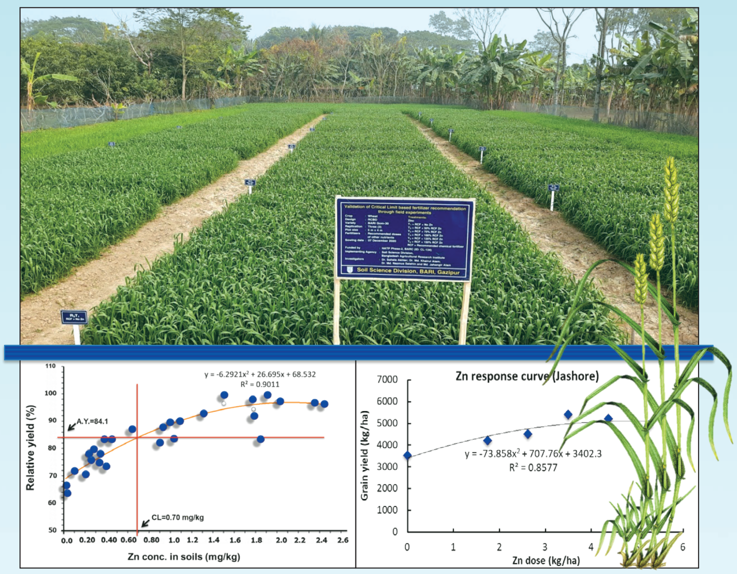
Sub-Project ID- 134

Program Based Research Grant (PBRG)

Sub-Project Completion Report
on
Determination of Critical Limit of Nutrients for Soils and Crops

Sub-Project Duration
March 2018 to February 2022



Coordinating Organization

Soils Unit

Natural Resources Management Division
Bangladesh Agricultural Research Council

Project Implementation Unit
National Agricultural Technology Program-Phase II Project
Bangladesh Agricultural Research Council
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Implementing Organization

Bangladesh Agricultural Research Institute

Bangladesh Rice Research Institute

Bangladesh Institute of Nuclear Agriculture

Bangladesh Agricultural University

Project Implementation Unit
National Agricultural Technology Program-Phase II Project
Bangladesh Agricultural Research Council
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Abbreviation and Acronyms

Abbreviations	**Elaborations**
AAS	Atomic Absorption Spectrophotometer
AEZ	Agro-ecological Zone
B	Boron
BADC	Bangladesh Agricultural Development Corporation
BARC	Bangladesh Agricultural Research Council
BARI	Bangladesh Agricultural Research Institute
BAU	Bangladesh Agricultural University
BINA	Bangladesh Institute of Nuclear Agriculture
BRRI	Bangladesh Rice Research Institute
CL	Critical Limit
Co-PI	Co-Principal Investigator
CRD	Completely Randomized Design
Cu	Copper
DAT	Days after transplanting
GM	Green manure
GoB	Government of Bangladesh
IFAD	International Fund for Agricultural Development
K	Potassium
KCl	Potassium chloride
Mg	Magnesium
NATP	National Agricultural Technology Program
N	Nitrogen
OC	Organic carbon
P	Phosphorus
PI	Principal Investigator
P.I. Stage	Panicle initiation stage
PBRG	Program Based Research Grant
PIU	Project Implementation Unit
RCBD	Randomized Complete Block Design
RDCF	Recommended chemical fertilizer
RDF	Recommended dose of fertilizer
SOM	Soil organic matter
SSD	Soil Science Division
STB	Soil test based
WB	World Bank
Zn	Zinc
$ZnSO_4$	Zinc sulphate

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Executive Summary

Critical limit (C.L.) refers to a threshold value of a nutrient in soil below which the crop will readily respond to its application. It varies with crops, soils and extraction methods. The present CLs used in the country are very old, which need updating. Soil factors, soil type, soil pH and soil organic matter are important in this regard, which undergoes changes over times. Hence, the situation justifies a need to determine and update the critical limit of different plant nutrients in order to formulate an optimum fertilizer dose for deficient nutrients for different crops and soils for achieving satisfactory yield. The Sub-project was formulated to delineate the nutrient status of calcareous, non-calcareous, piedmont and terrace soils; and to determine CLs of different nutrients for cereal, vegetables and oilseed crops; and their validation through field experiments. Originally, the Sub-project approved for about three and half years from March 2018 to June 2021 with a total cost of Tk. 3,28,61,110/-. Later on, the Sub-project was extended until February 2022 and the project cost was revised to Tk. 3,12,97,796/-. The Sub-project has been coordinated by BARC, and Soil Science Divisions of BARI, BRRI, BINA and BAU are working as implementing components. Twelve AEZs representing the major soil types of the country were selected for determining Critical Limits of different nutrients for different soils and crops. Work distribution among different components is as follows:

Organization	AEZ for delineation of soil nutrient status	Nutrient & crop for determination of Critical Limit	
		Nutrient	Crop
BARI	11, 13, 28	K and Zn	Wheat, maize and cabbage
BRRI	18, 19, 20	P, K, S and Zn	Rice
BINA	25, 26, 27	P and Mg	Maize and mustard
BAU	1, 3, 9	Mg, S and B	Wheat and mustard

A bench mark survey was conducted in the study areas to know the present nutrient and fertilizer use. For the purpose a total of 720 soil samples (4 components x 3 AEZs/component x 2 Upazilas/AEZ x 3 villages/Upazila x 10 spots/ village) were collected and analyzed for macro- (N, P, K, Ca, Mg & S) and micro- (Fe, Mn, Cu Zn & B) nutrients and basic soil characteristics like pH, organic matter and texture. Soils with different nutrient levels were identified in the selected AEZs and bulk soils were collected from the identified spots for pot experiments. For determining Critical Limit of a particular nutrient and crop, pot experiments were conducted using soils with different levels of that particular nutrient and crop. At least 20 soils from 20 locations were used for one nutrient, of which 12 soils were of low fertility level, 4 soils were of medium fertility level and the remaining 4 soils were of high fertility level of the particular nutrient. Pot trials were conducted in CRD during Rabi season 2019-20 and Kharif-I season 2020 with two treatments (with and without intended nutrient) and three replications. Sprouted seeds of the test crops were sown in the pot and the crop was harvested at 8-10 weeks after seeding. Dry matter (DM) yield was recorded and plant samples were analyzed for all elements. Critical limit for a particular nutrient and crop was determined by Cate and Nelson method (1965) and also by statistical approach developed by Waugh *et al.* (1973). The results were validated through field experiments at the farm level.

Each implementing organization collected 180 soil samples from their assigned locations *i.e.* a total of 720 soil samples were collected by the four implementing organizations following the sampling protocol as described in the Methodology chapter. GPS reading of soil sample collection points have been recorded. All the samples were analyzed for macro- (N, P, K, Ca, Mg & S) and micro- (Fe, Mn, Cu Zn & B) nutrients and basic soil characteristics like pH, organic matter, texture etc. The analytical data for different nutrients of all 720 soil samples were pooled together in an Excel sheet and sorted in ascending order. Soils having Low, Medium and High levels of the test nutrients were identified. Based on this analysis, locations for bulk soil collection for pot trials were selected. Soils for pot trials were collected from the selected locations by the respective component organizations. Critical limits of the nutrients were estimated from the results of pot trials by the respective organizations, which were validated with field experiments in the following cropping seasons. A total of 22 Critical Limits of different nutrients for different soils and crops were determined. The estimated critical limits compared to the present critical limits (as in FRG-2018) of different nutrients for different soils and cops are presented in the Table below.

Critical Limits of different crops and nutrients estimated by different component organization

Nutrient	Crop	Present CL (FRG-2018)	Estimated CL	Estimated by
Phosphorus	Rice	8.00 mg kg^{-1}	8.70 mg kg^{-1}	BRRI
	Maize (Rabi)	10 mg kg^{-1}	16.1 mg kg^{-1}	BINA
	Maize (Kharif-I)	10 mg kg^{-1}	14.5 mg kg^{-1}	BINA
	Mustard	10 mg kg^{-1}	14.8 mg kg^{-1}	BINA
Potassium	Rice	0.12 meq 100 g^{-1}	0.09 meq 100 g^{-1}	BRRI
	Wheat	0.12 meq $100g^{-1}$	0.17 meq $100g^{-1}$	BARI
	Maize	0.12 meq $100g^{-1}$	0.16 meq $100g^{-1}$	BARI
	Cabbage	0.12 meq $100g^{-1}$	0.19 meq $100g^{-1}$	BARI
Magnesium	Maize (Rabi)	0.50 meq $100g^{-1}$	0.60 meq $100g^{-1}$	BINA
	Maize (Kharif-I)	0.50 meq $100g^{-1}$	0.52 meq $100g^{-1}$	BINA
	Wheat	0.50 meq $100g^{-1}$	0.50 meq $100g^{-1}$	BAU
	Mustard	0.50 meq $100g^{-1}$	0.55 meq $100g^{-1}$	BAU
	Mustard	0.50 meq $100g^{-1}$	0.59 meq $100g^{-1}$	BINA
Sulphur	Rice	10.0 mg kg^{-1}	15.0 mg kg^{-1}	BRRI
	Wheat	10.0 mg kg^{-1}	13.5 mg kg^{-1}	BAU
	Mustard	10.0 mg kg^{-1}	14.0 mg kg^{-1}	BAU
Zinc	Rice	0.60 mg kg^{-1}	0.70 mg kg^{-1}	BRRI
	Wheat	0.60 mg kg^{-1}	0.72 mg kg^{-1}	BARI
	Maize	0.60 mg kg^{-1}	0.72 mg kg^{-1}	BARI
	Cabbage	0.60 mg kg^{-1}	0.74 mg kg^{-1}	BARI
Boron	Wheat	0.20 mg kg^{-1}	0.30 mg kg^{-1}	BAU
	Mustard	0.20 mg kg^{-1}	0.25 mg kg^{-1}	BAU

Key words: Critical Limit, phosphorus, potassium, magnesium, sulphur, zinc, boron, rice, maize, mustard, wheat and cabbage

PBRG Sub-Project Completion Report (PCR)

A. Sub-project Description

1. Title of the PBRG sub-project: Determination of Critical Limit of Nutrients for Soils and Crops

2. Implementing Organization:

Sl. No.	Organization	Status
1.	Bangladesh Agricultural Research Council	Coordinating organization
2.	Bangladesh Agricultural Research Institute	Implementing organization
3.	Bangladesh Rice Research Institute	Implementing organization
4.	Bangladesh Institute of Nuclear Agirulture	Implementing organization
5.	Bangladesh Agricultural University	Implementing organization

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4. Sub-project budget (Tk.)

4.1 Approved Budget: Tk. 3,28,61,110/- **(**Taka three crore twenty-eight lac sixty one thousand one hundred and ten) only

4.2: Latest Revised (if any): Tk. 3,12,97,796/- **(**Taka three crore twelve lac ninety seven thousand seven hundred and ninety six) only

5. Duration of the sub-project

5.1 Start date (based on LoA signed): March 11, 2018

5.2 End date: 28 February 2022.

6. Background of the sub-project

Soil testing is a useful tool for measuring extractable (available) quantity of a nutrient in soil which would help predict the crop yield response to an application of that nutrient through fertilizers and manure. As soil test value for a particular nutrient increase, the crop yield response to an addition of that nutrient decreases. A good soil test should be able to predict the amount of plant-available nutrient as well as the fertilizer responsiveness of crops growing on a wide range of soils. In this regard, determination of critical limit (C.L.) is important to determine optimum fertilizer requirement for a crop. Now the country's soils are reported to be broadly deficient in N, P, K. S, Mg, Zn and B.

Critical limit (C.L.) refers to a threshold value of a nutrient in soil below which the crop will readily respond to its application. Critical limit is useful for delineating responsive (deficiency) sites from non-responsive (sufficiency) sites. The C. L. of a nutrient varies with crops, soils and extraction methods. Concerning soil factors, soil type, soil pH, and soil organic matter are important. Hence, the situation justifies a need to determine and update the critical limit of different plant nutrients in order to formulate an optimum fertilizer dose of deficient nutrients for different crops and soils for achieving satisfactory crop yield.

7. Sub-project general objective (s)

i) Delineation of the present status of different nutrients in calcareous, non-calcareous, piedmont and terrace soils.

ii) Determination of critical limit of different nutrients for cereal, vegetable and oilseed crops.

iii) Validation of critical limits through field experiments.

8. Sub-project specific objectives (component wise)

BARI component:

i) To delineate the present status of macro- and micro-nutrients in calcareous and terrace soils (AEZs 11, 13, 28)

ii) To determine critical limit of K and Zn for different soils and crops (wheat, maize, and cabbage)

iii) To validate the C. L. results from pot experiments by field experiments

BRRI component:

i) To delineate the present status of macro- and micro-nutrients in Meghna and Surma-Kushiara Floodplain soils (AEZ 18, 19 and 20).

ii) To determine critical limit of P, K, S and Zn for different soils and rice

iii) To validate the C. L. results from pot experiments by field experiments

BINA component:

i) To delineate the present status of macro- and micro-nutrients in terrace soils (AEZs 25, 26, 27)

ii) To determine critical limit of P and Mg for different soils and crops (Maize and mutard)

iii) To validate the C. L. results from pot experiments by field experiments

BAU component:

i) To delineate the present status of macro- and micro-nutrients in piedmont and non-calcareous soils (AEZs 1, 3, 9)

ii) To determine critical limit of S, B and Mg for different soils and crops (wheat and mustard)

iii) To validate the C. L. results from pot experiments by field experiments

9. Implementing locations:

Implementation organization	Location
BARI component	BARI farm, Gazipur, Jashore and Rajshahi
BRRI component	BRRI farm, Gazipur, Katchua, Chandpur (AEZ-19) and Companiganj, Sylhet (AEZ-20)
BINA component	BINA farm, Mymensingh; Nalitabari, Sherpur and Sadar, Dinajpur
BAU component	BAU farm, Mymensingh Sadar, Tetulia, Panchagar Sadar, Muktagacha, Mymensingh, and Taraganj, Rangpur

10. Methodology in brief

The sub-project has been coordinated by BARC, and Soil Science Divisions of BARI, BRRI, BINA and BAU are working as the implementing organizations. Tweleve AEZs representing the major soil types of the country were selected for determing Critical Limits of different nutrients for different soils and crops. Standard approaches and methodologies were followed to achieve the objectives of the sub-project. To achieve the above-mentioned three major objectives three major experiments were conducted by different component organizations, which are as follows:

Expt. 1. Delineation of different nutrients status in some selected AEZs of Bangladesh

Expt. 2: Determination of critical limits of different nutrients for different soils and crops- Pot trial

Expt. 3: Verification of estimated critical limit through field experiments at the farmers' fields

However, each component organization conducted one or more experiments under each of these three major experiments to fulfill their specific objectives. The materials and methods of the experiments are briefly described as follows:

Expt. 1. Delineation of different nutrients status in some selected AEZs of Bangladesh

All four component organizations conducted research activities on delineation of nutrient status among the selected AEZs. However, different organizations worked with different AEZs. The assigned AEZs for different component organizations are as follows:

Assigned AEZs for different component organizations for delineation of the present status of macro- and micro-nutrients in soils.

Organization	AEZ
BARI	11, 13, 28
BRRI	18, 19, 20
BINA	25, 26, 27
BAU	1, 3, 9

Expt. 1.1: Delineation of nutrient status in calcareous and terrace soils (BARI component)

For delineation of nutrient status in calcareous and terrace soils, BARI component conducted the following activities:

(a) Collection of soil samples

For delineation of nutrient status and selecting sites for bulk soil sample collection for pot trials BARI component collected 180 soil samples from the intensively cropped areas of calcareous and terrace soils based on land type and soil texture. The samples were collected as per the protocol described below from the following 3 AEZs, 2 upazilas from each AEZ and 3 villages from each upazila. From each village, 10 composite samples were collected from the surface soil (0-15 cm) of the selected sites.

AEZ 11. High Ganges River Floodplain – calcareous
AEZ 13. Ganges Tidal Floodplain – calcareous
AEZ 28. Madhupur Tract – terrace

Soil sampling protocol:

- 3 AEZs
- 2 Upazilas/AEZ
- 3 villages/Upazila
- 10 Spots/Village
- 1 Soil depth (0-15 cm)
- No. of soil samples for each component: 180 Nos. (3 AEZs x 2 Upazilas/AEZ x 3 villages/ Upazila x 10 spots/ village)
- Total no. of soil samples for 4 components: 720 Nos. (180 x 4)

Expt. 1.2: Delineation of different nutrients status in calcareous, non-calcareous and piedmont soils (BRRI Component)

For delineation of nutrient status in calcareous, non-calcareous and piedmont soils, BRRI component conducted the following activities:

(a) Collection of soil samples

For delineation of nutrient status and selecting sites for bulk soil sample collection for pot trials BRRI component collected 180 soil samples from the intensively cropped areas of Young Meghna Estuarine Floodplain soils of Noakhali and Laxmipur, Old Meghna Estuarine Floodplain soils of Cumilla and B. Baria and Eastern Surma Kushiara Floodplain soils of Sylhet and Moulovi Bazar based on land type and soil texture. The samples were collected as per the protocol described above under the Expt. 1.1 from the following 3 AEZs, 2 upazilas from each AEZ and 3 villages from each upazilla. From each village, 10 composite samples were collected from the surface soil (0-15 cm) of the selected sites.

AEZ 18. Young Meghna Estuarine Floodplain
AEZ 19. Old Meghna Estuarine Floodplain and
AEZ 20. Eastern Surma Kushiara Floodplain

Expt 1.3: Delineation of different nutrients status in terrace soils (BINA Component)

For delineation of nutrient status in terrace soils, BINA component conducted the following activities:

(a) Collection of soil samples

For delineation of nutrient status and selecting sites for bulk soil sample collection for pot trials BINA component collected 180 soil samples from the intensively cropped areas representing terrace soils based on land type and soil texture. The samples were collected as per the protocol described above under the Expt. 1.1 from the following 3 AEZs, 2 upazilas from each AEZ and 3 villages from each upazilla. From each village, 10 composite samples were collected from the surface soil (0-15 cm) of the selected sites.

AEZ 25. Level Barind Tract – terrace
AEZ 26. High Barind Tract – terrace
AEZ 27. North Eastern Barind Tract – terrace

Expt. 1.4: Delineation of different nutrients status in piedmont and non-calcareous soils (BAU Component)

For delineation of nutrient status in piedmont and non-calcareous soils, BAU component conducted the following activities:

(a) Collection of soil samples

For delineation of nutrient status and selecting sites for bulk soil sample collection for pot trials BAU component collected 180 soil samples from the intensively cropped areas of Old Himalayan Piedmont Plain soils, Tista Meander Floodplain soils and Old Brahmaputra Floodplain soils based on land type and soil texture. The samples were collected as per the protocol described above under the Expt. 1.1 from the following 3 AEZs, 2 upazilas from each AEZ and 3 villages from each upazilla. From each village, 10 composite samples were collected from the surface soil (0-15 cm) of the selected sites.

AEZ 1. Old Himalayan Piedmont Plain
AEZ 3. Tista Meander Floodplain
AEZ 9. Old Brahmaputra Floodplain

(b) Analysis of soil samples (All components)

Soil samples for all the components were analyzed by the respective component organization for macro- & micro-nutrient contents and basic soil characteristics like pH, organic matter, texture etc. Analysis was done primarily for determining available status of pH, SOM, total N, P, K, Mg, S, Zn, B, Ca and Mg following the standard extraction methods as mentioned in the table below:

Element	Extraction method	Reference
Phosphorus (P)	i. 0.5M $NaHCO_3$, pH 8.5 extraction (neutral and calcareous soils) ii. 0.03N NH_4F+0.025 HCl (acidic soils, <pH 6.0)	Olsen and Sommers, 1982 Bray and Kurtz Method
Potassium (K)	NH_4OAc extraction, pH 7.0 (Flame photometry)	Schollenberger, Simon 1945
Sulphur (S)	Calcium dihydrogen phosphate [$Ca(H_2\text{-}PO_4)_2$ $2H_2O$]	Fox *et al.,* 1964 and Hunt, J., 1980
Magnesium (Mg)	NH_4OAc extraction, pH 7.0 (AAS)	Schollenberger, Simon 1945
Zinc (Zn)	0.005M DTPA, pH 7.3 extraction (AAS)	Lindsay and Norvell, 1978
Boron (B)	Extraction: Hot water-$CaCl_2$ (0.02M) Determination: Azomethane – H method	John *et al.,* 1975 Shamina et.al (1967); John et.al. (1975)

Analysis of other soil properties were done by the following methods (All components):

Parameter	Method	Reference
Texture	Hydrometer method	Jackson, 1973
pH	Glass electrode pH meter (1:2.5 soil-water ratio)	McLean, 1982
Organic matter	Wet oxidation method	Nelson and Sommers, 1982
Nitrogen (N)	Micro-Kjeldahl method	Bremner and Mulvaney, 1982
Calcium (Ca)	NH_4OAc extraction, pH 7.0	Barker and Surh, 1982
Iron (Fe)	0.005M DTPA, pH 7.3 extraction	Lindsay and Norvell, 1978
Manganese (Mn)	0.005M DTPA, pH 7.3 extraction	Lindsay and Norvell, 1978
Copper (Cu)	0.005M DTPA, pH 7.3 extraction	Lindsay and Norvell, 1978

(c) Identification of spots for bulk soil sample collection (All components)

Every copmponent organization collected and analyzed 180 soil samples for their assigned AEZs *i.e.,* a total of 720 soil samples were collected and analyzed by the four components. All 720 analytical data for each of the desired nutrients were arranged in an Excel sheet and sorted in ascending order. The soil sapmples were categorized into Low, Medium and High nutrient content groups for each of the desired nutrients. Thus, the bulk soil sample collection spots for each desired nutrient for conduction of pot trials for determining Critical Limits of different nutrients for different soils and crops were identified. The bulk soil samples were collected from the surface layer (0-15 cm) from the identified spots.

Expt. 2: Determination of Critical Limits of different nutrients for different soils and crops-Pot trial

The Critical Limits of different nutrients for different soils and crops were estimated by different component organizations. Different nutrients and crops assigned to different component organizations are as follows:

Organization	Nutrient	Crop
BARI	K and Zn	Wheat, maize and cabbage
BRRI	P, K, S and Zn	Rice
BINA	P and Mg	Maize and mustard
BAU	Mg, S and B	Wheat and mustard

Expt. 2.1: Determination of critical limit of K and Zn for wheat, maize and cabbage- Pot trial

BARI Component

a) Collection of bulk soil samples

As per decision of the coordination meeting held at BARC in September 2019 thirty soil samples for potassium and 27 soil samples for zinc were selected. Of the 30 soil samples for potassium (K), 16 soil samples were selected from low, 7 samples from medium and 7 samples from highly fertile soils; while of the 27 soil samples for Zn, 15 soil samples were selected from low, 6 samples from medium and 7 samples from highly fertile soils. Sampling locations were selected based on the first year soil analyses data generated by BARI, BRRI, BINA and BAU components of the Critical Limit sub-project *i.e.* from a total of 720 soil samples from across the country.

However, for pot trials 27 bulk soil samples for K and 28 bulk samples for Zn were collected from 0-15 cm depth from the following selected locations (Table 1 and 2). The detailed chemical analysis of the soils is presented in Appendix 1.

Table 1. Selected soil samples having Low, Medium and High levels of Potassium (K) for collection of bulk soil for Pot Study, SSD, BARI, Gazipur, 2019-20.

Sl. No.	Sample name	Location details	Soil series	GPS	K concentrat'n (meq/100g)
Low					
1	BRRI 94	Changini, Katchua	Chandina, Burichong, Debiddar	23° 16' 24.56"/ 90° 59" 20.72"	0.019
2	BRRI 99	Changini, Katchua	Chandina, Burichong, Debiddar	23° 16' 22.62"/ 90° 59" 27.19"	0.023
3	BRRI 100	Changini, Katchua	Chandina, Burichong, Debiddar	23° 16' 23.48"/ 90° 59" 28.72"	0.023
4	BRRI 71	Dhodda, Haziganj	Chandina, Burichong, Debiddar	23° 17' 42.22"/ 90° 51" 4.18"	0.037
5	BRRI 75	Dhodda, Haziganj	Chandina, Burichong, Debiddar	23° 17' 40"/ 90° 51" 15.66"	0.037
6	BARI 96	Paba, Rajshahi	Sara, Gopalpur & Ishurdi	24° 25' 07"/ 88° 41' 28"	0.13
7	BARI 13	Durbati, Kaligonj	Sonatala, Silmondi	23° 56' 29.04"/ 90° 32' 49.92"	0.07
8	BARI 14	Durbati, Kaligonj	Sonatala, Silmondi	23° 56' 30.12"/ 90° 32' 54.52"	0.07
9	BARI 15	Durbati, Kaligonj	Sonatala, Silmondi	23° 56' 38.76"/ 90° 32'50.64"	0.07
10	BARI 16	Durbati, Kaligonj	Sonatala, Silmondi	23° 56' 39.12"/ 90° 32' 45.6"	0.06
11	BARI 20	Durbati, Kaligonj	Sonatala, Silmondi	23° 56'28.32"/ 90° 32' 33.0"	0.07
12	BARI 24	Baktarpur, Kaligonj	Tejgaon, Belabo	23° 56' 56.2"/ 90° 32' 53.1"	0.07
Medium					
13	BARI 62	Swarupdaha, Chowgacha	Sara, Gopalpur, Ishurdi	23° 15' 23"/ 88° 59' 42"	0.16
14	BARI 64	Swarupdaha, Chowgacha	Sara, Gopalpur, Ishurdi	23° 15' 34"/ 88 ° 59' 39"	0.17
15	BARI 84	Anderkota, Chowgacha	Sara, Gopalpur, Ishurdi	23° 16' 20"/ 88° 59' 05"	0.17
16	BARI 9	Baraid, Kaligonj	Tejgaon, Belabo	23° 58' 5.52"/ 90° 32" 57.5"	0.16
17	BARI 27	Baktarpur, Kaligonj	Tejgaon, Belabo	23° 59' 46.2"/ 90° 32' 33.4"	0.16
18	BARI 90	Anderkota, Chowgacha	Sara, Gopalpur, Ishurdi	23 ° 15' 60"/ 89 ° 00' 15"	0.16
High					
19	BRRI 1	Charkossopia, Companiganj	Chandina, Chilania, Ramgati	22° 45' 98.25"/ 91° 16" 28.6"	0.31
20	BRRI 2	Charkossopia, Companiganj	Chandina, Chilania, Ramgati	22° 45' 49.68"/ 91° 16" 31.87"	0.31
21	BRRI 4	Charkossopia, Companiganj	Chandina, Chilania, Ramgati	22° 45' 56.38"/ 91° 16" 41.38"	0.35
22	BARI 128	Vurulia, Shyamnagar	Bajwa, Jalkati, Barishal	22° 22' 51"/ 89° 06' 09"	0.43
23	BARI 130	Vurulia, Shyamnagar	Bajwa, Jalkati, Barishal	22° 22' 60"/ 89° 06' 05"	0.45
24*	S3	Godagari, Rajshahi	Ghior	24° 25' 57.37"/ 88° 23' 30.9"	0.87
25*	S16	Gazipur Sadar	Chhiata	23° 59' 27"/ 90° 24' 52"	0.98

Table 2. Selected soil samples having Low, Medium and High levels of Zinc (Zn) for collection of bulk soil for Pot Study, SSD, BARI, Gazipur, 2019-20.

Sample no.	Sample name	Location details	Soil series	GPS	Zn concentrat'n (mg/kg)
Low					
1	BARI 161	Babuganj	Sara, Gopalpur	22°45'23"/ 90°19'04"	0.37
2	BARI 169	Babuganj	Sara, Gopalpur	22°46'20"/ 90°18'46"	0.22
3	BARI 165	Babuganj	Sara, Gopalpur	22°46'07"/ 90°18'53"	0.32
4	BARI 170	Babuganj	Sara, Gopalpur	22°46'35"/ 90°18'43"	0.33
5	BARI 171	Babuganj	Sara, Gopalpur, Muladi	22°47' 53"/ 90°17'44"	0.35
6	BARI 175	Babuganj	Sara, Gopalpur, Muladi	22°48'43"/ 90° 17'47"	0.34
7	BARI 168	Babuganj	Sara, Gopalpur	22°46'26"/ 90°18'48"	0.39
8	BRRI 43	Kamalnagar (Ramgati), Char Monosa	Ramgati, Nilkamal	22° 50' 31.85"/ 90° 52" 54.73"	0.02
9	BRRI 45	Kamalnagar (Ramgati), Char Monosa	Ramgati, Nilkamal	22° 49' 53.94"/ 90° 52" 13.04"	0.04
10	BRRI 48	Kamalnagar (Ramgati), Char Monosa	Ramgati, Nilkamal	22° 49' 32.48"/ 90° 52" 17.72"	0.10
11	BRRI 117	Katchua, Budumda	Chandina, Burichong, Debiddar	23° 24' 38.27"/ 90° 50" 40.88"	0.26
12	BRRI 119	Katchua, Budumda	Chandina, Burichong, Debiddar	23° 24' 41.08"/ 90° 50" 43.4"	0.20
13	BRRI 120	Katchua, Budumda	Chandina, Burichong, Debiddar	23° 24' 39.89"/ 90° 50" 43.44"	0.24
Medium					
14	BARI 91	Paba	Sara, Gopalpur & Ishurdi	24° 24' 13"/ 88 ° 41' 30"	1.07
15	BARI 92	Paba	Sara, Gopalpur & Ishurdi	24° 24' 05"/ 88° 41' 34"	0.96
16	BARI 96	Paba	Sara, Gopalpur & Ishurdi	24° 25' 07"/ 88° 41' 28"	1.05
17	BARI 100	Paba	Sara, Gopalpur & Ishurdi	24° 24' 35"/ 88° 41' 51"	1.08
18	BARI 101	Paba	Sara, Gopalpur & Ishurdi	24° 28'17"/ 88° 37' 59"	0.92
19	BARI 119	Paba	Gopalpur, Ghior, Sara	24° 28' 00"/ 88° 37' 55"	0.91
High					
20	BRRI 144	Companiganj, Dolirgaon Purbopara	Ghoainghat, Fagu, Terchibari	25° 01' 22.15"/ 91° 48" 24.3"	1.76
21	BRRI 145	Companiganj, Dolirgaon Purbopara	Ghoain ghat, Fagu, Terchibari	25° 01' 25.18"/ 91° 48" 24.66"	1.78
22	BRRI 146	Companiganj, Dolirgaon Purbopara	Ghoain ghat, Fagu, Terchibari	25° 01' 25.97"/ 91° 48" 27.25"	2.02
23	BRRI 174	Jaintapur, Vitrikhel	Bijipur, Pritimpasha, Monu	25° 07' 8.87"/ 92° 07" 22.58"	2.00
24	BRRI 179	Jaintapur, Vitrikhel	Bijipur, Pritimpasha, Monu	25° 07' 18.19"/ 92° 07" 14.41"	2.36
25	BRRI 180	Jaintapur, Vitrikhel	Bijipur, Pritimpasha, Monu	25° 07' 17.54"/ 92° 11" 30.28"	2.44

b) Pot trials

BARI Component

Pot trials were conducted on wheat and cabbage during Rabi season 2019-20. Pot trials on maize were conducted during Khari-1 season 2020. For pot trials bulk soils were collected from the surface layer (0-15 cm) from the selected locations as mentioned in Tables 1 and 2. The soils were processed (ground and sieved). Pot trials on response of wheat and cabbage to each of K and Zn were conducted in completely randomized design (CRD) with two treatments (with and without K and Zn) and three replications. For wheat trial 6 kg soils were used per pot; while 8 kg soils were used per pot for cabbage trial for both the nutrients. On the basis of soil analysis, nutrients were used at the rate of $N_{120}P_{24}K_{90}S_{15}Mg_6Zn_{10}$ $B_{1.5}$ ppm for wheat, $N_{150}P_{40}K_{55}S_{22}Zn_3B_1$ ppm for cabbage and $N_{150}P_{60}$ $K_{100}S_{40}Mg_{10}B_2$ for maize in each pot to support normal plant growth. The processed soils were weighed for individual pot and mixed with all the nutrients (except N and the nutrient in study) thoroughly and poured into the pot. Potassium and Zn were used as per treatment. Potassium was mixed with the soil along with other nutrients during pot preparation; but Zn was applied at 7 days after emergence of the crops as nutrient solution. Reagent grade chemicals (KCl for K and $ZnSO_4.H_2O$ for Zn) were used as the sources of nutrients. Nitrogen was applied in three equal splits during pot preparation and at 15 and 40 days after emergence.

For K response trials wheat, cabbage and maize seeds were sown on 15 January 2020, 22 January 2020 and 28 March 2020 and for Zn response trials the seeds were sown on 16 January 2020, 23 January 2020 and 29 March 2020, respectively. Twelve (12) sprouted seeds of wheat (BARI Gom-30) and 5-6 sprouted seeds of cabbage (Atlas-70) were sown per pot, while four (4) maize seeds were sown per pot. Distilled water was added to the soil for 'Zou' condition after sowing. Seedlings were thinned to desired population (5 seedlings/pot for wheat and 1 seedling/pot for cabbage) within 15 days after emergence. Intercultural operations like irrigation, weeding etc. were maintained for proper plant growth. Wheat plants for K response trial were harvested on 15 March 2020 and that of Zn response trial on 16 March 2020 at 50% flowering. Fresh and dry weights of wheat plants were recorded, which are being processed for chemical analysis. The cabbage plants of both K and Zn response trials were harvested on 3 April 2020. Maize plants were harvested on 27 May 2020.

c) Plant analysis

Plant concentration of K and Zn was determined. Plant samples of wheat and cabbage were dried in an oven at 65 ^{o}C for about 24 hours, after which the samples were ground by a grinding mill. The ground samples will be sieved through a 20-mesh sieve. The samples will then be chemically analyzed for all elements except N following HNO_3-$HClO_4$ digestion procedure and N by H_2SO_4-H_2O_2 digestion (Jones and Case, 1990; Watson and Issac, 1990).

d) Determination of critical limit

Critical limits of K and Zn were derived by plotting the relative crop yield (%) on the Y axis and the soil nutrient concentration on the X axis for each crop per nutrient following Cate and Nelson method (1965). A polynomial trend line was drawn using the data points. The relative yield percentages were calculated from the ratio of the crop yields without and with nutrients as below. The average of the 27 relative yield data was calculated and pointed on the Y axis. A horizontal line parallel to X axis was drawn from that point. From the cut point of horizontal line and trend line a perpendicular line parallel to Y axis was drawn on the X axis. The cut point of perpendicular line on the X axis was the critical limit of the specific crop for the specific nutrient.

$$\text{\% Relative yield} = \frac{\text{Yield without addition of nutrient}}{\text{Yield with addition of nutrient}} \times 100$$

Expt. 2.2: Determination of critical limit of P, K, S and Zn for rice - Pot trial

BRRI Component

a) Collection of bulk soil sample

As per decision of the coordination meeting held at BARC in September 2019 twenty soil samples for each of phosphorus, potassium, Sulphur and zinc were selected. Out of each 20 soil samples for P, K, S and Zn, 12 soil samples were selected from low, 4 samples from medium and 4 samples from highly fertile soils for pot trials. The soils were collected from 0-15 cm depth from the selected locations as in Tables 3, 4, 5 and 6. Sampling locations were selected based on the first-year soil analyses data generated by BARI, BRRI, BINA and BAU components of the Critical Limit project *i.e.* from a total of 720 soil samples from across the country. However, for pot trials 20 bulk soil samples for each of P, K, S and Zn were selected. The detailed chemical analysis of the soils is presented in Appendix 2.

Table 3. Selected soil samples having Low, Medium and High levels of Phosphorus (P) for collection of bulk soil for Pot Study, SSD, BRRI, Gazipur, 2019-20.

Sl. no.	Sample name	Location details	Soil series	GPS	Ava. P (ppm)
Low P					
1	BRRI 121	Gourinagar, Companiganj, Sylhet	Goainghat	N.25°03ʹ.363, E.91°81ʹ.267	1.75
2	BRRI 122	Gourinagar, Companiganj, Sylhet	Goainghat	N.25°03ʹ.349, E.91°81ʹ.215	1.75
3	BRRI 123	Gourinagar, Companiganj, Sylhet	Goainghat	N.25°03ʹ.375, E.91°81ʹ.109	3.25
4	BRRI 124	Gourinagar, Companiganj, Sylhet	Goainghat	N.25°03ʹ.314, E.91°81ʹ.062	2.75
5	BRRI 125	Gourinagar, Companiganj, Sylhet	Goainghat	N.25°03ʹ.267, E.91°81ʹ.029	2.95
6	BRRI 127	Gourinagar, Companiganj, Sylhet	Goainghat	N.25°03ʹ.132, E.91°80ʹ.998	0.75
7	BRRI 129	Gourinagar, Companiganj, Sylhet	Goainghat	N.25°03ʹ.141, E.91°81ʹ.18	1.18
8	BRRI 131	Khagail, Companiganj, Sylhet	Fagu	N.25°02ʹ.175, E.91°81ʹ.746	0.60
9	BRRI 133	Khagail, Companiganj, Sylhet	Fagu	N.25°02ʹ.101, E.91°81ʹ.706	0.55
10	BRRI 135	Khagail, Companiganj, Sylhet	Fagu	N.25°01ʹ.999, E.91°81ʹ.629	0.15
11	BRRI 137	Khagail, Companiganj, Sylhet	Fagu	N.25°01ʹ.882, E.91°81ʹ.516	0.60
12	BRRI 139	Khagail, Companiganj, Sylhet	Fagu	N.25°02ʹ.244, E.91°81ʹ.845	1.75

Sl. no.	Sample name	Location details	Soil series	GPS	Ava. P (ppm)
Medium P					
13	BRRI 23	Char Fokira, Companigang, Noakhali	Ramgati	N.22°79′.036, E.91°27′.093	12.88
14	BRRI 25	Char Fokira, Companigang, Noakhali	Ramgati	N.22°79′.003, E.91°27′.220	15.38
15	BRRI 27	Char Fokira, Companigang, Noakhali	Ramgati	N.22°79′.081, E.91°27′.247	11.25
16	BRRI 29	Char Fokira, Companigang, Noakhali	Ramgati	N.22°79′.120, E.91°27′.076	15.25
High P					
17	BRRI 111	Budumda, Katchua, Chandpur	Chandina	N.23°41′.288, E.90°84′.544	55.34
18	BRRI 113	Budumda, Katchua, Chandpur	Chandina	N.23°41′.313, E.90°84′.343	45.05
19	BRRI 115	Budumda, Katchua, Chandpur	Chandina	N.23°41′.098, E.90°84′.32	33.71
20	BRRI 116	Budumda, Katchua, Chandpur	Chandina	N.23°41′.027, E.90°84′.389	25.20

Table 4. Selected soil samples having Low, Medium and High levels of Potassium (K) for collection of bulk soil for Pot Study, SSD, BRRI, Gazipur, 2019-20.

Sl. no.	Sample name	Location details	Soil series	GPS	Excha. K (meq/100g)
Low K					
1	BRRI 71	Dhodda, Haziganj, Chandpur	Burichong	N.23°29′.506, E.90°85′.116	0.037
2	BRRI 72	Dhodda, Haziganj, Chandpur	Burichong	N.23°29′.452, E.90°85′.223	0.046
3	BRRI 73	Dhodda, Haziganj, Chandpur	Burichong	N23°29′.470, E.90°85′.295	0.042
4	BRRI 74	Dhodda, Haziganj, Chandpur	Burichong	N.23°29′.431, E.90°85′.328	0.037
5	BRRI 75	Dhodda, Haziganj, Chandpur	Burichong	N.23°29′.445, E.90°85′.435	0.037
6	BRRI 76	Dhodda, Haziganj, Chandpur	Burichong	N.23°29′.504, E.90°85′.495	0.037
7	BRRI 77	Dhodda, Haziganj, Chandpur	Burichong	N.23°29′.602, E.90°85′.478	0.042
8	BRRI 94	Changini, Katchua, Chandpur	Chandina	N.23°27′.349, E.90°98′.909	0.019
9	BRRI 95	Changini, Katchua, Chandpur	Chandina	N.23°27′.301, E.90°98′.86	0.019
10	BRRI 96	Changini, Katchua, Chandpur	Chandina	N.23°27′.262, E.90°98′.914	0.019
11	BRRI 99	Changini, Katchua, Chandpur	Chandina	N.23°27′.295, E.90°99′.088	0.023

Sl. no.	Sample name	Location details	Soil series	GPS	Excha. K (meq/100g)
12	BRRI 100	Changini, Katchua, Chandpur	Chandina	N.23°27′.319, E.90°99′.131	0.023
Medium K					
13	BRRI 23	Char Fokira, Companigang, Noakhali	Ramgati	N.22°79′.036, E.91°27′.093	0.14
14	BRRI 25	Char Fokira, Companigang, Noakhali	Ramgati	N.22°79′.003, E.91°27′.220	0.13
15	BRRI 27	Char Fokira, Companigang, Noakhali	Ramgati	N.22°79′.081, E.91°27′.247	0.14
16	BRRI 29	Char Fokira, Companigang, Noakhali	Ramgati	N.22°79′.120, E.91°27′.076	0.15
High K					
17	BRRI 1	Char Kossopia, Companigang, Noakhali	Ramgati	N.22°76′.618, E.91°27′.461	0.31
18	BRRI 3	Char Kossopia, Companigang, Noakhali	Ramgati	N.22°76′.490, E.91°27′.682	0.31
19	BRRI 5	Char Kossopia, Companigang, Noakhali	Ramgati	N.22°76′.441, E.91°27′.916	0.37
20	BRRI 8	Char Kossopia, Companigang, Noakhali	Ramgati	N.22°76′.386, E.91°28′.056	0.42

Table 5. Selected soil samples having Low, Medium and High levels of Sulphur (S) for collection of bulk soil for Pot Study, SSD, BRRI, Gazipur, 2019-20.

Sl. no.	Sample name	Location details	Soil series	GPS	Ava. S (ppm)
Low S					
1	BRRI 146	Dholirgaon, Companiganj, Sylhet	Terchibari	N.25°02′.388, E.91°80′.757	11.65
2	BRRI 147	Dholirgaon, Companiganj, Sylhet	Terchibari	N.25°02′.362, E.91°80′.781	12.75
3	BRRI 148	Dholirgaon, Companiganj, Sylhet	Terchibari	N.25°02′.295, E.91°80′.803	11.75
4	BRRI 154	Vitorgram, Jaintapur, Sylhet	Bijipur	N.25°05′.817, E.92°12′.449	11.95
5	BRRI 156	Vitorgram, Jaintapur, Sylhet	Bijipur	N.25°05′.875, E.92°12′.352	12.85
6	BRRI 158	Vitorgram, Jaintapur, Sylhet	Bijipur	N.25°06′.034, E.92°12′.471	12.25
7	BRRI 159	Vitorgram, Jaintapur, Sylhet	Bijipur	N.25°06′.109, E.92°12′.459	12.55
8	BRRI 160	Vitorgram, Jaintapur, Sylhet	Bijipur	N.25°06′.160, E.92°12′.469	12.70
9	BRRI 162	Kholagram, Jaintapur, Sylhet	Pritimpasha	N.25°06′.417, E.92°12′.381	11.65
10	BRRI 163	Kholagram, Jaintapur, Sylhet	Pritimpasha	N.25°06′.445, E.92°12′.396	11.90

Sl. no.	Sample name	Location details	Soil series	GPS	Ava. S (ppm)
11	BRRI 166	Kholagram, Jaintapur, Sylhet	Pritimpasha	N.25°06′.596, E.92°12′.238	12.50
12	BRRI 170	Kholagram, Jaintapur, Sylhet	Pritimpasha	N.25°06′.396, E.92°12′.231	12.35
Medium S					
13	BRRI 173	Vitrikhel, Jaintapur, Sylhet	Monu	N.25°11′.832, E.92°12′.228	18.45
14	BRRI 176	Vitrikhel, Jaintapur, Sylhet	Monu	N.25°12′.059, E.92°12′.324	15.90
15	BRRI 178	Vitrikhel, Jaintapur, Sylhet	Monu	N.25°12′.164, E.92°12′.216	18.10
16	BRRI 179	Vitrikhel, Jaintapur, Sylhet	Monu	N.25°12′.172, E.92°12′. 067	16.35
High S					
17	BRRI 51	Char Monosa, Rangati, Laxipur	Nilkamal	N.22°82′.810, E.90°86′.476	75
18	BRRI 53	Char Monosa, Rangati, Laxipur	Nilkamal	N.22°82′.850, E.90°86′.359	98
19	BRRI 55	Char Monosa, Rangati, Laxipur	Nilkamal	N.22°82′.896, E.90°86′.403	84
20	BRRI 57	Char Monosa, Rangati, Laxipur	Nilkamal	N.22°82′.710, E.90°86′.038	80

Table 6. Selected soil samples having Low, Medium and High levels of Zinc (Zn) for collection of bulk soil for Pot Study, SSD, BRRI, Gazipur, 2019-20.

Sl. no.	Sample name	Location details	Soil series	GPS	Ava. Zn (ppm)
Low Zn					
1	BRRI 41	Char Monosa, Ramgati, Laxmipur	Ramgati	N.22°83′.089, E.90°86′.779	0.26
2	BRRI 42	Char Monosa, Ramgati, Laxmipur	Ramgati	N.22°83′.313, E.90°86′.698	0.26
3	BRRI 43	Char Monosa, Ramgati, Laxmipur	Ramgati	N.22°84′.218, E.90°88′.187	0.02
4	BRRI 44	Char Monosa, Ramgati, Laxmipur	Ramgati	N.22°83′.211, E.90°86′.915	0.14
5	BRRI 45	Char Monosa, Ramgati, Laxmipur	Ramgati	N.22°83′.165, E.90°87′.029	0.04
6	BRRI 47	Char Monosa, Ramgati, Laxmipur	Ramgati	N.22°82′.820, E.90°86′.979	0.16
7	BRRI 48	Char Monosa, Ramgati, Laxmipur	Ramgati	N.22°82′.569, E.90°87′.02	0.10
8	BRRI 49	Char Monosa, Ramgati, Laxmipur	Ramgati	N.22°82′.723, E.90°86′.666	0.60
9	BRRI 50	Char Monosa, Ramgati, Laxmipur	Ramgati	N.22°83′.022, E.90°86′.851	0.22
10	BRRI 111	Budumda, Katchua, Chandpur	Chandina,	N.23°41′.288, E.90°84′.544	0.58

Sl. no.	Sample name	Location details	Soil series	GPS	Ava. Zn (ppm)
11	BRRI 112	Budumda, Katchua, Chandpur	Chandina,	N.23°41′.308, E.90°84′.468	0.42
12	BRRI 117	Budumda, Katchua, Chandpur	Chandina,	N.23°41′.063, E.90°84′.469	0.26
Medium Zn					
13	BRRI 155	Vitorgram, Jaintapur, Sylhet	Bijipur	N.25°05′.799, E.92°12′.355	0.86
14	BRRI 156	Vitorgram, Jaintapur, Sylhet	Bijipur	N.25°05′.875, E.92°12′.352	1.76
15	BRRI 158	Vitorgram, Jaintapur, Sylhet	Bijipur	N.25°06′.034, E.92°12′.471	1.06
16	BRRI 160	Vitorgram, Jaintapur, Sylhet	Bijipur	N.25°06′.160, E.92°12′.469	1.24
	High Zn				
17	BRRI 121	Gourinagar, Companiganj, Sylhet	Goainghat	N.25°03′.363, E.91°81′.267	2.50
18	BRRI 122	Gourinagar, Companiganj, Sylhet	Goainghat	N.25°03′.349, E.91°81′.215	3.10
19	BRRI 123	Gourinagar, Companiganj, Sylhet	Goainghat	N.25°03′.375, E.91°81′.109	3.32
20	BRRI 124	Gourinagar, Companiganj, Sylhet	Goainghat	N.25°03′.314, E.91°81′.062	3.02

b) Pot trials

BRRI Component

Pot trials were conducted on rice during Boro 2019-20 season at Soil Science Division, BRRI net house. For pot trials bulk soils were collected from the surface layer (0-15 cm) from the selected locations as mentioned in Tables 3, 4, 5 and 6. Twenty top soils from 20 selected areas were used in one pot trial. Pot trials on response of rice to each of P, K, S and Zn were conducted in completely randomized design (CRD) with two treatments (with and without P, K, S and Zn) and three replications. For each trial 6 kg soils were used per pot. On the basis of soil analysis, nutrients were used at the rate of $N_{160}P_{25}K_{80}S_{15}Zn_5$ kg ha^{-1} for rice. The processed soils were weighed for individual pot and mixed with all the nutrients (except N and the nutrient in study) thoroughly and poured into the pot. Phosphorus, K, S and Zn were used as per treatment. Nutrient solutions were used in the pot soil, mixed thoroughly and puddled with distilled water. Reagent grade chemicals (KH_2PO_4 for P, KCl for K, $CaSO_4$ for S and $ZnSO_4$ $1H_2O$ for Zn) were used as the sources of nutrients. Nitrogen was applied in three equal splits during pot preparation and at 20 and 45 days after transplanting of rice seedlings. BRRI dhan89 was used as the test crop of rice. The sprouted rice seeds were densely sown in trays on 5 and 7 February 2020. The seedlings were grown only with distilled water. After 10 days the small seedlings were transplanted in pots. Six seedlings per pot were transplanted in well prepared puddled earthen pots. Seedlings were thinned to desired population (4 seedlings/pot) within 10 days after transplanting. Intercultural operations like irrigation, weeding, pesticide application etc. were maintained equally for proper plant growth. Rice plants for P and K response trials were harvested on 10 April 2020 and that of S and Zn response trials on 12 April 2020 at maximum tillering stage (after 9 weeks of seeding). Fresh and dry weights of rice plants were recorded, which are being processed for chemical analysis. Dry matter yields (g/4 hills) of the rice plants were recorded (Table 5, 7, 9 and 11) for the determination of critical limit of rice for P, K, S and Zn.

c) Plant analysis

Plant concentration of P, K, S and Zn were determined. Plant samples were dried in an oven at 65 °C for about 24 hours, after which the samples were ground by a grinding mill. The ground samples were sieved through a 20-mesh sieve. The samples were then chemically analyzed for all elements except N following HNO_3-$HClO_4$ digestion procedure and N by H_2SO_4-H_2O_2 digestion (Jones and Case, 1990; Watson and Issac, 1990).

d) Determination of critical limit

Critical limits of P, K, S and Zn were derived by plotting the relative crop yield % on the Y axis and the soil nutrient concentration on the X axis for each crop per nutrient following Cate and Nelson method (1965). A polynomial trend line was drawn using the data points. The relative yield percentage were calculated from the ratio of the crop yield without and with nutrients as below. The average of the twenty relative yield data was calculated and pointed on the Y axis. A horizontal line parallel to X axis was drawn from that point. From the cut point of horizontal line and trend line a perpendicular line parallel to Y axis was drawn on the X axis. The cut point of perpendicular line on the X axis was the critical limit of the specific crop for the specific nutrient.

$$\textbf{\% Relative yield} = \frac{\text{Yield without addition of nutrient}}{\text{Yield with addition of nutrient}} \times 100$$

Expt 2.3: Determination of critical limit of P and Mg for maize and mustard- Pot trial

BINA Component

a) Collection of bulk soil samples

As per decision of the coordination meeting held at BARC in September 2019 twenty six soil samples for each of phosphorus and magnesium were selected. Of the 26 soil samples for each of phosphorus (P) and magnesium, 14 soil samples were selected from low, 6 samples from medium and 6 samples from highly fertile soils for each nutrient. Sampling locations were selected based on the first year soil analyses data generated by BINA and BAU components of the Critical Limit sub-project *i.e.* from a total of 720 soil samples from across the country.

However, for pot trials 20 bulk soil samples for each of P and Mg were selected from 0-15 cm depth from the following selected locations (Table 7 and 8). The detailed chemical analysis of the soils is presented in Appendix 3.

Table 7. Selected soil samples having Low, Medium and High levels of Phosphorus (P) for collection of bulk soil for pot study, Soil Science Division, BINA, Mymensingh, 2019-20

Sample no.	Sample name	Location details (Vill./Uni./Upazil./Distri.)	Soil series	GPS	Avail. P (ppm)
Low P					
1	BAU-92	Shatmera, Shatmera, Sadar, Panchagarh	Pirgacha	N26^{0}28'7.9", E88^{0}31'39.8"	11.51
2	BAU-98	Titihepara, Shatmera, Sadar, Panchagarh	Pirgacha	N26^{0}28'8.4", E88^{0}31'41.7"	8.40
3	BAU-101	Muhurijhot, Shatmera, Sadar, Panchagarh	Sonatala	N26^{0}28'6.3", E88^{0}31'7.9"	8.40

Sample no.	Sample name	Location details (Vill./Uni./Upazil./Distri.)	Soil series	GPS	Avail. P (ppm)
4	BAU-103	Muhurijhot, Shatmera, Sadar, Panchagarh	Sonatala	N26^{0}28'5.7", E88^{0}31'9.0"	12.90
5	BINA-3	Sormongla, Rahi, Godagari, Rajshahi	Amnura	N24^{0}29'6.9", E88^{0}20'46.8"	13.33
6	BINA-18	Digram, Mohanpur, Godagari, Rajshahi	Atahar	N24^{0}31'46.5", E88^{0}22'36.1"	7.75
7	BINA-21	Kazipara, Mohanpur, Godagari, Rajshahi	Atahar	N24^{0}32'52", E88^{0}22'55.1"	12.84
8	BINA-29	Kazipara, Mohanpur, Godagari, Rajshahi	Dudnai	N24^{0}32'56.2", E88^{0}22'51.1"	12.47
9	BAU-152	Sardar, Rangpur	Sonatala	N25^{0}48'7.2", E89^{0}8'16.1"	14.13
10	BINA-86	Kituli, Kusumba, Manda, Naogoan	Amnura	N24^{0}42'48.2", E88^{0}40'36.7"	14.56
11	BINA-74	Kaligram, Manda, Naogoan	Nijuri	N24^{0}42'29.8", E88^{0}40'28.1"	12.04
12	BINA-148	Baluha, Hamidpur, Mithapukur, Rangpur	Belabo	N25^{0}31'24.7", E89^{0}9'55.9"	10.75
13Medium P					
13	BINA-80	Kaligram, Manda, Naogoan	Amnura	N24^{0}42'28.1", E88^{0}40'39"	16.80
14	BINA-124	Banderpara, Gopalpur, Mithapukur, Rangpur	Noadda	N25^{0}31'40", E89^{0}11'30.4"	16.50
15	BAU-136	North Hajipur, Ekurchali, Taragonj, Rangpur		N25^{0}48'49", E89^{0}4'6.4"	19.67
16	BINA-146	Baluha, Hamidpur, Mithapukur, Rangpur	Belabo	N25^{0}31'24.3", E89^{0}9'58.7"	18.06
High P					
17	BAU-123	North Hajipur, Ekurchali, Taragonj, Rangpur	Sonatala	N25^{0}48'7.4", E89^{0}5'3.3"	31.40
18	BINA-81	Kituli, Kusumba, Manda, Naogoan	Amnura	N24^{0}42'54", E88^{0}40'32.6"	42.57
19	BAU-154	Sardar, Rangpur	Sonatala	N25^{0}48'7.4", E89^{0}8'18.7"	39.99
20	BINA-101	Kataham, Bhatgram, Nandigram, Bogura	Amnura	N24^{0}40'6", E89^{0}16'26"	33.60

Table 8. Selected soil samples having Low, Medium and High levels of Magnesium (Mg) for collection of bulk soil for pot study, Soil Science Division, BINA, Mymensingh, 2019-20

Sample no.	Sample name	Location details (Vill./Uni./Upazil./Distri.)	Soil series	GPS	Excha. Mg (meq/100 g)
Low Mg					
1	BINA-105	Kataham, Bhatgram, Nandigram, Bogura	Amnura	N24^{0}40'5.3", E89^{0}16'21.1"	0.58
2	BINA-107	Kataham, Bhatgram, Nandigram, Bogura	Amnura	N24^{0}40'11.2", E89^{0}16'22.3"	0.58
3	BINA-121	Banderpara, Gopalpur, Mithapukur, Rangpur	Noadda	N25^{0}31'38.2", E89^{0}11'31.3"	0.57
4	BINA-127	Banderpara, Gopalpur, Mithapukur, Rangpur	Noadda	N25^{0}31'40.7", E89^{0}11'26.8"	0.55
5	BINA-130	Banderpara, Gopalpur, Mithapukur, Rangpur	Noadda	N25^{0}31'43.4", E89^{0}11'25.3"	0.36
6	BINA-150	Baluha, Hamidpur, Mithapukur, Rangpur	Belabo	N25^{0}31'25.1", E89^{0}9'53.9"	0.32
7	BAU-111	Laipara, Shatmera, Sadar, Panchagarh	Sonatala	N26^{0}27'7.3", E88^{0}32'9.6"	0.17
8	BAU-112	Laipara, Shatmera, Sadar, Panchagarh	Sonatala	N26^{0}27'6.8", E88^{0}32'9.0"	0.17
9	BAU-138	Taragonj, Rangpur	Sonatala	N25^{0}48'5.5", E89^{0}4'11.7"	0.29
10	BAU-139	Taragonj, Rangpur	Sonatala	N25^{0}48'7.2", E89^{0}4'18.8"	0.29
11	BAU-158	Sardar, Rangpur	Sonatala	N25^{0}48'6.9", E89^{0}7'56"	0.28
12	BAU-167	Sardar, Rangpur	Sonatala	N25^{0}48'6.7", E89^{0}7'56.2"	0.28
Medium Mg					
13	BINA-13	Digram, Mohanpur, Godagari, Rajshahi	Atahar	N24^{0}31'28.3", E88^{0}22'40.1"	0.79
14	BINA-15	Digram, Mohanpur, Godagari, Rajshahi	Atahar	N24^{0}32.1'11.4", E88^{0}22'37.2"	0.92
15	BINA-103	Kataham, Bhatgram, Nandigram, Bogura	Amnura	N24^{0}40'4", E89^{0}16'21"	0.79
16	BINA-112	Nandigram, Nandigram, Bogura	Amnura	N24^{0}38'56", E89^{0}15'47.7"	0.79
	High Mg				
17	BINA-4	Sormongla, Rahi, Godagari, Rajshahi	Amnura	N24^{0}29'5.7", E88^{0}20'49.5"	1.67
18	BINA-20	Digram, Mohanpur, Godagari, Rajshahi	Atahar	N24^{0}31'46.5", E88^{0}22'43.4"	1.67
19	BINA-79	Kaligram, Manda, Naogoan	Amnura	N24^{0}42'29.5", E88^{0}40'38.3"	1.67
20	BINA-87	Kituli, Kusumba, Manda, Naogoan	Amnura	N24^{0}42'52.4", E88^{0}40'45.6"	1.35

b) Pot trial

BINA Component

Pot trials were conducted on mustard and maize during Rabi season 2019-20. Pot trials on maize was also repeated in Kharif-1 season 2020. For pot trials bulk soils were collected from the surface layer (0-15 cm) from the selected locations as mentioned in Tables 7 and 8. The soils were processed (ground and sieved). Pot trials on response of mustard and maize to each of P and Mg were conducted in completely randomized design with two treatments (with and without P and Mg) and three replications. For mustard trial 5 kg soils were used per pot; while 10 kg soils were used per pot for maize trial for both the nutrients. On the basis of soil analysis, nutrients were used at the rate of 150 kg N, 35 kg P, 90 kg K, 25 kg S, 6 kg Mg, 2 kg Zn and 1 kg B per hectare for mustard and 250 kg N, 60 kg P, 120 kg K, 45 kg S, 10 kg Mg, 3 kg Zn and 2 kg B per hectare for maize. The processed soils were weighed for individual pot and mixed all the nutrients (except N and the nutrient in study) will be thoroughly and filled up the pot. Phosphorus and magnesium were mixed with the soil along with other nutrients during pot preparation as per treatment. Reagent grade chemicals (TSP for P and MgO for Mg) were used as the sources of nutrients. Nitrogen was applied in two equal splits at 15 and 30 days after emergence of maize and at 11 and 25 days after emergence of mustard.

For P and Mg response trials for mustard, seeds were sown on 4 December 2019 and for maize trials the seeds were sown on 11 December 2019, respectively. Ten (10) sprouted seeds of mustard (Binasarisha-9) and 6 sprouted seeds of maize (BARI Hybrid Maize-7) were sown per pot. Distilled water was added to the soil for 'Zou' condition after sowing. Seedlings were thinned to desired population (5 plants/pot for mustard and 3 plants/pot for maize) within 15 and 25 days after emergence, respectively. Intercultural operations like irrigation, weeding etc. were maintained for proper plant growth. Mustard plants for P and Mg response trials were harvested on 15 January 2020 (six weeks after sowing). Fresh and dry weights of mustard plants were recorded, which are being processed for chemical analysis. The maize plants of both P and Mg response trials were harvested on 14 February 2020 (nine weeks after sowing). Pot trials on maize with P and Mg in Kharif-1 season was sown on 2 March 2020 and harvested on 20 April 2020 (seven weeks after sowing).

c) Plant analysis

Plant concentration of P and Mg was determined. Plant samples were dried in an oven at 65 ^{o}C for about 24 hours, after which the sample was ground by a grinding mill. The ground samples were sieved through a 20-mesh sieve. Then samples were chemically analyzed for all elements except N following HNO_3-$HClO_4$ digestion and N by H_2SO_4-H_2O_2 digestion (Jones and Case, 1990; Watson and Issac, 1990).

d) Determination of critical limit

Critical limits of P and Mg was derived by plotting the relative crop yield (%) on the Y axis and the soil nutrient concentration on the X axis for each crop per nutrient following Cate and Nelson method (1965). A polynomial trend line was drawn using the data points. The relative yield percentage was calculated from the ratio of the crop yields without and with nutrients as below. The average of the twenty relative yield data was calculated and pointed on the Y axis. A horizontal line parallel to X axis was drawn from that point. From the cut point of horizontal line and trend line a perpendicular line parallel to Y axis was drawn on the X axis. The cut point of perpendicular line on the X axis was the critical limit of the specific crop for the specific nutrient.

$$\textbf{\% Relative yield} = \frac{\text{Yield without addition of nutrient}}{\text{Yield with addition of nutrient}} \times 100$$

Expt. 2.4: Determination of critical limit of Mg, S and B for wheat and mustard

BAU Component

a) Collection of bulk soil sample

As per decision of the coordination meeting held at BARC in September 2019 twenty extensively cultivated soils were collected for each pot trial from 12 AEZs covering the major cropping areas in Bangladesh for determination of critical limits of sulphur, magnesium and boron. Among the 20 soils, 12 soil samples were of low nutrient status, 4 were of medium status and 4 were of high nutrient status for each of B, S and Mg. The soils were collected from 0-15 cm depth from the selected locations as in Tables 9, 10 and 11. Sampling locations were selected based on the first year soil analyses data generated by BARI, BRRI, BINA and BAU components of the Critical Limit sub-project *i.e.* from 720 soil samples from across the country.

Table 9. Selected soil samples having Low, Medium and High levels of Magnesium (Mg) for collection of bulk soil for Pot Study by BAU, 2019-20

Sample No.	Sample name	Location details	Soil series	GPS	Excha. Mg (meq/100g)
Low Mg					
1.	BAU 97	Sadar, Panchagar	Ruhia	N. $26^{0}28^{/}.068$ E. $88^{0}31^{/}.037$	0.12
2.	BAU 112	Sadar, Panchagar	Ranisongkail	N. $26^{0}27^{/}.248$ E. $88^{0}32^{/}.207$	0.17
3.	BAU 71	Tetulia, Panchagar	Atoary	N. $26^{0}28^{/}.468$ E. $88^{0}30^{/}.341$	0.19
4.	BAU 131	Teragonj, Rangpur	Polasbari	N. $25^{0}48^{/}.923$ E. $89^{0}04^{/}.075$	0.21
5.	BAU 128	Teragonj, Rangpur	Sonatola	N. $25^{0}48^{/}.197$ E. $89^{0}05^{/}.319$	0.27
6.	BAU 158	Sadar, Rangpur	Sonatola	N. $25^{0}48^{/}.106$ E. $89^{0}07^{/}.685$	0.28
7.	BAU 139	Teragonj, Rangpur	Polasbari	N. $25^{0}48^{/}.702$ E. $89^{0}04^{/}.188$	0.29
8.	BAU 65	Tetulia, Panchagar	Atoary		0.31
9.	BAU 155	Sadar, Rangpur	Pirgacha	N. $25^{0}48^{/}.445$ E. $89^{0}08^{/}.201$	0.39
10.	BAU 73	Tetulia, Panchagar	Atoary	N. $26^{0}28^{/}.495$ E. $88^{0}30^{/}.288$	0.42
11.	BAU 76	Tetulia, Panchagar	Atoary	N. $26^{0}28^{/}.758$ E. $88^{0}30^{/}.277$	0.5
12.	BAU 87	Tetulia, Panchagar	Baliadangi	N. $26^{0}28^{/}.735$ E. $88^{0}30^{/}.471$	0.63
Medium Mg					
13.	BAU 61	Tetulia, Panchagar	Baliadangi	N. $26^{0}28^{/}.729$ E. $88^{0}30^{/}.705$	0.8
14.	BAU 17	Muktagacha,Mymensingh	Silmondi	N. $24^{0}46^{/}.008$ E. $90^{0}10^{/}.148$	1.2

Sample No.	Sample name	Location details	Soil series	GPS	**Excha.** Mg **(meq/100g)**
15.	BAU 27	Muktagacha,Mymensingh	Silmondi	N. $24^{0}44^{/}.054$ E. $90^{0}12^{/}.557$	1.3
16.	BAU 37	Sadar,Mymensingh	Sonatola	N. $24^{0}39^{/}.514$ E. $90^{0}27^{/}.921$	1.49
High Mg					
17.	BAU 13	Muktagacha,Mymensingh	Silmondi	N. $24^{0}46^{/}.288$ E. $90^{0}10^{/}.076$	1.51
18.	BAU 34	Sadar,Mymensingh	Sonatola	N. $24^{0}39^{/}.738$ E. $90^{0}27^{/}.621$	1.61
19.	BAU 21	Muktagacha,Mymensingh	Silmondi	N. $24^{0}44^{/}.049$ E. $90^{0}12^{/}.162$	1.81
20.	BAU32	Sadar,Mymensingh	Sonatola	N. $24^{0}39^{/}.868$ E. $90^{0}27^{/}.213$	1.83

Table 10. Selected soil samples having Low, Medium and High levels of Sulphur (S) for collection of bulk soil for Pot Study by BAU, 2019-20

Sample No.	Sample name*	Location details	Soil series	GPS	Avail. S (ppm)
Low S					
1.	BAU 8	Muktagacha, Mymensingh	Sonatola	N. $24^{0}47^{/}.138$ E. $90^{0}12^{/}.597$	15.1
2.	BAU 96	Sadar, Panchagar	Vojonpur	N. $26^{0}28^{/}.696$ E. $88^{0}31^{/}.029$	8.81
3.	BAU 128	Taragonj, Rangpur	Sonatola	N. $25^{0}48^{/}.197$ E. $89^{0}05^{/}.319$	10.3
4.	BAU 119	Sadar, Panchagar	Atoary	N. $26^{0}27^{/}.681$ E. $88^{0}33^{/}.573$	11.44
5.	BINA 9	Godagari	Atahar	N 24°29' 11.4" E088 21' 06.5"	6.46
6.	BAU 98	Sadar, Panchagar	Vojonpur	N. $26^{0}28^{/}.651$ E. $88^{0}31^{/}.040$	8
7.	BAU37	Sadar, Mymensingh	Sonatola	N. $24^{0}39^{/}.514$ E. $90^{0}27^{/}.921$	9
8.	BAU 136	Taragonj, Rangpur	Polasbari	N. $25^{0}48^{/}.942$ E. $89^{0}04^{/}.227$	10
9.	BAU 31	Sadar, Mymensingh	Sonatola	N. $24^{0}39^{/}.860$ E. $90^{0}27^{/}.823$	11
10.	BAU 42	Sadar, Mymensingh	Silmondi	N. $24^{0}40^{/}.373$ E. $90^{0}26^{/}.459$	12
11.	BAU 51	Sadar, Mymensingh	Sonatola	N. $24^{0}40^{/}.224$ E. $90^{0}27^{/}.516$	13
12.	BAU 47	Sadar, Mymensingh	Silmondi	N. $24^{0}40^{/}.471$ E. $90^{0}26^{/}.560$	15

Sample No.	Sample name*	Location details	Soil series	GPS	Avail. S (ppm)
Medium S					
13.	BAU 27	Muktagacha, Mymensingh	Silmondi	N. $24^{0}44^{/}.054$ E. $90^{0}12^{/}.557$	22
14.	BAU 159	Sadar, Rangpur	Menanogor	N. $25^{0}48^{/}.522$ E. $89^{0}07^{/}.346$	23
15.	BAU 50	Sadar, Mymensingh	Silmondi	N. $24^{0}40^{/}.623$ E. $90^{0}26^{/}.842$	24
16.	BINA 2	Godagari	Nachole	N 24° 29' 8.7" E088 20'35.9"	16
High S					
17.	BAU 56	Sadar, Mymensingh	Sonatola	N. $24^{0}40^{/}.787$ E. $90^{0}27^{/}.658$	32
18.	BAU 41	Sadar, Mymensingh	Silmondi	N. $24^{0}40^{/}.055$ E. $90^{0}26^{/}.089$	36
19.	BAU 43	Sadar, Mymensingh	Silmondi	N. $24^{0}40^{/}.693$ E. $90^{0}26^{/}.567$	37
20.	BAU 49	Sadar, Mymensingh	Silmondi	N. $24^{0}40^{/}.914$ E. $90^{0}26^{/}.641$	38

Table 11. Selected soil samples having Low, Medium and High levels of Boron (B) for collection of bulk soil for Pot Study by BAU, 2019-20

Sample No.	Sample name	Location details	Soil series	GPS	Avail. B (ppm)
Low B					
1.	BAU 87	Tetulia, Panchagar	Baliadangi	N. $26^{0}28^{/}.735$ E. $88^{0}30^{/}.471$	0.07
2.	BINA 29	Godagari	Dudhnai	N 24° 32' 56.2" E088° 22' 51.1"	0.045
3.	BAU 168	Sadar.Rangpur	Sonatola	N. $25^{0}48^{/}.418$ E. $89^{0}07^{/}.138$	0.15
4.	BAU 74	Tetulia, Panchagar	Atoary	N. $26^{0}28^{/}.568$ E. $88^{0}30^{/}.169$	0.08
5.	BAU 109	Sadar, Panchagar	Ruhia	N. $26^{0}28^{/}.855$ E. $88^{0}31^{/}.149$	0.09
6.	BINA 2	Godagari	Nachole	N 24° 29' 8.7" E088 20'35.9"	0.13
7.	BAU 152	Sadar, Rangpur	Pirgacha	N. $25^{0}48^{/}.417$ E. $89^{0}08^{/}.536$	0.15
8.	BAU 13	Muktagacha, Mymensingh	Silmondi	N. $24^{0}46^{/}.288$ E. $90^{0}10^{/}.076$	0.2
9.	BAU 42	Sadar, Mymensingh	Silmondi	N. $24^{0}40^{/}.373$	0.23

Sample No.	Sample name	Location details	Soil series	GPS	Avail. B (ppm)
				E. 90^{0}26$^{/}$.459	
10.	BAU 36	Sadar, Mymensingh	Sonatola	N. 24^{0}39$^{/}$.628 E. 90^{0}27$^{/}$.201	0.24
11.	BAU 79	Tetulia, Panchagar	Atoary	N. 26^{0}28$^{/}$.633 E. 88^{0}30$^{/}$.154	0.28
12.	BAU 112	Sadar, Panchagar	Ranisonkail	N. 26^{0}27$^{/}$.248 E. 88^{0}32$^{/}$.207	0.28
Medium B					
13.	BAU 124	Taragonj, Rangpur	Sonatola	N. 25^{0}48$^{/}$.079 E. 89^{0}04$^{/}$.501	0.36
14.	BAU 16	Muktagacha, Mymensingh	Silmondi	N. 24^{0}46$^{/}$.740 E. 90^{0}10$^{/}$.930	0.39
15.	BAU 151	Sadar, Rangpur	Pirgacha	N. 25^{0}48$^{/}$.629 E. 89^{0}08$^{/}$.648	0.4
16.	BAU 45	Sadar, Mymensingh	Silmondi	N. 24^{0}40$^{/}$.554 E. 90^{0}26$^{/}$.777	0.47
High B					
17.	BAU 104	Sadar, Panchagar	Ruhia	N. 26^{0}28$^{/}$.584 E. 88^{0}31$^{/}$.913	0.67
18.	BAU 37	Sadar, Mymensingh	Sonatola	N. 24^{0}39$^{/}$.514 E. 90^{0}27$^{/}$.921	0.71
19.	BAU 43	Sadar, Mymensingh	Sonatola	N. 24^{0}40$^{/}$.693 E. 90^{0}26$^{/}$.567	0.94
20.	BAU 3	Muktagacha, Mymensingh	Sonatola	N. 24^{0}47$^{/}$.138 E. 90^{0}12$^{/}$.491	0.98

b) Pot trial:

BAU Component

Pot trials were conducted at the back yard net house of Department of Soil Science, BAU with wheat and mustard crops for 3 nutrients *viz.* magnesium, sulphur and boron during Rabi season 2019-20. For pot trials bulk soils were collected from the surface layer (0-15 cm) from the selected locations as mentioned in Tables 9, 10 and 11. The soils were processed (ground and sieved). Pot trials were conducted in completely randomized design (CRD) with two treatments (with and without Mg, S and B) and three replications. On the basis of soil analysis, nutrients were used at the rate of $N_{120}P_{25}K_{90}S_{15}Mg_{6}Zn_{3}B_{1.4}$ ppm for wheat and $N_{150}P_{45}K_{95}S_{26}Mg_{6}$ $Zn_{2}B_{1.2}$ ppm for mustard. Reagent grade chemicals ($MgSO_4$ for Mg, $CaSO_4$ for S and H_3BO_3 for B) were used as the sources of critical nutrients. Mustard variety Binasarisha-9 and Wheat variety BARI Gom-24 were used as the test crops. Three kg of processed soils was used per pot. Mustard and wheat seeds were sown on 24/11/19 and 26/11/19, respectively. Ten seeds of each crop were sown in each pot and after germination six plants were kept. Intercultural operations like irrigation, weeding etc. were maintained for uninterrupted plant growth. The plants were grown for 7 weeks and harvested by cutting at the ground level. Dry matter yields (g/6 plants) of the crops were recorded (Table 1, 2 and 3) for the determination of critical limit of wheat and mustard for S, Mg and B.

c) Plant analysis:

Plant concentration of the nutrient elements (S, Mg and B) will be determined. Plant samples were dried in an oven at 65 ^{o}C for about 24 hours, after which the sample were ground by a grinding mill. The ground samples were sieved through a 20-mesh sieve. The samples were then be chemically analyzed for all elements except N following HNO_3-$HClO_4$ digestion procedure and for N by H_2SO_4-H_2O_2 digestion procedure (Jones and Case, 1990; Watson and Issac, 1990).

d) Determination of critical limit:

Critical limits of S, B and Mg were derived by plotting the relative crop yield % on the Y axis and the soil nutrient concentration on the X axis for each crop per nutrient following Cate and Nelson method (1965). A polynomial trend line was drawn using the data points. The relative yield percentage was calculated from the ratio of the crop yield without and with nutrients as below. The average of the twenty relative yield data was calculated and pointed on the Y axis. A horizontal line parallel to X axis was drawn from that point. From the cut point of the horizontal line and trend line a perpendicular line parallel to Y axis was drawn on the X axis. The cut point of the perpendicular line on the X axis was the critical limit of the specific crop for the specific nutrient.

$$\textbf{\% Relative yield} = \frac{\text{Yield without addition of nutrient}}{\text{Yield with addition of nutrient}} \times 100$$

Expt. 3: Verification of Estimated Critical Limit through Field Experiments at the Farmers' Field

The Critical Limits of different nutrients for different soils and crops estimated by different component organizations were verified through on-farm trials at the farmers' fields. Different component organizations conducted field trials with their assigned nutrients and crops as mentioned in the Methodology chapter of experiment 2.

