head thrower were 3.32×10^{-2} mm and 5.83×10^{-5}, respectively. It revealed that maximum stress and strain of the tine were found in the connection point of the tine and the pocket. The maximum displacement of the tine may occur at the tip.

Laboratory Test

The laboratory test result is summarized in Table 3. The rotary blade speed was 450 rpm in the laboratory trial without load but the speed was reduced to 525 rpm when the weeder was used in the field. The theoretical field capacity of the improved power weeder was 0.09 ha/h. The fuel consumption was low (0.55 l/h) because the engine was only 4.0 hp.



(a)



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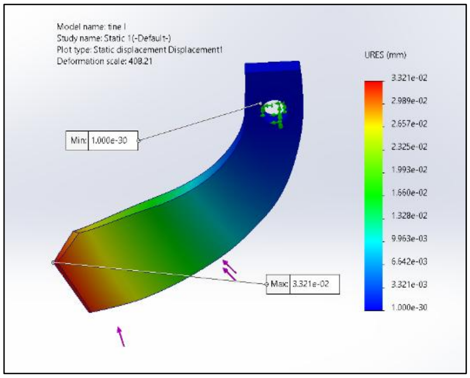

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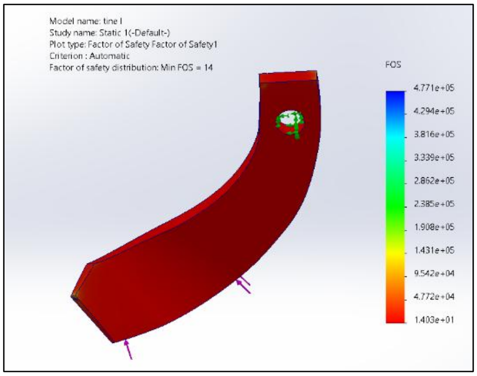

(d)

Fig. 12. Tine analyses with application of 100 N force for: (a) stress; (b) strain; (c) displacement; and (d) factor of safety.

Table 3. Laboratory test of power weeder

Parameter	Values
Rated engine speed, rpm	2000
Rotary blade speed, rpm	400-500*
Fuel consumption, l/h	0.55
Theoretical field capacity, ha/h	0.09

* Field speed was 450 rpm

Field Test

The forward speed, depth of weeding, and field capacity were found good for the machine (Table 4). The soil was in friable condition and weeder was operated to the desired depth (3-4 cm). A chain-cover was also used to protect the chain-sprockets from dust. The dust protector also gave the advantage to reduce dust through to the operator in back. The field test results showed that the weeds in the malta orchard were effectively killed or uprooted in mechanical method. The effective field capacity of the improved weeder in the malta orchard was 0.068 ha/h and the field efficiency was 73.71%. The effective field capacity and field efficiency of the improved weeder in the kitchen garden as mini tiller was 0.075 ha/h and 87.22%, respectively. When the machine was used as weeder in the kitchen garden and orchard, the weeding index was 0.88 and 0.80, respectively (Fig. 13).

Table 4. Field performance of improved weeder during 2021-22

Crop	Forward speed (km/h)	Weeding width (mm)	Weeding depth (mm)	Effective field capacity (ha/h)	Field efficiency (%)
Orchard	2.25	410	45	0.068	73.71
Kitchen garden	2.35	410	50	0.075	77.84

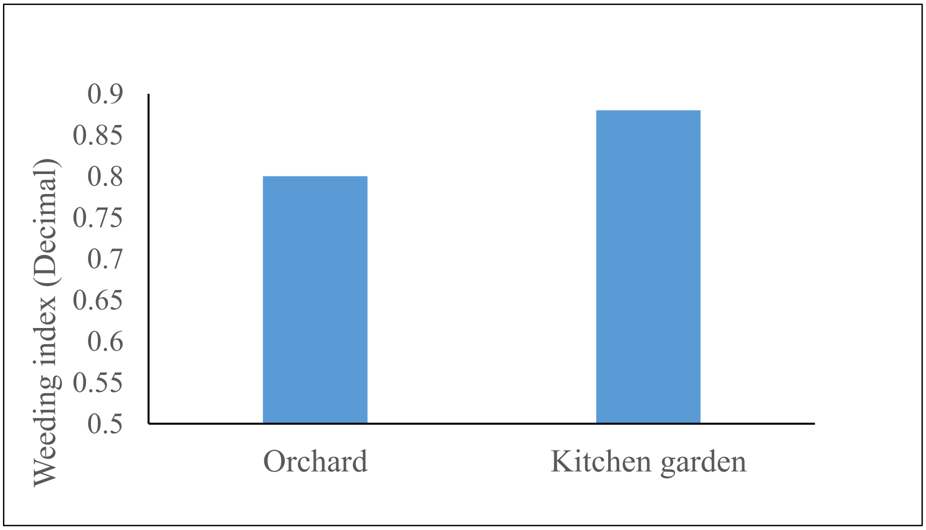

Fig. 13. Weeding index in orchard weeder and kitchen garden.

Financial analysis of the orchard weeder cum mini tiller is shown in Table 5. The operating cost of the orchard weeder cum mini tiller was 1700 Tk/ha. Net profit of the orchard weeder cum mini tiller was 15000 Tk/year. The BCR of the machine was 1.64. The payback period of orchard weeder cum mini tiller was 0.33 year.

Table 5. Financial analysis of the orchard weeder cum mini tiller

Cost Item	Orchard weeder cum mini tiller
Price, Tk	50000.00
Working days per year	100.00
Machine life, year	5.00
Salvage value, Tk	5000.00
Capital consumption cost (CC), Tk	9743.25
Shelter, Tk	250.00
Total fixed cost, Tk/year	9993.25
Total fixed cost, Tk/h	12.49
Labour cost per hour, Tk/h	62.50
Diesel cost, Tk/h	35.75
Repairing cost, Tk/h	2.19
Lubricating cost, Tk/h	1.0725
Total variable cost, Tk/h	101.51
Total operating cost, Tk/h	114.00
Capacity of the machine, ha/h	0.07
Operating cost, Tk/ha	1701.52
Operating cost, Tk/yr	91201.25
Custom hire-based income (@4500 Tk/ha), Tk/yr	241200.00
Net profit, Tk/yr	149998.75
BCR	1.64
Payback period (year)	0.33

Conclusion

An improved power weeder was designed and fabricated to operate with 4.0 hp diesel engine to operate in orchard and kitchen garden. The weight of the weeder was 140 kg. The width of weeding/tilling was 410 mm. The power weeder could be an effective means for fast and low-cost weeding of fruit orchard. This machine could be used year-round. The effective field capacity of the improved weeder in the orchard and kitchen garden as mini tiller were 0.068 and 0.075 ha/h and field efficiency were 73.71 and 77.84%, respectively. The BCR of the machine was 1.64. The payback period of orchard weeder cum mini tiller was 0.33 year. The orchard weeder cum mini tiller can be used in high density orchard since the width is less than the power tiller. Thus, this orchard weeder cum mini tiller could be recommended for the orchard farmers.

References

Ascard, J. and B. Mattsson. 1991. Mechanical weed control - the effect of hoeing and brush hoeing on yield of weed free carrots. In: 32 Swedish crop t2il protection conference - weeds and weed control, Uppsala, Sweden: 163-172.

Dauda SM, Desa A, Abdan K, Jamarei O. 2013. Performance evaluation of a tractor mounted kenaf harvesting machine. *Academic Research International* **4**(2):70.

Bond, W and R.J. Turner. 2005. A review of mechanical weed control, Technical Report HDRA, Ryton Organic Garden. Coventry, UK, pp. 1-16.

Dilipkumar, M., T.S. Chuah, S.S. Goh, and I. Sahid. 2020. Weed management issues, challenges, and opportunities in Malaysia, *Crop Prot*. **134**:104347.

Frayer, I.D. 1970. Weed Control Handbook. R.J. Makepeace, Black Well Scientific Publications, 6th Edition.

Gulandaz, M.A., M.I. Hossain, M.A. Hossain, M.A. Matin and M.A. Hoque. 2019. Design and development of a low cost battery operated rotary type weeder for up-land crop. Annual research report of Farm Machinery and Postharvest Process Engineering Division, BARI, Gazipur.

Home, M.C.W., N.D. Tillett, and R.J. Godurn. 2001, Wheat lateral position accuracy is required for weed control by inter-row cultivation? In: Proceedings Brighton crop protection conference – weeds, Brighton, UK: 325-328.

Hoque, M.A., M.A. Matin, M.A. Wohab, M.A. Hossain and S. Ahmed. 2010. Design and development of a power weeder for row crop. Journal of Agricultural Engineering. The Institute of Engineers, Bangladesh. Vol 38/AE, Number 2, December.

Hunt, D. 2008. Farm power and machinery management, 9th edition, Iowa State University Press, Ames, Iowa 50014, 4-6 and 65-75.

Islam, M.M., M.M. Rahman, S.S. Sarker, M.N. Islam, F.H. Bhuiyan, M. S. Khanam, and I. Alam. 2024. Beyond yield: Unveiling farmer perceptions and needs regarding weed management in Bangladesh. Front Bioeng Biotechnol. 12:1410128. doi: 10.3389/fbioe.2024.1410128

Kurstiens, D.A.G. 2002. Mechanics of selective mechanical weed control harrowing. PhD, Dissertation, Deptt. Agrotechnology & Food Sciences. Wageningen University, The Netherlands, p 156.

Kushal, G., E. Rao, B. Boraiah, M.T. Sanjay and S. Araganji. 2024. A review on challenges and emerging opportunities for weed management in organic agriculture. International Journal of Research in Agronomy. SP-**7**(8): 859-869 DOI: https://doi.org/10.33545/2618060X.2024.v7.i8Sk.1401

Manuwa, S.I. 1998. Design and Performance evaluation of A push-type weeding hoe. Presented at the Annual Conference of Weed Science Society of Nigeria held at the Federal University of acia held al the Eederal U Technology, Nov. 8-12. Azure, Nigeria,pp: 1-11.

Manuwa, S.I., O.O. Odubanjo, B.O. Malumi and S.G. Olofinkua. 2009. Development and Performance Evaluation of a Row-Crop Mechanical Weeder. *Journal of Engineering and Applied Sciences* **4** (4): 236-239

Melanders B and P. Hortvig. 1997. Yield responses of weed-free seeded onions (Alliumcepa L.) to hoeing close to the row. Crop protection. 16: 687- 691.

Mganilwa Z. M., P. J. Makungu, and S.M. Mpanduji. 2003. Development and assessment of an engine powered handheld weeder in Tanzania. Proceedings of the International Conference on Industrial Design Engineering, UDSM. Dar Es Salam, 17-18 July: 146-151.

Northway, R.G. and O.J.N. Tullberg. 2000. Precision physical weed control. In: Abstracts 4 EWRS workshop on physical weed control. Elspeet, The Netherlands. www.cwrs.org/physicalcontrol/meeting.htm.

Olukunle, O.J. and P. Oguntunde. 2006. Design of a row crop weeder. Cof. on International Agricultural Research for Development, University of Bonn. 11-13, 2006.

Oni, K.C. 1990. An ox-drown straddle row rotary weeder. *Samaru Journal of Agricultural Research* **3** (1&2).

Paul, S., B. C. Nath, M.D. Huda, M.G.K. Bhuiyan, and H. Paul. 2025. Assessment of mechanical weeders in paddy fields: A study on operational effectiveness in Bangladesh. Heliyon 11:e42639

Paul, S., B.C. Nath, A. Hossen, K. Pintu, H. Paul, S. Islam, A.U. Khan, and M. Ahmmed. 2023. Development and fabrication of manually push-pull type conical weeder for Bangladesh condition, *Agric. Sci.* **14**:685–709.

Prasad, B. H., D. Ganapathi and V. Balasundaram. 2019. Development and field evaluation of rotary power weeder for dryland crops. Res. Jr. of Agril. Sci. 10(2): 349-352

RNAM. 1993. Testing, evaluation and modifications of weeders, Technical Series No.11. Regional Network for Agricultural Machinery, Passay City, Metro Manila, Philippines, p 3.

Robbins, W.W. and A.S. Craft, 1962. Weed Control: A Text Book and Manual. 1st Edn. McGraw-Hill Book of Company, New York.

Saha, K.K., A. Hossain, M.A. Hoque, M.A.H.S. Jahan, S. Ahmed, and J. Timsina**.** 2021**.** Development and Performance Evaluation of a Two-Wheeled Power-Tiller Multi-row Weeder Bangladesh**.** *Journal of Biosystems Engineering* **44**(4): 609-620.

Zimdahl, R.L. 2018. Chapter 10 - Methods of Weed Management, Editor(s): Robert L. Zimdahl, Fundamentals of Weed Science (Fifth Edition), Academic Press, 271-335, https://doi.org/10.1016/B978-0-12-811143-7.00010-X.

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EFFECT OF LIMING ON GROWTH, YIELD AND PROFITABILITY OF NAGA CHILI (*CAPSICUM CHINENSE JACQ*) IN ACIDIC SOIL

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Abstract

Acidic soil conditions often limit the nutrient availability and plant development, thereby reducing agricultural productivity. Hence, a field investigation was conducted during 2020 and 2021 cropping seasons at the Spices Research Sub-Station, Jaintapur, Bangladesh Agricultural Research Institute, Sylhet to evaluate the effect of liming on acidic soils to optimize the vegetative growth, yield, and profitability of Naga chili (*Capsicum chinense* Jacq.). In this study, dolomite was used as a liming material. A randomized complete block design was employed with three replications. The experiment consisted of six treatments as liming doses which were- 0 (control), 0.5, 1.0, 1.5, 2.0, and 2.5 t ha^{-1}. Results revealed that lime application in acidic soil significantly boosted plant growth, fruit yield attributes, fruit yield, and economic profitability. The highest fruit yields of Naga chili were recorded 9.89 t ha^{-1} in 2020 and 7.51 t ha^{-1} in 2021 with 2.5 t ha^{-1} lime application. This was followed by 2.0 t ha^{-1} lime, which produced fruit yield, 9.20 t ha^{-1} in 2020 and 6.64 t ha^{-1} in 2021. The control treatment yielded the lowest, with 3.89 t ha^{-1} in 2020 and 3.61 t ha^{-1} in 2021. In 2020, the maximum marginal rate of return (MRR) was 1,515% with 1.5 t ha^{-1} of lime, while in 2021, it reached 970% with 1.0 t ha^{-1}. The highest average MRR (1,115%) was recorded at a liming rate of 1.0 t ha^{-1}. Consequently, applying either 1.0 t ha^{-1} or 1.5 t ha^{-1} of lime proved to be the most economically viable treatment for Naga chili cultivation in the acidic soils of Bangladesh.

Keywords: Naga chili, liming, dolomite, soil acidity, yield and MRR.

Introduction

Crops are facing a wide range of environmental stressors in the field condition, a direct consequence of global climate change (Chaki *et al*., 2020). Among these, soil acidity, characterized by a low soil pH, is a major hindrance to agricultural productivity, second only to drought. It not only reduces crop yields but also negatively impacts the structural and functional diversity of microbial communities in the soil (Hao *et al.,* 2020). Soil acidity results from various factors, including the removal of basic elements through leaching and crop uptake, the decomposition of organic matter, acid rain, the nitrification of ammonium-based nitrogen

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fertilizers, and natural soil-forming processes. Globally, acidic soils are found across 30–40% of the world's arable land, being particularly common in humid tropical, subtropical, and temperate climates (Bhuyan *et al.*, 2019). Bangladesh has approximately, 8.59 million hectares of cropland, with a substantial portion suffering from acidity. About 2.78 million hectares are extremely acidic (pH below 4.5), and another 3.64 million hectares are very strongly acidic (pH 4.5 to 5.5) (SRDI, 2020). Furthermore, acid soils often contain excessive levels of aluminum (Al), iron (Fe), and manganese (Mn). These can create toxic conditions for crops, leading to stunted crop growth and significantly reduced yields (Bhuyan *et al.,* 2019). As a result, farmers frequently struggle to achieve expected harvests from their fields. To attain optimal crop yields, it becomes essential to adopt an appropriate measure for managing the high levels of soil acidity. Various soil amendments, liming stands out as a well-established and effective method for reducing soil acidity in agricultural settings (Kätterer *et al.,* 2019). Liming increases soil pH by neutralizing excess hydrogen ions (H^+) in the soil solution, which in turn boosts crop production. Chemically, liming displaces the acidic cations like H^+, Fe^{2+}, Al^{3+}, Mn^{4+}, and Cu^{2+}, from the plant root zone. This process also increases the availability of essential plant nutrients like calcium (Ca^{2+}) and magnesium (Mg^{2+}) in the soil. Some common materials are used for liming, including: calcium carbonate (lime), calcium/magnesium carbonate (dolomitic lime or agricultural lime), calcium oxide and calcium hydroxide. Beyond pH adjustment, lime application promotes the growth of beneficial soil microorganisms and supports earthworm activity in soil. Both of these contribute positively to overall soil structure and health (Mahmud and Chong, 2022).

