Agricultural Sciences, 2024, 15, 780-799
https://www.scirp.org/journal/as
ISSN Online: 2156-8561
ISSN Print: 2156-8553

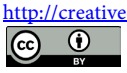
Development and Validation of Integrated Nutrient Management Practices of Industrial Processing Varieties: Asterix and Courage in Bangladesh

Azizul Hoque[1], Md. Maniruzzaman Sikder[2*], Abul Khair[2,3]

[1]Bangladesh Agricultural Development Corporation, Dhaka, Bangladesh
[2]Department of Botany, Jahangirnagar University, Dhaka, Bangladesh
[3]Hamdard University, Gazaria, Bangladesh
Email: *mmsbot@juniv.edu

How to cite this paper: Hoque, A., Sikder, M.M. and Khair, A. (2024) Development and Validation of Integrated Nutrient Management Practices of Industrial Processing Varieties: Asterix and Courage in Bangladesh. *Agricultural Sciences*, **15**, 780-799.
https://doi.org/10.4236/as.2024.157043

Received: June 21, 2024
Accepted: July 26, 2024
Published: July 29, 2024



Abstract

An experiment was meticulously conducted at the research field of Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur, Bangladesh, during the 2011-2012 potato growing season to develop integrated crop management practices for the potato seed production of industrial processing varieties Asterix and Courage. Significantly, higher growth and yield parameters were found in the BADC-recommended practice. Later, another experiment was conducted to validate the BADC practice during the 2013-2014 potato growing season in two locations in Bangladesh. Results showed that the production of tuber per hill, tuber weight per hill as well as gross tuber yield per plot, higher proportion of storable seed tubers, and more quality seed potatoes (A-grade and B-grade) seed tubers were found significantly higher in the "BADC developed practice" compared to other treatments. Viral diseases (PLRV and PVY) prevalence was lower in "BADC developed practice". Moreover, "BADC developed practice" contributed more economic yield by minimizing input cost compared to "Munshiganj advanced farmers' practice". Therefore, the "BADC developed practice" was found "superior" regarding yield, quality, and profitability in seed potato production of industrial varieties—Asterix and Courage in Bangladesh.

Keywords

Integrated, Nutrient, Industrial, Processing, Potatoes

1. Introduction

Potatoes are a global crop and are ranked fourth as major food crops in the world, after maize, rice, and wheat, in terms of yield. It is a profitable business compared to rice in Bangladesh [1]. It is the world's number one non-grain food commodity, grown and consumed in more countries than any other crop, with production reaching a record 376 million metric tons in 2013 [2]. Bangladesh is now the seventh-highest potato-producing country (10,432,000 metric tons) among the 158 countries in the world [3]. However, the country is positioned behind the 67 countries in yield [2]. The average yield of potatoes in Bangladesh is only 14 - 15 tons/ha, which is much lower than the Netherlands (41.3 tons/ha), Ukraine (44.0 tons/ha), the USA and other countries [4]. The primary cause of this low potato yield in our country is mainly the use of poor-quality seed potatoes. This research is crucial as it highlights the importance of quality seeds and the adaptation of scientific management practices to increase the average yield of potatoes. Using organic manures and inorganic fertilizers is essential in raising potato yields in tropical and sub-tropical countries. The concept of integrated use of organic matter and chemical fertilizers is increasingly realized in maintaining soil fertility and crop productivity.

Dry matter is an essential characteristic of tubers used for processing into chips and French fries as it decides the product recovery and oil content in chips. Potassium chloride seems more detrimental in reducing the dry matter content of tubers and, thus, tuber quality for processing into chips and French Fries [5]. Tubers' dry matter was significantly affected by the interaction effect of zinc and phosphorus; the maximum dry matter was obtained with the application of 225 kg/ha phosphorus plus 50 kg/ha zinc [6]. It was found that N, P, and K not only increase the tuber size, but also the dry matter content, and protein content of potato tubers [7] [8]. The treatment receiving Zn, B, S, and Mg together gave the highest tuber yield (30.90 tons/ha) and the yield increment of 21.65% by the combined treatment of Zn, B, S, and Mg compared to the control [9]. Likewise, the highest potato yield was recorded when the optimum doses of inorganic fertilizers (N, P, K, S, Mg, B, and Zn) organic fertilizer was used [10]-[12].

Our country's low potato crop yield is mainly attributed to the non-adoption of modern production technology. The most common fertilizer application method for potato cultivation in our country is broadcasting the fertilizers during land preparation and before planting the seed tubers in the soil. These enhance the loss of fertilizers and sometimes damage the seed tubers.

In Bangladesh, fertilizer doses are used per recommendations made by the Tuber Crops Research Center (TCRC), Bangladesh Agricultural Research Institute (BARI). These doses have been suggested about ten years earlier based on table potatoes. So, such recommendations (both for macro and micronutrients) must be revised or cross-checked, considering both table and processing purposes. In addition, many organic fertilizers are available in the market, and their potential still needs to be adequately documented. Although Bangladesh is Asia's

fourth-largest potato producer, potato processing is still prolonged due to the need for more suitable potato varieties. All the released varieties in the country except Asterix, Courage, Lady Rosetta, and Meridian are meant for table purposes only. These varieties generally have low dry matter (15% - 18%) and high reducing sugar content, considered undesirable traits for industrial processing. Our previous research findings provide a foundation regarding the importance of macro, micronutrient, and organic fertilizers to produce potatoes [12]. Under the above scenario, the present research works were designed with aims to optimize the doses of inorganic fertilizer for both macro and micronutrients, to search for suitable organic fertilizer for seed potatoes, and to develop standard management practices for seed potato production and control of diseases; to validate of BADC developed practices in comparison with Advanced (Munshigonj) farmer practice and absolute control.

2. Methodology

2.1. Location and Experimental Design

The first experiment integrating different treatments was conducted at the research field of Bangabandhu Sheikh Mujibur Rahman Agriculture University, Gazipur, Bangladesh during the winter season, 2011-12. The study used two popular industrial potato varieties, namely Asterix and Courage. The soil was characterized as highly acidic (pH 5.3) at the experimental site (Table 1). The foundation class of seeds of both varieties was used in the study. Factorial randomized completely block design with two factors (potato cultivars—Asterix and Courage) and ten treatments with three replications each were used.

Table 1. Initial soil status of three experimental fields.

Location	Soil pH	Organic matter (%)	Total Nitrogen (%)	Calcium meq/100g soil	Magnesium meq/100g soil	Potassium meq/100g soil	Phosphrus ug/g of soil
Kashimpur, Gazipur	5.0	1.14	0.057	2.54	0.60	0.20	43.1
	Highly acidic	low	very low	low	low	optimum	very high
Domar seed Farm	6.04	1.10	0.06	-	0.56	0.16	19.12
	Slightly acidic	low	very low	-	low	medium-low	very high
BSMRAU Gazipur	5.3	1.15	0.056	2.53	0.60	0.32	6.4
	Highly acidic	Low	Very low	Low	Low	Very high	Low

Source: Soil tested by Soil Resource Development Institute, Dhaka, Bangladesh.

