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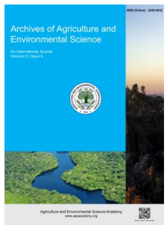

ORIGINAL RESEARCH ARTICLE

Effect of technological interventions on yield gap analysis and profitability of winter onion (*Allium cepa* L.) varieties

M. A. Khan[1], M. M. Haque[2], M.A. Islam[3], R. Sarker[4] and M. M. Rahman[4*]

[1]Principal Scientific Officer, Spices Research Sub-Centre, Bangladesh Agricultural Research Institute, Faridpur - 7800, Bangladesh
[2]Principal Scientific Officer, Regional Spices Research Centre, Bangladesh Agricultural Research Institute, Gazipur, Bangladesh
[3]Principal Scientific Officer, Spices Research Centre, Bangladesh Agricultural Research Institute, Bogura, Bangladesh
[4]Scientific Officer, Spices Research Sub-Centre, Bangladesh Agricultural Research Institute, Faridpur - 7800, Bangladesh
[*]Corresponding author's E-mail: musfiqur.bari@gmail.com

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ABSTRACT

The present study was conducted in growing onion through front line demonstrations (FLDs) by Spices Research Sub-Centre, Bangladesh Agricultural Research Institute, Faridpur, Bangladesh during winter season of 2023-2024. The experiment was set up at five farmers' fields under five villages such as Ramchandrapur, Bajarkandi, Bisnudia, Chilarkandi and Narasinghdia of Faridpur district. Under the present investigation, two high yielding recent varieties (BARI Piaz-4 and BARI Piaz-6) with improved management practices was intervened to exhibit its performance, to find out yield gaps and to assess profitability of onion. A local variety with farmers' traditional practices was grown (as check) adjacent to the demonstration plot. The study revealed a large average yield gap (5.33 t/ha). The demonstration variety produced higher average yield (20.01 t/ha) as compared to the local variety (16.67 t/ha). The average demonstration yield was 19.97% higher than that of local variety. The technology gap and extension gap had higher in BARI Piaz-4 (2.22 & 3.66 t/ha) as compared to those of BARI Piaz-6 (1.76 & 3.01 t/ha), respectively. The technology index of BARI Piaz-4 and BARI Piaz-6 were 9.65 and 8.38%, respectively. Lower technology index proves the strength of new technology with recommended package of practices. Adoption index value of BARI Piaz-6 was higher (77.78%) than that of BARI Piaz-4 (66.66%). The demonstration varieties performed also better over control based on the quality parameters. Demonstration variety gave higher average gross return (Tk. 927770 ≅ $7731), net return (Tk. 690110 ≅ $5751) and benefit-cost ratio (3.90) over local variety (Tk. 707000 ≅ $5892, Tk. 463450 ≅ $3862 & 2.90), respectively. Considering yield, quality and profitability; farmers expressed their satisfaction to the performance of BARI Piaz-4 and BARI Piaz-6 with improved management practices. But farmers preferred BARI Piaz-6 over BARI Piaz-4 based on quality and market price of onions.

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INTRODUCTION

Onion (*Allium cepa* L.) is a member of the family Alliacea grown throughout the world including Bangladesh. It is one of the most important spice crops popularly known as 'piaz' in the country. Among the spice crops, onion ranks first in Bangladesh based on the daily intake (35-40 g/day/person) and production as well. The total area for onion production in the country is about 2.04 lakh hectare, which produces about 25.47 lakh metric tons per annum and the average yield is very low, being 12.51 t/ha (BBS, 2024) as compared to Indian onion yield, being 16.34 t/ha (DAFW, 2023). The production of the country does not fulfill country's demand. To fulfill this demand, the government of Bangladesh imports around 9 lakhs metric tons' onions & shallots per year expensing hard earned foreign currency about 4 lakh crore Tk. (BBS, 2024). Bangladesh Agricultural Research Institute (BARI) has released improved onion varieties to growers. Among the varieties, BARI Piaz-4 and BARI Piaz-6 are more recent ones that have high potential in yield, being 23 and 21 t/ha, respectively (BARI, 2020). On the other hand, local variety is low yielder cultivated by farmers. Considering the country's average yield of 12.51 t/ha, the yield gap of onion in Bangladesh is about 8-10 t/ha. It is learnt that indicator-13 of Sustainable Development Goals (SDGs) aims to decrease crop yield gap. Main cause of low yield is due to uses of local variety (having admixture substandard seeds) with traditional growing practices adopted by farmers. The reason for non-adoption of improved management technologies is mainly inadequate and inappropriate extension activities. Demonstration is one of the most important tools for directly transfer of technologies at grass root level (Tiwari *et al*., 2020). The onion growers have keen desire to receive improved varieties and scientific management technologies as most of the farmers use conventional practices in growing onions. Hence, Spices research Sub-Centre, BARI, Faridpur, Bangladesh deserved the interventions on growing onions with recent improved varieties (BARI Piaz-4 and BARI Piaz-6) and improved management technologies as compared to local variety with farmers' traditional practices through front line demonstrations. Therefore, the present experiment was conducted to exhibit the performance of high yielding varieties along with improved management practices; to find out yield gaps and to assess profitability of onion under the FLDs.