Soil acidity in the northeastern hilly region of Bangladesh, caused by high rainfall, leaching of basic cations, and organic matter decomposition, results in a low soil pH. This acidic environment hampers Naga chili (*Capsicum chinense* Jacq.) cultivation, leading to stunted growth, nutrient deficiencies and poor fruit development, preventing the plants from reaching their full genetic potential (Zahid *et al.*, 2020). Naga chili, locally known as 'Naga Morich,' or Dorset Naga, is economically and culturally significant in Bangladesh, especially in the northeastern hilly region, due to its intense pungency and unique flavor. It is a crucial cash crop and a staple in traditional cuisine, supporting local farmers' livelihoods (Bhuyan *et al*., 2015; Kumar *et al.,* 2022). While chili peppers (*Capsicum annuum* L.) are known to respond well to lime application in acidic soils, with several studies highlighting its positive impact on chili cultivation. But specific and detailed information on liming for Naga chili is lacking. Therefore, determining the appropriate lime application rate for Naga chili cultivation is essential. Keeping the above facts in view, a study was conducted to find out the efficacy of liming in acidic soils on the growth, yield and profitability of Naga chili (*Capsicum chinense* Jacq.) cultivation in the northeastern hilly region of Bangladesh.

Materials and Methods

Study location

The experiment was carried out at Spices Research Sub-Station, Citrus Research Station, Bangladesh Agricultural Research Institute (BARI) during 2020 to 2021. The study area is situated at 25.13562° N latitude and 92.13217° E longitude, with an average elevation of 34 meters. The experimental site is located on the northern and eastern piedmont plains (AEZ-22). The soil of the study area is sandy loam in texture with gravels and exhibits a reaction from extremely acidic to very strongly acidic (4.2 to 4.5). The soil analysis stated that the present status of nitrogen 0.14%, potassium 0.26 meq 100 g^{-1} soil, calcium 1.09 meq 100 g^{-1} soil, magnesium 0.57 meq 100 g^{-1} soil, sulfur 20.62 μg g^{-1} soil, zinc 3,07 μg g^{-1} soil and boron 1.56 μg g^{-1} soil. The organic matter content in these soils is low to medium.

Climatic condition of the study location

The experimental site is experienced with a unimodal rainfall pattern, with the highest rainfall occurring in June and July. The area is characterized by hot and humid summers and relatively cool and dry winter Average annual temperatures range from a low of 9.48°C in January to a peak of 35.5°C in May. Mean monthly rainfall is highest in June (762 mm) and lowest in January (2 mm) (Islam *et al.,* 2019).

Seed source, seedling rising and land preparation

For the first-year experiment, healthy Naga chili seeds were sourced from a local farmer in Jaintapur Upazila, Sylhet district. Subsequently, the seeds for the second-year study were obtained from the Naga chili plants cultivated during that initial experiment. Seeds were manually sown in seed beds during the first week of October in both experimental years. Watering occurred immediately after seed sowing. After one week, the emerging seedlings were transplanted into 3x5-inch poly tubs to promote optimal growth. These transplanted seedlings received irrigation twice weekly. Seedlings were secured from diseases and insects by application of Autostin®50WG fungicide and Sevin® insecticide. During the seedling growth period, the main research plots underwent methodical preparation, involving cross-ploughing and laddering. Subsequent to this, all weeds and debris were manually cleared.

Experimental design, treatments and fertilizer application

A randomized complete block design was employed with six treatments (liming rates): T_1: control (No lime), T_2: 0.5 t ha^{-1}, T_3: 1.0 t ha^{-1}, T_4: 1.5 t ha^{-1}, T_5: 2.0 t ha^{-1}, T_6: 2.5 t ha^{-1} lime. Each treatment was replicated three times. Dolomite lime [$CaMg(CO_3)_2$] was applied as the liming material. Fertilizers were applied @ 100-

50-120-20-2-1.5 kg ha^{-1} N-P-K-S-Zn-B along with 10 t ha^{-1} decomposed cow dung (Sarker *et al.,* 2018). The experimental unit plot size was 2.4 m × 1.5 m, with plants spaced at 100 cm × 60 cm. The adjacent plots were separated by a 0.75 m space, and each replication was separated by a 1 m space. Dolomitic lime was incorporated into each plot according to the specific treatment. The plots were then left for two weeks to ensure the lime was thoroughly mixed with the soil. The sources of N, P, K, S, Zn and B were urea, triple super phosphate (TSP), muriate of potash (KCL), gypsum, zinc sulphate heptahydrate and boric acid, respectively. During the final plot preparation, 50% of the cowdung and TSP, along with the entire quantities of gypsum, zinc sulfate, and boric acid, were applied to the plots. The remaining cowdung and TSP were incorporated into the seedling transplanting pits. Urea and MoP were applied as a top dressing in five equal splits at different growth stages which are- a) at 15 days after transplanting, b) at flowering, c) at fruit setting, d) at first harvest, and e) at 2nd harvest of chilies.

Transplanting of seedlings and intercultural operation

In both experimental years, fifty-day-old Naga chili seedlings were transplanted to the main plots during the third week of November, with a spacing of 100 cm between rows and 60 cm between plants. The planted seedlings were immediately watered by a hose pipe. The irrigations were done as per requirement to enable the proper establishment of plants. The research field was monitored regularly to ensure healthy crops during establishment. Any injured, dead, or weak seedlings were replaced with vigorous new ones in the same planting pit. The entire experimental area was covered with a blue net to control insect pests and prevent outcrossing. To maintain weed-free plots, three manual weeding were conducted at 15, 45, and 75 days after transplanting. Irrigation was scheduled based on soil moisture requirements to ensure optimal plant growth. During the experiment, minor infestations of aphids and mites occurred, which were managed using appropriate insecticides and acaricides. Additionally, fruit rot was observed during harvest, and this issue was controlled through timely fungicide applications. Green chilies were ready for harvest 105 days after transplanting, while ripening began at 120 days post-transplanting. Harvesting was conducted on a bright, sunny day, with great care taken to avoid any injury to the plants. Both green and ripe chilies were then transported to the laboratory for analysis of fruit quality parameters.

Data collection

For data collection, three plants were randomly selected from each treatment plot. Before harvest, the following parameters were measured from the standing plants. Plant height was measured from the soil surface to the topmost point of the plant and expressed in meters (m). Canopy volume was determined by first measuring plant spread in both east–west and north–south directions at the widest points in centimeters. Afterwards, the canopy volume was calculated using the appropriate geometric formula and expressed in cubic meters (m^3). Stem diameter was measured at 15 cm above the ground using a caliper and recorded in centimeters (cm). Five fruits from each treatment were randomly selected to measure fruit size (length and breadth) and single fruit weight. However, fruit length was measured from the apex to the base of the chili fruit and expressed in centimeters (cm). Fruit breadth was measured at the widest point using two perpendicular directions, and the average of the two values was taken and recorded in centimeters (cm). Single fruit weight was measured individually using a precision balance and expressed in grams (g). The number of primary branches was counted at the point of first branching, representing the actual number of main branches. The number of fruits per plant was determined by counting fruits from randomly selected three plants. Fruit yield was calculated after the final harvest from each treatment, averaged, and converted to a per-hectare basis.

Economic analysis

To assess the economic viability of the treatments, partial budget, dominance and marginal analyses were done. This post-experimental MRR estimation was performed to provide valuable insights to the farmers. For determining the most economically acceptable liming doses, dominance and marginal analyses were used (Elias and Karim, 1984). Marginal rate of return is calculated by the following equation:

MRR= (AdB/AdC) × 100, where, MRR=marginal rate of return, AdB=Additional benefits between each pair of cost Undominated treatments, AdC=Additional costs between each pair of cost Undominated treatments.

Data analysis and interpretation of the results

The collected data underwent compilation, rectification, and validation prior to statistical analysis, which was performed using R statistical software (version 4.2.0). For interpreting the results, treatment means were separated using the Least Significant Difference (LSD) test at 5% probability level.

Result and Discussion

Influence of liming on the growth parameters of Naga chili

The application of different liming doses significantly influenced the growth parameters of Naga chili. The growth parameters showed an increasing trend with the increasing rates of lime application, and marked variations were observed across the growing seasons of the two consecutive study years 2020 and 2021 (Table 1). The results clearly demonstrated that liming significantly influenced the vegetative growth parameters of Naga chili. The observed improvements in plant height, canopy volume, stem diameter, and number of primary branches in response to lime application can be attributed to the amelioration of soil acidity and the consequent enhancement of nutrient availability and uptake.

Plant height

This character exhibited slight but consistent significant improvements with liming (Table 1). In 2020, the tallest plants (1.00 m) were recorded at 2.5 t ha^{-1} while the shortest plant (0.95 m) was observed at 0.5 t ha^{-1}. Notably, plant height showed a more pronounced response to liming and was significantly higher in 2021 than in 2020 across all the treatments. In 2021, plant height ranged from 1.37 m to 1.63 m. The tallest plant (1.63 m) was found at 2.5 t ha^{-1} while the shortest plant (1.37 m) was found from the control treatment. Plant height reflects overall vigor and shoots elongation of the plants which increased modestly in the first year but more markedly in the second year of the present study. The maximum plant height at 2.5 t ha^{-1} suggested that, the alleviation of sub-optimal pH conditions likely enhanced uptake of essential nutrients such as nitrogen and calcium—both of which play pivotal roles in cell division and elongation (Marschner, 2012). The observation of the present study also corroborated the findings of other researchers. Liming can boost plant height by raising the pH of acidic soil, which encourages root growth and improves nutrient availability (Shaheb *et al.*, 2014). The result also aligns with the findings of other researchers, who noted that by increasing soil pH, liming enhances phosphorus availability and subsequently improve vegetative growth of the crops. Taufiq *et al.* (2011) also found that applying dolomite lime enhanced plant height compared to not using it. The greater difference in plant height in 2021 may also indicate a delayed but more substantial benefit as the lime continued to interact with the soil profile.

Canopy volume

This parameter responded notably to liming and increased steadily with liming dose, particularly in 2021 (Table 1). The control plots recorded the smallest canopy volumes (0.33 m^3 in 2020 and 0.92 m^3 in 2021 respectively), while the maximum canopy spread was observed at 2.5 t ha^{-1} (0.45 m^3 in 2020 and 1.27 m^3 in 2021 respectively). The increase of the canopy volume from the control to the highest liming level was statistically significant in both the study years suggesting enhanced vegetative growth under improved soil conditions. Canopy expansion depends on both vertical and lateral growths, which are highly sensitive to nutrient availability and hormonal regulation within the plant. The significant increase in canopy volume at higher lime rates, especially in the second year, underscores the role of liming in promoting balanced vegetative growth. Acidic soils often limit root expansion, which in turn restricts canopy development due to poor water and nutrient acquisition. By neutralizing hydrogen ions toxicity, lime can improve soil structure and root proliferation, thereby enhancing shoot architecture and ultimately larger canopy of the plants (Barros *et al.*, 2020). The improvement in canopy volume is further supported by the findings and interpretation of other researchers, who stated that liming raised soil pH, enhanced nutrient availability in the soil resulting in improved root growth, which positively increased the growth and biomass (Shaheb *et al.*, 2014).

Stem diameter

Stem diameter progressively increased with higher rate of lime application (Table 1). In 2020, the diameter ranged from 1.53 cm in the control to 1.77 cm at 2.0 t ha^{-1}. In 2021, a more notable response was observed with stem thickness reaching 1.30 cm in the control to1.87 cm in 1.5 t ha^{-1} having statistically significant differences among treatments. The increase in stem diameter with higher lime rates improved structural development of the plants. A thicker stem is often correlated with stronger vascular tissues, which facilitate better translocation of water and nutrients. Enhanced stem diameter observed in liming treatments is probably the result of improved calcium nutrition, as calcium is a key component of cell walls and plays a crucial role in maintaining structural integrity (Marschner, 2012). Gopalakrishnan *et al.* (2015) reported a significant increase in stem diameter in chili plants grown in limed acid soils compared to non-limed control, which was attributed to better nutrient uptake and reduced H^+ and Al^{3+} toxicity. Similarly, Singh *et al.* (2019) found that, liming increased stem girth in *Capsicum annuum*, supporting that lime application can effectively ameliorate the constraints under acid soil conditions.

Table 1: Effect of liming rates on the growth parameters of Naga chili

Liming dose (t ha^{-1})	Plant height (m)		Canopy volume (m^3)		Stem diameter (cm)	
	2020	2021	2020	2021	2020	2021
Control (No lime)	0.96	1.37	0.33	0.92	1.53	1.30
0.5	0.95	1.58	0.36	1.18	1.60	1.43
1 .0	0.98	1.43	0.40	0.96	1.68	1.63
1.5	0.96	1.42	0.40	0.97	1.70	1.87
2.0	0.98	1.60	0.45	1.03	1.77	1.43
2.5	1.00	1.63	0.45	1.27	1.73	1.70
LSD (0.05)	2.44	17.97	0.03	0.41	0.11	0.19
CV (%)	1.38	6.57	3.74	21.37	3.56	6.58

Lime material: Dolomite

Influence of liming on the fruit characters of Naga chili

The application of varying liming doses significantly influenced the fruit quality parameters of Naga chili during the study years (2020 and 2021) (Table 2). The key parameters studied were fruit length**,** fruit breadth, and single fruit weigh which exhibited a positive response to liming, although the degree of improvement varied between years and treatments.

Fruit length

Fruit length increased progressively with liming peaking (6.43 cm) at 0.5 t ha^{-1} in 2020 (Table 2). However, in 2021, maximum fruit length (6.10 cm) was observed at both 2.0 t ha^{-1} and 2.5 t ha^{-1} of lime, indicating a stronger positive response to higher liming rates in that specific year (2021). This suggests that while moderate liming was effective in the first year, higher doses may be needed to buffer inter-annual soil variability or differences in environmental conditions. The LSD values (0.35 in 2020 and 1.11 in 2021) confirm that these differences were statistically significant. Liming improves soil pH, enhances nutrient availability, particularly Ca, Mg, K and B and reduces H^+ and Al^{3+} toxicity in acidic soils, all of which are critical for cell elongation and division as well as fruit expansion and development during fruit development (Mengel and Kirkby, 2001). Similar trends were reported by Singh *et al.* (2017) in *Capsicum annum*, who found liming significantly increased fruit length. The broader fruits at higher lime rates could also be indicative of improved water and turgor regulation, both of which are often disrupted in acidic soils due to poor root function.

Fruit breadth

Fruit breadth was also positively influenced by liming (Table 2). The highest fruit breadth was recorded at 2.5 t ha^{-1} in both years (2.43 cm and 2.27 cm in 2020 and 2021, respectively), clearly exceeding the control (1.97 cm and 1.60 cm in 2020 and 202,1 respectively). Notably, the differences were significant, with relatively low coefficients of variation (CV) in both years (5.15% and 3.20%), indicating consistency in response. Increased calcium is known to strengthen cell walls and support better fruit girth and integrity (Marschner, 2012), which was probably attributed to liming. Moreover, enhanced availability of micronutrients such as boron and zinc due to improved soil pH may also play a role in cell wall formation and expansion, thereby improving fruit breadth (Mengel and Kirkby, 2001). Interestingly, the broader fruit dimensions under limed conditions could also signal better cell division and elongation during fruit formation.