Expt. 3.1: Response of wheat, cabbage and maize to potassium and zinc applications (Field Experiment)

BARI Component

The Critical Limits of potassium and zinc for different soils and crops determined by pot experiments were validated through field experiments during Rabi, 2020-21 and Kharif-1, 2021 seasons.

Twelve field experiments were conducted at farmer's field at Chowgacha, Jashore, Paba, Rajshahi and Joydebpur, Gazipur. The experiments were conducted under low and medium levels for both of K and Zn. Response of wheat, cabbage and maize to applied K and Zn was studied at Chowgacha, Jashore; response of wheat and maize to applied K and Zn was studied at Paba, Rajshahi and response of cabbage to applied K and Zn was studied at Gazipur. Initial soil samples were collected from all of the experimental fields. The lands were prepared properly as per crop requirement before setting up of the experiments. Randomized Complete Block Design (RCBD) was used in the experiments with the following six treatments and three replications.

Treatments:

For K	For Zn
T_1: 0 K	T_1: 0 Zn
T_2: 50% STB of K	T_2: 50% STB of Zn
T_3: 75% STB of K	T_3: 75% STB of Zn
T_4: 100% STB of K	T_4: 100% STB of Zn
T_5: 125% STB of K	T_5: 125% STB of Zn
T_6: 150% STB of K	T_6: 150% STB of Zn

Fertilizer dose used in K experiments (on STB basis):

Wheat (at Jashore): 120-35-75-20-3 kg NPKSZn ha^{-1}
Cabbage (at Jashore): 190-30-75-30-3-1 kg NPKSZnB ha^{-1}
Maize (at Jashore): 255-55-90-40-1 NPKSB ha^{-1}
Wheat (at Rajshahi): 120-35-95-20-3 NPKSZn ha^{-1}
Cabbage (at Gazipur): 190-30-100-30-3-1 kg NPKSZnB ha^{-1}
Maize (at Rajshahi): 255-55-110-40-3-1 kg NPKSZnB ha^{-1}

Fertilizer dose used in Zn experiment (on STB basis):

Wheat (at Jashore) : 120-35-75-20-2.5 kg NPKSZn ha^{-1}
Cabbage (at Jashore): 190-30-75-30-2.5-1 kg NPKSZnB ha^{-1}
Maize (at Jashore): 255-55-90-40-3-1 NPKSZnB ha^{-1}
Wheat (at Rajshahi): 120-35-75-20-3.5 NPKSZn ha^{-1}
Cabbage (at Gazipur): 190-30-100-30-1.75-1 kg NPKSZnB ha^{-1}
Maize (at Rajshahi): 255-55-110-40-4-1 kg NPKSZnB ha^{-1}

K and Zn fertilizers were appilied as per treatments. All other fertilizers were applied as blanket dose as basal except urea. Urea was applied in two equal splits for wheat and three equal splits for maize and cabbage. One third of urea was applied during final land preparation. The 2^{nd} split (1/3) of urea was applied at maximum vegetative growth stage and the 3^{rd} split was applied at or before P.I. stages. Other intercultural operations were done as and when necessary.

Data on initial soil properties, yield and yield components were collected. Grain and straw samples were collected during harvesting of crops from individual plots. The samples were dried in an oven at 65 ^{0}C for about 24 hours and ground by a grinding mill. The ground samples were sieved through a 20-mesh sieve. The prepared samples were then analyzed for K and Zn following NH_4OAc extraction, pH 7.0 (Flame photometry) (Schollenberger and Simon 1945) and 0.005M DTPA, pH 7.3 extraction (Lindsay and Norvell 1978) methods, respectively. Standard laboratory analytical methods were used for soil and plant tissue analysis. Data on nutrient concentration and uptake by the plants (grain plus straw) were recorded. The data were statistically analyzed and mean separation was done by Duncan's Multiple Range Test (Gomez and Gomez, 1984). As stated above,

Data collection

- i) Initial soil properties (texture, pH, OC, total N, available P, K, S, Mg, Zn & B)
- ii) Crop yield (main product and by-product)
- iii) Nutrient concentration of main product and by-product
- iv) Nutrient uptake by crops (by calculation from nutrient concentration and crop yield)

Expt. 3.2: Response of rice to Phosphorus, Potassium, Sulphur and Zinc applications (Field experiments)

BRRI Component

Field experiments were conducted at farmer's field on Boro (dry season rice) 2020-21 season according to the plan of the sub-project. Four field experiments were conducted at Companiganj upazilla in Sylhet district, AEZ-20 (P & S for rice) and Katchua upazilla in Chandpur district, AEZ-19 (K & Zn for rice). The experiments were conducted in the particular nutrient deficient soil from the respective farmer's field where the initial and bulk soil samples were collected for pot experiments. Again, initial soil samples were collected from the four experimental sites. Soil texture and other chemical properties were analyzed from the initial soil. By this time rice seeds were sown in the seed bed for all respective farmer's field. The tested rice variety was BRRI dhan28 a most popular one in all experiments. There were six treatments viz. $T_{1:}$ control, T_2:50% STB, T_3:75% STB, T_4:100% STB, T_5:125% STB and T_6:150% STB were assigned in Randomized Complete Block Design (RCBD) with three replications. On the basis of soil analysis, the STB dose and other nutrients were calculated and applied to experimental plots. A blanket dose of chemical fertilizers for P, K, S and Zn were applied in the experiments in addition to the treatment elemrents.

Treatments:

P	K	S	Zn
T_1: 0 P (control)	T_1: 0 K (control)	T_1: 0 S (control)	T_1: 0 Zn (control)
T_2: 50% STB of P	T_2: 50% STB of K	T_2: 50% STB of S	T_2: 50% STB of Zn
T_3: 75% STB of P	T_3: 75% STB of K	T_3: 75% STB of S	T_3: 75% STB of Zn
T_4: 100% STB of P	T_4: 100% STB of K	T_4: 100% STB of S	T_4: 100% STB of Zn
T_5: 125% STB of P	T_5: 125% STB of K	T_5: 125% STB of S	T_5: 125% STB of Zn
T_6: 150% STB of P	T_6: 150% STB of K	T_6: 150% STB of S	T_6: 150% STB of Zn

In the phosphorus response experiment, the six P doses were; P- 0, P-19, P-29, P-38, P-48 and P-57 $kgha^{-1}$, respectively and the blanket fertilizer dose for N-K-S and Zn was 140-60-15 and 1 kg ha^{-1}, respectively. In the potassium response experiment, the six K doses were; K- 0, K-56, K-84, K-112, K-140 and K-168 $kgha^{-1}$, respectively and the blanket fertilizer dose for N-P-S and Zn was 140-20-10 and 2.5 $kgka^{-1}$, respectively. In the sulphur response experiment, the six S doses were; S- 0, S-10, S-15, S-20, S-25 and S-30 $kgha^{-1}$, respectively and the blanket fertilizer dose for N-P-K and Zn was 140-38-60 and 1 $kgka^{-1}$, respectively. In the zinc response experiment, the six Zn doses were; Zn- 0, Zn-1.20, Zn-1.85, Zn-2.46, Zn-3.08 and Zn-3.69 $kgha^{-1}$, respectively and the blanket fertilizer dose for N-P-K and S was 140-20-110 and 10 $kgka^{-1}$, respectively. All fertilizers except urea were applied as basal at final land preparation. Urea was applied into three equal splits in which first top-dressing on 15 days after transplanting (DAT), second one on 30 DAT and the rest one on 5 days before panicle initiation (PI) stage. Thirty-five days older seedlings of BRRI dhan28 was transplanted on 25 to 30 December 2020. Irrigation, weeding and other cultural management practices were done equally as per needed. At maturity, the rice of the experiments was harvested on 15-20 April 2021 manually in the area of 5 m^2 at 15 cm above ground level, however, 16 hills from each experimental plot were harvested at the ground level for straw yield. The grain yield was recorded at 14% moisture content and straw yield as oven dry basis. The tiller and panicle number per meter square were recorded. Chemical analysis of grain and straw samples were done for the respective nutrient element (viz. P/K/S/Zn) and also for N content following the standard methods. The data were statistically analyzed with the software STAR. For each experiment a quadratic regression model was fitted (R^2= 0.72 to 0.99) to the grain yield vs. respective nutrient rates to find out the optimum nutrients rate.

Data Collection

(i) Initial soil properties (texture, pH, OC, total N, available P, K, S and Zn)
(ii) Crop yield (main product and by-product)
(iii) Nutrient concentration of main product and by-product
(iv) Nutrient uptake by crops (by calculation from nutrient concentration and crop yield)

Expt. 3.3: Response of maize and mustard to phosphorus and Magnesium applications (Field experiment)

BINA Component

The Critical Limits of phosphorus and magnesium for different soils and crops determined by pot experiments were validated through field experiments during Rabi, 2020-21 and Kharif-1, 2021 seasons.

A total of four field experiments were conducted for validation of the estimated Critical Limits, of which two experiments on response of mustard and maize to applied P at Ramchandracura, Nalitabari, Sherpur; and another two experiments on response of mustard and maize to applied Mg were conducted at Sunderban, Sadar, Dinajpur. Initial soil samples were collected from both the experimental sites. The experiment was conducted in Randomized Complete Block Design with six treatments and four replications. The nutrient under investigation was used as per the treatments as follows:

Treatments:

For P	For Mg
T_1: 0 P	T_1: 0 Mg
T_2: 50% STB of P	T_2: 50% STB of Mg
T_3: 75% STB of P	T_3: 75% STB of Mg
T_4: 100% STB of P	T_4: 100% STB of Mg
T_5: 125% STB of P	T_5: 125% STB of Mg
T_6: 150% STB of P	T_6: 150% STB of Mg

The STB dose was calculated on the basis of soil analysis as 150 kg N, 35 kg P, 90 kg K, 25 kg S, 6 kg Mg, 2 kg Zn and 1 kg B per hectare for mustard and 250 kg N, 60 kg P, 120 kg K, 45 kg S, 10 kg Mg, 3 kg Zn and 2 kg B per hectare for maize. All the fertilizers were applied as basal except urea. Urea was applied in two equal splits for mustard and three equal splits for maize. One-third of urea was applied during final land preparation, thoroughly mixed with the soil. The 2nd split (1/3) of urea was applied at maximum vegetative growth stage and the 3rd split at or before panicle initiation stage. Other intercultural operations were done as and when necessary. Data were collected on initial soil properties, yields and yield components, nutrient concentrations and uptake by the plants (grain plus straw). Grain and straw samples were collected during harvesting of crops. The data were statistically analyzed and the mean separation was done by Duncan's Multiple Range Test (Gomez and Gomez, 1984).

Data Collection

i) Initial soil properties (texture, pH, OC, total N, available P, K, S, Mg, Zn & B)
ii) Crop yield (main product and by-product)
iii) Nutrient concentration of main product and by-product
iv) Nutrient uptake by crops (by calculation from nutrient concentration and crop yield)

Expt. 3.4: Response of wheat and mustard to Magnesium, Sulphur and Boron applications (Field experiment)

BAU Component

The estimated Critical Limits of magnesium, sulphur and boron for different soils and crops determined by the pot experiments were validated through field experiments during Rabi season 2020-21.

A total of six field experiments were conducted for validation of the estimated Critical Limits of Mg, S and B, of which two experiments on response of mustard to applied S and B were conducted at Sadar, Mymensingh; two experiments on response of wheat to applied S and B were conducted also at Sadar, Mymensingh; and another two experiments on response of mustard and wheat to applied Mg were conducted at Tetulia, Panchagar. Binasarisha-9 and BARI Gom-30 were used as the test crop in the experiment. The field experiment on a particular nutrient was conducted in the field from where the bulk soil samples were collected for the pot trial for that particular nutrient. Initial soil samples were collected again from all the experimental fields before setting up the experiment and analyzed for soil texture and other chemical properties. The experiment was conducted in Randomized Complete Block Design with six treatments and four replications.

Treatments:

For Mg	For S	For B
T_1: 0 Mg	T_1: 0 S control	T_1: 0 B control
T_2: 50% STB of Mg	T_2: 50% STB of S	T_2: 50% STB of B
T_3: 75% STB of Mg	T_3: 75% STB of S	T_3: 75% STB of B
T_4: 100% STB of Mg	T_4: 100% STB of S	T_4: 100% STB of B
T_5: 125% STB of Mg	T_5: 125% STB of S	T_5: 125% STB of B
T_6: 150% STB of Mg	T_6: 150% STB of S	T_6: 150% STB of B

Soil test based fertilizer was applied at the rate of 109-15-80 kg NPK/ha for both of wheat and mustard as urea, TSP and MoP. Calcite was applied @ 741 kg/ha (3 kg/decimal) in the experimental field at Tetulia for soil amendment in acidic soil. Mustard and wheat seeds were sown on the 1st and 2nd weeks of November 2020. All the fertilizers and test nutrients were applied as basal doses except urea. Urea was applied in two equal splits. Intercultural operations like urea top dressing, thinning, irrigation, weeding, pest control etc. were maintained for uninterrupted plant growth. Mustard was harvested when 80 percent of siliquae were turned yellowish-brown. Wheat was harvested when the whole plant turned yellowish-brown. Growth and yield parameters were recorded at harvest.

Data Collection

(i) Initial soil properties (texture, pH, OC, total N, available P, K, S and Zn)
(ii) Crop yield (main product and by-product)
(iii) Nutrient concentration of main product and by-product
(iv) Nutrient uptake by crops (by calculation from nutrient concentration and crop yield)

11. Results and Discussion

Expt. 1. Delineation of different nutrients status in some selected AEZs of Bangladesh

All four component organizations conducted research activities on delineation of nutrient status among the selected AEZs. However, different organizations worked with different AEZs. The results of the research activities conducted by different component organizations are described as follows:

Expt. 1.1: Delineation of different nutrients status in calcareous and terrace soils

BARI Component

Soil samples were collected from the intensive cropping area of AEZ 11- High Ganges River Floodplain – calcareous (Chowgacha, Jashore and Paba, Rajshahi), AEZ 13- Ganges Tidal Floodplain – calcareous (Shyamnagar, Satkhira and Babugonj, Barishal) and AEZ 28- Madhupur Tract – terrace (Madhupur of Tangail and Kaligonj of Gazipur). Analysis of collected soil samples for soil texture, pH, organic carbon, total nitrogen, available phosphorus, sulphur, zinc, iron, cupper and manganese and exchangeable potassium, calcium and magnesium were done following standard methods.

Results of soil samples collected from Chowgacha, Jashore and Paba Rajshahi (AEZ-11) have been presented in Appendix 1 and Figure 1. The soil texture was mostly clay loam to silty clay loam. Soil pH ranged from 5.42 to 8.10 (slightly acidic to slightly alkaline) with a mean value of 6.76. The organic carbon of the collected soil samples varied from 0.41% to 1.12% (very low to medium) with a mean value 0.765%. The total nitrogen ranged from 0.03% to 0.106% (very low to low) with a mean value 0.065%. The available phosphorus also varied and ranged from 6.0 ppm to 18.0 ppm (low to medium) with a mean value 12.0 ppm which is well above the present critical limit (8.0 ppm) reported in FRG 2018. Exchangeable K concentration in the soils ranged from 0.07 to 0.28 meq/100 g soil (very low to medium) with an average of 0.175 meq/100 g soil which is higher than the present critical limit of K (0.12 meq/100 g soil). Available S concentration ranged from 3.9 to 26.4 ppm (very low to optimum) with an average value of 15.2 ppm which is above the present critical limit of S (10 ppm). Exchangeable Mg content in the soils collected from Chowgacha, Jashore and Paba, Rajshahi ranged from 2.2 meq/100 g soil to 6.3 meq/100 g soil (very low to low). The average Mg content in the soils was 4.25 meq/100 g soil, while the critical limit of Mg in Bangladesh soils is 0.5 meq/100 g soil (FRG 2018). The Ca concentration in the soil samples ranged from 6.1 to 16.3 meq/100 g soil (low to medium) with an average value of 11.2 meq/100 g. The critical limit of Ca for paddy soils in Bangladesh is 2.0 meq/100 g soil. Available Zn content in the soils ranged from 0.7 to 2.91 ppm (very low to optimum). The average Zn content in the soils was 1.81 ppm while the critical limit of Zn in Bangladesh soils is 0.6 ppm (FRG 2018).

Figure 1 showed that 82% of the collected soil samples were very low and 15% were low in N fertility class indicating that N fertility of soil are very poor. In case of P status of collected soil samples, 50% of soils fell within low and 33% within medium, while only 14% of soils were within high to very high soil P fertility classes. For K status in soil, 82% soils were under low to very low soil K fertility classes, while only 13% collected soil samples fell in medium K fertility class. The S, Ca and Mg fertility statuses also showed similar exhausted fertility levels in collected soil samples indicating very poor soil health that warn us to take urgent actions for improving soil fertility and soil health.

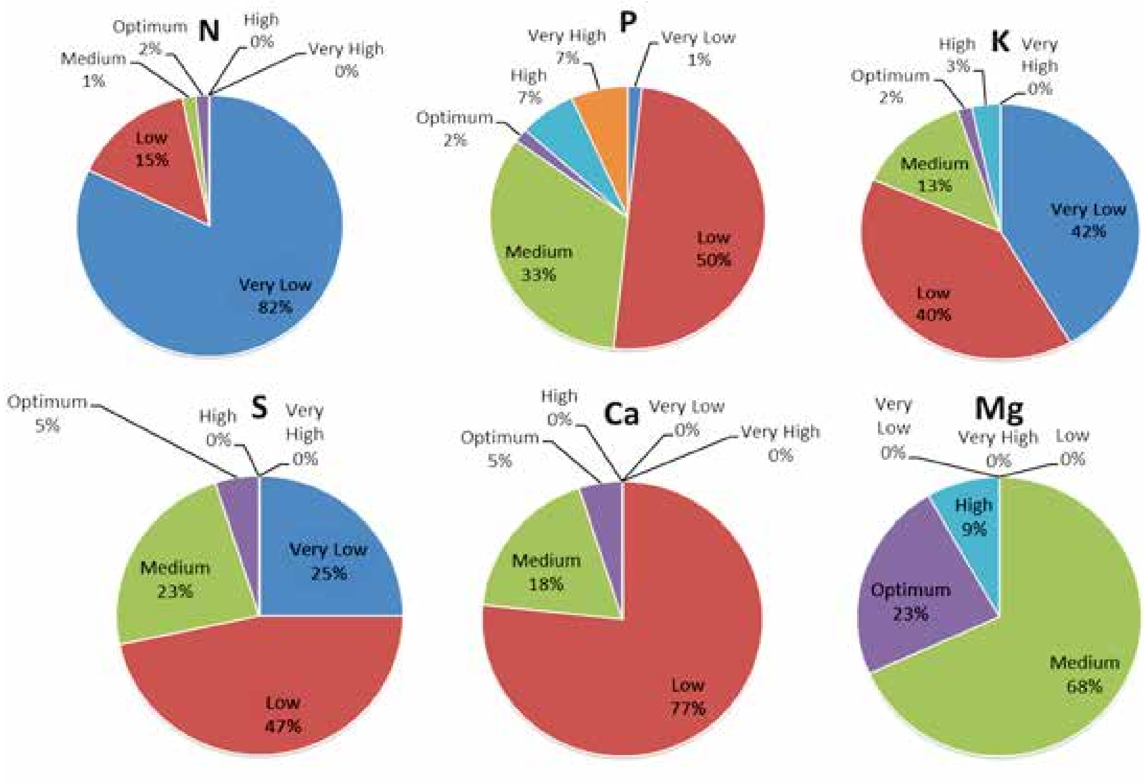


Figure 1. Percent distribution of collected soil samples from Agro-Ecological Zone 28 according to interpretation of soil test values based on critical limits (soil fertility classes) following FRG 2018, SSD, BARI, Gazipur, 2019-20

The Appendix 1 and Figure 2 showed the soil samples analysis results collected from Shyamnagar Satkhira and Babugonj, Barishal (AEZ-13). The soils were mainly sandy clay to sandy clay loam in texture. Soil pH ranged from 6.03 to 8.5 (slightly acidic to slightly alkaline) with a mean value of 7.26. The organic carbon of the collected soil samples varied from 0.43% to 1.32% (very low to medium) with a mean value 0.875%. The total nitrogen ranged from 0.029% to 0.25% (very low to low) with a mean value 0.14%. The available phosphorus ranged from 6.0 ppm to 14.8 ppm (low to medium) with a mean value 10.4 ppm which is well above the present critical limit (8.0 ppm) reported in FRG 2018. Exchangeable K in the soils ranged from 0.11 to 0.5 meq/100 g soil (very low to very high) with an average of 0.305 which is lower than the present critical limit of K (0.12 meq/100 g soil). Available S ranged from 19.2 to 249 ppm (medium to very high) with an average value of 124.1 ppm which is much higher than the present critical limit of S (10 ppm). Exchangeable Mg content in the collected soils ranged from 1.7 to 2.3 meq/100 g soil (high to very high). The average Mg content in the soils was 2.0 meq/100 g soil while the critical limit of Mg in Bangladesh soils is 0.5 meq/100 g soil (FRG 2018). The Ca concentration in the soil samples ranged from 5.0 to 6.3 meq/100 g soil (optimum to high) with an average value of 5.65 meq/100 g. The critical limit of Ca for soils in Bangladesh is 2.0 meq/100 g soil. Available Zn content in the soils ranged from 0.21 to 1.20 ppm (very low to medium). The average Zn content in the soils was 0.705 ppm, while the critical limit of Zn in Bangladesh soils is 0.6 ppm (FRG 2018).

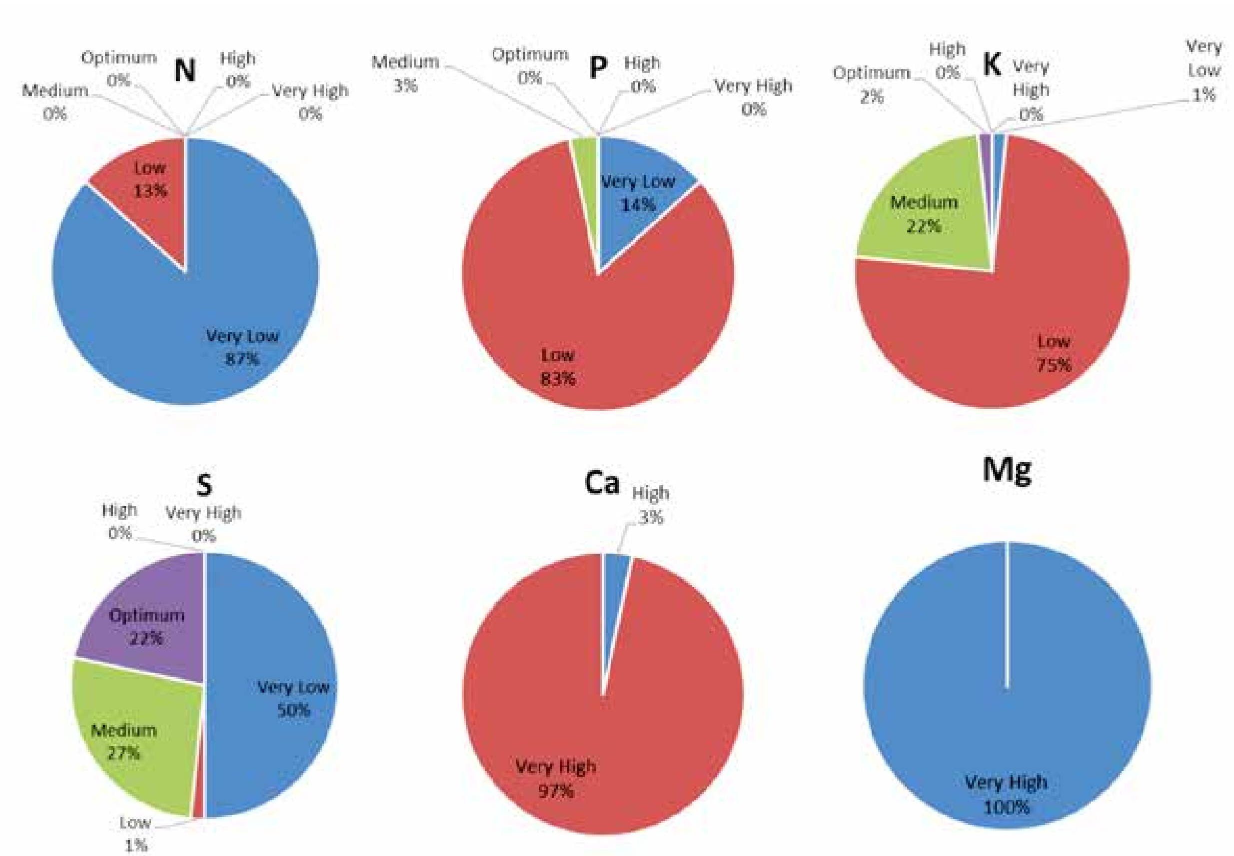


Figure 2. Percent distribution of collected soil samples from Agro-Ecological Zone 11 according to interpretation of soil test values based on critical limits (soil fertility classes) in the FRG 2018, SSD, BARI, Gazipur, 2019-20

Results of soil samples collected from Kaligonj, Gazipur and Madhupur, Tangail in AEZ-28 have been presented in Appendix 1 and Figure 3. The soil texture was mostly silty clay loam. Soil pH ranged from 5.44 to 8.1 (slightly acidic to slightly alkaline) with a mean value of 6.72. The organic carbon of the collected soil samples varied from 0.50% to 2.30% (very low to high) with a mean value 1.40%. The total nitrogen ranged from 0.04% to 0.128% (very low to medium) with a mean value 0.084%. The available phosphorus varied widely ranging from 6.0 ppm to 52.0 ppm (very low to very high) with a mean value 29.0 ppm which is well above the present critical limit (8.0 ppm) reported in FRG 2018. Exchangeable K concentration in the analyzed soils ranged from 0.06 to 0.63 meq/100 g soil (low to very high) with an average of 0.345 meq/100 g soil which is much higher than the present critical limit of K (0.12 meq/100 g soil). Available S concentration ranged from 1 to 24.4 ppm (very low to high) with an average value of 12.7 ppm which is higher than the present critical limit of S (10 ppm). Exchangeable Mg content in the soils collected from the AEZ-28 (Kaligonj, Gazipur and Madhupur, Tangail) ranged from 0.84 to 1.7 meq/100 g soil (very high). The average Mg content in the soils was 1.27 meq/100g soil, while the critical limit of Mg in Bangladesh soils is 0.5 meq/100 g soil (FRG 2018). The Ca concentration in the soil samples ranged from 2.1 to 4.8 meq/100 g soil (low to optimum) with an average value of 3.45 meq/100 g. The critical limit of Ca for paddy soils in Bangladesh is 2.0 meq/100 g soil. Available Zn content in the soils ranged from 0.5 to 17.6 ppm (low to very high). The average Zn content in the soils was 9.0 ppm while the critical limit of Zn in Bangladesh soils is 0.6 ppm (FRG 2018).

Figure 2 also illustrated a sick picture of the fertility of the collected soil. Eighty seven percent (87%) of the collected soil samples were very low and 13% were low in N fertility class. No soils showed to fall in the optimum and high soil N fertility cleasses. In case of P status of collected soil samples, 83% of soils belonged to low and 14% to very low, while only 3% of soils were within medium soil P fertility classes. In case of K status in soil, 75% soils were under low to very low soil K fertility classes, while only 22% collected soil samples fell in medium K fertility class. The S, Ca and Mg fertility statuses also showed similar fatigued fertility levels in collected soil samples that indicate to take immediate actions for improving the soil fertility and soil health status.

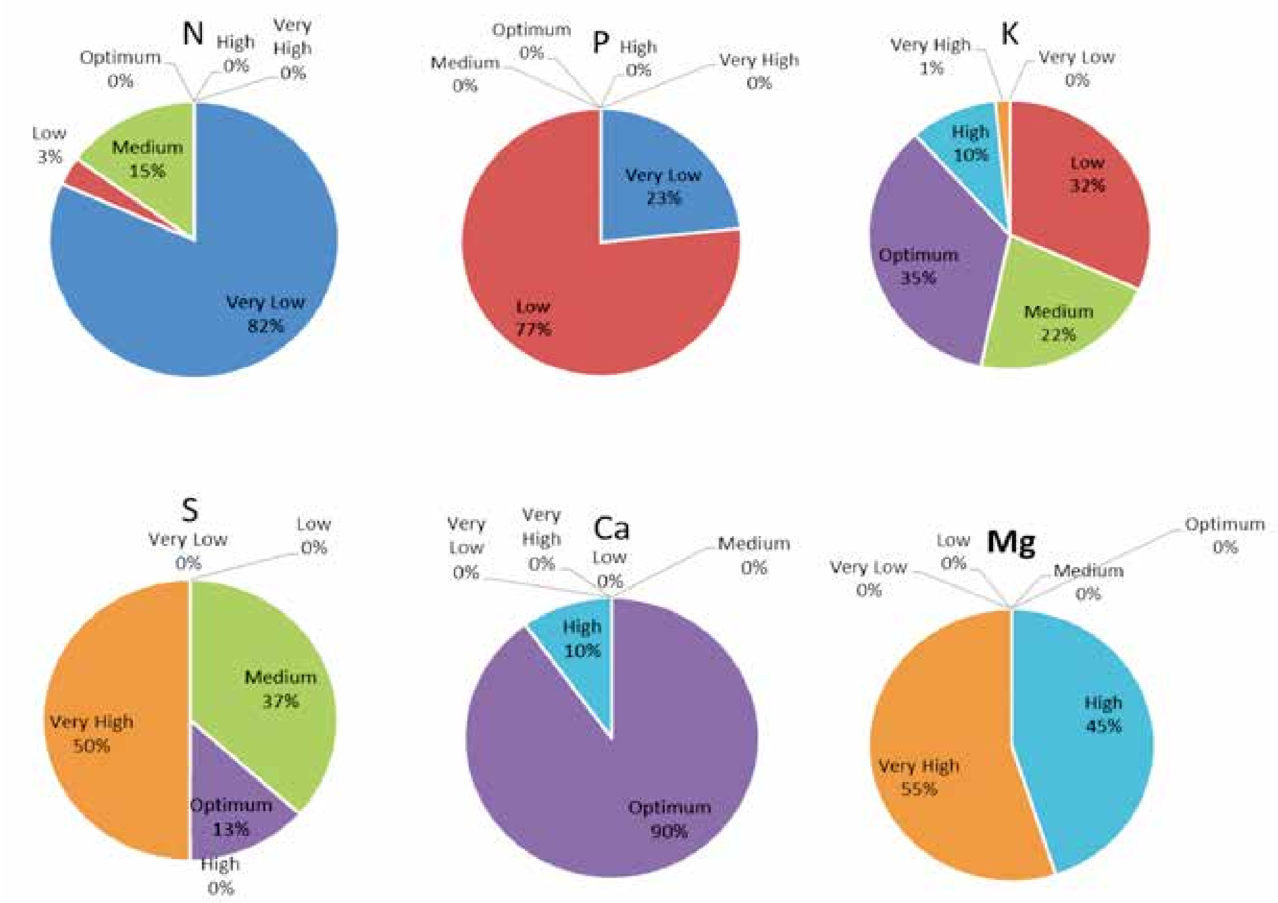


Figure 3. Percent distribution of collected soil samples from Agro-Ecological Zone 13 according to interpretation of soil test values based on critical limits (soil fertility classes) in the FRG 2018, SSD, BARI, Gazipur, 2019-20

Photo 1: Soil sampling from AEZ 11, SSD, BARI

Photo 2: Soil sampling from AEZ 13, SSD, BARI

Photo 3: Soil samples processed for analysis, SSD, BARI

Expt. 1.2: Delineation of nutrient status in Meghna and Surma-Kushiara Floodplant soils

BRRI Component

Soil samples were collected from the intensive cropping area of AEZ 18-Young Meghna Estuarine Floodplain (Companigang of Noakhali district and Ramgati of Laxmipur district), AEZ 19- Old Meghna Estuarine Floodplain (Katchua and Haziganj of Chandpur district) and AEZ 20- Eastern Surma Kushiara Floodplain (Companiganj and Jaintapur of Sylhet district). Analysis of collected soil samples for soil texture, pH, organic carbon, total nitrogen, available phosphorus, sulphur, zinc, iron, cupper and manganese and exchangeable potassium, calcium and magnesium were done following standard methods.

Results of soil samples collected from Companiganj, Noakhali (AEZ-18) have been presented in Appendix 2. The soil texture was mostly silty clay to silty clay loam. Soil pH ranged from 5.66 to 7.44 (slightly acidic to slightly alkaline) with a mean value of 6.87. The organic carbon of the collected soil samples varied from 0.41% to 0.85% (very low to low) with a mean value 0.65%. The total nitrogen ranged from 0.07% to 0.19% (very low to low) with a mean value 0.12%. The available phosphorus varied widely ranging from 3.92 ppm to 64.82 ppm (very low to very high) with a mean value 31.76 ppm which is well above the present critical limit (8.0 ppm) reported in FRG 2018. Exchangeable K concentration in the soils ranged from 0.12 to 0.46 meq/100 g soil (low to very high) with an average of 0.29 meq/100 g which is higher than the present critical limit of K (0.12 meq/100 g soil). Available S concentration ranged from 83 to 158 ppm (very high) with an average value of 121 ppm which is very much higher than the present critical limit of S (10 ppm). Exchangeable Mg content in the soils collected from Companiganj, Noakhali ranged from 0.216 to 0.427 meq/100 g soil (very low to low). The average Mg content in the soils was 0.39 meq. while the critical limit of Mg in Bangladesh soils is 0.5 meq/100 g soil (FRG 2018). The Ca concentration in the soil samples ranged from 2.53 to 4.25 meq/100 g soil (low to medium) with an average value of 3.26 meq/100 g. The critical limit of Ca for paddy soils in Bangladesh is 2.0 meq/100 g soil. Available Zn content in the soils ranged from 0.08 ppm to 1.36 ppm (very low to optimum). The average Zn content in the soils was 0.60 ppm while the critical limit of Zn in Bangladesh soils is 0.6 ppm (FRG 2018). The average Fe, Mn and Cu content of the collected soil samples from Companiganj, Noakhali were 26.23 ppm, 45.53 ppm and 6.81 ppm, respectively.

The Appendix 2 showed the soil samples analysis results collected from Ramgati, Laxmipur (AEZ-18). The soils were mainly silty clay loam in texture. Soil pH ranged from 6.22 to 7.94 (slightly acidic to slightly alkaline) with a mean value of 7.24. The organic carbon of the collected soil samples varied from 0.50% to 1.02% (very low to medium) with a mean value 0.73%. The total nitrogen ranged from 0.09% to 0.15% (very low to low) with a mean value 0.12. The available phosphorus ranged from 16 ppm to 84.74 ppm (medium to very high) with a mean value 55.39 ppm which is well above the present critical limit (8.0 ppm) reported in FRG 2018. Exchangeable K in the soils ranged from 0.05 to 0.15 meq/100 g soil (very low to low) with an average of 0.08 meq/100 g which is lower than the present critical limit of K (0.12 meq/100 g soil). Available S ranged from 68 to 448 ppm (very high) with an average value of 170 ppm which is very much higher than the present critical limit of S (10 ppm). Exchangeable Mg content in the collected soils ranged from 0.391 to 0.421 meq/100 g soil. The average Mg content in the soils was 0.40 meq/100 g while the critical limit of Mg in Bangladesh soils is 0.5 meq/100 g soil (FRG 2018). The Ca concentration in the soil samples ranged from 2.54 to 5.54 meq/100 g soil (low to optimum) with an average value of 3.86 meq/100 g. The critical limit of Ca for paddy soils in Bangladesh is 2.0 meq/100 g soil. Available Zn content in the soils ranged from 0.04 to 1.20 ppm (very low to medium). The average Zn content in the soils was 0.41 ppm, while the critical limit of Zn in Bangladesh soils is 0.6 ppm (FRG 2018). The average Fe, Mn and Cu content of the collected soil samples from Ramgati, Laxmipur were 49.23 ppm, 26.95 ppm and 4.38 ppm, respectively.

Results of soil samples collected from Haziganj, Chandpur in AEZ-19 have been presented in Appendix 2**.** The soil texture was mostly silty clay loam. Soil pH ranged from 5.81 to 6.82 (slightly acidic to neutral) with a mean value of 6.18. The organic carbon of the collected soil samples varied from 0.55 to 2.50% (very low to high) with a mean value 1.40%. The total nitrogen ranged from 0.09 to 0.35% (very low to optimum) with a mean value 0.2%. The available phosphorus varied widely and ranged from 1.05 ppm to 50.40 ppm (very low to very high) with a mean value 20.84 ppm which is well above the present critical limit (8.0 ppm) reported in FRG 2018. Exchangeable K concentration in the analyzed soils ranged from 0.037 to 0.083 meq/100 g soil (low to low) with an average of 0.050 meq/100 g which is much lower than the present critical limit of K (0.12 meq/100 g soil). Available S concentration ranged from 13 to 21.25 ppm (low to medium) with an average value of 15.65 ppm which is higher than the present critical limit of S (10 ppm). Exchangeable Mg content in the soils collected from Haziganj, Chandpur ranged from 2.64 to 7.77 meq/100 g soil (very high). The average Mg content in the soils was 4.27 meq. while the critical limit of Mg in Bangladesh soils is 0.5 meq/100 g soil (FRG 2018). The Ca concentration in the soil samples ranged from 1.96 to 3.59 meq/100 g soil (low to medium) with an average value of 2.57 meq/100 g. The critical limit of Ca for paddy soils in Bangladesh is 2.0 meq/100 g soil. Available Zn content in the soils ranged from 0.14 to 3.06 ppm (very low to very high). The average Zn content in the soils was 0.66 ppm while the critical limit of Zn in Bangladesh soils is 0.6 ppm (FRG 2018). The average Fe, Mn and Cu content of the collected soil samples from Haziganj, Chandpur were 177 ppm, 39 ppm and 3.29 ppm, respectively.

The Appendix 2 represented the soil samples analysis results collected from Katchua, Chandpur (AEZ-19). The soils were mainly silty loam to silty clay loam in texture. Soil pH ranged from 5.36 to 6.52. (slightly acidic) with a mean value of 5.96. The organic carbon of the collected soil samples ranged from 0.92 to 2.2% (low to high) with a mean value 1.55%. The total nitrogen varied from 0.14 to 0.25% (low to medium) with a mean value 0.19%. The available phosphorus ranged from 8.03 to 72.14 ppm (low to very high) with a mean value 32.34 ppm which is well above the present critical limit (8.0 ppm) reported in FRG 2018. Exchangeable K in the soils ranged from 0.019 to 0.12 meq/100 g soil (very low to low) with an average of 0.05 meq/100 g which is lower than the present critical limit of K (0.12 meq/100 g soil). Available S ranged from 13.15 to 34.30 ppm (low to medium) with an average value of 16.01 ppm which is closer to the present critical limit of S (10 ppm). Exchangeable Mg content in the collected soils ranged from 1.82 to 6.27 meq/100 g soil (very high). The average Mg content in the soils was 3.43 meq/100g soil. while the critical limit of Mg in Bangladesh soils is 0.5 meq/100 g soil (FRG 2018). The available Ca in the collected soil samples ranged from 1.14 to 3.30 meq/100 g soil (very low to medium) with an average value of 2.21 meq/100 g. The critical limit of Ca for paddy soils in Bangladesh is 2.0 meq/100 g soil. Available Zn content in the soils ranged from 0.16 to 2.38 ppm (low to very high). The average Zn content in the soils was 0.92, while the critical limit of Zn in Bangladesh soils is 0.6 ppm (FRG 2018). The average Fe, Mn and Cu content of the collected soil samples from Katchua, Chandpur were 191.93 ppm, 15.08 ppm and 2.31 ppm, respectively, which are sufficiently hogh for crop production.

Results of soil samples collected from Companiganj, Sylhet in AEZ-20 have been presented in Appendix 2. The soil texture was mostly sandy clay loam to silty loam. Soil pH ranged from 4.22 to 5.97 (very strongly acidic to slightly acidic) with a mean value of 5.03. The organic carbon of the collected soil samples varied from 0.80 to 2.0% (low to high) with a mean value 1.24%. The total nitrogen ranged from 0.11 to 0.29% (very low to optimum) with a mean value 0.19%. The available phosphorus ranged from 0.15 to 4.93 ppm (very low) with a mean value 1.70 ppm which is far below from the present critical limit (8.0 ppm) reported in FRG 2018. Exchangeable K concentration in the analyzed soils ranged from 0.048 to 0.175 meq/100 g soil (very low to medium) with an average of 0.08 meq/100 g which is lower than the present critical limit of K (0.12 meq/100 g soil). Available S concentration ranged from 11.65 to 27.80 ppm (low to optimum) with an average value of 14.99 ppm which is higher than the present critical limit of S (10 ppm). Exchangeable Mg content in the soils collected from Companiganj, Sylhet ranged from 0.53 to 1.32 meq/100 g soil (low to optimum). The average Mg content in the soils was 0.87 meq/100 g, while the critical limit of Mg in Bangladesh soils is 0.5 meq/100 g soil (FRG 2018). The Ca concentration in the soil samples ranged from 0.76 to 2.97 meq/100 g soil (very low to low) with an average value of 1.52 meq/100 g. The critical limit of Ca for paddy soils in Bangladesh is 2.0 meq/100 g soil. Available Zn content in the soils ranged from 0.78 to 5.98 ppm (low to very high). The average Zn content in the soils was 3.08 ppm, while the critical limit of Zn in Bangladesh soils is 0.6 ppm (FRG 2018). The average Fe, Mn and Cu content of the collected soil samples from Companiganj, Sylhet were also very high and the mean value were 268 ppm, 39 ppm and 4.59 ppm, respectively.

The soil texture was mostly sandy clay to silty loam. Soil pH ranged from 5.14 to 5.98 (strongly acidic to slightly acidic) with a mean value of 5.47. The organic carbon of the collected soil samples varied from 0.80 to 1.9% (low to medium) with a mean value 1.37%. The total nitrogen ranged from 0.14 to 0.42% (very low to high) with a mean value 0.23%. The available phosphorus ranged from 1.5 to 6.28 ppm (very low to low) with a mean value 3.67 ppm which is far below from the present critical limit (8.0 ppm) reported in FRG 2018. Exchangeable K concentration in the analyzed soils ranged from 0.042 to 0.145 meq/100 g soil (very low to low) with an average of 0.08 meq/100 g which is lower than the present critical limit of K (0.12 meq/100 g soil). Available S concentration ranged from 11.65 to 16.45 ppm (low) with an average value of 14.07 ppm which is higher than the present critical limit of S (10 ppm). Exchangeable Mg content in the soils collected from Jaintapur, Sylhet ranged from 0.31 to 1.54 meq/100 g soil (very low to high). The average Mg content in the soils was 0.74 meq, while the critical limit of Mg in Bangladesh soils is 0.50 meq/100 g soil (FRG 2018). The Ca concentration in the soil samples ranged from 0.40 to 1.41 meq/100 g soil (very low) with an average value of 0.86 meq/100 g. The critical limit of Ca for paddy soils in Bangladesh is 2.0 meq/100 g soil. Available Zn content in the soils ranged from 0.58 to 2.92 ppm (low to very high). The average Zn content in the soils was 1.34 ppm, while the critical limit of Zn in Bangladesh soils is 0.6 ppm (FRG 2018). The average Fe, Mn and Cu content of the collected soil samples from Jaintapur, Sylhet were very high and the value were 127.7 ppm, 20.29 ppm and 3.31 ppm, respectively.

Photo 4: Soil sample collection from AEZ-18 in Ramgati of Laxmipur district in 2018-19, SSD, BRRI

Photo 5: Chemical analysis of soil samples at SSD laboratory in BRRI, 2019

Expt. 1.3: Delineation of different nutrients status in terrace soils

BINA Component

Soil samples were collected from AEZ 25- Level Barind Tract (Manda, Naogaon; Nandigram, Bogra and Hakimpur, Dinajpur), AEZ 26- High Barind Tract (Nachole, Chapai Nawabganj and Godagari, Rajshashi) and AEZ 27- North Eastern Barind Tract (Mithapukur, Rangpur). The results of soil analysis have been presented in Appendix 3.

Results of soil samples collected from Manda, Naogaon had pH 6.4-7.4 (slightly acidic to neutral), OM 0.69-1.46% (low), total N 0.064-0.139% (very low to low), available P 4.9-37.5 ppm (very low to high), available S 12.8-41.7 ppm (low to very high), available Zn 0.47-1.32 ppm (very low to very high), available B 0.012-1.17 ppm (very low to very high), exchangeable K 0.026-0.131 meq/100 g (very low to optimum) and exchangeable Mg 1.11-1.90 meq/100 g (very low to very high).

Soil samples from Nandigram, Bogra had pH 5.0-5.9 (strongly acidic to slightly acidic), OM 1.23-1.87% (low to medium), total N 0.093-0.163% (very low to low), available P 4.7-39.9 ppm (very low to very high), available S 6.46-24.25 ppm (very low to optimum), available Zn0.61-2.62 ppm (low to very high), available B 0.073-0.221 ppm (very low to low), exchangeable K 0.028-0.155 meq/100 g (very low to medium) and exchangeable Mg 1.11-1.90 meq/100 g (low to high).

Soil samples from Hakimpur, Dinajpur (Appendix-3) had pH 5.5-5.9 (slightly acidic), OM 0.85-2.10% (very low to medium), total N 0.095-0.203% (very low to medium), available P 4.2-41.4 ppm (very low to very high), available S 6.65-29.95 ppm (very low to optimum), available Zn0.98-2.65 ppm (medium to very high), available B 0.042-0.228 ppm (very low to low), exchangeable K 0.060-0.156 meq/100 g (very low to medium) and exchangeable Mg 0.45-1.46 meq/100 g (low to optimum).

Soil samples from Godagari, Rajshashi had pH 5.4-6.8 (strongly acidic to neutral), OM 0.72-1.44% (very low to low), total N 0.082-0.147% (very low to low), available P 3.6-47.7 ppm (very low to very high), available S 6.46-21.10 ppm (very low to medium), available Zn0.49-1.70 ppm (low to optimum), available B 0.045-0.45 ppm (very low to medium), exchangeable K 0.042-0.163 meq/100 g (very low to medium) and exchangeable Mg 0.79-4.01 meq/100 g (medium to very high).

Soil samples collected from Nachole, Chapai Nawabganj had pH 5.9-7.3 (slightly acidic to neutral), OM 0.76-1.71% (low), total N 0.074-0.157% (very low to low), available P 3.2-27.83 ppm (very low to optimum) and available S 3.3-26.3 ppm (very low to optimum),available Zn0.36-1.90 ppm (very low to optimum), available B 0.121-0.833 ppm (very low to high), exchangeable K 0.028-0.254 meq/100 g (very low to optimum) and exchangeable Mg 1.22-2.90 meq/100 g (low to optimum).

The soils from Mithapukur, Rangpur had pH 5.4-6.0 (strong acidic to slightly acidic), OM 0.66-1.75% (very low to medium), total N 0.090-0.151% (very low to low), available P 5.4-25.2 ppm (very low to optimum), available S 5.0-30.1 ppm (very low to optimum),available Zn0.47-2.42 ppm (low to very high), available B 0.087-0.290 ppm (very low to low), exchangeable K 0.064-0.128 meq/100 g (very low to low) and exchangeable Mg 0.45-1.46 meq/100 g (very low to low).


Photo 6: Soil sample collection and processed samples for chemical analysis by BINA

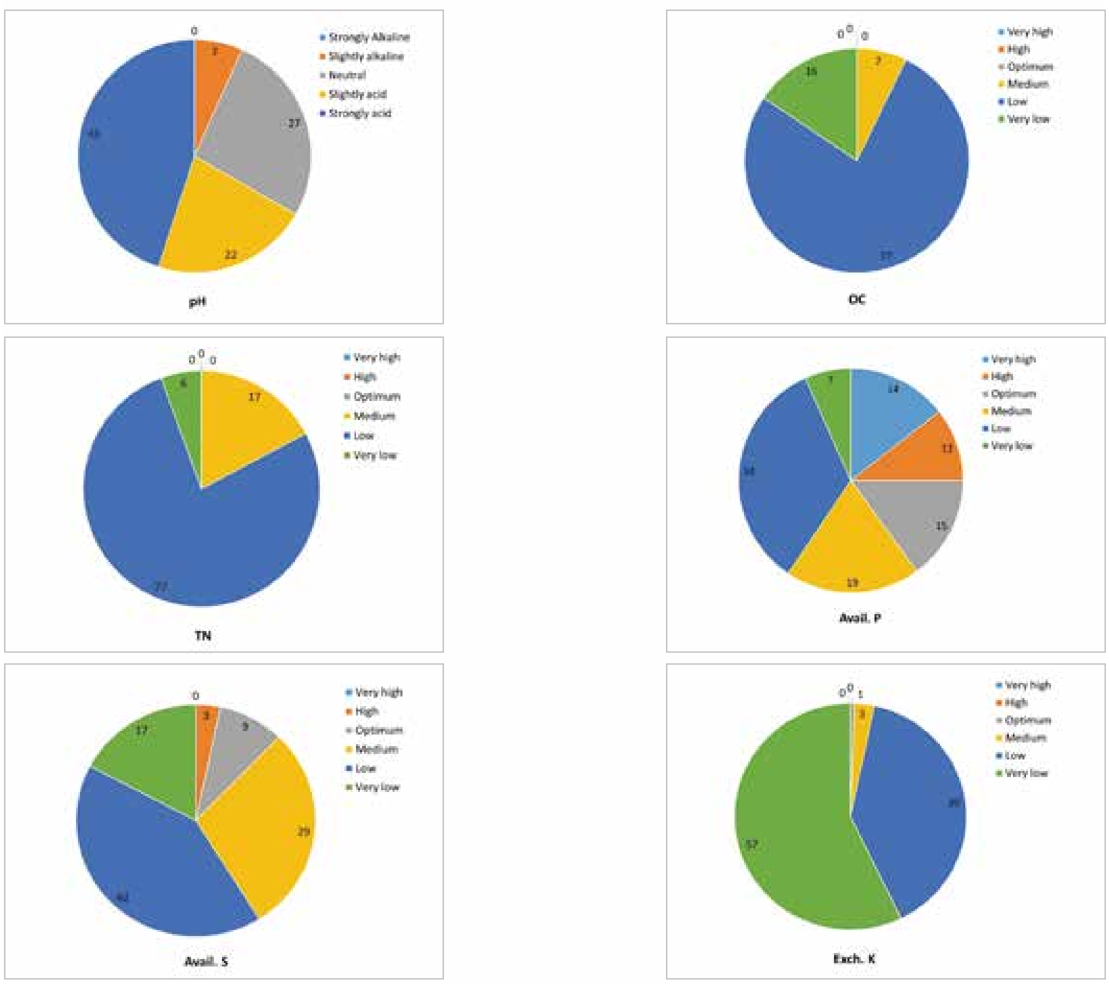


Figure 4: Status of 180 soil samples in percentage for soil pH, organic matter (%), total nitrogen (%), available phosphorus (ppm), available sulphur (ppm) and exchangeable K (meq/100 g), SSD, BINA, Mymensingh, 2019-20

Results of 180 collected soil samples

Following results are evident from the Figure 4:

- pH (strongly acidic 45%, slightly acidic 22%, neutral 27% and slightly alkaline 7%);
- Organic matter (very low 16%, low 77% and medium 7%);
- Total nitrogen (very low 6%, low 77% and medium 17%);
- Available P (very low 7%, low 34%, medium 19%, optimum 15%, high 11% and very high 14%);
- Available S (very low 17%, low 42%, medium 29%, optimum 9%, high 3%) and
- Exchangeable K (very low 77%, low 39%, medium 3% and optimum 1%), respectively.

Expt. 1.4: Delineation of different nutrients status in piedmont and non-calcareous soils

BAU Component

Soil samples were collected from AEZ 1- Old Himalayan Piedmont Plain (Tetulia and Panchagar Sadar), AEZ 3: Tista Meander Floodplain (Taragonj and Rangpur Sadar) and AEZ 9: Old Brahmaputra Floodplain (Muktagacha and Mymensingh Sadar). Analysis of collected soil samples for texture, pH, organic matter, total nitrogen, available phosphorus, sulphur, boron, potassium, calcium, magnesium, zinc, copper, iron and manganese were done following standard methods.

Results of soil samples collected from Muktagacha, Mymensingh have been presented in Appendix 4. Soil pH ranged from 4.85-5.97 (strongly acidic to moderately acidic) with a mean value of 5.19. Out of 30 soil samples 28 samples were strongly acid soil pH ranged from 4.5 – 5.5 while only two soils were moderately acid. OM content in the soils collected from Muktagacha (Table 1) ranged from 1.32-2.44% with a mean value of 1.75%. Among the macronutrients total N content in soils were 0.07-0.12% (very low to low) with an average value of 0.09% which is below the current critical limit reported in FRG 2018. The available P in different soils was 7.3-26.6 ppm (low to high). The average P content in Mutagacha soils was 12.7 ppm which is well above the present critical limit (8.0 ppm) reported in FRG 2018. Among the soil samples, only three samples were below the critical limit while the rest were well above the critical limit. Available S concentration ranged from 9 to 24 ppm (low to medium) with an average value of 19 ppm which is well above the present critical limit of S (10 ppm). Available K concentration in the soils ranged from 0.08 to 0.2 meq/100 g soil (low to medium) with an average of 0.11 meq/100 g. Two third of the soil samples fall below the critical limit. Available Mg content in the soils collected from Muktagacha ranged from 0.43 to 2.73 meq/100 g soil (low to very high). The average Mg content in the soils was 1.22 while the critical limit of Mg in Bangladesh soils is 0.5 meq/100 g soil (FRG 2018). All the soil samples had Mg content above the critical limit except one among the soil samples collected from Muktagacha. Available Ca concentration in the samples collected from Muktagacha ranged from 1.74 to 7.41 meq/100 g soil (low to optimum) with an average value of 3.97 meq/100 g. The critical limit of Ca for paddy soils in Bangladesh is 2.0 meq/100 g soil. Only two soil samples of Muktagacha had Ca concentration below the critical limit among the 30 soil samples collected for this project. Available Zn content in the soils collected from Muktagacha ranged from 1.36 to 8.12 ppm (optimum to very high). The average Zn content in the soils was 4.29 ppm while the critical limit of Zn in Bangladesh soils is 0.6 ppm (FRG 2018). All the soil samples had Zn content above the critical limit. Available B concentration in the soils ranged from 0.2 to 0.98 ppm (low to very high) with an average of 0.4 ppm. Among the soils collected for this project, one third of the soil samples had B content same as the critical limit (0.2 ppm) while the rest of the samples were well above the critical limit (FRG 2018).

Results of soil samples collected from Mymensingh Sadar, have been presented in Appendix 4. Soil pH ranged from 5.64-6.33 (slightly acidic) with a mean value of 5.86. OM content in the soils collected from Mymensingh Sadar, ranged from 1.33-2.33% (low to medium) with a mean value of 1.81%. Among the macronutrients total N content in soils ranged from 0.07-0.12% (very low to low) with an average value of 0.09%, which is below the current critical limit. Available P content ranged from 8.5-17.4 ppm (medium to high). The average P content was 12.3 ppm which is well above the present critical limit (8.0 ppm). All the soil samples collected, were well above the present critical limit of P. Available S concentration ranged from 9-38 ppm (low to high) with an average value of 21 ppm. Out of 30 samples 28 were above the present critical limit of S (10 ppm) while only two were below critical limit (FRG 2018). The exchangable K concentration in the soils ranged from 0.09-0.16 meq/100 g soil (low to medium) with an average of 0.12 meq/100 g. Forteen soil samples had K content below the critical limit. Available Mg content in the soils ranged from 1.24-4.01 meq/100 g soil (optimum to very high). The average Mg content in the soils was 2.52 meq/100 g while the critical limit of Mg in Bangladesh soils is 0.5 meq/100 g soil. All the soil samples had Mg content above the critical limit. Available Ca concentration in the samples ranged from 2.91-14.35 meq/100 g soil (low to very high) with an average value of 7.34 meq/100 g.

The critical limit of Ca for paddy soils in Bangladesh is 2.0 meq/100 g soil. The Ca content in 30 collected soil samples was above the present critical limit. Available B concentration in the soils ranged from 0.24-0.94 ppm (low to very high) with an average 0.44 ppm. Among the soils collected, twelve soil samples were found to have low B content and two soil samples had B content very high (0.94 ppm).

Results of soil samples collected from Tetulia have been presented in Appendix 4. Soil pH ranged from pH ranges from 4.38-5.43 (very strongly acidic to strongly acidic) with a mean value of 4.9 Out of 30 soil samples 02 samples were very strongly acidic while the rest soil samples were strongly acidic. OM content in the soils collected from Tetulia, ranged from 1.4-2.4% (low to medium) with a mean value of 1.96%. Among the macronutrients total N content in soils were 0.07-0.13% (very low to low) with an average value of 0.1% which is below the current critical limit (0.12%) reported in FRG 2018. The available P content in Tetulia soils ranged from 8.9-29.1 ppm (medium to very high) with an average of 18.2 ppm, which is well above the present critical limit (8.0 ppm). Available S concentration ranged from 15-21 ppm (low to medium) with an average value of 17 ppm which is well above the present critical limit of S (10 ppm). Exchangable K content in the soil samples from Tetulia ranged from 0.09-0.16 meq/100 g soil (low to medium) with an average of 0.12 meq/100 g. Eleven of the collected soil samples had K concentration (0.12 meq/100 g soil) below the critical limit. Available Mg content in the soil samples collected ranged from 0.002-0.72 meq/100 g soil (very low to low). The average Mg content in the soils was 0.560 meq/100 g soil while the critical limit of Mg in Bangladesh soils is 0.5 meq/100 g soil. All the soil samples had Mg content above the critical limit except seven soil samples. Available Ca concentration in the samples ranged from 0.27-11.26 meq/100 g soil (very low to very high) with an average value of 3.59 meq/100 g soil. The critical limit of Ca for paddy soils in Bangladesh is 2.0 meq/100 g soil. Out of 30 soil samples from Tetulia five soil samples had Ca concentration below the critical limit. Available B concentration in the soils ranged from 0.08-0.71 ppm (very low to high) with an average of 0.4 ppm. Only two of the soil samples had B content below the critical limit (0.2 ppm) while the rest of the samples were well above the critical limit.

Results of soil samples collected from Panchagar Sadar have been presented in Appendix 4. Soil pH ranged from 4.32-5.33 (very strongly acidic to strongly acidic) with a mean value of 4.95. Out of 30 soil samples, two samples were very strongly acidic while the rest soil samples were strongly acidic. Organic matter content in the soils ranged from 1.26-2.46% (low to medium) with a mean value of 1.97%. Total N content in soils were in the range of 0.06-0.13% (very low to low) with an average value of 0.1% which is below the current critical limit (0.12%). The available P content in soils ranged from 8.4-25.1 ppm (medium to very high) with an average of 14.4 ppm, which is well above the present critical limit (8.0 ppm). Available S concentration ranged from 8-16 ppm (low to very high) with an average value of 12 ppm, of which 3 samples were found below the critical limit and rest were above the present critical limit (10 ppm). All the soil samples had available K concentration in the range from 0.09-0.16 meq/100 g soil (low to medium) with an average of 0.13 meq/100 g. Seven of the collected soil samples had K content below the critical limit (0.12 meq/100 g soil). Available Mg content in the soils ranged from 0.07-0.54 meq/100 g soil (very low to low). The average Mg content in the soils was 0.29 meq/100 g soil, while the critical limit of Mg in Bangladesh soils is 0.5 meq/100 g soil. Two-third of the soil samples had Mg content below the critical limit. Available Ca concentration in the soil samples ranged from 0.29-1.45 meq/100 g soil (very low to low) with an average value 0.847 meq/100 g, while the critical limit of Ca for paddy soils in Bangladesh is 2.0 meq/100 g soil. Available B concentration in the soils ranged from 0.08-0.67 ppm (very low to high) with an average of value of 0.44 ppm. All of the soil samples had B content well above the critical limit (0.2 ppm) except one sample.

Results of soil samples collected from Taragonj, have been presented in Appendix 4. Soil pH ranged from 4.61-5.44 (strongly acidic) with a mean value of 5.08. Organic matter content in the soils ranged from 1.2-2.46% (low to medium) with a mean value of 1.82%. Total N content in soils were in the range of 0.06-0.12% (very low to low) with an average value of 0.1% which is below the current critical limit (0.12%). The available P content in soils was in the range of 10.7-39.7 ppm (medium to very high) with an average of 23.3 ppm, which is well above the present critical limit (8.0 ppm). Available S concentration in soils ranged from 9.0-28.0 ppm (very low to optimum) with an average value of 14.0 ppm of which only one sample had S content below the critical limit and rest were above the present critical limit (10 ppm). Available K concentration in the soils ranged from 0.11-0.21 meq/100 g soil (low to medium) with an average of 0.14 meq/100 g. Four of the collected soil samples had K content below the critical limit (0.12 meq/100 g soil). Available Mg content in the soils ranged from 0.07-0.67 meq/100 g soil (very low to low). The average Mg content in the soils was 0.24 meq/100 g. Except one, all the soil samples had Mg content below the critical limit. Available Ca concentration in the samples ranged from 0.16-2.4 meq/100 g soil (very low to low) with an average value 1.18 meq/100 g. Available B concentration in the soils ranged from 0.36-0.71 ppm (medium to high) with an average 0.5 ppm. All of the soil samples had B content well above the critical limit (0.2 ppm).

Results of soil samples collected from Rangpur Sadar, have been presented in Appendix 4. Soil pH ranged from 4.22-5.56 (very strongly acidic to strongly acidic) with a mean value of 5.0. Among the soil samples 3 were found very strongly acidic and the rest were strongly acidic. Organic matter content in the soils ranged from 1.4-2.4% (low to medium) with a mean value of 1.89%. Total N content in soils were from 0.08-0.12% (very low to low) with an average value of 0.1% which is below the current critical limit (0.12%). The available P content in soils ranged from 14.3-46.2 ppm (optimum to very high) with an average value of 21.6 ppm, which is well above the present critical limit (8.0 ppm). Available S concentration in soils ranged from 12-26 ppm (low to medium) with an average value of 17 ppm. Sulphur content of all the samples were found above the present critical limit (10 ppm). All the soil samples had available K concentration ranging from 0.11-0.18 meq/100 g soil (low to medium) with an average of 0.13 meq/100 g. Five soil samples had K concentration below the critical limit (0.12 meq/100 g soil). Available Mg content in the soils ranged from 0.07-0.45 meq/100 g soil (very low to low). The average Mg content in the soils was 0.28 meq/100 g while the critical limit of Mg in Bangladesh soils is 0.5 meq/100 g soil. All of the soil samples had Mg content below the critical limit. Available Ca concentration in the soil samples ranged from 0.36-16 meq/100 g soil (very low to very high) with an average of 1.96 meq/100 g. Available B concentration in the soils ranged from 0.15-0.65 ppm (very low to high) with an average 0.41 ppm. Seven soil samples had B concentration below the critical limit (0.2 ppm).

Results of soil samples collected from 3 AEZs have been presented in Appendix 4. Soil pH ranged from 4.84-5.98 (strongly acidic to moderately acidic) with a mean value of 5.17. Organic matter content among the soils collected ranged from 1.67-2.08% with a mean value of 1.87%. Total N content in soils were 0.08-0.11% (very low to low) with an average value of 0.09% which is below the current critical limit (0.12%). The average P content among the collected soils of 3 AEZs were 17.09 ppm which is well above the present critical limit (7.0 ppm). Available S concentration ranged from 10.79 to 23.96 ppm (low to medium) with an average value of 16.76 ppm which is well above the present critical limit of S (10 ppm). Available K concentration in the soils ranged from 0.10 to 0.14 meq/100 g soil (low to medium) with an average of 0.12 meq/100 g. Available B concentration in the soils ranged from 0.33 to 0.5 ppm (low to very high) with an average of 0.43 ppm. About one-third of the soil samples had B content very close to the critical limit (0.2 ppm) while rest of the samples had B content well above the critical limit. Available Mg content in the soils collected ranged from 0.14-3.39 meq/100 g soil (low to very high). The average Mg content in the soils was 0.86 meq/100 g while the critical limit of Mg in Bangladesh soils is 0.5 meq/100 g soil. Available Ca concentration in the samples collected from different locations ranged from 0.79 to 8.36 meq/100 g soil (low to optimum) with an average value of 3.15 meq/100g. All the soil samples had average Mg and Ca concentration below the critical limit. Available Zn content among the soil samples ranged from 0.19 to 5.70 ppm (very low to very high). The average Zn content in the soils was 1.94 while the critical limit of Zn in Bangladesh soils is 0.6 ppm. Soil samples from Panchagorh sadar and two villages of Taragonj had average Zn content below the critical limit (Apendix 4). Copper content in the soils ranged from 0.72-4.73 ppm with an average value 1.79 ppm which is well above the present critical limit (0.2 ppm). All the soil samples collected had Cu content well above the present critical limit. Available Fe concentration ranged from 25.39-242 ppm (very high) with an average value of 109.77 ppm. Available Mn concentration of the samples ranged from 1.76-49.9 ppm (medium to very high) with an average of 13.12 ppm.

Photo 7: Soil sample collection and analysis at BAU component

Expt. 2: Determination of critical limits of different nutrients for different soils and crops- Pot trial

Critical limits of different nutrients for different soils and crops were determined through pot culture experiment. Different component organizations conducted a number of pot culture experiments on their assigned nutrients and crops. Evaluation was done on the growth response (in terms of dry matter yield) of crop to the added nutrient. The results of pot experiments on different nutrients and crops, and estimation of Critical Limits by different component organizations are described below.

Expt. 2.1: Determination of critical limit of K and Zn for soils and crops (wheat, maize and cabbage)

BARI Component

Relative yield and Critical Limit of K for wheat

The biomass yield of wheat plants without K treatment was lower than those soils treated with K (Table 12). Application of K increased the dry matter yield in almost all soils, the highest response being in low K status soils followed by medium and high K status soils. Among the soil groups, when applied with K, the average biomass in low K soil group was 10.74 g pot^{-1}, while medium K soil group had 12.5 g pot^{-1} and the high K soil group had 11.5 g pot^{-1} average biomass. The similar trend of biomass yield was observed for soil groups under without K treatment. However, higher dry matter yields were obtained from medium and high K status soils as compared to the low K status soils that might be due to the better inherent qualities of the soils with medium and high K contents. The highest dry matter yields were obtained in plants with K applied on almost all soils (Table 12) indicating that K was a limiting nutrient for wheat in the selected low K status soils. The study concluded that a response to K fertilization is likely when the NH_4OAc value is at low and very low status and decreases when the value exceeds the critical level (Figure 5). When wheat plants were grown in soil with K treatment, the average yield ranged from 3.99 to 16.2 g pot^{-1} in low K soil group, 7.76 to 20.9 g pot^{-1} in medium K soil group and 8.97 to 13.2 g pot^{-1} in high K soil group. On the other hand, in soils under 'without K' treatment, the average biomass yield ranged from 2.99 to 13.0 g pot^{-1} in low K soil group, 6.50 to 17.5 g pot^{-1} in medium K soil group and 7.79 to 11.8 g pot^{-1} in high K soil group. The average relative yields (av. R.Y.) were 71.7 %, 81.1 % and 86.8 % recorded in low, medium and high K soil group, respectively (Table 12), while the average relative yield of wheat plants grown in the total 26 soils was 78.8%.

The critical value of K for wheat was calculated according to the procedure of Cate and Nelson (1965), scattered diagrams of relative yields (Bray's percent yield) in Y-axis versus soil test values of K (1 M NH_4OAc) in X-axis were plotted to find out the critical level. The critical value of K for wheat cultivation in Bangladesh soil was 0.17 meq $100g^{-1}$ soil (Figure 5). Therefore, the use of critical limit for the interpretation of soil test value for fertilizer recommendation can hardly be used for two successive crops only if crop is cultivated without K application.

About 0.12 meq percent of NH_4OAc extractable K is considered critical limit for the soils of Bangladesh (BARC 2018). Research findings reported critical limits of available K in different crops in different locations outside Bangladesh are 0.42 meq 100 g^{-1} soil (Gajbhiye et al. 1993), 0.17 meq meq 100 g^{-1} soil in Tennessee, USA (Savoy 2018) and 0.34 meq 100 g^{-1} soil in Uruguay (Barbazán et al. 2011). In Bangladesh, K is severely deficient in 6% of the land, strongly deficient in 45% of soils, and moderately deficient in 33% soils. The established CL of K in the present study (0.17 meq/100g soil) is higher than the value used currently (BARC 2018).

Table 12: Relative yield of wheat (BARI Gom-30) and cabbage (Atlus (70) with and without K, SSD, BARI, 2019-2020

Soil sample No.	Sample name	Exch. K (meq/100 g)	Wheat (cv. BARI Gom-30)			Cabbage (cv. Atlas-70)		
			Dry matter yield (g/pot)		Relative yield (%)	Dry matter yield (g/pot)		Relative yield (%)
			With K	Without K		With K	Without K	
Low K								
1.	BRRI 94	0.019	8.74	5.90	69.0	27.1	18.1	66.7
2.	BRRI 99	0.023	13.8	9.32	67.8	11.7	8.06	68.9
3.	BRRI 100	0.023	-	-	-	17.8	12.6	71.9
4.	BRRI 71	0.037	11.4	7.77	68.9	12.8	8.69	67.8
5.	BRRI 75	0.037	9.62	6.54	65.7	12.9	9.04	70.1
6.	BARI 96	0.13	9.75	7.73	79.2	13.4	10.9	81.4
7.	BARI 13	0.06	13.6	9.04	66.6	14.3	10.2	71.8
8.	BARI 14	0.06	11.4	8.07	70.3	18.6	13.5	72.6
9.	BARI 15	0.07	10.1	7.16	70.7	14.1	9.99	71.0
10.	BARI 16	0.07	3.99	2.99	74.8	14.6	11.0	75.7
11.	BARI 20	0.08	9.59	7.26	75.8	14.9	11.6	77.8
12.	BARI 24	0.10	16.2	13.0	80.0	13.0	10.1	78.8
Medium K								
13.	BARI 62	0.16	7.76	6.50	83.7	9.47	7.55	78.5
14.	BARI 64	0.17	10.3	8.08	78.2	18.7	15.0	80.6
15.	BARI 84	0.17	11.1	9.08	81.5	22.9	18.3	79.9
16.	BARI 9	0.16	10.1	7.94	78.5	17.0	13.6	79.8
17.	BARI 27	0.2/0.16	15.0	12.1	80.8	17.6	14.3	80.6
18.	BARI 90	0.25	20.9	17.5	83.6	20.9	17.1	81.8
High K								
19.	BRRI 1	0.31	14.6	10.7	73.3	19.4	16.6	85.7
20.	BRRI 2	0.28	9.21	7.79	84.4	7.82	6.86	87.4
21.	BRRI 3	0.31	8.97	8.09	90.3	-	-	-
22.		0.31	10.1	8.17	80.6	-	-	-
23.	BRRI 4	0.35	11.6	10.7	91.7	10.1	9.33	92.7
24.	BARI 128	0.43	13.1	11.8	90.3	13.7	12.6	91.4
25.	BARI 130	0.45	12.9	11.7	90.8	15.5	15.0	96.6
26.	BRRI 3	0.55	-	-		10.2	9.65	94.2
27.	S16(Gazipur Sadar)	0.58	-	-	-	9.73	9.35	96.1
28.	BARI 132	0.78	-	-	-	11.7	11.1	94.9
29.	S1 (Kaliakoir)	0.67	-	-	-	11.0	10.8	97.1
30.	S3 (Godagari)	0.49	9.45	8.84	93.2	-	-	-

*Some soils were used for having variations in the soil values and types

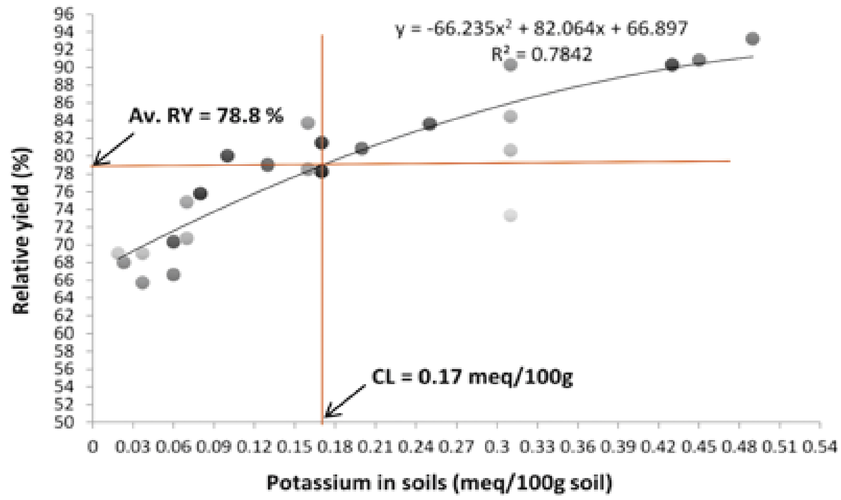


Figure 5: Critical Limit of potassium for wheat in Bangladesh, SSD, BARI, 2019-20

Photo 8: Pot trial on wheat with and without K application, SSD, BARI, Gazipur during 2019-2020.