MATERIALS AND METHODS

The front line demonstrations (FLDs) study was conducted for growing onion bulbs by Spices Research Sub-Centre, Bangladesh Agricultural Research Institute, Faridpur, Bangladesh during winter season of 2023-2024. The experiment was carried out at five farmers' fields under five villages (Ramchandrapur, Bajarkandi, Bisnudia, Chilarkandi and Narasinghdia) of Faridpur Sadar, Faridpur district. Under the investigation, two high yielding recent varieties (BARI Piaz-4 and BARI Piaz-6) along with improved management practices (Table 1) were intervened to exhibit its performance, to find out yield gaps and to assess profitability of onion. A local variety (admixture substandard seeds) with farmers' traditional practices was grown for comparison as check (control), shown in the Table 1. The varieties BARI Piaz-4 and BARI Piaz-6 were transplanted side by side with local variety. Before establishment of the experiment, all selected farmers were trained up on the improved management technologies in growing onion. Farmers who established the demonstrations were considered as replication. Each demonstration and control plot were comprised of 33 decimals.

Soil properties of Experimental plots

The experimental site belongs to Agro Ecological Zone-12 (AEZ-12, Low Ganges River Floodplain). The soils of five experimental plots were characterized by texturally clay loam, 7.0-7.5 p^H, 1.40 -1.85% organic matter, 0.41-0.58 meq/100 g K, 0.10-0.13% total N, 9.7-11.2 mg/g soil P, 12.1-14.2 mg/g soil S and 0.31-0.39 mg/g soil B. Among the crops grown in the area, onion is predominantly cultivated as irrigated crop.

Table 1. Technology details for the study of onion through FLDs.

S. No.	Practice	Technology for onion cultivation	
		Demonstrated improved technology	**Farmers' traditional practice**
1.	Variety	BARI Piaz-4 and BARI Piaz-6	Local variety (locally available and admixture substandard seeds)
2.	Seeds treatment	Treating seeds with Provax 200 WP @ 2.5g/kg seeds	No treatment of onion seeds
3.	Seedling size	More or less uniform and thickened seedlings	Admixture of thinned and thickened seedlings
4.	Treatment of seedling roots	Treating by immersing seedlings roots in Rovral 50 WP solution @ 2g/litre of water for one hour	No treatment of seedling roots
5.	Fertilizer management	Organic manure: Kazi organic fertilizer1000 kg/ha Chemical fertilizer: NPKSBZn: @ 120 (from urea), 50 (from TSP), 85, 40, 1.5 and 5kg/ha, respectively	Organic manure: No incorporation of organic manure Chemical fertilizer: NPKSBZn: @ 165 (121 from urea & 44 from DAP), 164 (50 from TSP & 114 from DAP), 157, 45, 0.75 and 5.40kg/ha, respectively
6.	Irrigation management	Irrigation application at transplanting of seedling, 25 and 45 days after transplanting.	Irrigation application at transplanting of seedling, 25 and 65 days after transplanting.
7.	Weed management	Pre-emergence application of pendimethalin 33 EC @ 330g a.i/litre solution in wet soil @ 2 l/ha 5 days before transplanting of seedlings + post-emergence spray of Quizalofop P-ethyl 15% EC solution @ 0.5 l/ha 20 days after transplanting + two hand weedings at 45 & 65 days after transplanting of seedings	Pre-emergence application of pendimethalin 33 EC @ 330g a.i/litre solution in wet soil @ 2 l/ha 5 days before transplanting of seedlings + post-emergence spray of Quizalofop P-ethyl 15% EC solution @ 0.5 l/ha 20 days after transplanting + two hand weedings at 30 & 50 days after transplanting of seedings
8.	Disease and insect management	For diseases: 6 times alternate spray (15 days interval) of Rovral 50 WP (Iprodione, @ 2g/litre of water), Amistar Top 325 SC (Azoxystrobin + Difenoconazole, @ 1ml/litre of water), Luna Sensation 50 SC (Fluopiram + Trifloxystrobin, @ 1ml/litre of water) at 15 days interval For insects: Spraying of imidacloprid (Imitaf 20 SL) solution @0.5 ml/litre of water 60, 70 and 80 days after transplanting	For diseases: 12 times alternate spray (7-8 days interval) of Rovral 50 WP (Iprodione, @ 2g/litre of water), Amistar Top 325 SC (Azoxystrobin + Difenoconazole, @ 1ml/litre of water), Luna Sensation 50 SC (Fluopiram + Trifloxystrobin, @ 1ml/litre of water) at 15 days interval. For insects: Spraying of imidacloprid (Imitaf 20 SL) solution @0.5 ml/litre of water 60, 70 and 80 days after transplanting
9.	Nematode management	Application of nematicide: Carbofuran 5g (Corfuran) @ 30kg/ha	No application of nematicide