Single fruit weight

Single fruit weight showed noticeable response to liming (Table 2). In both the experimental years, liming 2.5 t ha^{-1} treatment produced the heaviest fruits (5.37 g in 2020 and 5.36 g in 2021) representing a substantial increase over the control (3.63 g and 4.20 g in 2020 and 2021, respectively). Improved fruit weight can be attributed to enhance nutrient uptake, particularly N, P, and Ca, essential for biomass accumulation and fruit filling. Acidic soils often inhibit root function and nutrient mobility; liming reverses these effects leading to better plant growth and fruiting. Besides, Calcium is essential for cell wall formation and firmness and its uptake is severely limited in acidic soils (Marschner, 2012). Therefore, the significant increase in single fruit weight with liming could be attributed to improved calcium nutrition from liming. Despite some environmental variability, the consistent improvement in fruit weight across the years, underlines the stabilizing effect of lime on nutrient availability and plant metabolism. The findings align with Mishra *et al.* (2014) who reported significant increases in fruit weight of chili with lime application in acidic soils of northeast Indian region.

Table 2: Effect of liming rates on fruit quality parameters of Naga chili

Liming dose (t ha^{-1})	Fruit length (cm)		Fruit breadth (cm)		Single fruit weight (g)	
	2020	2021	2020	2021	2020	2021
Control (No lime)	5.8	5.17	1.97	1.60	3.63	4.20
0.5	6.43	5.07	2.10	1.97	4.47	4.78
1 .0	6.17	5.37	2.17	2.03	4.70	5.11
1.5	6.37	5.50	2.23	1.90	4.57	4.94
2.0	6.07	6.10	2.37	2.07	4.83	4.98
2.5	6.40	6.10	2.43	2.27	5.37	5.36
LSD (0.05)	0.35	1.11	0.21	0.11	0.32	0.26
CV (%)	3.08	11.01	5.15	3.20	3.85	2.97

Lime material: Dolomite

Influence of lime on yield attributes and yield

The yield-contributing parameters and fruit yield of Naga chili were significantly influenced by the application of lime. which regulates soil pH and maximizes crop productivity in acidic soils. Acidic soils often suffer nutrient deficiencies, particularly Ca, Mg, and P, and may exhibit H^+ and Al^{3+} toxicity, all of which severely affect the yield contributing parameters and yield Naga chili. In our study the data demonstrated a consistent positive trend in number of primary branches, and number of fruits per plant, which lead to increase fruit yield per hectare, particularly at higher liming rates during the experimental years 2020 and 2021.

Number of primary branches per plant

Number of primary branches per plant increased in response to liming (Table 3). All the treatments showed a modest increase over the control. In 2020, the lowest number of primary branches 2.00 was found from both control and 2.0 t ha^{-1} treatments, while the maximum number of primary branches was from 2.5 t ha^{-1} (2.67). The effect was more distinct in 2021, where plants received 0.5 and 2.5 t ha^{-1} lime produced the highest number of primary branches (3.00), compared to the control (2.00). The differences were statistically significant, highlighting the role of lime in promoting lateral growth. Branching is closely regulated by plant growth regulators (PGRs) especially auxins and cytokinins. The balance between these two PGRs can be disturbed by nutrient stress induced by soil acidity. In this study, the number of primary branches significantly influenced by liming, particularly in the second year and plants grown under 2.5 t ha^{-1} lime producing more branches, suggesting better lateral growth and potentially higher flowering and fruiting sites. By mitigating soil acidity and its associated nutrient imbalances, lime likely created a more conducive environment for hormonal regulation and meristem activity thereby promoting branching. This observation also corroborates with the findings of Singh *et al.* (2019), who reported that liming increased the number of primary branches per plant in *Capsicum annuum* grown in acidic soils. This was attributed to improved calcium availability and overall nutrient uptake. In a study by Gopalakrishnan *et al.* (2015), chili plants grown in limed plots had significantly more primary branches compared to non-limed controls. Similar outcomes have been observed in other horticultural crops, such as tomato and eggplant, where lime application promoted branching and flowering due to improved nutrient status.

Number of fruits per plant

This parameter increased progressively with the increased application of lime, which rose from control (119 in 2020) and 76 in 2021) to 2.5 t ha^{-1} lime (204 in 2020 and 155 in 2021) (Table 3). These results suggest that liming improved the reproductive capacity of the plants by alleviating stress caused by acidic conditions and increasing the availability of key nutrients (Roy *et al.*, 2014). This substantial increase also underlines the profound effect of lime on reproductive growth, likely due to improved root activity and better hormonal balance, photosynthate translocation and nutrient partitioning and all of which are essential for flowering and fruit set (Marschner, 2012). The greater number of fruits also aligns with the observed improvements in vegetative traits (Table 1) such as branching and canopy development which directly influence fruit-bearing potential. However, the decline in fruit number at the highest lime rate in 2020 may indicate that excessive liming could lead to micronutrient imbalances or other soil-chemical interactions that marginally affect reproductive efficiency.

Fruit yield per hectare

Fruit yield per hectare followed a similar trend and showed a marked and statistically significant response to lime application (Table 3). The result illustrated that the control treatment yielded the lowest-3.89 t ha^{-1} in 2020 and 3.61 t ha^{-1} in 2021, whereas the maximum yield was recorded at 2.5 t ha^{-1} lime (9.89 t ha^{-1} in 2020 and 7.51 t ha^{-1} in 2021) which were significantly higher than all other treatments. The results also showed that, the yield increment from non-limed control to liming at 2.5 t ha^{-1} representing yield increment of over 150% compared to the control. Such a dramatic improvement reinforces the role of lime in unlocking the productive capacity of acidic soils. This result is consistent with previous findings that, liming not only improves soil chemical properties but also boosts biological activity and root efficiency resulting in greater yield potential (Barros *et al.*, 2020). By raising soil pH and reducing exchangeable aluminum, liming improves soil chemical environment leading to enhance plant growth and fruiting efficiency. Moreover, even moderate lime applications (1.0–1.5 t ha^{-1}) significantly improve yields, the highest response was observed at 2.5 t ha^{-1} suggesting this as a possible optimum dose under the given conditions. Moreover, calcium plays a crucial role in developing a more extensive root network facilitates, absorbing greater quantities of other essential mineral nutrients and consequently enabling higher fruit yields. The highest fruit yield ha^{-1} resulted from the combined application of lime, organic, and inorganic fertilizers (Chuong, 2019). This observation also corroborated the findings of other researchers. Taufiq *et al.* (2011) found that applying dolomitic lime improved overall yield compared to not using it. This is likely because liming optimizes the soil's chemical environment, improving plant nutrient uptake and translocation from roots to fruits. Consequently, plots treated with lime consistently produce significantly more marketable fruits than non-limed plots. However, this should be evaluated further through cost-benefit analyses to ensure economic viability for farmers.

Table 3. Effect of liming rates on the yield contributing characters and yield of Naga chili

Liming dose (t ha^{-1})	Primary branches (No.)		Fruits $plant^{-1}$ (No.)		Fruit yield (t ha^{-1})	
	2020	2021	2020	2021	2020	2021
Control (No lime)	2.00	2.00	119	76	3.89	3.61
0.5	2.33	3.00	133	96	5.33	4.49
1 .0	2.33	2.33	158	121	6.69	5.56
1.5	2.33	2.67	201	135	8.30	6.03
2.0	2.00	2.33	211	148 b	9.20	6.64
2.5	2.67	3.00	204	155	9.89	7.51
LSD (0.05)	NS	NS	15.51	5.26	0.90	0.34
CV (%)	19.08	22.21	4.99	2.37	6.82	3.30

Lime material: Dolomite

Economics

Partial budget analysis

A partial budget was developed as a part of economic analysis to calculate the total costs that vary (lime cost) and the gross margin for each treatment of the liming experiment. The highest gross return (Tk 19,78,000 ha^{-1} in 2020 and Tk 15,02,000 ha^{-1} in 2021) and gross margin (Tk 18,78,000 ha^{-1} in 2020 and Tk 14,02,000 ha^{-1} in 2021) was obtained from 2.5 t ha^{-1} liming dose followed by 2.0 t ha^{-1} lime and so on upto 1.0 t ha^{-1} lime (Table 5). The lowest gross margin (Tk 7,78,000 ha^{-1} in 2020 and Tk 722000 ha^{-1} in 2021) was obtained from control treatment (Table 4).

Table 4. Partial budget analysis of Naga chili production as influenced by different lime doses during 2020 and 2021 cropping seasons

Lime dose (t ha^{-1})	Lime cost (Tk ha^{-1}) (2020 & 2021)	Gross return (Tk ha^{-1})		Gross margin (Tk ha^{-1})	
	2020	2020	2021	2020	2021
0.0 (control)	0.0	7,78,000	7,22,000	7,78,000	7,22,000
0.5	20,000	10,66,000	8,98,000	10,46,000	8,78,000
1.0	40,000	15,02,000	11,12,000	12,98,000	10,72,000
1.5	60,000	16,60,000	12,06,000	16,00,000	11,46,000
2.0	80,000	18,40,000	13,28,000	17,60,000	12,48,000
2.5	100,000	19,78,000	15,02,000	18,78,000	14,02,000

Lime (dolomite) price: Tk 40 kg^{-1}, produce (fresh fruit) sale price: 200 kg^{-1}

Dominance analysis

For dominance analysis, the treatments were listed in order of increasing total costs that vary (lime cost). The gross margin also increased with the increasing rate of lime (Table 5). Table 5 showed that there was no cost dominated treatments because no treatment had higher lime cost but lower in gross margin. The treatment which possesses higher lime cost but lower in gross margin is called a cost dominated treatment. It is seen that all liming treatments including control (no lime) are cost undominated.

Table 5. Dominance analysis of Naga chili production as influenced by different doses of lime during 2020 and 2021 cropping seasons

Lime dose (t ha-1)	Lime cost (Tk ha^{-1})	Gross margin (Tk ha^{-1})		Remarks	
	(2020 & 2021	2020	2021	2020	2021
2.5	100,000	1,87,8000	14,02,000	CUD	CUD
2.0	80,000	1,76,0000	12,48,000	CUD	CUD
1.5	60,000	1,60,0000	11,46,000	CUD	CUD
1.0	40,000	1,29,8000	10,72,000	CUD	CUD
0.5	20,000	10,46,000	8,78,000	CUD	CUD
Control (no lime)	0.0	7,78,000	7,22,000	CUD	CUD

CUD = Cost Undominated

Table 6. Marginal analysis of Cost- undominated treatments applied in Naga chili at TCRC, Bogura

Lime dose (t ha^{-1})	Lime cost (Tk ha^{-1}) (2020 & 2021	Gross margin (Tk ha^{-1})		Marginal increase in lime cost (Tk ha^{-1})	Marginal increase in gross margin (Tk ha^{-1})		MRR (%)		
	2020	2020	2021	2020 & 2021	2020	2021	2020	2021	Mean
2.5	100,000	18,78,000	14,02,000	20,000	1,18,000	1,54,000	590	770	680
2.0	80,000	17,60,000	12,48,000	20,000	1,60,000	1,02,000	800	510	655
1.5	60,000	16,00,000	1,146,000	20,000	3,02,000	74,000	1510	370	940
1.0	40,000	12,98,000	10,72,000	20,000	2,52,000	1,94,000	1260	970	1115
0.5	20,000	10,46,000	8,78000	20,000	2,68,000	1,56,000	1340	780	1060
Control (no lime)	0.000	77,8000	7,22,000	-	-	-		-	-

Marginal rate of return (MRR)

The highest marginal rate of return for changing from 1.0 t ha^{-1} lime to 1.5 t t ha^{-1} lime was 1510% in 2020 and from 0.5 t ha^{-1} lime to 1.0 t ha^{-1} lime was 970% (Table 6). In this way, in 2020, the other higher marginal rate of returns found from 0.5 t ha^{-1} lime to 1.0 t ha^{-1} lime treatment, and 1.0 t ha^{-1} lime to 1.50 t ha^{-1} treatment was 1340 and 1260%, respectively. In 2021, the other higher marginal rate of returns observed from 0.5 t ha^{-1} lime to 1.0 t ha^{-1} lime treatment and 0.0 t ha^{-1} lime to 1.0 t ha^{-1} lime were 970% and 780%, respectively. In average MRR over two years, the maximum MRR recorded from changing 0.5 t ha^{-1} to 1.0 t ha^{-1} lime was 1115% which revealed that for every Tk 100 of additional investment, Tk 1115 was returned; this also means, if a farmer invests Tk 40,000, he could recover Tk 40,000, plus an additional amount of Tk 223,000. Application of 1.0 t ha^{-1} or 1.5 t ha^{-1} lime appeared as the best treatments for cultivation of Naga chili from economic point of view when considering MRR.

Conclusion

Based on the above results, it revealed that liming with dolomite significantly improved Naga chili growth and yield in acidic soils. Application of lime @ 2.5 t ha^{-1} consistently produced the best results across all measured growth, yield attributes and yield. While the control treatment consistently exhibited the lowest performance, even intermediate lime doses (0.5–1.5 t ha^{-1}) led to considerable improvements. However, the superior and consistent performance of 2.5 t ha^{-1} dose of lime over two years indicates that higher application of lime may be necessary to fully neutralize soil acidity and maximize Naga chili yield potential. Application of 1.0 t ha^{-1} or 1.5 t ha^{-1} lime was found the best treatments for cultivation of Naga chili from economic point of view when considering MRR. These results suggest that lime is a critical input for sustainable Naga chili production in acidic regions, offering both significant agronomic benefits and high economic returns. Future studies should be investigated regarding the impact of liming on the physicochemical properties of the soil and chili quality parameters, including the Scoville Heat Unit (SHU). This can provide a more integrated understanding of how liming affects chili production in acidic soil environments.

References

Barros, N. F., R. F. Novais and V. H. Alvarez. 2020. Soil acidity and liming: Theory and practice for tropical conditions. *Rev. Bras. Ciênc. Solo.* **44**: e0200024.

Bhuyan, M.H.M.B., M. Hasanuzzaman, K. Nahar, J.A. Mahmud, K. Parvin, T.F. Bhuiyan and M. Fujita. 2019. Plants behavior under soil acidity stress: Insight into morphophysiological, biochemical, and molecular responses. *In: Plant abiotic stress tolerance* (Ed. Hasanuzzaman, M., Hakeem, K., Nahar, K., Alharby, H.). Springer, Cham. pp.35-82.

Bhuyan, MHMB., SML. Rahman, R. Ara and JC. Sarker. 2015. Evaluation of Naga Chilli (*Capsicum chinense* Jacq.) genotypes under North eastern region of Bangladesh. *Sci. Agric.* **12**:40-45.

Chaki, M., J.C. Begara-Morales and J.B. Barroso. 2020. Oxidative stress in plants. *Antioxidants.* **9**: 481.

Chuong, N. V. 2019. Effect of lime, organic and inorganic fertilizers on soil chemical properties and yield of chilli (*Capsicum frutescens* L.). *AGU Int. J. Sci.* **7:**84 –90.

Elias, S. and M. Karim. 1984. Application of partial budget technique on cropping system research at Chittagong. AEER No 10 April. Report of Agri-cultural Economics Division, BARI, Joydebpur, Gazipur. pp. 75–71.

FAO. 2005. Fertilizer Use by Crop. Food and Agriculture Organization of the United Nations.

Gopalakrishnan, S., V. Srinivas, G. Alekhya and J. Prakash. 2015. Influence of liming on soil acidity and nutrient uptake in chili (*Capsicum annuum* L.). *Int. J. Plant Soil Sci.* **7:**102–110.

Hao, X., Zhu, Y.G., Nybroe, O. and Nicolaisen, M.H., 2020. The composition and phosphorus cycling potential of bacterial communities associated with hyphae of Penicillium in soil are strongly affected by soil origin. *Front. microbial.* **10**, p.2951.

Harter, R. D. 2007. Acid Soils: Causes, Management and Effects. *In: Encyclopedia of Soil Science*-2nd ed. (Ed. Lal, R.). CRC Press, Boca Raton, Florida, USA.

