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MICRONUTRIENT FERTILIZER QUALITY IN BANGLADESH

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Abstract

Micronutrient fertilizer marketing policy is not subjected to regulation in the way that macronutrient fertilizers are in Bangladesh. The present study investigated quality of 512 zinc (Zn) and 286 boron (B) fertilizers at field level in selected areas from 2018 to 2022. Fertilizer samples were collected and analyzed following standard protocols. Results revealed that most of the zinc fertilizers and a notable number of boron fertilizers were non-compliant to the specification of Bangladesh Government. About 97% of zinc sulfate monohydrate were non-compliant with the standard where 13% of them contained <1% Zn, 20% contained 1-5% Zn, 26% were close to the standard (>30% Zn) and only 3% complied with the standard. About 69% of zinc sulfate heptahydrate were non-compliant including 15% that contained <1% Zn, 18% contained 1-5% Zn, while 31% were compliant to the standard. Among zinc chelate fertilizers, 53% were compliant but the quality was highly variable among different sampling locations. It was observed that about 19% of boron containing solubor was non-compliant, while 42% of boric acid, fertilizer was non-compliant. The findings visualized poor qualities of zinc and boron fertilizers used by the farmers in Bangladesh which might have serious negative impacts on crop production. Government initiative is urged for immediate action for improving qualities of micronutrient fertilizers. This may be achieved by the Government through strict control during micronutrient production, import and marketing.

Keywords: Adulteration, Fertilizer quality audit, Nutrient concentration, Zinc fertilizers, Boron fertilizers

1. Introduction

Micronutrient deficiency is one of the emerging challenges to food and nutritional security particularly in developing countries (Bell and Dell, 2008). There is a growing realization of the merits of a food-based approach for addressing this issue. Micronutrients are essential for most living organisms, including humans who need a supply of 16 mineral microelements, which can be obtained through a balanced diet (Brog *et al.,* 2009). Current estimates suggested that almost half of the world population suffers from mineral deficiencies, primarily

of iron and zinc. The Copenhagen Consensus (2008) ranks the alleviation of iron and zinc deficiencies as a top priority (Copenhagen Consensus, 2008). Bio-fortification with micronutrients in edible parts of crop can be achieved by utilizing crop and soil management (Zuo and Zhang, 2011). Rice feeds almost 50-58% of the world's population (Zeng *et al.,* 2010), but it is considerably deficient in micronutrients (Bouis and Welch, 2010). Therefore, even a small increase in the nutritive value of rice can be highly significant for human nutrition (Zhang *et al.,* 2012).

Bangladesh agriculture has made an outstanding achievement in food sufficiency. Even in the midst of the Covid-19 pandemic and made a significant contribution to the country's food security. High yielding varieties, hybrids and high value crops have been introduced to its agriculture. Bangladesh agriculture has been passing through a transition from subsistence farming to commercial agriculture. Crop production and cropping intensity increased several times during the last three decades. It is apprehended that there creates a chance of nutrient depletion in terms of nutrient mining. Farmers are mostly using macronutrient fertilizers like urea, triple superphosphate (TSP), di-ammonium phosphate (DAP), muriate of potash (MoP) and gypsum. On the other hand, there is very little or no use of micronutrient fertilizers like zinc (Zn) and boron (B). One possible reason for low use of Zn and B fertilizer is lack of confidence in fertilizer quality by farmers. A long-term study finding of Soil Resource Development Institute (SRDI) showed that low to very low soil Zn status in soils increased from 28.7% to 78.8% in arable land from 2010 to 2020 in Bangladesh and in case of boron (B) it was increased from 26% to 30.8% in arable land area in the same period (Hasan *et al.,* 2020). Add some information about Zn also Boron is a limiting factor in crop productivity in rice-based cropping system (Farooq *et al.,* 2018). Various soil factors including pH, organic matter, clay minerals, sesquioxides (Fe and Al oxides), carbonates, and tillage significantly influence the plant availability to B, the content of soil extractable B, and different B fractions transformations in soil (Jin *et al.,* 1987, Tsalidas *et al.,* 1994, Yermiyahu, 1995).