Management practices

Forty-day old seedlings were transplanted on 20 December 2023 with a spacing of 11-12 cm x 7-8 cm. Before transplanting, one third of seedlings tops was cut with knife. In case of demonstration technology, the sources of organic manure, N, P, K, S, B and Zn were Kazi organic fertilizer, urea, triple super phosphate (TSP), muriate of potash (MOP), gypsum, solubor boron (Bingo) and zinc sulphate (Grozin), respectively. Entire quantity of organic manure was added during land preparation but entire quantity of TSP, MOP, gypsum, solubor boron (Bingo), zinc sulphate (Grozin) and one third of urea were incorporated at final land preparation. The rest of urea was added in two equal splits at 25 and 45 days after transplanting of seedlings. In regards to farmers' fertilizer management, no organic manure was applied in the field. Farmers used N from two sources i.e., urea and diammonium phosphate (DAP). Phosphorus also was applied from two sources by farmers i. e. TSP and DAP. The rates of N from urea and DAP were 121 and 44 kg/ha, respectively. However, the rates of P from TSP and DAP were 50 and 114 kg/ha, respectively. Farmers used their K, S, B and Zn from the sources of MOP, gypsum, solubor boron (Bingo) and zinc sulphate (Grozin), respectively. Entire quantity of TSP, MOP, gypsum, solubor, zinc sulphate, half of urea and half of DAP were incorporated at final land preparation. The rest of urea and DAP were added at 25 and 65 days after seedling transplanting. Except package of practices, all other intercultural operations were done timely. The bulbs were harvested on 27 March 2024.

Data recorded

The data were recorded on input used, yield, quality parameters and production cost. Yield gaps, technology gap, extension gap, technology index and adoption index were calculated as suggested by Kumari *et al.* (2022), Jogi (2021), Tiwari *et al.* (2020), Karabhantanal *et al.* (2015) and Van Ittersum *et al.* (2013):

Yield gap = Potential yield - Farmers' yield (control)

Technology gap = Potential yield - Demonstration yield

Extension gap = Demonstration yield – Farmers' yield (control)

Percent increase in yield = {(Demonstration yield – Farmer's yield)/Farmer's yield} × 100

Technology index = {(Potential yield - Demonstration yield)/ Potential yield} × 100

The lower the value of the index, higher the level of adoption of technology. The adoption of technology in front line demonstrations was studied through technology index.

Adoption index = {(Adoption score by respondent)/ (Possible maximum score)} × 100

Technology adoption = {(Adoption index of demonstration variety - Adoption index of control variety)/ (Adoption index of control variety)} × 100

Profitability analysis was also done. Cost, return and cost-benefit ratio (BCR) were calculated based on the market price of all the applied inputs and wholesale price of the produce prevailed during the study of demonstrations.