Islam, M., T.I. Imon and A.G. Polash. 2019. Analysis of rainfall variability in Sylhet region of Bangladesh. *J. Water Resour. Eng. Manage*. **6:**1-10.

Kätterer, T., D. Roobroeck, O. Andrén, G. Kimutai, E. Karltun, H. Kirchmann, G. Nyberg, B. Vanlauwe and K.R. de Nowina. 2019. Biochar addition persistently increased soil fertility and yields in maize-soybean rotations over 10 years in sub-humid regions of Kenya. *Field Crops Res*. **235**:18-26.

Kumar, R., A. Malik, and S. Kumar. 2022. Chilli (Capsicum chinense Jacq.) production and post-harvest management: An overview. *Pharma Inno. J.* **11:**752-756.

Lal, R. 2015. Restoring soil quality to mitigate soil degradation. *Sustainability*.**7:**5875-5895.

Mahmud, M.S. and K.P Chong. 2022. Effects of liming on soil properties and its roles in increasing the productivity and profitability of the oil palm industry in Malaysia. *Agriculture*. **12:**322.

Marschner, H. 2012. Marschner's mineral nutrition of higher plants. Academic press.

Mengel, K., and E. A. Kirkby. 2001. Principles of Plant Nutrition (5th ed.). Springer.

Mishra, A.C., V.K. Pandey and V.P. Rai. 2014. Effectiveness of fertilizer doses, liming and Rhizobium inoculation in vegetable pea under acidic soil of Jharkhand. *Asian J. Hort.* **9**: 140-142.

Roy, B., M.A. Satter and P.K. Saha. 2014. Liming to improve productivity of crops in acidic soils of Bangladesh. *Bangladesh J. Agric. Res.* **39:** 683–695.

Sarker, J.C., M.H.M.B. Bhuyan, S.M.L. Rahman, K. Chandra and M.M. Haque. 2018. Effect of NPKS on Growth and Yield of Naga Chili (*Capsicum chinense* Jacq.). *J. Hort. Sci. Forest.* **1**:1–7

Shaheb, M.R., M.I. Nazrul and M.A. Rahman. 2014. Production potential and economics of wheat as influenced by liming in north eastern region of Bangladesh. *Asian J. Agric. Biol*. **2**:152-160.

Singh, B., M.M. Dolk, Q. Shen and M. Camps-Arbestain. 2017. Biochar pH, electrical conductivity and liming potential. *In: Biochar: A guide to analytical methods* (Ed. Singh, B. Camps-Arbestain, M. and Lehmann, J.) Csiro Publishing. p.23.

Singh, R., P. Sharma and A. Verma. 2019. Effect of liming and nutrient management on growth and yield of chili under acidic soil conditions. *J. Pharma. Phytochem.* **8:**1776–1780.

SRDI (Soil Resource Development Institute). 2020. Land and Soil Resource Utilization Guide: Sylhet District. Ministry of Agriculture, Government of the People's Republic of Bangladesh.

Taufiq, A., A. Wijanarko and Suyamto. 2011. Effect of NPKS fertilizer, dolomite and manure on soybean yield in tidal land (in Indonesian). *J. Penelitian. Pertanian*. **30:** 52-57.

Zahid, A.M., N.A. Kohinoor, M.A. Hossain and J.U. Shoaib. 2020. Land degradation in Bangladesh: baseline study of land degradation processes 1985–2000. FAO supported Research Report, SRDI, Dhaka.

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MOLECULAR IDENTIFICATION OF *MELOIDOGYNE INCOGNITA* INFECTING *BASELLA ALBA* IN BANGLADESH

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M. M. RAHMAN[4] AND M. I. FARUK[5]

Abstract

Indian spinach (*Basella alba*) plants were found to be infected with root-knot nematode in a pot experiment of Plant Pathology division, Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh. The molecular diagnosis of root-knot nematodes of Indian spinach at species level was done. Utilizing DNA sequencing of the rDNA 28S D2/D3 gene and PCR with SCAR primers *Meloidogyne incognita* was detected from infected Indian spinach.

Keywords: Indian spinach, *Meloidogyne incognita*, SCAR primer, PCR amplification, Bangladesh.

Indian spinach (*Basella alba* L.) is a popular green leafy vegetable grows well throughout Bangladesh. This vegetable is very popular and rich in vitamin A, vitamin C, calcium and iron. During the year 2022-23, about 1,07955 metric tons of Indian spinach produced in 28,364 acres of land in Bangladesh (BBS, 2023). The yield of Indian spinach is reduced due to infestation of various diseases such as leaf spot, foot rot, anthracnose, stem rot and root knot (Talukder, 1974). In Bangladesh, four species of root-knot nematode (RKN) association is common in many crops. They are *Meloidogyne incognita, M. javanica, M. graminicola* and *M. arenaria*. Among them, *Meloidogyne incognita* is the most abundant (Mian, 1986). According to Castillo and Jiménez-Díaz (2003), *M. incognita* and *M. javanica* are the most common and damaging nematode species infecting Indian spinach. In Bangladesh, previously root-knot nematodes species have been identified from brinjal and tomato based on molecular techniques (Das *et al.*, 2021; Elahi *et al.,* 2024). However, the molecular identification of *Meloidogyne* spp. of Indian spinach in Bangladesh has not been done so far. Hence, the present study was carried out to identify root-knot nematode species of Indian spinach based on molecular techniques.

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Fig. 1. A. Root-knot nematode infected Indian spinach plot B. Severely infected Indian spinach root C. Perineal pattern of *M. incognita* obtained from Indian spinach roots.

Seeds of Indian spice (var. BARI Puishak-1) were sown in the pot house of Plant Pathology division (PPD), Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh (23° 59′ 20.4504" N, 90° 25′ 5.4012" E) in November 2022. At 45 DAS, it was noticed that the Indian spinach plants with the symptoms of pale yellow leaves, declined plants with big root galls. These symptoms are typical symptoms of root-knot nematode infestation (Fig. 1). The collected samples were brought to the laboratory of PPD and stored at 4 °C for further use. For perineal patterns preparation, female nematodes were dissected under compound microscope following the protocol of (Sasser *et al.*, 1983). A dissecting needle was used to remove the posterior part of female nematode and the cuticle was trimmed in a square pattern in the center. The body was transferred in a glycerol solution. This process was done for up to ten patterns for the same *Meloidogyne incognita* species. Finally, the slide was covered with cover slip and sealed with nail polish. The perineal region generally had an angularly oval structure with a high dorsal arch. Inverted-V shape was formed by striae in the dorsal to the tail. Striae were in distinct waves which bent towards the lateral lines. Striae were straighter with an oval appearance in ventral region (Jepson, 1987). Nematode galls were collected from the infected m. spinach plants roots and second stage juveniles were collected from the rhizosphere soil through Baermann funnel method as source of DNA. Genomic DNA was extracted using Wizard DNA purification kit (Promega Corporation, Madison, WI, USA) following the standard protocol from eggs of the galls and second stage of juveniles (approx. 150), which were counted under stereo-microscope. The DNA quality was measured using spectrophotometer at the absorbance ratio A260/280. The quantity was 1.89 which is considered as pure DNA. For molecular identification, SCAR primer pair;

Inc-K14- F/Inc-K14-R (CCCGCTACACCCTCAACTTC/ GGGATGTGTAAATGCTCCTG) and a universal primer pair; RK28SF/R (CGGATAGAGTCGGCGTATC/GATGGTTC GATTAGTCTTTCGCC) was used as universal primer pair for the targeted gene 28S D2/D3 (Ye *et al*., 2015). PCR were performed in a thermal cycler (Bio-Rad PTC-200, California, USA) in a total volume of 25 µL for both type of PCR. Per PCR reaction containing 12.5 µL GoTaq Green master mix (Promega Corporation, Madison, WI), 9.5 µL nuclease-free water, 1 µL of each primer (10 µM), and 1 µL template DNA. The PCR condition for universal primer (genus specific) RK28SF/R was: one cycle of denaturation at 94 °C for 4 min, followed by 35 cycles at 94°C for 30 s, 53 °C for 30 s, 72 °C for 45 s, and a final extension at 72 °C for 8 min. Moreover, the PCR condition for *M. inocgnita* specific primers (SCAR) was: one cycle of denaturation at 95 °C for 5 min, followed by 40 cycles at 94°C for 30 s, 55 °C for 45 s, 72 °C for 1 min, and a final extension at 72 °C for 10 min. The genus-specific marker RK28SF/R identified *Meloidogyne* genus, which produced the amplicon size of 612 bp. The amplified PCR product was sequenced (National Institute of Biotechnology, Bangladesh) and submitted to GenBank under accession no. OQ207705. Blast analysis of the obtained sequence of the isolate found 97% nucleotide homology with *M. incognita* isolates MK102788, MK102791, and MK102789 that were previously identified in USA and submitted in GenBank database (National Center for Biotechnology Information [NCBI]) under the US National Institute of Health, Bethesda, MD, USA.

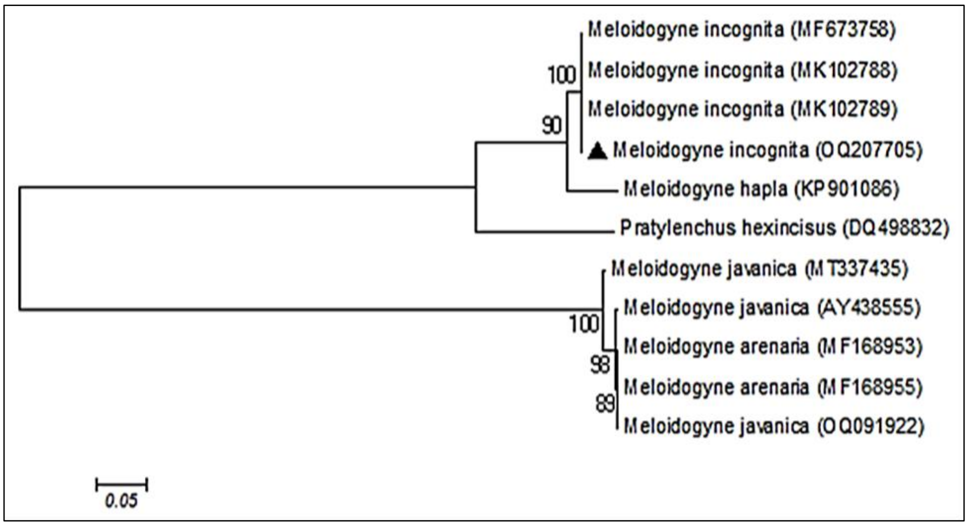

Fig. 2. Phylogenetic relationship of *M. incognita* along with other *Meloidogyne* spp. concluded by Tamura-Nei model of the 28S gene sequences using MEGA 6.0 software. The isolate used in this study was highlighted in tri-angle and *Pratylenchus hexincisus* (DQ498832) was used as out group. Values at the nodes indicate bootstrap support values based on 100 replicates. GenBank accession numbers are indicated in parentheses.

Phylogenetic analysis of the 28S gene sequence data was done by means of Maximum Composite Likelihood (MCL) method using MEGA 6.0 software. The sequence distance was calculated by Tamura-Nei parameter model. The sequence alignments of the rDNA regions were performed utilizing ClustalW program. Bootstrap values were obtained 1000 replicates to determine the support from each group. In the Phylogenetic tree, the isolate of Bangladesh (OQ207705) was placed in distinct *M. incognita* group with 100% bootstrap support while other species of *Meloidogyne* clustered in different group (Fig. 2). Moreover, SCAR primer pair produced a specific fragment of 399 bp for *M. incognita* (Fig. 3). According to Tesarova *et al*. (2003), utilization of DNA sequencing and species-specific methods are better options for *Meloidogyne* spp. diagnosis compared to conserved ITS regions or morphological identification. In addition, for the identification of tropical root-knot nematode, species-specific PCR recommended because of the genes of tropical root-knot nematodes are too conserved to identify only with DNA sequencing method and BLAST search (Danso *et al*., 2023).

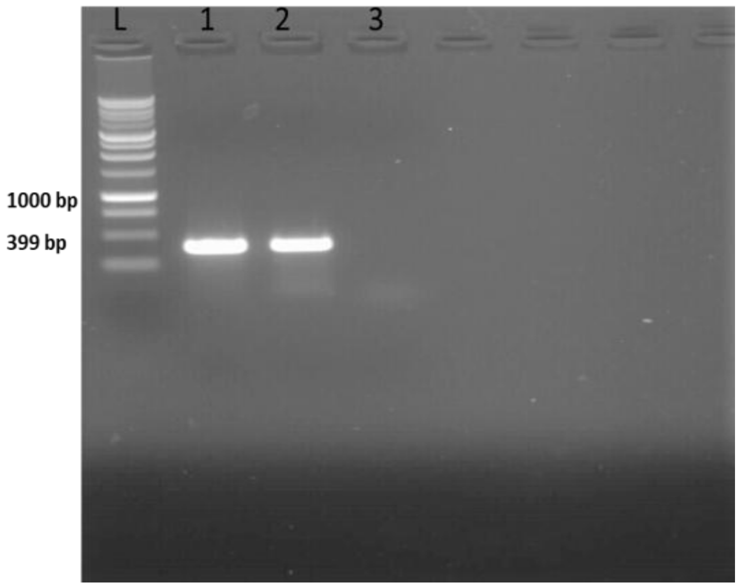

Fig. 3. Amplified product (399 bp) with *Meloidogyne incognita* species–specific primer pair Inc-K14-F/Inc-K14-R. L denotes 1 kb-DNA ladder; Lane 1 was positive control (GenBank acc.-OR351387); Lane 2 was Indian spinach isolate (OQ207705) and Lane 3 was nuclease-free water (negative control).

In Bangladesh, for the first time, *M. incognita* the root-knot nematode, infecting Indian spinach was identified by molecular markers. The results showed that *M. incognita* was present in Indian spinach in the Gazipur district of Bangladesh.

References

BBS (Bangladesh Bureau of Statistics), (2023). Year Book of Agricultural Statistics of Bangladesh. Bangladesh Bureau of Statistics, Ministry of Planning, GOB. Dhaka, Bangladesh, p: 278.

Castillo, P. and R. M. Jiménez-Díaz. 2003. First report of *Meloidogyne incognita* infecting spinach in Southern Spain. *Phytopatholgy.* DOI: https :// doi. org/ 10.1094 /PDIS. 2003.87. 7.756.

Danso, Yaw., B. A. Danso., B. Armooh and B. Abugri. 2023. Molecular detection of root-knot nematodes (Nematoda: Meloidogynidae) infecting okra in Ghana. *J. Agri. Food Sci. Biotech.* **1**(3): 219-223.

Das, S., M. A. Wadud and M. A. R. Khokon. 2021. Genetic variation of *Meloidogyne* spp. of brinjal reveals their difference in pathogenicity and hatching. *Arch. Phytopathol. Plant Protect.* **54**:19-20, 2375-2396. DOI: 10.1080/03235408.2021.1983383.

Elahi, F., M. M. Islam., M. I. Faruk and M. M. Rahman. 2024. Molecular identification of root-knot nematodes (*Meloidogyne* spp.) of tomato at Gazipur in Bangladesh. *Bangladesh J. Agri*. **49**(1): 136-140. DOI: https://doi.org/10.3329/bjagri.v49i1.74044.

Jepson, S. B. 1987. Identification of root-knot Nematodes *Meloidogyne* species. CABI Wallingford, UK. p. 265.

Mian, I. H. 1986. Plant parasitic nematodes associated with some crop species in Bangladesh. *Bangladesh J. Plant Pathol.* 2(1):7–13.

Sasser, J. N., J. D. Eisenback, C. C. Carter and A. C. Triantaphyllou. 1983. The international *Meloidogyne* project- its goal and accomplishments. *Annual Review of Phytopathology* **21**(1): 271-288.

Talukder, M. J. 1974. Plant diseases of Bangladesh. *Bangladesh J. Agril. Res.* **1**: 61-86.

Tesarova, B., M. Zouha and P. Rysanek. 2003. Development of PCR for specific determination of root-knot nematode *Meloidogyne incognita*. Plant Protec. Sci. **39**(1): 23-28. DOI: https://doi.org/10.1094/PDIS09-18-1539-RE.