The second experiment was conducted at the Domar Foundation Seed Potato Production Farm, Nilphamari, and Farmer's Field, Kashimpur, Gazipur, Ban-

gladesh during the winter season, 2013-2014. The soil was characterized as highly acidic (pH 5.0) at Kashimpur, Gazipur, and slightly acidic (pH 6.04) at Domar Seed Potato Farm (Table 1). The study used two popular industrial potato Varieties, Asterix and Courage. The foundation class of seeds of both varieties was used in the study. Factorial randomized completely block design, and split-split plot designs were used where potato variety and spray condition were assigned to the main plot, and treatment/practices were used to subplots with three replications.

2.2. Treatments

First experiment:

T0: Control

T1 (Inorganic-1): Urea @ 350 kg/ha + TSP @ 220 kg/ha + MoP @ 264 kg/ha + Gyp @ 84 kg/ha

T2 (Inorganic-2): Urea @ 350 kg/ha + TSP @ 220 kg/ha + MoP @ 264 kg/ha + Gyp @ 84 kg/ha + $ZnSO_4$ @ 14 kg/ha

T3 (Organic-1): Northern organic fertilizer @ 100 kg/ha

T4 (Organic-2): Cowdung @ 1390 kg/ha + Oilcake @ 83 kg/ha

T5 (Combination-1): Northern organic fertilizer @ 50 kg/ha + Urea @ 175 kg/ha + TSP @ 110 kg/ha + MoP @ 132 kg/ha + Gyp @ 42 kg/ha

T6 (Combination-2): Cowdung @ 695 kg/ha + Oilcake @ 41.6 kg/ha + Urea @ 175 kg/ha + TSP @ 110 kg/ha + MoP @ 132 kg/ha + Gyp @ 42 kg/ha

T7 (BADC practice): Urea @ 300 kg/ha + TSP @ 200 kg/ha + MoP @ 300 kg/ha + Gyp @ 100 kg/ha + $ZnSO_4$ @ 10 kg/ha + $MgSO_4$ @ 100 kg/ha + Solobor @ 2.5 l/ha

T8 (Farmer's practice-I, Bogra region): Urea @ 375 kg/ha + TSP @ 375 kg/ha + MoP @ 375 kg/ha + Gyp @ 37.5 kg/ha + $ZnSO_4$ @ 7.5 kg/ha + Borax @ 7.5 kg/ha

T9 (Farmer's practice-II, Rajshahi region): Urea @ 225 kg/ha + TSP @ 375 kg/ha + MoP @ 375 kg/ha + Gyp @ 225 kg/ha

Second experiment:

Treatment-0: Absolute control.

Treatment-1 (BADC practice): Urea @ 300 kg/ha + TSP @ 200 kg/ha + MoP @ 300 kg/ha + Gypsum @ 100 kg/ha + Zinc sulphate @ 10 kg/ha + Magnesium sulphate @ 100 kg/ha + Solobor @ 2.5 l/ha

Treatment-2 (Advanced (Munshiganj) Farmer's Practice): Urea @ 625 kg/ha + TSP @ 750 kg/ha + MoP @ 500 kg/ha + Gypsum @ 100 kg/ha + Zinc sulfate @ 10 kg/ha + Magnesium sulfate @ 100 kg/ha + Solobor @ 2.5 l/ha

2.3. Land Preparation and Fertilizer Application

Plot size was 3 m × 2 m each. The experimental field was plowed mechanically and leveled correctly for a good tilth. Half of the area and murate of potash (MoP) and the whole quantity of TSP were applied to the soil of the growing potato crops as a

top dressing after 35 days of planting seed potatoes. Organic fertilizer (Northern), Cowdung, and Oilcake were applied at the time of final plowing.

In the second experiment, in T1 (BADC practice), Half of the Urea and Murate of Potash (MoP), the whole quantity of TSP, Gypsum, Zinc sulfate, and Magnesium sulfate were applied at the time of sowing of seed potato. The remaining 50% of Urea, MoP, and Solubor (as a source of boron) were applied to the soil of the growing potato crops as a top dressing after 35 days of seed potato planting. In T2 (Advanced farmer's practice (Munshiganj), the whole quantity of Urea, TSP, MoP, Gypsum, Zinc sulfate, and Solubor was applied at the time of sowing of seed potato.

2.4. Sowing of Seed Potato and Intercultural Operation

In the first experiment, the seed potato was kept in a defused light in the storeroom for about 72 hours for pre-sprouting. Then, the grade A (28 - 40 mm) seed tubers were cut into two pieces and grade B seed tubers were cut into 2 - 3 pieces and kept the cut tubers in a cool, shady place for 48 - 72 hours for healing or suberization. Then, the seed potatoes were planted in the experimental potato field. Row A row distance of 60 cm and tuber-to-tuber distance of 20 cm was maintained. Mulching and weeding were carried out after 20 days of planting. Just after mulching, the first irrigation was done. Another four times irrigation was given in the experimental field.

In the second experiment, six hundred forty kg of seed potato was used for T1 (BADC practice), whereas six hundred eighty-seven kg of seed potato was used in T2. Row A row distance of 60 cm and tuber-to-tuber distance of 20 cm was maintained in T1 (BADC practice) but row a row distance of 30 cm and tuber-to-tuber distance of 10 cm was maintained in T2. Straw was used as mulch in the T2 treatment. After 15 days of planting, the first weeding was done. Just after the wedding, the first irrigation was done. Three times weeding was done at BADC Horticulture Farm, Kashimpur, and eight times irrigation was done at Domar Potato Seed Production Farm.

2.5. Fungicide, Pesticides Application, Data Collection, and Harvesting

To control fungal diseases, the fungicide (Companion @ 2 g/l of water) was applied six times, and the insecticide (Imitaf @ 0.5 ml/l of water) was applied six times per the spray schedule. Data was taken on days to tuberization, number of stem/hills at 60 days after sowing (DAS), plant height (60 DAS), number of tuber/hill and tuber weight/hill at harvest, etc, as per schedule. The potato plants were uprooted as branches were not left in the field. After hauling and pulling, the potato was kept in the field for ten days to harden the skin. The potato was harvested and taken to a calm, shady place where sorting, grading, and weighting were done. DASA-ELISA was used to detect PVY and PLRV following the method Clark and Adams [13] outlined with a few modifications.

2.6. Data Analysis

The experimental data was analyzed using Statistix 10.0. software. Data were subjected to a two-way analysis of variance (ANOVA) for mean comparison, and significant differences were calculated according to the Least Significance Difference test (LSD) and percentage of coefficient of variation (CV). Data were reported as mean value ± standard error (SE). Differences at $p < 0.05$ were considered statistically significant.

3. Results

3.1. First experiment

3.1.1. Days to Tuberization, Number of Stem/Hills, Plant Height, Number of Tuber/Hills

Notably, the Asterix and Courage varieties exhibited an early tuberization 5 days earlier when the BADC practice (NPKS + ZnMgB) was applied (Table 2). This is a significant finding, suggesting the potential for accelerated potato growth with this treatment. In contrast, the control groups of both varieties required a more extended period for tuberization, even with the use of inorganic and organic fertilizers.