RESULTS AND DISCUSSION

Yield gap

In this study, a big average yield gap (5.33 t/ha) was found between the potential yield of demonstration variety (22 t/ha) and local variety (16.67 t/ha) under FLDs (Table 2). However, higher yield gap was observed (5.88 t/ha) between the variety BARI Piaz-4 (23 t/ha) and the local variety (17.12 t/ha). Probable reasons for yield gap in onion might be due to lack of improved variety, inadequate access to quality seeds, poor soil health & fertility management, inappropriate irrigation systems, pest & disease pressure, unpredictable weather, lack of modern farming techniques, limited extension service, farmers' improper knowledge on modern technologies etc. These results are in line with those of Kumari *et al.* (2022) who found a large yield gap in onion.

Technology gap

On an average, a 1.99 t/ha of technology gap was found under the FLDs (Table 2). Between the two varieties, comparatively BARI Piaz-4 had higher technology gap (2.22 t/ha). Several factors might be responsible for failing to touch potential yield by the demonstration variety such as inadequate soil preparation, inconsistent watering practices, unwell local climate, inadequate spacing or planting depth/time, suboptimal nutri-pest/weed management, inadequate farmers' training etc. The present result corroborates the findings of Kishor *et al.* (2020) who found that the demonstration variety remained behind to touch its potential yield. Technology gap indicates researchable issues for realization of potential yield (Joshi *et al.*, 2014). Singh *et al.* (2011) suggested that more location specific recommendation and precise use of technology would be followed in the fields to bridge the technology gap.

Extension gap

The result in the Table 2 exhibited that the average extension gap was 3.34 t/ha. The extension gap could be due to inadequate knowledge on improved scientific technologies and high yielding varieties with standard quality of seeds. Higher extension gap (3.66 t/ha) was recorded in BARI Piaz-4 and lower (3.01 t/ha) in BARI Piaz-6. The demonstration variety gave higher average yield (20.01 t/ha) under scientific interventions of FLDs as compared to traditional farmers' practices (16.67 t/ha). The average demonstration yield was 19.97% higher than that of control. The present result agrees with the finding of OFRD (2023) and Kishor *et al.* (2020). Farmers' practices including excess fertilizer doses (NPK @ 205:125:100 kg/ha) reduced the productivity of onion yield, as stated by OFRD (2023).

Table 2. Potential yield, demonstration yield, yield gap, technology gap and extension gap of onion through FLDs.

Variety	Potential yield (kg/ha)	Demonstration yield (t/ha)		Yield gap (t/ha)	Yield increases over control (%)	Technology gap (t/ha)	Extension gap (t/ha)
		Demo	Control				
BARI Piaz-4	23	20.78	17.12	5.88	21.38	2.22	3.66
BARI Piaz-6	21	19.24	16.23	4.77	18.55	1.76	3.01
Average	22	20.01	16.67	5.33	19.97	1.99	3.34

Table 3. Quality characteristics influenced by onion varieties through FLDs.

S. No.	Quality parameters	Variety			LSD (0.05)	Level of sig.
		BARI Piaz-4	BARI Piaz- 6	Local variety		
1.	Days to maturity (days)	113.12	110.93	112.85	-	NS
2.	Single bulb weight (g)	32.89	31.04	25.94	1.420	**
3.	Shape of bulb	Torpedo	Flat globe	Admixture of torpedo and flat globe	-	-
4.	Color of bulb	Red	Nearly bronze red (attractive to farmers)	Variegated	-	-
5.	Uniformity of bulb	Uniform	Uniform	Non-uniform	-	-
6.	Split bulb (%)	9.68	8.38	18.71	1.722	**
7.	Bolting (%)	10.48	12.63	40.25	6.511	**
8.	Bulb dry matter (%)	16.26	16.68	17.42	0.791	*
9.	TSS of bulb (°brix)	15.95	16.08	17.14	-	NS
10.	Disease reaction (0-5 scale)	2.32	2.10	2.22	-	NS
11.	Thrips reaction (0-5 scale)	2.50	2.33	2.45	-	NS
12.	Market preference of onion	Moderate price	Higher price	Lower price	-	-

Note: TSS-Total soluble solid, ** Significant at the 1% level of significance, * Significant at the 5% level of significance and NS-Not significant