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EFFECT OF DIFFERENT ORGANIC FERTILIZERS AND BIO-FERTILIZERS ON GROWTH, YIELD, QUALITY AND PROFITABILITY OF ORGANIC POTATO PRODUCTION

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Abstract

The field experiment was conducted to find out the effect of organic manure and bio-fertilizers on growth, yield, quality and profitability of organic potato production. The experiment was conducted at the organic block under Tuber Crops Research Centre (TCRC), Joydebpur during rabi season of two consecutive years 2022-23 and 2023-24. The experiment was laid out in a randomized complete block (RCB) design with 3 replications. The treatments comprised of two bio-fertilizers viz. Azotobacter and Phosphate solublizing bacteria (PSB) each one @8 ml per kg seed potato in liquid form and three organic manures with different dosages namely 10 ton/ha and 8 ton/ha were chosen as the treatment. The treatment combinations were T_1: Control, T_2: Vermicompost 10 t/ha, T_3: Trico-compost 10 t/ha, T_4: ACI Organic Fertilizer 10 t/ha, T_5: Bio-manure (Azotobacter + PSB), T_6: Vermicompost 8 t/ha + (Azotobacter + PSB), T_7: Trico-compost 8 t/ha + (Azotobacter + PSB, T_8: ACI Organic Fertilizer 8 t/ha + (Azotobacter + PSB). Potato variety BARI Alu-25 was used as test crop. The growth parameters, yield attributes, yield and quality parameters were significantly influenced by the integrated use of organic manure and biofertilizer. The maximum (23.8 t/ha) tuber yield was found in T_6 (VC 8 t/ha + Azotobacter 8ml/kg seed + PSB 8ml/kg seed). Moreover, the highest gross return (Tk 1189500/ha) and net return (Tk. 634500/ha) and Benefit Cost Ratio (BCR: 2.14) was also recorded in the same treatment.

Keywords: Organic potato, Organic Fertilizers, Bio-fertilizers, Growth, Yield and Quality

Introduction

The potato (Solanum tuberosum L.) is ranked as the 4th most important harvested food crop after wheat, corn and rice and is considered as the world's most vital non-cereal food crop (De Haan, 2016). Considering its yield potential and nutritional value it may contribute to ensure food and nutritional security. Potato (Solanum tuberosum L.) is a member of solanaceae family and considered as one

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of the most valuable and widely distributed crops that is used for human food in most part of the world. Potato is being a high yielding, nutrient exhaustive and short duration crop needs higher quantities of fertilizers and pesticides as compare to other crops. Bangladesh ranks in the 7^{th} position in potato production among the potato producing countries around the world, and the potato is considered the 2^{nd} most important food crop in the country (FAO-STAT, 2020). It has been reported by Naik and Khurana (2003) that indiscriminate use of chemical fertilizers has affected the soil quality adversely in terms of decreasing organic carbon contents and development of micronutrients deficiencies and ultimately culminating into deterioration of produce quality. Due to consumer concern for excessive use of chemical fertilizers to avoid deleterious effects on the environment, there is increasing interest in the use of organic fertilizers. Hafez *et al*. (2004) reported that organic fertilizers, such as compost, provide a slow release of nutrients as micro-organisms in soil. Bio fertilizers from microorganisms can replace chemical fertilizers to increase crop production. In principle, bio fertilizers are less expensive and are more environmental-friendly than the chemical fertilizers. The benefits from using bio fertilizers, beside their role in saving chemical fertilizers is well known reported by Yazdani *et al.* (2009). This necessitates the immediate attention of researchers to evolve nutrient management strategies solving the problems of crop quality as well as soil conditions in holistic manner. Furthermore; bio fertilizers play a significant role in either synthesizing plant usable form of nutrients or increase the availability of nutrients already present in the soil. They have been shown to improve growth and subsequent yield; colonize the rhizosphere and the interior of the plant, promoting plant growth when applied to the seed, plant surface or the soil reported by Waithaka *et al*. (2019). They not only improve soil fertility and crop productivity by adding nutrients to the soil but also protect the plant from pests and diseases. They have been shown to enhance the growth of the root system, extend its life, degrade harmful microorganisms, increase the survival of seedlings, and reduce the time to flowering (Nosheen *et al.,* 2021). Application of P-solublizing bacteria would help in increasing the efficiency of available P in the soil by converting unavailable P into available form. Similarly, N fixing biofertilizers like Azotobactor take the potential to meet a successful availability of N requirement of potato (Giller and Cadisch, 1995). Biofertilizers are easy to apply, low-cost in nature and eco-friendly. Application of different bio-fertilizers alone or in combination with others as seed, soil and foliar spray revealed that the bio-fertilizers have stimulatory effect on germination, sprouting behavior and growth parameter of potato (Morajdhwaj, 2017). So, farmers need a combined application of bio fertilizers and organic fertilizers in potato production. Studies on the effect of organic manure and bio-fertilizers on potato production in Bangladesh are varied, but they generally indicate that combining organic and bio-fertilizers can improve potato yield and quality by enhancing soil fertility, nutrient availability, and overall plant health. Therefore, the present investigation was initiated to determine the response of potatoes to different combinations of organic manure and bio fertilizers.

Materials and methods

Experimental site and soil characteristics: The experiment was conducted at 'Organic Block' at the tuber Crops Research Centre, Bangladesh Agricultural Research Institute, Gazipur during *rabi season* of two consecutive years 2022-23 and 2023-24. The experimental site was located in the centre of the Madhupur Tract (AEZ-28) at about $24^0 23'$ north latitude and $90^0 08'$ east longitude having a mean elevation of 8.4 m above mean sea level. Organic practices have been being followed in this block since 2015. After harvesting the crops in each year, the land was allowed to grow green manure like *Sesbania* sp. and they were fully decomposed before the commencing of the next season. The experimental plot was a high land having sandy clay loam soil. The soil as well as soil organic amendments were analysed in Soil Science Division, BARI and presented in Table 1 and Table 2, respectively.

Table 1. Initial properties of soil of the experimental plot

Soil Properties	pH	OM (%)	Total-N (%)	K	Ca	Mg	P	S	Zn	B	Pb	Cd	Cr	Ni
				(meq/100 g)			µg/ml							
Value	6.6	1.29	0.068	0.056	5.9	1.7	24.6	21.0	0.76	0.23	2.4	0.10	94.0	34.0
Critical value	-	-	-	0.12	2.0	0.5	7.0	10	0.6	0.2	100	3	100	50

Table 2. Result of the chemical analysis of different types of organic soil amendment

Type of compost	Nutrient content						Heavy metal (ppm)			
	Nitrogen (%)	Phosphorus (%)	Potassium (%)	Sulfur (%)	Calcium (%)	Zinc (ppm)	Pd	Cd	Cr	Ni
Trichocompost	1.39	0.61	0.76	0.11	2.18	0.019	0.78	0.76	31.2	5.98
Vermicompost	2.18	0.83	1.13	0.26	3.45	0.020	0.72	0.87	34.5	6.45
ACI Organic Fertilizer	2.91	0.71	1.15	0.28	3.81	0.013	5.35	0.56	19.2	4.01
Critical Value							100	3	100	50

Experimental materials and design

Two bio-fertilizers viz. Azotobacter and Phosphate Solubilizing bacteria (PSB) at the rate of 8 ml per kg seed potato in liquid form and three organic fertilizers at the rate of 10 ton/ha and 8 ton/ha were chosen as the treatment. The number of treatment was eight viz. T_1 : Control, T_2 : Vermicompost 10 t/ha, T_3 : Trico-compost 10 t/ha, T_4 : ACI Organic Fertilizer 10 t/ha, T_5 : Bio-fertilizer (Azotobacter

+ PSB), T_6 : Vermicompost 8 t/ha + (Azotobacter + PSB), T_7 : Trico-compost 8 t/ha + (Azotobacter + PSB), T_8 : ACI Organic Fertilizer 8 t/ha + (Azotobacter + PSB). BARI Alu-25 (Asterix) was used as a test material. The experiment was laid out in a randomized complete block design (RCBD) with three replications. The unit plot size was 3.0 m x 3.0 m. Whole tuber of the potato variety 'Asterix' were were planted with a spacing of 60 cm x 25 cm.

Tuber seed treatment

The jars of Azotobacter and Phosphate solubilizing inoculum each of 500 ml collected from Soil Science Division, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur. Seed tubers were treated with two bio-fertilizers namely Azotobacter and Phosphate Solubilizing bacteria (PSB) each was used @ 8 ml per kg seed potato in liquid form. The seed tubers were treated by dipping the tuber in prepared solution separately. Then the tubers were kept in shade for dry. The treatments were given for 2 hours before the sowing of tuber.

Experimental Procedures and Management

Two bio-fertilizer namely Azotobacter and Phosphate solubilizing bacteria-(PSB) 400ml was taken into a large container and mixed with 40 liters water. Then 50 kg seed tuber of BARI Alu-25 (Asterix) was soaked into the bio-fertilizer solution for half an hour. Soaked potato tuber kept spreading on jute sack in shady place so that surface water might dried. The whole tuber were planted set on 1st December 2022 and 25th November, 2023, respectively. At maturity, potato was harvested on 5th March 2023 and 28th February 2024, respectively. Neem oil cake (NOC) @ 5t/ha was applied in equal 3 installments in each plot. The first one is in pit and the other two installments was applied at the side of the row and covered with soil at the time of first and 2nd time of earthing up followed by irrigation. Pest management was done following organic practices and standards. For pest management, Mahogany and karam cha oil @ 2ml/L, each one was applied following the cyclic order at one-week interval at 35 days after planting to second last week of harvesting. In addition, barrier crops (sunflower, wheat and soybean) were planted surrounding the field to reduce the pest and disease infection, mainly virus diseases. The plots were kept weed-free and earthing up done twice. The crops were irrigated three times, at 7, 30and 60 days after planting (DAP). The first irrigation was given at 7 DAP to ensure appropriate tuber emergence; the second and third irrigations were applied at 30 and 60 DAP, respectively. By spading in between the ridges and covering the ridges with loose soil, two hand weeding was done before the second (at 30 DAP) and last (at 60 DAP) irrigations. The haulm was removed 10 days before harvesting to harden the skin of the potato tubers, and they were left for ten days in the field.

Data collection

Data were taken on days to start of emergence, emergence (%) at 30 DAP, plant height at 45 & 60 DAP, number of stem per hill at 45 & 60 DAP, foliage coverage (%) at 45 & 60 DAP, plant vigor (1-10) Scale at 45 and 60 DAP, tuber Grade (% by number & weight), tuber fresh yield (t/ha) at 95 DAP, dry matter percentage, total soluble solids (TSS%), starch content (mg g^{-1} FW) and Cost Benefit Ratio.

Parameters estimation

Determination of Dry Matter Content

Three tubers from the harvested potatoes of each treatment were randomly selected for tuber dry matter estimation. After that, the samples were chopped and weighted to 100 g samples, then were made sundry. After sun drying; the samples are kept in oven (Memmert GmbH, UN-260, Schwabach, Germany) for 72 h at 70° C. The dry matter was computed as a percentage based on the ratio of dry to fresh mass (Mostofa, 2019).

Determination of Total Soluble Solids (TSS)

TSS of harvested fresh tubers was measured in a drop of potato juice by using Hand Sugar Refractometer "ERMA" Japan, Range: 0-32% according to (AOAC 1990) and recorded as percentage (%) Brix from an immediate reading of the instrument.

Extraction of Sugar

For the analysis of sugar contents like reducing sugar (glucose) and non-reducing sugar (sucrose), potato flesh was extracted from each treatment. Sugars were extracted using 5 ml of 80% ethanol heated at 80°C for 30 min in a dry block heat bath and the extracts were centrifuged at 5000 rpm for 10 min and decanted the supernatant and it was repeated 4 and 5 times in total. All the supernatants were mixed properly and the final volume was made 25 ml using 80% ethanol. For starch analysis the residue was used 100 ˚C. Then 1 ml Amyloglucosidase solution was added and mixed properly and heated at 50-60˚C

Measurement of Starch content (mg/g FW) in potato tubers

After extraction of sugar, the remained residue was washed for several times with water to ensure that there was no more soluble sugar in the residues. After that using tap water marked up to 250 ml in a beaker and stirred properly by using a magnetic stirrer. During the stirring, 0.5 ml solution was taken from the beaker and boiled for 10 min at for 2 hrs. in hot water. After cooling, a 0.5 ml copper solution was added and mixed properly, heated at 100^0C for 10 min. Then cooled in tap water, added 0.5 ml nelson solution, mixed properly and added

7 ml distilled water (final volume was 9.5 ml) and measured the absorbance at 660 nm. The starch content was calculated using the glucose standard curve and expressed as mg/g FW.

Statistical analysis

Analysis of variance for yield parameters and yield were done following the ANOVA test and the mean values were compared by LSD (p <_0.05). Statistix 10 software was used to analyse the data.

Results and Discussion

Growth characteristics

The growth characteristics namely days to start of emergence, emergence percentage, plant height and number of stem per hill were significantly variable among the treatments (Table 3). The days to start of emergence was earlier in T_8 (11.7 days) where ACI organic manure+Azotobacter+PSB was applied which was followed by T_5 and T_6 whereas the latest germination (13.8) occurred in T_1. The highest emergence percentage (95.5%) at 30 DAP was found in T_6 which was followed by T_8 and T_2 whereas the lowest value (76.5%) was noted in the control (Table 3). The highest plant height (51.6 cm) was found in T_6 which was statistically at par with T_8, T_2 and T_7 whereas the lowest (33.4 cm) was recorded in T_1 (control). Similar trend was found in 60 DAP.

Table 3. Effect of different organic manures and bio-fertilizers on days to start of emergence, emergence percentage, plant height, number of stem/hill (pooled of two years)

Treatments	Days to start of emergence	Emergence Percentage at 30 DAP	Plant height at 45 DAP	Plant height at 60 DAP	Number of stem/hill at 45DAP
T_1	13.8a	76.5d	33.4c	39.88d	3.38b
T_2	12.6b	90.1abc	50.0ab	55.05bc	3.88b
T_3	12.6b	86.2c	43.7b	49.15c	3.58b
T_4	12.5bc	87.1c	45.2b	52.70bc	4.58a
T_5	11.8bc	85.9c	45.2b	50.17c	3.83b
T_6	11.8bc	95.5a	51.6a	56.29ab	4.48a
T_7	12.0bc	89.2bc	48.2ab	58.72a	3.78b
T_8	11.7c	93.6 ?ab	50.8a	59.41a	3.73b
Level of significance	**	**	**	**	**
CV (%)	5.99	5.35	10.10	9.01	11.56

Means bearing same letter (s) do not differ significantly at 1 or 5% level of probability by DMRT.

*= Significant at 5% level of probability, **= Significant at 1% level of probability

T_1= (Control), T_2 = (Vermicompost 10 t/ha), T_3 = (Trico-compost 10 t/ha), T_4 = (ACI Organic Fertilizer 10 t/ha), T_5 = (Bio-fertilizer (Azotobacter + PSB), T_6 = (Vermicompost 8 t/ha + Azotobacter + PSB), T_7 = (Trico-compost 8 t/ha + Azotobacter + PSB) and T_8 = (ACI Organic Fertilizer 8 t/ha+ Azotobacter + PSB).

Stem per hill, foliage coverage and plant vigor were significantly varied among the treatments (Table 4). The highest (5.58cm) number of stem/hill was recorded in T_4 which was significantly higher than the other treatments. The lowest number of stem per hill (3.77) was found in the control. In case of foliage coverage (%) at 45 DAP, T_6 (Vermicompost 8 t/ha + (Azotobacter + PSB) showed the highest foliage coverage (89.0%) followed by T_8 (Table 4). The lowest foliage coverage (57.0%) was found in the control. The similar trend was followed in 60 DAP. In case of plant vigority, at 45 DAP; the maximum vigorous plant (8.88) was found in T_6 (Vermicompost 8 t/ha + (Azotobacter + PSB) while the minimum value (5.78) was noted in the control. The similar trend was followed in 60 DAP. It was observed that (Vermicompost 8 t/ha + Azotobacter + PSB) was found to be superior to other dose of organic manures and bio fertilizers and had significant effect on growth characteristics of potato which was followed by T_8 and T_7. This might be due to presence of enzymes, hormones, growth regulators along with plant nutrients in vermicompost while Azotobacter and PSB are bio fertilizers which improves the nutrient up take and provide better condition for plant growth. Azotobacter and PSB are improves the availability of nitrogen and phosphorus by nitrogen fixation and phosphorus solubilization. Similar, results were also reported by Ali *et al*. (2020), Saxena and Singh (2020) and Gangele *et al*. (2020).