Table 2. Effect of different inorganic and organic fertilizer treatment and treatment combinations on days to tuberization and the number of stems/hills of two industrial potato varieties.

Treatments	Days to tuberization		Number of stem/hills	
	Asterix	Courage	Asterix	Courage
T0: Control	32.67a	28.00b-f	5.96b-f	4.44f
T1: Inorganic 1: NPKS	30.00a-e	25.67fg	8.89a	5.85b-f
T2. Inorganic2: NPKS + Zn	31.67ab	27.00d-g	8.96a	6.22b-f
T3: Organic 1: Northern	31.33ab	25.33fg	8.04ab	7.96abc
T4: Organic 2: Cowdung + Oilcake	31.67ab	26.67d-g	6.00b-f	5.71c-f
T5: 1/2 (T1 + T3)	32.00a	27.33c-f	8.07ab	5.11ef
T6: 1/2 (T1 + T4)	30.33a-d	26.33efg	7.59a-d	6.19b-f
T7: BADC Practice: NPKS + ZnMgB	27.00d-g	23.33g	8.11ab	5.48def
T8: Farmer's Practice l: NPKS + ZnMg	31.67ab	27.33c-f	7.92abc	5.70c-f
T9: Farmer's Practice 2: NPKS + Zn	31.00abc	27.00d-g	6.74a-e	5.15ef
LSD	3.33		1.94	
CV	7.03%		17.47%	

Values with the same letters within row and column are not significantly ($p < 0.05$) different.

The highest number of stems per hill (8.96) was obtained in the treatment T2 of Asterix, which was statistically similar to the treatment T1 of Asterix, followed by 8.11 due to treatment T7, 8.07 in T5 and 8.04 in T3 of Asterix (Table 2). The range of the stem per hill varied from 4.44 to 7.96 in the variety Courage, which was generally less than in the variety Asterix, which ranged from 5.99 to 8.96 stems per hill. The least number of stems per hill was found in control of variety Courage.

In the case of Asterix (Table 3), the treatment T7 (BADC Practice: NPKS + BZnMg) resulted in the highest plant height (78.15 cm), followed by T2 (NPKS + Zn) and T8 (Farmer Practice 1: NPKS + Zn). The control group of Asterix had the least plant height (51.37 cm). For the Courage variety, the maximum plant height was 62.67 cm and 61.34 cm in T2 and T8, respectively, while the control group had the minimal plant height (36.44 cm).

In Asterix, the highest number of tubers per hill (15.30) was found in the treatment T7 (BADC practice), followed by T3, T2, and T1 (Table 3). Interestingly, similar results were found in the variety Courage, where BADC practice also gave the maximum number of tubers per hill. There were a lower number of tubers found in control of both varieties.

Table 3. Effect of different inorganic and organic fertilizer treatment and treatment combinations on the plant height and number of tubers/hill of two industrial potato varieties.

Treatments	Plant height (cm)		Number of stem/hills	
	Asterix	Courage	Asterix	Courage
T0: Control	51.37d-g	36.44g	10.07cde	9.26e
T1: Inorganic 1: NPKS	64.48a-e	54.37c-g	12.48a-d	10.18cde
T2: Inorganic2: NPKS + Zn	73.70ab	62.67a-e	12.89abc	11.00b-e
T3: Organic 1: Northern	52.22c-g	51.52d-g	13.44ab	9.590de
T4: Organic 2: Cowdung + Oilcake	49.55d-g	42.66fg	10.59b-e	9.630de
T5: 1/2 (T1 + T3)	53.33c-g	47.44efg	11.15b-e	10.93b-e
T6: 1/2 (T1 + T4)	61.81a-e	46.33efg	12.30a-e	10.89b-e
T7: BADC Practice: NPKS + ZnMgB	78.15a	61.34a-f	15.30a	11.52b-e
T8: Farmer's Practice l: NPKS + ZnMg	66.59a-d	52.56c-g	11.52b-e	11.19b-e
T9: Farmer's Practice 2: NPKS + Zn	70.44abc	56.85b-f	12.03b-e	11.11b-e
LSD	15.82		3.157	
CV	16.88%		16.82%	

Values with the same letters within row and column are not significantly ($p < 0.05$) different.

3.1.2. Tuber Weight (g/hills) and Tuber Yield (tons/ha)

In Asterix (Table 4), the maximum weight/hill of 777.78 g was observed in BADC Practices, followed by 675.92 g in Farmer Practice-2 (Rajshahi region) and 655.93 g in Farmer Practice-1 (Bogra region). Similar trends were noticed in the case of variety Courage, where BADC Practices gave the utmost weight of 618.52 g, followed by 594.44 g in Farmer Practice 2 (Rajshahi region). The lowest tuber weight per hill of 390.74 g of Asterix and 370.37 g of Courage were found in control. Results indicate that based on their experience, farmers have learned or developed their practice along with BADC practice to have more tuber per hill.

In Asterix (Table 4), the topmost tuber yield (34.93 tons/ha) was obtained where BADC practice was applied, followed by 27.49 tons/ha in the Farmer Practice-1(Bogra region). Similar trends of tuber yield were found in the case of variety Courage. The least amount of tuber yield of 17.77 tons/ha and 15.61 tons/ha were found in control of Asterix and Courage, respectively. Results indicate that BADC recommended inorganic and organic fertilizers as the best way to increase the potato production of our country's industrial processing varieties—Asterix and Courage.

Table 4. Effect of different inorganic and organic fertilizer treatment and treatment combinations on the tubers weight (g)/hill and tuber weight (tons/ha) of two industrial potato varieties.

Treatments	Tubers weight (g/hill)		Tuber weight (tons/ha)	
	Asterix	Courage	Asterix	Courage
T0: Control	390.74ef	370.37f	17.77fg	15.61g
T1: Inorganic 1: NPKS	592.59a-d	562.96b-e	24.42bcd	20.10c-g
T2. Inorganic2: NPKS + Zn	653.70abc	585.19bcd	26.15b	19.14efg
T3: Organic 1: Northern	545.55b-f	475.18c-f	19.68c-g	19.33d-g
T4: Organic 2: Cowdung + Oilcake	511.11b-f	381.48ef	21.23c-f	16.27fg
T5: 1/2 (T1 + T3)	531.48b-f	475.92c-f	20.84c-f	17.40fg
T6: 1/2 (T1 + T4)	547.04b-f	431.48def	23.09b-e	17.66fg
T7: BADC Practice: NPKS + ZnMgB	777.78a	618.52a-d	34.93a	26.53b
T8: Farmer's Practice l: NPKS + ZnMg	655.93abc	544.45b-f	27.49b	20.85c-f
T9: Farmer's Practice 2: NPKS + Zn	675.92ab	594.44bcd	24.69bc	20.27c-g
LSD	162.00		4.39	
CV	17.95%		12.27%	

Values with the same letters within row and column are not significantly ($p < 0.05$) different.