Relative yield and Critical Limit of K for cabbage

The biomass yield of cabbage crops grown in soils under ‘with K’ was higher than the biomass of cabbage in soils without K treatment (Table 12). Application of K increased the dry matter yield in collected soils, the highest response being in low K status soils followed by medium and high K status soils. Among the soil groups, when K was applied (with K), the average biomass in low K soil group was 15.4 g pot^{-1}, while it was 17.8 g pot^{-1} in medium K soil group and 12.8 g pot^{-1} average biomass yield in and the high K soil group. Under without K treatment, the biomass yields were 11.2, 14.3 and 11.7 g pot^{-1} in the low, medium and high K soil groups, respectively. However, higher dry matter yields were obtained from medium and high K status soils as compared to the low K status soils that might be due to the better inherent qualities of the soils with medium and high K contents. The highest dry matter yields were obtained in plants with K applied on almost all soils (Table 12). The results indicated that K was a limiting nutrient for cabbage in the selected low K status soils. The study concluded that a response to K fertilization is likely when the K value is at low and very low status and decreases when the value exceeds the critical level (Figure 6). When cabbage plants were grown in soil with K treatment, the average yield ranged from 11.7 to 27.1 g pot^{-1} in low K soil group, 9.47 to 22.9 g pot^{-1} in medium K soil group and 7.82 to 19.4 g pot^{-1} in high K soil group. On the other hand, in soils under 'without K' treatment, the average biomass yield ranged from 8.06 to 18.1 g pot^{-1} in low K soil group, 7.55 to 18.3 g pot^{-1} in medium K soil group and 6.86 to 16.6 g pot^{-1} in high K soil group. The average relative yields were 72.7 %, 80.2 % and 92.9 % in low, medium and high K soil group, respectively (Table 12), while the average relative yield of cabbage plants grown in the total 26 soils was 81.2%.

The critical value of K for cabbage was calculated according to the procedure of Cate and Nelson (1965), scattered diagram was drawn by plotting the relative yields (Bray's percent yield) in Y-axis versus soil test values of K in X-axis. The critical value of K for cabbage cultivation in Bangladesh soil was 0.19 meq $100g^{-1}$ soil.

Presently, about 0.12 meq percent of K is considered critical limit for the soils of Bangladesh (BARC 2018). Research findings reported critical limits of available K in different crops in different locations outside Bangladesh are 0.42 meq 100 g^{-1} soil (Gajbhiye et al. 1993), 0.17 meq meq 100 g^{-1} soil in Tennessee, USA (Savoy 2018) and 0.34 meq 100 g^{-1} soil in Uruguay (Barbazán et al. 2011). In Bangladesh, K is severely deficient in 6% of the land, strongly deficient in 45% of soils, and moderately deficient in 33% soils. The established CL of K in the present study (0.19 meq $100g^{-1}$ soil) is higher than the value used currently (BARC 2018).

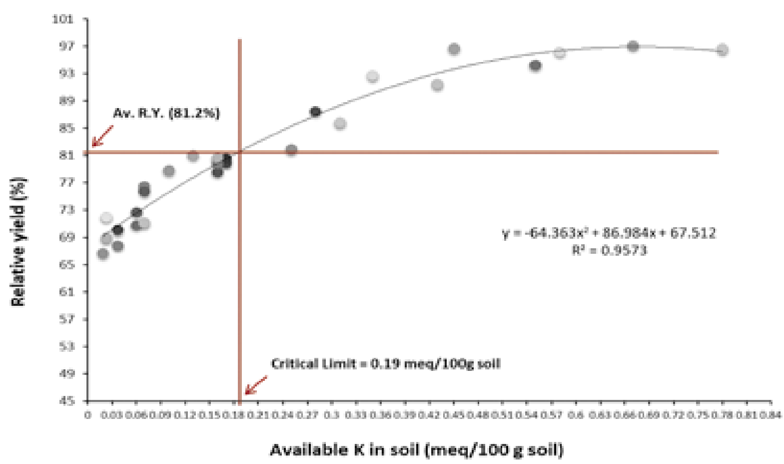


Figure 6: Critical limit of potassium in soil for cabbage in Bangladesh (Cate and Nelson method). The experiment was conducted at greenhouse of Soil Science Division, BARI, Gazipur in 2019-2020.

Photo 9: Pot trial on cabbage response to K application and without application on Chandina soil series at Dhodda, Haziganj, Bangladesh. The experiment was conducted at greenhouse of Soil Science Division, BARI, Gazipur in 2019-2020 to determine critical limit of zinc in soil for cabbage in Bangladesh.

Relative yield and Critical Limit of K for maize

The biomass yield of maize in K treated soils was higher than the biomass of maize recorded in soils without K application (Table 13). Maize plants grown in earthen pots responded positively to K application, resulting in increased plant biomass, the highest response being in low K contained soils followed by medium and high K status soils. Among the soil groups of different K content, the average biomass in low K soil group with K application was 91.7 g pot^{-1}, while it was 89.4 g pot^{-1} in medium K soil group and 68.9 g pot^{-1} average biomass yield in the high K soil group. In case of soils without K treatment, the biomass yields of maize were 61.0, 76.5 and 61.5 g pot^{-1} in the low, medium and high K soil groups, respectively. However, higher dry matter yields were obtained from medium and high K status soils as compared to the low K status soils, indicating the better inherent qualities of the soils with medium and high K contents have potentials of increasing plant biomass. The highest dry matter yields of maize were obtained in plants with K applied on almost all soils (Table 13) that indicate K is a limiting nutrient for maize in the soils containing low K. The study concluded that a response to K fertilization is likely when the available K value is at low status and decreases when the value exceeds the critical level (Figure 7). When maize plants were grown in soil treated with K, the average yield ranged from 64.8 to 111.1 g pot^{-1} in low K soil group, 62.7 to 123.7 g pot^{-1} in medium K soil group and 56.9 to 89.8 g pot^{-1} in high K soil group. On the other hand, in soils without applied K, the average cabbage biomass yield ranged from 39.9 to 95.8 g pot^{-1} in low K soil group, 52.6 to 107.6 g pot^{-1} in medium K soil group and 49.0 to 78.1 g pot^{-1} in high K soil group. The average relative yields were 65.8 %, 85.9 % and 89.9 % in low, medium and high K soil group, respectively (Table 13).

The critical value of K for maize was 0.16 meq/100g soil which was calculated by plotting a scattered diagram with the relative yields (Bray's percent yield) in Y-axis versus soil test values of K in X-axis (Figure 3). For fertilizer recommendation in Bangladesh, resently, about 0.12 meq percent of K is considered CL for the soils of Bangladesh (BARC 2018). Research findings reported critical limits of available K in different crops in different locations outside Bangladesh are 0.42 meq 100 g^{-1} soil (Gajbhiye et al. 1993), 0.17 meq meq 100 g^{-1} soil in Tennessee, USA (Savoy 2018) and 0.34 meq 100 g^{-1} soil in Uruguay (Barbazán et al. 2011). In Bangladesh, K is severely deficient in 6% of the land, strongly deficient in 45% of soils, and moderately deficient in 33% soils. The established CL of K in the present study (0.19 meq 100g^{-1} soil) is higher than the value used currently (BARC 2018).

Table 13: Relative yield of maize with and without K, SSD, BARI, 2019-2020

Soil sample No.	Sample name	Exch. K (meq/100g)	Maize		
			Dry matter yield (g/pot)		Relative yield (%)
			With K	Without K	
Low K					
1.	BRRI 94	0.019	91.2	55.4	60.90
2.	BRRI 99	0.023	95.9	63.7	66.43
3.	BRRI 100	0.023	77.2	43.7	56.32
4.	BRRI 71	0.037	92.7	58.8	63.15
5.	BRRI 75	0.037	83.1	54.7	65.75
6.	BARI 96	0.13	93.3	70.4	75.44
7.	BARI 13	0.06	78.5	44.5	56.66
8.	BARI 14	0.06	64.8	39.9	62.73
9.	BARI 15	0.07	99.5	70.3	70.54

Soil sample No.	Sample name	Exch. K (meq/100g)	Maize		
			Dry matter yield (g/pot)		Relative yield (%)
			With K	Without K	
10.	BARI 16	0.07	108.4	69.5	63.82
11.	BARI 20	0.08	104.3	65.0	62.10
12.	BARI 24	0.10	111.1	95.8	86.44
Medium K					
13.	BARI 62	0.16	62.7	52.6	84.24
14.	BARI 64	0.17	65.7	61.4	93.47
15.	BARI 84	0.17	123.7	107.6	87.08
16.	BARI 9	0.16	70.1	61.0	86.98
17.	BARI 27	0.2/0.16	96.6	72.4	75.01
18.	BARI 90	0.25	117.7	103.9	88.62
High K					
19.	BRRI 1	0.31	89.8	78.1	87.10
20.	BRRI 2	0.28	58.8	49.0	83.68
21.	BRRI 4	0.35	80.1	69.7	88.23
22.	BARI 128	0.43	67.0	61.0	90.23
23.	BARI 130	0.45	65.9	54.9	84.64
24.	S16 (Gazipur Sadar)	0.58	63.7	62.8	96.92
25.	S3 (Godagari)	0.49	56.9	55.2	98.52

*Some soils were used for having variations in the soil values and types

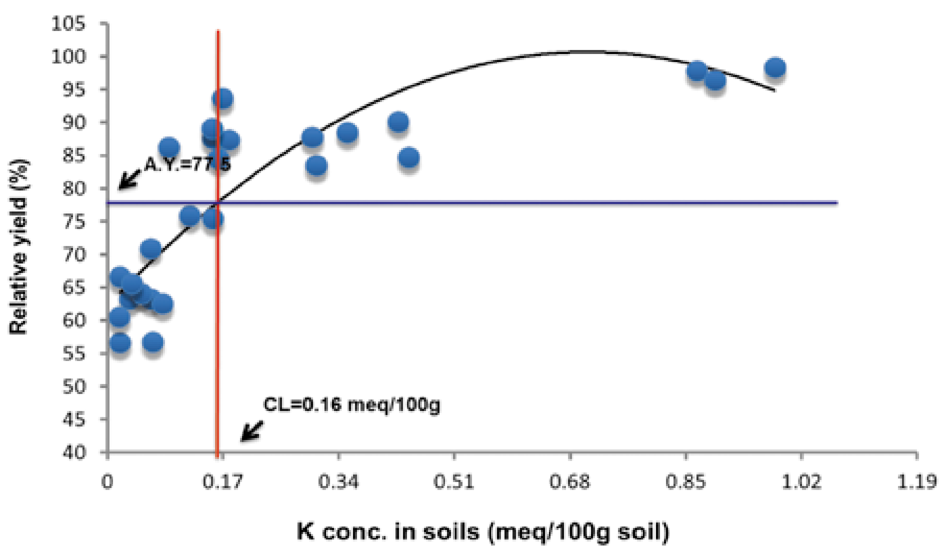


Figure 7. Critical limit of K for maize determined by pot trial on 24 different soils in Bangladesh (Cate and Nelson method). The experiment was conducted at greenhouse of Soil Science Division, BARI, Gazipur in 2019-2020.

Photo 10: Pot trial on maize with and without K application, SSD, BARI, Gazipur during 2019-2020.

Relative yield and Critical Limit of Zn for wheat

The wheat biomass yield in Zn treated soils (soils under 'with Zn' treatment) was higher than the biomass of wheat recorded in soils without Zn treatment (Table 14). Wheat plants respond positively to Zn application, resulting in increased plant biomass, the highest response being in low Zn contained soils followed by medium and high Zn status soils. Among the soil groups of Zn content, the average biomass in low Zn soil group was 13.7 g pot^{-1}, while it was 14.7 g pot^{-1} in medium Zn soil group and 12.9 g pot^{-1} average biomass yield in the high Zn soil group. On the other hand, when no Zn was applied (soils under 'without Zn treatment), the wheat biomass yields were 10.3, 14.5 and 15.0 g pot^{-1} in the low, medium and high Zn soil groups, respectively. However, higher dry matter yields were obtained from medium and high Zn status soils as compared to the low Zn status soils that indicate the better inherent qualities of the soils with medium and high Zn contents have potentials of increasing plant biomass. The highest dry matter yields of wheat were obtained in plants with Zn applied on almost all soils (Table 14). Therefore, it can be said that Zn was a limiting nutrient for wheat in the soils containing low Zn. The study concluded that a response to Zn fertilization is likely when the DTPA-Zn value is at low and very low status and decreases when the value exceeds the critical level (Figure 8). When wheat plants were grown in soil with Zn treatment, the average yield ranged from 8.51 to 20.4 g pot^{-1} in low Zn soil group, 11.0 to 17.8 g pot^{-1} in medium Zn soil group and 11.4 to 16.5 g pot^{-1} in high Zn soil group. On the other hand, in soils without applied Zn, the average biomass yield ranged from 6.60 to 14.5 g pot^{-1} in low Zn soil group, 9.30 to 15.6 g pot^{-1} in medium Zn soil group and 11.1 to 15.8 g pot^{-1} in high Zn soil group. The average relative yields were 75.8 %, 87.5 % and 96.5 % in low, medium and high Zn soil group, respectively (Table 14).

The critical value of Zn for wheat was calculated by drawing a scattered diagram with the relative yields (Bray's percent yield) in Y-axis versus soil test values of Zn in X-axis. The critical value of Zn for wheat cultivation in Bangladesh soil was 0.72 mg kg^{-1} soil (Figure 8). The critical level of Zn for wheat crop was also determined by Akhter et al. (2019) which was 0.82 mg kg^{-1} soil. At present, CL of Zn in soils is 0.6 mg kg^{-1} (BARC 2018) and Zn status in many soils is below the CL. The established CL of Zn in the present study is higher than the value used currently (BARC 2018). Mehra et al. (2005) reported that both graphical and statistical methods indicated 0.95 mg kg^{-1} as the critical value of Zn in soils for maize. Madhavi et al. (2013) reported that CL of Zn in soils was 0.75 mg kg^{-1}. In another report, Mahata et al. (2014) reported that CL of DTPA–Zn in soils was 0.82 mg kg^{-1}. On the other hand, the CL reported in the present study was also close to the critical level of Zn (0.82 and 0.83 mg kg^{-1}) as observed by Akhter et al. (2019) for maize and Rahman et al. (2007) for rice.

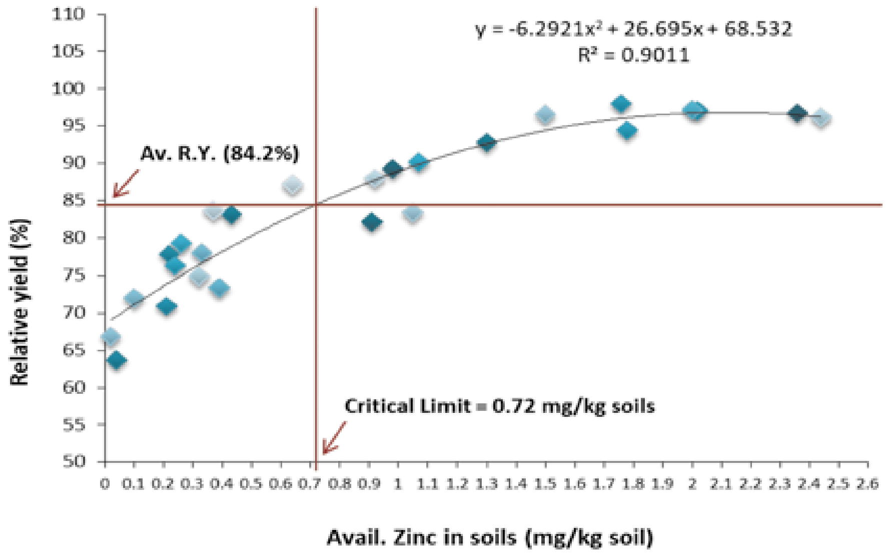


Figure 8: Critical limit of zinc in soil for wheat in Bangladesh (Cate and Nelson method). The experiment was conducted at greenhouse of Soil Science Division, BARI, Gazipur in 2019-2020.

Photo 11: Pot trial on wheat response between Zn application and without application on Burichong soil series at Katchua, Chandpur, Bangladesh. The experiment was conducted at greenhouse of Soil Science Division, BARI, Gazipur in 2019-2020 to determine critical limit of zinc in soil for cabbage in Bangladesh.

Relative yield and Critical Limit of Zn for cabbage

The biomass yield of cabbage in Zn treated soils was higher than the biomass of cabbage recorded in soils without Zn application (Table 14). Cabbage plants grown in earthen pots responded positively to Zn application, resulting in increased plant biomass, the highest response being in low Zn contained soils followed by medium and high Zn status soils. Among the soil groups of different Zn content, the average biomass in low Zn soil group was 16.4 g pot^{-1}, while it was 18.8 g pot^{-1} in medium Zn soil group and 16.6 g pot^{-1} average biomass yield in the high Zn soil group. In case of soils without Zn treatment, the biomass yields of cabbage were 10.3, 14.5 and 15.0 g pot^{-1} in the low, medium and high Zn soil groups, respectively. However, higher dry matter yields were obtained from medium and high Zn status soils as compared to the low Zn status soils, indicating the better inherent qualities of the soils with medium and high Zn contents have potentials of increasing plant biomass. The highest dry matter yields of cabbage were obtained in plants with Zn applied on almost all soils (Table 14) that indicate Zn is a limiting nutrient for cabbage in the soils containing low Zn. The study concluded that a response to Zn fertilization is likely when the available Zn value is at low status and decreases when the value exceeds the critical level (Figure 9). When cabbage plants were grown in soil treated with Zn, the average yield ranged from 7.2 to 25.1 g pot^{-1} in low Zn soil group, 13.5 to 27.7 g pot^{-1} in medium Zn soil group and 14.4 to 19.7 g pot^{-1} in high Zn soil group. On the other hand, in soils without applied Zn, the average cabbage biomass yield ranged from 3.8 to 13.8 g pot^{-1} in low Zn soil group, 9.70 to 22.1 g pot^{-1} in medium Zn soil group and 11.9 to 18.1 g pot^{-1} in high Zn soil group. The average relative yields were 63.4 %, 76.7 % and 89.3 % in low, medium and high Zn soil group, respectively (Table 14).

The critical value of Zn for cabbage was 0.74 mg kg^{-1} soil which was calculated by plotting a scattered diagram with the relative yields (Bray's percent yield) in Y-axis versus soil test values of Zn in X-axis (Figure 10). No studies on critical level of Zn in soil were reported in the literature on cabbage grown soil. However, Akhter et al. (2019) determined the critical level of Zn for wheat crop which was 0.82 mg kg^{-1} soil. At present, CL of Zn in soils is 0.6 mg kg^{-1} (BARC 2018) and Zn status in many soils is below the CL. The established CL of Zn in the present study is higher than the value used currently (BARC 2018). Mehra et al. (2005) reported that both graphical and statistical methods indicated 0.95 mg kg^{-1} as the critical value of Zn in soils for maize. Madhavi et al. (2013) reported that CL of Zn in soils was 0.75 mg kg^{-1}. In another report, Mahata et al. (2014) reported that CL of DTPA–Zn in soils was 0.82 mg kg^{-1}. On the other hand, the CL reported in the present study (0.74 mg kg^{-1}) was also close to the critical level of Zn (0.83 mg kg^{-1}) as observed by Rahman et al. (2007) for rice.

Table 14: Relative yield of wheat and cabbage with and without Zn, SSD, BARI, 2019-2020

Soil sample No.	Sample name	Zn level (mg/kg)	Wheat (cv. BARI Gom-30)			Cabbage (cv. Atlas-70)		
			Dry matter yield (g/pot)		Relative yield (%)	Dry matter yield (g/pot)		Relative yield (%)
			With Zn	Without Zn		With Zn	Without Zn	
Low Zn								
1.	BARI 161	0.37	14.4	12.0	83.6	16.8	12.6	73.9
2.	BARI 169	0.22	16.3	12.7	77.7	15.8	8.9	56.8
3.	BARI 165	0.32	11.1	8.29	74.8	12.9	9.2	70.8
4.	BARI 170	0.33	13.3	10.3	77.9	-	-	-
5.	BARI 171	0.64	12.3	10.8	87.2	14.7	11.6	78.7
6.	BARI 175	0.34	11.1	9.24	83.1	-	-	-
7.	BARI 168	0.39	17.8	13.1	73.3	9.6	6.4	63.2
8.	BRRI 43	0.02	14.7	9.82	66.7	18.3	9.6	52.7
9.	BRRI 45	0.04	19.3	12.2	63.6	21.1	10.6	50.5
10.	BRRI 48	0.10	10.0	7.29	73.9	7.2	3.8	54.9
11.	BRRI 117	0.26	9.42	7.70	79.2	18.3	12.6	69.4
12.	BRRI 119	0.21	20.4	14.5	70.8	25.1	13.8	55.0
13.	BRRI 120	0.24	8.51	6.60	76.2	24.9	16.5	66.7
14.	BARI 132	0.51	-	-	-	11.6	8.1	70.0

Soil sample No.	Sample name	Zn level (mg/kg)	Wheat (cv. BARI Gom-30)			Cabbage (cv. Atlas-70)		
			Dry matter yield (g/pot)		Relative yield (%)	Dry matter yield (g/pot)		Relative yield (%)
			With Zn	Without Zn		With Zn	Without Zn	
Medium Zn								
15.	S1 (Kaliakoir)	0.62	-	-	-	13.5	9.70	72.0
16.	S4 (Charghat)	0.8	-	-	-	21.9	15.0	68.8
17.	BARI 91	1.07	14.3	12.7	90.1			
18.	BARI 92	0.96	15.9	14.0	89.2	18.4	15.0	77.7
19.	BARI 96	1.05	17.8	14.8	83.3	27.7	22.1	81.9
20.	BARI 100	1.30	16.9	15.6	92.7	16.0	12.9	80.4
21.	BARI 101	0.92	12.2	10.8	87.9	15.2	12.1	79.2
22.	BARI 119	0.91	11.0	9.30	82.0	-	-	
High Zn								
23.	S3	1.28	-	-	-	14.4	11.9	82.6
24.	S16	1.50	12.4	12.1	96.5	17.3	14.5	83.9
25.	BRRI 144	1.76	14.1	13.8	97.9	19.7	18.1	86.5
26.	BRRI 145	1.78	16.5	15.6	94.4	17.7	15.6	86.6
27.	BRRI 146	2.02	12.2	11.9	97.0	15.0	14.0	93.6
28.	BRRI 174	2.00	11.4	11.1	97.1	16.3	14.4	89.2
29.	BRRI 179	2.36	14.0	13.6	96.7	16.5	15.8	96.3
30.	BRRI 180	2.44	16.4	15.8	96.1	16.0	15.3	95.6

*Some soils were used for having variations in the soil values and types

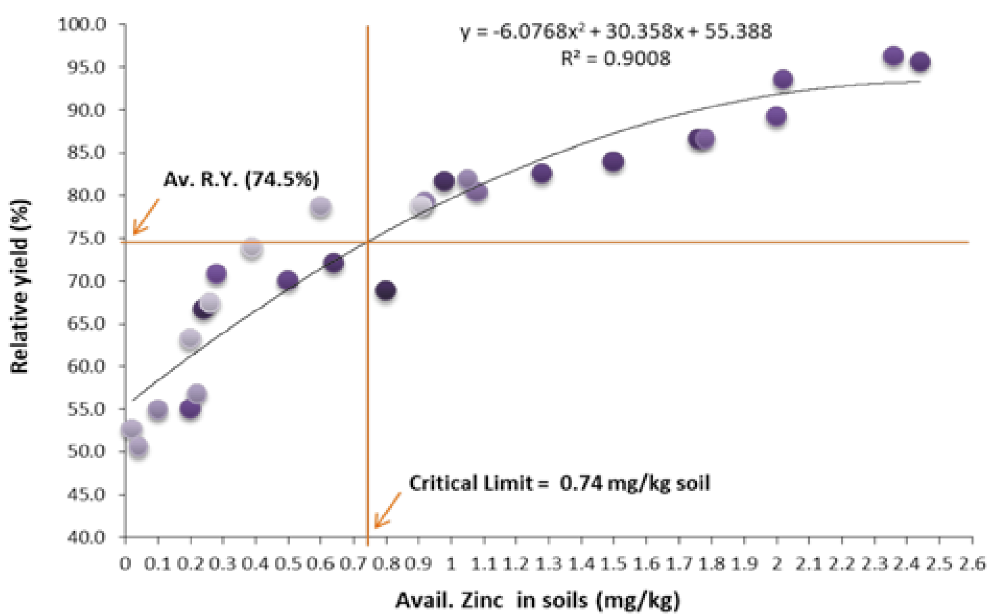


Figure 9: Critical limit of zinc in soil for cabbage in Bangladesh (Cate and Nelson method). The experiment was conducted at greenhouse of Soil Science Division, BARI, Gazipur in 2019-2020.

Photo 12: Pot trial on cabbage response to Zn application and without application on Sara soil series at Babugonj, Barisal, Bangladesh. The experiment was conducted at greenhouse of Soil Science Division, BARI, Gazipur in 2019-2020 to determine critical limit of zinc in soil for cabbage in Bangladesh.

Relative yield and Critical Limit of Zn for maize

The biomass yield of maize in Zn treated soils was higher than the biomass of maize recorded in soils without Zn application (Table 15). Maize plants grown in earthen pots responded positively to Zn application, resulting in increased plant biomass, the highest response being in low Zn contained soils followed by medium and high Zn status soils. Among the soil groups of different Zn content, the average biomass in low Zn soil group was 101.5 g pot^{-1}, while it was 95.3 g pot^{-1} in medium Zn soil group and 92.1 g pot^{-1} average biomass yield in the high Zn soil group. In case of soils without Zn treatment, the biomass yields of maize were 67.7, 79.8 and 80.8 g pot^{-1} in the low, medium and high Zn soil groups, respectively. However, higher dry matter yields were obtained from low and medium Zn status in soils as compared to the low Zn status soils, indicating the better inherent qualities of the soils with medium and high Zn contents have potentials of increasing plant biomass. The highest dry matter yields of maize were obtained in plants with Zn applied on almost all soils (Table 15) that indicate Zn is a limiting nutrient for maize in the soils containing low Zn. The study concluded that a response to Zn fertilization is likely when the available Zn value is at low status and decreases when the value exceeds the critical level (Figure 10). When maize plants were grown in soil treated with Zn, the average yield ranged from 44.8 to 88.2 g pot^{-1} in low Zn soil group, 66.82 to 123.8 g pot^{-1} in medium Zn soil group and 59.63 to 139.7 g pot^{-1} in high Zn soil group. On the other hand, in soils without applied Zn, the average cabbage biomass yield ranged from 44.78 to 88.18 g pot^{-1} in low Zn soil group, 44.50 to 106.7 g pot^{-1} in medium Zn soil group and 54.16 to 121.1 g pot^{-1} in high Zn soil group. The average relative yields were 65.8 %, 82.9 % and 90.1 % in low, medium and high Zn soil group, respectively (Table 15).

The critical value of Zn for maize was 0.72 mg kg^{-1} soil which was calculated by plotting a scattered diagram with the relative yields (Bray's percent yield) in Y-axis versus soil test values of Zn in X-axis (Figure 6). Mehra et al. (2005) reported that both graphical and statistical methods indicated 0.95 mg kg^{-1} as the critical value of Zn in soils for maize. Again, Akhter et al. (2019) determined the critical level of Zn for wheat crop which was 0.82 mg kg^{-1} soil. At present, the reference value of CL of Zn in soils is 0.6 mg kg^{-1} (BARC 2018) and Zn status in many soils is below the CL. The established

CL of Zn in the present study is higher than the value used currently (BARC 2018). Madhavi et al. (2013) reported that CL of Zn in soils was 0.75 mg kg^{-1}. In another report, Mahata et al. (2014) reported that CL of DTPA–Zn in soils was 0.82 mg kg^{-1}. On the other hand, the CL reported in the present study (0.72 mg kg^{-1}) was also close to the critical level of Zn (0.83 mg kg^{-1}) as observed by Rahman et al. (2007) for rice.

Table 15: Relative yield of maize with and without Zn, SSD, BARI, 2019-2020

Soil sample No.	Sample name	Zn level (mg/kg)	Maize (BARI Hybrid Maize-9)		
			Dry matter yield (g/pot)		Relative yield (%)
			With Zn	Without Zn	
Low Zn					
1	BARI 161	0.37	128.5	88.12	67.63
2	BARI 169	0.22	116.6	88.18	75.67
3	BARI 165	0.32	85.18	50.74	60.09
4	BARI 170	0.33	99.60	82.18	60.32
5	BARI 171	0.64	117.6	54.46	47.06
6	BARI 175	0.34	96.66	74.07	77.46
7	BRRI 43	0.02	95.58	52.5	82.62
8	BRRI 45	0.04	95.08	54.04	56.16
9	BRRI 48	0.10	82.94	44.78	57.27
10	BRRI 117	0.26	97.26	71.42	53.69
11	BRRI 119	0.21	96.99	76.04	73.12
12	BRRI 120	0.24	106.2	75.91	78.80
Medium Zn					
1.	BRRI 99	0.65	123.8	106.7	86.62
2.	BARI 91	1.07	66.82	44.50	65.88
3.	BARI 92	0.96	115.8	98.63	85.14
4.	BARI 96	1.05	96.62	85.36	88.40
5.	BARI 100	1.30	88.34	68.55	77.74
6.	BARI 101	0.92	83.38	81.56	98.21
7.	BARI 119	0.91	92.77	73.08	78.50
High Zn					
8.	BRRI 144	1.76	93.01	74.04	88.36
9.	BRRI 145	1.78	76.91	66.89	86.95
10.	BRRI 146	2.02	95.78	82.06	88.19
11.	BRRI 174	2.00	59.63	54.16	91.36
12.	BRRI 179	2.36	139.7	121.1	87.06
13.	BRRI 180	2.44	87.84	86.49	98.74

*Some soils were used for having variations in the soil values and types

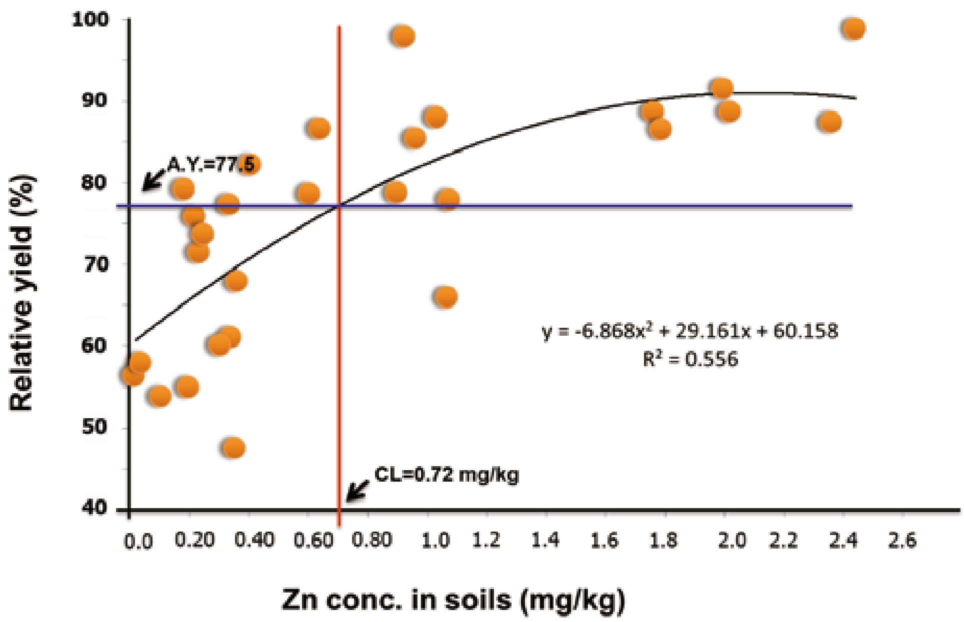


Figure 10. Critical limit of zinc for maize determined by pot trial on 25 different soils in Bangladesh (Cate and Nelson method). The experiment was conducted at greenhouse of Soil Science Division, BARI, Gazipur in 2019-2020.

Photo 13: Pot trial on maize response to Zn application and without application on soils of different soil series in Bangladesh. The experiment was conducted at greenhouse of Soil Science Division, BARI, Gazipur in 2019-2020 to determine critical limit of Zn in soil for maize in Bangladesh.

Potassium and Zn concentration in plant tissue and critical limit of plant tissue K and Zn

To determine the CL of plant tissue of maize, wheat and cabbage the harvested plants were processed and dried at 68ºC for three days (72 hours). The samples were ground and analyzed for K and Zn concentration. Out of 950 samples, 350 samples were analyzed. A scatter diagram of the relative yields (Bray's per cent yield) as Y-axis versus plant tissue test values as X- axis were plotted to determine the CL value of each crop (according to the procedure of Cate and Nelson, 1965).

Potassium concentration in plant tissue

K in wheat tissue

Wheat plants grown in K added soils had greater K in plant biomass than plants grown in soils without K addition (Table 16). The highest increase in K concentration (76.7%) in plant biomass was recorded in soils of Tejgaon series (Kaligonj, Gazipur location and having sandy clay loam texture, Madhupur Tract Agro Ecological Zone (AEZ-28)), followed by K content increase (68 %) in wheat biomass grown in soils of Tejgaon series (Kaligonj, Gazipur location and having clay loam texture, Madhupur Tract Agro Ecological Zone (AEZ-28)). The wheat crop growing in soils under Ghior series of Godagari, Rajshahi location and Chandina series series of Katchua had the lowest increase in K (-13.8 and 9.4%, respectively) concentration after external addition.

Table 16: Relative yield and potassium concentration in wheat and cabbage tissue by treating with and without K. The experiment was conducted at greenhouse of Soil Science Division, BARI during 2019-2020

Soil sample No.	Sample name	Exch. K (meq/100g)	Wheat (cv. BARI Gom-30)			Cabbage (cv. Atlas-70)		
			K concentration in plant tissue (g kg^{-1})		Relative yield (%)	K concentration in plant tissue (g kg^{-1})		Relative yield (%)
			With K	Without K		With K	Without K	
Low K								
1.	BRRI 94	0.019	25.1	22.9	69.0	14.2	9.10	66.7
2.	BRRI 99	0.023	15.8	10.0	67.8	21.8	11.9	68.9
3.	BRRI 100	0.023	18.9	16.2	-	22.1	15.4	71.9
4.	BRRI 71	0.037	23.7	20.3	68.9	18.9	10.1	67.8
5.	BRRI 75	0.037	21.5	16.2	65.7	15.2	12.1	70.1
6.	BARI 96	0.13	20.5	13.3	79.2	23.7	21.1	81.4
7.	BARI 13	0.06	27	19.2	66.6	18.7	13.4	71.8
8.	BARI 14	0.06	32.7	20.2	70.3	23.7	12.7	72.6
9.	BARI 15	0.07	24.8	18.4	70.7	21.3	15.2	71.0
10.	BARI 16	0.07	16.5	13.8	74.8	27.9	18.9	75.7
11.	BARI 20	0.08	31.6	18.8	75.8	36.3	27.9	77.8
12.	BARI 24	0.10	22.1	19.3	80.0	32.7	26.9	78.8
Medium K								
13.	BARI 62	0.16	27	17.3	83.7	30.5	20.2	78.5
14.	BARI 64	0.17	19.2	11.7	78.2	31.7	28.1	80.6
15.	BARI 84	0.17	32.2	28.9	81.5	20.0	15.1	79.9
16.	BARI 9	0.16	29.6	24.3	78.5	29.6	23.5	79.8
17.	BARI 27	0.2/0.16	20.5	11.6	80.8	36.1	27.1	80.6
18.	BARI 90	0.25	24.8	17.1	83.6	29.3	30.5	81.8

Soil sample No.	Sample name	Exch. K (meq/100g)	Wheat (cv. BARI Gom-30)			Cabbage (cv. Atlas-70)		
			K concentration in plant tissue (g kg^{-1})		Relative yield (%)	K concentration in plant tissue (g kg^{-1})		Relative yield (%)
			With K	Without K		With K	Without K	
High K								
19.	BRRI 1	0.31	30.5	24.8	73.3	36.3	29.0	85.7
20.	BRRI 2	0.28	12.8	11.7	84.4	31.7	28.3	87.4
21.	BRRI 3	0.31	-	-	90.3	-	-	-
22.		0.31	-	-	80.6	-	-	-
23.	BRRI 4	0.35	24.0	16.2	91.7	36.5	35.0	92.7
24.	BARI 128	0.43	20.7	14.9	90.3	36.5	27.8	91.4
25.	BARI 130	0.45	26.7	21.5	90.8	28.0	23.9	96.6
26.	BRRI 3	0.55	-	-	-	-	-	-
27.	S16 (Gazipur Sadar)	0.58	16.9	12.0	69.0	37.2	34.0	96.1
28.	BARI 132	0.78	-	-	-	29.5	28.0	94.9
29.	S1 (Kaliakoir)	0.67	-	-	-	26	21.9	97.1
30.	S3 (Godagari)	0.49	23.7	27.5	93.2	33.9	30.5	94.2

*Some soils were used for having variations in the soil values and types

Critical Limit of K for wheat tissue

The critical value of K for wheat tissue was calculated by drawing a scattered diagram with the relative yields (Bray's percent yield) in Y-axis versus wheat tissue test values of K conc. in X-axis. The critical value of K for wheat tissue growing in 25 soils of Bangladesh was 17 g kg^{-1} biomass (Figure 11).

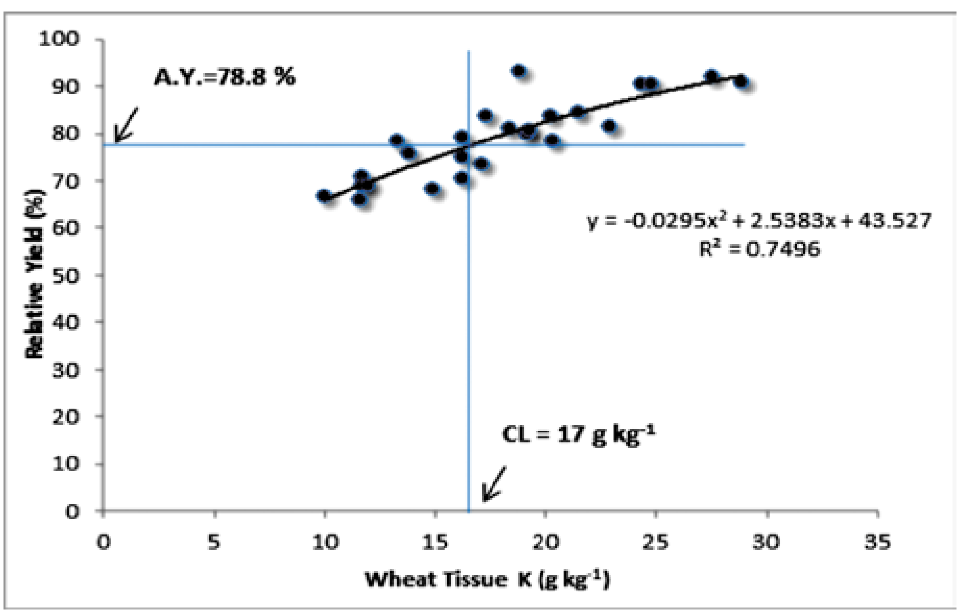


Figure 11. Critical limit of potassium (g kg^{-1}) for wheat tissue on 25 different soils in Bangladesh (Cate and Nelson method). The experiment was conducted at greenhouse of Soil Science Division, BARI, Gazipur in 2019-2020.

Potassium in cabbage tissue

Cabbage plants grown in K added soils had greater K in plant biomass than plants grown in soils without K addition (Table 16). The highest increases in K concentration (86.6 %) in plant biomass was recorded in soils of Sonatola series (Durbati, Kaligonj, Gazipur location and having clay loam texture, Madhupur Tract Agro Ecological Zone (AEZ-28)), followed by K content increase (83.2 %) in cabbage biomass grown in soils of Chandina series (Changini, Katchua location and having sandy clay loam texture, Madhupur Tract Agro Ecological Zone (AEZ-28)). The cabbage crop growing in soils under Sara and Gopalpur series of Anderkota, Chowgacha, Jashore and Chilania series of Chorkossopia, Companiganj, Noakhali had the lowest increase in K (-3.9 and 4.3 %, respectively) concentration after external addition.

Critical Limit of K for cabbage tissue

The critical value of K for cabbage tissue was calculated by drawing a scattered diagram with the relative yields (Bray's percent yield) in Y-axis versus wheat tissue test values of K conc. in X-axis. The critical value of K for cabbage tissue growing in 25 soils of Bangladesh was 21.5 g kg^{-1} biomass (Figure 12).

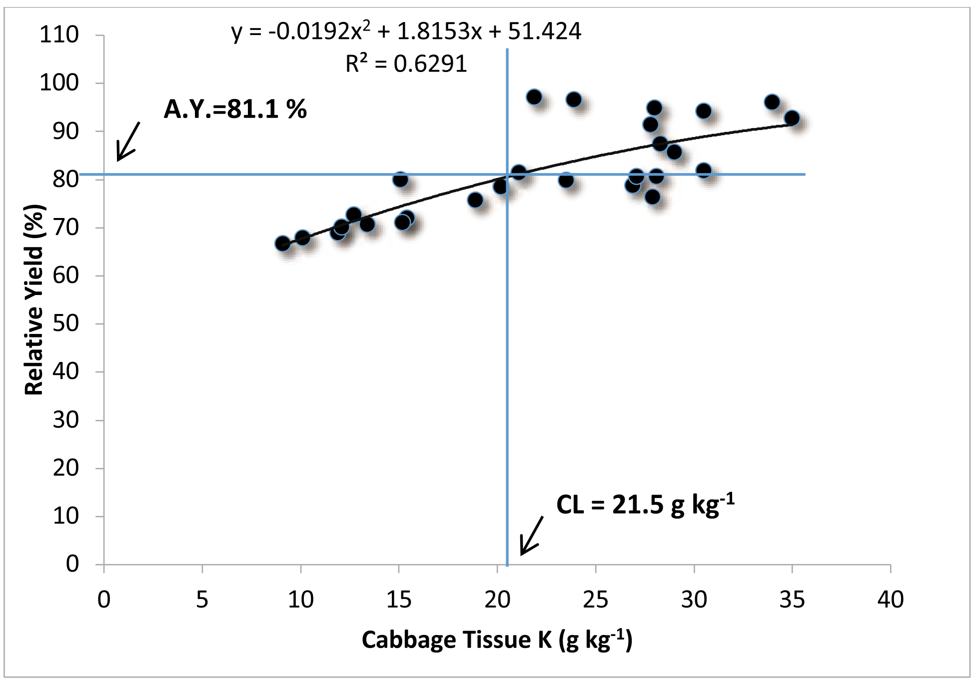


Figure 12. Critical limit of potassium (g kg^{-1}) for cabbage tissue determined by using 25 different soils in Bangladesh (Cate and Nelson method). The experiment was conducted at greenhouse of Soil Science Division, BARI, Gazipur in 2019-2020.

K in maize tissue

Maize plants grown in K added soils had greater K in plant biomass than plants grown in soils without K addition (Table 17). The highest increase in K concentration (103.0 %) in plant biomass was recorded in soils of Sonatola/Silmondi series (Durbati, Kaligonj location and having clay loam texture, Barind Tract Tract Agro Ecological Zone (AEZ-28)), followed by K content increase (63.7%) in maize biomass grown in soils of Sara series (Paba, Rajshahi location and having silty clay loam texture, Madhupur Tract Agro Ecological Zone (AEZ-28)). The maize crop growing in soils under Gopalpur series of Anderkota, Chowgacha, Jashore location (having sandy loam soil texture, Ganges

Tidal Flood Plain (AEZ-13) had the lowest increase in K (6.5 %, respectively) concentration after external addition.

Table 17: Relative yield and potassium concentration in tissue of maize as influenced by potassium application. The experiment was conducted in greenhouse of Soil Science Division, BARI during 2019-2020

Soil sample No.	Sample name	Exch. K (meq/100g)	Maize (BARI Hybrid Maize-9)		
			Tissue K concentration ($g\ kg^{-1}$)		Relative yield (%)
			With K	Without K	
Low K					
1.	BRRI 94	0.019	18.9	12.5	60.90
2.	BRRI 99	0.023	18.0	14.4	66.43
3.	BRRI 100	0.023	20.9	13.0	56.32
4.	BRRI 71	0.037	21.5	17.6	63.15
5.	BRRI 75	0.037	19.0	16.2	65.75
6.	BARI 96	0.13	28.0	17.1	75.44
7.	BARI 13	0.06	20.5	10.1	56.66
8.	BARI 14	0.06	21.5	14.5	62.73
9.	BARI 15	0.07	23.3	15.3	70.54
10.	BARI 16	0.07	21.4	16.6	63.82
11.	BARI 20	0.08	21.3	13.6	62.10
12.	BARI 24	0.10	31.1	19.2	86.44
Medium K					
13.	BARI 62	0.16	23.0	18.6	84.24
14.	BARI 64	0.17	31.5	21.0	93.47
15.	BARI 84	0.17	28.2	19.2	87.08
16.	BARI 9	0.16	24.8	21.0	86.98
17.	BARI 27	0.2/0.16	22.0	14.0	75.01
18.	BARI 90	0.25	21.3	20.0	88.62
High K					
19.	BRRI 1	0.31	20.9	16.1	87.10
20.	BRRI 2	0.28	24.0	17.9	83.68
21.	BRRI 4	0.35	27.0	20.9	88.23
22.	BARI 128	0.43	29.4	24.8	90.23
23.	BARI 130	0.45	24.5	16.3	84.64
24.	S16 (Gazipur Sadar)	0.58	29.0	20.3	96.92
25.	S3 (Godagari)	0.49	31.0	23.0	98.52

Results are the means of three replications, With Zn = Addition of Zn, Zn = without addition of Zn

Critical Limit of K for maize tissue

The critical value of K for maize tissue was calculated by drawing a scattered diagram with the relative yields (Bray's percent yield) in Y-axis versus wheat tissue test values of K conc. in X-axis. The critical value of K for maize tissue growing in 25 soils of Bangladesh was 17.2 g kg^{-1} biomass (Figure 13).

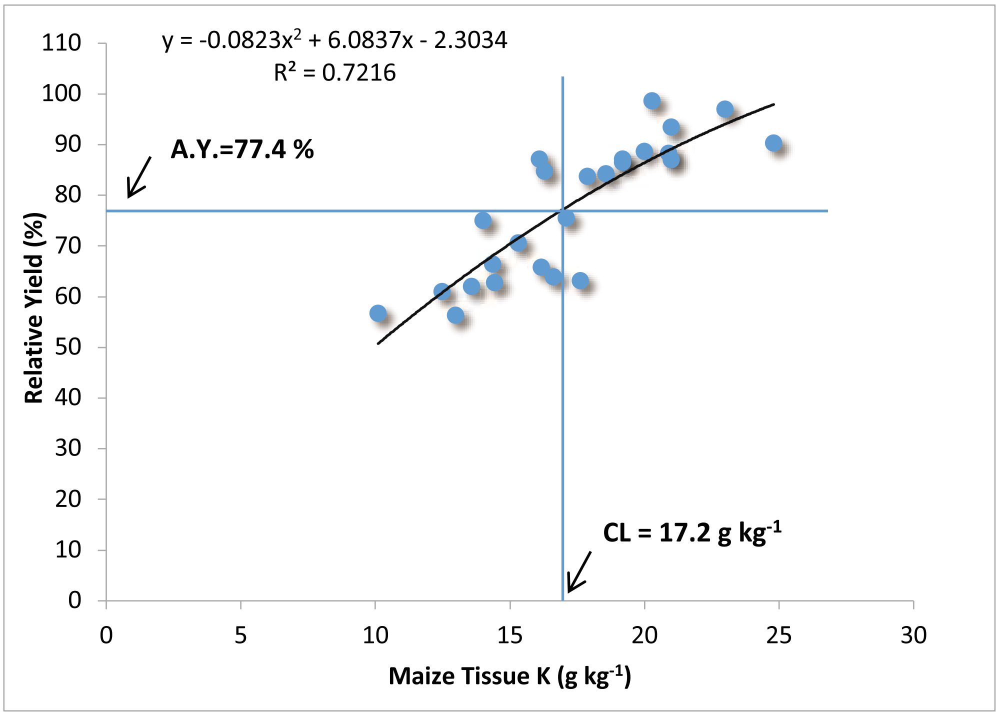


Figure 13. Critical limit of potassium (g kg^{-1}) for maize tissue determined by using 25 different soils in Bangladesh (Cate and Nelson method). The experiment was conducted at greenhouse of Soil Science Division, BARI, Gazipur in 2019-2020.

Zinc concentration in wheat tissue

Wheat plants grown in Zn added soils had greater Zn in plant biomass than plants grown in soils without Zn addition (Table 18). The highest increase in Zn concentration (103 %) in plant biomass was recorded in soils of Ramgati series (Kamalnagar (Ramgati), Chor Monosa, Noakhali and having sandy clay loam texture), followed by Zn content increase (99.8 %) in wheat biomass grown in soils of Sara series (Babugonj, Barisal location and having clay loam texture, Ganges Tidal Flood Plain (AEZ-13)). The wheat crop growing in soils under Ghoain ghat series of Companiganj, Dolirgaon Purbopara, Sylhet location and Bijipur series of Jaintapur, Vitrikhel, Sylhet location had the lowest increase in Zn (4.1 and 8.0 %, respectively) concentration after external addition.

Table 18: Relative yield and zinc concentration in wheat and cabbage tissue by treating with and without zinc at greenhouse of Soil Science Division, BARI during 2019-2020

Soil sample No.	Sample name	Zn level (mg/kg)	Wheat (cv. BARI Gom-30)			Cabbage (cv. Atlas-70)		
			Zn concentration (mg kg^{-1})		Relative yield (%)	Zn concentration (mg kg^{-1})		Relative yield (%)
			With Zn	Without Zn		With Zn	Without Zn	
Low Zn								
1.	BARI 161	0.37	33.24	24.54	83.6	38.92	27.36	73.9
2.	BARI 169	0.22	31.68	18.60	77.7	39.24	23.82	56.8
3.	BARI 165	0.32	41.10	22.40	74.8	39.72	22.4	70.8
4.	BARI 170	0.33	36.72	21.60	77.9	35.34	21.6	61.1
5.	BARI 171	0.64	35.16	17.60	87.2	47.06	25.62	78.7
6.	BARI 175	0.34	39.12	25.90	83.1	36.72	22.08	60.1
7.	BARI 168	0.39	36.54	20.64	73.3	32.82	18.72	63.2
8.	BRRI 43	0.02	38.22	18.80	66.7	39.24	18.80	52.7
9.	BRRI 45	0.04	28.68	17.00	63.6	30.48	24.84	50.5
10.	BRRI 48	0.10	32.46	20.64	73.9	35.7	19.68	54.9
11.	BRRI 117	0.26	33.72	23.90	79.2	38.88	34.44	69.4
12.	BRRI 119	0.21	30.72	23.16	70.8	45.12	36.30	55.0
13.	BRRI 120	0.24	37.26	24.10	76.2	38.92	27.36	66.7
14.	BARI 132	0.51	-	-	-	39.24	23.82	70.0
Medium Zn								
15.	S1 (Kaliakoir)	0.62	-	-	-	39.10	30.66	72.0
16.	S4 (Charghat)	0.80	-	-	-	37.48	31.26	68.8
17.	BARI 91	1.07	34.8	27.18	90.1	32.52	25.26	77.7
18.	BARI 92	0.96	40.14	29.22	89.2	54.30	35.46	77.7
19.	BARI 96	1.05	38.46	34.44	83.3	38.56	30.72	81.9
20.	BARI 100	1.30	32.52	27.24	92.7	44.46	31.26	80.4
21.	BARI 101	0.92	45.4	32.22	87.9	39.10	30.66	79.2
22.	BARI 119	0.91	46.9	41.41	82.0	-	-	-
High Zn								
23.	S3	1.28	-	-	-	45.12	39.6	82.6
24.	S16	1.50	61.32	45.98	96.5	54.65	40.5	83.9
25.	BRRI 144	1.76	39.18	35.76	97.9	53.88	41.76	86.5
26.	BRRI 145	1.78	61.38	41.41	94.4	45.54	45.22	86.6
27.	BRRI 146	2.02	49.61	47.64	97.0	53.50	47.82	93.6
28.	BRRI 174	2.00	57.90	45.43	97.1	45.2	44.46	89.2
29.	BRRI 179	2.36	53.70	36.96	96.7	45.66	32.52	96.3
30.	BRRI 180	2.44	40.68	37.68	96.1	65.40	36.72	95.6

*Some soils were used for having variations in the soil values and types

Critical Limit of Zn for wheat tissue

The critical value of Zn for wheat tissue was calculated by drawing a scattered diagram with the relative yields (Bray's percent yield) in Y-axis versus wheat tissue test values of Zn conc. in X-axis. The critical value of Zn for wheat tissue growing in 25 soils of Bangladesh was 27.2 mg kg^{-1} biomass (Figure 14).

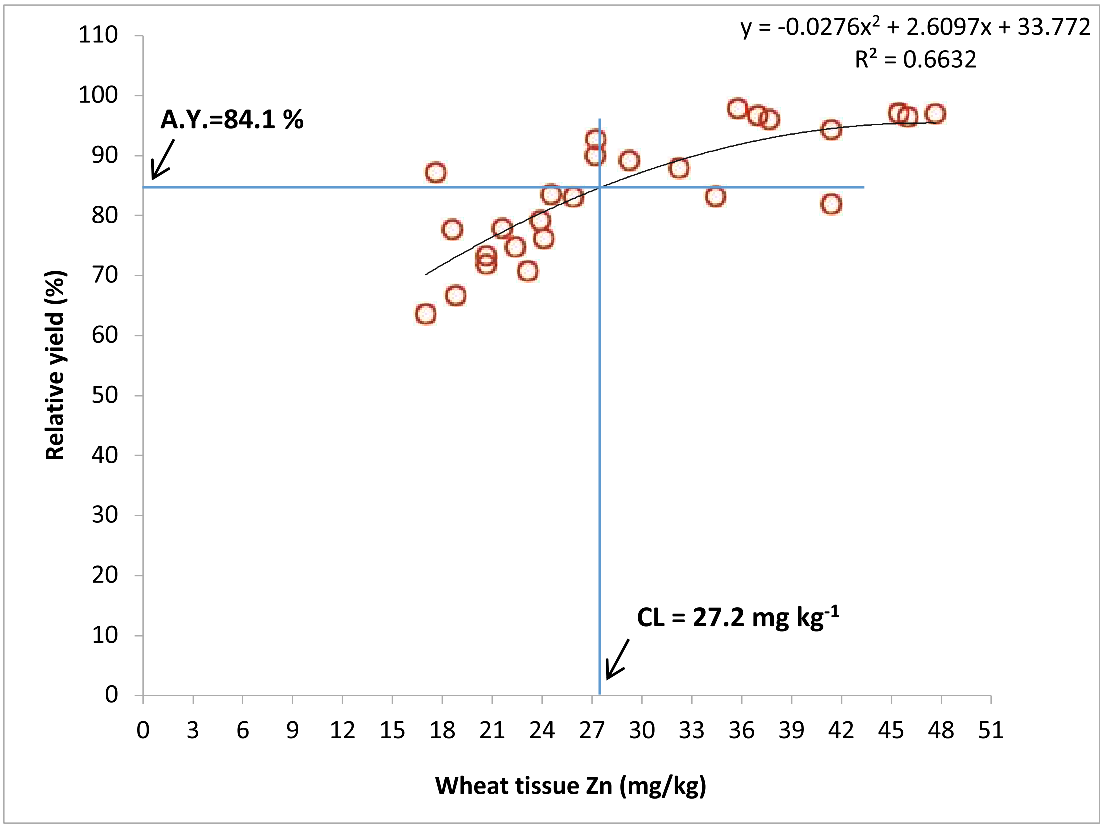


Figure 14. Critical limit of zinc (mg kg^{-1}) for wheat tissue determined by using 25 different soils in Bangladesh (Cate and Nelson method). The experiment was conducted at greenhouse of Soil Science Division, BARI, Gazipur in 2019-2020.

Zinc concentration in cabbage tissue

Cabbage plants grown in Zn added soils had greater Zn in plant biomass than plants grown in soils without K addition (Table 18). The highest increases in Zn concentration (86.6 %) in plant biomass was recorded in soils of Ramgati series (Kamalnagar, Ramgati), Chor Monosa, Noakhali, followed by Zn content increase (84%) in cabbage biomass grown in soils of Sara series (Babugonj, Barisal location and having clay loam texture, Ganges Tidal Flood Plain (AEZ-13)). The cabbage crop growing in soils under Ghoainghat series of Companiganj, Dolirgaon Purbopara, Companigonj, Sylhet and Bijipur series of Jaintapur, Vitrikhel, Sylhet location had no increase in Zn (0.7 and 1.7%, respectively) concentration after external addition.

Critical Limit of Zn for cabbage tissue

The critical value of Zn for cabbage tissue was calculated by drawing a scattered diagram with the relative yields (Bray's percent yield) in Y-axis versus wheat tissue test values of Zn conc. in X-axis. The critical value of Zn for cabbage tissue growing in 25 soils of Bangladesh was 29 mg kg^{-1} biomass (Figure 15).

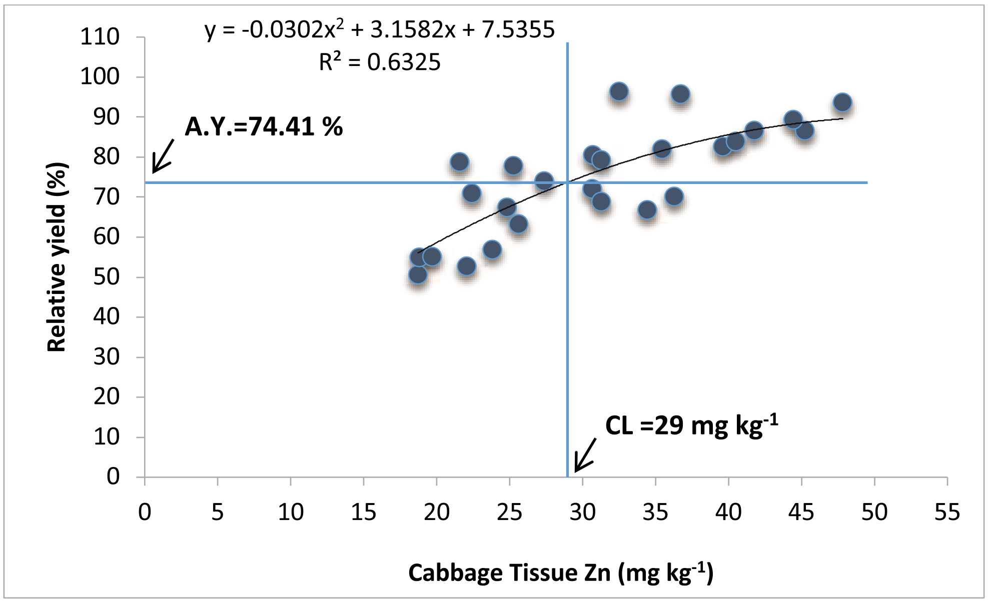


Figure 15. **Critical limit of zinc (mg kg^{-1}) for cabbage tissue determined by using 25 different soils in Bangladesh (Cate and Nelson method). The experiment was conducted at greenhouse of Soil Science Division, BARI, Gazipur in 2019-2020.**

Zinc concentration in maize tissue

Maize plants grown in Zn added soils had greater Zn in plant biomass than plants grown in soils without Zn addition (Table 19). The highest increase in Zn concentration (112.0 %) in plant biomass was recorded in soils of Chandina series (Katchua, Budumda location and having sandy clay loam texture), followed by Zn content increase (95.8%) in maize biomass grown in soils of Chandina series (Katchua, Budumda location). The maize crop growing in soils under Bijipur series of Jaintapur, Vitrikhel location (having sandy clay loam soil texture) had the lowest increase in Zn (8.6%) concentration after external addition.

Table 19: **Relative yield and zinc concentration in tissue of maize as influenced by zinc application. The experiment was conducted in greenhouse of Soil Science Division, BARI during 2019-2020**

Soil sample No.	Sample name	Zn level (mg/kg)	Miaze (BARI Hybrid Maize-9)		
			Zn concentration (mg kg^{-1})		Relative yield (%)
			With Zn	Without Zn	
Low Zn					
1.	BARI 161	0.37	36.54	30.00	67.63
2.	BARI 169	0.22	52.44	31.26	75.67
3.	BARI 165	0.32	32.22	23.90	60.09
4.	BARI 170	0.33	53.34	35.22	60.32
5.	BARI 171	0.64	34.14	19.10	47.06
6.	BARI 175	0.34	57.48	35.88	77.46
7.	BRRI 43	0.02	30.36	20.30	82.62
8.	BRRI 45	0.04	47.83	32.82	56.16
9.	BRRI 48	0.10	32.46	22.14	57.27
10.	BRRI 117	0.26	66.84	34.14	53.69
11.	BRRI 119	0.21	43.37	32.52	73.12
12.	BRRI 120	0.24	57.48	27.00	78.80

Soil sample No.	Sample name	Zn level (mg/kg)	Miaze (BARI Hybrid Maize-9)		
			Zn concentration (mg kg^{-1})		Relative yield (%)
			With Zn	Without Zn	
Medium Zn					
13.	BRRI 99	0.65	44.85	28.68	86.62
14.	BARI 91	1.07	40.14	24.66	65.88
15.	BARI 92	0.96	70.26	40.68	85.14
16.	BARI 96	1.05	42.4	28.74	88.40
17.	BARI 100	1.3	52.23	33.72	77.74
18.	BARI 101	0.92	60.96	42.91	98.21
19.	BARI 119	0.91	49.9	47.48	78.50
High Zn					
20.	BRRI 144	1.76	60.72	39.18	88.36
21.	BRRI 145	1.78	47.95	42.91	86.95
22.	BRRI 146	2.02	58.68	49.14	88.19
23.	BRRI 174	2.00	42.91	46.93	91.36
24.	BRRI 179	2.36	53.7	38.46	87.06
25.	BRRI 180	2.44	40.68	39.18	98.74

*Some soils were used for having variations in the soil values and types

Critical Limit of Zn for maize tissue

The critical limit of Zn for maize tissue was calculated by drawing a scattered diagram with the relative yields (Bray's percent yield) in Y-axis versus wheat tissue test values of Zn conc. in X-axis. The critical limit of Zn for maize tissue growing in 25 soils of Bangladesh was 32 mg kg^{-1} biomass (Figure 16).

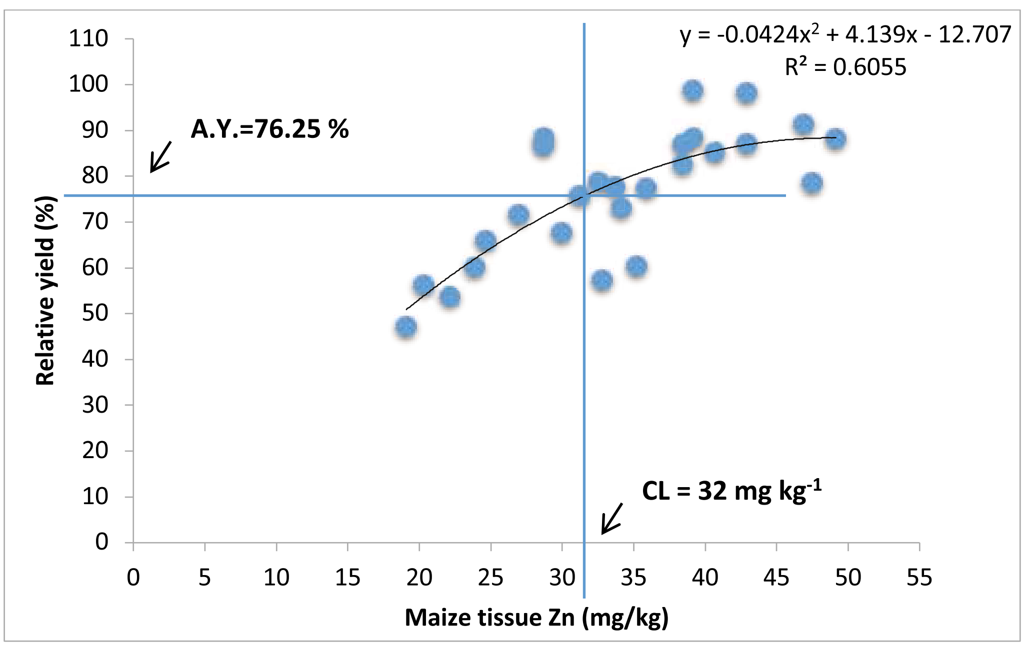


Figure 16. Critical limit of zinc (mg kg^{-1}) for maize tissue determined by using 25 different soils in Bangladesh (Cate and Nelson method). The experiment was conducted at greenhouse of Soil Science Division, BARI, Gazipur in 2019-2020.

Expt. 2.2: Determination of critical limit of P, K, S and Zn for rice (Pot expt.)

BRRI Component

Relative yield and Critical Limit of P for rice

The biomass yield of rice after eight weeks of transplanting influenced rightly with the application of P in soil compared to no application of P in soil in a low, medium and high soil native available P conditions (Table 20). In low soil P condition, the biomass yield in without P condition ranges from 6.53 to 16.47 g pot $^{-1}$. Whereas in added recommended P condition, the biomass yield ranges from 35.07 to 43.64 g pot $^{-1}$ which is much higher than without P application pots. The relative yield percent in low soil P condition ranges from 16.81 to 46.96 % and the average relative yield in low soil P condition was 32.75%. In medium soil P condition, the biomass yield in without P applied pots ranges from 20.84 to 23.50 g pot $^{-1}$ and in P applied pots it ranges from 40.70 to 41.69 g pot $^{-1}$. The relative yield varied from 51.0 to 57.74% and the average relative yield in medium soil P condition was 53.86%. The biomass yield in high soil P levels of without added P condition ranges from 33.88 to 37.81 g pot $^{-1}$ whereas in added P condition, it ranges from 40.96 to 41.91 g pot $^{-1}$. The relative yield in high soil P conditions varied from 81.93 to 92.20% and the average relative yield was 47.89%. The overall relative yield in P experimental pots ranges from 16.81 to 92.20 % and the average overall relative yield was 48.10 %.

The estimated limit of P for rice soil was 8.7 mg kg^{-1} in graphical method (Figure17) and 15 mg kg^{-1} in statistical method (Table 20) whereas, the present critical limit of P as mentioned in FRG 2018 for rice soil was 8.00 mg kg^{-1} (modified Olsen method). Kalala et al. (2016) reported that the soil critical concentration of P for flooded rice is 8.0 mg kg^{-1} and below which P fertilization will result in increase in rice yield. This finding is almost similar with that obtained in this present study. The P content in rice tissue with and without P application in pot culture after eight weeks presented in Table 22. The critical limit of rice plant P concentration was found 0.218 (%) in graphical method (Figure 18) and 0.216 (%) in statistical method (Table 21). Kalala et al. in 2016 also found the critical concentration of P in rice shoots is 0.16%.