The aim of the present study was to perform a quality audit of fertilizer used by farmers as fertilizer adulteration might one of the causes for yield loss and lack of farmers' confidence in fertilizer application. The fertilizer recommendations from NARS and FRG were based on pure and appropriate concentration of N, P, K, S, Zn and B; however, adulterated fertilizers might not provide expected results to the farmers, thus the farmers would deprive of the satisfactory yield of a crop and farmers had to buy and apply more fertilizers to their field for yield maximization. Moreover, continuous application of adulterated fertilizers might have played adverse effect on soil nutrient balance which affected soil health. Quality of fertilizers played an important role to ensure desirable crop yield as well as crop quality. It is important to ensure the quality of fertilizers at field level before establishment of crops in the selected cropping patterns for efficient nutrient management in the project hub areas and analyze the samples to verify the nutrient concentrations in fertilizers. It would also help on policy

guidelines to ensure quality fertilizer at field level. Considering the above perspectives, SRDI, performed the fertilizer quality audit in representative localities and determined the nutrient content of different company's micronutrient fertilizers available in markets accessed by farmers.

2. Materials and Methods

The Soil Resource Development Institute (SRDI) conducted a study to determine the nutrient content of different fertilizers that were applied by the farmers by the support of Nutrient Management for diversified in Bangladesh (NUMAN) Project. In 2018 to 2019, SRDI analysed macronutrient fertilizer samples (urea, TSP, DAP, MoP, Gypsum, Magnesium sulphate) and micronutrient fertilizers (Zinc sulphate monohydrate, Zinc sulphate heptahydrate, Chelated zinc; solubor boron, boric acid) collected from six localities and determined the nutrient and heavy metal concentrations. The fertilizer quality study findings in 2018 and 2019, showed that urea, TSP, DAP and MoP were of high quality (compliant to Government specifications) as well as were low-cost fertilizer like gypsum. So, no further quality audits of those macronutrient fertilizers were conducted. On the other hand, micronutrient fertilizers continued to be sampled in the 3rd year to 5th year. Samples were identified by different marketing companies. In the 5th year, Damuddya of Shoriatpur district and Saidpur of Nilphamari district were included in the study area. The fertilizers samples were collected from Mymensingh, Thakurgaon, Gudagari, Durgapur, Saidpur and Damuddya hub areas before Rabi season in January as more micronutrient fertilizers were used in rabi crops. On the other hand, from Dacope of Khulna district and Amtali of Barguna district fertilizer samples were collected before Kharif season in July-August where more fertilizers were used in Kharif season. On the basis of availability of the micronutrient fertilizer in the local market, neighbouring the fertilizer samples were collected along with trade names, pack size, unit price and address of the marketing companies. From 2018 to 2022 a total of 918 fertilizer samples (Urea-24; TSP-24; DAP-24; MoP-24; Gypsum-24; Zinc sulphate monohydrate-244; Zinc sulphate heptahydrate-72; Chelated zinc- 196; solubor boron- 170 and boric acid-116) were collected. Fertilizer sample collection was done following the 'Fertilizer Inspection Manual 2003' approved by the Government of the People's Republic of Bangladesh. Collected micronutrient fertilizer samples were analysed following the standard procedure 'Manual for Fertilizer Analysis, 2003' approved by the Government of the People's Republic of Bangladesh. MS excel software was used for statistical analysis.

3. Result & Discussion

3.1 Macronutrient fertilizers quality

The key macronutrient fertilizers, Urea, TSP, DAP, MoP and Gypsum, were collected from six localities during 2018-2019 where sample size was equal. A total of 120 macronutrient fertilizers sample were collected (Table 1).

Table 1. Numbers of macronutrient fertilizer samples collected from six localities during 2018-2019

Localities	Urea	Triple superphosphate	Di-ammonium phosphate	Muriate of potash	Gypsum
Mymensingh	4	4	4	4	4
Thakurgaon	4	4	4	4	4
Durgapur	4	4	4	4	4
Godgari	4	4	4	4	4
Dacope	4	4	4	4	4
Amtali	4	4	4	4	4
Total	24	24	24	24	24

All of the urea, TSP, DAP, MoP fertilizer samples were fully compliant with their government-approved specifications. Of the gypsum samples 96% were standard while 1 out of 24 collected was non-compliant. It is notable that in Bangladesh production, import and maintaining quality of urea, TSP, DAP, MoP fertilizers are regulated by different Government organizations. Therefore, the adulteration of macronutrient fertilizer was almost absent. It is suspected that sometimes dolomite or calcite are sold as gypsum by misbranding or mis-bagging which explains the low frequency of non-compliant gypsum (Table 2).