3.1.3. Seed Tuber Grade

In variety Asterix (Figure 1), the highest (52.34% tuber weight) A-grade tuber was found in T8 (Farmer practice-1), followed by T4 (organic-1), T2 (inorganic-2), and the least amount of A-grade tuber was observed in T5 (combination-1). The maximum B-grade tuber was obtained in BADC practice, followed by T6 (combination-1), T9 (Farmer practice-2), and the minimal amount of B-grade tuber was found in T8 (Farmer practice-1). The utmost amount of over-grade tuber was noticed in BADC practice, followed by T3 (organic-1), T9 (Farmer practice-2), and the minimum amount of over-grade tuber was found in T8 (Farmer practice-1). The highest under-grade tuber was found in T1 (inorganic-1), followed by T0 (control), and lowest in T9 (Farmer practice-2).

In variety Courage (Figure 2), the maximum undersized tuber was found in control, followed by T9 (Farmer practice-2), and the lowest was in BADC practice.

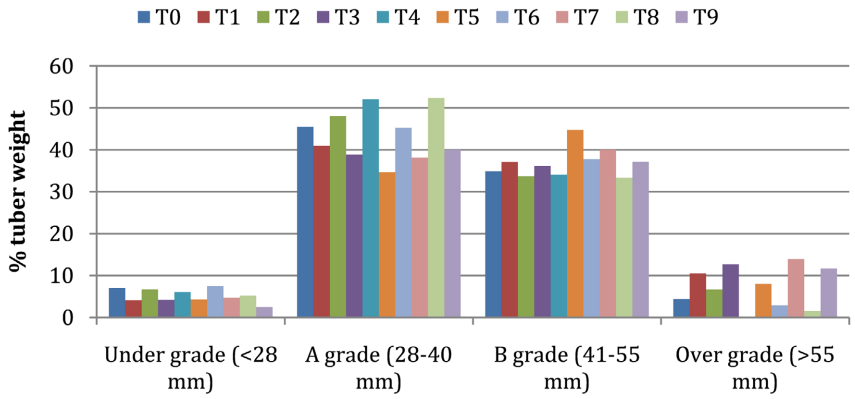


Figure 1. Effect of different inorganic & organic fertilizer treatment and treatment combination on seed tuber grade of industrial potato variety Asterix. Here, T0: Control, T1: Inorganic 1: NPKS, T2: Inorganic 2: NPKS + Zn, T3: Organic 1: Northern, T4: Organic 2: Cowdung + Oilcake, T5: 1/2 (T1 + T3), T6: 1/2 (T1 + T4), T7: BADC Practice: NPKS + ZnMgB, T8: Farmer's Practice l: NPKS + ZnMg, T9: Farmer's Practice 2: NPKS + Zn.

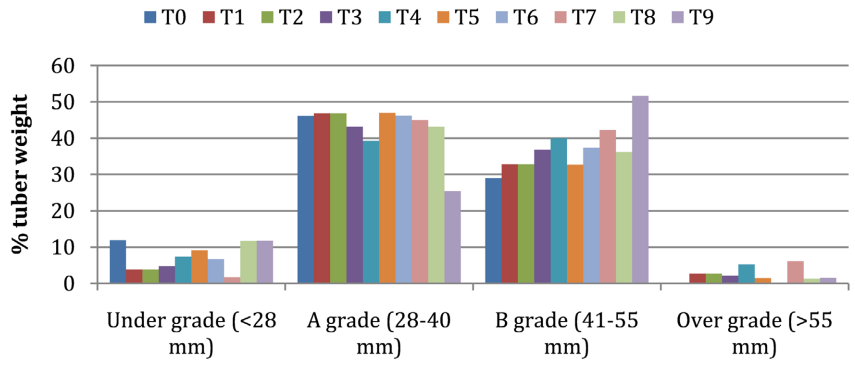


Figure 2. Effect of different inorganic & organic fertilizer treatment and treatment combinations on different seed tuber grades of industrial potato variety Courage. Here, T0: Control, T1: Inorganic 1: NPKS, T2: Inorganic 2: NPKS + Zn, T3: Organic 1: Northern, T4: Organic 2: Cowdung + Oilcake, T5: 1/2 (T1 + T3), T6: 1/2 (T1 + T4), T7: BADC Practice: NPKS + ZnMgB, T8: Farmer's Practice l: NPKS + ZnMg, T9: Farmer's Practice 2: NPKS + Zn.

The highest A-graded tuber was obtained in T5 (combination-1), followed by T2, T1, and T6, and the least amount was obtained in the treatment T9 (Farmer practice-2). The most B-graded tuber was observed in T9 (Farmer practice-2), followed by BADC practice. The maximum overgraded tuber was found in BADC practice, and no overgraded tuber was controlled. Interestingly, 87% of tubers with A and B-graded belong to BADC practice, indicating better practices for potato production in Bangladesh.

3.2. Second Experiment

3.2.1. Plant Height, Number of Stem/Hill, Percentage of Foliage Coverage, Number of Tuber/Hill

In Kashimpur BADC Farm (Table 5), the highest of 55.40 cm of Asterix and 46.33 cm of Courage were obtained in spray (insecticides and fungicides) plots, followed by 55.26 cm of Asterix in the BADC Practice, which was statistically identical to treatment T2. In the non-spray plot, the maximum plant height of 48.80 cm of Asterix was observed in the BADC Practice, followed by 46.07 cm of variety Courage due to treatment T2, where an Advanced Farmer practice was applied. Control plots gave statistically significantly lower plant height in spray and non-spray conditions. In Domar farm, similar trends of results were found, except the highest plant of 40.27 cm of variety Courage was obtained in the BADC practice (Table 5).

Table 5. Plant height (cm) of two processing varieties cultivated at Kashimpur and Domar BADC farm at 60 DAS.

Treatment	Kashimpur BADC farm				Domar BADC farm			
	Spray plots		Non-spray plots		Spray plots		Non-spray plots	
	Asterix	Courage	Asterix	Courage	Asterix	Courage	Asterix	Courage
T0	43.66bcd	33.20g	44.33abc	37.13c	44.33abc	37.13c	42.33bc	40.73bc
T1	55.26a	37.33efg	45.60abc	40.26bc	45.60abc	40.26bc	51.06ab	42.33bc
T2	55.40a	46.33bc	55.60a	39.66bc	55.60a	39.66bc	42.73bc	46.06abc
LSD	5.624				11.72			
CV	7.55				15.74			

Values with the same letters within rows and columns are not significantly ($p < 0.05$) different. Here, T1: BADC Practice, T2: Advanced Farmer's (Munshigonj) Practice, T0: Control.

The maximum number of stems per hill was found in BADC practice in spray plots of both Asterix and Courage in Kashimpur and Domar farm (Table 6), followed by Advanced farmer practices, and the minimal number of stems per hill was found in control plots. Non-spray plots had the lowest number of stems per hill at Kashimpur and BADC farms (Table 6). This suggests that adopting BADC Practice and using spray plots can significantly increase the number of stems per hill, thereby enhancing crop yield.