Table 20: Relative yield of Boro rice with and without phosphorus (P) applied in pot culture, Soil Science Division, BRRI, Gazipur, 2019-20

Soil sample No.	Sample name	Ava. P (ppm)	Dry matter yield (g/pot)		Relative yield (%)
			With P	Without P	
Low P					
1.	BRRI 121	1.75	42.33	14.55	34.38
2.	BRRI 122	1.75	40.81	10.44	25.58
3.	BRRI 123	3.25	43.64	15.39	35.26
4.	BRRI 124	2.75	42.68	15.04	35.23
5.	BRRI 125	2.95	40.52	16.42	40.52
6.	BRRI 127	0.75	35.07	16.47	46.96
7.	BRRI 129	1.18	37.93	16.22	42.78
8.	BRRI 131	0.60	37.11	10.36	27.93
9.	BRRI 133	0.55	37.39	11.33	30.29
10.	BRRI 135	0.15	38.82	6.53	16.81

Soil sample No.	Sample name	Ava. P (ppm)	Dry matter yield (g/pot)		Relative yield (%)
			With P	Without P	
11.	BRRI 137	0.60	39.88	12.76	31.99
12.	BRRI 139	1.75	40.03	10.11	25.25
Medium P					
13.	BRRI 23	12.88	40.86	20.84	51.00
14.	BRRI 25	15.38	40.70	23.50	57.74
15.	BRRI 27	11.25	41.12	21.49	52.26
16.	BRRI 29	15.25	41.69	22.70	54.44
High P					
17.	BRRI 111	55.34	41.91	37.20	88.76
18.	BRRI 113	45.05	41.00	37.81	92.20
19.	BRRI 115	33.71	40.96	35.47	86.58
20.	BRRI 116	25.20	41.36	33.88	81.93

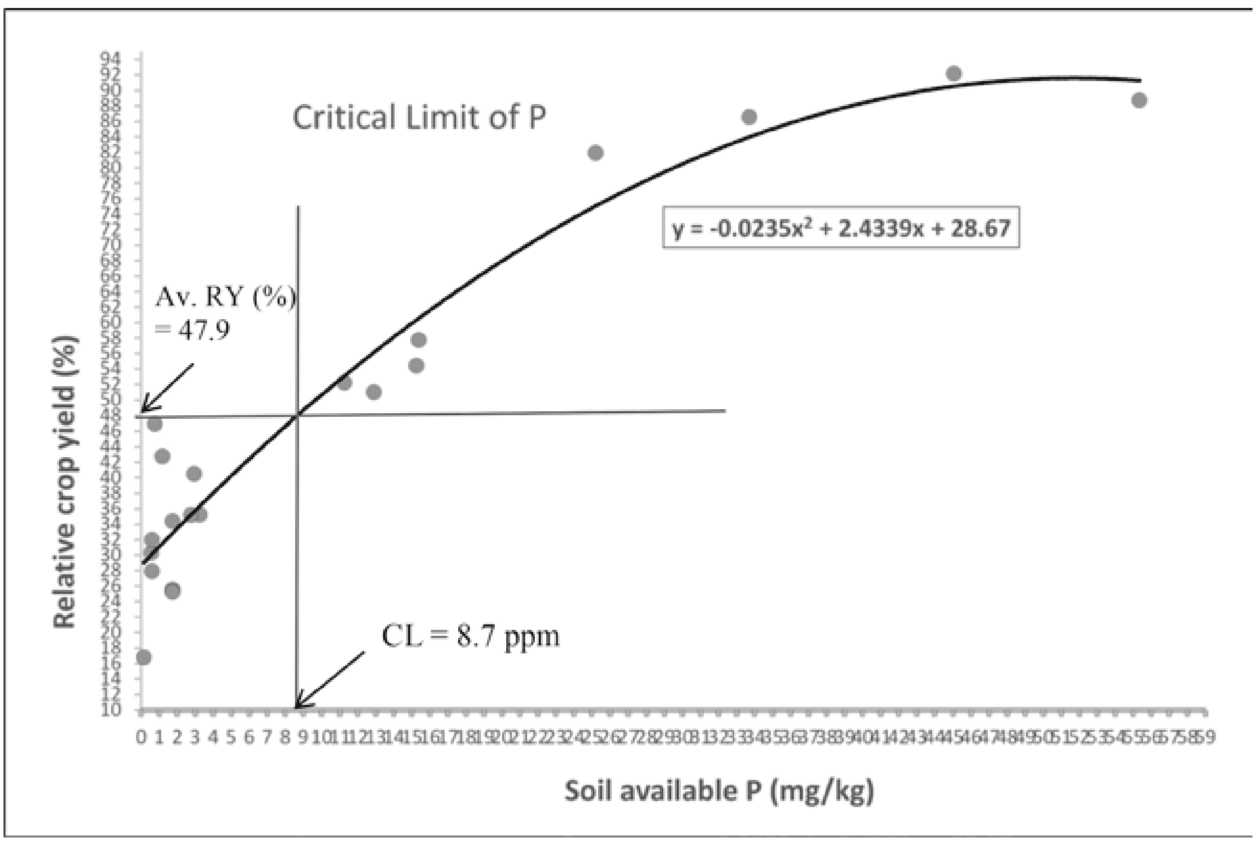


Figure 17: Critical Limit of P for rice soils in Bangladesh, Soil Science Division, BRRI 2019-20

Photo 14: Response Boro rice to P in low soil P condition at SSD, BRRI, 2019-20

Photo 15: Response Boro rice to P in medium soil P condition at SSD, BRRI, 2019-20

Photo 16: Response Boro rice to P in high soil P condition at SSD, BRRI, 2019-20

Table 21: Soil P content, Bray's % yield and predictability values (R^2) of rice soil

Sl. No.	Soil P content (ppm)	Bray's % yield	Corrected Sum of Squares of population1(CSS-I)	Corrected Sum of Squares of population I1(CSS-II)	R^2 TSS - (CSSI-CSSII) /TCSS
1	0.15	16.81	0	8572	0.1411
2	0.55	30.29	91	8205	0.1687
3	0.6	31.99	138	7605	0.2241
4	0.6	27.93	140	7563	0.2280
5	0.75	46.96	467	7438	0.2079
6	1.18	42.78	586	6525	0.2874
7	1.75	25.25	635	5482	0.3870
8	1.75	25.58	668	4811	0.4510

Sl. No.	Soil P content (ppm)	Bray's % yield	Corrected Sum of Squares of population1(CSS-I)	Corrected Sum of Squares of population I1(CSS-II)	R^2 TSS - (CSSI-CSSII) /TCSS
9	1.75	34.38	678	4055	0.5257
10	2.75	35.23	692	3439	0.5861
11	2.95	40.52	763	2327	0.6904
12	3.25	35.26	769	1942	0.7283
13	11.25	52.26	1121	1365	0.7509
14	12.88	51.00	1381	758	0.7857
15	**15.25**	**54.44**	**1718**	**56**	**0.8223**
16	15.38	57.74	2133	16	0.7847
17	25.2	81.93	3947	6	0.6039
18	33.71	86.58	5943	0	0.4045
19	45.05	92.20			
20	55.34	88.76			
			TCSS	9979.275	

Table 22. Phosphorus content of Boro rice with and without phosphorus (P) applied in pot culture, Soil Science Division, BRRI, Gazipur, 2019-20

Soil sample No.	Sample name	Ava. P (ppm)	Phosphorus content (%)		Relative yield (%)
			With P	Without P	
Low P					
1.	BRRI 121	1.75	0.219	0.157	34.38
2.	BRRI 122	1.75	0.218	0.156	25.58
3.	BRRI 123	3.25	0.214	0.159	35.26
4.	BRRI 124	2.75	0.220	0.160	35.23
5.	BRRI 125	2.95	0.221	0.161	40.52
6.	BRRI 127	0.75	0.213	0.160	46.96
7.	BRRI 129	1.18	0.219	0.158	42.78
8.	BRRI 131	0.60	0.225	0.154	27.93
9.	BRRI 133	0.55	0.230	0.160	30.29
10.	BRRI 135	0.15	0.222	0.150	16.81
11.	BRRI 137	0.60	0.220	0.153	31.99
12.	BRRI 139	1.75	0.216	0.154	25.25
Medium P					
13.	BRRI 23	12.88	0.274	0.212	51.00
14.	BRRI 25	15.38	0.267	0.213	57.74
15.	BRRI 27	11.25	0.272	0.216	52.26
16.	BRRI 29	15.25	0.266	0.220	54.44
High P					
17.	BRRI 111	55.34	0.285	0.243	88.76
18.	BRRI 113	45.05	0.286	0.237	92.20
19.	BRRI 115	33.71	0.288	0.238	86.58
20.	BRRI 116	25.20	0.289	0.246	81.93

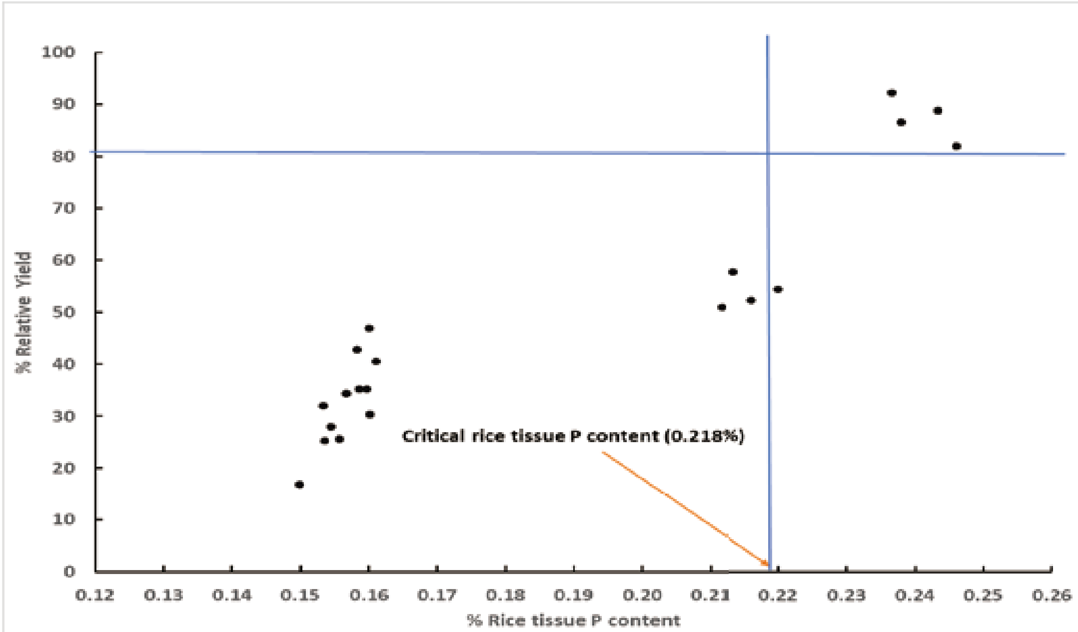


Figure 18. Scatter diagram showing relationship between Bray's per cent yield and tissue concentration in rice plant

Table 23. Rice tissue P content, Bray's % yield and predictability values (R^2) of rice plant

Sl. No.	P content in rice plant (%)	Bray's % yield	Corrected Sum of Squares of population1(CSS-I)	Corrected Sum of Squares of population I1(CSS-II)	R^2 TSS - (CSSI-CSSII) /TCSS
1	0.150	16.8	0.000	8637.350	0.1345
2	0.153	32.0	115.162	7962.194	0.1906
3	0.154	25.3	115.649	7347.001	0.2522
4	0.154	27.9	123.543	6515.925	0.3347
5	0.156	25.6	123.549	6044.421	0.3819
6	0.157	34.4	189.043	5830.965	0.3967
7	0.158	42.8	402.623	5273.766	0.4312
8	0.159	35.3	434.259	4613.809	0.4941
9	0.160	35.2	458.613	4362.854	0.5169
10	0.160	47.0	700.096	3132.216	0.6160
11	0.160	30.3	703.458	2327.320	0.6963
12	0.161	40.5	769.400	1887.768	0.7337
13	0.212	51.0	1077.010	1601.213	0.7316
14	0.213	57.7	1593.820	923.136	0.7478
15	**0.216**	**52.3**	**1845.451**	**55.523**	**0.8095**
16	0.220	54.4	2132.716	24.357	0.7838
17	0.237	92.2	4895.249	23.339	0.5071
18	0.238	86.6	6839.167	0.000	0.3147
19	0.243	88.8			
20	0.246	81.9			
			TCSS	9979.27	

Relative yield and Critical Limit of K for rice

The biomass yield of rice influenced largely with the application of K in soil compared to no application of K in soil in a low, medium and high soil native available K conditions (Table 24). In low soil K condition, the biomass yield in without K condition ranges from 34.34 to 39.75 g pot $^{-1}$. But when added recommended P, the biomass yield increases and ranges from 39.15 to 46.16 g pot $^{-1}$ which is higher than without K application pots. The relative yield percent in low soil K condition ranges from 86.10 to 96.38% and the average relative yield in low soil K condition was 90.78%. In medium soil K condition, the biomass yield in without K pots ranges from 40.26 to 40.72 g pot $^{-1}$ and in K applied pots it ranges from 42.40 to 45.27 g pot $^{-1}$. The relative yield varied from 89.94 to 95.17% and the average relative yield in medium soil K condition was 91.72 %. The biomass yield in high soil K levels of without added K condition ranges from 42.30 to 45.19 g pot $^{-1}$ whereas in added K condition, it ranges from 44.54 to 47.81 g pot $^{-1}$. The relative yield in high soil K conditions varied from 94.53 to 95.67 % and the average relative yield was 95.10 %. The overall relative yield in K experimental pots ranges from 86.10 to 95.67 % and the average overall relative yield was 91.83 % (Table 24). The K content in rice tissue with and without K application in pot culture after eight weeks presented in Table 26.

The estimated limit of K for rice soil was 0.09 meq 100 g soil^{-1} in graphical method (Fig 19) and 0.042 meq 100 g soil^{-1} in statistical method (Table 6) whereas, the present critical limit of soil K as mentioned in FRG 2018 for rice was 0.12 meq 100 g soil^{-1} (N NH_4 OAc method). Kalala et al. (2016) reported the soil critical concentration of K for flooded rice is 0.2 cmol (+) kg-1, below which a positive response to K fertilization is expected in KilomberoValley. The critical limit of rice plant K concentration was found 1.8 (%) in graphical method (Figure 20) and 1.737 (%) in statistical method (Table 27). Kalala et al. (2016) also reported the critical concentration of K in rice shoots is 1.4%.

Table 24: Relative yield of Boro rice with and without potassium (K) applied in pot culture, Soil Science Division, BRRI, Gazipur, 2019-20

Soil sample No.	Sample name	Excha. K (meq/100g)	Dry matter yield (g/pot)		Relative yield (%)
			With K	Without K	
Low K					
1.	BRRI 71	0.037	42.28	38.91	92.03
2.	BRRI 72	0.046	40.23	37.25	92.59
3.	BRRI 73	0.042	41.18	36.76	89.25
4.	BRRI 74	0.037	42.16	39.21	93.00
5.	BRRI 75	0.037	39.26	35.99	91.68
6.	BRRI 76	0.037	39.15	34.34	87.71
7.	BRRI 77	0.042	40.59	39.12	96.38
8.	BRRI 94	0.019	42.02	39.27	93.45
9.	BRRI 95	0.019	46.16	39.75	86.10
10.	BRRI 96	0.019	39.43	35.44	89.88
11.	BRRI 99	0.023	43.24	37.46	86.65
12.	BRRI 100	0.023	41.06	37.21	90.62
Medium K					
13.	BRRI 23	0.14	45.27	40.72	92.03
14.	BRRI 25	0.13	44.22	40.57	92.59
15.	BRRI 27	0.14	42.99	40.26	89.25
16.	BRRI 29	0.15	42.40	40.35	93.00

Soil sample No.	Sample name	Excha. K (meq/100g)	Dry matter yield (g/pot)		Relative yield (%)
			With K	Without K	
High K					
17.	BRRI 1	0.31	44.54	42.30	94.98
18.	BRRI 3	0.31	45.55	43.37	95.21
19.	BRRI 5	0.37	46.21	44.21	95.67
20.	BRRI 8	0.42	47.81	45.19	94.53

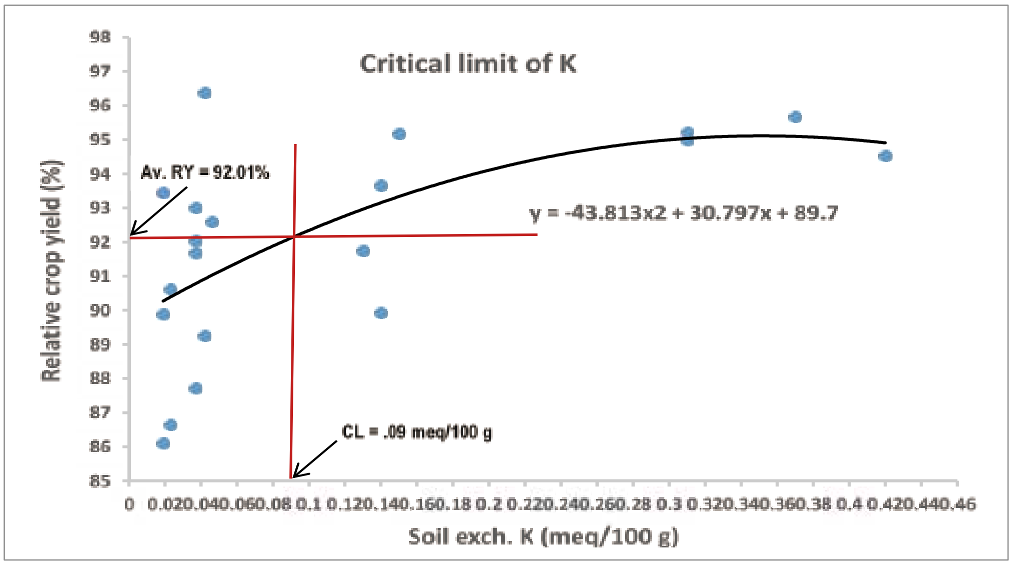


Figure 19: Critical Limit of K for rice soil in Bangladesh, Soil Science Division, BRRI 2019-20

Table 25. Soil K content, Bray's % yield and predictability values (R^2) of rice soil

Sl. No.	Soil K content (meq/100g)	Bray's % yield	Corrected Sum of Squares of population1(CSS-I)	Corrected Sum of Squares of population I1(CSS-II)	R^2 TSS - (CSSI-CSSII) /TCSS
1	0.0190	93.45	0.000	136.594	0.2182
2	0.0190	86.10	26.993	130.593	0.0981
3	0.0190	89.88	27.000	95.420	0.2993
4	0.0230	86.65	34.499	90.513	0.2845
5	0.0230	90.62	36.539	89.696	0.2775
6	0.0370	92.03	42.578	89.694	0.2429
7	0.0370	93.00	51.441	87.909	0.2024
8	0.0370	91.68	53.238	56.628	0.3712
9	0.0370	87.71	59.768	36.238	0.4505
10	**0.0420**	**89.25**	**60.453**	**29.887**	**0.4829**
11	0.0420	96.38	97.010	28.453	0.2819
12	0.0460	92.59	100.601	23.329	0.2907
13	0.1300	91.75	101.464	2.454	0.4052
14	0.1400	89.94	102.246	0.688	0.4109
15	0.1400	93.66	109.933	0.684	0.3669
16	0.1500	95.17	126.427	0.665	0.2726
17	0.3100	94.98	139.576	0.656	0.1974
18	0.3100	95.21	152.883	0.000	0.1250
19	0.3700	95.67			
20	0.4200	94.53			
			TCSS	174.719	

Table 26. Potassium content of Boro rice with and without potassium (K) applied in pot culture, Soil Science Division, BRRI, Gazipur, 2019-20

Soil sample No.	Sample name	Excha. K (meq/100g)	Potassium content (%)		Relative yield (%)
			With K	Without K	
Low K					
1.	BRRI 71	0.037	2.52	1.63	92.03
2.	BRRI 72	0.046	2.64	1.83	92.59
3.	BRRI 73	0.042	2.57	1.77	89.25
4.	BRRI 74	0.037	2.62	1.75	93.00
5.	BRRI 75	0.037	2.66	1.74	91.68
6.	BRRI 76	0.037	2.63	1.70	87.71
7.	BRRI 77	0.042	2.60	1.75	96.38
8.	BRRI 94	0.019	2.65	1.61	93.45
9.	BRRI 95	0.019	2.58	1.60	86.10
10.	BRRI 96	0.019	2.64	1.67	89.88
11.	BRRI 99	0.023	2.73	1.74	86.65
12.	BRRI 100	0.023	2.59	1.71	90.62
Medium K					
13.	BRRI 23	0.14	2.72	2.05	92.03
14.	BRRI 25	0.13	2.77	2.07	92.59
15.	BRRI 27	0.14	2.71	2.11	89.25
16.	BRRI 29	0.15	2.66	2.13	93.00
High K					
17.	BRRI 1	0.31	3.02	2.76	94.98
18.	BRRI 3	0.31	3.03	2.83	95.21
19.	BRRI 5	0.37	3.07	2.85	95.67
20.	BRRI 8	0.42	3.04	2.81	94.53

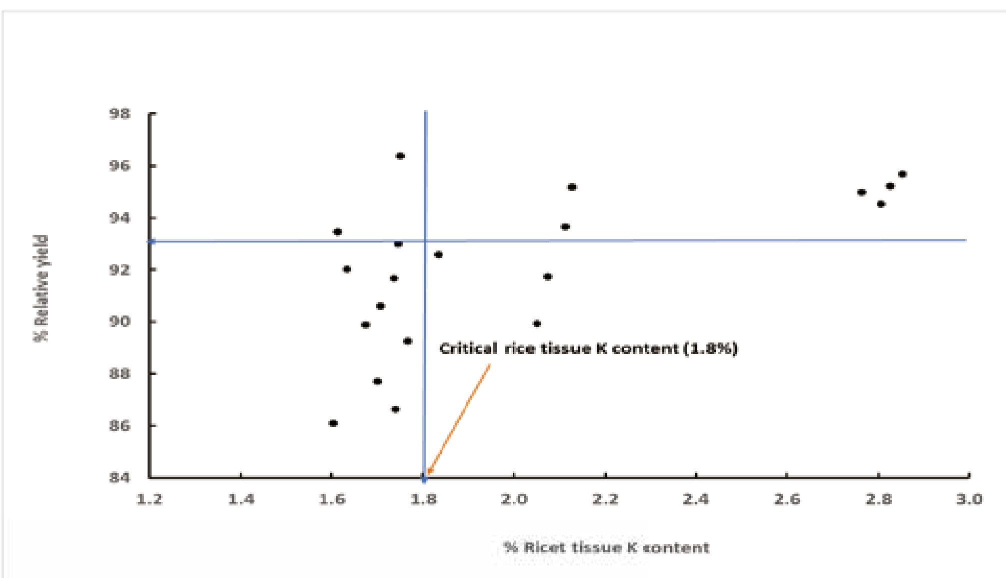


Figure 20. Scatter diagram showing relationship between Bray's per cent yield and tissue K concentration in rice plant, SSD, BRRI, Gazipur, 2020

Photo 17: Response of rice to K in low soil K condition at BRRI, 2020

Photo 18: Response of rice to K in medium soil K condition at BRRI, 2020

Photo 19: Response of rice to K in high soil K condition at BRRI, 2020

Table 27. Rice tissue K content, Bray's % yield and predictability values (R^2) of rice plant

Sl. No.	K content in rice plant (%)	Bray's % yield	Corrected Sum of Squares of population1(CSS-I)	Corrected Sum of Squares of population I1(CSS-II)	R^2 TSS - (CSSI-CSSII) /TCSS
1	1.603	86.10	0.000	136.594	0.2182
2	1.613	93.45	26.993	136.538	0.0640
3	1.633	92.03	30.386	130.447	0.0795
4	1.673	89.88	30.699	106.795	0.2131
5	1.700	87.71	36.315	101.968	0.2085
6	1.707	90.62	36.823	100.391	0.2147
7	**1.737**	**91.68**	**39.343**	**56.910**	**0.4491**
8	1.740	86.65	50.448	56.628	0.3872
9	1.747	93.00	59.768	47.871	0.3839
10	1.750	96.38	94.969	29.887	0.2854
11	1.767	89.25	97.010	28.453	0.2819

Sl. No.	K content in rice plant (%)	Bray's % yield	Corrected Sum of Squares of population1(CSS-I)	Corrected Sum of Squares of population I1(CSS-II)	R^2 TSS - (CSSI-CSSII) /TCSS
12	1.833	92.59	100.601	10.825	0.3623
13	2.050	89.94	101.257	2.454	0.4064
14	2.073	91.75	102.246	0.688	0.4109
15	2.113	93.66	109.933	0.684	0.3669
16	2.127	95.17	126.427	0.665	0.2726
17	2.763	94.98	139.576	0.105	0.2005
18	2.807	94.53	148.455	0.000	0.1503
19	2.827	95.21			
20	2.853	95.67			
			TCSS	174.7192	

Relative yield and Critical Limit of S for rice

The biomass yield and of rice after eight weeks of transplanting influenced rightly with the application of S in soil compared to no application of S in soil in a low, medium and high soil native available S conditions (Table 28). In low soil S condition, the biomass yield in without S condition ranges from 35.18 to 39.74 g pot $^{-1}$. Whereas in added recommended S condition, the biomass yield ranges from 39.71 to 49.34 g pot $^{-1}$ which is higher than without S application pots. The relative yield percent in low soil S condition ranges from 81.84 to 94.53 % and the average relative yield in low soil S condition was 85.99 %. In medium soil S condition, the biomass yield in without S applied pots ranges from 42.08 to 44.99 g pot $^{-1}$ and in S applied pots it ranges from 44.88 to 48.65 g pot $^{-1}$. The relative yield varied from 92.0 to 93.8 % and the average relative yield in medium soil S condition was 92.69 %. The biomass yield in high soil S levels of without added S condition ranges from 43.77 to 46.88 g pot $^{-1}$ whereas in added S condition, it ranges from 46.95 to 49.23 g pot $^{-1}$. The relative yield in high soil S conditions varied from 93.24 to 95.67 % and the average relative yield was 94.30 %. The overall relative yield in S experimental pots ranges from 81.84 to 95.67 % and the average overall relative yield was 88.99 % (Table 28). The S content in rice tissue with and without S application in pot culture after eight weeks presented in Table 30.

The estimated value of critical limit of S for rice is 15.0 mg kg^{-1} and the present critical limit of S as mentioned in FRG 2018 for rice was 10.0 mg kg^{-1} (Calcium dihydrogen phosphate extraction method). The estimated critical limit of S for rice soil was 15.0 mg kg^{-1} in graphical method (Figure21) and 12.85 mg kg^{-1} in statistical method (Table 29) whereas, the present critical limit of S as mentioned in FRG 2018 for rice soil was 10 mg kg^{-1} (Calcium dihydrogen phosphate extraction method). The critical limit of rice plant S concentration was found 0.140 (%) in graphical method (Figure 22) and 0.137 (%) in statistical method (Table 31). The scatter diagram and statistical methods were employed to determine the critical S concentration in dry matter for obtaining dry matter yield at 56 days of transplanting and the critical limit for plant S was found to be 0.12% at 56 days of crop growth (Huda et al., 2004). Islam et al. (1997) reported similar critical concentration of sulphur (0.11%) in rice plants by using graphical method. Ganeshamurthy *et al*. (1995) estimated that the critical limit of sulphur in rice plant was 0.175% at 45 days after sowing.

Table 28: Relative yield of rice with and without sulphur (S), Soil Science Division, BRRI, Gazipur, 2019-20

Soil sample No.	Sample name	Ava. S (ppm)	Dry matter yield (g/pot)		Relative yield (%)
			With S	Without S	
Low S					
1.	BRRI 146	11.65	45.65	37.36	81.84
2.	BRRI 147	12.75	39.71	35.18	88.60
3.	BRRI 148	11.75	45.67	39.32	86.11
4.	BRRI 154	11.95	46.74	38.38	82.10
5.	BRRI 156	12.85	44.89	38.36	85.44
6.	BRRI 158	12.25	49.34	39.74	80.55
7.	BRRI 159	12.55	41.61	36.96	88.81
8.	BRRI 160	12.70	47.50	39.41	82.97
9.	BRRI 162	11.65	43.89	38.68	88.12
10.	BRRI 163	11.90	44.53	38.02	85.37
11.	BRRI 166	12.50	40.59	35.48	87.41
12.	BRRI 170	12.35	40.62	38.40	94.53
Medium S					
13.	BRRI 173	18.45	44.88	42.10	93.80
14.	BRRI 176	15.90	46.44	42.95	92.48
15.	BRRI 178	18.10	48.65	44.99	92.48
16.	BRRI 179	16.35	45.74	42.08	92.00
High S					
17.	BRRI 51	75	49.01	46.88	95.67
18.	BRRI 53	98	46.95	43.77	93.24
19.	BRRI 55	84	48.76	45.84	94.01
20.	BRRI 57	80	49.23	46.41	94.26

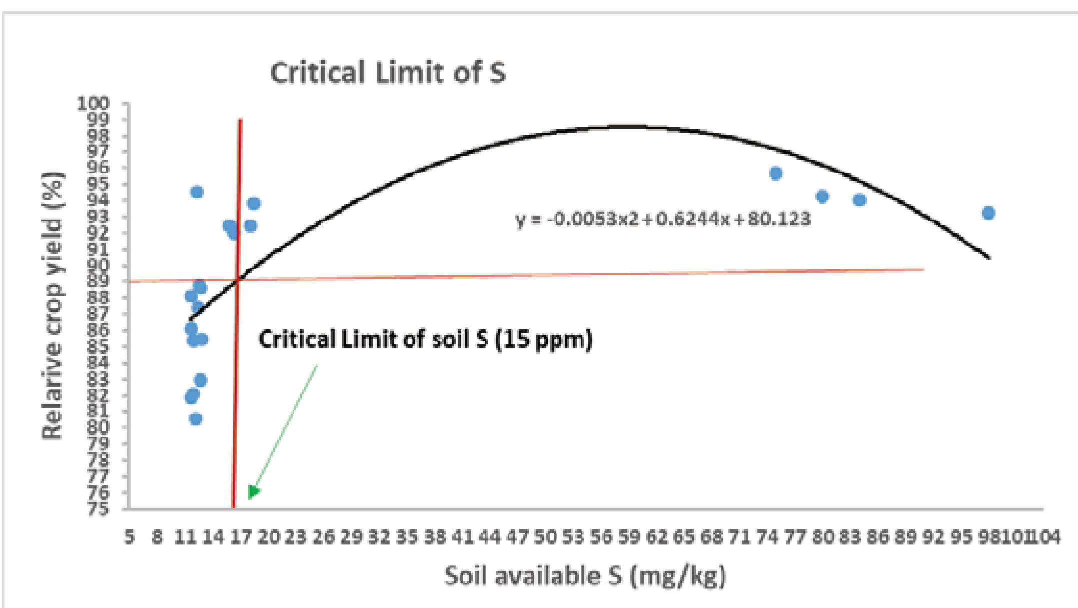


Figure 21: Critical Limit of S for rice soils in Bangladesh, Soil Science Division, BRRI, 2019-20

Table 29. Soil S content, Bray's % yield and predictability values (R^2) of rice soil

Sl. No.	Soil S content (ppm)	Bray's % yield	Corrected Sum of Squares of population1(CSS-I)	Corrected Sum of Squares of population I1(CSS-II)	R^2 TSS - (CSSI-CSSII) /TCSS
1	11.65	81.84	0.0000	390.8803	0.1242
2	11.65	88.12	19.7274	379.1667	0.1062
3	11.75	86.11	20.5748	359.9122	0.1475
4	11.90	85.37	20.5750	295.0751	0.2928
5	11.95	82.10	29.0830	190.7605	0.5074
6	12.25	80.55	43.5031	178.2169	0.5032
7	12.35	94.53	138.3323	165.3328	0.3196
8	12.50	87.41	141.4633	159.3746	0.3259
9	12.55	88.81	149.7548	82.0369	0.4806
10	12.70	82.97	158.5192	67.6611	0.4932
11	12.75	88.60	165.7379	10.0234	0.6062
12	**12.85**	**85.44**	**166.0672**	**8.8476**	**0.6081**
13	15.90	92.48	204.9321	5.7148	0.5280
14	16.35	92.00	233.1247	3.2735	0.4703
15	18.10	92.48	262.4149	3.0764	0.4051
16	18.45	93.80	302.5510	0.5641	0.3208
17	75.00	95.67	362.8333	0.2975	0.1864
18	80.00	94.26	398.2499	0.0000	0.1077
19	84.00	94.01			
20	98.00	93.24			
			TCSS	446.308	

Table 30. Sulphur content of Boro rice with and without sulphur (S), Soil Science Division, BRRI, Gazipur, 2019-20

Soil sample No.	Sample name	Ava. S (ppm)	Sulphur content (%)		Relative yield (%)
			With S	Without S	
Low S					
1.	BRRI 146	11.65	0.235	0.137	81.84
2.	BRRI 147	12.75	0.229	0.138	88.60
3.	BRRI 148	11.75	0.230	0.127	86.11
4.	BRRI 154	11.95	0.234	0.135	82.10
5.	BRRI 156	12.85	0.245	0.127	85.44
6.	BRRI 158	12.25	0.236	0.137	80.55
7.	BRRI 159	12.55	0.226	0.135	88.81
8.	BRRI 160	12.70	0.234	0.126	82.97
9.	BRRI 162	11.65	0.246	0.124	88.12
10.	BRRI 163	11.90	0.211	0.125	85.37
11.	BRRI 166	12.50	0.228	0.134	87.41
12.	BRRI 170	12.35	0.231	0.123	94.53
Medium S					
13.	BRRI 173	18.45	0.276	0.246	93.80
14.	BRRI 176	15.90	0.284	0.254	92.48
15.	BRRI 178	18.10	0.274	0.249	92.48
16.	BRRI 179	16.35	0.281	0.257	92.00

Soil sample No.	Sample name	Ava. S (ppm)	Sulphur content (%)		Relative yield (%)
			With S	Without S	
High S					
17.	BRRI 51	75	0.288	0.275	95.67
18.	BRRI 53	98	0.292	0.281	93.24
19.	BRRI 55	84	0.285	0.276	94.01
20.	BRRI 57	80	0.294	0.279	94.26

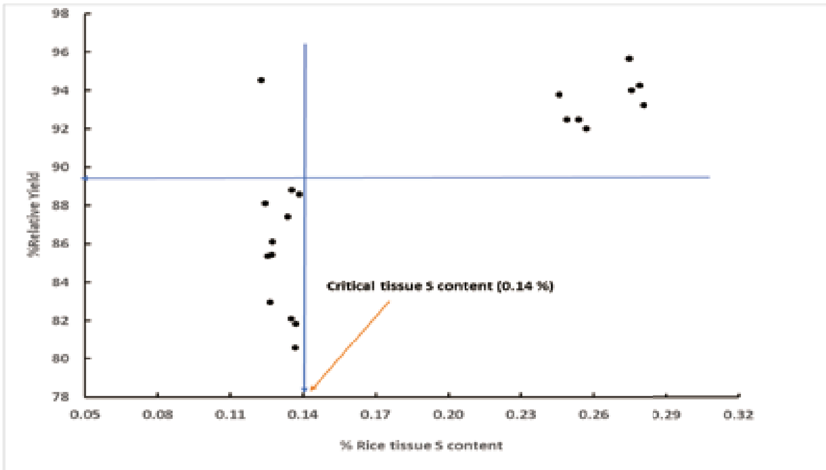


Figure 22. Scatter diagram showing relationship between Bray's per cent yield and tissue S concentration in rice plant, SSD, BRRI, Gazipur, 2020

Table 31. Rice tissue S content, Bray's % yield and predictability values (R^2) of rice plant

Sl. No.	S content in rice plant (%)	Bray's % yield	Corrected Sum of Squares of population1(CSS-I)	Corrected Sum of Squares of population I1(CSS-II)	R^2 TSS - (CSSI-CSSII) /TCSS
1	0.123	94.53	0.0000	413.5994	0.0733
2	0.124	88.12	20.5568	401.6731	0.0540
3	0.125	85.37	44.1939	364.0128	0.0854
4	0.126	82.97	74.6233	348.1170	0.0528
5	0.127	85.44	78.8992	335.3807	0.0718
6	0.127	86.11	80.0588	329.2145	0.0830
7	0.134	87.41	80.1456	261.8299	0.2338
8	0.135	82.10	102.3466	258.1559	0.1923
9	0.135	88.81	107.0544	142.3222	0.4412
10	0.137	80.55	141.8079	31.2904	0.6122
11	0.137	81.84	158.6263	10.0234	0.6221
12	0.138	88.60	166.0672	9.9162	0.6057
13	0.246	93.80	222.3606	8.8308	0.4820
14	0.249	92.48	254.6185	7.2949	0.4132
15	0.254	92.48	282.5142	3.0764	0.3601
16	0.257	92.00	302.5510	0.5641	0.3208
17	0.275	95.67	362.8333	0.5182	0.1859
18	0.276	94.01	395.4534	0.0000	0.1139
19	0.279	94.26			
20	0.281	93.24			
			TCSS	446.3085	

Photo 20: Response of rice to S in low soil S condition at BRRI, 2020

Photo 21: Response of rice to S in medium soil S condition at BRRI, 2020

Photo 22: Response of with and without Sulphur in high soil Sulphur condition at BRRI pot culture 2020

Relative yield and Critical Limit of Zn for rice

The biomass yield of rice influenced greatly with the application of Zn in soil compared to no application of Zn in soil in a low, medium and high soil native available Zn conditions (Table 32). In low soil Zn condition, the biomass yield in without Zn condition ranges from 29.38 to 41.69 g pot $^{-1}$. Whereas in added recommended Zn condition, the biomass yield ranges from 38.02 to 57.37 g pot $^{-1}$ which is higher than without Zn application pots. The relative yield percent in low soil Zn condition ranges from 57.44 to 85.12 % and the average relative yield in low soil Zn condition was 73.07 %. In medium soil Zn condition, the biomass yield in without Zn applied pots ranges from 40.11 to 44.18 g pot $^{-1}$ and in Zn applied pots it ranges from 49.08 to 52.73 g pot $^{-1}$. The relative yield varied from 80.54 to 84.80 % and the average relative yield in medium soil Zn condition was 82.53 %. The biomass yield in high soil Zn levels of without added Zn condition ranges from 41.43 to 45.47 g pot $^{-1}$ whereas in added Zn condition, it ranges from 48.12 to 48.71 g pot $^{-1}$. The relative yield in high soil Zn conditions varied from 85.05 to 94.50 % and the average relative yield was 89.61 %. The overall relative yield in Zn experimental pots ranges from 57.44 to 94.5 % and the average overall relative yield was 78.27 % (Table 32). The Zn content in rice tissue with and without Zn application in pot culture after eight weeks presented in Table 34. The estimated critical limit of Zn for rice soil was 0.70 mg kg^{-1} in graphical method (Figure 23) and 0.10 mg kg^{-1} in statistical method (Table 14) whereas, the present critical limit of Zn as mentioned in FRG 2018 for rice soil was 0.60 mg kg^{-1} (DTPA extraction method). The critical limit of rice plant Zn concentration was found 24 (ppm) in graphical method (Figure 24) and 23.29 (ppm) in statistical method (Table 35). Nivedita et al. (2017) reported that the critical limit of Zn in the respective soils was established at 0.78 mg kg^{-1} for rice and critical limit of 75 days old rice plants is 24.5 mg kg^{-1}, below which response to Zn fertilization may be expected. She also mentioned that soil containing Zn below this critical limit may be responded economically to Zn fertilization for rice growing (Nivedita et al., 2017). This study is highly correlated with the present study for rice cultivation.

Table 32: Relative yield of rice with and without zinc, Soil Science Division, BRRI, Gazipur, 2019-20

Soil sample No.	Sample name	Ava. Zn (ppm)	Dry matter yield (g/pot)		Relative yield (%)
			With Zn	Without Zn	
Low Zn					
1.	BRRI 41	0.26	53.97	41.69	77.25
2.	BRRI 42	0.26	38.36	32.65	85.12
3.	BRRI 43	0.02	51.21	32.04	62.56
4.	BRRI 44	0.14	46.77	29.38	62.81
5.	BRRI 45	0.04	51.44	37.70	73.30
6.	BRRI 47	0.16	44.27	35.93	81.15
7.	BRRI 48	0.10	57.37	32.96	57.44
8.	BRRI 49	0.60	44.73	36.19	80.91
9.	BRRI 50	0.22	38.02	31.21	82.10
10.	BRRI 111	0.58	46.05	36.33	78.89
11.	BRRI 112	0.42	48.79	33.12	67.88
12.	BRRI 117	0.26	47.01	31.67	67.37
Medium Zn					
13.	BRRI 155	0.86	49.08	41.62	84.80
14.	BRRI 156	1.76	49.52	40.11	80.99
15.	BRRI 158	1.06	52.73	44.18	83.78
16.	BRRI 160	1.24	51.63	41.58	80.54
High Zn					
17.	BRRI 121	2.50	48.29	42.62	88.27
18.	BRRI 122	3.10	48.71	41.43	85.05
19.	BRRI 123	3.32	48.30	43.76	90.61
20.	BRRI 124	3.02	48.12	45.47	94.50

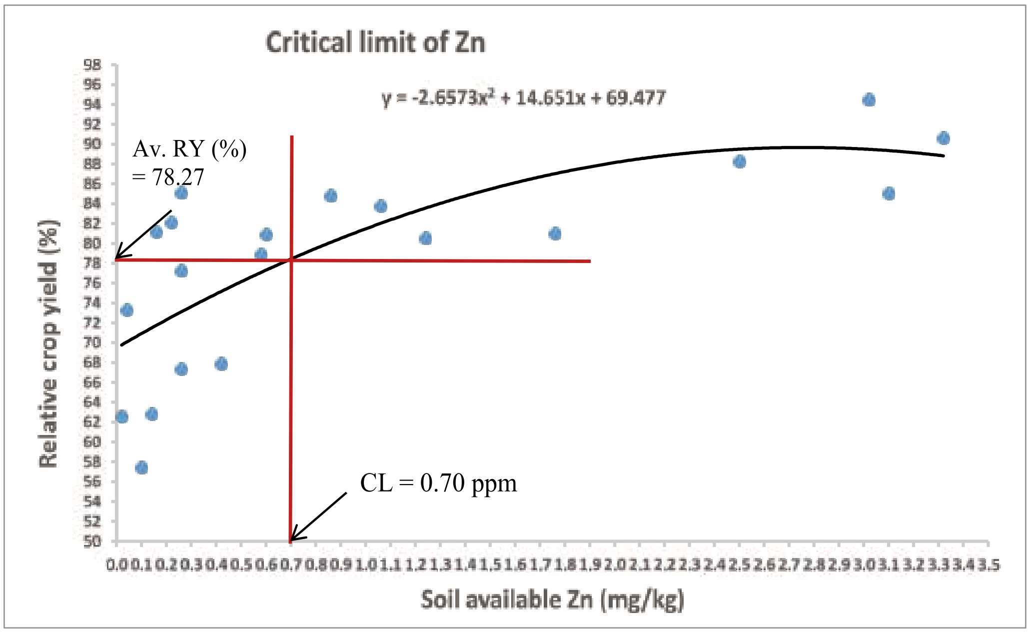


Figure 23: Critical Limit of Zn for rice soils in Bangladesh, Soil Science Division, BRRI, 2019-20

Table 33. Soil Zn content, Bray's % yield and predictability values (R^2) of rice soil

Sl. No.	Soil Zn content (ppm)	Bray's % yield	Corrected Sum of Squares of population1(CSS-I)	Corrected Sum of Squares of population I1(CSS-II)	R^2 TSS - (CSSI-CSSII) /TCSS
1	0.02	62.56	0.0000	1601.3682	0.1556
2	0.04	73.30	57.5909	1090.2078	0.3947
3	0.10	57.44	130.9108	750.0294	0.5355
4	0.14	62.81	132.8799	749.5428	0.5347
5	0.16	81.15	367.3813	749.4841	0.4111
6	0.22	82.10	546.2660	726.6428	0.3288
7	0.26	77.25	592.6104	717.4330	0.3092
8	0.26	85.12	768.5004	485.0936	0.3390
9	0.26	67.37	793.9107	223.7669	0.4634
10	0.42	67.88	810.1318	184.4843	0.4755
11	0.58	78.89	857.0996	160.8119	0.4632
12	0.60	80.91	924.1701	158.9788	0.4288
13	0.86	84.80	1051.2891	151.8684	0.3655
14	1.06	83.78	1140.6704	106.8737	0.3421
15	1.24	80.54	1172.7984	47.5036	0.3565
16	1.76	80.99	1205.7906	45.1260	0.3404
17	2.50	88.27	1360.9775	15.4497	0.2742
18	3.02	94.50	1677.7425	0.0000	0.1153
19	3.10	85.05			
20	3.32	90.61			
			TCSS	1896.378	

Table 34. Zinc content of Boro rice with and without zinc (Zn), Soil Science Division, BRRI, Gazipur, 2019-20

Soil sample No.	Sample name	Ava. Zn (ppm)	Zinc content (ppm)		Relative yield (%)
			With Zn	Without Zn	
Low Zn					
1.	BRRI 41	0.26	32.34	23.29	77.25
2.	BRRI 42	0.26	35.28	16.04	85.12
3.	BRRI 43	0.02	31.78	20.48	62.56
4.	BRRI 44	0.14	35.37	19.43	62.81
5.	BRRI 45	0.04	35.46	21.96	73.30
6.	BRRI 47	0.16	34.24	22.81	81.15
7.	BRRI 48	0.10	39.58	23.46	57.44
8.	BRRI 49	0.60	34.34	19.13	80.91
9.	BRRI 50	0.22	35.47	21.82	82.10
10.	BRRI 111	0.58	32.45	22.38	78.89
11.	BRRI 112	0.42	37.73	18.61	67.88
12.	BRRI 117	0.26	37.93	20.19	67.37
Medium Zn					
13.	BRRI 155	0.86	86.93	65.28	84.80
14.	BRRI 156	1.76	90.13	69.52	80.99
15.	BRRI 158	1.06	92.18	75.94	83.78
16.	BRRI 160	1.24	94.23	71.60	80.54
High Zn					
17.	BRRI 121	2.50	112.40	89.44	88.27
18.	BRRI 122	3.10	115.66	90.59	85.05
19.	BRRI 123	3.32	121.89	93.31	90.61
20.	BRRI 124	3.02	118.32	95.85	94.50

Photo 23: Response of rice to Zn in low soil Zn condition at BRRI, 2020

Photo 24: Response of rice to Zn in medium soil Zn condition at BRRI, 2020

Photo 25: Response of rice with and without Zn in high soil Zinc condition at BRRI pot culture 2020

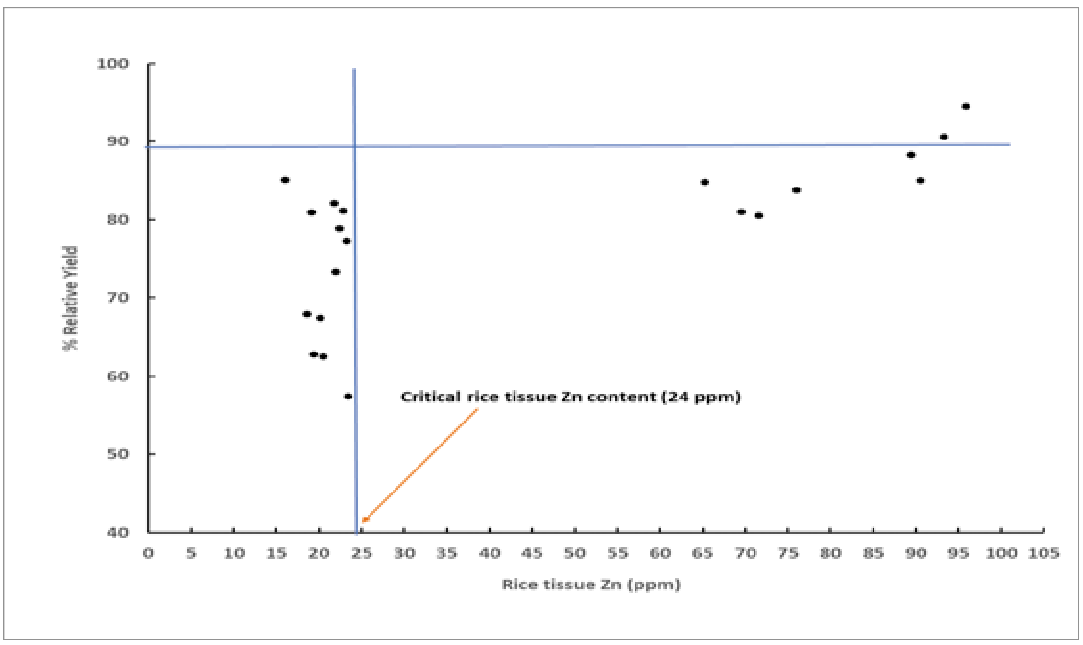


Figure 24. Scatter diagram showing relationship between Bray's per cent yield and tissue Zn concentration in rice plant, SSD, BRRI, Gazipur, 2020

Table 35. Rice tissue Zn content, Bray's % yield and predictability values (R^2) of rice plant, SSD, BRRI, Gazipur, 2020

Sl. no.	Zn content in rice plant (ppm)	Bray's % yield	Corrected Sum of Squares of population1(CSS-I)	Corrected Sum of Squares of population I1(CSS-II)	R^2 TSS - (CSSI-CSSII) /TCSS
1	16.04	85.12	0.000	1740.754	0.0821
2	18.61	67.88	148.700	1734.429	0.0070
3	19.13	80.91	161.638	1479.010	0.1349
4	19.43	62.81	333.910	1327.545	0.1239
5	20.19	67.37	371.004	998.737	0.2777
6	20.48	62.56	458.641	998.096	0.2318
7	21.82	82.10	562.262	929.146	0.2135
8	21.96	73.30	562.594	918.987	0.2187
9	22.38	78.89	595.993	917.736	0.2018
10	22.81	81.15	649.517	889.125	0.1886
11	**23.29**	**77.25**	**657.911**	**160.812**	**0.5683**
12	23.46	57.44	924.170	158.979	0.4288
13	65.28	84.80	1051.289	126.754	0.3788
14	69.52	80.99	1097.104	74.674	0.3821
15	71.60	80.54	1131.449	47.504	0.3783
16	75.94	83.78	1205.791	45.126	0.3404
17	89.44	88.27	1360.977	7.576	0.2783
18	90.59	85.05	1435.160	0.000	0.2432
19	93.31	90.61			
20	95.85	94.50			
			TCSS	1896.378	

Expt 2.3: Determination of critical limit of P and Mg for soils and crops (Maize and mustard; Pot trial)

BINA Component

Pot trials were conducted on mustard and maize during Rabi season 2019-20. Pot trials on maize was also repeated in Khari-1 season 2020. For pot trials bulk soils were collected from the surface layer (0-15 cm) from the selected locations as mentioned Appendix 3. The soils were processed (ground and sieved). Pot trials on response of mustard and maize to each of P and Mg were conducted in completely randomized design (CRD) with two treatments (with and without P and Mg) and three replications. For mustard trial 5 kg soils were used per pot; while 10 kg soils were used per pot for maize trial for both the nutrients. On the basis of soil analysis, nutrients were used at the rate of 150 kg N, 35 kg P, 90 kg K, 25 kg S, 6 kg Mg, 2 kg Zn and 1 kg B per hectare for mustard and 250 kg N, 60 kg P, 120 kg K, 45 kg S, 10 kg Mg, 3 kg Zn and 2 kg B per hectare for maize. The processed soils were weighed for individual pot and mixed with all the nutrients (except N and the nutrient in study) thoroughly and poured into the pot. Phosphorus and magnesium were mixed with the soil along with other nutrients during pot preparation as per treatment. Reagent grade chemicals (TSP for P and MgO for Mg) were used as the sources of nutrients. Nitrogen was applied in two equal splits at 15 and 30 days after emergence in maize and at 11 and 25 days after emergence in mustard.

For P and Mg response trials for mustard, seeds were sown on 4 December 2019 and for maize trials the seeds were sown on 11December 2019, respectively. Ten sprouted seeds of mustard (Binasarisha-

9) and 6 sprouted seeds of maize (BARI hybrid maize 7) were sown per pot. Distilled water was added to the soil for 'Zou' condition after sowing. Seedlings were thinned to desired population (5plants/pot for mustard and 3plants/pot for maize) within 15 and 25 days after emergence, respectively. Intercultural operations like irrigation, weeding etc. were maintained for proper plant growth. Mustard plants for P and Mg response trials were harvested on 15 January 2020 (six weeks after sowing). Fresh and dry weights of mustard plants were recorded, which are being processed for chemical analysis. The maize plants of both P and Mg response trials were harvested on 14 February 2020 (nine weeks after sowing). Pot trials on maize with P and Mg in Kharif-1 season was sown on 2 March 2020 and harvested on 20April 2020 (seven weeks after sowing).

Relative yield and Critical Limit of P for mustard

Table 36 reveals that in low P soil the dry matter yield of mustard ranges from 2.02-3.06 g/pot without P and 2.52-3.83 g/pot with P application and the percent relative yield ranges from 74-92. In medium P soil, the dry matter yield ranges from 4.05-4.81 g/pot without P and 4.25-5.40 g/pot with P application. The percent relative yield ranges from 82-95. In high P soil, the dry matter yield ranges from 4.48-5.67 g/pot without P and 4.80-6.95 g/pot with P application. The percent relative yield ranges from 82-95. The overall, the dry matter yields of mustard ranges from 2.02-5.67 g/pot without P and 2.52-6.95 g/pot with P application. The percent relative yield ranges from 74-95 with a mean value of 84.1. The estimated critical limit of P by graphical method for mustard crop was 14.8 ppm (Figure 25) compared with the value of 10 ppm mentioned in FRG-2018. On the other hand, the critical limit of P by statistical method for mustard crop was 14.56 ppm (Table 37).

Table 36: Relative yield of mustard and Rabi maize with and without P at SSD, BINA, Mymensingh during 2019-20

Soil sample No.	Sample name	Avail P (ppm)	Mustard			Rabi Maize		
			Dry matter yield (g/pot)		Relative yield (%)	Dry matter yield (g/pot)		Relative yield (%)
			With P	Without P		With P	Without P	
Low P								
1.	BAU-92	11.51	3.00	2.25	75	5.49	4.43	81
2.	BAU-98	8.40	2.65	2.06	78	4.70	3.53	75
3.	BAU-101	8.40	2.55	2.10	82	5.70	4.43	78
4.	BAU-103	12.90	3.03	2.40	79	5.29	4.61	87
5.	BINA-3	13.33	3.25	2.70	83	5.57	4.76	85
6.	BINA-18	7.75	3.10	2.61	84	3.55	3.33	94
7.	BINA-21	12.84	3.26	2.82	87	5.88	4.93	84
8.	BINA-29	12.47	3.70	3.06	83	7.19	5.87	82
9.	BAU-152	14.13	3.83	2.82	74	6.28	4.72	75
10.	BINA-86	14.56	3.16	2.92	92	6.50	5.95	92
11.	BINA-74	12.04	3.32	2.52	76	6.03	4.75	79
12.	BINA-148	10.75	2.52	2.02	80	4.98	3.68	74
Medium P								
13.	BINA-80	16.80	5.18	4.81	93	7.10	6.21	87
14.	BINA-124	16.50	5.40	4.49	83	7.88	6.10	77
15.	BAU-136	19.67	4.25	4.05	95	7.51	6.83	91
16.	BINA-146	18.06	5.23	4.31	82	7.50	6.82	91

Soil sample No.	Sample name	Avail P (ppm)	Mustard			Rabi Maize		
			Dry matter yield (g/pot)		Relative yield (%)	Dry matter yield (g/pot)		Relative yield (%)
			With P	Without P		With P	Without P	
High P								
17.	BAU-123	31.40	5.70	5.23	92	9.64	8.75	91
18.	BINA-81	42.57	6.95	5.67	82	9.52	8.26	87
19.	BAU-154	39.99	4.80	4.55	95	8.64	8.08	94
20.	BINA-101	33.60	5.28	4.48	85	8.89	7.24	81

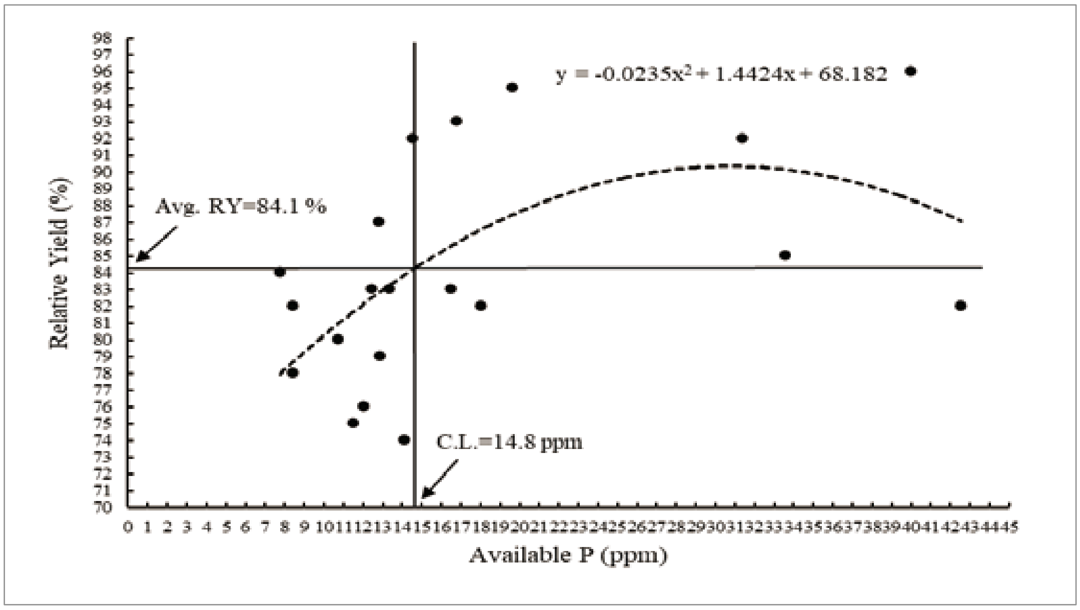


Figure 25: Critical limit of P for mustard in Bangladesh, SSD, BINA, 2019-20

Table 37: Calculation of co-efficient of determination (R^2) and critical limit of P for mustard for the best two population split using 2-mean discontinuous model, BINA, Mymensingh during 2019-20

Sl no.	Least value of Soil P (ppm) included in population-1	% RY	Population-1		Population-2		Postulated critical limit between values	R^2 for postulated critical limit
			Mean relati-ve yield	Corrected sum of squares of deviations from mean (CSS^1)	Mean relati-ve yield	Corrected sum of squares of deviations from mean (CSS^2)		
1	7.75	74	0	-	84	798.00		-
2	8.40	75	74.50	0.50	85	692.74	8.40	0.131
3	8.40	76	75.00	2.00	85	596.94	9.58	0.249
4	10.75	78	75.75	8.75	86	510.12	11.13	0.350
5	11.51	79	76.40	17.20	86	448.94	11.78	0.4169
6	12.04	80	77.00	28.00	87	395.73	12.26	0.469
7	12.47	82	77.71	49.43	87	350.00	12.66	0.500
8	12.84	82	78.25	65.50	87	323.08	12.87	0.513
9	12.90	82	78.67	78.00	88	291.67	13.12	0.537
10	13.33	83	79.10	94.90	88	254.55	13.73	0.562
11	14.13	83	79.45	108.73	89	222.90	14.35	0.584

Sl no.	Least value of Soil P (ppm) included in population-1	% RY	Population-1		Population-2		Postulated critical limit between values	R^2 for postulated critical limit
			Mean relati-ve yield	Corrected sum of squares of deviations from mean (CSS^1)	Mean relati-ve yield	Corrected sum of squares of deviations from mean (CSS^2)		
12	**14.56**	**83**	**79.75**	**120.25**	**90**	**184.22**	**15.53**	**0.695**
13	16.50	84	80.08	136.92	90	135.88	16.65	0.688
14	16.80	85	80.43	159.43	91	89.43	17.43	0.658
15	18.06	87	80.87	199.73	92	43.33	18.87	0.619
16	19.67	92	81.56	315.94	93	9.20	25.54	0.594
17	31.40	92	82.18	418.47	94	6.75	32.50	0.467
18	33.60	93	82.78	529.11	94	2.67	36.80	0.334
19	39.99	95	83.42	670.63	95	0	41.28	0.160
20	42.57	95	84.00	798.00	95	-		-

Photo 26: Pot experiment on mustard with and without P at BINA, Mymensingh during 2019-2020

Relative yield and Critical Limit of P for maize (Rabi and Kharif-1)

Rabi maize

Table 36 shows that in low P soil, the dry matter yield ranges from 3.33-5.87 g/pot without P and 3.55-7.19 g/pot with P application. The percent relative yield ranges from 74-94. In medium P soil, the dry matter yield ranges from 6.10-6.83 g/pot without P and 7.10-7.88 g/pot with P application. The percent relative yield ranges from 77-91. In high P soil, the dry matter yield ranges from 7.24-8.75 g/pot without P and 8.64-9.64 g/pot with P application. The percent relative yield ranges from 81-94. The overall, the dry matter yields of maize ranges from 3.33-8.75 g/pot without P and 3.55-9.64 g/pot with P application. The percent relative yield ranges from 74-94 with a mean value of 84.3 in case of maize. The estimated critical limit of P by graphical method for maize crop was 16.1 ppm (Figure 26) compared with the value of 10 ppm mentioned in FRG-2018. On the other hand, the critical limit of P by statistical method for maize crop was 13.33 ppm (Table 40).

Kharif-I maize

Table 38 reveals that in low P soil, the dry matter yields range from 93.92-125.88 g/pot without P and 115.95-148.84 g/pot with P application. The percent relative yield ranges from 72-88. In medium P soil, the dry matter yield ranges from 124.07-132.99 g/pot without P and 131.82-144.52 g/pot with P application. The percent relative yield ranges from 89-94. In high P soil, the dry matter yield ranges from 136.36-167.32 g/pot without P and 145.27-185.91 g/pot with P application. The percent relative yield ranges from 84-95. The overall, the dry matter yields of maize ranges from 93.92-167.32 g/pot without P and 115.95-185.91 g/pot with P application. The percent relative yield ranges from 72-95 with a mean value of 85.5 in case of maize. The estimated critical limit of P by graphical method for maize crop was found 14.5 ppm (Figure 27) compared with the value of 10 ppm mentioned in FRG-2018. On the other hand, the critical limit of P by statistical method for maize crop was 12.04 ppm (Table 41).

Table 38: Dry matter yield (g/pot), percent relative as affected by phosphorus (P) and magnesium (Mg) application in maize at SSD, BINA, Mymensingh during Kharif-I season 2020

Soil sample No.	Sample name	Avail. P (ppm)	Dry matter yield (g/pot)		% RY	Sample name	Excha. Mg (meq/100 g)	Dry matter yield (g/pot)		% RY
			Without P	With P				With-out Mg	With Mg	
Low P						**Low Mg**				
1.	BAU-92	11.51	98.56	115.95	85	BINA-105	0.58	116.48	156.11	75
2.	BAU-98	8.40	106.89	133.61	80	BINA-107	0.58	104.44	124.71	84
3.	BAU-101	8.40	93.92	130.44	72	BINA-121	0.57	93.96	121.65	77
4.	BAU-103	12.90	107.97	143.96	75	BINA-127	0.55	109.29	124.45	88
5.	BINA-3	13.33	95.02	122.32	78	BINA-130	0.36	87.46	122.43	71
6.	BINA-18	7.75	125.34	142.43	88	BINA-150	0.32	104.14	130.84	80
7.	BINA-21	12.84	103.16	135.74	76	BAU-111	0.17	95.62	116.60	82
8.	BINA-29	12.47	109.97	129.53	85	BAU-112	0.17	96.44	128.72	75
9.	BAU-152	14.13	116.25	135.00	86	BAU-138	0.29	83.81	116.94	72
10.	BINA-86	14.56	125.05	148.84	84	BAU-139	0.29	88.04	117.55	75
11.	BINA-74	12.04	125.88	143.19	88	BAU-158	0.28	106.60	122.82	87
12.	BINA-148	10.75	120.29	136.69	88	BAU-167	0.28	120.12	137.05	88
Medium P						**Medium Mg**				
13.	BINA-80	16.80	132.99	144.52	92	BINA-13	0.79	141.15	156.53	90
14.	BINA-124	16.50	126.34	142.40	89	BINA-15	0.92	127.08	151.29	84
15.	BAU-136	19.67	127.32	135.88	94	BINA-103	0.79	140.62	149.60	94
16.	BINA-146	18.06	124.07	131.82	94	BINA-112	0.79	142.10	148.02	96
High P						**High Mg**				
17.	BAU-123	31.40	136.36	162.56	84	BINA-4	1.67	133.14	150.00	89
18.	BINA-81	42.57	150.28	172.74	87	BINA-20	1.67	157.96	168.19	94
19.	BAU-154	39.99	138.40	145.27	95	BINA-79	1.67	137.10	166.51	82
20.	BINA-101	33.60	167.32	185.91	90	BINA-87	1.35	143.59	159.88	90

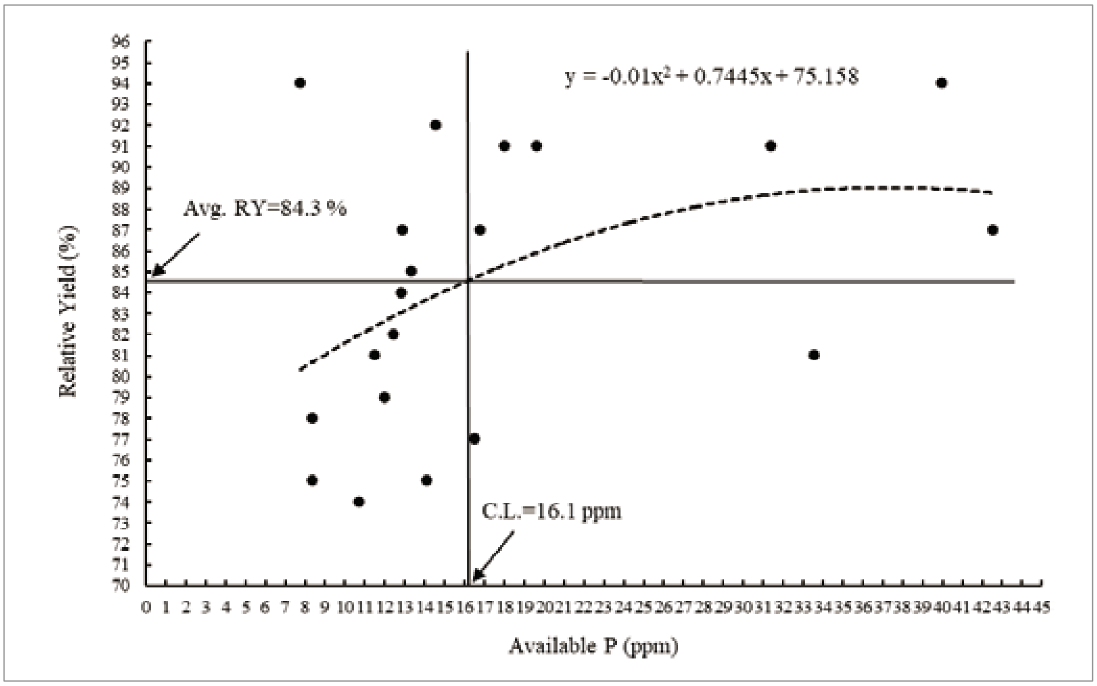


Figure 26: Critical limit of P for Rabi maize in Bangladesh, SSD, BINA, 2019-20

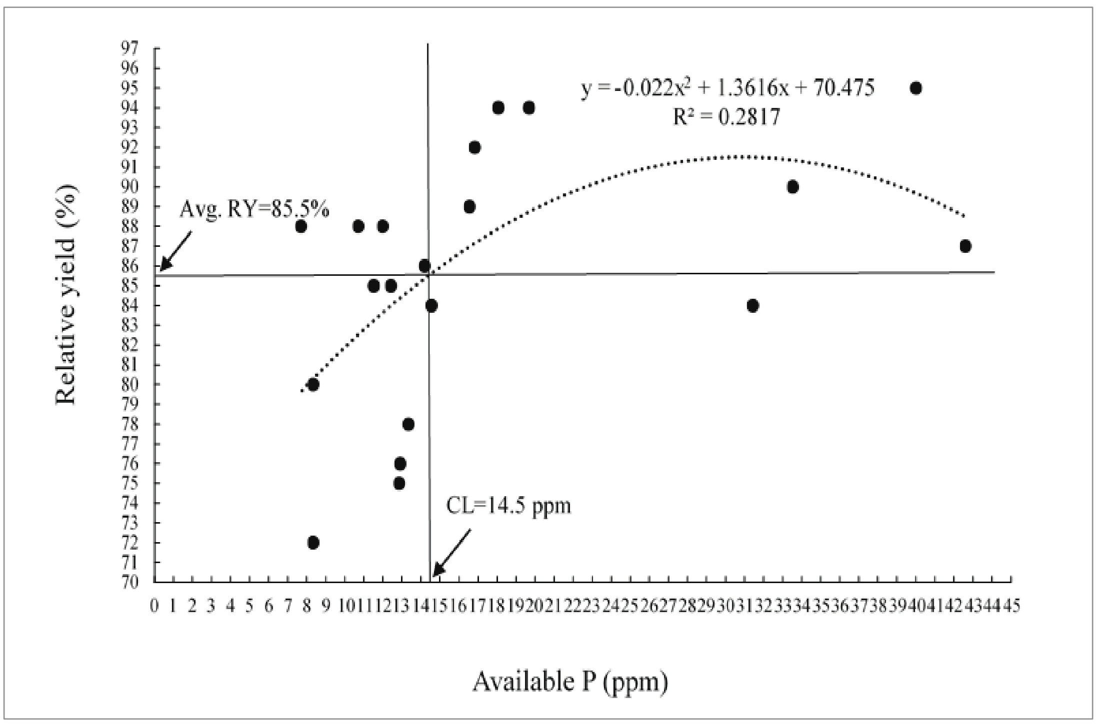


Figure 27: Critical limit of P for Kharif maize in Bangladesh, SSD, BINA, 2019-20

Table 39: Calculation of co-efficient of determination (R^2) and critical limit of P for maize (Rabi) for the best two population split using 2-mean discontinuous model, BINA, Mymensingh during 2019-20

Sl no.	Least value of Soil P (ppm) included in population- 1	% rela-tive yield	Population-1		Population-2		Postulated critical limit between values	R^2 for postulated critical limit
			Mean relati-ve yield	Corrected sum of squares of deviations from mean (CSS^1)	Mean relati-ve yield	Corrected sum of squares of deviations from mean (CSS^2)		
1	7.75	74	0	-	84	831.75	-	-
2	8.40	75	74.50	0.50	85	721.16	8.40	0.132
3	8.40	75	74.67	0.67	85	620.00	9.58	0.254
4	10.75	77	75.25	4.75	86	506.94	11.13	0.385
5	11.51	78	75.80	10.80	87	422.00	11.78	0.480
6	12.04	79	76.33	19.33	87	344.93	12.26	0.562
7	12.47	81	77.00	38.00	88	275.21	12.66	0.623
8	12.84	81	77.50	52.00	88	227.69	12.87	0.664
9	12.90	82	78.00	70.00	89	172.25	13.12	0.709
10	**13.33**	**84**	**78.60**	**102.40**	**89**	**122.55**	**13.73**	**0.730**
11	14.13	85	79.18	139.64	90	90.90	14.35	0.723
12	14.56	87	79.83	195.67	90	64.22	15.53	0.688
13	16.50	87	80.38	243.08	91	50.88	16.65	0.647
14	16.80	87	80.86	283.71	91	33.71	17.43	0.618
15	18.06	91	81.53	379.73	92	10.83	18.87	0.530
16	19.67	91	82.13	463.75	92	9.20	25.54	0.431
17	31.40	91	82.65	537.88	93	6.75	32.50	0.345
18	33.60	92	83.17	620.50	93	2.67	36.80	0.251
19	39.99	94	83.74	731.68	94	0	41.28	0.120
20	42.57	94	84.25	831.75	94	-	-	-

Table 40: Calculation of co-efficient of determination (R^2) and critical limit of P for maize (Kharif) for the best two population split using 2-mean discontinuous model, BINA, Mymensingh during 2020

Sl no.	Least value of Soil P (ppm) included in population- 1	% rela-tive yield	Population-1		Population-2		Postulated critical limit between values	R^2 for postulated critical limit
			Mean relati-ve yield	Corrected sum of squares of deviations from mean (CSS^1)	Mean relati-ve yield	Corrected sum of squares of deviations from mean (CSS^2)		
1	7.75	72	0	-	86	805.00	-	-
2	8.40	75	73.50	4.50	86	613.16	8.40	0.233
3	8.40	76	74.33	8.67	87	480.50	9.58	0.392
4	10.75	78	75.25	18.75	87	356.24	11.13	0.534
5	11.51	80	76.20	36.80	88	260.94	11.78	0.630
6	**12.04**	**84**	**77.50**	**87.50**	**89**	**191.60**	**12.26**	**0.653**
7	12.47	84	78.43	123.71	89	168.93	12.66	0.637
8	12.84	85	79.25	161.50	89	142.77	12.87	0.622

Sl no.	Least value of Soil P (ppm) included in population- 1	% relative yield	Population-1		Population-2		Postulated critical limit between values	R^2 for postulated critical limit
			Mean relative yield	Corrected sum of squares of deviations from mean (CSS^1)	Mean relative yield	Corrected sum of squares of deviations from mean (CSS^2)		
9	12.90	85	79.89	190.89	90	122.67	13.12	0.611
10	13.33	86	80.50	224.50	90	98.91	13.73	0.598
11	14.13	87	81.09	262.91	91	80.50	14.35	0.573
12	14.56	88	81.67	306.67	91	66.89	15.53	0.536
13	16.50	88	82.15	343.69	91	57.50	16.65	0.502
14	16.80	88	82.57	375.43	92	45.43	17.43	0.477
15	18.06	89	83.00	414.00	92	29.33	18.87	0.449
16	19.67	90	83.44	459.94	93	16.00	25.54	0.409
17	31.40	92	83.94	528.94	94	4.75	32.50	0.337
18	33.60	94	84.50	624.50	94	0.67	36.80	0.223
19	39.99	94	85.00	710.00	95	0	41.28	0.117
20	42.57	95	85.50	805.00	95	-	-	-

Photo 27: Pot experiment on Rabi maize with & without P at BINA, Mymensingh during 2019-2020

Photo 28: Pot experiment on Kharif maize with & without P at BINA, Mymensingh during 2019-2020

Table 41: Calculation of co-efficient of determination (R^2) and critical limit of P for Maize (Rabi) on plant P concentration for the best two population split using 2-mean discontinuous model, BINA, Mymensingh during 2019-20

Sl no.	Least value of Plant P (ppm) included in population- 1	% rela-tive yield	Population-1		Population-2		Postulated critical limit between values	R^2 for postulated critical limit
			Mean relati-ve yield	Corrected sum of squares of deviations from mean (CSS^1)	Mean relati-ve yield	Corrected sum of squares of deviations from mean (CSS^2)		
1	0.053	74	-	-	84	831.75	-	-
2	0.074	75	74.50	0.500	85	721.16	0.08	0.132
3	0.076	75	74.67	0.667	85	620.00	0.08	0.254
4	0.092	77	75.25	4.750	86	506.94	0.09	0.385
5	0.096	78	75.80	10.800	87	422.00	0.10	0.480
6	0.098	79	76.33	19.333	87	344.93	0.10	0.562
7	0.098	81	77.00	38.000	88	275.21	0.11	0.623
8	0.126	81	77.50	52.000	88	227.69	0.14	0.664
9	0.153	82	78.00	70.000	89	172.25	0.16	0.709
10	0.162	84	78.60	102.400	89	122.55	0.16	0.723
11	0.166	85	79.18	139.636	90	90.90	0.17	0.723
12	0.178	87	79.83	195.667	90	64.22	0.18	0.688
13	0.185	87	80.38	243.077	91	50.88	0.19	0.647
14	0.196	87	80.86	283.714	91	33.71	0.21	0.618
15	0.218	91	81.53	379.733	92	10.83	0.22	0.530
16	0.224	91	82.13	463.750	92	9.20	0.23	0.431
17	0.235	91	82.65	537.882	93	6.75	0.25	0.345
18	0.27	92	83.17	620.500	93	2.67	0.28	0.251
19	0.290	94	83.74	731.684	94	0.00	0.32	0.120
20	0.350	94	84.25	831.750	94	0.00	-	-

Relative yield and Critical Limit of Mg for mustard

It was observed that in low Mg soil, the dry matter yields range from 1.32-1.86 g/pot without Mg and 1.48-2.47 g/pot with Mg application (Table 42). The percent relative yield ranges from 73-97. In medium Mg soil, the dry matter yields range from 5.08-5.79 g/pot without Mg and 5.48-6.68 g/pot with Mg application. The percent relative yield ranges from 87-93. In high Mg soil, the dry matter yields range from 6.02-7.10 g/pot without Mg and 6.52-7.78 g/pot with Mg application. The percent relative yield ranges from 88-95. The overall, the dry matter yields of mustard ranges from 1.32-7.10 g/pot without Mg and 1.48-7.78 g/pot with Mg application. The percent relative yield ranges from 73-97 with a mean value of 84.6 in case of mustard. The estimated critical limit of Mg by graphical method for mustard crop was found 0.59 meq/100 g (Figure 28) compared with the value of 0.50 meq/100 g mentioned in FRG-2018. On the other hand, the critical limit of Mg by statistical method for mustard crop was 0.55 meq/100 g (Table 43).