Kishor *et al.* (2020) also found higher yield from the demonstration variety over local variety. Between two varieties BARI Piaz-4 produced higher yield (20.78 t/ha) than BARI Piaz-6 (19.24 t/ha). Under the trial, BARI Piaz-4 and BARI Piaz-6 gave 21.38% and 18.55% higher productivity than those of control, respectively. The variation in bulb yield between varieties could be attributed due to genetic potential of the varieties. In regards to scientific intervention, undoubtedly a package of improved management practices (treatment of seeds & seedling roots, use of uniformity thickened seedlings, use of organic manure & optimum chemical fertilizer, timely application of irrigation and appropriate weeds & pests management) along with high yielding varieties applied in the FLD plot involved in augmenting the yield of onion bulbs. Treating the seeds with fungicides produced healthy seedlings and treating the seedlings roots with fungal solution kept plants comparatively free from diseases and thus these treatments boosted the plants for quick and good establishment by minimizing fungal diseases in the field. Nematicide reduced the damage of roots. Pre-emergence application of weedicide might be suppressed emergence of different weeds which reduced the crop-weed competition to a great extent and thus this assisted in faster growth of plant resulted in higher bulb yield. Timely and alternate spray of different fungicides reduced the diseases on plant. On the other hand, farmers produced onion seeds of different varieties simultaneously in the same field without proper scientific managements. These were mainly admixture substandard seeds and the seeds consisted of a heterogeneous material. Hence, these seeds reduced yield and quality of bulbs. Besides traditional practices, used by farmers in control plot, also reduced the yield of bulb. In farmer's practices, application of irrigation and nitrogen either from urea or di ammonium phosphate (DAP) at 60-65 days after transplanting reduced bulb size and yield of onion due to increased vegetative growth and root growth instead of bulb development. Besides, excess rates of nitrogen and phosphorus in farmer's practices could be reduced yield. This result also concurs with those of Teggelli *et al.* (2015). They explained that the progressive use of improved crop production technologies with high yielding variety would be subsequently changed the alarming trend of galloping extension gap. Extension gap implies what can be achieved by the transfer of existing technologies (Joshi *et al.*, 2014).

Quality of onions

The data in the Table 3 depicted that varieties showed significant influence on quality characteristics of onion in the FLDs except days to maturity of bulb, TSS content and pest reaction. The quality differences between demonstration variety and local variety were due to various factors such as genetic uniformity/diversity, maturity time, bulb shape & size, splitting & bolting behavior, disease and pest reaction, dry matter & TSS content, color of bulb etc. These results are in agreement with the findings of Khan *et al.* (2024) who found variation among the varieties on the quality characters of onion. The incidence of disease was ranged from 2.10 to 2.32. While the incidence of thrips was varied from 2.33 to 2.50. In the present experiment, farmers applied pesticides two times more than that of the FLDs. On the contrary, Karabhantanal *et al.* (2015) found significant variation on the incidence of diseases and thrips between the FLDs and farmers' practices. They stated that the severity of diseases and pests in check plot (farmers' practices) could be due to fact that many farmers have a tendency to use pesticides indiscriminately at higher dose, it might had caused pest outbreak in check plot.

Table 4. Technology index, adoption index and technology adoption of onion varieties through FLDs.

Variety	Technology index (%)	Adoption score by respondent		Possible maximum score	Adoption index (%)		Technology adoption (%)
		Demo	Control		Demo	Control	Increase over control
BARI Piaz-4	9.65	6	2	9	66.66	22.22	200.00
BARI Piaz-6	8.38	7	2	9	77.78	22.22	250.05
Average	9.02	6.5	2	9	72.22	22.22	225.02

Table 5. Profitability analysis of onion production through FLDs (Tk./ha).

Variety	Yield (kg/ha)		Cost of cultivation (A)		Gross returns (B)		Net returns (B-A)		BCR (B/A)	
	Demo	Control	Demo	Control	Demo	Control	Demo	Control	Demo	Control
BARI Piaz-4	20780	18120	237660 ($1980)	243550 ($20296)	893540 ($7446)	724800 ($6040)	655880 ($5466)	481250 ($4010)	3.76	2.97
BARI Piaz-6	19240	17230	237660 ($1980)	243550 ($20296)	962000 ($8017)	689200 ($5743)	724340 ($6036)	445650 ($3714)	4.05	2.83
Average	20010	17675	237660 ($1980)	243550 ($20296)	927770 ($7731)	707000 ($5892)	690110 ($5751)	463450 ($3862)	3.90	2.90

Note: Approximately equal values in US dollar were shown in the parenthesis.