Table 6. Number of stems per hill of two processing varieties cultivated at Kashimpur BADC farm at 60 DAS.

Treatment	Kashimpur BADC farm				Domar BADC farm			
	Spray plots		Non-spray plots		Spray plots		Non-spray plots	
	Asterix	Courage	Asterix	Courage	Asterix	Courage	Asterix	Courage
T0	2.53cd	2.46de	2.70bcd	1.86e	3.00abcd	1.93e	2.86bcd	2.26cde
T1	3.53a	3.50a	2.80bcd	3.16abc	3.80a	2.46cde	3.33ab	2.40cde
T2	3.20ab	2.767bcd	3.00abcd	2.56bcd	3.06abc	2.20de	3.333ab	2.40cde
LSD	0.654				0.829			
CV	13.60				17.78			

Values with the same letters within rows and columns are not significantly ($p < 0.05$) different. Here, T1: BADC Practice, T2: Advanced Farmer's (Munshigonj) Practice, T0: Control.

At the Kashimpur BADC Farm, the BADC Practice demonstrated its superiority in terms of foliage coverage. The maximum percentage foliage coverage of 91.67 and 88.35 of Asterix were found in the Advanced Farmer Practice for spray and non-spray plots, respectively (Table 7). However, the BADC Practice gave the utmost percentage of foliage coverage in the variety Courage in spray and non-spray plots, highlighting its positive impact on crop growth. In general, spray plots had better foliage coverage than non-spray plots. In the Domar farm (Table 7), there was no statistically significant difference in spray plots between BADC Practice and Advanced Farmer Practice. However, treatments T1 and T2 had significantly higher foliage coverage than control plots. The Advanced Farmer Practice gave better foliage coverage in non-spray plots than in the control.

Table 7. BADC Percent foliage coverage of two processing varieties cultivated at Kashimpur and Domar BADC farm at 60 DAS.

Treatment	Kashimpur BADC farm				Domar BADC farm			
	Spray plots		Non-spray plots		Spray plots		Non-spray plots	
	Asterix	Courage	Asterix	Courage	Asterix	Courage	Asterix	Courage
T0	66.66de	56.66fg	60.00ef	50.00g	70.00c	63.33c	71.66c	68.33c
T1	90.00a	88.33ab	71.66cd	80.00bc	86.66ab	76.66bc	71.67c	73.33bc
T2	91.66a	83.33abc	88.33ab	73.33cd	91.66a	76.66bc	76.66bc	73.33bc
LSD	9.69				13.80			
CV	7.63				10.87			

Values with the same letters within rows and columns are not significantly ($p < 0.05$) different. Here, T1: BADC Practice, T2: Advanced Farmer's (Munshigonj) Practice, T0: Control.

At the Kashimpur BADC Farm, the highest number of tubers per hill, which

refers to the number of potatoes produced by a single plant, of 6.53 of Asterix and 6.07 of Courage were found in the BADC practice treatment in spray plots, a significant increase in crop yield. This was statistically significant compared to other treatments (Table 8). Similar trends were also observed in the Domar Farm regarding the number of tubers per hill in spray plots (Table 8). In the non-spray plot of the Kashimpur BADC Farm, the utmost number of tubers of 5.93 per hill of Courage was found in the Advanced Farmer Practice, followed by 5.60 of both Asterix and Courage in the BADC Practice, which was significant compared to control (Table 8). Similar trends were observed in the Domar BADC Farm regarding the number of tubers per hill in non-spray plots where Advanced Farmer Practices performed better (Table 8).

Table 8. Number of tubers per hill of two processing varieties cultivated at Kashimpur and Domar BADC farm.

Treatment	Kashimpur BADC farm				Domar BADC farm			
	Spray plots		Non-spray plots		Spray plots		Non-spray plots	
	Asterix	Courage	Asterix	Courage	Asterix	Courage	Asterix	Courage
T0	4.00d	4.40d	4.20d	4.06d	3.50e	3.93de	3.40e	4.10de
T1	6.53a	6.06a	5.60abc	5.66abc	7.13a	6.40abc	4.70cde	4.53de
T2	4.66cd	5.73ab	4.73bcd	5.93ab	5.26bcd	6.60ab	4.80cde	5.26bcd
LSD	1.033				1.63			
CV	11.88				19.11			

Values with the same letters within rows and columns are not significantly ($p < 0.05$) different. Here, T1: BADC Practice, T2: Advanced Farmer's (Munshigonj) Practice, T0: Control.

3.2.2. Plot-Wise Yield of A & B Grade Tubers, Yield of over and under Grade Tuber

At the Kashimpur BADC farm, the highest yield (kg) per plot of A-grade seed was achieved in the sprayed plot of Asterix in the Advanced Farmer Practices (Table 9). Similarly, the maximum B grade of 8.99kg per plot of variety Courage was found in the BADC practice on the sprayed treatment, which was highly significant compared to the control (Table 9). In the Domar BADC farm (Table 9), the maximum A grade seed of 9.12 kg per plot and 8.57 kg per plot of variety Asterix were recorded in the sprayed plots of Advanced Farmer Practice and BADC practice treatments, respectively. These results underscore the effectiveness of the sprayed plots in both treatments. In the case of Courage, the highest 8.18 kg per plot was obtained in the sprayed plot of BADC practices, further emphasizing the positive impact of this practice. The maximum B grade seed of 11.23 kg per plot was found in the sprayed plot of BADC practice, followed by 9.42 and 9.3 kg per plot of non-sprayed and sprayed treatment, respectively, in Advanced Farmer Practices (Table 10). The non-sprayed control had the lowest A and B-graded seed (Table 9, Table 10).

Table 9. Yield per plot (kg) of A and B-grade tubers of two processing varieties cultivated at Kashimpur and Domar BADC farm.

Treatment	Kashimpur BADC farm				Domar BADC farm			
	Spray plots		Non-spray plots		Spray plots		Non-spray plots	
	Asterix	Courage	Asterix	Courage	Asterix	Courage	Asterix	Courage
T0	2.98bc	3.59abc	3.21abc	4.33ab	6.99abc	4.63d	4.80cd	5.23cd
T1	3.16abc	2.46c	2.81bc	2.87bc	7.97ab	8.99a	6.63bcd	8.61ab
T2	4.36ab	3.02bc	3.78ab	4.72a	6.83abcd	5.37cd	6.67bcd	6.86abcd
LSD	1.61				2.27			
CV	27.45				20.23			

Values with the same letters within rows and columns are not significantly ($p < 0.05$) different. Here, T1: BADC Practice, T2: Advanced Farmer's (Munshigonj) Practice, T0: Control.

Table 10. Yield per plot (kg) of A and B grade tubers of two processing varieties cultivated at Kashimpur and Domar BADC farm.