Table 42: Relative yield of mustard and Rabi maize with and without Mg at SSD, BINA, Mymensingh during 2019-20

Soil sample No.	Sample name	Excha. Mg (meq/100 g)	Mustard Dry matter yield (g/pot)		Relative yield (%)	Maize Dry matter yield (g/pot)		Relative yield (%)
			With Mg	Without Mg		With Mg	Without Mg	
Low Mg								
1.	BINA-105	0.58	1.77	1.57	89	8.82	7.26	82
2.	BINA-107	0.58	1.89	1.83	97	8.42	6.34	75
3.	BINA-121	0.57	1.48	1.32	89	8.08	7.09	88
4.	BINA-127	0.55	1.90	1.33	70	8.01	6.76	84
5.	BINA-130	0.36	2.00	1.45	73	8.00	5.96	75
6.	BINA-150	0.32	2.12	1.63	77	7.00	5.43	78
7.	BAU-111	0.17	2.00	1.62	81	8.90	7.52	85
8.	BAU-112	0.17	2.10	1.73	82	10.50	7.68	73
9.	BAU-138	0.29	2.32	2.12	91	6.80	5.88	86
10.	BAU-139	0.29	2.47	1.86	75	6.65	5.83	88
11.	BAU-158	0.28	2.23	1.62	73	7.19	5.56	77
12.	BAU-167	0.28	1.76	1.37	78	6.65	4.71	71
Medium Mg								
13.	BINA-13	0.79	6.68	5.79	87	10.08	8.34	83
14.	BINA-15	0.92	6.65	5.34	80	10.65	9.06	85
15.	BINA-103	0.79	6.27	5.66	90	9.20	7.53	82
16.	BINA-112	0.79	5.48	5.08	93	9.25	7.64	83
High Mg								
17.	BINA-4	1.67	7.10	6.72	95	11.31	10.41	92
18.	BINA-20	1.67	7.32	6.46	88	11.77	10.02	85
19.	BINA-79	1.67	7.78	7.10	91	12.90	10.47	81
20.	BINA-87	1.35	6.52	6.02	92	10.98	10.56	96

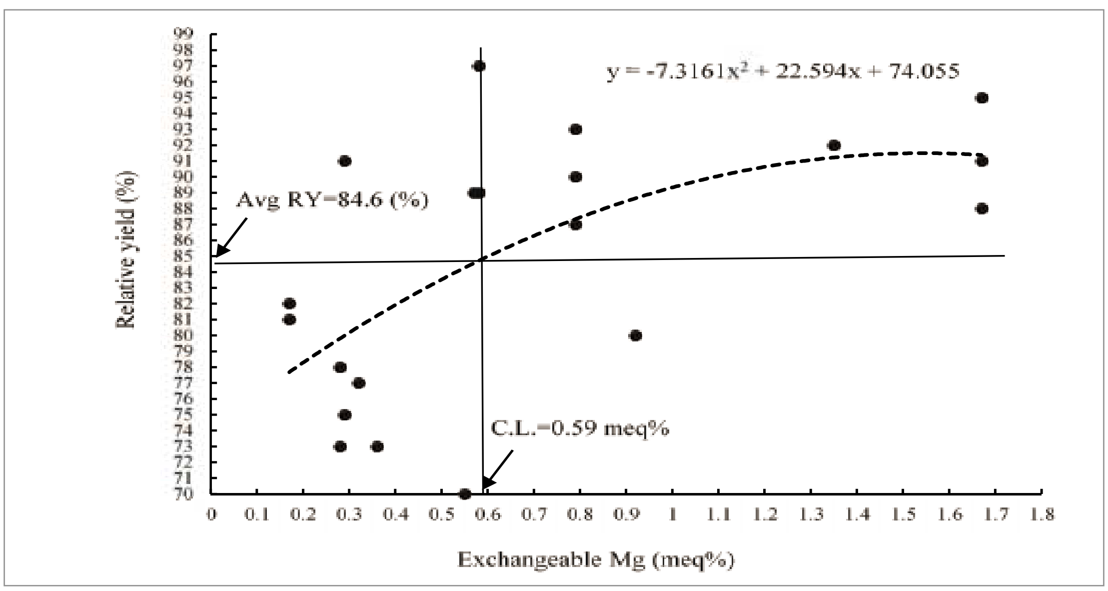


Figure 28: Critical limit of Mg for mustard in Bangladesh, SSD, BINA, 2019-20

Photo 29: Response of mustard at high Mg soil at BINA, Mymensingh during 2019-2020

Photo 30: Response of mustard at medium Mg soil at BINA, Mymensingh during 2019-2020

Table 43: Calculation of co-efficient of determination (R2) and critical limit of Mg for mustard for the best two population split using 2-mean discontinuous model, BINA, Mymensingh during 2019-20

Sl No.	Least value of Soil Mg (meq/100 g) included in population- 1	% RY	Population-1		Population-2		Postulated critical limit between values	R^2 for postulated critical limit
			Mean relati-ve yield	Corrected sum of squares of deviations from mean (CSS^1)	Mean relati-ve yield	Corrected sum of squares of deviations from mean (CSS^2)		
1	0.17	70	0	-	85	1270.95	-	-
2	0.17	73	71.50	4.50	85	1048.11	0.17	0.172
3	0.28	73	72.00	6.00	86	888.00	0.28	0.297
4	0.28	75	72.75	12.75	87	709.06	0.28	0.432
5	0.29	77	73.60	27.20	88	562.00	0.29	0.536
6	0.29	78	74.33	43.33	88	444.40	0.29	0.616
7	0.32	80	75.14	70.86	89	332.93	0.32	0.682
8	0.36	81	75.88	100.88	90	247.08	0.36	0.726
9	**0.55**	**82**	**76.56**	**134.22**	**90**	**166.67**	**0.55**	**0.763**
10	0.57	87	77.60	232.40	91	90.91	0.57	0.746
11	0.58	88	78.55	330.73	92	72.50	0.58	0.683
12	0.58	89	79.42	430.92	92	58.89	0.58	0.615
13	0.79	89	80.15	515.69	92	49.50	0.79	0.555
14	0.79	90	80.86	605.71	93	37.43	0.79	0.494
15	0.79	91	81.53	701.73	93	28.83	0.79	0.425
16	0.92	91	82.13	785.75	94	23.20	0.92	0.364
17	1.35	92	82.71	877.53	94	14.75	1.35	0.298
18	1.67	93	83.28	977.61	95	8.00	1.67	0.225
19	1.67	95	83.89	1107.79	96	2.00	1.67	0.127
20	1.67	97	84.55	1270.95	97	-	-	-

Table 44: Calculation of co-efficient of determination (R^2) and critical limit of Mg for Mustard on plant Mg concentration for the best two population split using 2-mean discontinuous model, BINA, Mymensingh during 2019-20

Sl No.	Least value of Plant Mg (%) included in population-1	% RY	Population-1		Population-2		Postulated critical limit between values	R^2 for postulated critical limit
			Mean relati-ve yield	Corrected sum of squares of deviations from mean (CSS^1)	Mean relati-ve yield	Corrected sum of squares of deviations from mean (CSS^2)		
1	0.68	70	-	-	85	1270.95	-	-
2	0.42	73	71.50	4.500	85	1048.11	0.44	0.172
3	0.461	73	72.00	6.000	86	888.00	0.47	0.297
4	0.48	75	72.75	12.750	87	709.06	0.49	0.432
5	0.49	77	73.60	27.200	88	562.00	0.51	0.536
6	0.52	78	74.33	43.333	88	444.40	0.53	0.616
7	0.53	80	75.14	70.857	89	332.93	0.53	0.682
8	0.53	81	75.88	100.875	90	247.08	0.54	0.726
9	**0.54**	**82**	**76.56**	**134.222**	**90**	**166.67**	**0.63**	**0.763**

Sl No.	Least value of Plant Mg (%) included in population-1	% RY	Population-1		Population-2		Postulated critical limit between values	R^2 for postulated critical limit
			Mean relati-ve yield	Corrected sum of squares of deviations from mean (CSS^1)	Mean relati-ve yield	Corrected sum of squares of deviations from mean (CSS^2)		
10	0.72	87	77.60	232.400	91	90.91	0.72	0.746
11	0.72	88	78.55	330.727	92	72.50	0.73	0.683
12	0.73	89	79.42	430.917	92	58.89	0.73	0.615
13	0.73	89	80.15	515.692	92	49.50	0.76	0.555
14	0.79	90	80.86	605.714	93	37.43	0.83	0.494
15	0.87	91	81.53	701.733	93	28.83	0.90	0.425
16	0.93	91	82.13	785.750	94	23.20	0.94	0.364
17	0.95	92	82.71	877.529	94	14.75	1.01	0.298
18	1.06	93	83.28	977.611	95	8.00	1.12	0.224
19	1.18	95	83.89	1107.789	96	-	1.34	0.127
20	1.49	97	84.55	1270.950	97	-	-	-

Relative yield and Critical Limit of Mg for maize (Rabi and Kharif-1)

Rabi season:

It was observed that in low Mg soil, the dry matter yields maize range from 4.71-7.68 g/pot without Mg and 6.65-10.50 g/pot with Mg application (Table 42). The percent relative yield ranges from 71-88. In medium Mg soil, the dry matter yields range from 7.73-9.06 g/pot without Mg and 9.20-10.65 g/pot with Mg application. The percent relative yield ranges from 82-85. In high Mg soil, the dry matter yields range from 10.02-10.56 g/pot without Mg and 10.98-12.90 g/pot with Mg application. The percent relative yield ranges from 81-96. The overall, the dry matter yields of maize ranges from 4.71-10.56 g/pot without Mg and 6.65-12.90 g/pot with Mg application. The percent relative yield ranges from 71-96 with a mean value of 82.5 in case of maize. The estimated critical limit of Mg by graphical method for maize crop was found 0.60 meq/100 g (Figure 29) compared with the value of 0.50 meq/100 g mentioned in FRG-2018. On the other hand, the critical limit of Mg by statistical method for maize crop was found 0.55 meq/100 g (Table 45).

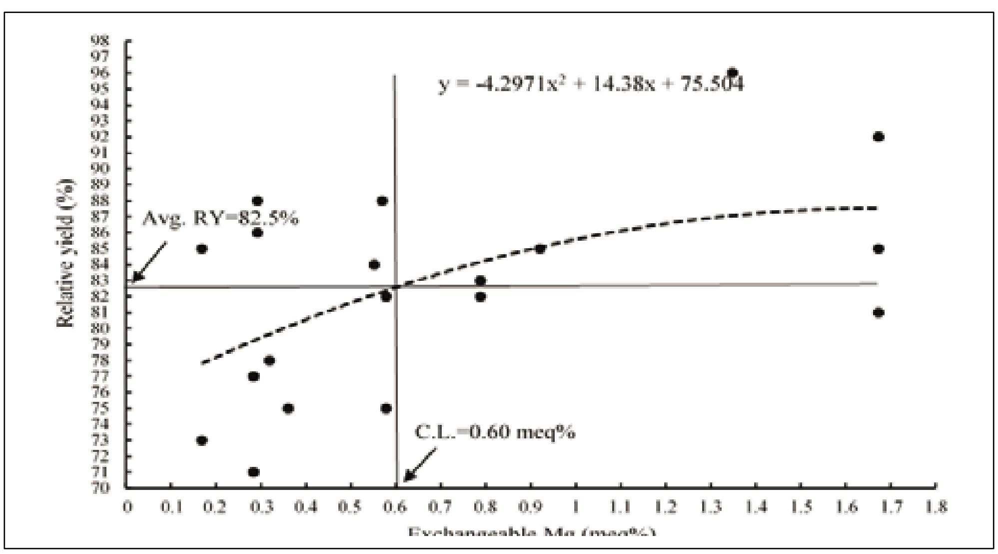


Figure 29. Critical limit of Mg for Rabi maize in Bangladesh, SSD, BINA, 2019-20

Table 45: Calculation of co-efficient of determination (R^2) and critical limit of Mg for maize (Rabi) for the best two population split using 2-mean discontinuous model, BINA, Mymensingh during 2019-20

Sl No.	Least value of Soil Mg (meq/100 g) included in population- 1	% RY	Population-1		Population-2		Postulated critical limit between values	R^2 for postulated critical limit
			Mean relati-ve yield	Corrected sum of squares of deviations from mean (CSS^1)	Mean relati-ve yield	Corrected sum of squares of deviations from mean (CSS^2)		
1	0.17	71	-	-	82	754.95	-	-
2	0.17	73	72.00	2.00	83	616.95	0.23	0.180
3	0.28	75	73.00	8.00	84	510.28	0.28	0.313
4	0.28	75	73.50	11.00	84	431.76	0.29	0.414
5	0.29	77	74.20	20.80	85	343.44	0.29	0.518
6	0.29	78	74.83	32.83	85	280.40	0.31	0.585
7	0.32	81	75.71	65.43	86	224.86	0.34	0.590
8	0.36	82	76.50	100.00	86	200.92	0.46	0.601
9	**0.55**	**82**	**77.11**	**126.89**	**86**	**182.92**	**0.56**	**0.615**
10	0.57	83	77.70	158.10	87	161.64	0.58	0.576
11	0.58	83	78.18	183.64	87	145.60	0.58	0.564
12	0.58	84	78.67	214.67	88	126.00	0.69	0.549
13	0.79	85	79.15	251.69	88	110.88	0.79	0.520
14	0.79	85	79.57	283.43	89	99.71	0.79	0.492
15	0.79	85	79.93	310.93	89	84.83	0.86	0.476
16	0.92	86	80.31	345.44	90	64.00	1.14	0.458
17	1.35	88	80.76	401.06	91	44.00	1.51	0.410
18	1.67	88	81.17	450.50	92	32.00	1.67	0.361
19	1.67	92	81.74	561.68	94	8.00	1.67	0.245
20	1.67	96	82.45	754.95	96	0.00	-	-

Table 46: Calculation of co-efficient of determination (R^2) and critical limit of Mg for Maize (Rabi) on plant Mg concentration for the best two population split using 2-mean discontinuous model, BINA, Mymensingh during 2019-20

Sl No.	Least value of Plant Mg %) included in population-1	% RY	Population-1		Population-2		Postulated critical limit between values	R^2 for postulated critical limit
			Mean relati-ve yield	Corrected sum of squares of deviations from mean (CSS^1)	Mean relati-ve yield	Corrected sum of squares of deviations from mean (CSS^2)		
1	0.28	71	-	-	82	704.55	-	-
2	0.28	73	72.00	2.00	83	568.95	0.29	0.190
3	0.29	75	73.00	8.00	84	464.50	0.30	0.329
4	0.3	75	73.50	11.00	84	388.00	0.31	0.434
5	0.32	77	74.20	20.80	85	301.94	0.32	0.542
6	0.32	78	74.83	32.83	85	240.93	0.33	0.611
7	**0.33**	**81**	**75.71**	**65.43**	**86**	**187.43**	**0.33**	**0.641**
8	0.33	82	76.50	100.00	86	164.92	0.33	0.624
9	0.33	82	77.11	126.89	86	148.25	0.35	0.610
10	0.36	83	77.70	158.10	87	128.55	0.38	0.593

Sl No.	Least value of Plant Mg %) included in population-1	% RY	Population-1		Population-2		Postulated critical limit between values	R^2 for postulated critical limit
			Mean relati-ve yield	Corrected sum of squares of deviations from mean (CSS^1)	Mean relati-ve yield	Corrected sum of squares of deviations from mean (CSS^2)		
11	0.39	83	78.18	183.64	87	114.00	0.39	0.578
12	0.39	84	78.67	214.67	87	96.22	0.40	0.559
13	0.41	85	79.15	251.69	88	82.88	0.42	0.525
14	0.42	85	79.57	283.43	88	73.43	0.44	0.494
15	0.46	85	79.93	310.93	89	60.83	0.47	0.472
16	0.48	86	80.31	345.44	90	43.20	0.48	0.448
17	0.48	88	80.76	401.06	91	27.00	0.52	0.392
18	0.56	88	81.17	450.50	91	18.67	0.60	0.334
19	0.63	92	81.74	561.68	93	2.00	0.66	0.200
20	0.68	94	82.35	704.55	94	0.00	-	-

Kharif Maize:

Table 38 shows that in low Mg soil, the dry matter yields range from 87.46-120.12 g/pot without Mg and 116.60-156.11 g/pot with Mg application. The percent relative yield ranges from 71-88. In medium Mg soil, the dry matter yields range from 127.08-142.10 g/pot without Mg and 148.02-156.53 g/pot with Mg application. The percent relative yield ranges from 84-96. In high Mg soil, the dry matter yields range from 133.14-157.96 g/pot without Mg and 150.00-168.19 g/pot with Mg application. The percent relative yield ranges from 82-94. The overall, the dry matter yields of maize ranges from 87.46-157.96 g/pot without Mg and 116.60-168.19 g/pot with Mg application. The percent relative yield ranges from 71-96 with a mean value of 83.8 in case of maize. The estimated critical limit of Mg by graphical method for maize crop was found 0.52 meq/100 g (Figure 30) compared with the value of 0.50 meq/100 g mentioned in FRG-2018. On the other hand, the critical limit of Mg by statistical method for maize crop was found 0.57 meq/100 g (Table 47).

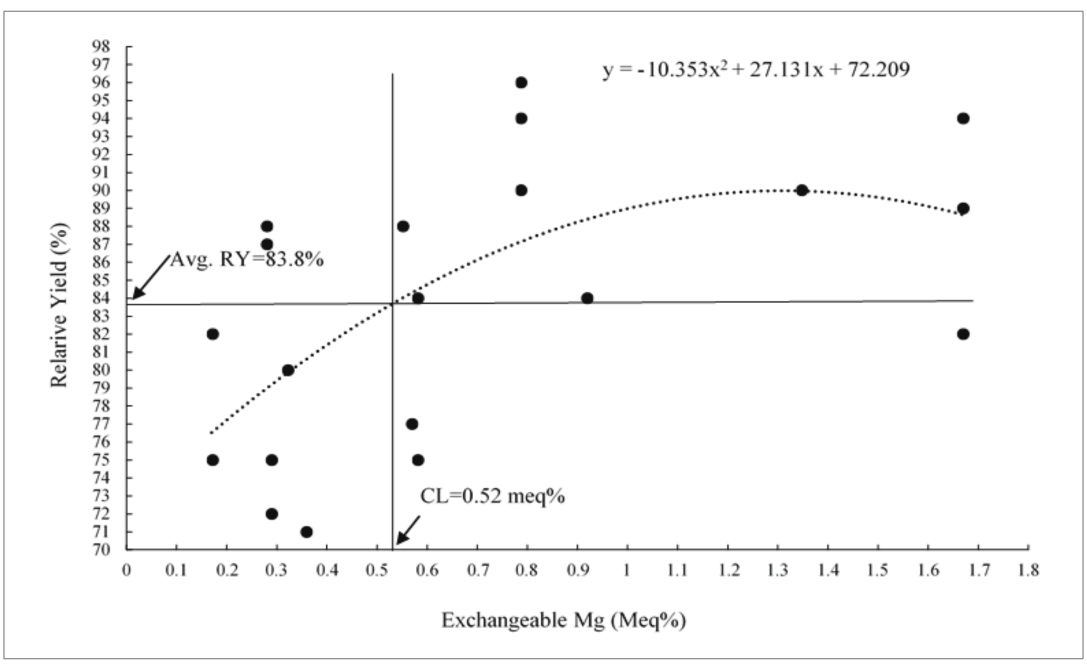


Figure 30. Critical limit of Mg for Kharif maize in Bangladesh, SSD, BINA, 2019-20

Table 47: Calculation of co-efficient of determination (R^2) and critical limit of Mg for maize (Kharif) for the best two population split using 2-mean discontinuous model, BINA, Mymensingh during 2020

Sl No.	Least value of Soil Mg (meq/100 g) included in population- 1	% RY	Population-1		Population-2		Postulated critical limit between values	R^2 for postulated critical limit
			Mean relati-ve yield	Corrected sum of squares of deviations from mean (CSS[1])	Mean relati-ve yield	Corrected sum of squares of deviations from mean (CSS[2])		
1	0.17	71	0	-	84	1108.5500	-	-
2	0.17	72	71.50	0.50	84	940.11	0.17	0.152
3	0.28	75	72.67	8.67	85	780.00	0.28	0.289
4	0.28	75	73.25	12.75	86	674.12	0.28	0.380
5	0.29	75	73.60	15.20	86	555.00	0.29	0.486
6	0.29	77	74.17	24.83	87	420.00	0.29	0.599
7	0.32	80	75.00	54.00	88	312.86	0.32	0.669
8	0.36	82	75.88	96.88	88	248.77	0.36	0.688
9	0.55	82	76.56	130.22	89	205.67	0.55	0.697
10	**0.57**	**84**	**77.30**	**180.10**	**89**	**154.73**	**0.57**	**0.698**
11	0.58	84	77.91	220.91	90	122.00	0.58	0.691
12	0.58	87	78.67	296.67	91	82.00	0.58	0.658
13	0.79	88	79.38	377.08	91	66.86	0.79	0.600
14	0.79	88	80.00	446.00	92	55.71	0.79	0.547
15	0.79	89	80.60	521.60	92	40.83	0.79	0.493
16	0.92	90	81.19	604.44	93	28.80	0.92	0.429
17	1.35	90	81.71	677.53	94	19.00	1.35	0.372
18	1.67	94	82.39	820.28	95	2.67	1.67	0.258
19	1.67	94	83.00	948.00	95	2.00	1.67	0.143
20	1.67	96	83.65	1108.55	96	-	-	-

Table 48. Critical Limits of soil P & Mg for mustard and maize as determined by graphical and statistical approaches, BINA, Mymensingh during 2019-20

Crops	Element	Methods for determining critical limit		R^2
		Statistical	Graphical	
Mustard	Phosphorus	14.56 ppm	14.8 ppm	0.695
	Magnesium	0.55 meq/100 g	0.59 meq/100 g	0.763
Maize (Rabi)	Phosphorus	13.33 ppm	16.1 ppm	0.730
	Magnesium	0.55 meq/100 g	0.60 meq/100 g	0.615
Maize (Kharif)	Phosphorus	12.04 ppm	14.5 ppm	0.653
	Magnesium	0.57 meq/100 g	0.52 meq/100 g	0.698

Phosphorus and magnesium content in mustard and maize (pot experiment) and their critical limit in plant tissue

Phosphorus content of mustard ranges from with P (0.240-0.379%) & without P (0.160-0.373%). On the other hand, phosphorus content of maize ranges from with P (0.166-0.321) & without P (0.053-0.350%). In case of magnesium content in mustard it ranges from with Mg (0.52-1.21%) & without Mg (0.42-1.18%). On the other hand, Mg content of maize ranges from (0.37-0.91%) with Mg & without Mg (0.28-0.68%). In general, nutrient contents increased with their application compared to without application (Tables 49 & 50).

The estimated plant tissue critical limit of P by graphical and statistical methods for mustard crop were found 0.33% and 0.314 %, repectively (Figure 31 and Table 51). The estimated plant tissue critical limit of P by graphical method for maize crop was found 0.13% (Figure 31). On the other hand, the critical limit of P by statistical method for maize crop was found 0.162% (Table 52).

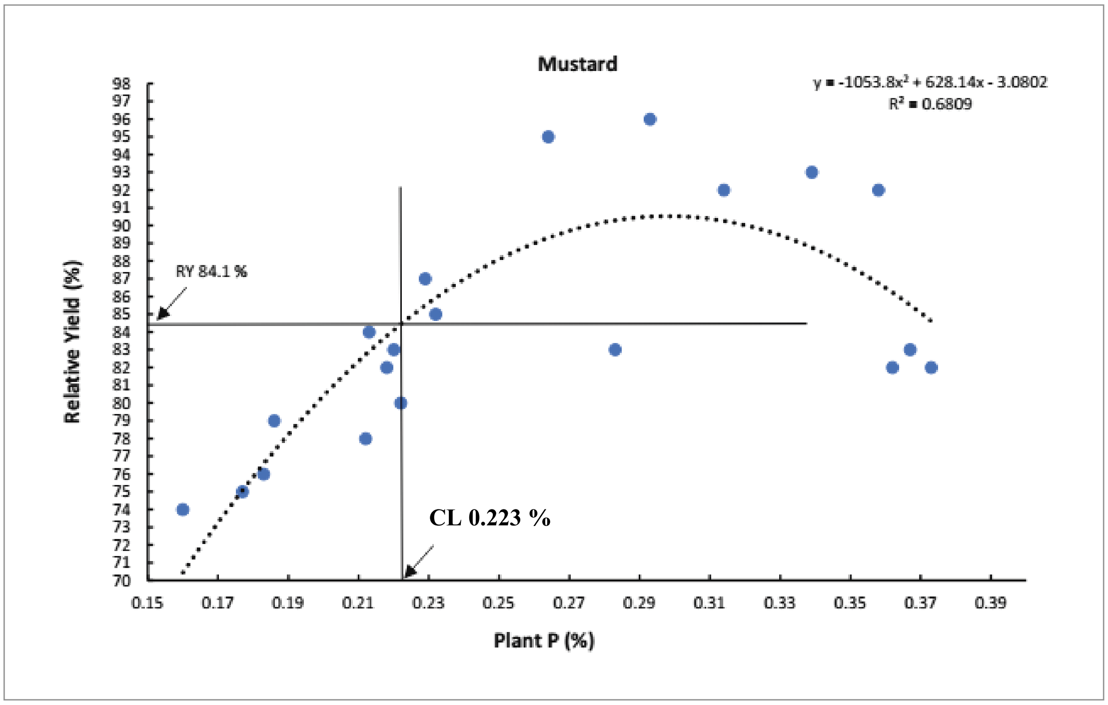
The estimated plant tissue critical limit of Mg by graphical and statistical methods for mustard crop was found 0.63 % and for statistical method was 0.54% (Figure 32 and Table 53). The estimated plant tissue critical limit of Mg by graphical method for maize crop was found 0.36 % (Figure 32). On the other hand, the critical limit of Mg by statistical method for maize crop was found 0.33 % (Table 54).

Table 49. Phosphorus content of mustard and Rabi maize with & without phosphorus at HQ, BINA, Mymensingh during 2019-20

Soil sample No.	Sample name	Avail P (ppm)	Mustard		Maize	
			Phosphorus content (%)		Phosphorus content (%)	
			With P	Without P	With P	Without P
Low P						
1.	BAU-92	11.51	0.266	0.177	0.274	0.350
2.	BAU-98	8.40	0.307	0.212	0.321	0.098
3.	BAU-101	8.40	0.343	0.218	0.240	0.096
4.	BAU-103	12.90	0.240	0.186	0.217	0.166
5.	BINA-3	13.33	0.398	0.367	0.291	0.290
6.	BINA-18	7.75	0.279	0.213	0.190	0.168
7.	BINA-21	12.84	0.282	0.229	0.235	0.162
8.	BINA-29	12.47	0.290	0.227	0.185	0.153
9.	BAU-152	14.13	0.301	0.160	0.166	0.076
10.	BINA-86	14.56	0.371	0.358	0.241	0.178
11.	BINA-74	12.04	0.256	0.183	0.198	0.098
12.	BINA-148	10.75	0.351	0.222	0.193	0.053
Medium P						
13.	BINA-80	16.80	0.352	0.339	0.217	0.074
14.	BINA-124	16.50	0.299	0.283	0.187	0.092
15.	BAU-136	19.67	0.267	0.264	0.176	0.185
16.	BINA-146	18.06	0.385	0.373	0.257	0.235
High P						
17.	BAU-123	31.40	0.343	0.314	0.182	0.196
18.	BINA-81	42.57	0.379	0.362	0.286	0.270
19.	BAU-154	39.99	0.341	0.293	0.199	0.224
20.	BINA-101	33.60	0.296	0.232	0.191	0.126

Table 50. Magnesium content of mustard and Rabi maize with & without magnesium at HQ, BINA, Mymensingh during 2019-20

Soil sample No.	Sample name	Excha. Mg (meq/100 g)	Mustard		Maize	
			Magnesium content (%)		Magnesium content (%)	
			With Mg	Without Mg	With Mg	Without Mg
Low P						
1	BINA-105	0.58	0.71	0.68	0.38	0.33
2	BINA-107	0.58	0.68	1.06	0.37	0.29
3	BINA-121	0.57	1.14	0.73	0.43	0.39
4	BINA-127	0.55	0.79	0.46	0.47	0.33
5	BINA-130	0.36	0.52	0.49	0.57	0.30
6	BINA-150	0.32	0.79	0.72	0.44	0.32
7	BAU-111	0.17	1.43	1.49	0.45	0.48
8	BAU-112	0.17	0.53	0.53	0.54	0.28
9	BAU-138	0.29	1.19	0.79	0.34	0.33
10	BAU-139	0.29	0.79	0.52	0.37	0.42
11	BAU-158	0.28	0.82	0.48	0.44	0.32
12	BAU-167	0.28	0.65	0.53	0.41	0.28
Medium P						
13	BINA-13	0.79	0.68	0.54	0.72	0.56
14	BINA-15	0.92	0.91	0.72	0.55	0.39
15	BINA-103	0.79	0.61	0.42	0.46	0.48
16	BINA-112	0.79	0.86	0.73	0.91	0.36
High P						
17	BINA-4	1.67	0.90	0.87	0.48	0.41
18	BINA-20	1.67	1.21	1.18	0.63	0.46
19	BINA-79	1.67	0.98	0.95	0.51	0.68
20	BINA-87	1.35	0.97	0.93	0.66	0.63



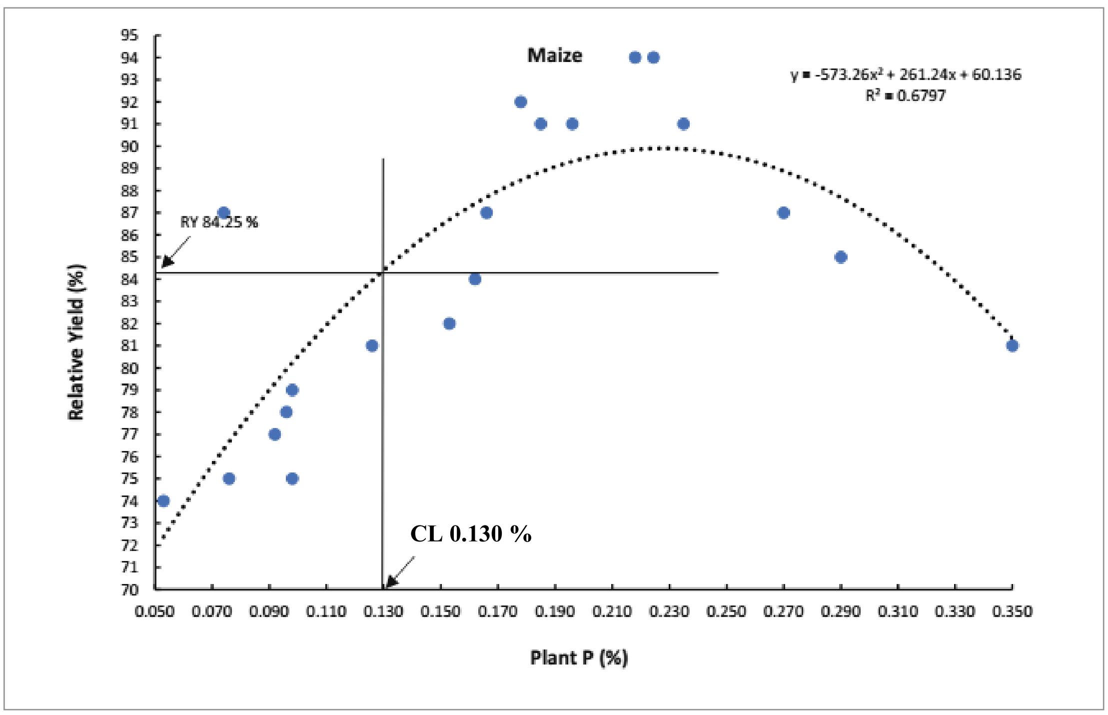


Figure 31. Critical limit of P for mustard and maize on plant P concentration, SSD, BINA, 2019-20

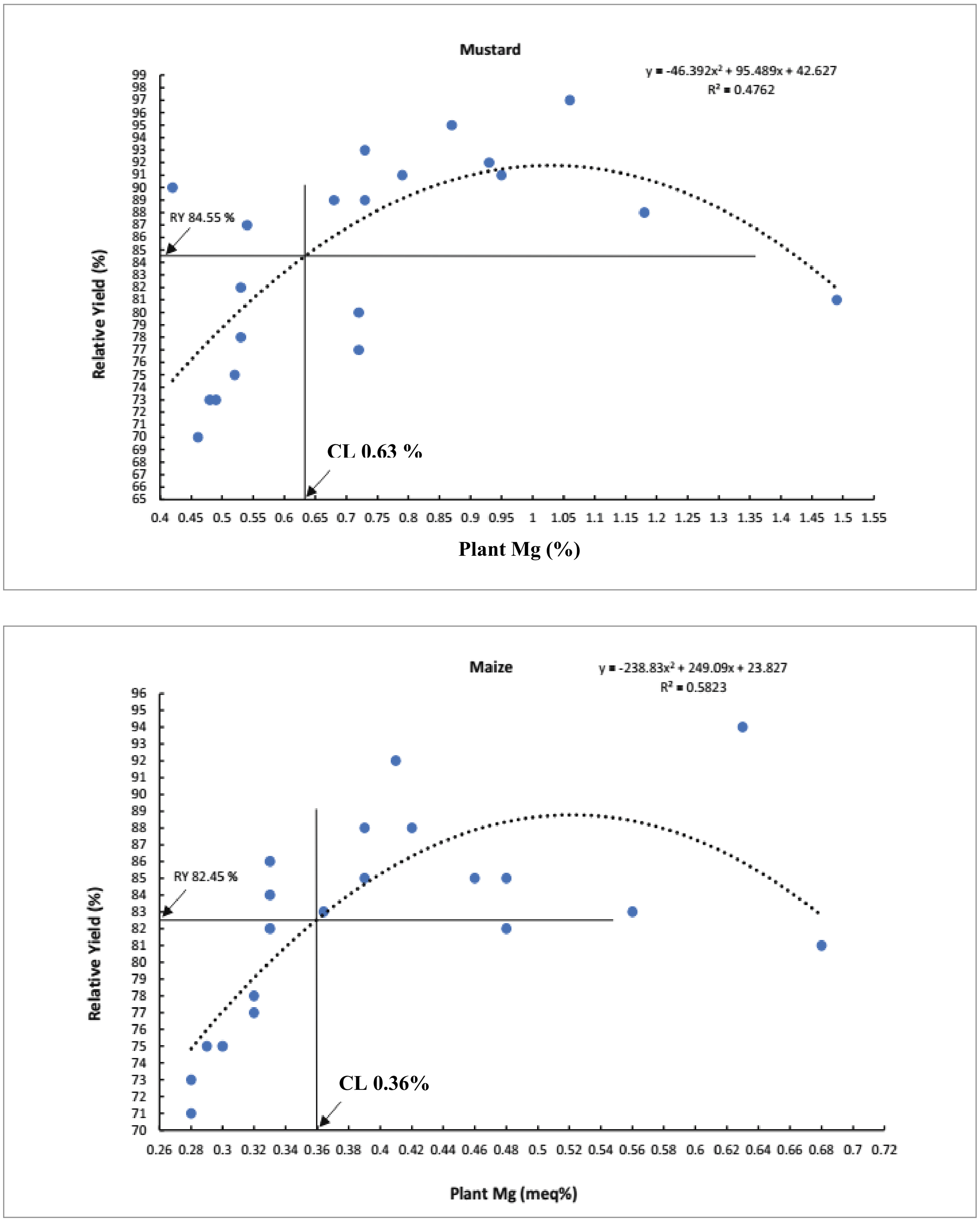


Figure 32. Critical limit of Mg for mustard and maize on plant Mg concentration

Table 51: Calculation of co-efficient of determination (R^2) and critical limit of P for Mustard on plant P concentration for the best two population split using 2-mean discontinuous model, BINA, Mymensingh during 2019-20

Sl No.	Least value of Plant P (%) included in population- 1	% RY	Population-1		Population-2		Postulated critical limit between values	R^2 for postulated critical limit
			Mean relati-ve yield	Corrected sum of squares of deviations from mean (CSS^1)	Mean relati-ve yield	Corrected sum of squares of deviations from mean (CSS^2)		
1	0.16	74	-	-	84	798.0000	-	-
2	0.177	75	74.50	0.500	85	692.7368	0.18	0.131
3	0.183	76	75.00	2.000	85	596.9444	0.18	0.249
4	0.186	78	75.75	8.750	86	510.1176	0.20	0.350
5	0.212	79	76.40	17.200	86	448.9375	0.21	0.416
6	0.213	80	77.00	28.000	87	395.7333	0.22	0.469
7	0.218	82	77.71	49.429	87	350.0000	0.22	0.500
8	0.222	82	78.25	65.500	87	323.0769	0.22	0.513
9	0.227	82	78.67	78.000	88	291.6667	0.23	0.537
10	0.229	83	79.10	94.900	88	254.5455	0.23	0.562
11	0.232	83	79.45	108.727	89	222.9000	0.25	0.584
12	0.264	83	79.75	120.250	90	184.2222	0.27	0.619
13	0.283	84	80.08	136.923	90	135.8750	0.29	0.658
14	0.293	85	80.43	159.429	91	89.4286	0.30	0.688
15	0.314	87	80.87	199.733	92	43.3333	0.33	0.695
16	0.339	92	81.56	315.938	93	9.2000	0.35	0.593
17	0.358	92	82.18	418.471	94	6.7500	0.36	0.467
18	0.362	93	82.78	529.111	94	2.6667	0.36	0.334
19	0.367	95	83.42	670.632	95	-	0.37	0.160
20	0.373	95	84.00	798.000	95	-	-	-

Table 52: Calculation of co-efficient of determination (R^2) and critical limit of P for Maize on plant P concentration for the best two population split using 2-mean discontinuous model, BINA, Mymensingh during 2019-20

Sl No.	Least value of Plant P (%) included in population- 1	% RY	Population-1		Population-2		Postulated critical limit between values	R^2 for postulate d critical limit
			Mean relati-ve yield	Corrected sum of squares of deviations from mean (CSS^1)	Mean relati-ve yield	Corrected sum of squares of deviations from mean (CSS^2)		
1	0.053	74	-	-	84	831.75	-	-
2	0.074	75	74.50	0.500	85	721.16	0.08	0.132
3	0.076	75	74.67	0.667	85	620.00	0.08	0.254
4	0.092	77	75.25	4.750	86	506.94	0.09	0.385
5	0.096	78	75.80	10.800	87	422.00	0.10	0.480
6	0.098	79	76.33	19.333	87	344.93	0.10	0.562
7	0.098	81	77.00	38.000	88	275.21	0.11	0.623
8	0.126	81	77.50	52.000	88	227.69	0.14	0.664
9	0.153	82	78.00	70.000	89	172.25	0.16	0.709

Sl No.	Least value of Plant P (%) included in population- 1	% RY	Population-1		Population-2		Postulated critical limit between values	R^2 for postulated critical limit
			Mean relati-ve yield	Corrected sum of squares of deviations from mean (CSS^1)	Mean relati-ve yield	Corrected sum of squares of deviations from mean (CSS^2)		
10	0.162	84	78.60	102.400	89	122.55	0.16	0.723
11	0.166	85	79.18	139.636	90	90.90	0.17	0.723
12	0.178	87	79.83	195.667	90	64.22	0.18	0.688
13	0.185	87	80.38	243.077	91	50.88	0.19	0.647
14	0.196	87	80.86	283.714	91	33.71	0.21	0.618
15	0.218	91	81.53	379.733	92	10.83	0.22	0.530
16	0.224	91	82.13	463.750	92	9.20	0.23	0.431
17	0.235	91	82.65	537.882	93	6.75	0.25	0.345
18	0.27	92	83.17	620.500	93	2.67	0.28	0.251
19	0.290	94	83.74	731.684	94	0.00	0.32	0.120
20	0.350	94	84.25	831.750	94	0.00	-	-

Table 53: Calculation of co-efficient of determination (R2) and critical limit of Mg for Mustard on plant Mg concentration for the best two population split using 2-mean discontinuous model, BINA, Mymensingh during 2019-20

Sl No.	Least value of Plant Mg (%) included in population- 1	% RY	Population-1		Population-2		Postulated critical limit between values	R^2 for postulated critical limit
			Mean relati-ve yield	Corrected sum of squares of deviations from mean (CSS^1)	Mean relati-ve yield	Corrected sum of squares of deviations from mean (CSS^2)		
1	0.68	70	-	-	85	1270.95	-	-
2	0.42	73	71.50	4.500	85	1048.11	0.44	0.172
3	0.461	73	72.00	6.000	86	888.00	0.47	0.297
4	0.48	75	72.75	12.750	87	709.06	0.49	0.432
5	0.49	77	73.60	27.200	88	562.00	0.51	0.536
6	0.52	78	74.33	43.333	88	444.40	0.53	0.616
7	0.53	80	75.14	70.857	89	332.93	0.53	0.682
8	0.53	81	75.88	100.875	90	247.08	0.54	0.726
9	**0.54**	**82**	**76.56**	**134.222**	**90**	**166.67**	**0.63**	**0.763**
10	0.72	87	77.60	232.400	91	90.91	0.72	0.746
11	0.72	88	78.55	330.727	92	72.50	0.73	0.683
12	0.73	89	79.42	430.917	92	58.89	0.73	0.615
13	0.73	89	80.15	515.692	92	49.50	0.76	0.555
14	0.79	90	80.86	605.714	93	37.43	0.83	0.494
15	0.87	91	81.53	701.733	93	28.83	0.90	0.425
16	0.93	91	82.13	785.750	94	23.20	0.94	0.364
17	0.95	92	82.71	877.529	94	14.75	1.01	0.298
18	1.06	93	83.28	977.611	95	8.00	1.12	0.224
19	1.18	95	83.89	1107.789	96	-	1.34	0.127
20	1.49	97	84.55	1270.950	97	-	-	-

Table 54: Calculation of co-efficient of determination (R^2) and critical limit of Mg for Maize on plant Mg concentration for the best two population split using 2-mean discontinuous model, BINA, Mymensingh during 2019-20

Sl No.	Least value of Plant Mg (%) included in population- 1	% RY	Population-1		Population-2		Postulated critical limit between values	R^2 for postulated critical limit
			Mean relati-ve yield	Corrected sum of squares of deviations from mean (CSS^1)	Mean relati-ve yield	Corrected sum of squares of deviations from mean (CSS^2)		
1	0.28	71	-	-	82	704.55	-	-
2	0.28	73	72.00	2.00	83	568.95	0.29	0.190
3	0.29	75	73.00	8.00	84	464.50	0.30	0.329
4	0.3	75	73.50	11.00	84	388.00	0.31	0.434
5	0.32	77	74.20	20.80	85	301.94	0.32	0.542
6	0.32	78	74.83	32.83	85	240.93	0.33	0.611
7	0.33	81	75.71	65.43	86	187.43	0.33	0.641
8	0.33	82	76.50	100.00	86	164.92	0.33	0.624
9	0.33	82	77.11	126.89	86	148.25	0.35	0.610
10	0.36	83	77.70	158.10	87	128.55	0.38	0.593
11	0.39	83	78.18	183.64	87	114.00	0.39	0.578
12	0.39	84	78.67	214.67	87	96.22	0.40	0.559
13	0.41	85	79.15	251.69	88	82.88	0.42	0.525
14	0.42	85	79.57	283.43	88	73.43	0.44	0.494
15	0.46	85	79.93	310.93	89	60.83	0.47	0.472
16	0.48	86	80.31	345.44	90	43.20	0.48	0.448
17	0.48	88	80.76	401.06	91	27.00	0.52	0.392
18	0.56	88	81.17	450.50	91	18.67	0.60	0.334
19	0.63	92	81.74	561.68	93	2.00	0.66	0.200
20	0.68	94	82.35	704.55	94	0.00	-	-

Table 55. Critical Plant P & Mg levels for mustard and maize as determined by graphical and statistical approaches, BINA, Mymensingh during 2019-20

Crops	Element	Methods for determining critical limit		R^2
		Statistical	Graphical	
Mustard	Phosphorus	0.33 %	0.23 %	0.695
	Magnesium	0.63 %	0.63 %	0.763
Maize (Rabi)	Phosphorus	0.16 %	0.13 %	0.730
	Magnesium	0.33 %	0.36 %	0.641

Expt. 2.4: Determination of critical limit of Mg, S and B for crops (Wheat and mustard)

BAU Component

Relative yield and Critical Limit of S for wheat

Dry matter yield of wheat at low soil S ranged between 3.05-4.11 g/pot (average 3.6 g/pot) with S fertilization; the yield declined to 2.63-3.63 g/pot (average 3.1 g/pot) in the pots without S fertilization (Table 56). The RY in the low S soils ranged 78-92% (average 86.5%).

In the pots with medium soil S, the dry matter yield of wheat ranged between 3.1-3.47 g/pot (average 3.29 g/pot) with S fertilization; the yield declined to 2.7-3.23 g/pot (2.99 g/pot) where S was not applied. The RY (%) in the medium soil S ranged 90-93% (average 91.25%).

The pots with high soil S had wheat dry matter yield of 3.37-3.76 g/pot (3.57 g/pot) with soil test based S fertilization, whereas the yield in the without S fertilization pots ranged 3.14-3.4 g/pot (average 3.28 g/pot). The RY in the high S soils ranged 91-93% (average 92%) (Table 56).

Table 56: Relative yield of wheat and mustard with and without S at BAU, Mymensingh during 2019-20.

Soil sample No.	Sample name	Avail.S (ppm)	Wheat			Mustard		
			Dry matter yield (g/pot)		Relative yield (%)	Dry matter yield (g/pot)		Relative yield (%) With **S**
			With **S**	Without **S**		With **S**	Without **S**	
Low S								
21.	BAU 8	15.1	3.51	3.16	90	3.83	3.37	88
22.	BAU 96	8.81	3.43	2.90	85	4.08	3.23	79
23.	BAU 128	10.3	3.49	2.94	84	3.82	3.21	84
24.	BAU 119	11.44	4.11	3.63	88	3.62	3.06	85
25.	BINA 9	6.46	3.43	2.67	78	3.60	2.82	76
26.	BAU 98	8	4.00	3.30	83	3.97	3.03	80
27.	BAU37	9	4.04	3.50	87	3.91	3.17	81
28.	BAU 136	10	3.98	3.40	86	4.73	3.95	83
29.	BAU 31	11	3.57	3.17	89	3.41	2.94	86
30.	BAU 42	12	3.05	2.63	86	3.76	3.29	85
31.	BAU 51	13	3.13	2.83	90	4.39	3.80	87
32.	BAU 47	15	3.54	3.11	92	3.63	3.24	89
Average			3.6	3.1	86.5	3.9	3.26	83.58
Medium S								
33.	BAU 27	22	3.13	2.86	91	3.82	3.47	91
34.	BAU 159	23	3.47	3.23	93	3.34	3.06	92
35.	BAU 50	24	3.45	3.15	91	3.50	3.23	92
36.	BINA 2	16	3.10	2.70	90	3.24	2.91	90
Average			3.29	2.99	91.25	3.48	3.17	91.25
High S								
37.	BAU 56	32	3.76	3.40	91	3.61	3.31	92
38.	BAU 41	36	3.68	3.38	92	4.04	3.77	93
39.	BAU 43	37	3.48	3.21	92	3.57	3.28	92
40.	BAU 49	38	3.37	3.14	93	3.59	3.33	93
Average			3.57	3.28	92	3.7	3.42	92.5

The critical limit of soil S for wheat was found 13.5 mg/kg (0.15% $CaCl_2$ extraction) in the graphical method (Figure 33) and 11.45 mg/kg in the statistical method (Table 56), which was previously 10 mg/kg (FRG 2018). Gupta *et al.* (1996) showed that the critical limit of S using the same extraction was 12.5 mg/kg for wheat.

The critical limit of wheat tissue S concentration was found 0.14 %, the same for both graphical (Figure 34) and statistical methods (Table 57).

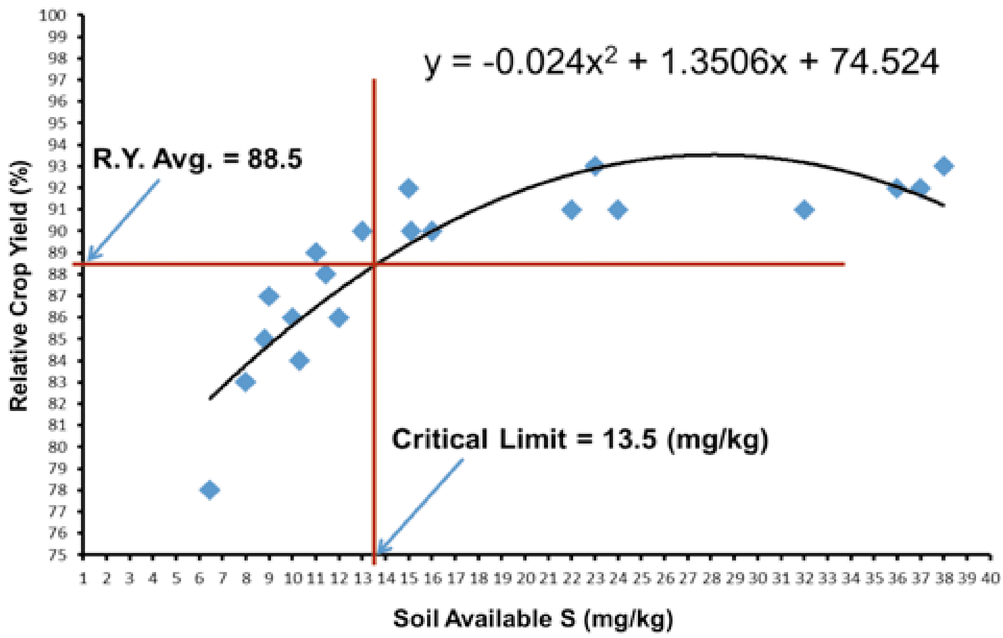


Figure 33: Critical Limit of S for wheat soil in Bangladesh, DSS, BAU, 2019-20

Photo 31: Pot trial on the effect of S on wheat plant, DSS, BAU, 2019-20

Table 57: Soil available S, Bray's per cent yield and predictability values (R2) of wheat soil, BAU, Mymensingh during 2019-20

Sl. No.	Soil available sulphur (ppm)	Bray's % yield	Mean Bray's % yield in population –I	Corrected sum of squares of deviation from mean of population CSS-I	Mean Bray's % yield in population –II	Corrected sum of squares of deviation from mean of population CSS-II	R2 TSS - (CSSI-CSSII) /TSS
1	6.84	78	80.50	12.50	89	134.44	0.99
2	8.16	83	82.00	26.00	90	113.53	0.99
3	8.82	85	83.25	44.75	90	105.75	0.99
4	9.33	87	83.80	50.80	90	89.73	0.99
5	9.87	86	83.83	50.83	91	49.43	0.99
6	10.31	84	84.57	73.71	91	46.77	0.99
7	10.82	89	85.00	84.00	91	38.92	0.99
8	**11.45**	**88**	**85.11**	**84.89**	**91**	**12.55**	**0.99**
9	12.19	86	85.60	106.40	92	10.50	0.99
10	13.06	90	86.18	143.64	91	10.22	0.99
11	15.14	92	86.50	157.00	92	7.88	0.99
12	15.30	90	86.77	168.31	92	4.86	0.99
13	16.00	90	87.07	184.93	92	4.00	0.99
14	22.08	91	87.47	217.73	92	2.80	0.98
15	22.87	93	87.69	229.44	92	2.00	0.98
16	24.25	91	87.88	239.76	92	0.67	0.98
17	31.72	91	88.11	255.78	93	0.50	0.98
18	36.19	92	88.32	270.11	93		
19	36.94	92	88.55				
20	38.43	93					
				SS	157113		
				CF	142565.50		
				TSS	14547.50		

Critical limit of S content of wheat plant

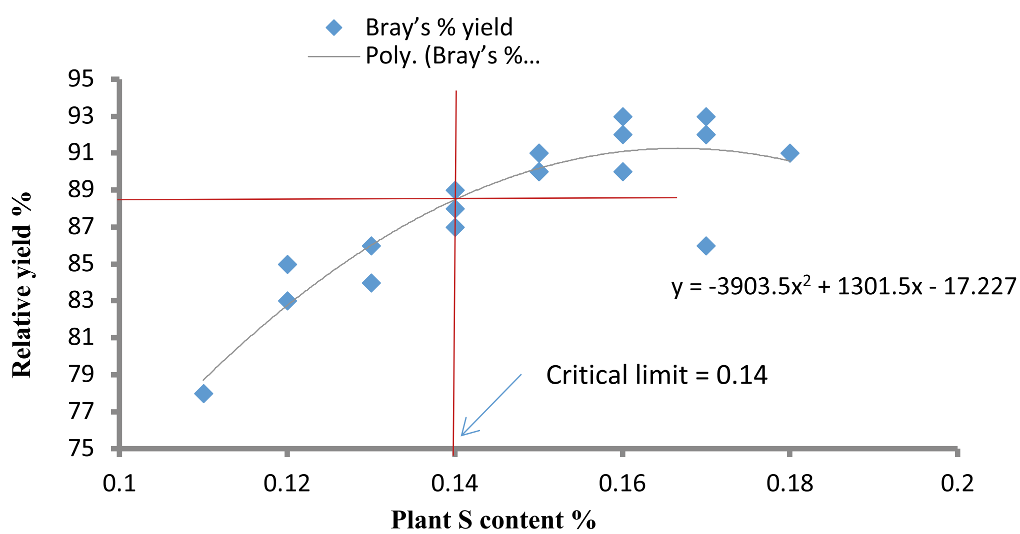


Figure 34: Scatter diagram showing relationship between Bray's per cent yield and tissue sulphur concentration in wheat plant

Table 58: Tissue S content, Bray's % yield and predictability values (R2) of wheat plant, BAU, Mymensingh during 2019-20

Sl. No.	Sulphur content in wheat plant (%)	Bray's % yield	Mean Bray's % yield in population –I	Corrected sum of squares of deviation from mean of population CSS-I	Mean Bray's % yield in population - II	Corrected sum of squares of deviation from mean of population CSS-II	R2 TSS - (CSSI-CSSII) /TSS
1	0.11	78.00	80.50	12.50	89.00	134.44	0.99
2	0.12	83.00	82.00	26.00	90.00	113.53	0.99
3	0.12	85.00	83.25	44.75	90.00	105.75	0.99
4	0.14	87.00	83.80	50.80	90.00	89.73	0.99
5	0.13	86.00	83.83	50.83	91.00	49.43	0.99
6	0.13	84.00	84.57	73.71	91.00	46.77	0.99
7	0.14	89.00	85.00	84.00	91.00	38.92	0.99
8	**0.14**	**88.00**	**85.11**	**84.89**	**91.00**	**12.55**	**0.99**
9	0.17	86.00	85.60	106.40	92.00	10.50	0.99
10	0.16	90.00	86.00	124.00	92.00	8.00	0.99
11	0.15	90.00	86.50	157.00	92.00	7.88	0.99
12	0.17	92.00	86.77	168.31	92.00	4.86	0.99
13	0.15	90.00	87.07	184.93	92.00	4.00	0.99
14	0.15	91.00	87.47	217.73	92.00	2.80	0.98
15	0.16	93.00	87.69	229.44	92.00	2.00	0.98
16	0.18	91.00	87.88	239.76	92.00	0.67	0.98
17	0.15	91.00	88.11	255.78	93.00	0.50	0.98
18	0.16	92.00	88.32	270.11	93.00	134.44	0.99
19	0.17	92.00	88.55				
20	0.17	93					
				SS	157113		
				CF	142565.5		
				TSS	14547.5		

Relative yield and Critical Limit of S for mustard

Dry matter yield of mustard at low soil S ranged between 3.41-4.73 g/pot (average 3.9 g/pot) with S fertilization; the yield declined to 2.82-3.95 g/pot (average 3.26 g/pot) in the pots without S fertilization (Table 56). The RY in the low S soils ranged 76-89 % (average 83.58%).

In the pots with medium soil S, the dry matter yield of mustard ranged between 3.24-3.82 g/pot (average 3.48 g/pot) with S fertilization; the yield declined to 2.91-3.47 g/pot (3.17 g/pot) where S was not applied. The RY (%) in the medium soil S ranged 90-92 % (average 91.25%).

The pots with high soil S had mustard dry matter yield of 3.57-4.04 g/pot (3.7 g/pot) with soil test based S fertilization, whereas the yield in the without S fertilization pots ranged 3.28-3.77 g/pot (average 3.42 g/pot). The RY in the high S soils ranged 92-93 % (average 92.5%) (Table 56).

The critical limit of soil S for mustard was found 14 mg/kg (0.15% $CaCl_2$ extraction) in the graphical method (Figure 35) and 11.45 mg/kg in the statistical method (Table 59), which was previously 10 mg/kg (FRG 2018). Prakash *et al.* (1999) showed that the critical limit of S using the same extraction was 10.3 mg/kg for cauliflower.

The critical limit of mustard tissue S concentration was found 0.35%, the same for both graphical (Figure 36) and statistical methods (Table 59).

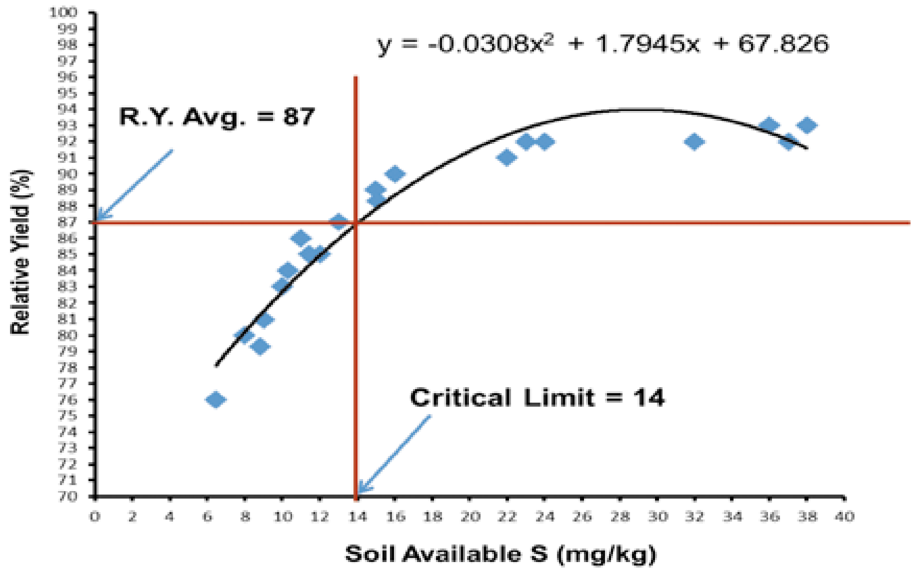


Figure 35: Critical Limit of S for mustard soil in Bangladesh, DSS, BAU, 2019-20

Photo 32: Pot trial on the effect of S on mustard plant, DSS, BAU, 2019-20

Table 59: Soil available S, Bray's percent yield and predictability values (R2) of mustard soil, BAU, Mymensingh during 2019-20

Sl. No.	Soil available sulphur (ppm)	Bray's % yield	Mean Bray's % yield in population –I	Corrected sum of squares of deviation from mean of population CSS-I	Mean Bray's % yield in population - II	Corrected sum of squares of deviation from mean of population CSS-II	R2 TSS - (CSSI-CSSII) /TSS
1	6.84	76	78.00	8.00	88.00	321.78	0.98
2	8.16	80	78.33	8.67	88.00	238.12	0.98
3	8.82	79	79.00	14.00	89.00	179.75	0.99
4	9.33	81	79.80	26.80	89.00	142.93	0.99
5	9.87	83	80.50	41.50	90.00	113.21	0.99
6	10.31	84	81.29	67.43	90.00	98.92	0.99
7	10.82	86	81.75	79.50	90.00	72.67	0.99
8	**11.45**	**85**	**82.11**	**88.89**	**91.00**	**41.64**	**0.99**
9	12.19	85	82.60	110.40	91.00	25.60	0.99
10	13.06	87	83.09	136.91	92.00	14.22	0.99
11	15.14	88	83.58	168.92	92.00	6.88	0.99
12	15.30	89	84.08	206.92	92.00	2.86	0.99
13	16.00	90	84.57	251.43	92.00	1.33	0.98
14	22.08	91	85.07	302.93	92.00	1.20	0.98
15	22.87	92	85.50	348.00	93.00	1.00	0.98
16	24.25	92	85.88	387.76	93.00	0.67	0.97
17	31.72	92	86.28	435.61	93.00	0.50	0.97
18	36.19	93	86.58	466.63	93.00		
19	36.94	92	86.90				
20	38.43	93					
				SS	151538		
				CF	137302		
				TSS	14236		

Critical limit of S content of mustard plant

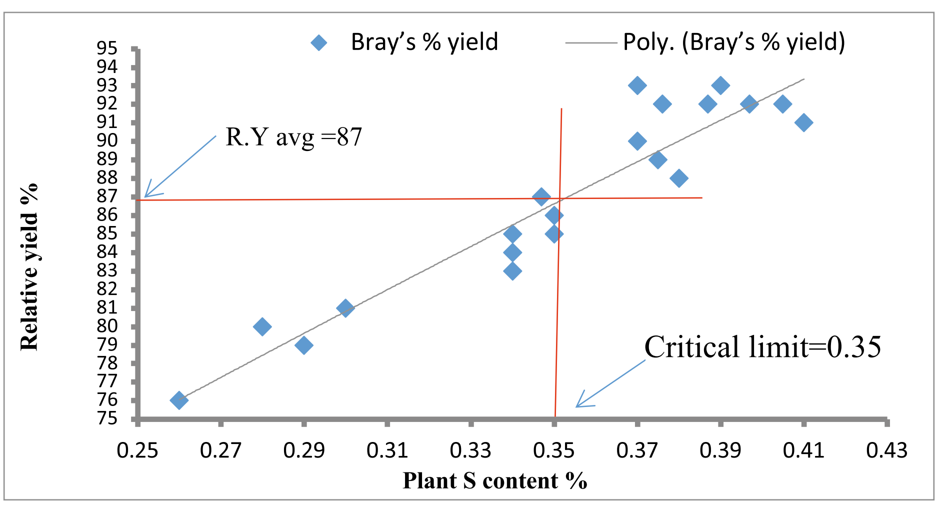


Figure 36: Scatter diagram showing relationship between Bray's per cent yield and tissue sulphur concentration in mustard plant

Table 60: Tissue S content, Bray's % yield and predictability values (R2) of mustard plant, BAU, Mymensingh during 2019-20

Sl. No.	Tissue Sulphur content in mustard plant (%)	Bray's % yield	Mean Bray's % yield in population –I	Corrected sum of squares of deviation from mean of population CSS-I	Mean Bray's % yield in population –II	Corrected sum of squares of deviation from mean of population CSS-II	R2 TSS - (CSSI-CSSII) /TSS
1	0.26	76	78.00	8.00	88.00	321.78	0.98
2	0.28	80	78.33	8.67	88.00	238.12	0.98
3	0.29	79	79.00	14.00	89.00	179.75	0.99
4	0.30	81	79.80	26.80	89.00	142.93	0.99
5	0.34	83	80.50	41.50	90.00	113.21	0.99
6	0.34	84	81.29	67.43	90.00	98.92	0.99
7	0.35	86	81.75	79.50	90.00	72.67	0.99
8	**0.35**	**85**	**82.11**	**88.89**	**91.00**	**41.64**	**0.99**
9	0.34	85	82.60	110.40	91.00	25.60	0.99
10	0.35	87	83.09	136.91	92.00	14.22	0.99
11	0.38	88	83.58	168.92	92.00	6.88	0.99
12	0.38	89	84.08	206.92	92.00	2.86	0.99
13	0.37	90	84.57	251.43	92.00	1.33	0.98
14	0.41	91	85.07	302.93	92.00	1.20	0.98
15	0.39	92	85.50	348.00	93.00	1.00	0.98
16	0.41	92	85.88	387.76	93.00	0.67	0.97
17	0.40	92	86.28	435.61	93.00	0.50	0.97
18	0.39	93	86.58	466.63	93.00		
19	0.38	92	86.90				
20	0.37	93					
				SS	151538		
				CF	137302		
				TSS	14236		

Relative yield and Critical Limit of Mg for wheat

Dry matter yield of wheat at low soil Mg ranged between 3.49-4.91 g/pot (average 4.18 g/pot) with Mg fertilization; the yield declined to 2.82-4.35 g/pot (average 3.62 g/pot) in the pots without Mg fertilization (Table 61). The RY in the low Mg soils ranged 79-91 % (average 86.58%).

In the pots with medium soil Mg, the dry matter yield of wheat ranged between 4.28-4.66 g/pot (average 4.52 g/pot) with Mg fertilization; the yield declined to 3.92-4.32 g/pot (4.19 g/pot) where S was not applied. The RY (%) in the medium soil Mg ranged 92-94 % (average 93%).

The pots with high soil Mg had wheat dry matter yield of 4.38-4.65 g/pot (4.6 g/pot) with soil test based Mg fertilization, whereas the yield in the without Mg fertilization pots ranged 4.01-4.49 g/pot (average 4.25 g/pot). The RY in the high Mg soils ranged 91-94% (average 92.5%) (Table 61).

Table 61: Relative yield of wheat and mustard with and without Mg at BAU, Mymebsingh during 2019-20.

Soil sample No.	Sample name	Mg level (mg/kg)	Wheat			Mustard		
			Dry matter yield (g/pot)		Relative yield (%)	Dry matter yield (g/pot)		Relative yield (%)
			With Mg	Without Mg		With Mg	Without Mg	
Low Mg								
1.	BAU 97	0.12	3.71	2.93	79	3.83	2.97	78
2.	BAU 112	0.17	3.49	2.82	81	4.24	3.43	81
3.	BAU 71	0.19	4.00	3.39	85	4.06	3.30	81
4.	BAU 131	0.21	3.73	3.26	87	3.95	3.29	83
5.	BAU 128	0.27	3.71	3.25	89	4.07	3.39	83
6.	BAU 158	0.28	4.91	4.35	89	4.18	3.56	85
7.	BAU 139	0.29	4.07	3.55	87	3.96	3.41	86
8.	BAU 65	0.31	4.42	3.77	85	3.97	3.39	85
9.	BAU 155	0.39	4.22	3.74	89	3.95	3.42	86
10.	BAU 73	0.42	4.56	4.01	88	3.81	3.37	88
11.	BAU 76	0.5	4.64	4.19	89	4.02	3.57	89
12.	BAU 87	0.63	4.66	4.17	91	4.12	3.70	90
			4.18	3.62	86.58	4.01	3.4	84.58
Medium Mg								
13.	BAU 61	0.8	4.28	3.92	92	3.89	3.58	92
14.	BAU 17	1.2	4.58	4.25	93	3.57	3.32	93
15.	BAU 27	1.3	4.66	4.32	93	3.89	3.63	93
16.	BAU 37	1.49	4.56	4.27	94	3.99	3.70	93
			4.52	4.19	93	3.84	3.56	92.75
High Mg								
17.	BAU 13	1.51	4.38	4.01	91	4.16	3.90	94
18.	BAU 34	1.61	4.55	4.21	93	4.00	3.76	94
19.	BAU 21	1.81	4.65	4.29	92	3.84	3.61	94
20.	BAU32	1.83	4.80	4.49	94	4.07	3.92	96
			4.6	4.25	92.5	4.02	3.8	94.5

The exchangeable Mg content in soil plotted against the relative yield of wheat grown in those soils produced the critical limit of 0.5 meq/100 g soil (NH_4OAc extraction) in graphical method (Figure 37) and 0.39 meq/100 g soil in statistical method (Table 62) which was previously determined 0.5 meq/100 g soil (FRG 2018).

The critical limit of wheat tissue Mg concentration was found 0.29% in graphical method (Figure 38) and 0.29% in statistical method (Table 64)

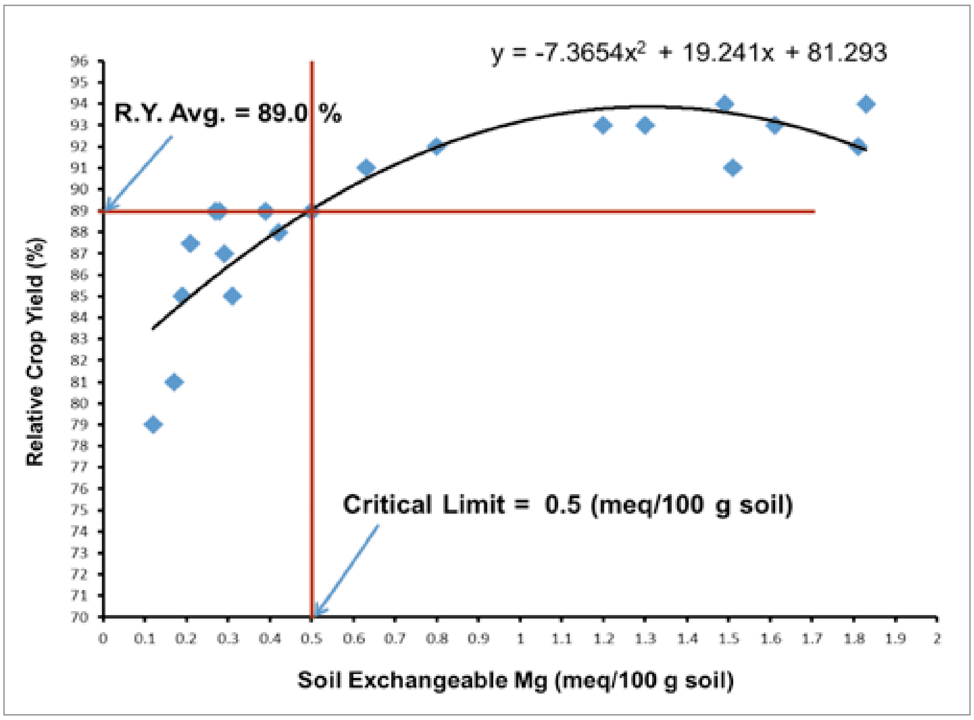


Figure 37: Critical Limit of Mg for wheat soil in Bangladesh, DSS, BAU, 2019-20

Photo 33: Pot trial on the effect of Mg on wheat plant, DSS, BAU, 2019-20

Table 62: Soil available Mg, Bray's % yield and predictability values (R2) of wheat, BAU, Mymensingh during 2019-20

Sl. No.	Available Mg conc. in soil (%)	Bray's % yield	Mean Bray's % yield in population –I	Corrected sum of squares of deviation from mean of population CSS-I	Mean Bray's % yield in population –II	Corrected sum of squares of deviation from mean of population CSS-II	R2 TSS - (CSSI-CSSII) /TSS
1	0.12	79.00	79.85	1.47	0.12	79.00	79.85
2	0.17	81.00	81.51	17.93	0.17	81.00	81.51
3	0.19	85.00	83.00	44.67	0.19	85.00	83.00
4	0.21	87.00	83.95	62.87	0.21	87.00	83.95
5	0.27	88.00	84.72	80.29	0.27	88.00	84.72
6	0.28	89.00	85.06	85.34	0.28	89.00	85.06
7	0.29	87.00	85.09	85.38	0.29	87.00	85.09
8	0.31	85.00	85.49	96.94	0.31	85.00	85.49
9	**0.39**	**89.00**	**85.73**	**102.01**	**0.39**	**89.00**	**85.73**
10	0.42	88.00	86.13	119.91	0.42	88.00	86.13
11	0.50	90.00	86.42	130.61	0.50	90.00	86.42
12	0.63	90.00	86.81	155.31	0.63	90.00	86.81
13	0.80	92.00	87.25	189.28	0.80	92.00	87.25
14	1.20	93.00	87.61	217.08	1.20	93.00	87.61
15	1.30	93.00	87.99	251.22	1.30	93.00	87.99
16	1.49	94.00	88.19	262.68	1.49	94.00	88.19
17	1.51	91.00	88.43	280.43	1.51	91.00	88.43
18	1.61	93.00	88.63	294.32	1.61	93.00	88.63
19	1.81	92.00	88.89		1.81	92.00	88.89
20	1.83	94					
				SS	158336.4		
				CF	143652.7		
				TSS	14683.74		

Critical limit of Mg content of wheat plant

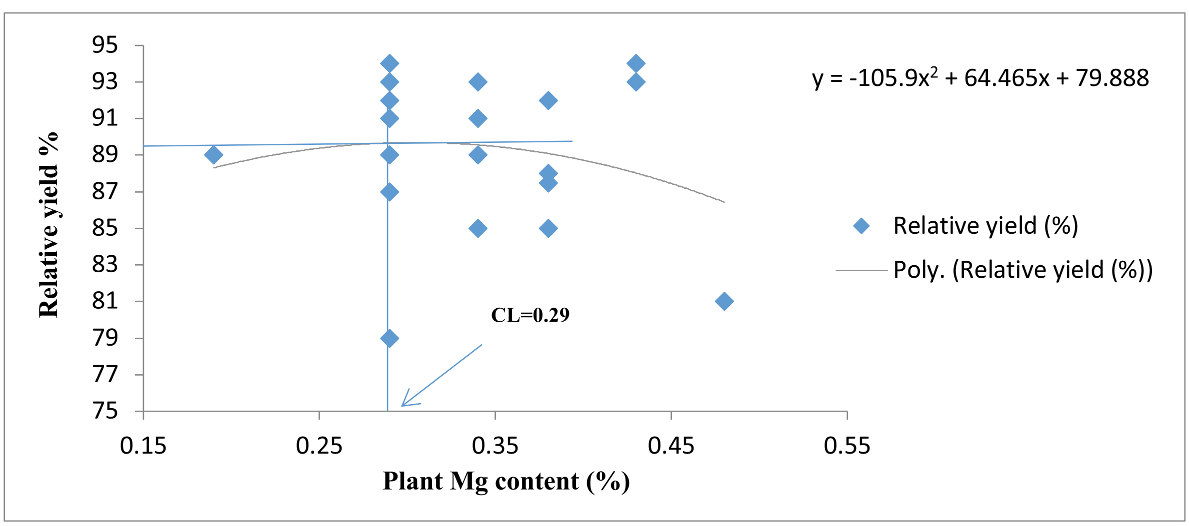


Figure 38: Scatter diagram showing relationship between Bray's per cent yield and tissue Mg concentration in wheat plant

Table 63: Tissue Mg content, Bray's % yield and predictability values (R2) of wheat plant, BAU, Mymensingh during 2019-20

Sl. No.	Mg content in wheat plant (%)	Bray's % yield	Mean Bray's % yield in population –I	Corrected sum of squares of deviation from mean of population CSS-I	Mean Bray's % yield in population –II	Corrected sum of squares of deviation from mean of population CSS-II	R2 TSS - (CSSI-CSSII) /TSS
1	0.19	89	89.00	0.00	89	327.18	0.98
2	0.19	89	85.67	66.67	90	219.54	0.98
3	**0.29**	**79**	**86.00**	**68.00**	**90**	**211.94**	**0.98**
4	0.29	87	86.60	75.20	90	211.18	0.98
5	0.29	89	87.33	91.33	90	209.88	0.98
6	0.29	91	88.14	118.86	90	198.99	0.98
7	0.29	93	88.63	131.88	89	192.63	0.98
8	0.29	92	89.22	157.56	89	169.28	0.98
9	0.29	94	89.20	157.60	89	169.27	0.98
10	0.34	89	88.82	173.64	89	151.95	0.98
11	0.34	85	89.17	189.67	89	137.27	0.98
12	0.34	93	89.31	192.77	89	132.40	0.98
13	0.34	91	89.00	210.00	89	116.93	0.98
14	0.38	85	88.90	212.15	90	113.20	0.98
15	0.38	87	88.84	212.90	90	110.00	0.98
16	0.38	88	89.03	222.29	89	104.67	0.98
17	0.38	92	89.25	237.18	88	84.50	0.98
18	0.43	93	89.50	258.57	81		
19	0.43	94	89.07				
20	0.48	81					
				SS	159011.3		
				CF	144258.3		
				TSS	14753.02		

Relative yield and Critical Limit of Mg for mustard

Dry matter yield of mustard at low soil Mg ranged between 3.81-4.24 g/pot (average 4.01 g/pot) with Mg fertilization; the yield declined to 2.97-3.56 g/pot (average 3.40 g/pot) in the pots without S fertilization (Table 61). The RY in the low Mg soils ranged 78-90 % (average 84.58%).