Table 2. Macronutrient fertilizer quality in the six-hub area during 2018-2019

Fertilizer	Total	Standard	Adulterated
Urea	24	24	0
Triple superphosphate	24	24	0
Di-ammonium phosphate	24	24	0
Muriate of potash	24	24	0
Gypsum	24	23	1
Total	120	119	1

3.2 Micronutrient fertilizer quality

Among the micronutrient fertilizers available at farmer level, Zn sulphate monohydrate, Zn sulphate heptahydrate, Chelated Zn, Solubor B and boric acid were collected from eight localities during 2018 to 2022. Micronutrient fertilizer samples were collected on the basis of the availability during the study period. Therefore, the sample size was inconsistent among the hub areas (Table 3).

Table 3. Numbers of micronutrient fertilizer samples collected from eight localities during 2018-2022

Localities	Zinc sulfate monohydrate	Zinc sulfate heptahydrate	Chelated -Zn	Solubor	Boric acid
Mymensingh	48	09	36	33	22
Thakurgaon	41	16	42	49	24
Durgapur	49	10	35	24	17
Godgari	40	14	35	29	17
Dacope	26	05	21	13	13
Amtali	21	04	15	08	11
Damuddya	11	07	03	04	03
Saidpur	08	07	09	10	09
Total	244	72	196	170	116

3.2.1 Zinc sulfate monohydrate

During 2018-2022, SRDI collected 244 Zn sulfate monohydrate samples from 90 marketing company from the study localities. Out of 244, Zn sulfate monohydrate fertilizer samples, 33% sample contained only 0-5% Zn, while 26% zinc sulfate monohydrate fertilizer samples contained 30-35% Zn. Only 3% samples maintained the Government minimum requirements which is 36.0% Zn and 17.5% S, respectively (Table 4). There was no consistency in the Zn and S content in Zn sulfate monohydrate fertilizer samples. Zinc sulfate monohydrate fertilizers were non-complaint not only in the shortage of Zn and S but also excessive presence of undesirable toxic heavy metal like lead, cadmium and nickel. The maximum allowable limit of unwanted heavy metal, like 100 mg lead (Pb) /kg, 10 mg cadmium (Cd) /kg, 500 mg chromium /kg (Cr) and 50mg Nickel (Ni) /kg, respectively. It was found that 19% Zn sulfate monohydrate samples contained above the maximum allowable limit of Cd with concentrations ranging from 11 mg/kg – 251 mg/kg. In case of Pb, 2 % Zn sulfate monohydrate samples contained above the maximum allowable limit with ranges from 107 mg/kg – 184 mg/kg and in case of Ni, 11 % of Zn sulfate monohydrate samples contained above the maximum allowable limit with ranges from 52 mg/kg – 1420 mg/kg (Table 5). It might be concluded that 97% of Zn sulfate monohydrate fertilizers were adulterated to some degrees. The adulteration trend of Zn sulfate monohydrate fertilizers was almost unchanged throughout the study period (Fig. 1).

Notwithstanding the overall findings, some micronutrient fertilizer companies like Cingenta Bangladesh Ltd, Pesticide unit of square pharmaceuticals Ltd, Eon Agro Industries Ltd, Intefa, ACI fertilizer Ltd produced Zn sulfate monohydrate fertilizers that contained 30% to 33% Zn but some of their product failed to maintain consistency in its Zn content (Fig.2). It is suspected that micronutrient fertilizers from an unregistered company are re-branded as that from another company.

Table 4. Overall quality of Zinc sulfate mono hydrate fertilizer in the sampling localities during 2018-2022

Zinc concentration (%)	Fertilizer quantity	Fertilizer (%)
<1.0	31	13
1.0-5.0	50	20
5.1-10.0	7	3
10.1-15.0	8	3
15.1-20.0	14	6
20.1-25.0	23	10
25.1-30.0	39	16
30.1-35.0	64	26
>35.0	8	3
Total	244	100

Table 5. Heavy metal content in Zinc sulfate mono hydrate fertilizer in the sampling localities during 2018-2022

Heavy metal	Maximum allowable limit (MAL: mg/kg)	Heavy metal concentrations in fertilizer (mg/kg)	samples over the MAL (%)
Cadmium	10	11-251	19
Lead	100	107- 184	02
Nickel	50	52-1420	11
Chromium	500	<500	0