Table 4. Effect of different organic manures and bio-fertilizers on number of stem/hill, foliage coverage (%) and plant vigor (pooled of two years)

Treatments	Number of stem/hill at 60DAP	Foliage coverage (%) at 45 DAP	Foliage coverage (%) at 60 DAP	Plant vigor at 45 DAP (1-10 scale)	Plant vigor at 60 DAP (1-10 scale)
T_1	3.77e	57.0d	67.3f	5.78d	6.57d
T_2	4.37cd	79.6bc	85.0de	8.43ab	8.58b
T_3	4.05de	79.7bc	87.18cd	8.11b	8.68b
T_4	5.58a	80.15bc	89.1bc	8.28ab	8.60b
T_5	4.32cd	75.5c	82.8e	7.48c	7.94c
T_6	4.93b	89.0a	93.4a	8.88a	9.38a
T_7	5.00b	82.3b	88.0bcd	7.87bc	8.54b
T_8	4.75bc	84.40ab	91.2ab	8.82a	9.05ab
Level of significance	**	**	**	**	**
CV (%)	8.47	5.80	3.99	6.76	5.51

Means bearing same letter (s) do not differ significantly at 1 or 5% level of probability by DMRT.

*= Significant at 5% level of probability, **= Significant at 1% level of probability

T_1= (Control), T_2 = (Vermicompost 10 t/ha), T_3 = (Trico-compost 10 t/ha), T_4 = (ACI Organic Fertilizer 10 t/ha), T_5 = (Bio-fertilizer (Azotobacter + PSB), T_6 = (Vermicompost 8 t/ha + Azotobacter + PSB), T_7 = (Trico-compost 8 t/ha + Azotobacter + PSB) and T_8 = (ACI Organic Fertilizer 8 t/ha+ Azotobacter + PSB).

Yield parameters

At 95 DAP, the number of tubers per plant, tuber weight (g) per hill and fresh tuber yield (t/ha) were varied significantly due to treatments effects as depicted in (Table 6). The maximum (9.03) number of tubers per hill at harvest was observed in T6 which was statistically similar to T8 and T7 while the minimum (6.41) number of tubers perplant at harvest was found in the control (Table 6). The maximum (424.4 g) tuber weight per hill at harvest was found in T6 (ACI Organic Fertilizer 8 t/ha + (Azotobacter + PSB) followed by T8 and T7. The minimum (205.8 g) tuber weight per hill was found in the control. The maximum (23.8 t/ha) tuber yield was found in T6 (Vermicompost 8 t/ha + (Azotobacter + PSB) which was identical to T7 and T8 but different from the rest of the treatments. The minimum tuber yield (11.44 t/ha) was recorded in the control (Table 4). The increase in the tuber numbers per plant could be attributed to the increased vegetative growth observed due to the balanced nutrient levels, which stimulated the initiation of more stolon, thus increasing the number of tubers per hill. The increased production is attributed to better photosynthetic activity and the accumulation of carbohydrates which helps in better growth of the crop. It is also known that phosphatic fertilizers affect potato tuber yield by influencing the number of tubers produced and the size of tubers. The result was corroborated with the findings of Kumar *et al.* (2013) who reported that applying sole bio fertilizers as seed treatment without inorganic fertilizers, and farmyard manure showed inferior performance productivity. Therefore, bio fertilizers need an organic fertilizer for enhanced early establishment, which is necessary to affect the tuber yield positively. Bio fertilizers required organic manuring for its early establishment necessary for exerting a beneficial effect on crop productivity reported by Kumar *et al* (2013). The application of organic fertilizers, Azotobacter and PSB might have enhanced the availability of native macro and micro nutrients, vitamins, enzymes, antibiotics, growth hormones and insoluble nutrients to the plants, as consequence of which increase the yield of potato tubers and plant. The increase in yield with the application of organic manures, Azotobacter and PSB could be attributed to corresponding increase in insoluble nutrients to soluble form, which was responsible for synthesizing photosynthate and increase in number and weight of tuber. The results are in agreement with the findings of Islam *et al*. (2017), Ali *et al.* (2020) and Saxena and Singh (2020).

Table 6. Effect of different organic manures and bio-fertilizers on tuber yield, number of tubers per hill and tuber weight (g) per hill at final harvest (pooled of two years)

Treatments	Tubers/ hill (no)	Weight of tuber/hill (g)	Yield (t/ha)
T_1	6.41c	205.8e	11.44e
T_2	7.69b	319.6bc	17.76bc
T_3	7.53b	295.8cd	16.21cd
T_4	7.96b	307.8bcd	17.10bcd
T_5	5.88c	250.3de	13.91de
T_6	9.03a	424.4a	23.79a
T_7	8.39ab	369.3ab	20.52ab
T_8	8.41ab	398.9a	22.16a
Lev. of sig.	**	**	**
CV (%)	10.82	16.92	17.09

Means bearing same letter (s) do not differ significantly at 1 or 5% level of probability by DMRT

*= Significant at 5% level of probability, **= Significant at 1% level of probability

T_1= (Control), T_2 = (Vermicompost 10 t/ha), T_3 = (Trico-compost 10 t/ha), T_4 = (ACI Organic Fertilizer 10 t/ha), T_5 = (Bio-fertilizer (Azotobacter + PSB), T_6 = (Vermicompost 8 t/ha + Azotobacter + PSB), T_7 = (Trico-compost 8 t/ha + Azotobacter + PSB) and T_8 = (ACI Organic Fertilizer 8 t/ha+ Azotobacter + PSB).

Quality characteristics

The quality parameters like dry matter percentage, total soluble solid (TSS % Brix) and starch content (mg g-1 FW) of tubers were significantly variable among the treatments (Table 7). The highest dry matter percentage (22.6), total soluble solid (4.85 % Brix) and starch content (33.4 mg g-1 FW) of tuber were found in T_6 which was followed by T_7 and T_8. The lowest (18.58%, 3.60% and 22.30 mg g-1 FW), respectively dry matter percentage, total soluble solid (% Brix) and starch content (mg g-1 FW) of tubers were observed in Control. It was observed that Vermicompost 8 t/ha + Azotobacter + PSB showed better performance producing quality potatoes in comparison to other manures and bio fertilizers. Increasing dry matter content was recorded when bio fertilizers were incorporated in combination with organic manures. It might be due to application of vermicompost, Azotobacter and PSB played positive role influencing quality parameters of potato like dry matter content, TSS and starch content. The highest TSS content might be due to maximum moisture content; dry weight of tuber because organic manures carry almost all micro and macro nutrients that are required for the plants growth and development. These results are in agreement with the findings of Abdel and Shams (2012), Islam et al. (2017) and Gangele et al. (2020).

Table 7. Effect of different organic manures and bio-fertilizers on dry matter percentage, total soluble solid (TSS % Brix) and starch content (mg g-1 FW)

Treatment Code	Dry matter content (%)	Total Soluble Solid (TSS % Brix) at harvest	Starch content (mg g-1 FW) of tubers at harvest
T_1	18.6e	3.60d	22.3f
T_2	21.2bc	4.17bc	29.2c
T_3	20.1cd	4.05bc	27.2de
T_4	20.7bcd	4.20bc	28.2cd
T_5	19.8d	3.85cd	26.3e
T_6	22.6a	4.85a	33.4a
T_7	21.2bc	4.30b	30.7b
T_8	21.6ab	4.21bc	31.9b
Lev. of sig.	**	**	**
CV (%)	4.62	8.42	4.11

Means bearing same letter (s) do not differ significantly at 5% level of probability by DMRT

*= Significant at 5% level of probability, **= Significant at 1% level of probability

T_1= (Control), T_2 = (Vermicompost 10 t/ha), T_3 = (Trico-compost 10 t/ha), T_4 = (ACI Organic Fertilizer 10 t/ha), T_5 = (Bio-fertilizer (Azotobacter + PSB), T_6 = (Vermicompost 8 t/ha + Azotobacter + PSB), T_7 = (Trico-compost 8 t/ha + Azotobacter + PSB) and T_8 = (ACI Organic Fertilizer 8 t/ha+ Azotobacter + PSB).

Economic analysis

T_6 showed the highest gross (Tk 1189500/ha) and net return (Tk. 634500/ha) and Benefit Cost Ratio (BCR: 2.14) which was followed by T_8 and T_7. The lowest gross return (Tk. 572000/ha), net return (Tk. 9700/ha and BCR-1.20) were found in the control (Table 8). It was observed that (Vermicompost 8 t/ha + (Azotobacter + PSB), is the suitable combination of organic manure and biofertilizers and showed significant effect on economical yield of potato. These results corrborated with the findings of Verma et al. (2011), and Gangele et al. (2020).

Table 8. Cost of potato cultivation through different organic manures and bio-fertilizers per hectare.

Variable cost		Fixed cost		Total cost of production (VC + FC)
Heads	Tk.	Heads	Tk.	
Labour	80000	Land use	15000/=	
Power tiller	12000			(595000+20000) /=
Seed	40000			
Khaul	300000	Interest on operating capital	5000 /=	
Organic fertilizer Biofertilizer	100000 40000			
Pesticides	8000			
Irrigation charge	15000			
Total	531000 /=	Total	14000/=	615000/=

Table 9. Cost and return analysis in potato cultivation through different organic manures and bio- fertilizers (pooled of two years)

Treatments	Organic Potato Yield (t/ha)	Avg Gross return (Tk)	Avg Cost of prod^n (tk)	Avg Net return (Tk)	BCR
T_1	11.44	572000	475000	97000	1.20
T_2	17.76	888000	575000	313000	1.54
T_3	16.21	810500	575000	235500	1.40
T_4	17.10	855000	575000	280000	1.48
T_5	13.91	695500	515000	180500	1.35
T_6	23.79	1189500	555000	634500	2.14
T_7	20.52	1026000	555000	471000	1.84
T_8	22.16	1108000	555000	553000	1.99

- PSB= Phosphate Solubilizing bacteria
- BCR= Benefit Cost RatioT_1= (Control), T_2 = (Vermicompost 10 t/ha), T_3 = (Trico-compost 10 t/ha), T_4 = (ACI Organic Fertilizer 10 t/ha), T_5 = (Bio-fertilizer, Azotobacter + PSB), T_6 = (Vermicompost 8 t/ha + Azotobacter + PSB), T_7 = (Trico-compost 8 t/ha + Azotobacter + PSB) and T_8 = (ACI Organic Fertilizer 8 t/ha+ Azotobacter + PSB)
- Organic Potato = 50Tk/Kg

Conclusion

Addition of organic manure along with bio fertilizer showed significant effect on yield parameters and yield of potato. The combination of vermicompost 8 t/ha + Azotobacter 8 ml/kg seed + PSB 8 ml/kg seed was found best for the cultivation of organic potato. The higher BCR was also recoded in this combination. Therefore, VC 8t/ha + Azotobacter (8 ml/kg seed) + PSB (8 ml/kg seed) can be recommended for the cultivation of organic potato in the study area (organic practice field).

References

Abdel-Salam, M. A. and A. S. Shams. 2012. Feldspar-K fertilization of potato (*Solanum tuberosum* L.) augmented by bio-fertilizer. American-Eurasian-Journal-of-Agricultural-and-Environmental Sciences.**12(6):**694-699.

Ali, A. M., M. Y. M. Awad., S.A. Hegab., A.M. Abd El Gawadand and A. Mamdouh Eissa. 2020. Effect of potassium solubilizing bacteria (Bacillus cereus) on growth and yield of potato. Journal of Plant Nutrition.**44(3):**1-10.

De Haan, S. and F. Rodriguez. 2016. Advances in Potato Chemistry and Technology; Academic Press: Cambridge, MA, USA, pp. 1–32. [CrossRef]

FAOSTAT. Food and Agriculture Data; Food and Agricultural Organization of United Nations: Rome, Italy. 2020. Available online: http://www.fao.org/faostat/en/#data/QC (accessed on 28 December 2021).

Gangele, P., R. Bajpai., A. Kashyap., S. Rai and S. K. Ahirwar. 2020. Effect of biofertilizers and levels of zinc and potassium on growth of potato (Solanum tuberosum L.). *Journal of Pharmacognosy and Phytochemistry*. 9(5):863-866.

Giller, K. E. and G. Cadisch. 1995. Future benefits from biological nitrogen fixation: An ecological approach to agriculture. *Plant and Soil*. **174:** 255-277.

Hafez, M., M. Magda., M. Mahmoud and R. Asmaa. 2004.Response of snap bean (Phaseolus vulgaris L.) to nitrogen fertilizer source. Annals of Agric. Sci., Mashtohor, **42 (1):** 261-270.

Islam, M. A., S. Islam., A. Akter., M. H. Rahman and D. Nandwani. 2017. Effect of organic and inorganic fertilizers on soil properties and the growth, yield and quality of tomato in Mymensingh, Bangladesh. Agriculture. 7(18):2-7.

Kumar, M., L. K. Baishya., D. C. Ghosh., M. Ghosh., V. K. Gupta and Verma. 2013. Effects of organic manures, chemical fertilizers, and biofertilizers on growth and productivity of rainfed potato in the eastern Himalayas. *Journal of plant nutrition*. **36(7):** 1065-1082.

Morajdhwaj, S., S. K. Biswas., D. Nagar, K. Lal and J. Singh. 2017. Impact of Bio-fertilizer on Growth Parameters and Yield of Potato *Int.J.Curr.Microbiol.App.Sci.* **6(5):** 1717-1724. doi: https://doi.org/10.20546/ijcmas.605.186.

Mostofa, M.; T. S. Roy., R. Chakraborty., S. Modak., P. K. Kundu., M. S. Zaman., M. Rahman and M. Shamsuzzoha. 2019. Effect of vermicompost and tuber size on processing quality of potato during ambient storage condition. *Int. J. Plant Soil Sci.* 26, 1–18. [CrossRef]

Naik, P. S. and S. M. P Khurana. 2003.Micropropagation in potatoseed production: need to revise seed certification standards. J. IndianPotato Assoc. **30:** 267-273.

Nosheen, S., I. Ajmal and Y. Song. 2021. Microbes as biofertilizers, a potential approach for sustainable crop production. Sustainability. **13(4):** 1868.

Saxena, A. K and S. Singh. 2020. Effect of bio fertilizers and inorganic fertilizers on growth and yield of potato (Solanum tuberosum L.) Cv. *Kufri Chandramukhi and Kufri Jyoti International* Journal of Current Advanced Research. **9(06):**22535-22538.

Verma, S. K., B. S. Asati., S. K. Tamrakar., H. C. Nanda and C. R. Gupta. 2011. Effects of organic components on growth yield and economics returns in potato. *Potato Journal.* **38:** 51-55.

Waithaka, P. N., E. M. Gathuru., B. M. Githaiga and C. O. Ouma. 2019. Microbial degradation of maize waste materials using actinomycetes isolated from Egerton University Soils, Njoro in Kenya. *Int Res J Biol Sci*. **1(1):** 31-36.

Yazdani, M., M. A. Bahmanyar., H. Pirdashti and M. A. Esmaili. 2009.Effect of phosphate solubilization microorganisms (PSM) and plant growth promoting rhizobacteria (PGPR) on yield and yield components of corn (Zea mays L.) Proceding of world academy science. *J Engin technol* 2070-3740.