In the pots with medium soil Mg, the dry matter yield of mustard ranged between 3.57-3.99 g/pot (average 3.84 g/pot) with Mg fertilization; the yield declined to 3.32-3.7 g/pot (3.56 g/pot) where Mg was not applied. The RY (%) in the medium soil Mg ranged 92-93% (average 92.75%).

The pots with high soil Mg had mustard dry matter yield of 3.84-4.16 g/pot (4.02 g/pot) with soil test based Mg fertilization, whereas the yield in the without Mg fertilization pots ranged 3.61-3.32 g/pot (average 3.8 g/pot). The RY in the high Mg soils ranged 94-96% (average 94.5%) (Table 61).

The exchangeable Mg content in soil plotted against the relative yield of mustard grown in those soils produced the critical limit 0.55 meq/100 g soil (Figure 39) and 0.31 meq/100 g soil in statistical method (Table 64) which was previously determined as 0.5 meq/100 g soil (FRG 2018). A soil Mg status of 0.64 meq/100g of soil was critical limit of soil magnesium in tomato crop as reported by Asiegbu and Uzo, 1983.

The critical limit of tissue Mg content in mustard plant 0.72 % in both graphical (Figure 40) and statistical method (Table 65)

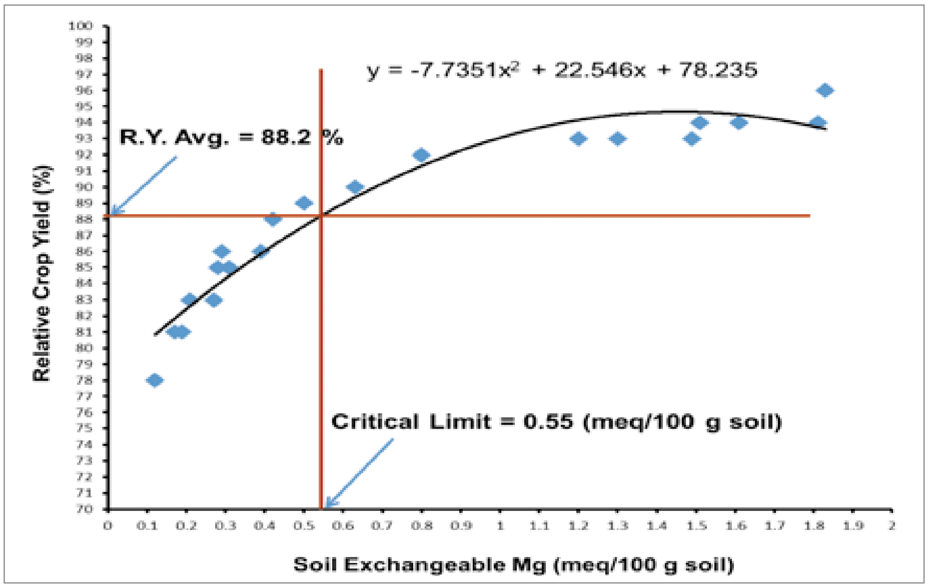


Figure 39: Critical Limit of Mg for mustard soil in Bangladesh, DSS, BAU, 2019-20

Table 64: Soil available Mg, Bray's percent yield and predictability values (R2) of mustard, BAU, Mymensingh during 2019-20

Sl. No.	Soil available Mg (meq/100 g soil)	Bray's % yield	Mean Bray's % yield in population –I	Corrected sum of squares of deviation from mean of population CSS-I	Mean Bray's % yield in population -II	Corrected sum of squares of deviation from mean of population CSS-II	R2 TSS - (CSSI-CSSII) /TSS
1	0.12	78	79.26	5.762	89	346.45	0.976048
2	0.17	81	79.93	8.436	90	278.28	0.980502
3	0.19	81	80.79	17.339	90	234.96	0.982843
4	0.21	83	81.32	22.962	91	186.82	0.985734
5	0.27	83	81.96	35.286	91	155.11	0.987052
6	0.28	85	82.58	51.174	91	131.03	0.98761
7	0.29	86	82.92	57.689	92	91.32	0.989867
8	**0.31**	**85**	**83.31**	**68.616**	**92**	**59.04**	**0.991319**
9	0.39	86	83.81	91.712	93	41.57	0.990936
10	0.42	88	84.26	113.695	93	23.56	0.990666
11	0.50	89	84.73	142.611	94	11.11	0.989546
12	0.63	90	85.29	191.813	94	8.22	0.986397
13	0.80	92	85.83	244.401	94	6.98	0.982905
14	1.20	93	86.33	296.639	94	6.38	0.979394
15	1.30	93	86.72	334.162	95	3.53	0.977035
16	1.49	93	87.14	381.632	95	2.85	0.973853
17	1.51	94	87.53	428.184	95	2.29	0.970726
18	1.61	94	87.87	468.019	96		
19	1.81	94	88.29				
20	1.83	96					
				SS	156423.3		
				CF	141718.3		
				TSS	14705		

Photo 34: Pot trial on the effect of Mg on mustard plant, DSS, BAU, 2019-20

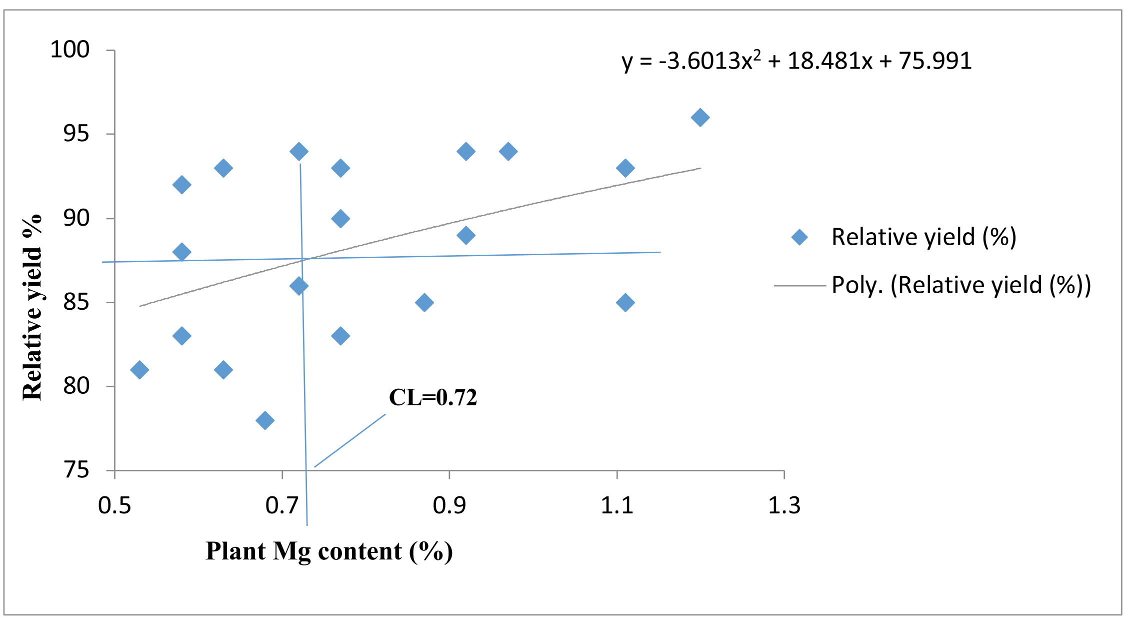


Figure 40: Scatter diagram showing relationship between Bray's per cent yield and tissue Mg concentration in mustard plant

Table 65: Tissue Mg content, Bray's % yield and predictability values (R2) of mustard plant, BAU, Mymensingh during 2019-20

Sl. No.	Tissue Mg content in mustard plant (%)	Bray's % yield	Mean Bray's % yield in population –I	Corrected sum of squares of deviation from mean of population CSS-I	Mean Bray's % yield in population –II	Corrected sum of squares of deviation from mean of population CSS-II	R2 TSS - (CSSI-CSSII) /TSS
1	0.53	81	82	2.00	89	453.78	0.969
2	0.58	83	84	26.00	89	452.94	0.967
3	0.58	88	86	74.00	89	443.00	0.965
4	0.58	92	85	94.00	89	378.93	0.968
5	0.63	81	86.33	147.33	89	364.00	0.965
6	0.63	93	85.14	206.86	90	233.69	0.970
7	0.68	78	85.25	207.50	90	217.67	0.971
8	**0.72**	**86**	**85.33**	**208.00**	**91**	**198.73**	**0.972**
9	0.72	86	86.2	275.60	90	185.60	0.969
10	0.72	94	85.91	284.91	91	128.00	0.972
11	0.77	83	86.25	300.25	91	126.88	0.971
12	0.77	90	86.77	342.31	91	122.86	0.968
13	0.77	93	86.64	345.21	92	82.83	0.971
14	0.87	85	86.8	350.40	92	73.20	0.971
15	0.92	89	87.25	399.00	92	70.00	0.968
16	0.92	94	87.65	441.88	91	64.67	0.966
17	0.97	94	87.5	448.50	95	4.50	0.969
18	1.11	85	87.79	477.16	96		
19	1.11	93	88.2				
20	1.2	96					
				SS	156126		
				CF	141440.7		
				TSS	14685.27		

Relative yield and Critical Limit of B for wheat

Dry matter yield of wheat at low soil B ranged between 3.65-4.67 g/pot (average 4.19 g/pot) with B fertilization; the yield declined to 2.87-4.08 g/pot (average 3.51 g/pot) in the pots without Mg fertilization (Table 66). The RY in the low B soils ranged 76-87 % (average 83.5%).

In the pots with medium soil B, the dry matter yield of wheat ranged between 4.42-4.85 g/pot (average 4.68 g/pot) with B fertilization; the yield declined to 4.01-4.36 g/pot (4.19 g/pot) where S was not applied. The RY (%) in the medium soil B ranged 89-91 % (average 89.75%).

The pots with high soil B had wheat dry matter yield of 4.43-4.82 g/pot (4.64 g/pot) with soil test based B fertilization, whereas the yield in the without Mg fertilization pots ranged 4.15-4.47 g/pot (average 4.31 g/pot). The RY in the high B soils ranged 92-94% (average 93%) (Table 66).

Table 66: Relative yield of wheat and mustard with and without B at BAU during 2019-20.

Soil sample No.	Sample name	Avail.B (ppm)	Wheat			Mustard		
			Dry matter yield (g/pot)		Relative yield (%)	Dry matter yield (g/pot)		Relative yield (%)
			With B	Without B		With B	Without B	
Low B								
1.	BAU 87	0.07	3.65	2.87	79	3.83	3.02	79
2.	BINA 29	0.045	3.96	3.02	76	3.92	3.02	77
3.	BAU 168	0.15	4.02	3.42	85	4.06	3.45	85
4.	BAU 74	0.08	3.77	3.01	80	3.91	3.16	81
5.	BAU 109	0.09	4.24	3.49	82	3.99	3.25	81
6.	BINA 2	0.13	4.21	3.55	84	3.96	3.28	83
7.	BAU 152	0.15	4.43	3.81	86	3.90	3.37	86
8.	BAU 13	0.2	4.32	3.67	85	4.05	3.49	86
9.	BAU 42	0.23	4.33	3.78	87	3.90	3.41	87
10.	BAU 36	0.24	4.39	3.72	85	3.79	3.29	87
11.	BAU 79	0.28	4.67	4.08	87	3.92	3.51	89
12.	BAU 112	0.28	4.30	3.68	86	3.86	3.39	88
Average			4.19	3.51	83.5	3.92	3.3	84.08
Medium B								
13.	BAU 124	0.36	4.63	4.14	89	3.79	3.40	90
14.	BAU 16	0.39	4.85	4.36	90	3.75	3.39	90
15.	BAU 151	0.4	4.80	4.26	89	3.81	3.48	91
16.	BAU 45	0.47	4.42	4.01	91	3.85	3.51	91
Average			4.68	4.19	89.75	3.8	3.45	90.5
High B								
17.	BAU 104	0.67	4.75	4.36	92	3.97	3.69	93
18.	BAU 37	0.71	4.82	4.47	93	3.91	3.63	93
19.	BAU 43	0.94	4.43	4.15	94	3.84	3.63	94
20.	BAU 3	0.98	4.57	4.25	93	3.88	3.55	91
Average			4.64	4.31	93	3.9	3.63	92.75

When the data were presented for wheat yield and soil available B content the critical limit came out 0.3 mg/kg (Figure 41) and 0.28 ppm in statistical method (Table 67) which was reported earlier as 0.2 mg/kg (FRG 2018). Ascher- Ellis *et al.* (2001) found that if the amount of B in soil is less than 0.5 mg/kg, symptom of B deficiency will appear in wheat crop. Feiziasl *et al.* (2009) recorded the critical limit of B in soil as 0.56 mg/kg for grain yield of dry land wheat.

The critical limit of plant tissue B in wheat was found out 9.8 mg/kg in graphical method (Figure 42) and 9.54 mg/kg in statistical method (Table 68).

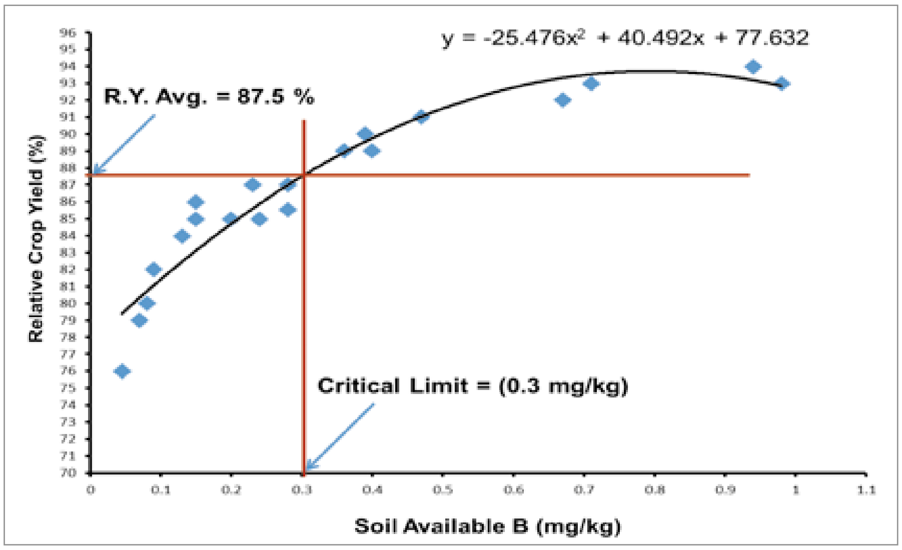


Figure 41: Critical Limit of B for wheat in Bangladesh, DSS, BAU, 2019-20

Table 67: Soil available B, Bray's % yield and predictability values (R2) of wheat, BAU, Mymensingh during 2019-20

Sl. No.	Soil available B (ppm)	Bray's % yield	Mean Bray's % yield in population –I	Corrected sum of squares of deviation from mean of population CSS-I	Mean Bray's % yield in population –II	Corrected sum of squares of deviation from mean of population CSS-II	R2 TSS - (CSSI-CSSII) /TSS
1	0.045	76	77.50	4.50	88	269.78	0.981
2	0.07	79	78.33	8.67	88	207.97	0.985
3	0.08	80	79.25	18.75	88	168.57	0.987
4	0.09	82	80.20	36.80	89	147.25	0.987
5	0.13	84	81.00	56.00	89	132.03	0.987
6	0.15	85	81.71	77.43	89	122.10	0.986
7	0.15	86	82.13	86.88	90	102.33	0.987
8	0.2	85	82.67	108.00	90	94.80	0.986
9	0.23	87	82.90	112.90	90	68.75	0.987
10	0.24	85	83.27	128.18	91	56.26	0.987
11	**0.28**	**87**	**83.46**	**132.84**	**91**	**25.88**	**0.989**
12	0.28	86	83.89	161.17	92	19.43	0.987
13	0.36	89	84.32	195.87	92	16.00	0.985
14	0.39	90	84.64	216.28	93	5.20	0.984
15	0.4	89	85.03	254.26	93	2.00	0.982
16	0.47	91	85.44	299.95	93	0.67	0.979
17	0.67	92	85.86	353.88	94	0.50	0.975
18	0.71	93	86.29	416.61	93		
19	0.94	94	86.63				
20	0.98	93					
				SS	150542		
				CF	136438.8		
				TSS	14103.25		

Critical limit of B content of wheat plant

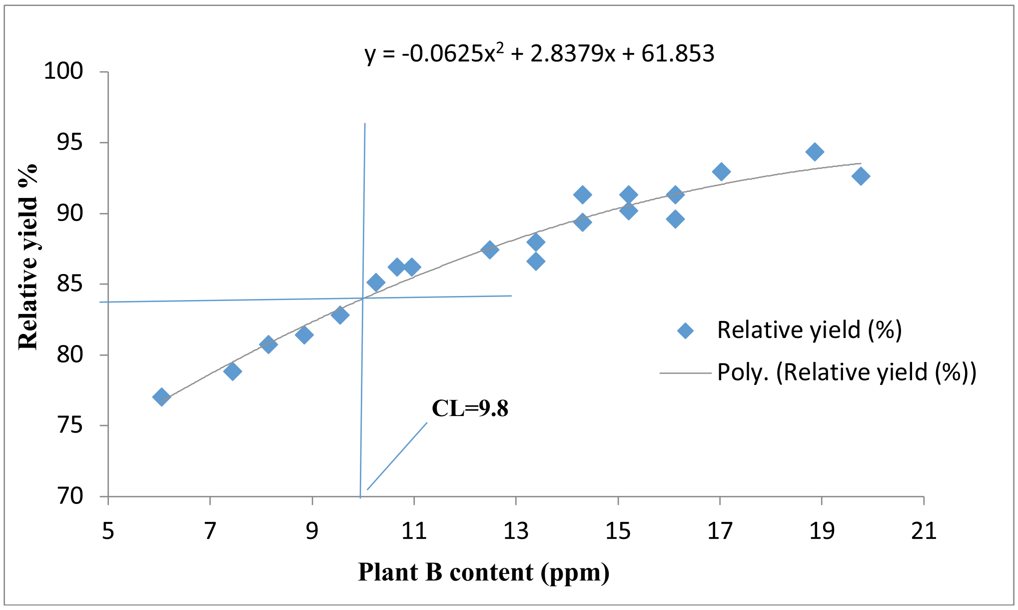


Figure 42: Scatter diagram showing relationship between Bray's per cent yield and tissue boron concentration in wheat plant

Table 68: Tissue B content, Bray's % yield and predictability values (R2) of wheat plant, BAU, Mymensingh during 2019-20

Sl. No.	Tissue B content in wheat plant (ppm)	Bray's % yield	Mean Bray's % yield in population –I	Corrected sum of squares of deviation from mean of population CSS-I	Mean Bray's % yield in population – II	Corrected sum of squares of deviation from mean of population CSS-II	R2 TSS - (CSSI-CSSII) /TSS
1	6.04	77	77.96	1.637	88	267.57	0.981
2	7.44	79	78.89	6.806	89	208.50	0.985
3	8.14	81	79.53	11.664	89	153.11	0.988
4	8.84	81	80.19	20.446	90	111.22	0.991
5	9.54	83	81.01	40.744	90	90.48	0.991
6	10.25	85	81.76	64.182	90	76.54	0.990
7	10.66	86	82.32	81.818	90	60.34	0.990
8	10.95	86	82.89	105.056	91	50.49	0.989
9	12.48	87	83.27	117.728	91	32.26	0.989
10	13.39	87	83.70	137.981	91	21.34	0.989
11	13.39	88	84.17	167.602	92	16.43	0.987
12	14.3	89	84.72	214.951	92	16.25	0.984
13	14.3	91	85.11	243.153	92	13.42	0.982
14	15.21	90	85.53	279.273	92	12.82	0.980
15	15.21	91	85.78	295.053	93	4.64	0.979
16	16.12	90	86.11	324.000	93	1.64	0.977
17	16.12	91	86.49	368.137	94	1.42	0.974
18	17.03	93	86.91	426.841	93		
19	18.85	94	87.19				
20	19.76	93					
				SS	152512.5		
				CF	138231		
				TSS	14281.56		

Photo 35: Pot trial on the effect of B on mustard plant, DSS, BAU, 2019-20

Relative yield and Critical Limit of B for mustard

Dry matter yield of mustard at low soil B ranged between 3.79-4.06 g/pot (average 3.92 g/pot) with B fertilization; the yield declined to 3.02-3.51 g/pot (average 3.3 g/pot) in the pots without Mg fertilization (Table 66). The RY in the low B soils ranged 77-89 % (average 84.08%).

In the pots with medium soil B, the dry matter yield of mustard ranged between 3.75-3.85 g/pot (average 3.8 g/pot) with B fertilization; the yield declined to 3.39-3.51 g/pot (3.45 g/pot) where S was not applied. The RY (%) in the medium soil B ranged 90-91 % (average 90.5%).

The pots with high soil B had mustard dry matter yield of 3.84-3.97 g/pot (3.9 g/pot) with soil test based B fertilization, whereas the yield in the without Mg fertilization pots ranged 3.58-3.69 g/pot (average 3.63 g/pot). The RY in the high B soils ranged 91-94% (average 92.75%) (Table 66).

When the data were presented for mustard yield and soil available B content the critical limit came out 0.25 mg/kg (Figure 43) and 0.13 mg/kg in statistical method (Table 69) which was reported earlier as 0.2 mg/kg (FRG 2018). Rashid and Rafique (1992) indicated that the critical limit of hot water-B was 0.50 mg/kg soil for eight-week old mustard plants grown on a B-deficient (HW-B 0.23 mg/kg) soil. Sims and Johnson (1991) expressed that B critical limits are 0.1-2.0 mg/kg for different crop plants.

The critical limit of plant tissue B content in mustard came out 24 mg/kg in both graphical (Figure 44) and statistical method (Table 70).

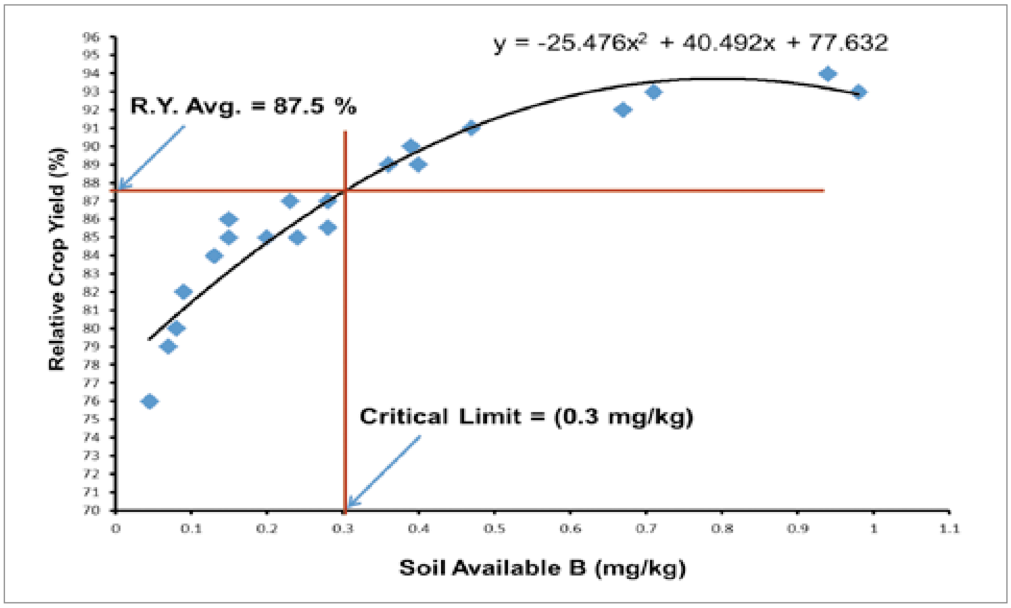


Figure 43: Critical Limit of B for mustard in Bangladesh, DSS, BAU, 2019-20

Table 69: Soil available B, Bray's % yield and predictability values (R2) of mustard, BAU, Mymensingh during 2019-20

Sl. No.	Soil available B (ppm)	Bray's % yield	Mean Bray's % yield in population –I	Corrected sum of squares of deviation from mean of population CSS-I	Mean Bray's % yield in population –II	Corrected sum of squares of deviation from mean of population CSS-II	R2 TSS - (CSSI-CSSII) /TSS
1	0.045	77	77.79	2.923	88	262.42	0.981
2	0.07	79	78.86	9.787	89	208.58	0.985
3	0.08	81	79.40	13.219	89	148.02	0.989
4	0.09	81	80.12	23.613	89	109.34	0.991
5	**0.13**	**83**	**80.93**	**43.487**	**90**	**88.37**	**0.991**
6	0.15	85	81.70	68.661	90	76.00	0.990
7	0.15	86	82.24	84.805	90	58.67	0.990
8	0.2	86	82.77	104.932	91	46.55	0.989
9	0.23	87	83.19	121.034	91	32.00	0.989
10	0.24	87	83.72	151.688	91	27.56	0.987
11	0.28	89	84.08	168.471	92	15.88	0.987
12	0.28	88	84.53	200.847	92	12.86	0.985
13	0.36	90	84.92	228.598	92	8.83	0.983
14	0.39	90	85.33	263.058	92	7.20	0.981
15	0.4	91	85.68	293.210	93	4.75	0.979
16	0.47	91	86.11	343.596	93	4.67	0.976
17	0.67	93	86.50	388.384	93	4.50	0.972
18	0.71	93	86.89	441.727	91		
19	0.94	94	87.10				
20	0.98	91					
				SS	152174.1		
				CF	137924		
				TSS	14250.16		

Critical limit of B content of mustard plant

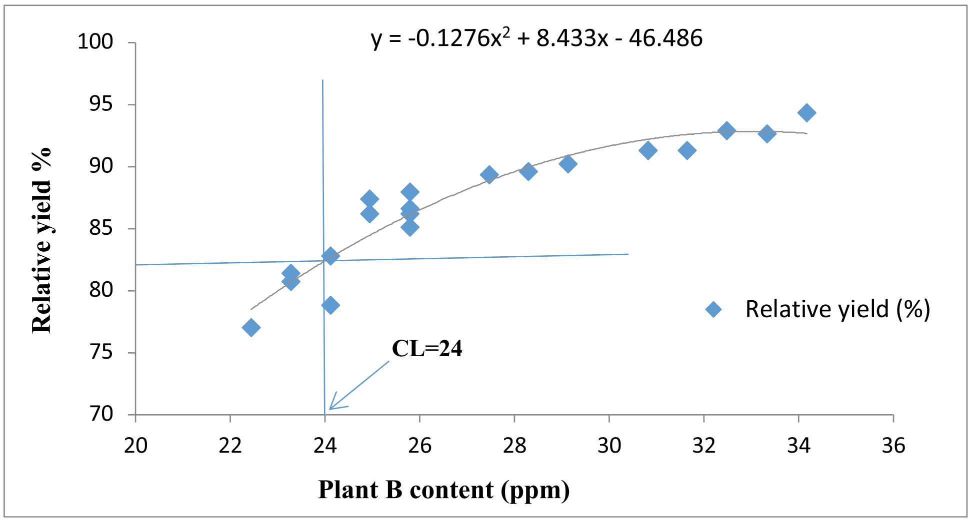


Figure 44: Scatter diagram showing relationship between Bray's per cent yield and tissue B concentration in mustard plant, DSS, BAU, 2019-20

Table 70: Tissue B content, Bray's % yield and predictability values (R2) of mustard plant, BAU, Mymensingh during 2019-20

Sl. No.	Tissue B content in mustard plant (ppm)	Bray's % yield	Mean Bray's % yield in population –I	Corrected sum of squares of deviation from mean of population CSS-I	Mean Bray's % yield in population –II	Corrected sum of squares of deviation from mean of population CSS-II	R2 TSS - (CSSI-CSSII) /TSS
1	22	77	78.90	6.81	88	298.99	0.978588
2	23	81	79.75	11.08	89	251.80	0.981593
3	23	81	79.53	11.66	89	153.11	0.988462
4	**24**	**79**	**80.19**	**20.45**	**90**	**111.22**	**0.990781**
5	24	83	81.20	51.04	90	99.72	0.989444
6	25	86	82.09	84.35	90	93.90	0.987519
7	25	87	82.47	92.41	90	68.80	0.988712
8	26	85	82.89	105.06	91	50.49	0.989109
9	26	86	83.27	117.73	91	32.26	0.989498
10	26	87	83.70	137.98	91	21.34	0.988844
11	26	88	84.17	167.60	92	16.43	0.987114
12	27	89	84.59	195.14	92	11.40	0.985538
13	28	90	84.99	224.70	92	7.62	0.983733
14	29	90	85.41	262.20	93	6.42	0.981191
15	31	91	85.78	295.05	93	4.64	0.979016
16	31	91	86.11	324.00	93	1.64	0.977198
17	32	91	86.49	368.14	94	1.42	0.974123
18	32	93	86.82	404.37	94		
19	33	93	87.19				
20	34	94					
				SS	152512.5		
				CF	138231		
				TSS	14281.56		

Expt. 3: Verification of Estimated Critical Limits through Field Trial at the Farmers' Field

Expt. 3.1: Response of cereal and vegetable crops to K and Zn applications (Field experiment)

BARI Component

Validation experiments have been done at three locations. Twelve experiments were carried out in soils of medium and low fertility.

Locations : Locations were selected within AEZ 11, 13 and 28 on the basis of soil analytical results.

Crops : Cereals–wheat and maize, Vegetables- Cabbage

Treatments

For K

T_1: 0 K
T_2: 50% STB of K
T_3: 75% STB of K
T_4: 100% STB of K
T_5: 125% STB of K
T_6: 150% STB of K

For Zn

T_1: 0 Zn
T_2: 50% STB of Zn
T_3: 75% STB of Zn
T_4: 100% STB of Zn
T_5: 125% STB of Zn
T_6: 150% STB of Zn

Design: Randomized Complete Block Design (RCBD)

Before establishment of the experiment soils were collected for determining initial properties of soils namely texture, pH, OC, total N, available P, K, S, Mg, Zn & B. The data were also collected on the following parameters:

(i) Crop yield (main product and by-product)
(ii) Nutrient concentration of main product and by-product.
(iii) Nutrient uptake by crops (by calculation from nutrient concentration and crop yield).

Response of wheat to applied K

The response of wheat to K was significant ($p<0.05$). Though the highest yield was recorded from 150% of K dose but the differences among 100% RDCF, 125% RDCF and 150% RDCF were insignificant (Table 71). The highest response validation experiment conducted in the medium and low fertile soils at Chowgacha and Rajshahi showed that the critical limit determined by pot experiments following Cate and Nelson Method reflected the present fertility status of soil. The R^2 value also showed that the polynomial model fit was significant for response of wheat to different rate of K at two locations (Figure 45 & 46). The wheat crop responded the best to 100% RDCF dose of K which was determined according to newly developed CL of K for wheat crop. The R^2 value also showed that the polynomial model fit was significant (Figure 45 & 46).

Table 71. Response of wheat to different potassium rates determined based on revised critical limit. The experiment was conducted at medium fertile soil at Jashore and low fertile soils at Rajshahi by SSD, BARI, Gazipur during 2020-21

Treatments			Wheat grain yield (t/ha)		Wheat straw yield (t/ha)	
% of STB dose	Kg K ha^{-1} (Jashore)	Kg K ha^{-1} (Rajshahi)	Jashore	Rajshahi	Jashore	Rajshahi
K0%	0	0	3.51	3.22	4.44	4.36
K50%	38	48	4.20	3.79	4.83	4.83
K75%	56	71	4.49	3.92	4.94	5.10
K100%	75	95	4.88	4.37	5.65	5.50
K125%	94	119	4.92	4.65	5.80	5.90
K150%	113	143	4.96	4.78	5.83	5.95
$LSD_{0.05}$			0.28	0.48	0.31	0.70
CV (%)			7.12	4.54	6.89	5.44

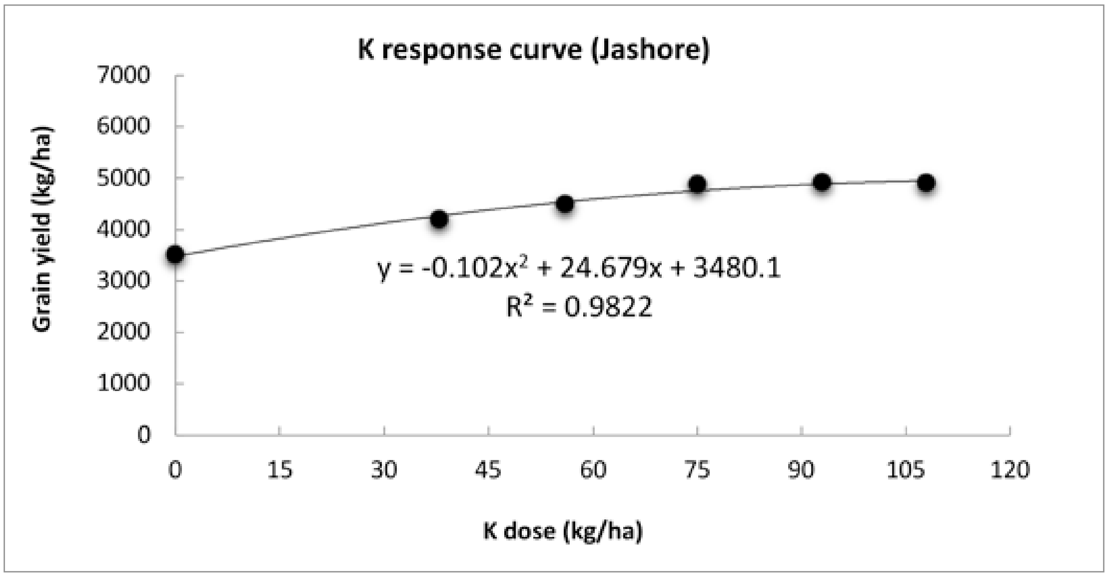


Figure 45. Response of wheat to different potassium rates determined based on revised critical limit. The experiment was conducted at medium fertile soil of Jashore by SSD, BARI, Gazipur during 2020-21

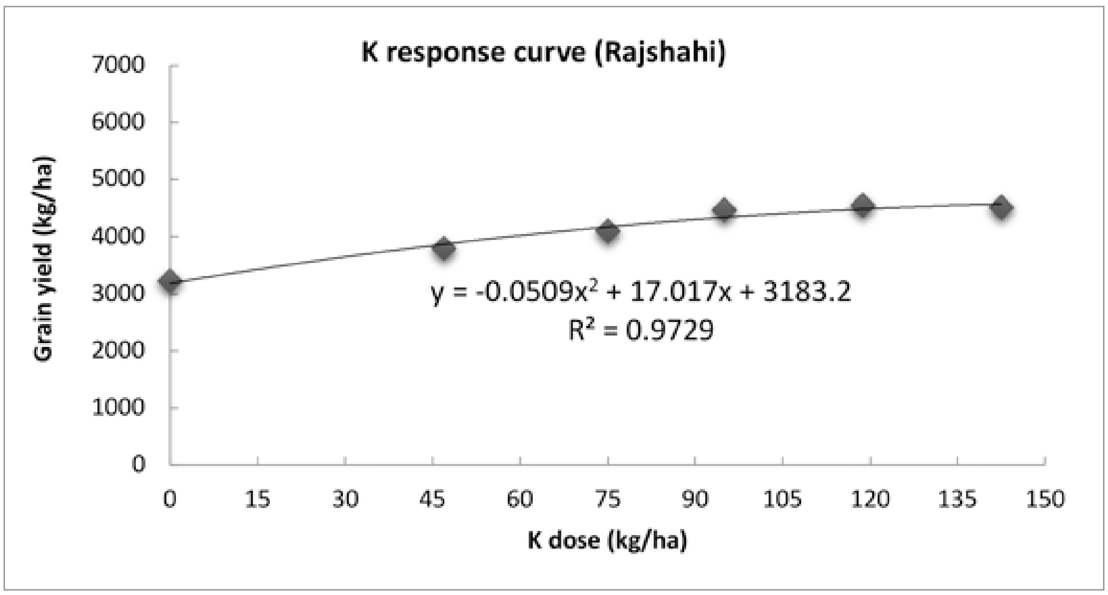


Figure 46. Response of wheat to different potassium rates determined based on revised critical limit. The experiment was conducted at low fertile soils of Rajshahi by SSD, BARI, Gazipur during 2020-21

Response of cabbage to applied K

The response of cabbage to K was significant ($p<0.05$). Though the highest yield was recorded from 150% of K dose but the differences among 100% RDCF, 125% RDCF and 150% RDCF were insignificant (Table 72). The highest response validation experiment conducted in the medium and low fertile soils at Chowgacha and Rajshahi showed that the critical limit determined by pot experiments following Cate and Nelson Method reflected the present fertility status of soil. However, the response of cabbage was more prominent in low fertile soils than in medium fertile soils. The R^2 value also showed that the polynomial model fit was significant for response of cabbage to different rate of K at two locations (Figure 47).

Table 72. Response of cabbage to different potassium rates determined based on revised critical limit. The experiment was conducted at medium fertile soil at Jashore and low fertile soils at Gazipur by SSD, BARI, Gazipur during 2020-21

Treatment (K rate)			Marketable cabbage head yield (t/ha)	
% of STB dose	kg K ha^{-1} (Jashore)	kg K ha^{-1} (Gazipur)	Jashore	Gazipur
K0%	0	0	64.4	58.1
K50%	37.5	50	74.8	71.1
K75%	56.3	75	86.7	74.4
K100%	75.0	100	94.2	88.1
K125%	93.8	125	94.8	90.4
K150%	112.5	150	95.2	90.7
$LSD_{0.05}$			3.65	2.84
CV (%)			7.41	6.80

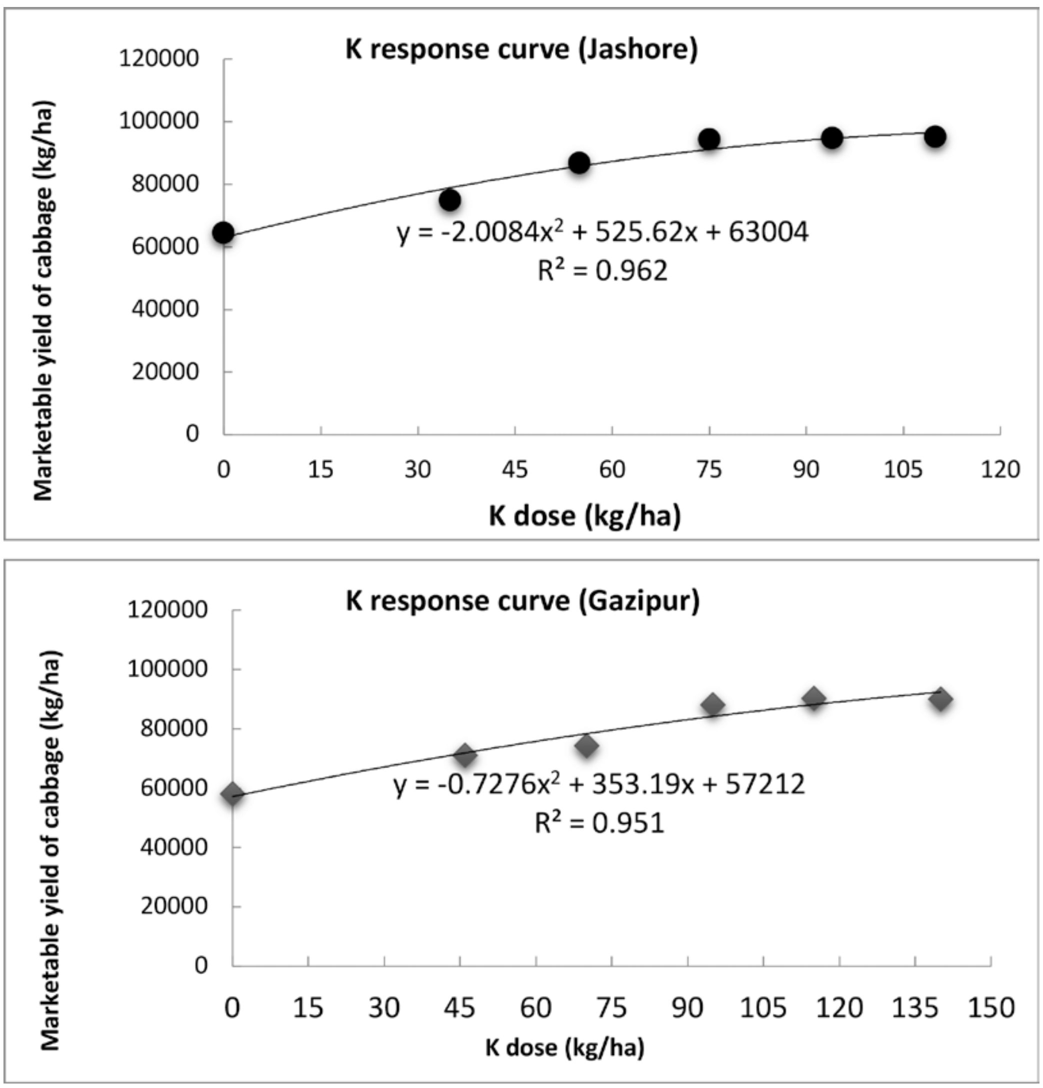


Figure 47. Response of vabbage to different potassium rates determined based on revised critical limit. The experiment was conducted at medium fertile soil at Jashore by SSD, BARI, Gazipur during 2020-21

Response of maize to applied K

The response of maize to K was significant ($p<0.05$). Though the highest yield was recorded from 100% of K dose but the differences among 100% RDCF, 125% RDCF and 150% RDCF were insignificant (**Table 73)**. The highest response validation experiment conducted in the medium and low fertile soils at Chowgacha and Rajshahi showed that the critical limit determined by pot experiments following Cate and Nelson Method reflected the present fertility status of soil. The R^2 value also showed that the polynomial model fit was significant for response of maize to different rate of K at two locations (Figure 48 & 49).

Table 73. Response of maize to different potassium rates determined based on revised critical limit. The experiment was conducted at medium fertile soil at Jashore and low fertile soils at Rajshahi by SSD, BARI, Gazipur during 2020-21

Treatment (K rate)			Maize grain yield (t/ha)		Maize straw yield (t/ha)	
% of STB dose	Kg K ha^{-1} (Jashore)	Kg K ha^{-1} (Rajshahi)	Jashore	Rajshahi	Jashore	Rajshahi
K0%	0.0	0.0	7.20	6.12	9.05	8.00
K50%	45.0	55.0	7.71	7.02	9.36	9.02
K75%	67.5	82.5	7.95	7.60	9.61	9.58
K100%	90.0	110.0	8.85	8.41	10.76	10.26
K125%	112.5	137.5	8.97	8.43	11.27	10.28
K150%	135.0	165.0	9.04	8.41	11.34	10.26
$LSD_{0.05}$					0.48	0.81
CV (%)					7.62	5.81

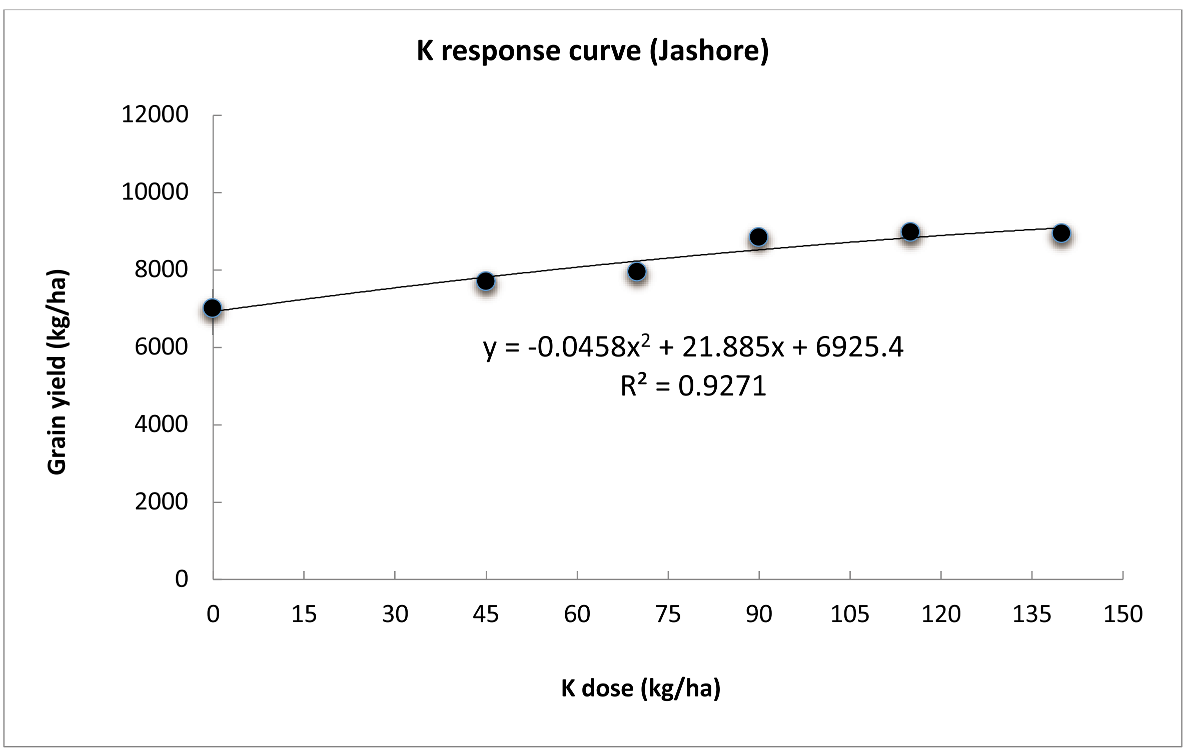


Figure 48. Response of maize to different potassium rates determined based on revised critical limit. The experiment was conducted at medium fertile soil of Jashore by SSD, BARI, Gazipur during 2020-21

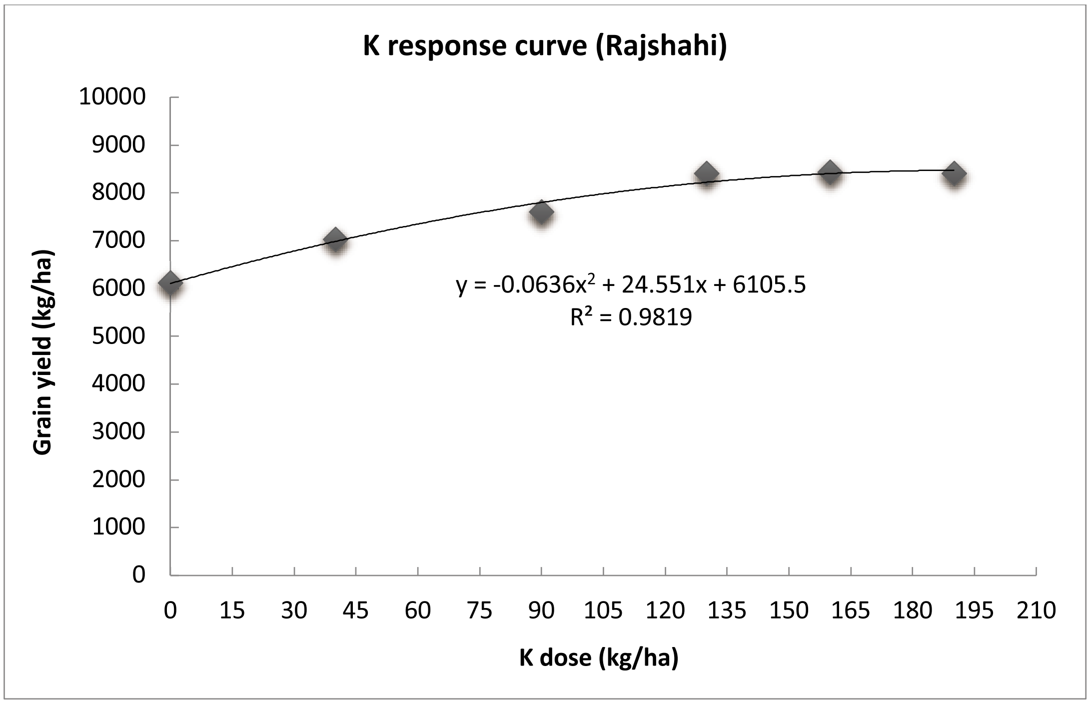


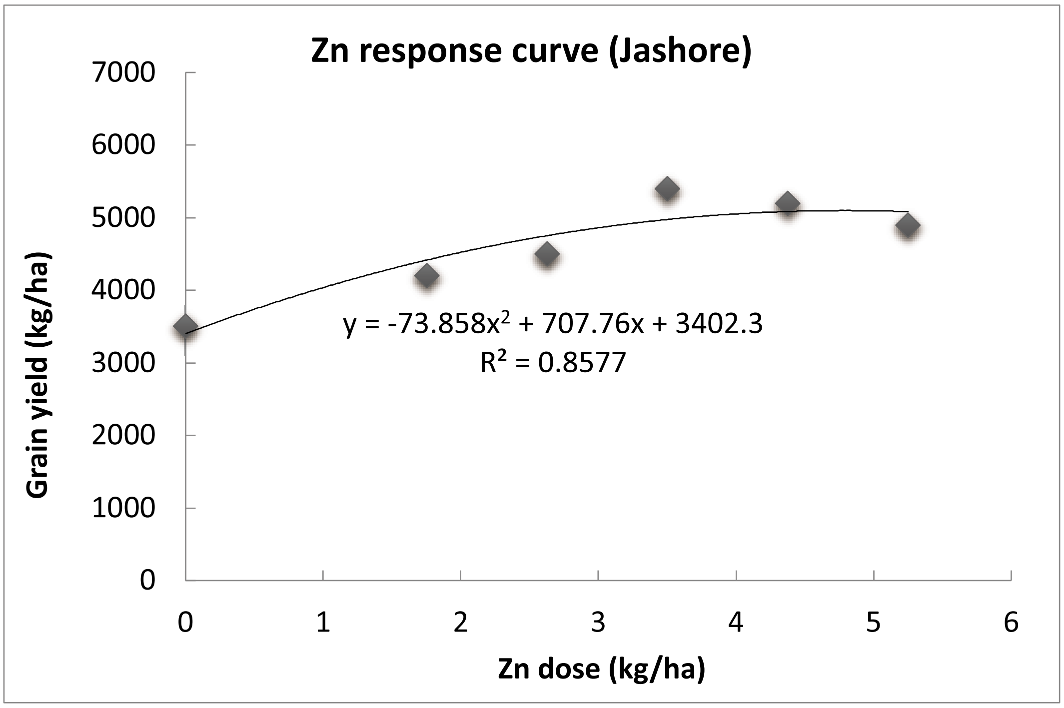
Figure 49. Response of maize to different potassium rates determined based on revised critical limit. The experiment was conducted at medium fertile soil at low fertile soils of Rajshahi by SSD, BARI, Gazipur during 2020-21

Response of wheat to applied Zn

The response of wheat to Zn was significant ($p<0.05$). In the low fertile soil, the response was more conspicuous than the response in medium fertile soil. Though the highest yield was recorded from 100% of Zn dose but the differences among 100% RDCF, 125% RDCF and 150% RDCF were insignificant (Table 74). The highest response validation experiment conducted in the medium and low fertile soils at Chowgacha and Rajshahi showed that the critical limit determined by pot experiments following Cate and Nelson Method reflected the present fertility status of soil. The R^2 value also showed that the polynomial model fit was significant for response of maize to different rate of Zn at two locations (Figure 50).

Table 74. Response of wheat to different potassium rates determined based on revised critical limit. The experiment was conducted at medium fertile soil at Jashore and low fertile soils at Rajshahi by SSD, BARI, Gazipur during 2020-21

Treatment (Zn rate)			Maize grain yield (t/ha)		Maize straw yield (t/ha)	
% of STB dose	Kg Zn ha^{-1} (Jashore)	kg Zn ha^{-1} (Rajshahi)	Jashore	Rajshahi	Jashore	Rajshahi
Zn 0%	0.0	0.0	3.51	3.10	4.20	3.80
Zn 50%	1.3	1.8	4.20	3.70	4.80	4.30
Zn 75%	1.9	2.6	4.50	3.98	5.10	4.80
Zn 100%	2.5	3.5	5.40	4.70	5.50	5.20
Zn 125%	3.1	4.4	5.20	4.85	5.80	5.63
Zn 150%	3.8	5.3	4.90	4.60	5.90	5.70
$LSD_{0.05}$			0.61	0.40	0.25	0.88
CV (%)			6.62	6.60	7.2	6.9



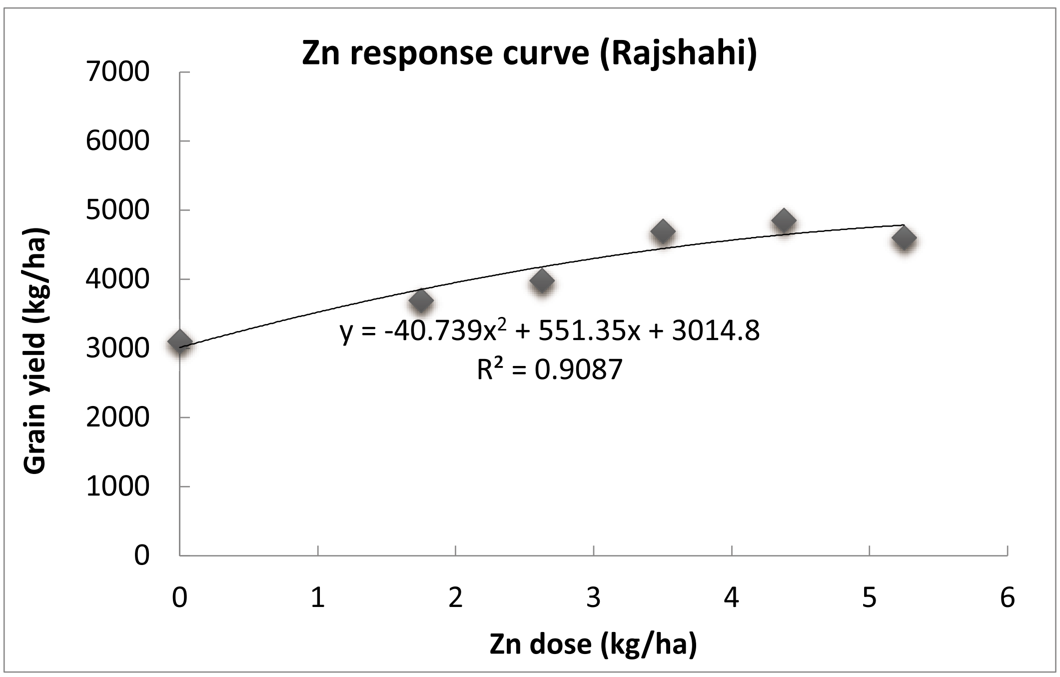


Figure 50. **Response of wheat to different potassium rates determined based on revised critical limit. The experiment was conducted at medium fertile soil at Jashore and low fertile soils at Rajshahi by SSD, BARI, Gazipur during 2020-21**

Response of cabbage to applied Zn

The response of cabbage to Zn was significant ($p<0.05$). Though the highest yield was recorded from 150% of K dose but the differences among 100% RDCF, 125% RDCF and 150% RDCF were insignificant (Table 75). The highest response validation experiment conducted in the medium and low fertile soils at Chowgacha and Gazipur showed that the critical limit determined by pot experiments following Cate and Nelson Method reflected the present fertility status of soil. However, the response of cabbage was more prominent in low fertile soils than in medium fertile soils. The R^2 value also showed that the polynomial model fit was significant for response of cabbage to different rate of Zn at two locations (Figure 51 & 52).

Table 75. Response of cabbage to different Zn rates determined on the basis of revised critical limit of the present study. The experiment was conducted at medium fertile soil at Jashore and low fertile soils at Gazipur by SSD, BARI, Gazipur during 2020-21

Treatment (Zn rate)			Marketable cabbage head yield (t/ha)	
% of STB dose	kg Zn ha^{-1} (Jashore)	kg Zn ha^{-1} (Gazipur)	Jashore	Gazipur
Zn0%	0.00	0.00	61.40	55.29
Zn50%	1.25	0.88	67.76	63.20
Zn75%	1.88	1.31	72.11	65.34
Zn100%	2.50	1.75	78.60	70.70
Zn125%	3.13	2.19	80.80	73.20
Zn150%	3.75	2.63	82.40	74.41
$LSD_{0.05}$			6.88	10.27
CV (%)			5.20	5.83

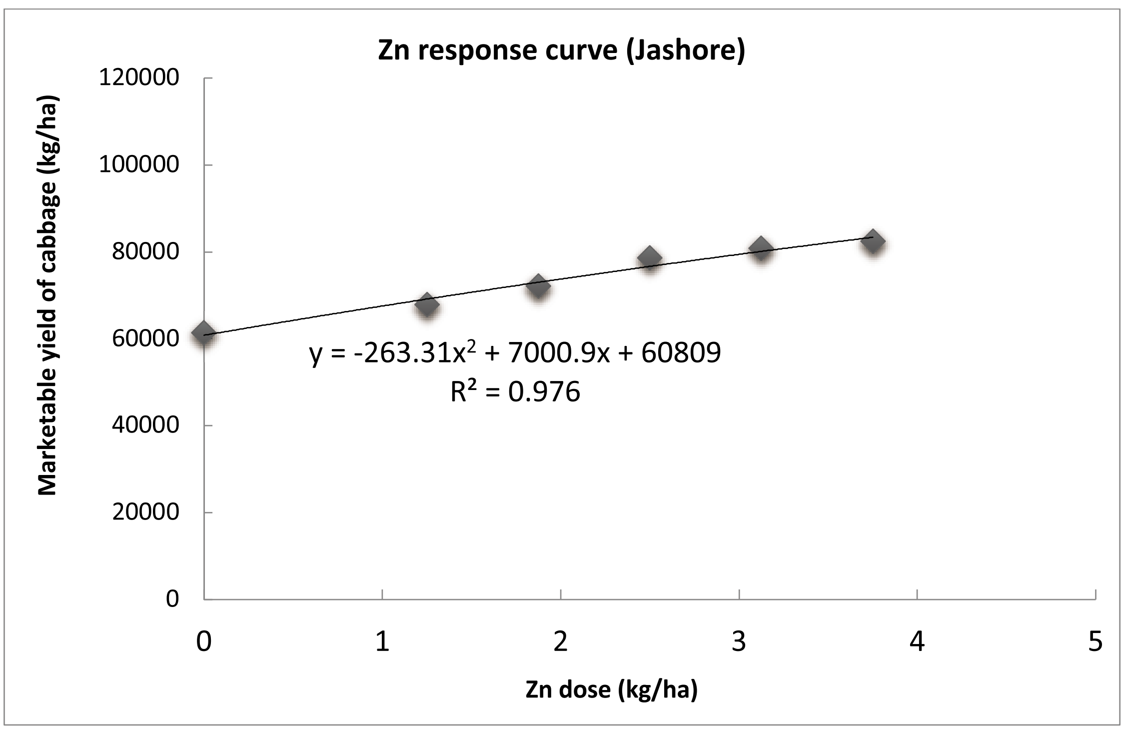


Figure 51. Response of cabbage to different Zn rates determined on the basis of revised critical limit of the present study. The experiment was conducted at medium fertile soil of Jashore by SSD, BARI, Gazipur during 2020-21

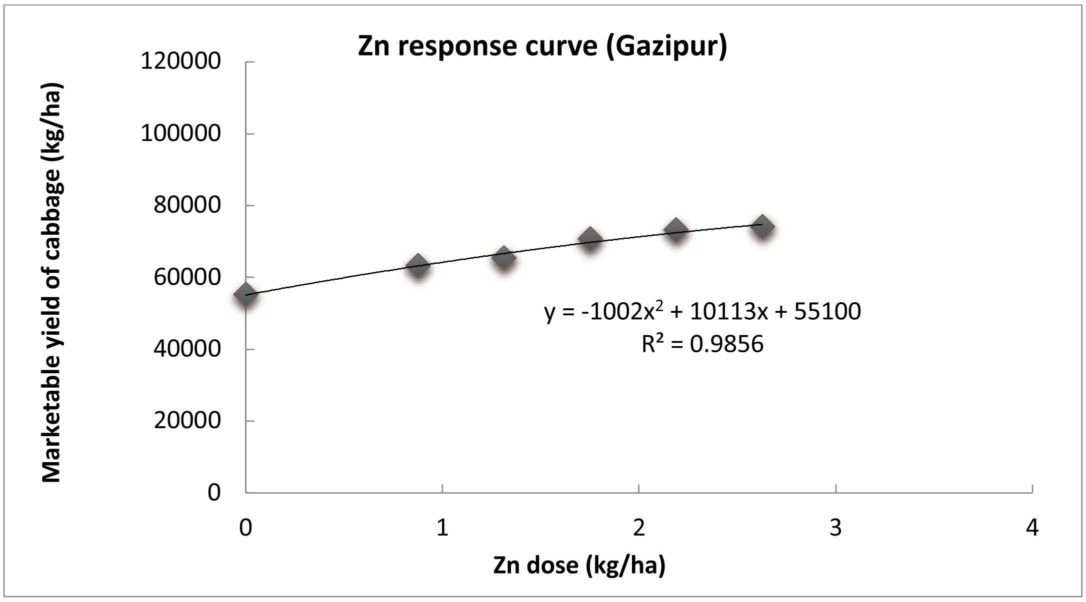


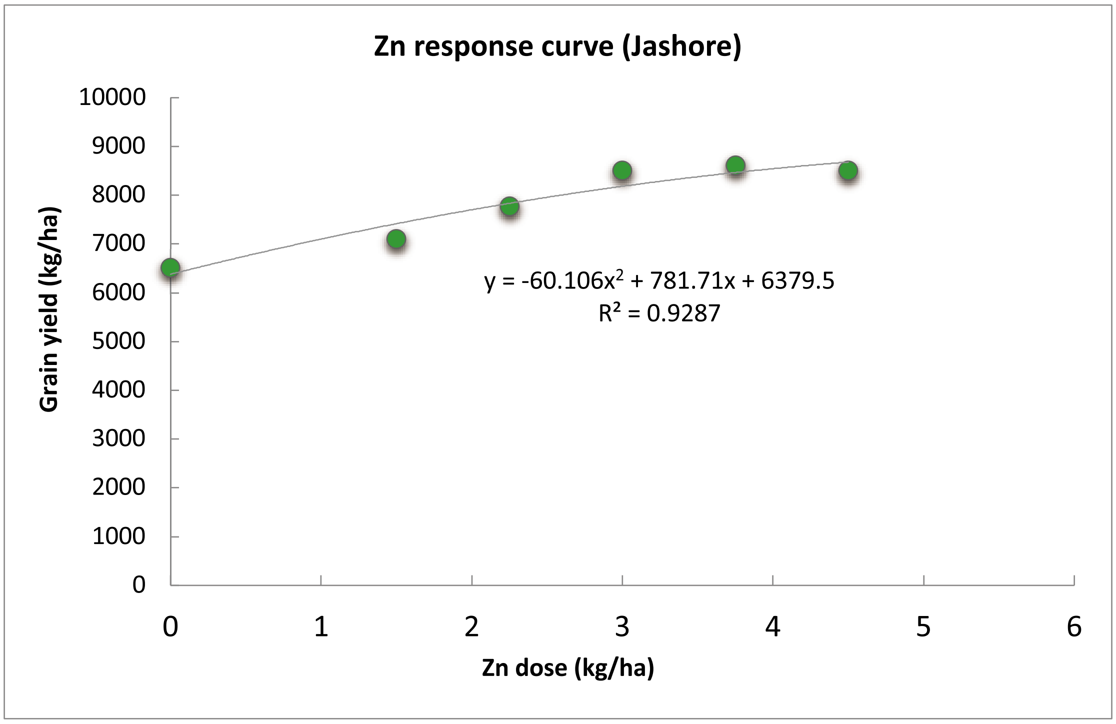
Figure 52. Response of cabbage to different Zn rates determined on the basis of revised critical limit of the present study. The experiment was conducted at low fertile soils of Gazipur by SSD, BARI, Gazipur during 2020-21

Response of maize to Zn

The response of maize to Zn was significant ($p<0.05$). In both the soils, the response was almost same but it was more conspicuous in low fertile soil than the response in medium fertile soil. Though the highest yield was recorded from 150% of Zn dose but the differences among 100% RDCF, 125% RDCF and 150% RDCF were insignificant (Table 76). The highest response validation experiment conducted in the medium and low fertile soils at Chowgacha and Rajshahi showed that the critical limit determined by pot experiments following Cate and Nelson Method reflected the present fertility status of soil. The R^2 value also showed that the polynomial model fit was significant for response of maize to different rate of Zn at two locations (Figure 53).

Table 76. Response of maize to different zinc rates determined based on revised critical limit. The experiment was conducted at medium fertile soil at Jashore and low fertile soils at Rajshahi by SSD, BARI, Gazipur during 2020-21

Treatment (Zn rate)			Maize grain yield (t/ha)		Maize straw yield (t/ha)	
% of STB dose	kg Zn ha^{-1} (Jashore)	kg Zn ha^{-1} (Rajshahi)	Jashore	Rajshahi	Jashore	Rajshahi
Zn 0%	0.0	0.0	6.50	5.40	8.10	7.20
Zn 50%	1.5	2.0	7.10	6.46	8.30	9.20
Zn 75%	2.3	3.0	7.76	6.75	9.20	9.50
Zn 100%	3.0	4.0	8.50	7.83	10.30	9.90
Zn 125%	3.8	5.0	8.60	8.08	10.90	10.80
Zn 150%	4.5	6.0	8.50	8.15	11.10	10.70
$LSD_{0.05}$			0.72	0.88	1.37	1.05
CV (%)			6.30	7.29	8.21	8.34



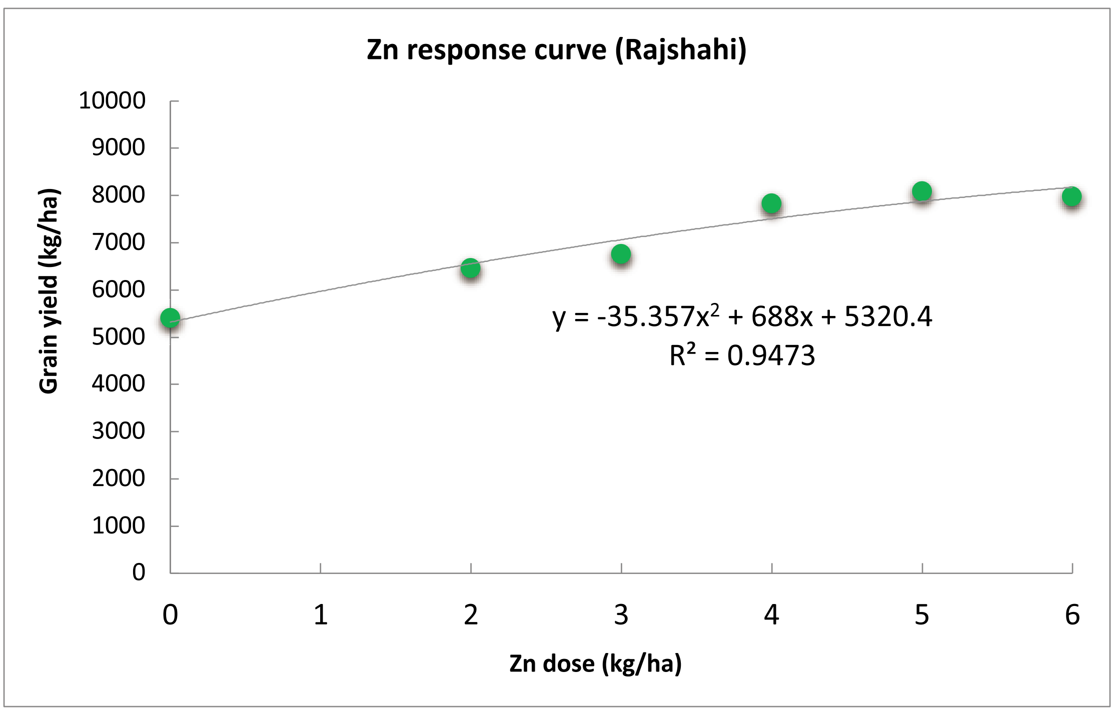


Figure 53. Response of maize to different zinc rates determined based on revised critical limit. The experiment was conducted at medium fertile soil at Jashore and low fertile soils at Rajshahi by SSD, BARI, Gazipur during 2020-21

Expt. 3.2: Response of rice crop to P, K, S and Zn applications (Four individual field experiment)

BRRI Component

Response of rice to phosphorus

The phosphorus response study was conducted in the P deficient soil of the respective farmers field at Khagail, Companiganj, Sylhet in Boro 2020-21 season. In the phosphorus response experiment, the six P doses were; P- 0, P-19, P-29, P-38, P-48 and P-57 kg ha^{-1}, respectively and the blanket fertilizer dose for N-K-S and Zn was 140-60-15 and 1 $kgka^{-1}$, respectively. The grain and straw yield are shown in Table 77. From the P response study, the grain yield increased significantly with increasing the P doses up to T4 treatment, where 100% STB P was applied and further increased the P doses, the grain yield decreased slightly. The highest grain yield (6.54 tha^{-1}) was obtained in T_4 treatment (100% STB P) which was significantly higher than T_2 (5.89 tha^{-1}) treatment. The T_3 (6.25 tha^{-1}), T_5 (6.46 tha^{-1}) and T_6 (6.37 tha^{-1}) treatment gave statistically similar grain yield to T_4. The P control plot yielded only 4.86 tha^{-1}. A similar yield trend was observed for obtained straw yield although higher P doses increased straw yield slightly. From the response curve the calculated optimum dose of P was found 42 $kgha^{-1}$ in the respective experimental field (Figure 54). An application of 40 mg P kg^{-1} soil was an optimum rate for soils deficient in P reported by Kalala et. al. (2016).

Table 77. Grain and straw yield of BRRI dhan28 in P response study at Companiganj, Sylhet, Boro 2020-21

P Treatment		Grain yield (tha^{-1})	Straw yield (tha^{-1})
% of STB dose	Kg P ha^{-1}		
T_1= P control	0.0	4.52	4.86
T_2= 50% STB P	19.0	5.89	6.10
T_3= 75% STB P	28.5	6.25	6.35
T_4= 100% STB P	38.0	6.54	6.65
T_5= 125% STB P	47.5	6.46	6.76
T_6= 150% STB P	57.0	6.37	6.77
LSD (0.05)		0.32	0.33
CV (%)		1.86	1.88

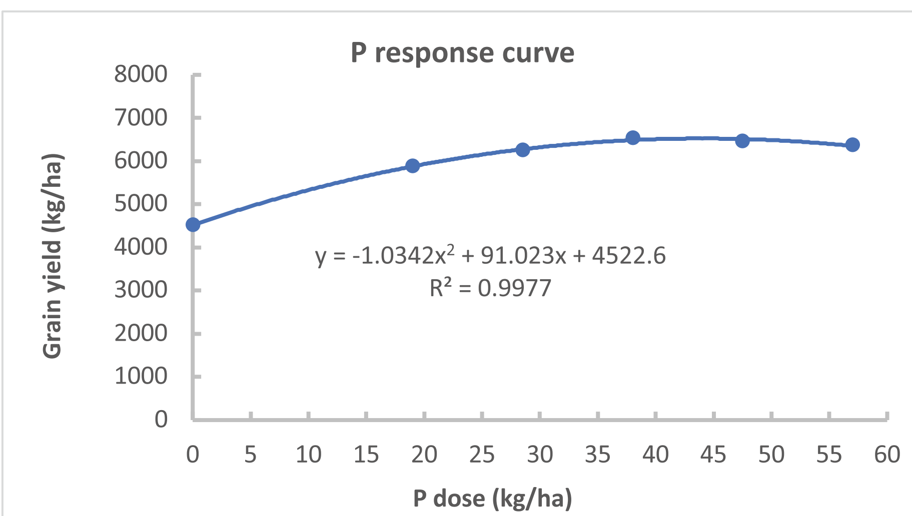


Figure 54. Phosphorus (P) response curve of BRRI dhan28 at Companiganj, Sylhet in Boro 2020-21, SSD, BRRI, Gazipur

Photo 36: Response of rice to phosphorus at Companiganj, Sylhet, Boro 2020-21

Response of rice to potassium

In Boro 2020-21, the potassium response study was conducted at the farmers' field of Katchua, Chandpur in K deficient soil. In the potassium response experiment, the six K doses were; K- 0, K-56, K-84, K-112, K-140 and K-168 $kgha^{-1}$, respectively and the blanket fertilizer dose for N-P-S and Zn was 140-20-10 and 2.5 $kgka^{-1}$, respectively. Table 78 represented the grain and straw yield of the K experiment. The highest grain yield was (6.68 tha^{-1}) was obtained in T_4 treatment (100% STB K) which was significantly higher than T_2 (6.04 tha^{-1}) treatment where 50% STB K dose was applied. The T_3 (6.46 tha^{-1}) T_5 (6.48 tha^{-1}) and T_6 (6.35 tha^{-1}) treatment gave statistically similar grain yield like T_4. In case of straw yield, a similar yield trend was observed. From the quadratic equation the calculated optimum dose of K was115 $kgha^{-1}$ for the respective farmer's field (Figure 55). Kalala et al. (2016) reported an application of 400 mg K kg^{-1} soil was an optimum rate for soils deficient in K.