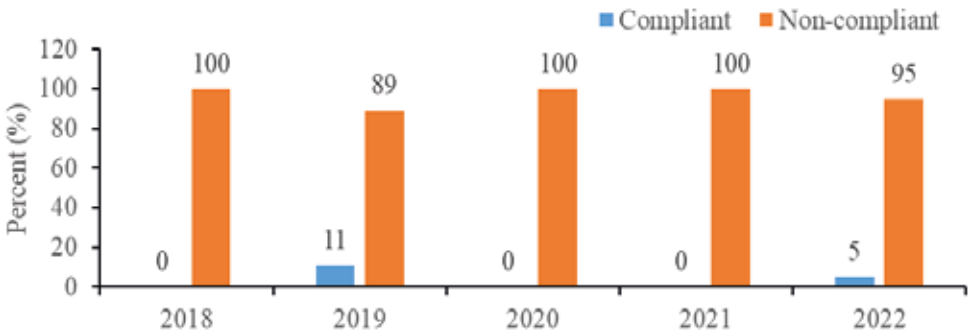

Fig. 1 Quality of zinc sulfate monohydrate during 2018 to 2022

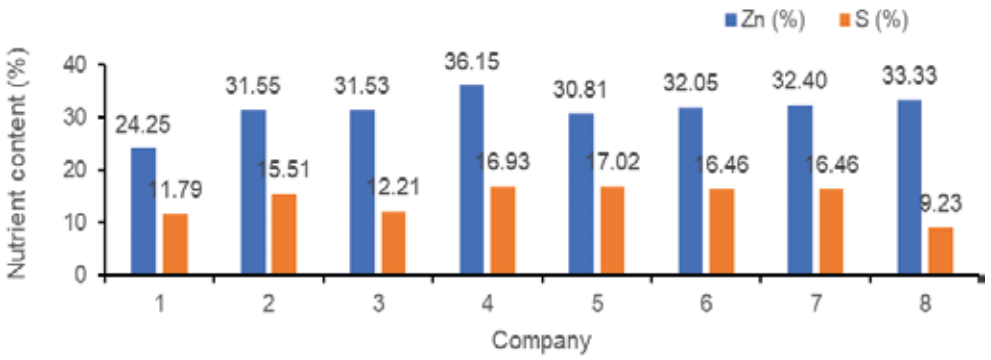

Fig. 2 Inconsistent zinc sulfate monohydrate fertilizer quality from eight companies during 2018 to 2022.

3.2.2 Zinc sulfate heptahydrate

A total of 72 Zn sulfate heptahydrate fertilizer samples were collected during the study period comprising products from 31 marketing companies. Among the Zn sulfate heptahydrate fertilizers, 31% were complaint with more than 20 % Zn while 33% of samples contained only 0-5% Zn (Table 6). The Government specification for Zn sulphate heptahydrate fertilizer is a minimum of 21% Zn and 10.5% S, respectively. In addition to the lack of a desirable amount of Zn and S concentration, undesirable toxic heavy metal like cadmium (Cd), nickel (Ni) and chromium (Cr) exceeded the allowable limit. Overall, 21% of Zn sulfate heptahydrate samples contained above the maximum allowable limit of Cd with ranges from 14.3 mg/kg – 47.7 mg/kg. Lead concentrations were all within the maximum allowable limit. For Ni, 10 % of Zn sulfate heptahydrate samples contained above the maximum allowable limit with concentrations ranging from 51.3 mg/kg – 150 mg/kg. Chromium concentration was much higher than the maximum allowable limit in only one sample that contained 4043 mg/kg where the maximum allowable limit was 500 mg/kg (Table 7). It was concluded that 31% of Zn sulfate heptahydrate fertilizer samples were complaint while 69 % were non-complaint due to different degrees of adulteration. It was observed that the adulteration trend of Zinc sulfate heptahydrate fertilizers declined over time (Fig. 3). During the last two years, Zn sulfate heptahydrate fertilizers had a crystalline appearance. Government of Bangladesh made some changes in the physical specification of Zn sulfate heptahydrate fertilizer. In the earlier specification there was no physical properties mentioned for this fertilizer. It is not easy to make a low-grade crystalline Zn sulfate heptahydrate fertilizer hence the changed specification appears to have improved the quality of this fertilizer.