Treatment	Kashimpur BADC farm				Domar BADC farm			
	Spray plots		Non-spray plots		Spray plots		Non-spray plots	
	Asterix	Courage	Asterix	Courage	Asterix	Courage	Asterix	Courage
T0	6.45bcd	5.35d	6.26cd	5.28d	4.33ef	3.10fg	1.01h	1.88gh
T1	8.56ab	8.18ab	7.75abc	7.55abc	11.23a	8.10bc	2.48fgh	5.40de
T2	9.11a	7.93abc	7.70abc	6.46bcd	7.20 cd	9.31ab	6.83cd	9.41ab
LSD	2.16				1.99			
CV	17.81				20.13			

Values with the same letters within rows and columns are not significantly ($p < 0.05$) different. Here, T1: BADC Practice, T2: Advanced Farmer's (Munshigonj) Practice, T0: Control.

At the Kashimpur BADC farm, the maximum over-graded seed (1.86 kg/plot) was recorded in the variety Courage of sprayed plots in the Advanced Farmer Practices (Table 11). Similarly, the maximum under-grade seed was found in the non-sprayed control treatment at Kashimpur BADC farm (Table 11). We could not find any over-graded Asterix seed in the non-sprayed plots of Advanced Farmer Practices. Similarly, there was no over-graded seed of Asterix and of Courage non-sprayed plots of BADC practices and sprayed plot Advanced Farmer Practices at Domar BADC farm (Table 12). Over-graded seeds of both potato varieties were absent in control treatment at Domar BADC farm. In the case of under-grade seed, non-sprayed plots gave a maximum of 1.28 kg /plot of Asterix in BADC practice, 1.12 kg per plot of Asterix in Advanced Farmer Practice, and 1.15 kg per plot of Courage in control (Table 12).

Table 11. Yield per plot (kg) of over and under-grade tubers of two processing varieties cultivated at Kashimpur and Domar BADC farm.

Treatment	Kashimpur BADC farm				Domar BADC farm			
	Spray plots		Non-spray plots		Spray plots		Non-spray plots	
	Asterix	Courage	Asterix	Courage	Asterix	Courage	Asterix	Courage
T0	0.63a-d	0.28cd	0.33cd	0.37bcd	0.28bc	0.23ab	0.20bc	0.59a
T1	1.63ab	1.37abc	0.86a-d	0.57bcd	0.31bc	0.10 c	0.14b	0.19b
T2	0.33cd	1.86a	0.00cd	0.40bcd	0.33abc	0.30 ab	0.37ab	0.21bc
LSD	1.27				0.276			
CV	91.14				61.01			

Values with the same letters within rows and columns are not significantly ($p < 0.05$) different. Here, T1: BADC Practice, T2: Advanced Farmer's (Munshigonj) Practice, T0: Control.

Table 12. Yield per plot (kg) of over and under-grade tubers of two processing varieties cultivated at Kashimpur and Domar BADC farm.

Treatment	Kashimpur BADC farm				Domar BADC farm			
	Spray plots		Non-spray plots		Spray plots		Non-spray plots	
	Asterix	Courage	Asterix	Courage	Asterix	Courage	Asterix	Courage
T0	0.00b	0.00b	0.00b	0.00b	0.66ab	1.04ab	0.97ab	1.15ab
T1	0.66ab	0.26ab	0.00b	0.05b	0.91ab	0.61b	1.28a	0.56b
T2	0.41ab	0.00b	0.04b	0.96a	0.75ab	0.66ab	1.11ab	0.68ab
LSD	0.812				0.617			
CV	215				45.60			

Values with the same letters within rows and columns are not significantly ($p < 0.05$) different. Here, T1: BADC Practice, T2: Advanced Farmer's (Munshigonj) Practice, T0: Control.

3.2.3. Total Yield (tons/ha)

The findings from the Kashimpur BADC farm, where the highest yield of 22.06 tons/ha and 21.96 tan/ha for Asterix and Courage, respectively, were found in sprayed plots of BADC practices, could potentially revolutionize our farming practices (Table 13). The maximum yield of 23.26 tons/ha was recorded in the non-sprayed plot of variety Courage in the Advanced Farmer Practices, a result that could lead to significant improvements in our farming methods (Table 13). The yield was remarkably high in the Domar BADC farm compared to the Kashimpur BADC farm, suggesting the possibility of identifying even more productive potato-growing regions in our country (Table 13). In the Domar BADC farm, the utmost yield of 37.47 tons/ha of variety Asterix was found in sprayed plots of BADC practice, a result that could potentially boost potato yields across

the country (Table 13). In the non-sprayed plot (Table 13), the higher yield (31.80 kg/ha) of variety Courage was found in Advanced Farmer Practice, followed by 28.22 kg/ha of Asterix in the same treatment (T2).

Table 13. Total yield (tons/ha) of two processing varieties at Kashimpur and Domar BADC farm.

Treatment	Kashimpur BADC farm				Domar BADC farm			
	Spray plots		Non-spray plots		Spray plots		Non-spray plots	
	Asterix	Courage	Asterix	Courage	Asterix	Courage	Asterix	Courage
T0	18.17cd	14.79ef	13.99f	18.09cd	19.97cd	16.01de	14.12e	14.15e
T1	22.06ab	21.95abc	17.64cde	20.72abc	37.47a	29.33b	19.66cd	23.23c
T2	20.41abc	15.92def	19.29bc	23.26a	32.94ab	31.33b	28.22b	31.80b
LSD	3.17				4.91			
CV	9.86				11.68			

Values with the same letters within rows and columns are not significantly ($p < 0.05$) different. Here, T1: BADC Practice, T2: Advanced Farmer's (Munshigonj) Practice, T0: Control.

3.2.4. Percent Disease (PVY & PLRV) Incidence

We found that there was no viral disease incidence on spray plots of various Asterix, both under BADC practice and control. However, a 0.67% viral disease incidence was observed on spray plots of Asterix under Advanced Farmer's practice (Table 14). This suggests that the choice of farming practice can significantly impact disease incidence. In the non-spray plot, viral diseases of potato variety Asterix were consistently prevalent in all treatments, indicating the importance of disease control measures. Similarly, for Courage, our findings were intriguing. We could not detect any viral diseases on spray plots of advanced farmer practices, but the rest of the treatments showed viral disease prevalence in both spray and non-spray plots at 45 DAS. At 60 DAS, we found disease prevalence in all treatments, with a trend of higher disease incidence in non-spray plots compared to spray plots. The highest disease incidence (8.67%) was found in non-spray of control plants, and the lowest (0.33%) was in spray plots of BADC practice (Table 14).

3.2.5. Cost and Return Analysis of Potato Cultivation

The result revealed that the cost of production per kg potato was Tk. 8.26 in BADC Practice, whereas Tk. 10.40 was in Advanced Farmer's Practice (Table 15). The net income from the BADC practice was Tk. 214665.00 per ha but Tk. 154948.00 per ha in Advanced Farmer's practice. The benefit-cost ratio (BCR) of BADC practice was 2.18, whereas 1.72 for Advanced Farmer's practice indicates BADC practice is the best-integrated practice for higher yield of potatoes and return of income (Table 15).

Table 14. Percent disease (PVY & PLRV) incidence (DAS-ELISA test) of two processing varieties cultivated at Kashimpur BADC farm.