Technology index

The Table 4 showed that average technology index of two varieties had 9.02%. The lower technology index value might be due to appropriate use of scientific application in the onion field. Higher technology index (9.65%) was obtained from BARI Piaz-4 and lower technology index (8.38%) was observed from BARI Piaz-6. The similar finding was also published by Jogi (2021). Lower technology index proves the strength of new technology with recommended package of practices, as stated by Jogi (2021). Technology index revealed the feasibility of the demonstration technologies (Joshi *et al*., 2014).

Adoption index

The number of scientific technologies under the study was 9 (Table 1). Among scientific technologies, farmers received 7 technologies (serial no. 1, 2, 3, 4, 5, 6 and 9) after completion of FLDs. But they had a stand on their weed and pest management (serial no. 7 and 8, Table 1) even farmers used fungicides 12 times during crop duration. The study revealed (Table 4) that average adoption index was maximum in demonstration plot (77.22%) as compared to control plot (22.22%). The probable causes for higher adoption index at the demonstration varieties might be due to timely intervention of improved management technologies, proper training of farmers and regular monitoring & advices on scientific technologies etc. The adoption index value of BARI Piaz-6 (77.78%) was higher than that of BARI Piaz-4 (66.66%). The result is in conformity with those of Rajput *et al.* (2018) who found varietal variation in adoption index and they also recorded higher adoption index in FLDs as compared to control. In addition, higher technology adoption was recorded at BARI Piaz-6 (250.05%). Average adoption index increased 225.02% over the control.

Profitability analysis

The data showed (Table 5) that local variety had higher cost of cultivation (Tk. 2435500 ▯ $20296) as compared to that of demonstration variety (Tk. 237660 ≅ $1980). Higher cost of cultivation in local variety was due to excessive use of chemical fertilizers and pesticides. The production cost between the varieties was similar one (Tk. 237660 ≅ $1980). Average maximum gross return (Tk. 927770 ≅ $7731) was calculated in demonstration variety as compared to local variety (Tk. 707000 ≅ $5892). Higher average gross returns were due to obtaining higher bulb yields in demonstration variety over control variety. The result supports the earlier findings of Hiremath and Nagraju (2010). Instead of higher yield in BARI Piaz-4, the gross return of BARI Piaz-6 (Tk. 962000 ≅ $8017) was higher to that of BARI Piaz-4 (893540 ≅ $7446). The higher gross return in BARI Piaz-6 was due to visible bulb quality (bronze red color, round & flat shape bulb) but BARI Piaz-4 exhibited red in color and torpedo shape bulb. Here it is noted that farmers in Bangladesh generally prefer bronze red and round-flat shaped onion over red and torpedo shaped onion. On an average, higher net return (Tk. 690110 ≅ $5751) was obtained in demonstration variety while lower net return (Tk. 463450 ≅ $3862) was observed at local variety. Comparatively BARI Piaz-6 had maximum net return (Tk. 724340 ≅ $6036) over BARI Piaz-4 (Tk. 655880 ≅ $5466). Maximum average benefit-cost ratio (BCR) was recorded at demonstration variety with the package of scientific technologies (3.90) and minimum BCR (2.90) was observed at local variety with farmers' traditional practice.

Conclusion

Based on the front line demonstrations (FLDs) a large average yield gap (6.32 t/ha) was found between demonstration variety (24 t/ha) and farmers' variety (17.68 t/ha). Considering the yield, quality and profitability of onion; farmers expressed their satisfaction to the performance of BARI Piaz-4 and BARI Piaz-6 with improved management technologies. But farmers preferred BARI Piaz-6 over BARI Piaz-4 based on quality and market price of onions.

DECLARATIONS

Author contribution statement

Conceptualization: M.A.K.; Methodology: M.A.K. and M.M.R.; Software and validation: M.A.K, and M.M.R.; Formal analysis and investigation: M.A.K, M.M.H., M.A.I., R.S. and M.M.R.; Resources: M.A.K.; Data curation: M.A.K; Writing—original draft preparation: M.A.K; Writing—review and editing: M.A.K, M.M.H., M.A.I., R.S. and M.M.R.; Visualization: M.A.K.; Supervision: M.A.K.; Project administration: M.A.K. and M.M.R; Funding acquisition: M.A.K, M.M.H., M.A.I., R.S. and M.M.R. All authors have read and agreed to the published version of the manuscript.

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