Table 6. Overall zinc sulfate heptahydrate fertilizer quality in the study area during 2018-2022

Zinc concentration (%)	Sample number collected	% of samples
<1.0	12	15
1.0-5.0	13	18
5.1-10.0	1	1
10.1-15.0	11	15
15.1-19.99	14	20
>20.0	22	31
Total	72	100

Table 7. Heavy metal content in Zinc sulfate mono hydrate fertilizer in the hub area during 2018-2022

Heavy metal	Maximum allowable limit (MAL: mg/kg)	Heavy metal content (mg/kg)	Samples above the MAL (%)
Cadmium	10	14.3- 47.7	21
Lead	100	<100	0
Nickel	50	51.3-150	10
Chromium	500	4043	1

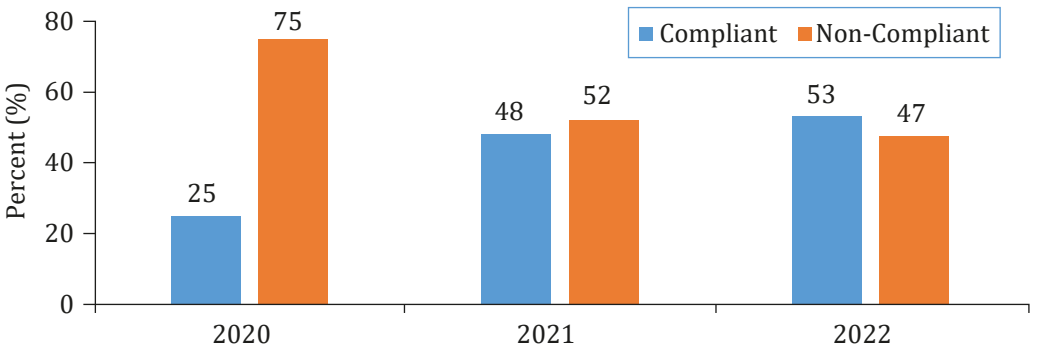

Fig. 3 Quality of zinc sulfate heptahydrate during 2020 to 2022

3.2.3 Chelated zinc

A total of 196 chelated zinc samples were collected from six localities during 2018- 2022. There were the products from 91 companies. The highest percent of compliant chelated zinc fertilizer were found at Damuddya (100%) while the lowest percent were collected at Godagari (46%). At Durgapur, Mymensingh, and Thakurgaon, the percent of compliant chelated Zn products was 54%, 53% and 48%, respectively. The Government specification for Chelated zinc fertilizer is a minimum of 10% while S will be absent. Some chelated zinc fertilizer samples contained more than 10% Zn but the presence of undesirable S in the sample indicated they were adulterated. Among the non-complaint chelated Zn products, those which contained 47 % Chelated zinc also contained S while the rest were

noncompliant due to inadequate Zn and 1% of chelated Zn fertilizers contained unwanted Cd at levels that exceeded the maximum allowable limit. It is established that Sulfur is a plant immobile nutrient element when it is present in Chelated zinc it restricts the easy mobility of Zn as well as reduced its use efficiency. Finally, it might be concluded that 53% chelated zinc fertilizers were found complaint and rest 47% were non- complaint marked in the eight-hub area (Table 8).

Out of 91 companies marketing chelated Zn fertilizer in the study areas very few companies like Square Pharmaceuticals Ltd, Sea Trade Fertilizer company marketed consistently compliant quality Chelated Zn fertilizers. For most of company's product, quality was inconsistent varying from compliant for some samples or non-compliant in others. This inconsistency was observed among the study areas and also among the study periods. Some company's chelated Zn fertilizers were devoid of Zn. In 2018-2019 it was observed that the purity percent was higher when the sampling intensity increased, but the percent of non-complaint Chelated Zn fertilizers increased. It was observed that 51% cases the noncompliance of Zinc chelate happened due to the absence of Zn at desirable level and 47 % cases happened due to the presence of undesirable S (Fig. 4). During 2021 and 2022 the sampling intensity was increased where 52% and 47 % Chelated Zn were found non-complaint, respectively (Fig. 5).