Treatments		Disease incidence (%) at 45 DAS		Disease incidence (%) at 60 DAS	
		Asterix	Courage	Asterix	Courage
T0: Control	Spray	0.00c	1.67abc	0.67de	1.83b-e
	Non-Spray	1.00abc	1.83ab	3.00b-e	8.67a
T1: BADC Practice	Spray	0.00c	0.33bc	0.33e	1.67b-e
	Non-Spray	1.00abc	0.33bc	2.17b-e	3.50bcd
T2: Advanced Farmer's Practice	Spray	0.67abc	0.00c	1.33cde	0.33e
	Non-Spray	2.17a	1.83ab	4.67abc	5.33ab

Values with the same letters within rows and columns are not significantly ($p < 0.05$) different.

Table 15. Cost and return analysis of potato cultivation followed by BADC and Advanced Farmer's Practice (Munshigonj).

Items		Unit price	BADC practice		Advanced farmer's practice	
A. Material Cost		Tk/kg	Quantity (Kg/ha)	Cost (TK/ha)	Quantity (Kg/ha)	Cost (TK/ha)
1.	Seed	35.00	1580.00	55300.00	1697.60	58786.00
2.	Cowdung/FYM	0.50	1800.00	900.00	1700.00	850.00
3.	Fertilizer					
	a. Urea	16.00	300.00	4800.00	625.00	10000.00
	b. TSP	22.00	200.00	4400.00	750.00	16500.00
	c. Mop	15.00	300.00	4500.00	500.00	7500.00
	d. Gypsum	10.00	100.00	1000.00	100.00	1000.00
	e. Magnesium	45.00	100.00	4500.00	100.00	4500.00
	f. Zinc	35.00	10.00	350.00	10.00	350.00
	g. Boron/Borax	280.00	2.50	700.00	8.00	1200.00
4.	Mulching (straw)					9342.00
5.	pesticide			3830.00		1480.00
6.	Irrigation cost			1976 .00		2476.00
	Sub Total (1 + 2 + 3 + 4 + 5 + 6)			82256.00		113984.00
B. Land preparation Cost (1 + 2)				4250.00		5100.00
1.	Tractor			3400.00		4250.00
2.	Bullock pair			850.00		850.00

Continued

C. Human Labour (Inter-culture operation)	250.00	326 man days	81500.00	311 man days	77750.00
D. Other nominal Cost			14427.00		15616.00
1. Rental value of Land			7410.00		7410.00
2. Interest in working capital			7017.00		8206.00
Total cost of cultivation (A + B + C + D)			182433.00		212450.00
Per kg cost of production (Tk)			8.26		10.40
Gross income	18.00	22061.00	397098.00	20411.00	367398.00
Net income			214665.00		154948.00
Benefit Cost Ratio (BCR)			2.18		1.72

4. Discussion

The efficient use of nitrogen by plants depends mainly on the soil type, environmental condition, method of application, and the cultivators of these. Applying urea in splits at different times reduces nutrient loss (through volatilization, leaching, denitrification, etc.) and better responds to potato crops [14].

In the BADC practice, urea fertilizer @ 300 kg/ha was used where 50% as basal doses and 50% as top dressing at 30-35 days after sowing and found higher yield potato in case of variety Asterix. These results were consistent with earlier studies, which also found that split application of urea (50% basal + 50% top dressing in two installments at 30 and 50 DAS) was an effective way to avoid the detrimental effect of urea on plant emergence and to maximize the tuber yield in Bangladesh [15]. This reaffirms the superiority of the BADC practice in potato production.

In BADC practice, phosphorus @ 200 kg/ha murate of potash @ 300 kg/ha were applied in the potato field, resulting in the maximum plant height, early tuberization, number of stems per hill, number of tubers per hill, tuber weight per hill and the higher yield (34.93 tons/ha). Singh and Lal [16] reported the maximum yield of 39.83 ton/ha was obtained when N and K were applied @ 225 kg/ha and 150 kg K_2O/ha compared to control (14 - 36 tons/ha) without N and K. Hopkins and Ellsworth [17] cited that phosphorus application at the recommended rate (227 kg/ha) resulted in significant yield and quality increases. Singh [18] noted that the maximum tuber yield of 50.3 tons/ha was obtained due to N @ 240, P_2O_5 @ 240, K_2O @ 240, and Mg @ 48 kg/ha. Besides, the highest tuber yield was observed when compost was used in combination with NPK compared to control [19]. Nutrient supply was found to be positively correlated with the protein and starch contents of tuber [20].

In the BADC practice, gypsum @ 100 kg/ha, zinc sulfate @ 10 kg/ha, magnesium sulfate @ 100 kg/ha, and solobor @ 2.5 l/ha were used to supply sufficient micronutrients in the soil. The research findings revealed that 97% of tubers of

variety Asterix, which belong to grade A, grade B, and over-grade, were produced. This indicates the high quality of the tubers. Micronutrients—zinc, boron, sulfur, and magnesium not only increase potato yield but also improve potato tubers' quality. Earlier results suggested that the combination of micronutrients such as N, P, K, S, Mg, Zn, and Northern organic or Chook Chook or Cowdung plus mustard oil cake was found to be suitable to produce potato varieties Asterix and Courage [12]. Similarly, the highest tuber weight and yield per hectare were reported where optimum chemical and organic manure doses were applied [8] [10] [11] [21].

The BADC-developed practice was also found to produce a higher proportion of storable tubers in both potato processing varieties (data not presented). Considering all the parameters, BADC practice was superior to all other treatments, and it was recommended that it be disseminated at farmer levels to have a higher yield with minimum fertilizer input.

The present study compared the outcomes of the superior management practice (BADC Practice) from the previous four experiments with the currently adopted Advanced Farmer's (Munshiganj) Practice. The critical parameters for quality seed potato production were considered, and data was taken on different dates in the growing period of the potato crop. In Kashimpur Farm, there was no difference in plant height between BADC and advanced farmer's practice, although Asterix's higher plant height was found in advanced farmer practices. The highest numbers of stems per hill in both the processing varieties were observed in BADC Practice. There was enough spacing between rows and between plants within rows in BADC practice, which might have enhanced the number of stems per hill. In the percentage of foliage coverage, the highest foliage coverage was observed in Advanced Farmer's Practice compared to BADC practice, possibly due to the dense plant population. The number of tubers per hill was higher in BADC Practice than in other treatments. These could be due to the higher number of stems/hills in BADC practice. Tuber yield per hill and tuber yield per plot were higher in BADC practice than treatment-T2 and control. When the yield per plot was converted to yield (ton)/ha, potato production was also higher in BADC practice compared to T2 and control.

In the case of grading of tubers, a higher proportion of A grade (28 - 40 mm) tubers was observed in Advanced Farmer's Practice, which was the outcome of a higher number of potato plants per unit area compared to BADC Practice. On the other hand, the proportion of A- and B-grade tubers in BADC practice was average, which increased yield. The production of higher quantities of A and B-grade tubers increases seed quantity and quality. In the non-spray plot, the yield of A-grade and B-grade tubers was lower in number in both the industrial potato varieties than in spray plots. We observed higher disease incidence (PVY and PLRV) and insect prevalence in non-spray plots compared to spray plots, resulting in lower yield. Our study observed a higher quantity of non-seed in Advanced Farmer's practice than in BADC practice. When the tuber yield per

plot was converted to tuber yield (tons/ha), we found a higher tuber yield in BADC than in Advanced Farmer's practice.