Table 78. Grain and straw yield of BRRI dhan28 in K response study at Katchua, Chandpur, Boro 2020-21

Treatment (K rate)		Grain yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)
% of STB dose	kg K ha^{-1}		
T_1= 0 K	0	5.35	5.44
T_2= 50% STB K	56	6.04	6.22
T_3= 75% STB K	84	6.46	6.66
T_4= 100% STB K	112	6.68	6.80
T_5= 125% STB K	140	6.48	6.84
T_6= 150% STB K	168	6.35	6.86
LSD (0.05)		0.35	0.32
CV (%)		1.96	1.77

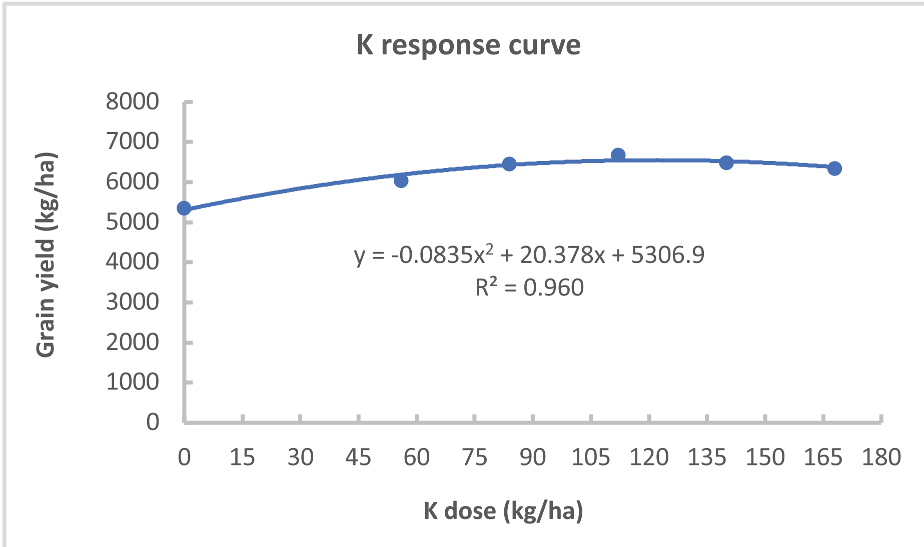


Figure 55. Response of rice (BRRI dhan28) to potassium at Katchua, Chandpur in Boro 2020-21, SSD, BRRI, Gazipur

Photo 37: Response of rice to potassium at Katchua, Chandpur, Boro 2020-21

Response of rice to Sulphur

The sulphur response study was conducted at the farmers' field of Khagail, Companiganj, Sylhet in Boro 2020-21 season. In the sulphur response experiment, the six S doses were; S- 0, S-10, S-15, S-20, S-25 and S-30 $kgha^{-1}$, respectively and the blanket fertilizer dose for N-P-K and Zn was 140-38-60 and 1 $kgka^{-1}$, respectively. The application of different doses of Sulphur in soil test basis significantly increased the grain and straw yield of BRRI dhan28 (Table 79). From the S response study, the highest grain yield was (6.75 tha^{-1}) was obtained in T_4 treatment (100% STB S) which was significantly higher than T_3 (6.23 tha^{-1}) and T_2 (5.85 tha^{-1}) treatment. The T_5 (6.59 tha^{-1}) and T_6 (6.45 tha^{-1}) treatment gave statistically similar grain yield to T_4. The S control plot yielded only 4.83 tha^{-1}. The similar yield trend was observed for obtained straw yield. From the quadratic equation of response curve, the calculated optimum dose of S was 24 $kgha^{-1}$ in the respective field (Figure 56).

Table 79. Grain and straw yield of BRRI dhan28 in S response study at Companiganj, Sylhet, Boro 2020-21, SSD, BRRI, Gazipur

Treatment (S rate)		Grain yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)
% of STB dose	kg S ha^{-1}		
T_1= S control	0	4.83	4.97
T_2= 50% STB S	10	5.85	6.00
T_3= 75% STB S	15	6.23	6.38
T_4= 100% STB S	20	6.75	6.91
T_5= 125% STB S	25	6.59	6.80
T_6= 150% STB S	30	6.45	6.74
LSD (0.05)		0.32	0.32
CV (%)		1.83	1.78

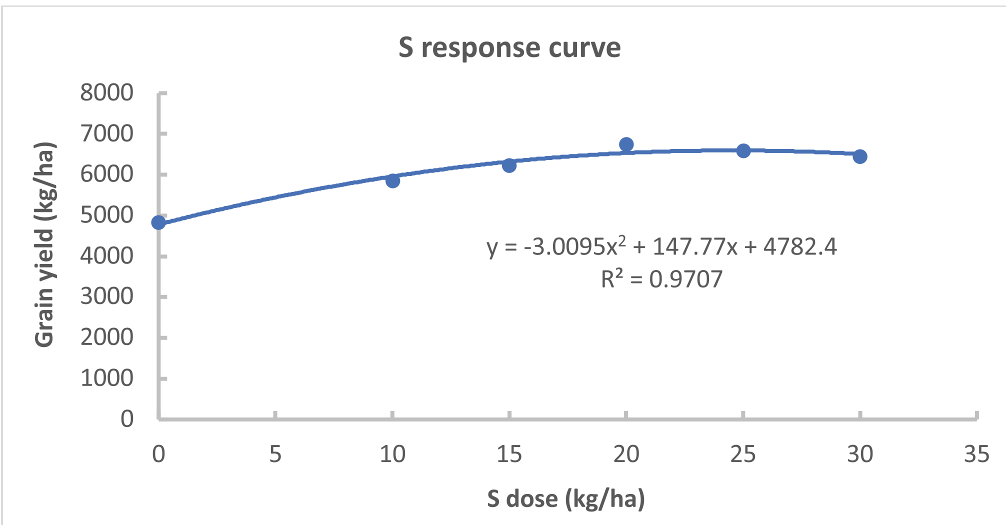


Figure 56. Sulphur (S) response curve of BRRI dhan28 at Companiganj, Sylhet in Boro 2020-21, SSD, BRRI, Gazipur

Photo 38. Response of rice to added sulphur at Companigang, Sylhet, Boro, 2020-21

Response of rice to Zn

In the farmer's field of Katchua, Chandpur the zinc response study was conducted in Boro 2020-21 season in Zn deficient soil. In the zinc response experiment, the six Zn doses were; Zn- 0, Zn-1.20, Zn-1.85, Zn-2.46, Zn-3.08 and Zn-3.69 kgha^{-1}, respectively and the blanket fertilizer dose for N-P-K and S was 140-20-110 and 10 kgka^{-1}, respectively. The application of zinc in different doses increased grain yield significantly (Table 80). The highest grain yield (6.52 tha^{-1}) was obtained in T_4 treatment (100% STB Zn) followed by T_5 (6.45 tha^{-1}), T_3 (6.36 tha^{-1}) and T_6 (6.35 tha^{-1}) and the lowest grain yield (5.52 tha^{-1}) was obtained in Zn control treatment. The T_2 (6.02 tha^{-1}) treatment gave significantly lower grain yield than other increased zinc fertilizer treatment. A similar yield trend was observed in case of obtained straw yield. From the response curve the calculated optimum dose of Zn was 2.27 kgha^{-1} (Figure 57) in Boro season.

Table 80. Grain and straw yield of BRRI dhan28 in Zn response study at Katchua, Chandpur, Boro 2020-21

Treatment (Zn rate)		Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
% of STB dose	Kg Zn ha^{-1}		
T_1= Zn control	0.00	5.52	5.66
T_2= 50% STB Zn	1.23	6.02	6.14
T_3= 75% STB Zn	1.85	6.36	6.50
T_4= 100% STB Zn	2.46	6.52	6.64
T_5= 125% STB Zn	3.08	6.45	6.61
T_6= 150% STB Zn	3.69	6.35	6.58
LSD (0.05)		0.24	0.22
CV (%)		1.37	1.22

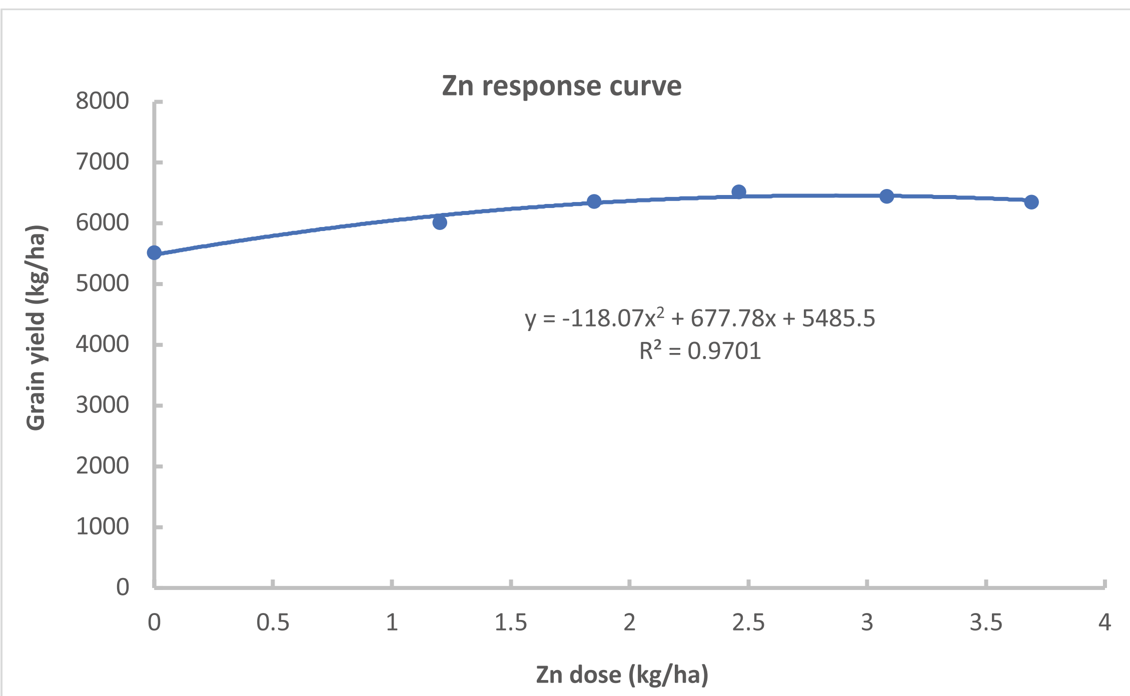


Figure 57. Zinc (Zn) response curve of BRRI dhan28 at Katchua, Chandpur in Boro 2020-21, SSD, BRRI, Gazipur

Photo 39. Response of rice to added Zinc at Katchua, Chandpur, Boro, 2020-21

Expt. 3.3: Response of maize and mustard to P and Mg applications (Field experiment)

BINA Component

According to the plan of the sub-project, four field experiments were conducted at farmer's field, Ramchandracura, Nalitabari, Sherpur (mustard & maize for P) and Sunderban, Sadar, Dinajpur (mustard & maize for Mg). Initial soil samples were collected from the different experimental sites. The lands were prepared properly as per crop requirement before setting up of the experiments. Randomized Complete Block Design (RCBD) was used in the experiments with six treatments (T_1: Control, T_2:50% STB, T_3:75% STB, T_4:100% STB, T_5:125% STB and T_6:150% STB) and four replications. Applications of fertilizers were made as per treatments. On the basis of soil analysis, nutrients were used at the rate of (120 kg N, 30 kg P, 75 kg K, 25 kg S, 5 kg Mg, 2 kg Zn and 1.5 kg B per hectare for mustard and 220 kg N, 50 kg P, 100 kg K, 42 kg S, 15 kg Mg, 4 kg Zn and 2 kg B per hectare for maize) $N_{120}P_{30}K_{75}S_{25}Mg_5Zn_2 B_{1.5}$ kg/ha for mustard and $N_{220}P_{50}K_{100}S_{42}Mg_{15}Zn_4B_2$ kg/ha for maize. All the fertilizers were applied as basal except urea. Urea was applied in two (for mustard) and three (for maize) splits. One third of urea was applied during final land preparation thoroughly incorporated into the soil. The 2nd split (1/3) of urea was applied at maximum vegetative growth stage and the 3rd split of urea was applied at or before panicle initiation stage. Other intercultural practices were done as and when necessary. Data were collected on initial soil properties, yields and yield contributing characters, nutrient concentrations and uptake by the plants (grain plus straw). Grain and straw samples were collected during harvesting of crops. At Nalitabari, Sherpur for P response trials for mustard (Binasarisha-9) seeds were sown on 23 November 2020 and for maize (BADC hybrid maize 2) trials the seeds were sown on 11 December 2021, respectively. Mustard was harvested on 28 February 2021 and maize was harvested on 16 June 2021. At Sunderban, Sadar, Dinajpur for Mg response trials for mustard (Binasarisha-9) seeds were sown on 21 November 2020 and for maize (Pionner-3255) trials the seeds were sown on 21 November 2020, respectively. Mustard was harvested on 04 March 2021 and maize was harvested on 12May 2021. Fresh and dry weights of mustard plants were recorded, which are being processed for chemical analysis. The recorded data were statistically analyzed to find out the significance of variance and the mean differences were adjudged by Duncan's Multiple Range Test (Gomez and Gomez, 1984). Standard laboratory analytical methods were used. The plant (grain and straw) samples were collected from individual plots. The samples were dried in an oven at 65 ^{0}C for about 24 hours and ground by a grinding mill. The ground samples were sieved through a 20-mesh sieve. The prepared samples were then analyzed for P, K and S following diacid digestion procedure (Jones and Case, 1990; Watson and Issac, 1990). Nitrogen was analyzed by conventional sulphuric acid-hydrogen peroxide digestion.

Mustard: At Nalitabari, Sherpur**,** the yield and yield contributing characters of mustard during Rabi 2020-2021 are shown in Table 81. In case of P response, the highest yield of mustard (1.97 tha^{-1}) was obtained in treatment T_4 (100% STB of P) which was remarkable difference with T_2, T_3 and T_5 treatments. Considering the yield contributing characters, all parameters also obtained higher in T_4 treatment. At Sundarban, Dinajpur**,** the yield and yield contributing characters of mustard during Rabi 2020-2021 are shown in Table 82. In case of Mg response, the highest yield of mustard (2.09 tha^{-1}) was obtained in treatment T_4 (100% STB of Mg) which was higher than T_5 and T_6 treatments. Considering the yield contributing characters, maximum parameters also obtained higher in T_4 treatment.

Table 81: Validation of critical limit of phosphorus on yield and yield contributing characters of mustard (var. Binasarisha-9) grown during 2020-2021 at Farmer's field, Ramchandracura, Nalitabari, Sherpur, SSD, BINA, Mymensingh

Treatment (P rate)		Plant height (cm)	Pod/plant (no.)	Seed/pod (no.)	1000 seeds wt (g)	Seed yield (t/ha)	Stover yield (t/ha)
% of STB dose	kg P ha^{-1}						
T_1: 0 P	0.0	66 c	59 b	20 c	3.50 c	0.68 c	1.69 d
T_2: 50% STB of P	15.0	95 b	95 a	26 ab	4.01 ab	1.86 ab	4.44 c
T_3: 75% STB of P	22.5	96 ab	96 a	24 b	3.87 b	1.88 ab	5.00 b
T_4: 100% STB of P	30.0	96 ab	96 a	24 b	3.88 b	1.97 a	4.38 a
T_5: 125% STB of P	37.5	99 a	99 a	29 a	4.13 a	1.71 ab	4.44 a
T_6: 150% STB of P	45.0	95 b	95 a	26 ab	3.89 b	1.42 b	3.56 c
CV (%)		4.86	8.88	7.84	2.20	10.10	8.70

Table 82: Validation of critical limit of magnisium on the yield and yield contributing characters of mustard (var. Binasarisha-9) grown during 2020-2021 at Farmer's field, Sundarban, Sadar, Dinajpur, SSD, BINA, Mymensingh

Treatment (Mg rate)		Plant height (cm)	Pod/plant (no.)	Seed/pod (no.)	1000 seeds wt (g)	Seed yield (t/ha)	Stover yield (t/ha)
% of STB dose	kg Mg ha^{-1}						
T_1: 0 Mg	0.0	111 c	80 d	22 b	3.32 e	1.61 c	3.15 c
T_2: 50% STB of Mg	2.5	113 bc	89 cd	23 ab	3.42 de	1.75 bc	3.28 c
T_3: 75% STB of Mg	3.8	117 ab	114 ab	24 a	3.67 cd	1.81 bc	4.05 c
T_4: 100% STB of Mg	5.0	117 ab	117 a	25 a	4.01 a	2.09 a	5.33 a
T_5: 125% STB of Mg	6.3	118 ab	112 b	24 a	3.84 ab	1.90 ab	4.24 b
T_6: 150% STB of Mg	7.5	120 a	97 c	24 a	3.78 bc	1.96 ab	4.19 b
CV (%)		5.60	10.16	4.49	2.24	8.92	9.18

Maize: At Nalitabari, Sherpur**,** the yield and yield contributing characters of maize during Kharif-I 2021 are shown in Table 83. In case of P response, the highest yield of maize (10.03 tha^{-1}) was obtained in treatment T_4 (100% STB of P) which was remarkable difference with T_5 and T_6 treatment. Considering the yield contributing characters, all parameters also obtained higher in T_4 treatment except plant height. At Sundarban, Dinajpur**,** the yield and yield contributing characters of maize during Kharif-I 2021 are shown in Table 84. In case of Mg response, the highest yield of maize (10.61 tha^{-1}) was obtained in treatment T_4 (100% STB of Mg) which was very close with T_5 and T_6 treatments. Considering the yield contributing characters, maximum parameters were also obtained higher in T_4 treatment.

Table 83: Validation of critical limit of phosphorus on yield and yield contributing characters of maize (var. BADC Hybrid maize-2) grown during 2021 at Farmer's field, Ramchandracura, Nalitabari, Sherpur, SSD, BINA, Mymensingh

Treatment (P rate)		Plant height (cm)	Cob/ Plant (no.)	Cob length (no.)	Row/ cob (no.)	Seed/ row (no.)	1000 seeds wt (g)	Seed yield (t/ha)	Stover yield (t/ha)
% of STB dose	kg P ha^{-1}								
T_1: 0 P	0.0	228 d	0.8	16.1 c	11.0 c	30 c	296 d	8.33 e	9.89 e
T_2: 50% STB of P	25.0	229 d	0.8	17.0 b	11.0 c	31 c	318 cd	8.93 d	10.54 d
T_3: 75% STB of P	37.5	233 cd	0.8	17.0 b	12.5 b	31 c	323 c	9.18 c	10.63 c
T_4: 100% STB of P	50.0	239 bc	0.9	18.5 a	13.5 a	35 a	377 a	10.03 a	12.60 a
T_5: 125% STB of P	62.5	247 ab	0.8	17.3 ab	12.5 b	34 a	348 b	9.63 b	11.11 b
T_6: 150% STB of P	75.0	255 a	0.9	18.0 a	12.0 b	33 b	330 bc	9.33 bc	11.28 b
CV (%)		5.62	-	3.20	4.89	6.20	2.48	7.90	8.20

Table 84: Validation of critical limit of magnisium on the yield and yield contributing characters of maize (var. Pionner-3255) grown during 2021 at Farmer's field, Sundarban, Sadar, Dinajpur, SSD, BINA, Mymensingh

Treatment (Mg rate)		Plant height (cm)	Cob/ Plant (no.)	Cob length (no.)	Row/ cob (no.)	Seed/ row (no.)	1000 seeds wt (g)	Seed yield (t/ha)	Stover yield (t/ha)
% of STB dose	kg Mg ha^{-1}								
T_1: 0 Mg	0.0	238 c	1.01	18.1 b	12.5 c	40	444 c	9.35 c	11.22 c
T_2: 50% STB of Mg	7.5	239 c	1.03	19.0 a	13.0 b	40	448 c	9.98 b	11.65 b
T_3: 75% STB of Mg	11.3	243 c	1.04	19.0 a	13.0 b	40	445 c	9.93 b	11.51 b
T_4: 100% STB of Mg	15.0	249 b	1.06	19.5 a	13.5 a	41	508 a	10.61 a	12.24 a
T_5: 125% STB of Mg	18.8	257 ab	1.05	19.3 a	13.5 a	41	477 b	10.57 a	11.76 b
T_6: 150% STB of Mg	22.5	265 a	1.05	19.2 a	13.0 b	40	471 b	10.54 a	12.04 a
CV (%)		6.50	-	3.32	2.72	-	1.69	7.48	9.00

Photo 40. Field view of mustard and maize experiments at Ramchandracura, Nalitabari, Sherpur

Expt. 3.4: Response of wheat and mustard to Mg, S and B applications (Field experiment)

BAU Component

Six field experiments were established at Mymensingh Sadar upazilla and Tetulia upazilla during Rabi season 2020-21, to validate the results obtained in pot experiment and observe the effect of doses of sulphur, magnesium and boron on the growth and yield of mustard (*Brassica napus* L.) and wheat (*Triticum aestivum* L) at the farmers' field. The experiment was conducted in Randomized Complete Block Design with six treatments and four replications. Soil test based fertilizer was applied at the rate of 109-15-80 kg NPK/ha for both of wheat and mustard as urea, TSP and MoP.

Table 85: Experimental details in brief, BAU, Mymensingh, 2020-21

Sl.No	Location	Crop	Treatment code	Test nutrient applied (kg/ha)
1	Mymensingh Sadar	Mustard-Sulphur	T_1:0	S_{28} (100 %)
2	do	Wheat-Sulphur	T_2: 50%	S_{27} (100 %)
3	do	Mustard-Boron	T_3:75%	B_1 (100 %)
4	do	Wheat-Boron	T_4:100%	B_1 (100 %)
5	Tetulia	Mustard-Magnesium	T_5:125%	Mg_{11} (100 %)
6	do	Wheat-Magnesium	T_6:150%	Mg_{10} (100 %)

Season of the experiment: Rabi 2020-21

Test crop and variety: i. Mustard var. Binasarisha 9
ii. Wheat var. BARI Gom-30

No. of treatments: 06

No. of replications: 04

Total no. of plots: 24 for each crop

Plot size: 5 m × 4 m

Spacing: Mustard and wheat: 25cm x 10cm

Experimental design: Randomized Complete Block design (RCBD)

Test nutrient: Three- i. Sulphur
ii. Boron
iii. Magnesium

Sulphur source: $CaSO_4.2H_2O$

Boron source: H_3BO_3

Magnesium source: $MgSO_4$

Calcite was applied @ 741 kg/ha (3 kg/decimal) in the experimental field at Tetulia for soil amendment in acidic soil. Mustard and wheat seeds were sown on the 1st and 2nd weeks of November 2020. All the fertilizers and test nutrients were applied as basal doses except urea. Urea was applied in two equal splits. Intercultural operations like urea top dressing, thinning, irrigation, weeding, pest control etc. were maintained for uninterrupted plant growth. Mustard was harvested when 80 percent of siliquae were turned yellowish-brown. Wheat was harvested when the whole plant turns yellowish-brown. Growth and yield parameters were recorded at harvest.

3.1 Effect of sulphur on wheat

Sulphur fertilizer was applied in different levels optimized based on the critical limit of sulphur to see their effect on the growth and yield of wheat var. BARI Gom-30; presented in Table 86. All the parameters studied for the experiment viz. plant height, effective tiller, non-effective tiller, no. of spikelet/spike, grains/spike, sterile spikelets/spike, grain yield (t/ha), straw yield (t/ha), 1000-grain weight weight (g) and biological yield (t/ha) were found statistically significant with sulphur application. T4 was found the best-performing treatment for all the parameters recorded in the experiment where sulphur was applied @ 27 kg/ha *i.e.*, 100% of the critical limit.

Table 86. Effect of sulphur on yield and yield contributing characters of wheat, BAU, Mymensingh, 2020-21

Treatment (S rate)		Plant height at harvest (cm)	Effective tiller	No of spikelet/ spike	Grain/ spike	Grain yield (t/ha)	Straw yield (t/ha)	1000 seed weight (g)	Biological yield (t/ha)
% of STB dose	kg S ha^{-1}								
T_1= S control	0.0	92.85	4.16	14.78	30.55	3.29	4.53	41.00	7.82
T_2= 50% STB S	13.5	95.83	4.44	15.70	34.60	3.46	4.76	43.80	8.23
T_3= 75% STB S	20.3	97.55	4.93	16.80	36.00	3.61	5.26	44.80	8.87
T_4= 100% STB S	27.0	100.08	5.54	18.03	46.00	4.36	5.92	48.25	10.27
T_5= 125% STB S	33.8	99.85	5.51	18.01	45.83	4.33	5.89	48.00	10.22
T_6= 150% STB S	40.5	98.75	5.30	17.08	41.83	4.34	5.88	47.20	10.22
LSD (.05)		3.70	0.18	0.35	1.44	0.19	0.16	2.69	0.30
Level of significance		**	**	**	**	**	**	**	**

Growth parameters

The tallest plants (100.08 cm) were recorded at T_5 (33.75 kg ha^{-1} S) and the shortest plants (92.85 cm) were observed at control plots. The maximum tillers (5.54) were recorded at T4, followed by (5.51) T5. The minimum tillers (4.16) were observed at control plots. The lowest number of non-effective tillers/plant (0.43) were recorded at T4, followed by T5 (0.44). The highest number of non-effective tillers (0.73) were observed at control plots.

Yield parameters

The maximum no. of spikelets/spike (18.03) was recorded at T4 and the minimum no. of spikelets/spike (14.78) was observed at control plots. The maximum number of sterile spikelets/spike 1.54 was recorded at control plots and the minimum number of sterile spikelets/spike (0.84) was observed at T_4 and T_5. The maximum grains spike^{-1} (46) was recorded at T4. The minimum grains spike^{-1} (30.55) was observed at control plots. The maximum seed index (100 seed weight) (48.25 g) was recorded at T4. The minimum seed index (41 g) was observed at control (untreated) plots.

The maximum grain yield (4.36 t ha^{-1}) was recorded at T4 followed by T5 (4.33 t ha^{-1}). The minimum grain yield (3.29 t ha^{-1}) was observed at control plots. The maximum straw yield (5.92 t ha^{-1}) was recorded at T4 followed by 5.89 t ha^{-1} recorded at T5. The minimum straw yield (4.53 t ha^{-1}) was observed at control plots. The maximum biological yield (10.27 t ha^{-1}) was recorded at T4. The minimum biological yield (7.82 t ha^{-1}) was observed at control (untreated) plots. Grain yield, straw yield and biological yield at T4, T5 and T6 had were statistically similar.

3.2 Effect of boron on wheat

The effect of boron fertilizer application levels on wheat cv. BARI Gom 30 following the critical limit of boron in soil has been presented in Table 87. All the parameters studied for the experiment viz. effective tiller, non-effective tiller, no. of spikelets/spike, grains/spike, sterile spikelets/spike, grain yield (t/ha), straw yield (t/ha), 1000-grain weight (g), biological yield (t/ha) except plant height were found statistically significant with boron fertilizer application. T4 was found the best-performing treatment for all the parameters recorded in the experiment where boron was applied @ 1.0 kg/ha i.e., 100% of the critical limit.

Table 87. Effect of boron on yield and yield contributing characters of wheat, BAU, Mymensingh, 2020-21

Treatment (B rate)		Plant height at harvest (cm)	Effective tiller	No of spikelet/ spike	Grain/ spike	Grain yield (t/ha)	Straw yield (t/ha)	Thousand seed weight (g)	Biological yield (t/ha)
% of STB dose	kg B ha^{-1}								
T_1= B control	0.0	92.90	4.41	15.40	35.00	3.66	4.70	40.50	8.36
T_2= 50% STB B	0.5	93.28	5.11	16.10	41.50	3.85	5.78	42.00	9.63
T_3= 75% STB B	0.8	93.90	5.51	17.90	43.10	4.23	6.01	42.80	10.24
T_4= 100% STB B	1.0	94.28	6.56	19.50	48.96	4.93	6.14	48.11	11.06
T_5= 125% STB B	1.3	94.00	6.52	19.40	48.90	4.81	6.11	47.95	10.92
T_6= 150% STB B	1.5	93.20	6.06	18.25	45.25	4.90	5.98	46.38	10.88
LSD (.05)		2.07	0.31	0.53	1.50	0.11	0.16	0.74	0.21
Level of significance		NS	**	**	**	**	**	**	**

Growth parameters

The highest plant height (94.28 cm) was recorded at T_4 (1 kg ha^{-1}). The lowest plant height (92.90 cm) was observed at control plot. The maximum tillers (6.56) were recorded at T_4, followed by 6.52 at T5. The minimum tillers (4.41) were observed at control plots. The minimum non effective tillers (0.36) were recorded at T_4, followed by 0.37 at T_5. The maximum non effective tillers (0.79) were observed at control plots.

Yield parameters

The maximum no. of spikelet/spike 19.5 was recorded at T_4, followed by 19.4 at T_5 and the minimum no. of spikelet/spike (15.4) was observed at control plots. The maximum no. of sterile spikelet/spike 1.58 was recorded at control plots and the minimum no. of sterile spikelet/spike (0.60) was observed at T_4 followed by 0.61 in T_5. The maximum grains $spike^{-1}$ 48.96 was recorded at T4. The minimum grains $spike^{-1}$ 35.0 was observed at control plots. The maximum seed index (48.11 g) was recorded at T_4 followed by 47.95 g at T_5. The minimum seed index (40.5 g) was observed at control (untreated) plots.

The maximum grain yield (4.93 t ha^{-1}) was recorded at T4 followed by 4.90 t ha^{-1} recorded at T6. The minimum grain yield (3.66 t ha^{-1}) was observed at control plots. The maximum straw yield (6.14 t ha^{-1}) was recorded at T4 followed by 6.11 t ha^{-1} recorded at T5. The minimum straw yield (4.7 t ha^{-1}) was observed at control plots. The maximum biological yield (11.06 t ha^{-1}) recorded at T4 followed by T5 (10.92 t ha^{-1}) while the minimum biological yield (8.36 t ha^{-1}) was observed at control (untreated) plots. Grain yield, straw yield and biological yield at T4, T5 and T6 were statistically similar.

3.3 Effect of magnesium on wheat

Magnesium fertilizer was applied in wheat cv. BARI Gom 30 at different levels based on the critical limit of magnesium in soil (Table 88). All the parameters studied for the experiment viz. Effective tiller, non-effective tiller, no. of spikelet/spike, Grain/spike, Sterile spikelets/spike, Grain yield (t/ha), Straw yield (t/ha), Thousand seed weight (g), Biological yield (t/ha) except Plant height were found statistically significant with magnesium fertilizer application. T4 was found the best-performing treatment for all the parameters recorded in the experiment where magnesium was applied @ 10 kg/ha i. e. 100% of the critical limit while Grain yield (t/ha), Straw yield (t/ha), Biological yield (t/ha) were found highest in treatment T6 where magnesium was applied at 150% of critical limit.

Table 88. Effect of magnesium on yield and yield contributing characters of wheat at Tetulia, BAU, Mymensingh, 2020-21

Treatment (Mg rate)		Plant height at harvest (cm)	Effective tiller	No of spikelet/ spike	Grain/ spike	Grain yield (t/ha)	Straw yield (t/ha)	Thousand seed weight (g)	Biological yield (t/ha)
% of STB dose	kg Mg ha^{-1}								
$T_{1:}$ 0 Mg	0.0	93.60	4.03	14.70	30.95	3.34	4.59	41.33	7.93
T_2: 50% STB of Mg	5.0	94.40	4.34	15.80	32.70	3.54	4.85	43.95	8.39
T_3: 75% STB of Mg	7.5	95.05	4.98	16.50	33.95	3.66	5.36	45.95	9.03
T_4: 100% STB of Mg	10.0	95.65	5.63	18.40	46.45	4.42	6.03	48.85	10.45
T_5: 125% STB of Mg	12.5	95.45	5.62	18.35	46.25	4.40	6.00	48.74	10.40
T_6: 150% STB of Mg	15.0	94.50	5.30	17.38	43.50	4.47	6.20	46.55	10.67
LSD (.05)		1.91	0.21	0.32	1.47	0.17	0.18	1.19	0.26
Level of significance		NS	**	**	**	**	**	**	**

** = Significant at 1% level of probability

Growth parameters

The tallest plants (95.65 cm) were observed at T_4 (1.1 kg ha^{-1}) followed by 95.45 cm was recorded at T_5 (1.38 kg ha^{-1}) and the shortest plants (93.60 cm) were observed at control plot. The maximum effective tillers (5.63) were recorded at T_4. The minimum tillers (4.03) were observed at control plots. The minimum non effective tillers (0.44) were recorded both at T_4 and T_5. The maximum non effective tillers (0.71) were observed at control plots.

Yield parameters

The maximum no. of spikelet/spike 18.4 was recorded at T_4, followed by 18.35 at T_5 and the minimum no. of spikelet/spike (14.7) was observed at control plots. The maximum no. of sterile spikelets/spike 1.44 was recorded at control plots and the minimum no. of sterile spikelet/spike (0.75) was observed at T_4 followed by 0.76 in T_5. The maximum grains $spike^{-1}$ (46.45) was recorded at T4 and the minimum grains $spike^{-1}$ (30.95) was observed at control plots.

The results for seed index (1000 seed weight, g) showed response for different doses of magnesium fertilizers. The maximum seed index (48.85 g) was recorded at T4. The minimum seed index (41.33 g) was observed at control (untreated) plots. The grain yield (t ha^{-1}) also showed significant response for magnesium fertilizer levels. The maximum grain yield (4.47 t ha^{-1}) was recorded at T6 followed by 4.42 t ha^{-1} recorded at T4. The minimum grain yield (3.34 t ha^{-1}) was observed at control plots. The maximum straw yield (6.20 t ha^{-1}) was recorded at T6 followed by 6.03 t ha^{-1} recorded at T4. The minimum straw yield (4.59 t ha^{-1}) was observed at control plots. The maximum biological yield (10.67 t ha^{-1}) was recorded at T6 while the minimum biological yield (7.93 t ha^{-1}) was observed at control (untreated) plots. Grain yield, straw yield and biological yield at T4, T5 and T6 had different numerical values but they were statistically similar.

3.4 Effect of sulphur on mustard

Sulphur fertilizer was applied in different levels formulated based on the critical limit of sulphur to see their effect on the growth and yield of mustard var. Binasarisha 9; presented in Table 89. All the parameters studied for the experiment viz. plant height at harvest (cm), branches/plant, total pods/plant, effective pods/plant, non-effective pods/plant, pod length (cm), seeds/pod, seed yield (t/ha), stover yield (t/ha), 1000-seed wt. (g) and biological yield (t/ha) were found statistically significant with sulphur application. T4 was found the best-performing treatment for all the parameters recorded in the experiment where sulphur was applied @ 28 kg/ha i.e. 100% of the critical limit.

Table 89. Effect of sulphur on yield and yield contributing characters of mustard, BAU, Mymensingh, 2020-21

Treatment (S rate)		Plant height harvest (cm)	Effective pod/ plant	Pod length (cm)	Seed/ pod	Seed yield (t/ha)	Stover yield (t/ha)	1000 seed wt. (g)	Biological yield (t/ha)
% of STB dose	kg S ha^{-1}								
T_1= S control	0.0	75.60	67.95	5.01	17.70	1.51	1.95	2.77	3.46
T_2= 50% STB S	14.0	83.10	73.35	5.54	20.25	1.61	2.16	3.01	3.77
T_3= 75% STB S	21.0	87.20	78.00	5.98	21.75	1.66	2.30	3.17	3.96
T_4= 100% STB S	28.0	94.80	86.13	8.90	25.30	1.87	2.56	3.44	4.43
T_5= 125% STB S	35.0	94.60	85.95	8.85	25.05	1.85	2.53	3.42	4.38
T_6= 150% STB S	42.0	92.45	82.75	7.70	23.35	1.86	2.49	3.38	4.35
LSD (.05)		2.24	1.27	0.33	0.94	0.05	0.05	0.05	0.07
Level of significance		**	**	**	**	**	**	**	**

** = Significant at 1% level of probability

Growth parameters

The maximum plant height (94.80 cm) was recorded at T_4 (28 kg ha^{-1}) and the minimum plant height (75.6 cm) was observed at control plot. The maximum no. of branches per plant was found at T_4 (4.55) followed by T_5 (4.5) and the minimum no. of branches per plant (2.35) was observed at control plot.

Yield parameters

Maximum number of total siliqua per plant was recorded at T4 (87.68) followed by T5 (87.58). Minimum number of total siliqua per plant was recorded from control (72.53) plot. There was significant increase in number of effective siliqua per plant with increasing doses of sulphur up to 28 kg S ha^{-1}. Application of 28 kg S ha^{-1} recorded highest number of effective siliqua per plant (86.13) which was statistically superior over rest of the sulphur doses. Minimum number of total effective siliqua per plant (67.95) was recorded from control. Maximum number of non-effective siliqua per plant (4.58) was recorded from control. Minimum number of non-effective siliqua per plant (1.55) was recorded at T4 followed by T5 (1.63). As the sulphur doses increased, the length of siliqua also increased up to T4 (8.9) followed by T5 (8.85). The shortest siliqua (5.01 cm) was observed at control plot. The maximum number of seeds per siliqua (25.3) was observed at T4. The number of seeds per siliqua increased significantly with the increment in sulphur doses up to 28 kg S ha^{-1}. The minimum value of number of seeds per siliqua (17.7) was recorded under control.

The maximum 1000-grain weight was (3.44 g) in T4 and the minimum grain weight (2.77) was found at untreated plot. The seed yield ranged between 1.51 to 1.87 t ha^{-1} and varied significantly among the treatments. The maximum seed yield was found at T4 and the minimum seed yield was found in untreated plots. The maximum stover weight (2.56 t ha^{-1}) was found at T4. The minimum stover yield (1.95 t ha^{-1}) was found in untreated plots. The maximum biological yield (4.43 t ha^{-1}) was found at T4 while the minimum biological yield (3.46 t ha^{-1}) was observed at control (untreated) plots. Grain yield, stover yield and biological yield at T4, T5 and T6 had different numerical values but they were statistically similar.

Photo 41: Experiments on Response of mustard and wheat to sulphur

3.5 Effect of boron on mustard

The effect of boron fertilizer application levels on mustard cv. Binasarisha 9 following the critical limit of boron in soil has been presented in Table 90. All the parameters studied for the experiment viz. effective tiller, non-effective tiller, no. of spikelets/spike, grains/spike, sterile spikelets/spike, grain yield (t/ha), stover yield (t/ha), 1000-seed weight (g) and biological yield (t/ha) were found statistically significant with boron application. T4 was found the best-performing treatment for all the parameters recorded in the experiment where boron was applied @ 1.0 kg/ha i.e. 100% of the critical limit.

Table 90. Effect of boron on yield and yield contributing characters of mustard, BAU, Mymensingh, 2020-21

Treatment (B rate)		Plant height harvest (cm)	Effective pod/ plant	Pod length (cm)	Seed/ pod	Seed yield (t/ha)	Stover yield (t/ha)	1000 seed wt. (g)	Biological yield (t/ha)
% of STB dose	kg B ha^{-1}								
T_1= B control	0.0	82.25	77.43	6.33	16.40	1.58	2.00	3.00	3.57
T_2= 50% STB B	0.5	82.75	79.75	7.85	21.25	1.67	2.08	3.16	3.74
T_3= 75% STB B	0.8	83.05	81.38	8.55	22.75	1.81	2.19	3.26	4.00
T_4= 100% STB B	1.0	84.83	88.31	9.08	26.28	1.95	2.29	3.50	4.24
T_5= 125% STB B	1.3	84.65	88.10	9.08	26.10	1.95	2.27	3.49	4.22
T_6= 150% STB B	1.5	83.40	84.45	8.48	24.75	1.90	2.26	3.39	4.16
LSD (.05)		1.41	2.50	0.53	0.73	0.05	0.08	0.07	0.08
Level of significance		**	**	**	**	**	**	**	**

Growth parameters

The plant height of mustard ranged from 84.83 cm at T_4 (1 kg ha^{-1}) to 82.25 cm observed at control plot.

The maximum no. of branches per plant was found at T_4 (4.86) followed by T_5 (4.83). The minimum no. of branches per plant (3.61) was observed at control plot.

Yield parameters

Maximum number of total siliqua per plant was recorded at T4 (89.58) followed by T5 (89.45) plot. Minimum number of total siliqua per plant was recorded at control (81.7) plot. The number of effective siliqua per plant varied from 88.31 at T4 to 77.43 at control plots. Maximum number of non-effective siliqua per plant (4.28) was recorded at control and the minimum number of non-effective siliqua per plant was recorded from T4 (1.26) followed by T5 (1.35). The maximum length of siliqua (9.08 cm) was observed due to 1 kg B ha^{-1} and the shortest length of siliqua (6.33 cm) was observed from control plot.

The maximum number of seeds per siliqua (26.28) was observed with T4 followed by T5 (26.1), which were statistically similar. The minimum value of seeds per siliqua (20.4) was recorded under control plot.

The maximum 1000-grain weight was (3.5 g) in T4, however, the minimum value (3.0) of the same character is found with untreated plot. Table 20 revealed that of seed yield (t ha^{-1}) of mustard significantly influenced by varying levels of boron fertilization. The maximum seed weight (1.95 t ha^{-1}) was found in both T4 and T5. The minimum seed yield (1.58 t ha^{-1}) was found in untreated plots. The maximum stover weight (2.29 t ha^{-1}) was found in T4. The minimum stover yield (2.0 t ha^{-1}) was found in untreated plots. The biological yield (t ha^{-1}) showed significant relationship in different treatments with B. The maximum biological yield (4.24 t ha^{-1}) was found at T4 while the minimum biological yield (3.57 t ha^{-1}) was observed at control (untreated) plots. Grain yield, stover yield and biological yield at T4, T5 and T6 had different numerical values but they were statistically similar though treated with varying levels of boron.

3.6 Effect of magnesium on mustard

Magnesium fertilizer was applied in mustard cv. Binasarisha 9 at different levels based on the critical limit of magnesium in soil (Table 91). All the parameters studied for the experiment viz. effective tiller, non-effective tiller, no. of spikelets/spike, grains/spike, sterile spikelets/spike, grain yield (t/ha), stover yield (t/ha), 1000-seed weight (g) and biological yield (t/ha) were found statistically significant with boron application. T4 was found the best-performing treatment for all the parameters recorded in the experiment where boron was applied @ 11 kg/ha i.e. 100% of the critical limit while seed yield (t/ha), stover yield (t/ha) and biological yield (t/ha) were found highest in treatment T6 where magnesium was applied at 150% of critical limit.

Table 91. Effect of magnesium on yield and yield contributing characters of mustard at Tetulia, BAU 2020-21

Treatment (Mg rate)		Plant height harvest (cm)	Effective pod/ plant	Pod length (cm)	Seed/ pod	Seed yield (t/ha)	Stover yield (t/ha)	1000 seed wt. (g)	Biological yield (t/ha)
% of STB dose	kg Mg ha^{-1}								
T_1= Mg control	0.0	80.70	76.95	6.25	19.85	1.50	1.90	2.87	3.40
T_2= 50% STB Mg	5.5	82.00	78.55	7.75	20.70	1.60	2.01	3.04	3.60
T_3= 75% STB Mg	8.3	82.25	80.45	8.31	22.40	1.76	2.13	3.12	3.89
T_4= 100% STB Mg	11.0	84.23	86.55	8.85	25.20	1.91	2.23	3.39	4.14
T_5= 125% STB Mg	13.8	84.00	86.25	8.78	25.00	1.89	2.21	3.37	4.10
T_6= 150% STB Mg	16.5	82.95	84.15	8.36	23.30	1.91	2.25	3.28	4.16
LSD (.05)		1.35	2.07	0.27	0.79	0.05	0.05	0.11	0.07
Level of significance		**	**	**	**	**	**	**	**

Growth parameters

The results of plant height (cm) showed variations with different treatments of magnesium in mustard. The maximum plant height 84.23 cm was recorded at T_4. The minimum plant height (80.7 cm) was observed at control plot. The number of branches per plant was varied from 4.70 at T4 followed by T_5 (4.68) to 3.58 at control plot.

Yield parameters

Data revealed that the Mg levels on number of siliqua per plant was found significant at harvest stage of the crop. Maximum number of total siliqua per plant was recorded from T4 (87.5) followed by T5 (87.4) plot. Minimum number of total siliqua per plant was recorded at control (81.05) plot. Maximum number of effective siliqua per plant was recorded from T4 (86.55) followed by T5 (86.25). Minimum number of effective siliqua per plant (76.95) was recorded at control. Maximum number of non-effective siliqua per plant (4.10) was recorded at control and the minimum number of non-effective siliqua per plant was recorded at T4 (0.95) followed by T5 (1.15). The longest siliqua was found at T4 (8.85 cm) followed by 8.78 cm observed at T5 and the shortest siliqua (6.25 cm) was observed from control plot which showed statistical inferiority over rest of the sulphur doses. The maximum number of seeds per siliqua (25.2) was observed at T4 followed by T5 (25.0). The minimum value of number of seeds per siliqua (19.85) was recorded under control.

Data on weight of 1000 grains (g) as influenced by application of Mg are presented in Table 7. The maximum 1000-grain weight (3.39 g) was found at T4, however, the minimum value (2.87) was recorded at the untreated plots. The seed yield of mustard varied from 1.91 t ha^{-1} at T4 & T6 to 1.5 t ha^{-1} at control plots. The maximum stover yield was found in T6 (2.25 t ha^{-1}) and the minimum stover yield (1.9 t ha^{-1}) was found in untreated plots. The results for biological yield (t ha^{-1}) showed significant relationship with magnesium applications formulated based on critical limit. The maximum biological yield (4.16 t ha^{-1}) was recorded at T6 while the minimum biological yield (3.40 t ha^{-1}) was observed at control (untreated) plots. Grain yield, stover yield and biological yield at T4, T5 and T6 were statistically similar though treated with varying levels of boron.

Present research of BAU component, PBRG, ID 134, NATP revealed that the critical limit of S in soil for mustard cultivation is 14 ppm and for wheat cultivation is 13.5 ppm. CL of B for mustard cultivation is 0.25 ppm and for wheat cultivation is 0.3 ppm. CL of Mg for mustard cultivation is 0.55 meq/100 g soil and for wheat cultivation is 0.5 meq/100g soil. The CL of S in mustard plant tissue is

0.35%, and for wheat plant tissue is 0.14%. The CL of B in mustard plant tissue is 24 ppm and in wheat plant tissue is 9.8 ppm. The critical limit of Mg in mustard plant tissue is 0.72% g and in wheat plant tissue is 0.29 %. Application of 28 kg S ha^{-1}, 1 kg B ha^{-1}, 11 kg Mg ha^{-1} in mustard variety Binasarisha 9 and 27 kg S ha^{-1}, 1 kg B ha^{-1}, 10 kg Mg ha^{-1} in wheat variety BARI Gom-30 along with RDF is recommended for higher yield and economic benefit of mustard and wheat grown in Bangladesh.

12. Research highlights (title of the sub-project, background, objectives, methodology, key findings, and key words)

BARI Component

Critical limits of nutrients were determined for soils and crops like wheat, cabbage and maize under the sub-project "Determination of Critical Limit of Nutrients for Soils and Crops". There is a need to determine and update the critical limit of different plant nutrients in order to formulate an optimum fertilizer dose of deficient nutrients for different crops and soils for achieving satisfactory crop yield. The bench mark survey was completed. A total 180 soil samples were collected as per protocol. Results varied from very low to very high level among different soils and chemical properties under study. BARI component determined CL of K and Zn for >25 soils and three crops (wheat, caggabe and maize) through pot trials and laboratory studies. Sprouted seeds of wheat, cabbage and maize were sown in the pot and the crop was harvested at 8-10 weeks of plant growth. Dry matter (DM) yield was recorded and plant samples were analyzed for the particular nutrients under study. From the pot trial critical limit of K was estimated for wheat, maize and cabbage cultivation in Bangladesh soil were 0.17, 0.18 and 16 meq $100g^{-1}$, respectively. The critical limit of Zn for wheat, maize and cabbage cultivation in Bangladesh soil was estimated to be 0.69, 0.75 and 0.71 ppm, respectively. The critical values of K for wheat, cabbage and maize tissue were 17, 21.5 and 17.2 g kg^{-1}, respectively, while the critical values of Zn for wheat, cabbage and maize tissue were 27.2, 29.0 and 32 mg kg^{-1}. The results were validated through field experiment at the farm level.

Keywords: Cabbage, Critcal limits, Maize, Potassium, Wheat, Zinc.

BRRI Component

Critical limits of nutrients were determined for soils and rice crop under the sub-project "Determination of Critical Limit of Nutrients for Soils and Crops". There is a need to determine and update the critical limit of different plant nutrients in order to formulate an optimum fertilizer dose of deficient nutrients for different crops and soils for achieving satisfactory crop yield. The bench mark survey was completed and a total 180 soil samples were collected from three AEZs as per protocol. Results varied from very low to very high level of nutrient status and chemical properties among different soils under study. BRRI was determine CL of P, K, S and Zn for 80 soils and rice crop through vigorous pot trials and laboratory study. Sprouted rice seeds were sown in the pot and the crop was harvested at 9 weeks of plant growth. Dry matter yield was recorded and plant samples were analyzed for the particular nutrients under study. The estimated critical limit of P, K, S and Zn for rice crop was found 8.7 $mgkg^{-1}$, 0.09 meq/100 g soil, 15.00 mg kg^{-1} and 0.70 mg kg^{-1}, respectively. The results were validated through field experiment at the farm level. From the quadratic equation, the economic optimum doses of P, K, S and Zn were 42,115, 24 and 2.72 $kgha^{-1}$, respectively. The calculated optimum dose of each nutrient was found almost nearer compared to 100% soil test-based dose.

Keywords: Critical limit, Phosphorus, Potassium, Sulphur, Zinc and Rice.

BINA Component

Critical limits of nutrients were determined for soils and crops like maize and mustard under the sub-project "Determination of Critical Limit of Nutrients for Soils and Crops". There is a need to determine and update the critical limit of different plant nutrients in order to formulate an optimum fertilizer dose of deficient nutrients for different crops and soils for achieving satisfactory crop yield. The bench mark survey was completed and a total 180 soil samples were collected as per protocol. Results varied from very low to very high level among different soils and chemical properties under study. BINA determined CL of P and Mg for 20 soils and 2 crops (maize and mustard) through vigorous pot trials and laboratory study. Sprouted seeds were sown in the pot and the crop was harvested at 8-10 weeks of plant growth. Dry matter (DM) yield was recorded and plant samples were analyzed for the particular nutrients under study. The estimated critical limit of P for mustard crop was found 14.8 ppm and critical limit of Mg for mustard crop was found 0.59 meq/100 g. On the other hand, the estimated critical limit of P for maize crop was found 14.5 ppm and critical limit of Mg for maize crop was found 0.60 meq/100 g.The results was validated through field experiment at the farm level.

Keywords: Phosphorus, Magnisium, Critcal limit, Mustard and Maize.

BAU Component

Critical limits of nutrients were determined for soils and crops like wheat and mustard under the sub-project "Determination of Critical Limit of Nutrients for Soils and Crops". The state-of-the-art methodologies were followed to update the decade-old critical limit values of some selected soils and crops in Bangladesh. In this connection, the benchmark survey was completed, and a total of 180 soil samples were collected as per protocol. Results varied from very low to very high levels among different soils and chemical properties under study. Bangladesh Agricultural University (BAU) had determined CL of S, Mg and B for 20 soils, of which 12 soils were of low fertility level, 4 soils were of medium fertility level and the remaining 4 soils were of high fertility level of the particular nutrient and 2 crops (Wheat and Mustard) through pot trials and laboratory study. Seeds were sown in the pot and the crop was harvested at 8-10 weeks of plant growth. Dry matter (DM) yield was recorded and plant samples were analyzed for the particular nutrients under study. The CL of soil S for wheat was found to be 14 mg/kg and 11 mg/kg in graphical and statistical methods, and the CL of plant tissue concentration was recorded as 0.14% in both methods. In the case of mustard, the CL of soil S was estimated to be 14 mg/kg by graphical procedure and 11.45 mg/kg in statistical method. At the same time, plant tissue concentration showed the CL of 0.35% in both methods, respectively. On the other hand, the CL of soil B for wheat was 0.3mg/kg and 0.28 mg/kg in graphical and statistical methods, and the CL of plant tissue concentration was recorded as 13.0% and 13.39%, in graphical and statistical methods, respectively. In the case of mustard, the CL of soil B was estimated to be 0.25 mg/kg by graphical procedure and 0.12 mg/kg in statistical method while the CL of plant tissue concentration was recorded as 26.5% and 24.0%, in graphical and statistical method, respectively. Again, the CL of soil Mg for wheat was 0.5 meq/100g soil and 0.39 meq/100g soil in graphical and statistical methods. In case of mustard, the CL of soil Mg was estimated to be 0.55 meq/100g soil by graphical procedure and 0.31 meq/100g in statistical method, respectively. The results were also validated through field experiments at farmer's field-level in both Mymensingh and Panchagar District, which were in line with the laboratory and pot experiments results.

Keywords: Sulphur, Magnesium, Boron, Critcal limit, Wheat and Mustard.

B. Implementation Status

1. Procurement (Component wise):

Description of equipment and capital items	PP Target		Achievement		Remarks
	Physical (No.)	Financial (Tk.)	Physical (No.)	Financial (Tk.)	
BARC Component					
(a) Office equipment	4	350000	Desktop computer-1	59800	
			Laptop-1	59900	
			UPS-1	9800	
			Photocopier-1	195500	
			Total	**325000**	
(b) Furniture	9	150000	Ex. Table-1	19900	
			Ex. Chair-1	19900	
			File Cabinet-2	69800	
			Steel Almira-1	23900	
			Visitor Chair-4	59800	
			Total	**149100**	
(b) Lab &field equipment	0	0		0	
(c) Small Vehicle	0	0		0	
BARI Component					
(a) Office equipment	8	305000/-	Laptop computer (USA)-1	120,000	
			Desktop computer -1	120,000	
			Laser printer-1	20,000	
			Camera -1	25000	
			UPS -2	20,000	
			Refrigerator-1	60,000	
			Total	365000	
(b) Furniture	11	122500.00/-	Ex. Table-1	20,000	
			Ex. Chair -1	10,000	
			File Cabinet -1	20,000	
			Steel Almira -2	48,000	
			Front Chair -4	16,000	
			Computer Table -1	5000	
			Computer Chair-1	3500	
			Total	**122,500**	
(b) Lab &field equipment		1268000/-	PH Metor Bench Top	45,000	
			Mechanical stirrer with Disperson up	60,000	
			Soil Grinder	1,45,000	
			Plant Sample Grinder Wiloy Mill	790,000	

Description of equipment and capital items	PP Target		Achievement		Remarks
	Physical (No.)	Financial (Tk.)	Physical (No.)	Financial (Tk.)	
			Electrical conductivity Meter (Bench Top)	10,000	
			GPS Machine (GPS Navigation)	50,000	
			Micropiloe He-04	17,000	
			Total	**972,000**	
BRRI Component					
(a) Office equipment	03	100000	Laptop - 1	59800	
			Laser Printer-1	14800	
			Digital Camera-1	24900	
			Total	**99500**	
(b) Furniture	08	81000	Office Table-1	8000	
			Front Chair-4	17600	
			Executive Chair-1	10200	
			Show Case-1	26200	
			File Cabinet-1	19000	
			Total	**81000**	
(c) Lab & field equipment	08	1005000	Soil Sample Grinder-1	198000	
			Soil Dispersion Mixture and Cup-3	180000	
			pH Meter-1	199000	
			Straw Sample Grinder-1	199000	
			AAS lamp for Ca-1	75000	
			AAS lamp for Mg-1	75000	
			AAS lamp for Zn-1	75000	
			Total	**1001000**	
BINA Component					
(a) Office equipment	05	1,60,000/-	Desktop computer-1	59,800	
			Laptop-1	59,500	
			Laser Printer-1	19,700	
			UPS (offline)-1	9,600	
			Scanner-1	10,000	
			Sub-total	**1,58,600/-**	
(b) Lab &field equipment	02	15,00,000/-	Spectrophotometer-1	10,96,000	
			Stirrer-1	3,90,000	
			Sub-total	**14,86,000**	
(c) Other capital items (furniture)	10	79,000/-	Executive Table-1	19,900	
			Executive Chair-1	9,930	
			Visitor Chair-5	19,950	
			Computer Table-1	5,000	

Description of equipment and capital items	PP Target		Achievement		Remarks
	Physical (No.)	Financial (Tk.)	Physical (No.)	Financial (Tk.)	
			Steel Almira-1	24,000	
			Sub-total	**78,780**	
(d) Small Transport	01	10,000/-	Bicycle-1	**10,000/-**	
			Grand total	**17,33,380/-**	
BAU Component					
(a) Office equipment	1	20000	Printer-1	19500	
(b) Lab &field equipment	7	1365450	Soil sampler (Auger)-2	25500	
			Micro-pipetter-2	48000	
			GPS machine-1	26500	
			Gistillation and Digestion unit-1	748950	
			De-ionized water system-1	496900	
			Sub-total	**1345950**	
			Grand total	1365450	
(c) Other capital items	-	-	-	-	

2. Establishment/renovation facilities:

Description of facilities	Newly established		Upgraded/refurbished		Remarks
	PP Target	Achievement	PP Target	Achievement	
BARC Component					
BARI Component					
BRRI Component					
BINA Component					
Digestion chamber, fume hood and net house renovation.	-	-	01	01	
BAU Component					

3. Training/study tour/ seminar/workshop/conference organized

Description	Number of participant			Duration (Days/weeks/ months)	Remarks
	Male	Female	Total		
BARC Component					
(a) Training					
(b) Workshop					
i.Inception workshop	57	8	65	28-06-2018 (1 day)	
ii.Annual Review Workshop, 2019	54	6	60	25-06-2019 (1 day)	
iii.Annual Review Workshop, 2020	54	6	60	22-09-2020 (1 day)	
(c) Others (if any)					
BARI Component (N/A)					
(a) Training					
(b) Workshop					
(c) Others (if any)					
BRRI Component (N/A)					
(a) Training					
(b) Workshop					
(c) Others (if any)					
BINA Component (N/A)					
(a) Training					
(b) Workshop					
(c) Others (if any)					
BAU Component (N/A)					
(a) Training					
(b) Workshop					
(c) Others (if any)					

C. Financial and physical progress (Combined & Component wise)

Fig in Tk

Items of expenditure/activities	Total approved budget	Fund received	Actual expenditure	Balance/ unspent	Physical progress (%)	Reasons for deviation
Summary						
a. Contractual staff salary	7829751	7813463	7813463	0	100	
b. Field research/lab expenses and supplies	10060894	10042531	10042531	0	100	
c. Operating expenses	2778215	2679016	2679016	0	100	
d. Vehicle hire and fuel, oil & maintenance	2081021	2061021	2061021	0	100	
e. Training/workshop/seminar	714680	631200	631200	0	100	
f. Publications and printing	410000	337500	337500	0	100	
g. Miscellaneous	723821	688094	688094	0	100	
h. Capital expenses	6465930	6465850	6465850	0	100	
Total	**31064312**	**30718675**	**30718675**	**0**	100	
BARC Component						
a. Contractual staff salary	2476422	2476422	2476422	0	100	
b. Field research/lab expenses and supplies	0	0	0	0	0	
c. Operating expenses	352524	352286	352286	0	100	
d. Vehicle hire and fuel, oil & maintenance	151084	151084	151084	0	100	
e. Training/workshop/seminar etc.	714680	631200	631200	0	100	
f. Publications and printing	300000	297500	297500	0	0	
g. Miscellaneous	193590	188590	188590	0	100	
h. Capital expenses	474100	474100	474100	0	100	
Total	**4662400**	**4571182**	**4571182**	**0**	100	
BARI Component						
a. Contractual staff salary	1341894	1344821	1344821	0	100	
b. Field research/lab expenses and supplies	2700560	2700260	2700260	0	100	
c. Operating expenses	587854	577473	577473	0	100	
d. Vehicle hire and fuel, oil & maintenance	359000	359000	359000	0	100	
e. Training/workshop/seminar etc.	0	0	0	0	0	
f. Publications and printing	60000	0	0	0	0	
g. Miscellaneous	147628	145056	145056	0	100	
h. Capital expenses	1711500	1711420	1711420	0	100	
Total	**6908436**	**6838030**	**6838030**	**0**	100	

Items of expenditure/activities	Total approved budget	Fund received	Actual expenditure	Balance/ unspent	Physical progress (%)	Reasons for deviation
BRRI Component						
a. Contractual staff salary	1598607	1579392	1579392	0	100	
b. Field research/lab expenses and supplies	2728926	2728823	2728823	0	100	
c. Operating expenses	676992	632698	632698	0	100	
d. Vehicle hire and fuel, oil & maintenance	553900	533900	533900	0	100	
e. Training/workshop/seminar etc.	0	0	0	0	0	
f. Publications and printing	25000	15000	15000	0	100	
g. Miscellaneous	98200	73200	73200	0	100	
h. Capital expenses	1181500	1181500	1181500	0	100	
Total	**6863125**	**6744513**	**6744513**	**0**	100	
BINA Component						
a. Contractual staff salary	844955	844955	844955	0	100	
b. Field research/lab expenses and supplies	2349858	2331898	2331898	0	100	
c. Operating expenses	660065	651079	651079	0	100	
d. Vehicle hire and fuel, oil & maintenance	467119	467119	467119	0	100	
e. Training/workshop/seminar etc.	0	0	0	0	0	
f. Publications and printing	25000	25000	25000	0	100	
g. Miscellaneous	142134	142134	142134	0	100	
h. Capital expenses	1733380	1733380	1733380	0	100	
Total	**6222511**	**6195565**	**6195565**	**0**	100	
BAU Component						
a. Contractual staff salary	1567873	1567873	1567873	0	100	
b. Field research/lab expenses and supplies	2281550	2281550	2281550	0	100	
c. Operating expenses	500780	465480	465480	0	100	
d. Vehicle hire and fuel, oil & maintenance	549918	549918	549918	0	100	
e. Training/workshop/seminar etc.	0	0	0	0	0	
f. Publications and printing	0	0	0	0	0	
g. Miscellaneous	142269	139114	139114	0	100	
h. Capital expenses	1365450	1365450	1365450	0	100	
Total	**6407840**	**6369385**	**6369385**	**0**	100	

D. Achievement of Sub-project by objectives (Tangible form): Technology generated/ developed

General/specific objectives of the sub-project	Major technical activities performed in respect of the set objectives	Output (i.e. product obtained, visible, measurable)	Outcome (short term effect of the research)
BARI Component			
i) To delineate the present status of macro- and micro-nutrients in terrace soils (AEZs 11, 13 and 28).	i. 180 soil samples were collected from AEZs 11, 13 and 28. ii. Chemical analysis of the collected soil samples were completed	Data base of current status of different nutrients plus basic soil properties (texture, pH & OM) were developed.	Use of optimum dose of K and Zn fertilizers in wheat, cabbage and Maize will be ensured, which will enhance higher productivity of these crops.
ii) To determine critical limit of K and Zn for different soils and crops (wheat, cabbage and Maize)	i. Pot culture experiments were conducted with K and Zn on wheat, cabbage and Maize ii. Plant analysis was done iii. Determined of critical limits of K and Zn for wheat, cabbage and Maize	6 critical limits were determined.	
iii) To validate the C. L. results from pot experiments by field experiments.	i. Conducted field experiments ii. Collected data and all other necessary information	The Critical Limits were validated through field trial at the farm level	
BRRI Component			
i) To delineate the present status of macro- and micro-nutrients in Meghna and Surma-Kushiara floodplain soils.	i. 180 soil samples were collected from AEZs 18, 19 and 20. ii. Chemical analysis of the collected soil samples were completed	Data base of current status of different nutrients plus basic soil properties (texture, pH & OM) were developed.	Use of optimum dose of P, K, S and Zn fertilizers in rice will be ensured, which will enhance higher productivity of the crop.
ii) To determine critical limit of P, K, S and Zn for rice crop	i. Pot culture experiment were conducted with different nutrients (viz. P, K, S and Zn) and crops (rice) ii. Plant analysis iii. Determination of critical limit	Critical limits of different nutrients (that are deficient in Bangladesh) for rice crop and soils were determined	
iii) To validate the C. L. results from pot experiments by some field experiments	i. Field experiments established as per protocol ii. Data Collection has been completed	Fertilizer effect on rice crop in different soils was validated.	
BINA Component			
i) To delineate the present status of macro- and micro-nutrients in terrace soils (AEZs 25, 26, 27)	i. 180 soil samples were collected from AEZs 25, 26 and 27. ii. Chemical analysis of the collected soil samples were completed	Data base of current status of different nutrients plus basic soil properties (texture, pH & OM) were developed.	Use of optimum dose of P and Mg fertilizers in Maize and mustard will be ensured, which will enhance higher productivity of these crops.

General/specific objectives of the sub-project	Major technical activities performed in respect of the set objectives	Output (i.e. product obtained, visible, measurable)	Outcome (short term effect of the research)
ii) To determine critical limit of P and Mg for different soils and crops (maize and mustard)	i. Pot culture experiments were conducted with P and Mg on maize and mustard ii. Plant analysis iii.Determination of critical limit	6 critical limits were determined.	
iii. To validate the C. L. results from pot experiments by some field experiments	i. Conducted field experiments ii. Collected data and all other necessary information	The Critical Limits were validated through field trial at the farm level	
BAU Component			
i) To delineate the present status of macro- and micro-nutrients in non-calcareous, piedmont and terrace soils (AEZs 1, 3, 9)	i. 180 soil samples were collected from AEZs 1,3 and 9 ii. Chemical analysis of the collected soil samples were completed	Data base of current status of different nutrients plus basic soil properties (texture, pH & OM) were developed.	Use of optimum dose of Mg, S and B fertilizers in wheat and mustard will be ensured, which will enhance higher productivity of these crops.
ii)To determine critical limit of Mg, S and B for different soils and crops (wheat and mustard)	i. Pot culture experiment were conducted with different nutrients (viz. Mg, S and B) and crops (wheat and mustard) ii. Plant analysis iii. Determination of critical limit	6 Critical Limits of Mg, S and B for wheat and mustard were determined	
iii) To validate the C. L. results from pot experiments by some field experiments	i. Field experiments established as per protocol ii. Data Collection has been continued	Fertilizer effect on crops and soil would be achieved.	

E: Information/knowledge generated/policy generated

General/specific objectives of the sub-project	Major technical activities performed in respect of the set objectives	Output	Outcome (short term effect of the research)
BARI Component			
To delineate the present status of macro- and micro-nutrients in terrace soils (AEZs 11, 13 and 28).	Collected a total of 180 soil samples (60 samples per AEZ). Analysis of all 180 soil samples completed.	Identified locations for collection of bulk soil samples to be used in pot trials.	Nutrient status of soils of AEZs 11, 13 and 28 were identified.
To determine critical limit of K and Zn for different soils and	Four pot trials were conducted for determined the critical limits of K and	Critical limit of K and Zn for wheat, Maize and cabbage were determined.	Optimum K and Zn fertilizer will be applied by the farmers for maximizing crop yield.

General/specific objectives of the sub-project	Major technical activities performed in respect of the set objectives	Output	Outcome (short term effect of the research)
crops (wheat, Maize and cabbage)	Zn for wheat, cabbage and maize crops.		
To validate the C. L. results from pot experiments by field experiments.	Twelve field experiments were conducted at Jashore, Rajshahi and Gazipur on wheat, cabbage and maize crops.	Validate the CL results from pot experiments by field experiments	Farmer's will be benifited by applying optimum K and Zn containing fertilizer recommendations in wheat, Maize and cabbage.
BRRI Component			
i) To delineate the present status of macro- and micro-nutrients in Meghna and Surma-Kushiara floodplain soils.	i. 180 soil samples were collected from AEZs 18, 19 and 20. ii. Chemical analysis of the collected soil samples were completed	Data base of current status of different nutrients plus basic soil properties (texture, pH & OM) were developed.	Nutrient status in AEZs of 18, 19 and 20 were identified.
ii) To determine critical limit of P, K, S, and Zn for different soils and rice	i. Pot culture experiment were conducted with different nutrients (viz. P, K, S, and Zn) on rice ii. Plant analysis iii. Determination of critical limit	Critical limits of different nutrients (that are deficient in Bangladesh) for different rice crop and soils were determined	Optimum doses of P, K, S, and Zn fertilizers will be applied by the farmers for maximizing rice yield.
iii) To validate the C. L. results from pot experiments by some field experiments	i. Field experiments established as per protocol ii. Data Collection has been completed	Fertilizer effect on crops and soil would be achieved.	Optimum doses of P, K, S, and Zn fertilizers will be recommended rice and used by the farmers.
BINA Component			
To delineate the present status of macro- and micro-nutrients in terrace soils (AEZs 25, 26, 27).	Collected a total of 180 soil samples (60 samples per AEZ). Analysis of all 180 soil samples completed.	Identified locations for collection of bulk soil samples to be used in pot trials.	Delineate the status of nutrients in terrace soils were identified.
To determine critical limit of P and Mg for different soils and crops (Maize and mustard.)	Four pot trials were conducted for determined the critical limits of P and Mg for maize and mustard crops.	Critical limit of phosphorus and magnesium for mustard & maizewere determined.	Optimum P and Mg fertilizer will be applied by the farmers for maximum crop yield.
To validate the C. L. results from pot experiments by field experiments.	Four field experiments were conducted at Dinajpur and Sherpur using mustard and maize crops.	Validate the CL results from pot experiments by field experiments	Farmer's will be benifited by applying optimum phosphorus and magnesium fertilizer.

General/specific objectives of the sub-project	Major technical activities performed in respect of the set objectives	Output	Outcome (short term effect of the research)
BAU Component			
i) To delineate the present status of macro- and micro-nutrients in non-calcareous, piedmont and terrace soils (AEZs 1, 3, 9)	i. 180 soil samples were collected from AEZs 1,3 and 9 ii. Chemical analysis of the collected soil samples were completed	Data base of current status of different nutrients plus basic soil properties (texture, pH & OM) were developed.	Nutrient status of soils of AEZs 1, 3, 9 were identified.
ii) To determine critical limit of Mg, S and B for different soils and crops (wheat and mustard)	ii. Pot culture experiment were conducted with different nutrients (viz. Mg, S and B) and crops (wheat and mustard) ii. Plant analysis iii. Determination of critical limit	Critical limits of different nutrients (that are deficient in Bangladesh) for different crops and soils were determined	Optimum Mg, S and B fertilizer will be applied by the farmers for maximizing wheat and mustard yield.
iii) To validate the C. L. results from pot experiments by some field experiments	ii.Field experiments established as per protocol ii. Data Collection has been continued	Fertilizer effect on crops and soil would be achieved.	Farmer's will be benifited by applying optimum Mg, S and B containing fertilizer recommendations in wheat, and mustard.

F. Materials Development/Publication made under the Sub-project:

Publication	Number of publication		Remarks (e.g. paper title, name of journal, conference name, etc.)
	Under preparation	Completed and published	
BARI Component			
Technology bulletin/ booklet/**leaflet**/flyer etc.	02	-	ক) ভুট্টা উৎপাদনে পটাসিয়ামের ক্রান্তিমান নির্ণয়। ক) সরিষা উৎপাদনে পটাসিয়ামের ক্রান্তিমান নির্ণয়।
Journal publication	06	-	Following journal articles are being prepared for publication in different journals: 1. Revision of critical limit of potassium for soils and maize crop 2. Revision of critical limit of Zinc for soils and maize crop 3. Revision of critical limit of potassium for soils and cabbage crop 4. Revision of critical limit of Zinc for soils and Cabbage crop 5. Revision of critical limit of potassium for soils and wheat crop 6. Revision of critical limit of Zinc for soils and wheat crop
Video clip/TV program			

Publication	Number of publication		Remarks (e.g. paper title, name of journal, conference name, etc.)
	Under preparation	Completed and published	
News Paper/Popular Article			
Other publications, if any			
BRRI Component			
Technology bulletin/ booklet/leaflet/flyer etc.	01	Ready for submission	ক) ধান চাষাবাদে ফসফসরাসের ক্রান্তিমান নির্ণয়। খ) ধান চাষাবাদে পটাসিয়ামের ক্রান্তিমান নির্ণয়।
Journal publication	02	Ready for submission	1.Revision of critical limit of phosphorus for soils and rice crop in Bangladesh 2. Revision of critical limit of potassium for soils and rice crop in Bangladesh
Video clip/TV program			
News Paper/Popular Article			
Other publications, if any	01		
BINA Component			
Technology bulletin/ booklet/**leaflet**/flyer etc.	02	02	ক) সরিষা চাষাবাদে ফসফসরাসেরক্রান্তিমাননির্নয়। খ) সরিষা চাষাবাদে ম্যাগনেশিয়ামের ক্রান্তিমান নির্নয়।
Journal publication	04		Following journal articles are being prepared for publication in different journals: 1. Revision of critical limit of phosphorus for soils and maize crop 2. Revision of critical limit of phosphorus for soils and mustard crop 3. Revision of critical limit of magnesium for soils and maize crop 4. Revision of critical limit of magnesium for soils and mustard crop
Video clip/TV program			
News Paper/Popular Article			
Other publications, if any			
BAU Component			
Technology bulletin/ booklet/leaflet/flyer etc.	-	-	-
Journal publication	01		Title: Critical limit refinement of sulphur in soil for wheat (*Triticum aestivum L.*) and mustard (*Brassica napus L.*) in Bangladesh **Author:** Rubina Yesmin, Mahmud Hossain, Mohammad Golam Kibria, M Jahiruddin, S M Bokhtiar, Md. Baktear Hossain, Md. Abdus Satter, Zakaria M. Solaiman and Md Anwarul Abedin* **Journal:** Sustainability

Publication	Number of publication		Remarks (e.g. paper title, name of journal, conference name, etc.)
	Under preparation	Completed and published	
Video clip/TV program	**01**	**Video-clip** https://we.tl/t-fSoS04qRLM **TV Program** https://www.facebook.com/JamunaTelevision/posts/3881785075250658	
News Paper/Popular Article	**01**	**News** https://m.somoynews.tv/pages/details/264646?fbclid=IwAR0AVFhOVpX1BDOJoPJGZEqGe_H7vIid_SP23o5N1yYNkjwRR5pIIospIKI	

G. Description of generated Technology/knowledge/policy:

i. **Technology Factsheet** (title of the technology, introduction, description, suitable location/ecosystem, benefits, name and contact address of author)

"Determination of Critical Limit of Nutrients for Soils and Crops" is a sub-project for conduction of basic research. The objectives of the sub-project have been fully achieved. A total of 22 Critical Limits (CL) of different macro- and micronutrients for different soils and crops have been developed under the project. The Critical Limits have also been validated through a number of field trials at the farm level under real field situation. Critical Limit of a nutrient for soil is a basic parameter based on which fertilizer recommendation for the nutrient for crops and cropping patterns in different AEZs of the country is determined. The estimated Critical Limits developed under the sub-project will be incorporated in the upcoming Fertilizer Recommendation Guides and will also be used in updating of fertilizer recommendations for crops and cropping patterns in different AEZs of the country.

ii. **Effectiveness in Policy Support** (if applicable)

As also mentioned above that the Critical Limits are used for determining fertilizer requirement of crops and cropping patterns in different AEZs of the country. So, this basic information is useful and widely used in planning of agricultural production and development programs in the county. The information is also useful in estimation of fertilizer requirement in the country, and thereby in planning for fertilizer production, import, marketing and distribution in the country. The CL will also be used extensively in the soil fertility and fertilizer management research in the country.