Table 8. Overall quality of Chelated zinc fertilizers in eight localities during 2018-2022

Hub	Compliant Sample	Non-compliant sample	Total	Compliant (%)	Non-compliant (%)
Mymensingh	19	17	36	53	47
Thakurgaon	20	22	42	48	52
Durgapur	19	16	35	54	46
Godagari	17	18	35	46	54
Dacope	14	07	21	67	23
Amtali	10	05	15	67	23
Damuddya	03	0	03	100	0
Saidpur	05	04	09	56	44
Total	107	89	196	53	47

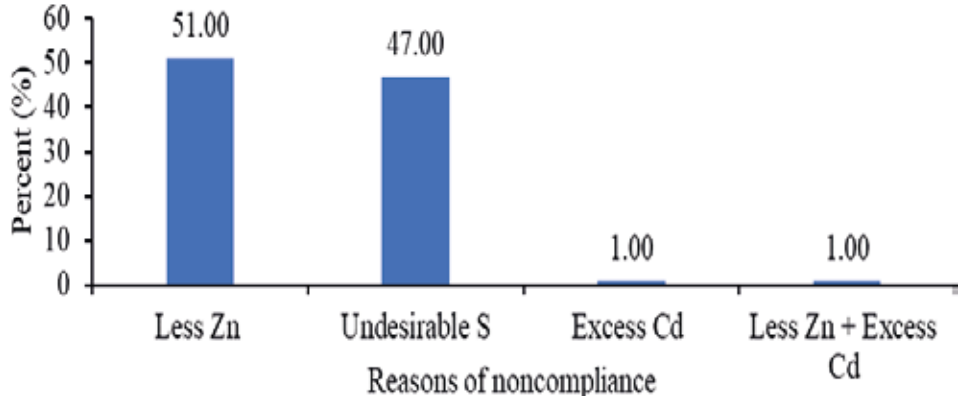

Fig. 4 Adulteration causes of chelated zinc fertilizer

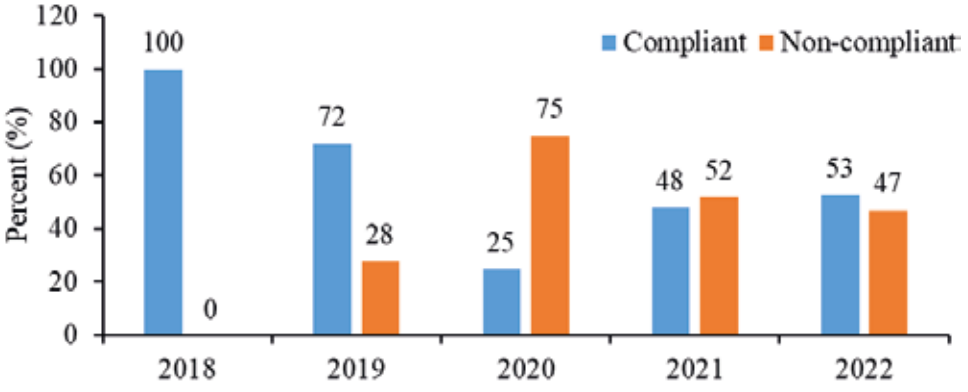

Fig. 5 Quality of chelated zinc marketed during 2018 to 2022

Table 9. Overall solubor boron fertilizer quality in different hub area during 2018-2022

Hub area	Compliant sample	Non-compliant sample	Total Sample	Compliant (%)	Non-compliant (%)
Mymensingh	29	04	33	88	12
Thakurgaon	36	13	49	73	27
Durgapur	18	06	24	75	25
Gudagari	25	04	29	86	14
Dacope	10	03	13	77	23
Amtali	06	02	08	75	25
Damuddya	04	0	4	100	0
Saidpur	10	0	10	100	0
Total	138	32	170	81	19

Table 10. Percentage of Solubor fertilizer samples according to range of boron concentration

Boron concentration (%)	Sample number	% of samples
0.0	24	14
1.0-2.0	2	1
8..0-14.0	2	1
16.0-18.0	5	3
>20.00	137	81
Total	170	100

3.2.4 Solubor boron

A total of 170 solubor boron fertilizer samples were collected from eight localities during the study period and these were the products of 36 fertilizer marketing companies. The highest percent of compliant Solubor B was found at Damuddya and Saidpur (100%) while the lowest percent was observed at Thakurgaon (73%). The Government specification requires a minimum B concentration in Solubor boron of 20% B but 19% were non-complaint (Table 9). It was found that 81% Solubor boron contained more than 20% B while 14% of Solubor boron samples contained no B (Table 10).