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GOOD AGRICULTURAL PRACTICES FOR BOTTLE GOURD: ADVANCING FOOD SAFETY IN BANGLADESH

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Abstract

Good Agricultural Practices (GAP) is designed to enhance the safety, quality and sustainability of agricultural products by covering areas such as soil management, water use, pest control and post-harvest handling. A GAP validation trial for bottle gourd (*Lagenaria siceraria*) was conducted at the Basna village, Dhamrai, Dhaka during summer season of 2024 with the variety 'BARI Lau-4'. The study aimed to assess the effectiveness of GAP in improving yield and quality. The trial involved meticulous site selection, land preparation, seedling management, and fertilizer application. Recommended practices including balanced fertilization, efficient irrigation, and disease management were implemented. Despite challenges such as drought, gummy stem blight, and high labour costs, the trial achieved a yield of 35 MT per hectare, surpassing the national average of 13.7 MT per hectare, and the benefit-cost ratio (BCR) was calculated as 1.93. Training sessions were conducted to equip farmers with GAP knowledge, resulting in enhanced productivity and higher profitability. The GAP-produced bottle gourd met international quality standards, creating strong export opportunities. Recommendations include adopting drought-resistant practices, improving farmer engagement, and involving the Hortex Foundation and Department of Agricultural Marketing (DAM) for better market access. Future efforts should focus on addressing challenges and leveraging export potential to strengthen both local and international market presence.

Keywords: Bottle gourd, GAP, Food safety, Sustainability and MRL test.

Introduction

Good Agricultural Practices (GAP) represent a comprehensive set of guidelines designed to promote the production of safe, high-quality, and environmentally sustainable agricultural products (FAO, 2003). These practices cover various aspects of farming, including soil management, water use efficiency, pest and disease control, and post-harvest handling (FAO, 2016). By implementing GAP, farmers can enhance productivity, reduce negative environmental impacts, and meet both local and international market standards (FAO, 2003). The adoption of GAP is critical for improving crop yields, ensuring food safety, and supporting sustainable agricultural development (World Bank, 2007).

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Bottle gourd (*Lagenaria siceraria* (Molina) Standl.), also known as white-flowered gourd or calabash, is a diploid species (2n = 2x = 22) belonging to Cucurbitaceae family (Beevy and Kuriachan, 1996; Morimoto *et al.*, 2005). The bottle gourd variety under study, BARI Lau-4, is specifically adapted for summer cultivation in Bangladesh. With its ability to thrive in the summer climatic conditions of Dhamrai, Dhaka, where it has been extensively validated, this variety represents a significant advancement in local vegetable production.

In Bangladesh, bottle gourd is a crucial vegetable crop cultivated across various regions. According to the Bangladesh Bureau of Statistics (BBS, 2023), bottle gourd production totalled 283918 MT from an area of 20710 hectares with a national average yield of 13.7 MT per hectare. Dhamrai, a prominent area in Dhaka Division, is known for its vegetable production, including bottle gourd. This crop contributes significantly to the local economy and food security. The cultivation of bottle gourd in Dhamrai supports many farmers and plays a vital role in the local vegetable market.

Beyond local consumption, bottle gourd has export potential due to its popularity in international markets. With increasing global demand for diverse and nutritious vegetables, bottle gourd offers opportunities for export growth and can contribute to solving problems related to micronutrient malnutrition (Nesamvuni *et al*., 2001; Flyman and Afolayan, 2006; Modi *et al*., 2006; Odhav *et al*., 2007; Schonfeldt and Pretorius, 2011). Properly managed production practices can enhance the quality of the produce, meeting international standards and expanding market access. Exploring export opportunities can provide additional income for farmers and contribute to the agricultural economy.

Although bottle gourd, represents a smaller fraction of the total vegetable production compared to other major crops, its contribution to crop diversity, dietary value, and local economies is substantial. By comparing bottle gourd production with overall vegetable production, it becomes evident that while it may not dominate in volume, its economic and nutritional importance remain significant. Improving production practices through GAP can enhance its competitiveness and contribute to a more balanced and resilient agricultural sector.

The GAP validation trial for bottle gourd conducted in Dhamrai, Dhaka, Bangladesh, was designed to assess and validate the effectiveness of Bangladesh GAP protocols specific to this region. This trial aimed to enhance the productivity, quality and sustainability of bottle gourd production. By evaluating the impact of GAP on local farming practices, the study sought to provide practical recommendations for farmers, improve crop management strategies and contribute to sustainable agricultural practices in the region.

Site selection and justification: The GAP validation trial of bottle gourd was conducted in the village of Basna, Dhamrai Upazila, Dhaka, Bangladesh, with the participation of two local farmers, Babul Hossain and Azmin Akter. This region was selected due to its favourable climatic conditions, which align well with the requirements of the BARI Lau-4 variety. Dhamrai is renowned for its optimal growing conditions for bottle gourd, including temperature, soil type, and water availability, as in AEZ 8 (Young Brahmaputra Jamuna Floodplain).

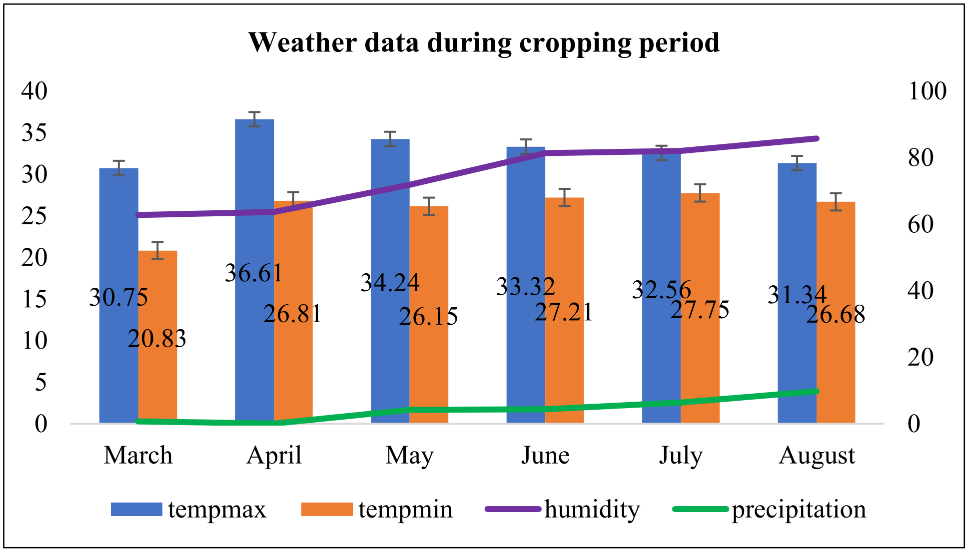

Fig. 1. Weather data during the cropping period at Dhamrai, Dhaka from March to August, 2024.

The precise location of the trial site at 23.9459171^{0}N Latitude and 90.1300177^{0}E Longitude. The region's climate is characterized by summer temperatures ranging from 20.83-36.61°C. Additionally, Dhamrai's soil quality and local farming expertise provide a supportive environment for validating and demonstrating the effectiveness of GAP in enhancing yield and quality.

Plate 1. Site selection at Dhamrai, Dhaka.

Land preparation: The land was cleared of previous crop residues, weeds, and debris. The soil was then ploughed and harrowed four times on 10 March 2024 in Azmin Akter's land and 12 April 2024 in Babul Hossain's land until a fine tilth was achieved, ensuring good seed-to-soil contact and optimal root development.

Azmin Akter and Babul Hossain cultivated bottle gourd in 40 decimal (0.162 ha) and 50 decimal (0.202 ha) plots, respectively. Soil samples were collected and tested for pH, nutrient levels, and organic matter content. Based on the results, appropriate soil amendments were applied to correct nutrient deficiencies in accordance with *FRG, 2018* guidelines.

Plate 2. Field layout for bottle gourd.

Seedling preparation: High-quality seeds of the BARI Lau-4 variety were selected based on their germination potential and health. Seeds were sown on 12 March 2024 for Azmin Akter's land and on 16 April 2024 for Babul Hossain's land in seed trays filled with a well-draining, nutrient-rich growing medium, such as compost and well-decomposed cow dung.

The seeds were treated with Carbendazim (Autostin) fungicide on 12 March and 16 April 2024 and the same day they were sown. The trays were covered by nylon net to protect the young seedlings from extreme temperatures and direct sunlight and attack of red pumpkin beetle. Regular watering was provided to maintain soil moisture. Seedlings were monitored for any signs of disease or pest incidence and necessary treatments such as applying D-limonene 5% (Bioclean) and Carbendazim (Autostin) fungicide to control red pumpkin beetle and fungal infections, respectively.

Plate 3. Seedling raising of bottle gourd.

Fertilizer application: Well-rotten compost or manure @ 5 ton/ha (3kg/pit) and N-P-K-S-Mg-Zn-B at 75-36-60-22-12-2.1-1.4 kg per hectare (45-22-36-13.2-7.2-0.60-0.84 g/pit) were applied for promoting growth and yield (FRG, 2018). In addition, Cadusafos 10% (Ragbi 10G) was used to manage soil-borne pests. This nutrient management strategy ensures the soil is adequately enriched, supporting the healthy growth and development of crops right from the onset of the planting season (Fageria, 2009 and Havlin *et al*., 2014). Full doses of all the manure and P-S-Mg-Zn-B and one-third of K were applied during final land preparation; the entire nitrogenous and two-thirds of the potassium fertilizers were applied in four splits throughout the growing season.

Plate 4. Mixing compost with fertilizers.

This strategy was implemented to ensure that plants receive a continuous supply of essential nutrients, particularly during critical growth stages such as vegetative growth, flowering, and fruit development. By splitting the application, the risk of nutrient leaching was reduced and nutrient use efficiency was enhanced, leading to improved crop performance and yield (Fageria *et al*., 2011; Singh *et al*., 2017).

Transplanting: Seventeen days old seedlings at 3-4 true leaf stage were transplanted in the field on 29 March 2024 in Azmin Akter's plot and on 03 May 2024 in Babul Hossain's plot. This transplanting into well-prepared pits encouraged the plants to establish a strong root system and become robust enough to handle field conditions. Seedlings were carefully removed from the seedling trays and transplanted into pre-prepared pits (50 cm x 50 cm x 45cm) in the field, maintaining 2.5 meters spacing in both directions as per GAP guidelines.

Irrigation: Irrigation was provided eight times in each plot from 05 April 2024 to 20 July 2024 during the growing season, carefully scheduled based on the crop's water requirements and prevailing weather conditions. The watering can irrigation method was preferred to ensure efficient water use, targeting the root zone directly and minimizing water wastage. Additionally, flood irrigation was applied 4 times in each plot at the same time during periods of dry soil conditions to ensure adequate soil moisture levels. This combination of irrigation techniques helped maintain optimal soil moisture, supporting healthy plant growth and maximizing yield potential (Allen *et al*., 1998; Steduto *et al*., 2012).

Fencing or netting around the GAP validation trial: To protect the GAP validation trial, a sturdy fence was constructed around the 90 decimal land area using nylon netting and bamboo sticks. This fencing served as a physical barrier to safeguard the crop from animals and unauthorized access, ensuring the integrity of the trial.

Plate 5. Signboard and fencing placed around the trial.

In addition, two signboards were strategically placed at the entrance of the trial area. These signboards provided essential information about the validation trial, including details such as the crop variety, the objectives of the trial, and the implementation of Good Agricultural Practices (GAP). The signboards also served as a communication tool to inform visitors and passersby about the research being conducted, reinforcing the importance of sustainable farming practices in enhancing crop yield and quality.

Previous crop history

The previous crop in the field was maize (*Zea mays*), which was harvested before starting bottle gourd cultivation process. Maize, being a heavy feeder, significantly depletes soil nutrients, particularly nitrogen, and can influence the soil's physical and biological properties. Consequently, the field required thorough preparation, including soil testing and nutrient replenishment to address any nutrient deficiencies and prepare it adequately for the bottle gourd crop. Additionally, managing any residual pests and diseases from the maize crop was essential to prevent potential impacts on the subsequent bottle gourd cultivation. The transition from maize to bottle gourd involved a comprehensive approach to restoring soil fertility and ensuring optimal growing conditions.

Soil and water analysis results

Plate 6. Collection of soil sample on 12 February, 2024.

After conducting soil and water analysis, it was confirmed that no hazardous materials were present in the trial site. Based on these analyses, adjustments were made following the Fertilizer Recommendation Guide (FRG, 2018), with guidance from a soil scientist. The adjusted fertilizer doses, including nitrogen (N), phosphorus (P), potassium (K), sulfur (S), calcium (Ca), magnesium

(Mg), zinc (Zn), and boron (B) were applied to the field. Fertilizers were incorporated into the soil prior to planting to ensure nutrient availability and additional applications were made throughout the growing season as needed. Regular monitoring of soil and water quality was conducted to ensure optimal nutrient levels and make any necessary adjustments to maximize plant growth and yield.

Plate 7. Collection of water sample on 12 February, 2024.

Intercultural operations

The successful cultivation of bottle gourd involved a series of intercultural operations aimed at optimizing plant growth and yield. Weeding was performed 12 times (10 April 2024 to 25 July 2024) to keep the field free of competitive weeds, which could otherwise impact plant growth and nutrient uptake. A trellis system was constructed using bamboo and nylon rope to support the climbing nature of the bottle gourd vines, facilitating better air circulation and exposure to sunlight. After each irrigation, the soil was loosened around the plants to enhance aeration and root development. Water suckers were regularly removed from the stem to direct more energy into fruit production. Efficient drainage systems were also implemented to remove excess water following heavy rains, preventing waterlogging and root rot. These intercultural practices were crucial for maintaining the health and productivity of the crop throughout the growing season.

Maintaining register book and documentation

A comprehensive register book was meticulously maintained for the GAP validation trial, documenting all relevant information and activities conducted throughout the project. The register included the names of the two participating farmers and recorded crucial details such as the crop name, variety name, soil and water test results and the precise location of the trial site. The register also tracked the dates of key operations, including irrigation, weeding, pesticide and fungicide applications, and other intercultural activities such as loosening the soil, removing water suckers and hand pollination. Additionally, the number of laborers used for each task was documented to ensure accurate records of resource utilization. This detailed register served as an essential tool for monitoring the trial's progress and ensuring the integrity of the data collected.

Pest management

During the GAP validation trial for bottle gourd, a variety of integrated pest and disease management practices were employed to ensure crop health and optimize yield. Fungicide of carbendazim group (Autostin WDG) was used for seed treatment before sowing. To control the red pumpkin beetle, the insecticide D-limonene 5% (Bioclean) was used at vegetative stage. For fruit fly management, sex pheromone (Cuelure sex pheromone) traps were strategically placed every twelve meters interval to attract and capture the pests, reducing their population and impact. Additionally, yellow sticky traps were deployed at ten meters intervals across the field to target a range of other insect pests, providing an eco-friendly method of pest control. For disease management, copper oxychloride 50% (Cupravit), a copper-based fungicide, was applied throughout the cropping period as a preventive measure against gummy stem blight, a common fungal disease of bottle gourd. To treat any instances of gummy stem blight that occurred, Bordeaux paste bandage was used to effectively cure the affected plants. These targeted interventions were crucial in maintaining the health of the bottle gourd plants, preventing significant yield losses, and ensuring the success of the GAP validation trial.

Table 1. List of pesticides applied to control insect and disease

Sl.	Generic name	Trade name	Application dose	Purpose
1.	Carbendazim	Autostin WDG	2.5 g/kg seed	Seed treatment
2.	Copper oxychloride	Cupravit 35WG	2.0 g/L of water	To control gummy stem blight
3.	Copper sulphate and quicklime	Bordeaux mixture	2.5 g/plant	To control gummy stem blight
4.	D-limonene	Bioclean	1.0 g/L of water	To control red pumpkin beetle

Worker health safety and environmental issues

Worker health safety, and environmental stewardship were prioritized throughout the GAP validation trial for bottle gourd. To ensure the safety and well-being of all workers, they were provided with protective gear including aprons, masks, hand gloves, caps, and shoes. Additionally, a comprehensive farm instrument manual was issued to guide the proper use of tools and machinery. Regular health checks were conducted every six months to monitor worker health, and essential health safety items such as soap were supplied, with washrooms being cleaned regularly using appropriate detergents like lysol.

Plate 8. Spraying with health safety measures.