In the BADC practice, the net return per ha was Tk. 214665.00, whereas a net return of Tk. 154948.00 in Advanced (Munshigonj) farmer practice. The difference between the two practices was Tk. 59717.00/ha; the benefit-cost ratio (BCR) of BADC practice was 2.18, whereas 1.72 in Advanced practice indicates that farmers in the Munshigonj region are misusing nationally valuable fertilizer. A previous survey revealed that potato production was a lucrative business, the net return amount was found BDT Tk. 109415.49 per hectare in selected areas of Munshiganj district and BCR was found at 1.78 and 1.75 [1].

5. Conclusion

Our findings demonstrate the economic benefits of adopting the BADC practice. Considering all the above parameters, BADC is the best practice for potato production with minimal fertilizer input, providing a practical solution for farmers to increase their net return.

Conflicts of Interest

The authors declared that there are no conflicts of interest about the publication of this paper.

References

[1] Mukul, A.Z.A. and Parvin, M.M. (2021) Profitability Analysis of Potato Cultivation: A Study in Munshiganj District of Bangladesh. *International Journal of Business, Management and Social Research*, **11**, 595-601.

[2] Food and Agricultural Organization (2015) FAO Production Yearbook.

[3] BBS (2023) Yearbook of Agricultural Statistics of Bangladesh. Bureau of Statistics, Statistical Division, Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka.

[4] Swaminathan, M.S. (2000) Potato for Global Security. In: Khurana, S.M.P., Shekhawat, G.S. and Pandey, S.K., Eds., *Potato Global Research and Development*, Indian Potato Assoc., 8-12.

[5] Bansal, S.K. and Trehan, S.P. (2011) Effects of Potassium on Yield and Processing Quality Attributes of Potato. *Karnataka Journal of Agricultural Sciences*, **24**, 48-54.

[6] Taheri, N., Sharif-Abad, H.H., Yousefi, K. and Mousavi, S.R. (2012) Effect of Compost and Animal Manure with Phosphorus and Zinc Fertilizer on Yield of Seed Potatoes. *Journal of Soil Science and Plant Nutrition*, **12**, 705-714. https://doi.org/10.4067/S0718-95162012005000026

[7] Zelalem, A., Tekalign, T. and Nigussie, D. (2009) Response of Potato (*Solanum tuberosum* L.) to Different Rates of Nitrogen and Phosphorus Fertilization on Vertisols at Debre Berhan, in the Central Highlands of Ethiopia. *African Journal of Plant Science*, **3**, 16-24.

[8] Bhujel, S., Pant, C. and Sapkota, S. (2021) Effect of Organic and Chemical Fertilizer on Growth and Yield of Potato (*Solanum tuberosum*) Varieties in Nepal. *SAARC Journal of Agriculture*, **19**, 103-112. https://doi.org/10.3329/sja.v19i1.54782

[9] Bari, M.S., Rabbani, M. G., Rahman, M.S., Islam, M.J. and Hoque, A.T.M.R. (2001) Effect of Zinc, Boron, Sulphur and Magnesium on the Growth and Yield of Potato. *Pakistan Journal of Biological Sciences*, **4**, 1090-1093. https://doi.org/10.3923/pjbs.2001.1090.1093

[10] Boke, S. (2014) Effect of Organic and Inorganic Fertilizer Application and Seedbed Preparation on Potato Yield and Soil Properties on Alisols of Chencha. *International Journal of Natural Sciences Research*, **2**, 123-132.

[11] Karangwa, A., Ndungutse, V., Fashaho, A., Habimana, S., Manirere, J.D.A., Nsengimana, V., Mulinga, N., Imanishimwe, C. and Nyagatare, G. (2023) Influence of Organic and Inorganic Fertilizers on Growth and Yield of Potato (*Solanum tuberosum* L.) in Nyabihu District of Rwanda. *Potato Journal*, **50**, 196-203.

[12] Hoque, A., Sikder, M**.** and Khair, A. (2024) Effect of Inorganic and Organic Fertilizers on Growth and Yield of Two Industrial Potato Varieties (Asterix and Courage) in Bangladesh. *American Journal of Plant Sciences*, **15**, 292-305. https://doi.org/10.4236/ajps.2024.154021

[13] Clark, M.F. and Adams, A.N. (1977) Characteristics of the Microplate Method of Enzyme-Linked Immunosorbent Assay for the Detection of Plant Viruses. *Journal of General Virology*, **34**, 475-483. https://doi.org/10.1099/0022-1317-34-3-475

[14] Sharma, S.P. and Shekhar, J. (1989) Effect of Split Application of Nitrogen on Yield of Potato. *The Indian Journal of Agricultural Sciences*, **59**, 737-739.

[15] Chowdhury, M.R.I., Sarwar, A.K.M.G. and Farooque, A.M. (2002) Effect of Different Methods of Urea Application on Growth and Yield in Potato. *Asian Journal of Plant Sciences*, **1**, 672-674. https://doi.org/10.3923/ajps.2002.672.674

[16] Singh, S.K. and Lal, S.S. (2012) Effect of Potassium Nutrition on Potato, Yield, Quality, and Nutrient Use Efficiency under Varied Levels of Nitrogen Application. *Potato Journal*, **39**, 155-165.

[17] Hopkins, B.G., Horneck, D.A., Pavek, M. J., Geary, B.D., Olsen, N.L., Ellsworth, J.W., Newberry, G.D., Miller, J.S., Thornton, R.E. and Harding, G.W. (2007) Evaluation of Potato Production Best Management Practices. *American Journal of Potato Research*, **84**, 19-27. https://doi.org/10.1007/BF02986295

[18] Singh, S.K. and Gupta, V.K. (2005) Influence of Farm Yard, Nitrogen and Bio-Fertilizer on Growth, Tuber Yield of Potato under Rain-Fed Condition in East Khasi Hill District of Meghalaya. *Agricultural Science Digest*, **25**, 281-283.

[19] Atanaw, T. and Zewide, I. (2021) Fertility Management of on Potato (*Solunum tuberosum* L.) Crop. Research and Reviews. *Journal of Crop Science and Technology*, **10**, 33-46.

[20] Islam, M.R. and B.S. Nahar. (2012) Effect of Organic Farming on Nutrient Uptake and Quality of Potato. *Journal of Environmental Science and Natural Resources*, **5**, 219-224. https://doi.org/10.3329/jesnr.v5i2.14818

[21] Kumar, A., Kumar, D., Kumar, S., Dwivedi, D.K., Dash, SS. and Kumar, M. (2023) Effect of Organic and Inorganic Fertilizers on Growth and Yield of Potato (*Solanum tuberosum* L.) in Northern Bihar. *The Pharma Innovation Journal*, **12**, 419-423.