3.2.5 Boric acid

A total of 116 boric acid fertilizer samples were collected from eight localities during 2018-2022 from 58 marketing companies (Table 3). Boron concentrations in boric acid fertilizers in different localities were highly variable. The highest percent of compliant boric acid was found at Saidpur (100%) while the lowest percent was observed at Dacope (38%). According to the Government specification, the minimum B concentration in boric acid is 17% B. Overall, 42% were non-complaint (Table 10) including 35% that contained no boron (Table 11). Some companies like Squire Pharmaceuticals, ACI fertilizer, Sea Trade Fertilizer Ltd. supplied in the sampled markets consistently quality boric acid irrespective of study period and localities.

Table 10. Overall boric acid fertilizer quality in the eight localities during 2018-2022

Hub	Compliant sample	Non-compliant sample	Total sample	Compliant (%)	Non-compliant (%)
Mymensingh	12	10	22	55	45
Thakurgaon	16	08	24	67	33
Durgapur	07	10	17	41	59
Godagari	07	10	17	41	59
Dacope	05	08	13	38	62
Amtali	09	02	11	82	18
Damuddya	02	1	3	67	33
Saidpur	09	0	9	100	0
Total	67	49	116	58	42

Table 11. Percent of boric acid fertilizers according to range of boron concentrations they contained

Boron concentrations (%)	Sample number	% of samples
0.0	41	35
12.0-13.0	03	3
14..0-16.0	05	4
>17.0	116	58

Presently, the Government of Bangladesh subsidies the cost to farmers of macronutrient fertilizers. In 2021-2022 fiscal year 5.6 million metric tons of fertilizer was eligible for the subsidy at a cost of 28 thousand crore Taka. These fertilizers are regulated for quality and the present survey in eight localities confirmed that all the macronutrient fertilizers were compliant to Government specifications in terms of nutrient concentrations. On the other hand, only 150,000 metric tons micronutrient fertilizers were produced, imported and marked by the private sector. While there are Government specifications for micronutrient fertilizers, there is no provision to enforce the specifications in products in the markets accessed by farmers. A large percentage of the Zn and B fertilizers sampled failed to meet the Government specifications. In some cases, the particular fertilizer contained none of the specified element. In other cases, when applied at the recommended rates to concentration in the fertilizer of Zn or B would be insufficient to alleviate a deficiency in the crop. Hence many farmers and spending money on products that cannot correct crop deficiencies.

One solution to the poor quality identified in this study is to apply similar regulation of quality to the micronutrient fertilizers as to macronutrient fertilizers, including the possibility of a subsidy on the cost of micronutrient fertilizers. Alternatively, the Government could take the stewardship in producing, importing and marketing micronutrient fertilizers through its own mechanism or channel without giving any subsidies to reduce the adulteration of micronutrient fertilizers. It is urgent for the sake of our soil health, farmers interest, food-based supplementation of micronutrients and ultimately for the safe and nutritious food production for the future of Bangladesh.

4. Conclusions

In the study area, macronutrient fertilizers (urea, TSP, DAP and MoP) sampled from markets where farmer purchase fertilizers were compliant with the standards. In the same localities among micronutrient fertilizers available in market for farmers to purchase, there was a high level of non-compliance with Government specifications. Most of the Zn sulfate monohydrate fertilizers (n=244) were non-compliant with the standard (97%), including 13 % that contained <1% Zn, 20 % that contained 1-5% Zn. While 26 % were close to the standard (i. e. > 30 % Zn), only 3% (i. e. 7 out of 244) fulfilled the Govt. minimum requirements. For Zn sulfate heptahydrate fertilizers, 69% were non-compliant with the standard including 15 % that contained <1% Zn and 18% contained 1-5% Zn. Both forms of

Zn sulfate fertilizers also contained excess Cd, Pb, Ni and Cr in some samples. Among zinc chelate fertilizers 53% were compliant but quality was highly variable among different localities. For solubor fertilizer only19% of samples were non-compliant. By contrast, 42 % of boric acid fertilizers were non-compliant. The quality of solubor boron and boric acid fertilizers were highly variable among different localities sampled.

Conflicts of Interest

The authors declare no conflict of interest

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