Pure drinking water was made available to all workers and their working hours were restricted to a maximum of eight hours per day to prevent fatigue. Training sessions were conducted to educate workers on health safety protocols, the correct use of pesticides and the provision of first aid treatment. These measures not only ensured a safe and healthy working environment but also reinforced the importance of environmental responsibility and the ethical treatment of workers within the framework of Good Agricultural Practices (GAP).

Harvesting based on maturity index

Fruits with obscure spine that can be easily indented with fingernail are usually harvested 12-15 days after anthesis, the more harvest the more bearing fruits, harvest must be done with sharp knife during cooler time of the day (early morning or evening).

Plate 9. Suitable harvesting stage of bottle gourd.

Harvested fruits were kept in plastic crates instead of bamboo basket and placed in shaded place. Before marketing, sorting and grading were performed, appropriate packaging material used for transportation, clean handling was ensured.

MRL analysis results

Plate 10. Bottle gourd sample taken for MRL test.

SGS Bangladesh Limited conducted a Maximum Residue Limit (MRL) test for copper oxychloride using a bottle gourd sample collected from Dhamrai, Dhaka, on 09 June, 2024. Following laboratory analysis, the company reported residue levels below 5 mg/kg, which falls within safe thresholds for human consumption, indicating no significant health risks.

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Farmers' Training

The first batch of training on bottle gourd production technology with GAP protocol was conducted in Dhamrai on 20 January 2024, with 30 participants. Following the success of this session, a second batch of training was held in Basna village on 21 March2024, involving five participants. These sessions focused on equipping farmers with the knowledge and skills needed to implement GAP effectively, thereby enhancing the quality and yield of their bottle gourd crops.

Plate 11. Farmers training

Results and Discussion

Yield and yield contributing characters

During the cropping season, there were 27 successful harvests over a 53-day period. The harvesting pattern showed an initial phase with fewer fruits, followed by a mid-period peak, and then a gradual decline in the later stages, consistent with typical cucurbit growth cycles (Patel and Naik, 2021). Peak fruit yield, with individual fruits averaging 2.5 kg, was observed between the 7th and 22nd harvests. This trend aligns with previous research on bottle gourd harvest patterns (Kader *et al*., 2019a). Individual fruit weights generally ranged from 2.1 kg to 2.8 kg throughout the harvesting period, indicating effective crop management and stable phenotypic expression under controlled conditions (Yadav and Kumar, 2022). The heaviest fruits, weighing 2.8 kg, were recorded during the 13th and 15th harvests, with a subsequent decrease in weight in later harvests. This reduction in fruit weight toward the end of the season may be attributed to nutrient depletion in the plants and cumulative photosynthetic stress, a phenomenon noted by Alam *et al*. (2020) and Sharma *et al*. (2018).

The number of marketable fruits steadily increased from 144 fruits at the first harvest, reaching its highest point of 212 fruits between the 11th and 14th harvests. Subsequently, the number of fruits per harvest decreased, dropping to 158 fruits by the 27th harvest. This suggests a peak production period between the 8th and 16th harvests, after which fruit production begins to decline. Similar yield patterns, characterized by an initial growth phase, a peak production period, and a subsequent decline, have been observed in other fruit-bearing crops (Singh *et al.*, 2019; Gómez *et al.*, 2020).

Overall, the data indicates that peak production occurs approximately 79 to 97 days after planting, followed by a consistent decline. While the weight of individual fruits remained relatively stable, the total number of marketable fruits significantly decreased over time, reflecting resource reallocation in ageing plants (Mondal *et al.*, 2023).

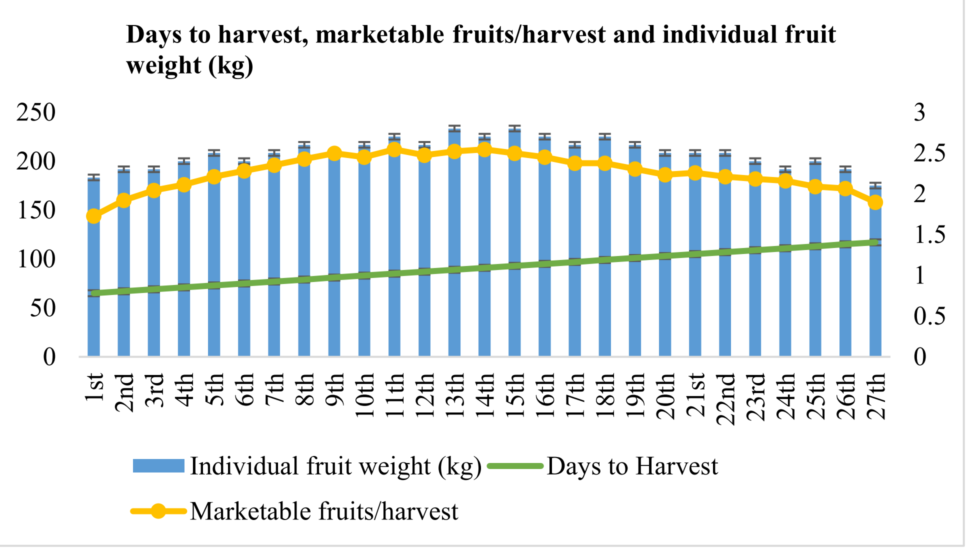

Fig. 2. Days to harvest, marketable fruits/harvest and individual fruit weight (kg) in different harvest stages.

Plate 12: Farmers harvested bottle gourds.

Good Agricultural Practices (GAP) for bottle gourd significantly outperformed the national average and aligned with Bangladesh Agricultural Research Institute (BARI) benchmarks. This superior performance was achieved by maximizing the number of high-quality fruits through optimized nutrient and harvest management (Kader *et al.*, 2019b; Alam *et al.*, 2020). From a 90-decimal (0.36 ha) plot, 5,098 fruits were harvested, yielding 12.75 MT.

Table 2. Yield of GAP produced bottle gourd compared to national average

Practice	Fruits number	Individual fruit weight (kg)	Yield (t/ 90 decimal land)	Yield (t/ha)
GAP	5098	2.5	12.75	35.0
National average	-	-	5.0	13.7
Research (BARI)	4800-5200	2.5	12-13	33-36

Benefit-cost analysis

The production of bottle gourd on 90 decimals of land adhering to Good Agricultural Practices (GAP) resulted in a total yield of 12.75 MT, with 5,098 gourds produced. The total production cost was Tk. 2,11,500/-, while the average market price per gourd was Tk. 80, generating a total revenue of 4,07,840 Taka. The Benefit-Cost Ratio (BCR) was calculated to be 1.93, indicating that for every 1 Taka invested, there was a return of 1.93 Taka. This demonstrates the economic viability of GAP-based cultivation, highlighting its potential for profitability and sustainability. The yield exceeded the national average, underscoring the effectiveness of improved practices in enhancing productivity and market competitiveness.

Farmer's Profile and Reaction

Babul Hossain, aged 40 with an eighth-grade education, and Azmin Akter, aged 32 and a Secondary School Certificate (SSC) holder, both residents of Basna village in Dhamrai, Dhaka, achieved successful bottle gourd cultivation by adhering to Good Agricultural Practices (GAP) guidelines.

They expressed satisfaction with the results, noting that the optimum use of compost, fertilizers, insecticides, fungicides and irrigation water significantly improved their yield. Compared to their previous farming methods, adopting GAP led to better crop performance and higher profitability, confirming the advantages of these sustainable farming practices.

Export opportunity

GAP-produced bottle gourd meets international standards for quality and safety, making it highly competitive in global markets. Adherence to GAP enhances the crop's appeal to foreign buyers, offering farmers the chance to access lucrative export opportunities. This not only boosts income but also strengthens Bangladesh's presence in the international agricultural market.

Marketing

GAP-produced bottle gourd was sold at the local market in Dhamrai, Dhaka. However, there was no noticeable difference in pricing or consumer preference between GAP-produced bottle gourd and those from normal production methods in the local market. There is considerable scope for positioning GAP-produced bottle gourd as a premium, safe and sustainable product. Strategies include targeting health-conscious consumers, supermarkets, emphasizing its compliance with international safety standards and positioning it for export to high demand markets. Leveraging certifications and promoting the benefits of GAP can also attract buyers looking for quality and traceable produce. The involvement of the Hortex Foundation and Department of Agricultural Marketing (DAM) can establish better marketing channels.

Challenges and way forward

During the seedling stage, drought condition caused the death of some plants, which was further compounded by an outbreak of gummy stem blight. Additionally, labour scarcity and high labour costs during April and May posed challenges. Moreover, the Sub-assistant Agriculture Officer (SAAO) requires training on record keeping for the GAP validation trial.

To overcome the challenges faced during the GAP validation trial, several steps can be taken for moving forward. Efficient irrigation methods, such as drip irrigation or mulching, should be introduced to mitigate the effects of drought during the seedling stage. Implementing disease-resistant varieties and enhancing monitoring systems will help manage outbreaks like gummy stem blight more effectively. The issue of labour scarcity and high costs during peak periods, particularly in April and May, can be addressed through mechanization or community labour-sharing initiatives. Additionally, training should be provided to the Sub-assistant Agriculture Officer (SAAO) on record-keeping and data management for GAP trials, ensuring more accurate tracking and reporting. These measures will enhance productivity and sustainability, leading to better outcomes in future GAP practices.

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References

Alam, M. K., M. A. Rahim and M. M. Hossain. 2020. Nutrient dynamics and fruit quality decline in late-season bottle gourd (*Lagenaria siceraria*) production. *J. Hort. Sci. Biotechnol.* **95**(6):789-797. [https://doi.org/10.1080/14620316.2020.1750852] (https: //doi. org/10.1080/14620316.2020.1750852)

Allen, R. G., L. S. Pereira, D. Raes and M. Smith. 1998. Crop evapotranspiration: Guidelines for computing crop water requirements (FAO Irrigation and Drainage Paper 56). FAO, Rome, Italy.

BARC (Bangladesh Agricultural Research Council). 2018. Fertilizer recommendation guide (FRG). BARC, Dhaka, Bangladesh.

BBS (Bangladesh Bureau of Statistics). 2023. Statistical yearbook of Bangladesh 2022. Ministry of Planning, Government of the People's Republic of Bangladesh.

Beevy, S. S. and P. Kuriachan. 1996. Cytomorphological studies on the genus *Lagenaria* Ser. (Cucurbitaceae). *Caryologia* **49**(3-4): 325–337.

Fageria, N. K. 2009. The use of nutrients in crop plants. CRC Press, Boca Raton, USA.

Fageria, N. K., V. C. Baligar and C. A. Jones. 2011. Growth and mineral nutrition of field crops (3rd ed.). CRC Press, Boca Raton, USA.

FAO (Food and Agriculture Organization). 2003. Good agricultural practices: A working concept. FAO, Rome, Italy.

FAO (Food and Agriculture Organization). 2016. Guidelines on good agricultural practices (GAP) for fruits and vegetables. FAO, Rome, Italy.

Flyman, M. V. and A. J. Afolayan. 2006. A survey of plants used as wild vegetables in four districts of Botswana. *Ecol. Food Nutr.* **45**(3): 173-181.

Gómez, J. A., J. López-Marín, and A. Gálvez. 2020. Yield evolution patterns in cucurbitaceous crops under intensive cultivation. *Sci. Hortic*. **267**: 109325. [https :// doi.org /10.1016/j.scienta.2020.109325](https://doi.org/10.1016/j.scienta.2020.109325)

Havlin, J. L., S. L. Tisdale, W. L. Nelson and J. D. Beaton. 2014. Soil fertility and fertilizers: An introduction to nutrient management (8th ed.). Pearson, New Jersey, USA.

Kader, M. A., S. R. Saha, and M. A. K. Mian. 2019a. Harvest interval optimization for maximising bottle gourd (*Lagenaria siceraria*) yield in subtropical conditions. *Agric. Syst.* **173**:73-80. [https://doi.org/10.1016/j.agsy.2019.02.005](https://doi.org/ 10.1016/ j.agsy.2019.02.005)

Kader, M. A., M. M. Rahman and M. S. Islam. 2019b. Harvest dynamics and yield performance of bottle gourd under GAP protocol. *J. Agric. Sci.* **10**(2): 50-56.

Modi, A. T., N. V. Nkongolo and M. F. Richards. 2006. *Moringa oleifera* and *Tylosema esculentum* leaf: Potential for human consumption. *Afr. J. Food Agric. Nutr. Dev.* **6**(2).

Mondal, S., A. Ghosh, and B. Mandal. 2023. Source-sink relationships and resource partitioning during reproductive senescence in cucurbits. *Ann. Appl. Biol.* **182**(1): 42-55. https://doi.org/10.1111/aab.12798

Morimoto, Y., E. Nakata and K. Iwabuchi. 2005. Phylogeny of bottle gourd, *Lagenaria siceraria* (Cucurbitaceae) as revealed by the matK sequence. *J. Plant Res*. **118**(5): 423-430.

Nesamvuni, C., N. P. Steyn and M. J. Potgieter. 2001. Nutritional value of wild, leafy plants consumed by the Vhavenda. *S. Afr. J. Sci*., **97**(1): 51-54.

Odhav, B., S. Beekrum, H. Baijnath and R. Govinden. 2007. Preliminary assessment of nutritional value of traditional leafy vegetables in KwaZulu-Natal, South Africa. *J. Food Compos. Anal.*, **20**(5): 430-435.

Patel, R. V. and H. R. Naik. 2021. Phenological growth stages and yield modeling in bottle gourd (*Lagenaria siceraria* (Molina) Standl.) using growing degree days. *J. Crop Sci. Biotechnol.* **24**(3): 279-288. [https://doi.org/10.1007/s12892-021-00081-w] (https:// doi. org/10.1007/s12892-021-00081-w)

Schonfeldt, H. C. and B. Pretorius. 2011. The nutrient content of five traditional South African dark green leafy vegetables: A preliminary study. *J. Food Compos. Anal*. **24**(8): 1141-1146.

Sharma, N., V. P. Singh and P. Kumar. 2018. Photosynthetic efficiency and fruit development dynamics in cucurbits under prolonged harvesting regimes. *Photosynthetica* **56**(2): 682-692. [https: //doi.org/10.1007/s11099-017-0720-5].

Singh, D. K., S.K. Pandey and V. Singh. 2019. Yield performance and harvest maturity indices in tropical cucurbits: A comparative analysis. *Int. J. Veg. Sci.* **25**(5): 453-467. [https://doi.org/10.1080/19315260.2018.1541768] (https://doi.org/10.1080/19315260. 2018.1541768).

Singh, J., V. P. Singh and R. Kumar. 2017. Nutrient management for sustainable crop production in subtropical environments. CRC Press, Boca Raton, USA.

Steduto, P., T. C. Hsiao, E. Fereres and D. Raes. 2012. Crop yield response to water (FAO Irrigation and Drainage Paper 66). FAO, Rome, Italy.

World Bank. 2007. World development report 2008: Agriculture for development. World Bank, Washington, DC, USA.

Yadav, S. K. and R. Kumar. 2022. Genotype × environment interaction and stability analysis for fruit weight traits in bottle gourd (*Lagenaria siceraria*). *Genet. Resour. Crop Evol.* **69**(1): 205-218. [https://doi.org/10.1007/s10722-021-01215-3] (https://doi.org/10. 1007/s10722-021-01215-3).

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Ahmed, F. and M. Z. Alam. 1993. Mango leaf consumption by *Cricula trifenestrata* Heifer (Lepidoptera: Saturnide) larvae under field conditions. *Bangladesh J. Entomol.* **31:** 9-17.

Cano, H., N. Gabas and J. P. Canselier. 2001. Experimental study on the ibuprofen crystal growth morphology in solution. *J. Crystal Growth* **224:** 335.

De Beer, G. R.1940. Embryology and Taxonomy. *In: The New Systematics.* (Ed. Huxely, J.). Oxford Univ. Press, London. pp. 365-393.

Dockery, D. J. and C. A. Pope, 1994. Acute respiratory effects of particulate air pollution. *Ann. Rev. Public Health* **15:** 107-110.

Edmonds, J. and K. M. Karp. 1997. Theoretical improvements in Algorithmic Efficiency for network flow problems. *J. Assoc. Comput. Mach.* **19:** 248-264.

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