H. Technology/Knowledge generation/Policy Support (as applied):

i. Immediate impact on generated technology (commodity & non-commodity): N/A

ii. Generation of new knowledge that help in developing more technology in future

A total of 22 Critical Limits (CL) of different macro- and micronutrients for different soils and crops have been developed under the project. Critical Limit is the basic parameter, based on which fertilizer recommendation for crops for a particular area is developed. The estimated Critical Limits will be incorporated in the upcoming Fertilizer Recommendation Guides and will also be used in updating of fertilizer recommendations for different crops and cropping patterns. The CL will also be used extensively in the soil fertility and fertilizer management research in the country.

iii. Technology transferred that help increased agricultural productivity and farmers' income: N/A

iv. Policy Support

As also mentioned before that the Critical Limits are used for determining fertilizer requirement of crops and cropping patterns in different AEZs of the country. So, this basic information is useful and widely used in planning of agricultural production and development programs in the county. The information is also useful in estimation of fertilizer requirement in the country, and thereby in planning for fertilizer production, import, marketing and distribution in the country. The CL will also be used extensively in the soil fertility and fertilizer management research in the country.

I. Information regarding Desk and Field Monitoring

BARI:

i. Desk Monitoring [description & output of consultation meeting, monitoring workshops/seminars etc.):

ii. Field Monitoring (date& no. of visit, name and addresses of team visit and output):

Date	No. of visit	Name and addresses of team	Output
31.03.2019	01	Dr. Aziz Zilani Chowdhury, MD (Crops), BARC Dr. Zakiah Moni, SSO, BARC	• Visited pot experiments ant BARI HQ. • Provided suggestions regarding implementation

iii. Weather data, flood/salinity/drought level (if applicable) and natural calamities: N/A

Photo 42: Monitoring Team of BARC and NATP consultant visited BARI experiments and hold meeting with the PI and scientists of BARI

BRRI:

i. Desk Monitoring [description & output of consultation meeting, monitoring workshops/seminars etc.):

ii. Field Monitoring (date& no. of visit, name and addresses of team visit and output):

Sl. No.	Date of visit	Name	Output
1	31.03.2019	Dr. Md. Aziz Zilani Chowdhuri with team	• Visited pot experiments ant BRRI HQ. • Provided suggestions regarding implementation
2	30.04.2019	World Bank team of Mid-term Review Mission	• Visited pot experiments ant BRRI HQ.
3	11.11.2020	Dr. Harunur Rashid with team	• Visited pot experiments ant BRRI HQ. • Provided suggestions regarding implementation
4	21.03.2021	Dr. Md. Sirajul Islam with team	• Visited pot experiments ant BRRI HQ. • Provided rovided suggestions regarding implementation

iii. Weather data, flood/salinity/drought level (if applicable) and natural calamities: N/A

Photo 43: Monitoring Team of BARC and Director PIU-BARC visited BRRI experiments and hold meeting with the PI and scientists of BRRI

BINA:

i. Desk Monitoring [description & output of consultation meeting, monitoring workshops/seminars etc.):

ii. Field Monitoring (date& no. of visit, name and addresses of team visit and output):

Date	No. of visit	Name and addresses of team	Output
15 Dec 2019	01	Dr. Md. Abdul Jalil, RMS, PIU/BARC Dr. Md. Abdullah Al Faroque, AM (Admin.), PIU/BARC Mr. Munshi Mamunur Rahman, Doc A, PIU/BARC Mr. Md. Asikur Rahman, AM (Accounts), PIU/BARC	• Visited pot experiments ant BINA HQ. • Provided suggestions regarding implementation
06-07 Mar 2019	01	Dr. Md. Mosharraf Uddin Mollah, CSO, BARC	• Visited pot experiments at BINA HQ for desk moniotoring. • Pleased to see the official recrods
2019 & 2020	02	Dr. Md. Baktear Hossain, CSO, NRM, BARC	• Visited pot expts at BINA HQ
2020	01	Dr. S. M. Bokhtiar, Executive Chairman, BARC & Dr. Md. Baktear Hossain, CSO, NRM, BARC	Pot expt
Jan 2021	01	Dr. S. M. Bokhtiar, Executive Chairman, BARC & Dr. Md. Baktear Hossain, CSO, NRM, BARC	Visited field experiment at Nalitabari, Sherpur

iii. Weather data, flood/salinity/drought level (if applicable) and natural calamities:

Photo 44: EC, BARC is visiting pot trials at BINA with the Coordinator

BAU:

i. Desk Monitoring [description & output of consultationmeeting, monitoring workshops/seminars etc.): N/A

ii. Field Monitoring (date & no. of visit, name and addresses of team visit and output):

Sl. No.	Date of visit	Name	Output
1	17.02.19	Mia Syed Hasan, Director, PIU	• Visited pot experiments at BAU, Mymensingh • Provided guidelines of implementation
2	21.03.19	Dr. Md. Mosharraf Uddin Mollah, CSO, BARC Mr. Dipak Kumar, PIU-BARC	• Visited pot experiments at BAU, Mymensingh • Provided guidelines of implementation

iii. Weather data, flood/salinity/drought level (if applicable) and natural calamities: N/A

Photo 45: Monitoring Team of PIU-BARC is visiting SSD Lab of BAU

J. Sub-project auditing (covers all types of audits performed)

Types of audit	Major observation/ issues/ objections raised; if any	Amount of Audit (Tk.)	Status at the sub-project end	Remarks
BARC Component				
FAPAD	No major objections	734764	2018-19	30-10-2019
FAPAD	No major objections	1360581	2019-20	09-12-2020
FAPAD	No major objections	1072945	2020-21	11-10-2021
BARI Component				
FAPAD	No major objections	34,26,550/-	2018-2019	18.11.2019 to 20.11.2019
FAPAD	No major objections	8,86,830/-	2019-2020	02.11.2020 to 17.11.2020
BRRI Component				
FAPAD	No major objections	18,89,492 /-	2018-19	14.11.2019 to 25.11.2019
FAPAD	No major objections	9,71,997 /-	2019-20	04.11.2020 to 17.11.2020
BINA Component				
FAPAD	No major objections	16,08,732	2018-2019	14.11.2019 to 25.11.2019
FAPAD	No major objections	31,49,400	2019-2020	04.11.2020 to 17.11.2020
FAPAD	No major objections	11,83,525	2020-2021	26.10.2021 to 03.11.2021
BAU Component				
FAPAD	No major objections	4944780	February 2021	

K. Lessons Learned:

i) A comprehensive understanding on soils, their fertility status, cropping and fertilizer practices was developed by visiting many places during soil collection.

ii) The sub-project work helped to upgrade skills in writing, planning, execution of research, calculating critical limits, report presentation, procurement etc.

iii) The expert comments made during workshops and report writing, planning, report presentation, procurement etc. upgraded the overall knowledge and skills of the concerned scientists.

L. Challenges (if any)

No major obstacles were faced during conduction of the overall sub-project activities. Some minor problems were encountered due to delay in fund release and lockdown due to COVID-19 situation.

M. Suggestions for future planning (if any)

Critical Limit is the basic element in fertilizer recommendation for crops. It varies with the crops, soils and extraction methods. Under this sub-project Critical Limits of P, K, S, Mg, and Zn for soils of different AEZs have been determined only for five major crops like rice, wheat, maize, mustard and cabbage. So many soils and crops of the country are still remaining pending. The research might be expanded to the other soils and crops of the country for determining their Critical Limits and recommendation of optimum fertilizer doses. Scientific visit and overseas training might be organized for the coordinators, principal investigators and co-principal investigators for upgrading their knowledge and skills on the research area.

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Signature of the Coordinator

Date: 07.02.2022

Seal Dr. M. Baktear Hossain
Director (Manpower and Training)
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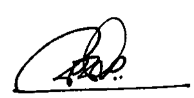

Counter signature of the Head of the organization/authorized representative

Date: 07.02.2022

Seal Dr. Shaikh Mohammad Bokhtiar
Executive Chairman
Bangladesh Agricultural Research Council
Farmgate, Dhaka-1215

BARI Component

Appendix 1. Soil sample analytical data along with baseline information

Sl.	AEZ	Farmer	Address	Geo location	Soil Series	Land type	Cropping patterns	pH	TN	P	S	K	Ca	Mg
								-	%	(mg/kg soil)		meq/100g soil		
1	28	Tanjil Bari	Baraid, Kaligonj	23°57’23.76”/ 90°32’43.8”	Tejgaon, Belabo	MHL	Vegetables-Jute-T.aman	5.72	0.057	22	8.3	0.17	2.6	1.6
2	28	Ahnaf Hossen	Baraid, Kaligonj	23°57’16.56”/ 90°32’46.7”	Tejgaon, Belabo	HL	Vegetables-Jute-T.aman	6.6	0.04	11	2.4	0.07	2.5	1.1
3	28	Md Mostofa Ali	Baraid, Kaligonj	23° 56’ 49.9”/ 90° 32’ 59.6”	Tejgaon, Belabo	HL	Fallow-fallow-T.aman	5.63	0.096	22	4.5	0.09	2.3	1.1
4	28	Rahman Bepari	Baraid, Kaligonj	23° 56’ 56.2”/ 90° 32’ 53.1”	Tejgaon, Belabo	MHL	Spices-GM-T.aman	6.7	0.068	21	6.5	0.09	2.7	1
5	28	Lehajuddin	Baraid, Kaligonj	23° 58’ 6.6”/ 90° 32’ 54.6”	Tejgaon, Belabo	MHL	Vegetables-Jute-T.aman	5.98	0.076	23	2	0.14	2.7	1.1
6	28	Alauddin Ali	Baraid, Kaligonj	23° 58’ 13.1”/ 90° 32’ 58.2”	Tejgaon, Belabo	HL	Vegetables-Jute-T.aman	5.88	0.117	34	10.8	0.09	2.1	1.1
7	28	Shamsul Alam	Baraid, Kaligonj	23° 59’ 46.2”/ 90° 32’ 33.4”	Tejgaon, Belabo	MHL	Spices-GM-T.aman	6.07	0.087	42	14.9	0.11	3.5	1.3
8	28	Alok Paul	Baraid, Kaligonj	23° 58’ 53.0”/ 90° 32’ 54.6”	Tejgaon, Belabo	HL	Fallow-Fallow- T.aman	5.5	0.092	41	16	0.13	3.3	1.7
9	28	Jiban Krishna	Baraid, Kaligonj	23° 58’ 5.52”/ 90° 32” 57.5”	Tejgaon, Belabo	MHL	Boro-Fallow-Fallow	5.54	0.124	52	22.9	0.16	4.8	1.5
10	28	Mojammel Haque	Baraid, Kaligonj	23° 58’6.96”/ 90° 32’ 56.8”	Tejgaon, Belabo	MHL	Boro-Fallow-Fallow	5.96	0.11	45	11.8	0.13	3.6	1.1
11	28	Masud Mia	Durbati, Kaligonj	23° 55’ 38.3”/ 90° 33’ 27.36”	Sonatala, Silmondi	MHL	Spices-Fallow-T.aman	7.21	0.048	18	14.2	0.1	2.9	1.2
12	28	Ismail Hossain	Durbati, Kaligonj	23° 56’36.24”/ 90° 32’51.36”	Sonatala, Silmondi	MHL	Vegetables-Fallow-T.aman	7.71	0.058	20	21.7	0.1	2.8	1.05
13	28	Sohel Rana	Durbati, Kaligonj	23° 56’29.04”/ 90° 32’49.92”	Sonatala, Silmondi	MHL	Vegetables-Fallow-T.aman	7.8	0.067	22	17	0.07	2.9	1.09
14	28	Chan Mia	Durbati, Kaligonj	23° 56’30.12”/ 90° 32’ 54.52”	Sonatala, Silmondi	MHL	Vegetables-Fallow-T.aman	6.66	0.068	20	8.6	0.07	2.8	1.06
15	28	Md Ashraul	Durbati, Kaligonj	23° 56’38.76”/ 90° 32’50.64”	Sonatala, Silmondi	HL	Vegetables-Fallow-T.aman	7.17	0.043	12	14.6	0.07	2.5	1.1
16	28	Sabbirullah	Durbati, Kaligonj	23°56’39.12”/ 90 ° 32’ 45.6”	Sonatala, Silmondi	HL	Pulses-GM/jute-T.aman	8.1	0.059	17	9.9	0.06	2.6	1.2
17	28	Afif Alam	Durbati, Kaligonj	23°56’31.56”/ 90°32’29.4”	Sonatala, Silmondi	MHL	Pulses-GM/jute-T.aman	7.19	0.044	15	11.1	0.09	2.4	1.2

Sl.	AEZ	Farmer	Address	Geo location	Soil Series	Land type	Cropping patterns	pH	TN	P	S	K	Ca	Mg
								-	%	(mg/kg soil)		meq/100g soil		
18	28	Laymat Ullah	Durbati, Kaligonj	23°56' 27.24"/ 90° 32' 31.92"	Sonatala, Silmondi	MHL	Vegetables-Fallow-T.aman	7.3	0.049	18	6.7	0.06	2.4	1.3
19	28	Aizaddin Molla	Durbati, Kaligonj	23° 56' 30.5"/ 90° 32' 32.28"	Sonatala, Silmondi	HL	Pulses-GM/jute-T.aman	7.14	0.043	13	10	0.08	2.5	1.3
20	28	Rahmat Ali	Durbati, Kaligonj	23° 56'28.32"/ 90° 32' 33.0"	Sonatala, Silmondi	MHL	Pulses-GM/jute-T.aman	6.65	0.047	12	5.9	0.07	2.1	1.1
21	28	Mahammad Sharif	Baktarpur, Kaligonj	23° 57'23.76"/ 90 ° 32 43.8"	Tejgaon, Belabo	HL	Vegetables-Jute-T.aman	5.63	0.103	33	9.8	0.16	2.2	1.2
22	28	Hafizul Islam	Baktarpur, Kaligonj	23°57'16.56"/ 90° 32' 46.7"	Tejgaon, Belabo	MHL	Vegetables-Jute-T.aman	5.48	0.103	32	16.6	0.26	2.2	1.2
23	28	Sujan Biswas	Baktarpur, Kaligonj	23° 56' 49.9"/ 90° 32' 59.6"	Tejgaon, Belabo	MHL	Fallow-fallow-T.aman	6.09	0.077	19	13.4	0.13	2.1	1.1
24	28	Jahangir Alam	Baktarpur, Kaligonj	23° 56'56.2"/ 90° 32'53.1"	Tejgaon, Belabo	MHL	Spices-GM-T.aman	7.63	0.049	17	10.7	0.07	2.7	1.4
25	28	Shyamol Dhar	Baktarpur, Kaligonj	23° 58' 6.6"/ 90° 32' 54.6"	Tejgaon, Belabo	MHL	Vegetables-Jute-T.aman	6.59	0.04	12	12.7	0.23	2.3	1.1
26	28	Chitto Ranjan Kar	Baktarpur, Kaligonj	23° 58' 13.1"/ 90° 32' 58.2"	Tejgaon, Belabo	MHL	Vegetables-Jute-T.aman	5.42	0.083	22	18.1	0.63	2.2	1.1
27	28	Mojnu Mia	Baktarpur, Kaligonj	23° 59' 46.2"/ 90° 32' 33.4"	Tejgaon, Belabo	MHL	Spices-GM-T.aman	5.66	0.128	32	23.9	0.16	2.6	1.3
28	28	Ranjit Biswas	Baktarpur, Kaligonj	23° 58' 53.0"/ 90° 32' 54.6"	Tejgaon, Belabo	HL	Fallow-Fallow- T.aman	5.43	0.092	20	18.8	0.08	2.6	1
29	28	Karim Munsi	Baktarpur, Kaligonj	23° 58' 5.52"/ 90° 32" 57.5"	Tejgaon, Belabo	MHL	Boro-Fallow-Fallow	5.83	0.074	16	24.4	0.62	2.9	1.3
30	28	Khokon Biswas	Baktarpur, Kaligonj	23° 58'6.96"/ 90° 32' 56.8"	Tejgaon, Belabo	HL	Boro-Fallow-Fallow	6.61	0.072	15	18.1	0.29	2.2	1
31	28	Prokash Sen	Ausnara, Madhupur	24° 35' 11.4"/ 90° 01' 16.3"	Tejgaon, Sonatola, Kolma	HL	Vegetables-Fallow-T.aman	5.96	0.049	22	2	0.08	4.5	1.6
32	28	Jaydhar	Ausnara, Madhupur	24° 35'11.04"/ 90° 01' 10.2"	Tejgaon, Sonatola, Silmondi	MHL	Boro-Fallow-T.aman	6.63	0.042	15.2	1	0.07	2.7	1.1
33	28	Imrul Kaysar	Ausnara, Madhupur	24° 35' 7.44"/ 90° 00' 58.3"	Tejgaon, Sonatola, Silmondi	HL	Vegetables-Fallow-Fallow	7.02	0.047	16	1.6	0.15	2.8	1.1
34	28	Dilip Biswas	Ausnara, Madhupur	24 ° 35' 5.28"/ 90 ° 00' 59"	Tejgaon, Sonatola, Kolma	MHL	Boro-Fallow-T.aman	5.82	0.041	14	13.4	0.17	2.4	1
35	28	Avijit Baral	Ausnara, Madhupur	24° 35'3.48"/ 90° 00' 56.9"	Tejgaon, Sonatola, Silmondi	MHL	Boro-Fallow-T.aman	6.4	0.051	15	8.8	0.09	2.6	1.1
36	28	Badal Hossain	Ausnara, Madhupur	24° 35'15.64"/ 90° 01'0.84"	Tejgaon, Sonatola, Kolma	MHL	Vegetables-Fallow-T.aman	6.3	0.068	6	1.4	0.12	2.8	1.1

Sl.	AEZ	Farmer	Address	Geo location	Soil Series	Land type	Cropping patterns	pH	TN	P	S	K	Ca	Mg
								-	%	(mg/kg soil)		meq/100g soil		
37	28	Debasis Karmaker	Ausnara, Madhupur	24°35’13.27”/ 90 ° 00’ 56.9”	Tejgaon, Sonatola, Silmondi	MHL	Boro-Fallow-T.aman	6.67	0.058	12	3.2	0.08	3.6	1.3
38	28	Dinesh Krishna	Ausnara, Madhupur	24° 35’13.92”/ 90° 00’ 47.5”	Tejgaon, Sonatola, Silmondi	MHL	Vegetables-Fallow-Fallow	6.48	0.048	15	1.3	0.07	4.7	1.7
39	28	Hasib Mollah	Ausnara, Madhupur	24° 35’13.2”/ 90° 00’ 50.9"	Tejgaon, Sonatola, Kolma	MHL	Vegetables-Fallow-T.aman	6.53	0.043	12	1.2	0.07	4.1	1.5
40	28	Kartik	Ausnara, Madhupur	24° 35’ 16.8”/ 90° 00’ 48.6”	Tejgaon, Sonatola, Silmondi	HL	Vegetables-Fallow-T.aman	5.44	0.072	9	6	0.19	2.7	1.1
41	28	Kanchan	Mirzabari, Madhupur	24° 37’ 38.6”/ 90° 07’ 30.4”	Hamidpur, Silmondi, Ghatail	HL	Vegetables-Vegetables-T.aman	6.38	0.069	16	10.9	0.11	2.4	1
42	28	Hiron Adhikari	Mirzabari, Madhupur	24° 37’ 39”/ 90° 01’ 30.7”	Hamidpur, Silmondi, Ghatail	MHL	Boro-Fallow-T.aman	6.22	0.085	16	13.9	0.2	2.5	1
43	28	Abdul Hamid	Mirzabari, Madhupur	24° 37’ 32”/ 90° 02’ 31”	Hamidpur, Ghatail	MHL	Vegetables-Vegetables-T.aman	6.09	0.078	12	17.9	0.16	2.3	0.94
44	28	Md Masum	Mirzabari, Madhupur	24° 37’ 28.6”/ 90 ° 02’ 24.6”	Hamidpur, Silmondi, Ghatail	MHL	Boro-Fallow-T.aman	5.67	0.072	11	17.2	0.18	3.7	1.4
45	28	Md. Enamul	Mirzabari, Madhupur	24° 37’ 20.3”/ 90° 02’ 24.6”	Hamidpur, Silmondi	MHL	Vegetables-Vegetables-T.aman	6.39	0.043	12	20.3	0.15	4.6	1.6
46	28	Amir Ali	Mirzabari, Madhupur	24° 37’ 19”/ 90° 01’ 15”	Hamidpur, Silmondi, Ghatail	MHL	Aroids – T.aman	6.83	0.07	17	15	0.09	4.2	1.5
47	28	Osman Gani	Mirzabari, Madhupur	24° 37’ 22”/ 90° 01’ 14”	Hamidpur, Silmondi, Ghatail	MHL	Boro-Fallow-T.aman	6.42	0.077	14	19.8	0.07	3.8	1.4
48	28	Nur Hossain	Mirzabari, Madhupur	24° 37’ 28”/ 90° 01’ 9.5”	Hamidpur, Silmondi, Ghatail	MHL	Turmeric – T.aman	6.37	0.09	14	8.1	0.08	3.6	1.3
49	28	Sakil Mia	Mirzabari, Madhupur	24° 37’ 38”/ 90° 00’ 54”	Hamidpur, Silmondi, Ghatail	MHL	Vegetables-Vegetables-T.aman	5.72	0.065	13	14.9	0.19	3.8	1.4
50	28	Abdul Mottaleb	Mirzabari, Madhupur	24° 37’ 39”/90 ° 00’ 51”	Hamidpur, Silmondi	MHL	Vegetables-Fallow-T.aman	6.81	0.069	8	15.2	0.2	2.2	0.84
51	28	Shahadat	Alokdia, Madhupur	24° 34’29.16”/ 90° 02’57.76”	Tejgaon, Khilgaon	MHL	Vegetables-Fallow-T.aman	5.54	0.059	12	15.1	0.21	2.4	1
52	28	Masum Abedin	Alokdia, Madhupur	24° 33’ 36”/ 90° 02’ 58.92”	Tejgaon, Khilgaon	MHL	Boro-Fallow-T.aman	5.83	0.094	10	12.3	0.15	2.3	0.96
53	28	Raihan Talukder	Alokdia, Madhupur	24°33’17.64”/ 90° 03’ 9.36”	Tejgaon, Khilgaon	HL	Vegetables-Fallow-T.aman	6.19	0.076	12	12.1	0.1	2.7	1.1
54	28	Shamim Wasiq	Alokdia, Madhupur	24°33’15.12”/ 90° 03’10.44”	Tejgaon, Khilgaon	MHL	Boro-Fallow-T.aman	5.96	0.076	12	12.1	0.1	2.7	1.1
55	28	Yousuf Mia	Alokdia, Madhupur	24° 33’15.48”/ 90 ° 03’ 10.1“	Tejgaon, Khilgaon	MHL	Boro-Fallow-T.aman	6.23	0.086	10	10.6	0.08	2.4	1

Sl.	AEZ	Farmer	Address	Geo location	Soil Series	Land type	Cropping patterns	pH	TN	P	S	K	Ca	Mg
								-	%	(mg/kg soil)		meq/100g soil		
56	28	Momimur Rahman	Alokdia, Madhupur	24° 33’30.24”/ 90° 03’24.48”	Tejgaon, Khilgaon	HL	Vegetables-Fallow-T.aman	6.55	0.089	13	6.6	0.09	2.7	1.08
57	28	Ahmed Anik	Alokdia, Madhupur	24° 33’ 8”/90° 03’40”	Tejgaon, Khilgaon	MHL	Boro-Fallow-T.aman	6.94	0.083	13	9.7	0.18	2.6	1.1
58	28	Julhas Mia	Alokdia, Madhupur	24° 33’ 05”/ 90° 03’ 42.5”	Tejgaon, Khilgaon	MHL	Boro-Fallow-T.aman	6.77	0.075	14	9.8	0.18	2.8	1.2
59	28	Abu Yousuf	Alokdia, Madhupur	24° 33’ 04”/ 90° 03’ 37”	Tejgaon, Khilgaon	HL	Vegetables-Fallow-T.aman	6.35	0.077	12	11	0.11	2.5	1.02
60	28	Md Zakir Hossain	Alokdia, Madhupur	24° 33’ 01”/ 90°03’33.12”	Tejgaon, Khilgaon	HL	Vegetables-Fallow-T.aman	6.12	0.094	12	21	0.23	2.7	1.11
61	11	Md Zahid Hasan	Swarupdaha, Chowgacha	23° 15’ 47”/ 89 ° 00’ 24”	Sara, Gopalpur, Ishurdi	MHL	Vegetables-Boro-T.aman	7.98	0.065	13	14	0.19	9.5	4.1
62	11	Md Shakibul Hasan	Swarupdaha, Chowgacha	23 ° 15’ 23”/ 88 ° 59’ 42”	Sara, Gopalpur, Ishurdi	MHL	Vegetables-Jute-T.aman	8.52	0.072	12	17.5	0.16	10.1	4.3
63	11	Md Delwar Mia	Swarupdaha, Chowgacha	23 ° 15’ 40”/ 88 ° 59’ 49”	Sara, Gopalpur, Ishurdi	MHL	Pulses-Jute-T.aman	8.32	0.061	13	23.4	0.21	14.8	5.4
64	11	Abul Kalam Azad	Swarupdaha, Chowgacha	23 ° 15’ 34”/ 88 ° 59’ 39”	Sara, Gopalpur, Ishurdi	MHL	Aus-pulses/jute-Boro	8.65	0.05	10	19.1	0.17	15.4	6.1
65	11	Nesar Uddin	Swarupdaha, Chowgacha	23 ° 14’ 59”/ 88 ° 59’ 38”	Sara, Gopalpur, Ishurdi	MHL	Vegetables-Vegetables-T.aman	8.78	0.03	9	22.2	0.12	14.4	5.2
66	11	Md. Riaz	Swarupdaha, Chowgacha	23 ° 14’ 59”/ 88 ° 59’ 29”	Sara, Gopalpur, Ishurdi	MHL	Vegetables-Boro-T.aman	8.73	0.039	11	24.6	0.07	11.5	4.2
67	11	Md. Shakil	Swarupdaha, Chowgacha	23 ° 14’ 58”/ 88 ° 59’ 57”	Sara, Gopalpur, Ishurdi	MHL	Boro-mungbean-T.aman	8.55	0.057	10	19	0.23	16.1	6.3
68	11	Salman Ali	Swarupdaha, Chowgacha	23 ° 15’ 07”/ 89 ° 00’ 07”	Sara, Gopalpur, Ishurdi	MHL	Potato-Jute-T.aman	8.5	0.051	11	19.5	0.22	16	6.1
69	11	Ali Hossain	Swarupdaha, Chowgacha	23 ° 15’ 34”/ 89 ° 00’ 47”	Sara, Gopalpur, Ishurdi	MHL	Vegetables-Vegetables-T.aman	8.54	0.061	13	18.2	0.22	16.3	6.2
70	11	Abu Taher Mukul	Swarupdaha, Chowgacha	23 ° 16’ 05”/ 89 ° 00’ 42”	Sara, Gopalpur, Ishurdi	MHL	Spices-Vegetables-T.aman	8.86	0.042	8	21.2	0.14	12.2	5
71	11	Akhtaruzzaman	Panchnamna, Chowgacha	23 ° 16’ 23”/ 89 ° 01’ 25”	Sara, Gopalpur, Ishurdi	MHL	Vegetables-Boro-T.aman	7.99	0.045	6	20.1	0.22	14	5.5
72	11	Motahar Hossain	Panchnamna, Chowgacha	23 ° 16’ 25”/ 89 ° 01’ 21”	Sara, Gopalpur, Ishurdi	MHL	Boro-Mungbean-T.aman	7.9	0.06	6	24.7	0.28	14.3	5.8
73	11	Bodor Uddin	Panchnamna, Chowgacha	23 ° 16’ 32”/ 89 ° 01’ 22”	Sara, Gopalpur, Ishurdi	MHL	Boro-Mungbean-T.aman	8.2	0.054	7	23.1	0.17	9.8	4
74	11	Abdul Gafur	Panchnamna, Chowgacha	23 ° 17’ 05”/ 89 ° 01’ 35”	Sara, Gopalpur, Ishurdi	MHL	Pulses-Jute-T.aman	8.7	0.048	9	16.6	0.12	10.3	4.7

Sl.	AEZ	Farmer	Address	Geo location	Soil Series	Land type	Cropping patterns	pH	TN	P	S	K	Ca	Mg
								-	%	(mg/kg soil)		meq/100g soil		
75	11	Musa Mia	Panchnamna, Chowgacha	23 ° 17' 07"/ 89 ° 01' 31"	Sara, Gopalpur, Ishurdi	LL	Aus-pulses/jute-Boro	8.26	0.047	8	17.2	0.15	10.6	4.9
76	11	Parimal Chandra Halder	Panchnamna, Chowgacha	23 ° 17' 12"/ 89 ° 01' 30"	Sara, Gopalpur, Ishurdi	MHL	Potato-Jute-T.aman	8.4	0.047	6	21.9	0.12	10.6	4.6
77	11	Jalil Mia	Panchnamna, Chowgacha	23 ° 17' 08"/ 89 ° 01' 24"	Sara, Gopalpur, Ishurdi	MHL	Vegetables-Vegetables-T.aman	8.42	0.059	7	24.7	0.11	12.6	5.2
78	11	Anwaruzzaman	Panchnamna, Chowgacha	23 ° 17' 07"/ 89 ° 01' 22"	Sara, Gopalpur, Ishurdi	MHL	Vegetables-Vegetables-T.aman	8.33	0.051	7	21.3	0.15	14	5.6
79	11	Md. Shahin	Panchnamna, Chowgacha	23 ° 17' 02"/ 89 ° 01' 21"	Sara, Gopalpur, Ishurdi	MHL	Vegetables-T.aman	8.22	0.06	12	23.1	0.18	15.5	6.2
80	11	Mosharraf Hossain	Panchnamna, Chowgacha	23 ° 16' 59"/ 89 ° 01' 24"	Sara, Gopalpur, Ishurdi	MHL	Spices-Vegetables-T.aman	8.58	0.049	11	24.5	0.1	10.2	4.4
81	11	Sobhan Uddin	Anderkota, Chowgacha	23° 27' 37"/ 88° 59'29"	Sara, Gopalpur, Ishurdi	MHL	Vegetables-Boro-T.aman	8.59	0.072	15	24.4	0.2	15.1	6
82	11	Madhob Saha	Anderkota, Chowgacha	23 ° 27' 17"/ 88 ° 59' 25"	Sara, Gopalpur, Ishurdi	MHL	Boro-mungbean-T.aman	8.29	0.064	14	20.4	0.19	10.5	4.2
83	11	Polash	Anderkota, Chowgacha	23 ° 16' 30"/ 88 ° 59' 26"	Sara, Gopalpur, Ishurdi	MHL	Potato-Jute-T.aman	8.41	0.071	14	21.9	0.27	15.1	6.1
84	11	Sukanto Kundu	Anderkota, Chowgacha	23 ° 16' 20"/ 88 ° 59' 05"	Sara, Gopalpur, Ishurdi	MHL	Vegetables-Vegetables-T.aman	7.18	0.042	11	16.1	0.17	6.1	2.2
85	11	Shahidul Islam	Anderkota, Chowgacha	23 ° 16' 15"/ 88 ° 59' 15"	Sara, Gopalpur, Ishurdi	MHL	Boro-mungbean-T.aman	8.34	0.077	12	22.7	0.26	11.8	5
86	11	Rashid Mohajon	Anderkota, Chowgacha	23 ° 16' 06"/ 88 ° 59' 09"	Sara, Gopalpur, Ishurdi	MHL	Pulses-Jute-T.aman	8.52	0.051	8	21.8	0.16	14.3	5.4
87	11	Abul Khaleq Mia	Anderkota, Chowgacha	23 ° 15' 57"/ 88 ° 59'21"	Sara, Gopalpur, Ishurdi	LL	Aus-pulses/jute-Boro	8.86	0.046	13	25.7	0.11	12.7	5.1
88	11	Avijit Karmaker	Anderkota, Chowgacha	23 ° 16' 01"/ 88 ° 59' 24"	Sara, Gopalpur, Ishurdi	MHL	Vegetables-Vegetables-T.aman	8.73	0.061	14	26.4	0.12	14.3	5.2
89	11	Md. Forkan	Anderkota, Chowgacha	23 ° 15' 36"/ 89 ° 00' 42"	Sara, Gopalpur, Ishurdi	MHL	Vegetables-Boro-T.aman	8.16	0.049	8	22.6	0.16	10.7	4.5
90	11	Hashem	Anderkota, Chowgacha	23° 15' 60"/ 89° 00' 15"	Sara, Gopalpur, Ishurdi	MHL	Spices-Vegetables-T.aman	7.92	0.05	7	24.9	0.16	6.9	3
91	11	Abu Daud	Paba	24° 24' 13"/ 88° 41' 30"	Sara, Gopalpur & Ishurdi	MHL	Mustard-Boro-T.aman	8.37	0.106	15	5.1	0.18	11.1	4.1
92	11	Md. Ekram	Paba	24° 24' 05"/ 88° 41' 34"	Sara, Gopalpur & Ishurdi	MHL	Wheat-Boro-T.aman	8.43	0.091	13	6.4	0.16	10.5	4
93	11	Zuboraj Sarker	Paba	24 ° 24' 06"/ 88 ° 41' 46"	Sara, Gopalpur & Ishurdi	MHL	Potato-Late Boro-T.aman	8.04	0.079	13	4.8	0.2	10.2	3.8

Sl.	AEZ	Farmer	Address	Geo location	Soil Series	Land type	Cropping patterns	pH	TN	P	S	K	Ca	Mg
								-	%	(mg/kg soil)		meq/100g soil		
94	11	Sheikh Masum	Paba	24° 24’ 07”/ 88° 41’ 58”	Sara, Gopalpur & Ishurdi	MHL	Vegetables-Boro-T.aman	8.19	0.091	12	4.4	0.14	10	3.8
95	11	Khalid Hasan	Paba	24° 25’ 10”/ 88° 41’ 44”	Sara, Gopalpur & Ishurdi	MHL	Lentil-Jute-T.aman	7.44	0.082	13	4.5	0.12	8	3
96	11	Suman Sarker	Paba	24° 25’ 07”/ 88° 41’ 28”	Sara, Gopalpur & Ishurdi	HL	Potato-Late Boro-T.aman	7.83	0.051	10	4.8	0.13	8.4	3.2
97	11	Lablu Mia	Paba	24 ° 25’ 13”/ 88 ° 41’ 35”	Sara, Gopalpur & Ishurdi	MHL	Boro-Mungbean-T.aman	7.74	0.054	8	5	0.1	8.1	3.1
98	11	Md Joynal	Paba	24 ° 24’ 50”/ 88 ° 40’ 58”	Sara, Gopalpur & Ishurdi	MHL	Fallow-Fallow-T.aman	7.82	0.05	7	6.1	0.12	9.2	3.4
99	11	Gazi Sarowar	Paba	24 ° 24’ 56”/ 88 ° 41’ 01”	Sara, Gopalpur & Ishurdi	HL	Potato-Late Boro-T.aman	8.18	0.05	12	5	0.13	9.6	3.6
100	11	Ruhul Amin	Paba	24 ° 24’ 35”/ 88 ° 41’ 51”	Sara, Gopalpur & Ishurdi	MHL	Onion-Late Boro-T.aman	8.26	0.067	13	4.8	0.14	10.1	4
101	11	Md Mannu	Paba	24° 28’17”/ 88 ° 37’ 59”	Sara, Gopalpur & Ishurdi	HL	Mustard-Boro-T.aman	7.91	0.095	14	5.5	0.16	8.3	3.2
102	11	Hossain Mallik	Paba	24 ° 28’ 27”/ 88 ° 38’ 13”	Sara, Gopalpur & Ishurdi	MHL	Wheat-Boro-T.aman	7.96	0.066	9	4.7	0.19	9.1	3.4
103	11	Aminul Islam	Paba	24 ° 28’ 60”/ 88 ° 39’ 07”	Sara, Gopalpur & Ishurdi	MHL	Potato-Late Boro-T.aman	8.19	0.086	15	5.2	0.12	12	4.3
104	11	Khalil Mia	Paba	24 ° 29’ 16”/ 88 ° 39’ 05”	Sara, Gopalpur & Ishurdi	HL	Vegetables-Boro-T.aman	7.37	0.097	15	4.7	0.16	8	3.1
105	11	Habibur Rahman	Paba	24 ° 29’ 01”/ 88 ° 39’ 22”	Sara, Gopalpur & Ishurdi	MHL	Lentil-Jute-T.aman	7.47	0.072	11	4.9	0.18	8.1	3.2
106	11	Bellal Hossain	Paba	24 ° 29’ 01”/ 88 ° 39’ 22”	Sara, Gopalpur & Ishurdi	MHL	Potato-Late Boro-T.aman	7.51	0.069	12	5.5	0.15	8.6	3.5
107	11	Imran Patwary	Paba	24 ° 29’ 30”/ 88 ° 39’ 40”	Sara, Gopalpur & Ishurdi	MHL	Boro-Mungbean-T.aman	8.25	0.08	10	5.3	0.14	10.4	4.1
108	11	Fokrul Islam	Paba	24 ° 29’ 39”/ 88 ° 39’ 44”	Sara, Gopalpur & Ishurdi	MHL	Fallow-Fallow-T.aman	8.37	0.077	13	5.7	0.13	11	4.2
109	11	Deepak Yadav	Paba	24 ° 29’ 38”/ 88 ° 39’ 46”	Sara, Gopalpur & Ishurdi	MHL	Potato-Late Boro-T.aman	8.16	0.094	17	4.8	0.11	11.1	4.2
110	11	Abdul Kuddus	Paba	24° 29’ 35”/ 88 ° 39’ 58”	Sara, Gopalpur & Ishurdi	MHL	Onion-Late Boro-T.aman	8.54	0.086	11	5.3	0.13	10.6	4.1
111	11	Meraj Munsi	Paba	24 ° 27’ 37”/ 88 ° 37’ 27”	Gopalpur, Ghior, Sara	MHL	Mustard-Boro-T.aman	8.48	0.076	13	5.6	0.18	11.1	4.3
112	11	Keramat Gazi	Paba	24 ° 27’ 32”/ 88 ° 37’ 41”	Gopalpur, Ghior, Sara	MHL	Wheat-Boro-T.aman	8.41	0.1	18	6.2	0.16	11.2	4.3

Sl.	AEZ	Farmer	Address	Geo location	Soil Series	Land type	Cropping patterns	pH	TN	P	S	K	Ca	Mg
								-	%	(mg/kg soil)		meq/100g soil		
113	11	Ehsanul Haque	Paba	24 ° 28’ 31”/ 88 ° 37’ 29”	Gopalpur, Ghior, Sara	MHL	Potato-Late Boro-T.aman	8.75	0.069	13	4.7	0.13	12.7	4.5
114	11	Rezaul	Paba	24 ° 28’ 19”/ 88 ° 37’ 38”	Gopalpur, Ghior, Sara	MHL	Vegetables-Boro-T.aman	8.38	0.084	15	5	0.12	10.8	4.1
115	11	Amanullah Aman	Paba	24 ° 28’ 31”/ 88 ° 37’ 41”	Gopalpur, Ghior, Sara	MHL	Boro-Fallow-T.aman	7.92	0.047	12	5.3	0.1	9.5	3.5
116	11	Jasim Uddin	Paba	24 ° 28’ 39”/ 88 ° 37’ 09”	Gopalpur, Ghior, Sara	MHL	Potato-Late Boro-T.aman	7.65	0.038	9	5.5	0.15	9.1	3.4
117	11	Mir Talib	Paba	24 ° 28’ 37”/ 88 ° 37’ 47”	Gopalpur, Ghior, Sara	MHL	Boro-Mungbean-T.aman	7.56	0.046	13	4.9	0.17	8.9	3.3
118	11	Druvesh Mondol	Paba	24 ° 28’ 03”/ 88 ° 37’ 47”	Gopalpur, Ghior, Sara	HL	Vegetables-Fallow-T.aman	8.41	0.096	15	5.4	0.18	11.3	4.3
119	11	Chanchal Mondol	Paba	24 ° 28’ 00”/ 88 ° 37’ 55”	Gopalpur, Ghior, Sara	MHL	Potato-Late Boro-T.aman	8.31	0.07	12	3.9	0.2	11.2	4.2
120	11	Muktadir Rahman	Paba	24 ° 27’ 54”/ 88 ° 38’ 01”	Gopalpur, Ghior, Sara	MHL	Onion-Late Boro-T.aman	7.84	0.061	9	5.2	0.17	9.8	3.6
121	13	Siafuddin Khan	Vurulia, Shyamnagar	22° 23’01”/ 89° 05’ 06”	Bajwa, Jalkati, Barisal	MLL	Khesari-Fallow-T.aman	6.38	0.063	11	153	0.13	5.1	1.7
122	13	Deepankar	Vurulia, Shyamnagar	22° 23’ 01”/ 89° 05’ 17”	Bajwa, Jalkati, Barisal	MLL	Fallow-Fallow-T.aman	6.41	0.066	6	160	0.29	5.2	1.8
123	13	Hasanul Kabir	Vurulia, Shyamnagar	22° 22’ 52”/ 89° 05’ 19”	Bajwa, Jalkati, Barisal	MLL	Gher/T.aman	6.3	0.09	7	186	0.27	5.1	1.7
124	13	Faizul Shaon	Vurulia, Shyamnagar	22° 23’ 07”/ 89° 05’ 32”	Bajwa, Jalkati, Barisal	MLL	Khesari-Fallow-T.aman	6.98	0.074	9	46	0.31	5.4	1.8
125	13	Akash Sornokar	Vurulia, Shyamnagar	22° 23’ 13”/ 89° 05’ 34”	Bajwa, Jalkati, Barisal	MLL	Fallow-Fallow-T.aman	7.46	0.095	6	191	0.33	5.6	1.9
126	13	Saiful Islam	Vurulia, Shyamnagar	22° 23’ 07”/ 89° 05’ 40”	Bajwa, Jalkati, Barisal	MLL	Gher/T.aman	6.85	0.089	7	196	0.36	5.3	1.8
127	13	Gias Uddin	Vurulia, Shyamnagar	22° 23’ 03”/ 89° 05’ 50”	Bajwa, Jalkati, Barisal	MLL	Khesari-Fallow-T.aman	6.5	0.073	8	161	0.32	5.2	1.8
128	13	Dhijendra Roy	Vurulia, Shyamnagar	22° 22’ 60”/ 89° 06’ 05”	Bajwa, Jalkati, Barisal	MLL	Fallow-Fallow-T.aman	6.65	0.084	7	212	0.45	5.4	1.8
129	13	Asim Datta	Vurulia, Shyamnagar	22° 22’ 53”/ 89° 06’ 06”	Bajwa, Jalkati, Barisal	MLL	Gher/T.aman	7.13	0.067	6	169	0.34	5.5	1.9
130	13	Kamrul Jame	Vurulia, Shyamnagar	22° 22’ 51”/ 89° 06’ 09”	Bajwa, Jalkati, Barisal	MLL	Khesari-Fallow-T.aman	6.46	0.062	6	220	0.43	5.3	1.8
131	13	Taposh Kumar	Shyamnagar	22° 18’ 56”/ 89° 05’ 37”	Bajwa, Jalkati	MLL	Khesari-Fallow-T.aman	6.8	0.068	8	150	0.36	5.2	1.7

Sl.	AEZ	Farmer	Address	Geo location	Soil Series	Land type	Cropping patterns	pH	TN	P	S	K	Ca	Mg
								-	%	(mg/kg soil)		meq/100g soil		
132	13	Premananda	Shyamnagar	22° 18 53”/ 89° 02’ 46”	Bajwa, Jalkati	MLL	Fallow-Fallow-T.aman	6.35	0.067	7	218	0.4	5.3	1.8
133	13	Waliullah Jihad	Shyamnagar	22° 18 44”/ 89° 02’ 53”	Bajwa, Jalkati	MLL	Gher/T.aman	6.25	0.065	9	245	0.3	5.2	1.8
134	13	Sajol Sikder	Shyamnagar	22° 18' 43”/ 89° 03’ 04”	Bajwa, Jalkati	MLL	Khesari-Fallow-T.aman	6.46	0.041	10	172	0.4	5.3	1.8
135	13	Shiblu Fakir	Shyamnagar	22° 18' 40”/ 89° 03’ 12”	Bajwa, Jalkati	MLL	Fallow-Fallow-T.aman	7.31	0.046	8	111	0.31	5.5	1.9
136	13	Bihari Lal	Shyamnagar	22° 19 05”/ 89° 02’ 31”	Bajwa, Jalkati	MLL	Gher/T.aman	7.11	0.029	7	142	0.36	5.4	1.9
137	13	Ahsan Habib	Shyamnagar	22° 19 00”/ 89° 02’ 28”	Bajwa, Jalkati	MLL	Khesari-Fallow-T.aman	7.31	0.058	10	197	0.33	5.6	1.9
138	13	Md. Sagor	Shyamnagar	22° 18 52”/ 89° 02’ 26”	Bajwa, Jalkati	MLL	Fallow-Fallow-T.aman	6.57	0.046	6	176	0.4	5.1	1.8
139	13	Md. Alfaz Alam	Shyamnagar	22° 18’ 48”/ 89° 02’ 30”	Bajwa, Jalkati	MLL	Gher/T.aman	6.6	0.07	8	155	0.36	5.2	1.8
140	13	Shekhor Roy	Shyamnagar	22° 18 46”/ 89° 02’ 36”	Bajwa, Jalkati	MLL	Khesari-Fallow-T.aman	6.88	0.069	7	249	0.5	5.1	1.7
141	13	Dipu Das	Shyamnagar	22° 17’ 19”/ 89° 05’ 44”	Bajwa, Jalkati, Barisal	MLL	Khesari-Fallow-T.aman	6.54	0.054	8	226	0.3	5.3	1.8
142	13	Supriya Dhar	Shyamnagar	22° 19’ 57”/ 89° 05’ 49”	Bajwa, Jalkati, Barisal	MLL	Fallow-Fallow-T.aman	6.51	0.074	9	90	0.35	5.1	1.7
143	13	Md Mohsin Hazi	Shyamnagar	22° 19’ 49”/ 89° 05’ 40”	Bajwa, Jalkati, Barisal	MLL	Gher/T.aman	6.32	0.083	8	155	0.29	5.3	1.8
144	13	Khitish Chandra	Shyamnagar	22° 19’ 47”/ 89° 05’ 32”	Bajwa, Jalkati, Barisal	MLL	Khesari-Fallow-T.aman	6.03	0.081	8	153	0.32	5.3	1.8
145	13	Ratan Pramanik	Shyamnagar	22° 19’ 42”/ 89° 05’ 29”	Bajwa, Jalkati, Barisal	MLL	Fallow-Fallow-T.aman	6.9	0.074	7	170	0.28	5.2	1.7
146	13	Reza Karim	Shyamnagar	22° 19’ 35”/ 89° 05’ 35”	Bajwa, Jalkati, Barisal	MLL	Gher/T.aman	6.6	0.09	7	226	0.3	5.4	1.8
147	13	Nozrul Islam	Shyamnagar	22° 19’ 44”/ 89° 05’ 07”	Bajwa, Jalkati, Barisal	MLL	Khesari-Fallow-T.aman	7.01	0.074	8	224	0.29	5.6	1.9
148	13	Hara Lal	Shyamnagar	22° 19’ 39”/ 89° 05’ 08”	Bajwa, Jalkati, Barisal	MLL	Fallow-Fallow-T.aman	6.61	0.074	8	229	0.34	5.3	1.8
149	13	Rubel Mahmud	Shyamnagar	22° 19’ 32”/ 89° 05’ 08”	Bajwa, Jalkati, Barisal	MLL	Gher/T.aman	6.49	0.073	7	144	0.31	5.4	1.9
150	13	Golam Kibria	Shyamnagar	22° 19’ 29”/ 89° 05’ 05”	Bajwa, Jalkati, Barisal	MLL	Khesari-Fallow-T.aman	6.5	0.082	10	162	0.37	5.3	1.8

Sl.	AEZ	Farmer	Address	Geo location	Soil Series	Land type	Cropping patterns	pH	TN	P	S	K	Ca	Mg
								-	%	(mg/kg soil)		meq/100g soil		
151	13	Babul Chandra	Babugonj	22°48’ 51”/ 90°19’35”	Sara, Gopalpur, Muladi	MHL	Maize-Fallow-T.aman	8.04	0.16	12	20.5	0.16	6	2.1
152	13	Azizul Haque	Babugonj	22°49’00”/ 90°19’34”	Sara, Gopalpur, Muladi	MHL	Mungbean-Fallow-T.aman	8.5	0.19	13	24.3	0.19	6.1	2.2
153	13	Biplob Akon	Babugonj	22°48’22”/ 90°19’43”	Sara, Gopalpur, Muladi	MHL	Jute-Fallow-T.aman	8.27	0.22	13	20.5	0.22	6	2.1
154	13	Liton Samaddar	Babugonj	22°48’14”/ 90°19’06”	Sara, Gopalpur, Muladi	MHL	Mungbean-Fallow-T.aman	7.75	0.21	14	22.9	0.21	5.7	2
155	13	Akinchon	Babugonj	22°48’03”/ 90°19’51”	Sara, Gopalpur, Muladi	MHL	Maize-Fallow-T.aman	7.79	0.2	15	20.7	0.2	5.5	1.9
156	13	Sanjit Paul	Babugonj	22°47’57”/ 90°20’09”	Sara, Gopalpur, Muladi	MHL	Maize-Fallow-T.aman	7.62	0.23	14	26	0.23	5.3	1.8
157	13	Saikat Biswas	Babugonj	22°47’45”/ 90°20’10”	Sara, Gopalpur, Muladi	MHL	Mungbean-Fallow-T.aman	7.81	0.2	13	22	0.2	5.4	1.9
158	13	Afzalur Rahman	Babugonj	22°47’55”/ 90°19’53”	Sara, Gopalpur, Muladi	MHL	Jute-Fallow-T.aman	7.74	0.24	14	22.5	0.24	5.6	2
159	13	Aksar Bepari	Babugonj	22°47’51”/ 90°19’51”	Sara, Gopalpur, Muladi	MHL	Maize-Fallow-T.aman	7.55	0.21	14	19.8	0.21	5.2	1.8
160	13	Md. Abdul Hakim	Babugonj	22°47’43”/ 90°19’51”	Sara, Gopalpur, Muladi	MHL	Mungbean-Fallow-T.aman	7.63	0.25	13	21.6	0.25	5.3	1.9
161	13	Rahimuddin	Babuganj	22°45’23”/ 90°19’04”	Sara, Gopalpur	MHL	Maize-Fallow-T.aman	8.13	0.06	14	20.5	0.12	6	2.1
162	13	Sayed Ajmol	Babuganj	22°45’56”/ 90°19’05”	Sara, Gopalpur	MHL	Mungbean-Fallow-T.aman	8.3	0.053	13	19.2	0.14	6.1	2.2
163	13	Enayet Ali	Babuganj	22°46’04”/ 90°18’41”	Sara, Gopalpur	MHL	Jute-Fallow-T.aman	7.24	0.048	14	21.4	0.16	5.5	1.9
164	13	Narayan Samaddar	Babuganj	22°46’07”/ 90°18’48”	Sara, Gopalpur	MHL	Mungbean-Fallow-T.aman	7.66	0.057	14	24.5	0.13	5.9	2.1
165	13	Md Naimul Islam	Babuganj	22°46’07”/ 90°18’53”	Sara, Gopalpur	MHL	Mungbean-Fallow-T.aman	7.29	0.056	13	21.5	0.16	5.6	2
166	13	Mehedi Hasan	Babuganj	22°46’14”/ 90°18’48”	Sara, Gopalpur	MHL	Jute-Fallow-T.aman	7.26	0.047	13	23.4	0.13	5.2	1.8
167	13	Md Mintu Mia	Babuganj	22°46’20”/ 90°18’46”	Sara, Gopalpur	MHL	Mungbean-Fallow-T.aman	8.01	0.04	13	20.3	0.11	5.9	2.1
168	13	Sanjay Chaki	Babuganj	22°46’26”/ 90°18’48”	Sara, Gopalpur	MHL	Mungbean-Fallow-T.aman	8.21	0.052	14	19.7	0.14	6.2	2.3
169	13	Mynul Islam	Babuganj	22°46’30”/ 90°18’45”	Sara, Gopalpur	MHL	Jute-Fallow-T.aman	8.5	0.05	13	22	0.12	6	2.1

Sl.	AEZ	Farmer	Address	Geo location	Soil Series	Land type	Cropping patterns	pH	TN	P	S	K	Ca	Mg
								-	%	(mg/kg soil)		meq/100g soil		
170	13	Sayan Madhukar	Babuganj	22°46’35”/ 90°18’43”	Sara, Gopalpur	MHL	Mungbean-Fallow-T.aman	7.88	0.057	14	23.4	0.13	5.6	2
171	13	Husnul Gomosta	Babuganj	22°47’ 53”/ 90°17’44”	Sara, Gopalpur, Muladi	MHL	Maize-Fallow-T.aman	8.36	0.065	14.5	20.8	0.13	6.3	2.3
172	13	Tahir Majhi	Babuganj	22°48’24”/ 90° 17’39”	Sara, Gopalpur, Muladi	MHL	Mungbean-Fallow-T.aman	7.59	0.081	13.3	23	0.17	6.1	2.2
173	13	Jahirul Talukder	Babuganj	22°48’45”/ 90°18’07”	Sara, Gopalpur, Muladi	MHL	Maize-Fallow-T.aman	6.97	0.089	14.4	19.9	0.19	5	1.7
174	13	Mizanur Rahman	Babuganj	22°48’41”/ 90° 17’44”	Sara, Gopalpur, Muladi	MHL	Mungbean-Fallow-T.aman	7.78	0.078	13.1	21.8	0.16	5.8	2
175	13	Indrajit Bishnu	Babuganj	22°48’43”/ 90° 17’47”	Sara, Gopalpur, Muladi	MHL	Maize-Fallow-T.aman	7.48	0.072	13.5	20.3	0.19	5.5	1.9
176	13	Md. Dulal	Babuganj	22°48’46”/ 90° 17’46”	Sara, Gopalpur, Muladi	MHL	Mungbean-Fallow-T.aman	7.16	0.073	14.8	23.4	0.18	5.6	2
177	13	Gajendra Projapati	Babuganj	22°48’12”/ 90° 17’04”	Sara, Gopalpur, Muladi	MHL	Maize-Fallow-T.aman	7.49	0.086	13.2	21.6	0.2	5.3	2
178	13	Gonopati Shah	Babuganj	22°48’21”/ 90° 17’5.5”	Sara, Gopalpur, Muladi	MHL	Mungbean-Fallow-T.aman	8.18	0.064	14.5	20.3	0.16	6.1	1.9
179	13	Md. Murad	Babuganj	22°48’03”/ 90° 17’57”	Sara, Gopalpur, Muladi	MHL	Maize-Fallow-T.aman	7.75	0.06	13.6	19.7	0.17	5.7	2.1
180	13	Rafiqul Islam	Babuganj	22°47’21”/ 90° 17’21”	Sara, Gopalpur, Muladi	MHL	Mungbean-Fallow-T.aman	7.41	0.063	13.8	22.3	0.15	5.6	2

BRRI Component

Appendix 2. Soil sample analytical data along with baseline information

Sl No.	AEZ	Village	GPS (Lat. /Long.)	Soil Series	Land type	Cropping pattern	Soil pH	Total N (%)	Ava. P (ppm)	Ex. K (meq/100g)	Ava. S (ppm)	Ex. Ca (meq/100g)	Ex. Mg (meq/100g)	Ava. Zn (ppm)
1.	18	Chorkossopia	N.22°76/.618, E.91°27/.461	Hatia	MHL	Grasspea-F.-Aman	5.66	0.29	15.23	0.31	131	2.99	0.412	0.92
2.	18	Chorkossopia	N.22°76/.380, E.91°27/.552	Hatia	MHL	Grasspea-F.-Aman	6.10	0.15	3.92	0.31	105	3.01	0.403	0.82
3.	18	Chorkossopia	N.22°76/.490, E.91°27/.682	Hatia	MHL	Grasspea-F.-Aman	6.11	0.15	11.31	0.31	113	3.12	0.407	0.84
4.	18	Chorkossopia	N.22°76/.566, E.91°27/.816	Hatia	MHL	Grasspea-F.-Aman	5.93	0.12	30.60	0.35	93	2.64	0.229	0.94
5.	18	Chorkossopia	N.22°76/.441, E.91°27/.916	Hatia	MHL	Grasspea-F.-Aman	6.28	0.19	32.05	0.37	90	2.86	0.406	0.82
6.	18	Chorkossopia	N.22°76/.202, E.91°27/.855	Hatia	MHL	Grasspea-F.-Aman	6.14	0.07	31.76	0.37	148	3.34	0.416	1.08
7.	18	Chorkossopia	N.22°76/.656, E.91°28/.170	Hatia	MHL	Grasspea-F.-Aman	6.57	0.12	37.70	0.42	108	2.87	0.216	0.9
8.	18	Chorkossopia	N.22°76/.386, E.91°28/.056	Hatia	MHL	Grasspea-F.-Aman	6.34	0.12	29.87	0.35	120	2.90	0.427	0.94
9.	18	Chorkossopia	N.22°76/.272, E.91°28/.002	Hatia	MHL	Grasspea-F.-Aman	6.36	0.15	35.53	0.35	118	2.98	0.421	1.4
10.	18	Chorkossopia	N.22°76/.118, E.91.27/.820	Hatia	MHL	Grasspea-F.-Aman	6.24	0.15	38.14	0.46	130	2.53	0.423	1.36
11.	18	Chorfokira	N.22°78/.406, E.91°26/.504	Hatia	MHL	Grasspea-F.-Aman	7.26	0.10	54.38	0.45	113	3.41	0.409	0.56
12.	18	Chorfokira	N.22°77/.933, E.91°26/.765	Hatia	MHL	Grasspea-F.-Aman	7.22	0.11	64.82	0.40	120	2.79	0.412	0.32
13.	18	Chorfokira	N.22°78/.173, E.91°26/.706	Hatia	MHL	Grasspea-F.-Aman	7.29	0.14	57.86	0.36	110	3.03	0.412	0.22
14.	18	Chorfokira	N.22°78/.124, E.91°26/.606	Hatia	MHL	Grasspea-F.-Aman	7.40	0.14	58.73	0.35	125	3.50	0.403	0.2
15.	18	Chorfokira	N.22°78/.134, E.91°26/.616	Hatia	MHL	Grasspea-F.-Aman	7.25	0.12	47.42	0.31	148	3.81	0.401	0.26
16.	18	Chorfokira	N.22°78/.232, E.91°26/.632	Hatia	MHL	Grasspea-F.-Aman	7.37	0.15	53.65	0.35	108	3.03	0.403	0.26
17.	18	Chorfokira	N.22°78/.247, E.91°26/.518	Hatia	MHL	Grasspea-F.-Aman	7.24	0.12	48.29	0.40	125	3.42	0.400	0.48

Sl No.	AEZ	Village	GPS (Lat. /Long.)	Soil Series	Land type	Cropping pattern	Soil pH	Total N (%)	Ava. P (ppm)	Ex. K (meq/100g)	Ava. S (ppm)	Ex. Ca (meq/100g)	Ex. Mg (meq/100g)	Ava. Zn (ppm)
18.	18	Chorfokira	N.22°78′.365, E.91.26′.530	Hatia	MHL	Grasspea-F.-Aman	7.24	0.12	51.48	0.38	113	3.10	0.403	0.46
19.	18	Chorfokira	N.22°78′.169, E.91°64′.930	Hatia	MHL	Grasspea-F.-Aman	7.14	0.10	59.89	0.34	125	3.61	0.410	0.48
20.	18	Chorfokira	N.22°78′.112, E.91°26′.539	Hatia	MHL	Grasspea-F.-Aman	7.28	0.15	61.05	0.26	118	3.40	0.397	0.44
21.	18	Chorfokira	N.22°79′.047, E.91°26′.977	Hatia	MHL	Grasspea-F.-Aman	7.06	0.05	12.63	0.13	173	4.25	0.406	0.5
22.	18	Chorfokira	N.22°79′.055, E.91°27′.053	Hatia	MHL	Grasspea-F.-Aman	7.44	0.11	18.88	0.13	83	3.35	0.406	0.14
23.	18	Chorfokira	N.22°79′.036, E.91°27′.093	Hatia	MHL	Grasspea-F.-Aman	7.09	0.07	12.88	0.14	128	3.50	0.398	0.22
24.	18	Chorfokira	N.22°79′.091, E.91°27′.098	Hatia	MHL	Grasspea-F.-Aman	7.50	0.11	17.13	0.12	110	3.69	0.396	0.08
25.	18	Chorfokira	N.22°79′.003, E.91°27′.220	Hatia	MHL	Grasspea-F.-Aman	7.27	0.08	15.38	0.13	108	3.03	0.404	0.48
26.	18	Chorfokira	N.22°79′.081, E.91°27′.247	Hatia	MHL	Grasspea-F.-Aman	7.26	0.14	9.63	0.15	140	3.84	0.407	0.44
27.	18	Chorfokira	N.22°79′.081, E.91°27′.247	Hatia	MHL	Grasspea-F.-Aman	7.08	0.08	11.25	0.14	158	3.46	0.410	0.48
28.	18	Chorfokira	N.22°79′.143, E.91°27′.212	Hatia	MHL	Grasspea-F.-Aman	7.09	0.11	8.38	0.17	128	3.34	0.397	0.9
29.	18	Chorfokira	N.22°79′.120, E.91°27′.076	Hatia	MHL	Grasspea-F.-Aman	7.17	0.15	15.25	0.15	120	3.97	0.407	0.42
30.	18	Chorfokira	22.79195/ 91.27045	Hatia	MHL	Grasspea-F.-Aman	6.71	0.11	7.75	0.14	123	3.01	0.402	0.62
31.	18	Chor Lorange	22.76224/ 90.8614	Ramgati	MHL	Soyabean-F.-T.Aman	7.20	0.11	19.50	0.10	263	3.35	0.400	0.34
32.	18	Chor Lorange	22.76534/ 90.8634	Ramgati	MHL	Soyabean-F.-T.Aman	7.13	0.10	18.88	0.07	174	3.46	0.400	0.64
33.	18	Chor Lorange	22.76188/ 90.86001	Ramgati	MHL	Soyabean-F.-T.Aman	7.01	0.12	16.00	0.05	322	3.75	0.410	0.86
34.	18	Chor Lorange	22.76209/ 90.85971	Ramgati	MHL	Soyabean-F.-T.Aman	7.04	0.11	17.88	0.05	116	4.23	0.409	0.5
35.	18	Chor Lorange	22.7627/ 90.85927	Ramgati	MHL	Soyabean-F.-T.Aman	7.14	0.12	18.38	0.05	185	4.04	0.409	0.3
36.	18	Chor Lorange	22.76223/ 90.85884	Ramgati	MHL	Soyabean-F.-T.Aman	7.05	0.05	35.91	0.05	264	4.33	0.402	0.38

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37.	18	Chor Lorange	22.76142/ 90.85811	Ramgati	MHL	Soyabean-F.-T.Aman	7.35	0.11	57.23	0.06	152	3.50	0.392	0.04
38.	18	Chor Lorange	22.76362/ 90.8578	Ramgati	MHL	Soyabean-F.-T.Aman	7.20	0.14	44.42	0.05	309	4.48	0.401	0.5
39.	18	Chor Lorange	22.76381/ 90.85938	Ramgati	MHL	Soyabean-F.-T.Amn	7.27	0.11	44.84	0.07	305	3.97	0.404	0.16
40.	18	Chor Lorange	22.76297/ 90.85957	Ramgati	MHL	Soyabean-F.-T.Aman	7.47	0.12	59.96	0.06	133	3.32	0.399	0.08
41.	18	Chor Monosa	22.83089/ 90.86779	Ramgati	MHL	Soyabean-F.-T.Aman	7.94	0.18	59.12	0.15	93	4.22	0.410	0.26
42.	18	Chor Monosa	22.83313/ 90.86698	Ramgati	MHL	Soyabean-F.-T.Aman	7.71	0.12	47.04	0.10	78	3.93	0.400	0.26
43.	18	Chor Monosa	22.84218/ 90.88187	Ramgati	MHL	Soyabean-F.-T.Aman	7.50	0.04	65.10	0.10	156	4.95	0.412	0.02
44.	18	Chor Monosa	22.83211/ 90.86915	Ramgati	MHL	Soyabean-F.-T.Aman	7.66	0.15	82.95	0.10	109	4.51	0.392	0.14
45.	18	Chor Monosa	22.83165/ 90.87029	Ramgati	MHL	Soyabean-F.-T.Aman	7.67	0.12	64.05	0.13	271	5.20	0.405	0.04
46.	18	Chor Monosa	22.8306/ 90.87073	Ramgati	MHL	Soyabean-F.-T.Aman	7.44	0.08	56.91	0.11	448	5.54	0.403	0.66
47.	18	Chor Monosa	22.8282/ 90.86979	Ramgati	MHL	Soyabean-F.-T.Aman	7.39	0.11	71.09	0.08	349	4.72	0.407	0.16
48.	18	Chor Monosa	22.82569/ 90.8702	Ramgati	MHL	Soyabean-F.-T.Aman	7.61	0.07	70.25	0.10	293	4.61	0.394	0.1
49.	18	Chor Monosa	22.82723/ 90.86666	Ramgati	MHL	Soyabean-F.-T.Aman	7.65	0.10	74.24	0.11	194	4.30	0.398	0.6
50.	18	Chor Monosa	22.83022/ 90.86851	Ramgati	MHL	Soyabean-F.-T.Aman	7.36	0.12	82.22	0.09	76	4.52	0.396	0.22
51.	18	Chor Monosa	22.8281/ 90.86476	Ramgati	MHL	Soyabean-F.-T.Aman	7.36	0.14	84.74	0.09	75	2.54	0.391	0.68
52.	18	Chor Monosa	22.82831/ 90.86397	Ramgati	MHL	Soyabean-F.-T.Aman	7.35	0.12	78.75	0.07	76	3.03	0.395	0.98
53.	18	Chor Monosa	22.8285/ 90.86359	Ramgati	MHL	Soyabean-F.-T.Aman	6.62	0.12	72.14	0.09	98	3.27	0.397	0.06
54.	18	Chor Monosa	22.82884/ 90.86305	Ramgati	MHL	Soyabean-F.-T.Aman	7.04	0.14	55.34	0.09	78	3.03	0.396	0.12
55.	18	Chor Monosa	22.82896/ 90.86403	Ramgati	MHL	Soyabean-F.-T.Aman	7.16	0.14	53.76	0.09	84	3.35	0.400	0.38

Sl No.	AEZ	Village	GPS (Lat. /Long.)	Soil Series	Land type	Cropping pattern	Soil pH	Total N (%)	Ava. P (ppm)	Ex. K (meq/100g)	Ava. S (ppm)	Ex. Ca (meq/100g)	Ex. Mg (meq/100g)	Ava. Zn (ppm)
56.	18	Chor Monosa	22.8276/ 90.86134	Ramgati	MHL	Boro-F-T.Aman	6.63	0.11	59.54	0.08	84	3.70	0.401	1.2
57.	18	Chor Monosa	22.8271/ 90.86038	Ramgati	MHL	Boro-Fallow-T.Aman	6.97	0.14	62.37	0.07	80	2.83	0.391	0.76
58.	18	Chor Monosa	22.82681/ 90.85964	Ramgati	MHL	Boro-Fallow-T.Aman	6.70	0.12	66.15	0.07	75	3.06	0.395	1.16
59.	18	Chor Monosa	22.82872/ 90.85969	Ramgati	MHL	Boro-Fallow-T.Aman	6.76	0.12	58.49	0.09	79	3.16	0.396	0.6
60.	18	Chor Monosa	22.82885/ 90.86057	Ramgati	MHL	Boro-Fallow-T.Aman	6.78	0.11	64.47	0.08	68	2.98	0.396	0.22
61.	19	Sendra	23.19862/ 90.85699	Debiddar	MLL,LL	Boro-F.-F.	6.67	0.10	7.46	0.046	13.70	2.25	3.52	0.58
62.	19	Sendra	23.19757/ 90.85703	Debiddar	MLL,LL	Boro-F.-F.	6.82	0.12	12.71	0.037	13.90	2.26	3.52	0.66
63.	19	Sendra	23.19991/ 90.85627	Debiddar	MLL,LL	Boro-F.-F.	6.76	0.08	19.74	0.042	13.05	2.23	4.58	0.14
64.	19	Sendra	23.19986/ 90.85726	Debiddar	MLL,LL	Boro-F.-F.	6.04	0.15	20.69	0.074	16.35	2.07	2.64	0.86
65.	19	Sendra	23.20051/ 90.85739	Debiddar	MLL,LL	Boro-F.-F.	6.46	0.07	23.52	0.051	14.55	2.01	4.33	0.34
66.	19	Sendra	23.19983/ 90.85829	Debiddar	MLL,LL	Boro-F.-F.	6.19	0.12	16.17	0.051	20.95	2.09	3.88	0.28
67.	19	Sendra	23.19997/ 90.85928	Debiddar	MLL,LL	Boro-F.-F.	6.23	0.14	28.46	0.056	15.10	1.97	3.42	0.50
68.	19	Sendra	23.1998/ 90.85933	Debiddar	MLL,LL	Boro-F.-F.	6.21	0.12	38.96	0.056	15.80	1.96	4.01	0.32
69.	19	Sendra	23.0013/ 90.86058	Debiddar	MLL,LL	Boro-F.-F.	6.2	0.11	50.40	0.051	16.35	2.12	4.03	0.80
70.	19	Sendra	23.2001/ 90.86114	Debiddar	MLL,LL	Boro-F.-F.	5.81	0.17	47.04	0.046	13.40	2.25	4.95	0.44
71.	19	Dhodda	23.29506/ 90.85116	Debiddar	MHL,MLL	Boro-F.-B. Aman	5.83	0.18	46.10	0.037	14.85	2.46	2.81	3.06
72.	19	Dhodda	23.29452/ 90.85223	Debiddar	MHL,MLL	Boro-F.-B. Aman	5.9	0.21	34.23	0.046	16.25	2.53	2.86	1.48
73.	19	Dhodda	23.2947/ 90.85295	Debiddar	MHL,MLL	Boro-F.-B. Aman	6.14	0.21	26.67	0.042	17.40	2.58	2.81	0.30
74.	19	Dhodda	23.29431/ 90.85328	Debiddar	MHL,MLL	Boro-F.-B. Aman	6.17	0.24	39.38	0.037	17.50	2.72	4.31	0.34

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75.	19	Dhodda	23.29445/ 90.85435	Debiddar	MHL,MLL	Boro-F.-B. Aman	6.08	0.25	32.55	0.037	15.65	2.30	3.71	0.44
76.	19	Dhodda	23.29504/ 90.85495	Debiddar	MHL,MLL	Boro-F.-B. Aman	6.13	0.14	7.88	0.037	15.00	2.68	2.90	0.88
77.	19	Dhodda	23.29602/ 90.85478	Debiddar	MHL,MLL	Boro-F.-B. Aman	6.09	0.21	4.20	0.042	16.10	2.45	4.49	0.62
78.	19	Dhodda	23.29615/ 90.85541	Debiddar	MHL,MLL	Boro-F.-B. Aman	5.86	0.26	2.10	0.065	17.45	2.73	5.47	0.92
79.	19	Dhodda	23.29626/ 90.85305	Debiddar	MHL,MLL	Boro-F.-B. Aman	6.05	0.25	2.42	0.083	13.90	3.59	2.99	0.60
80.	19	Dhodda	23.29666/ 90.85214	Debiddar	MHL,MLL	Boro-F.-B. Aman	5.87	0.12	17.12	0.083	21.25	2.74	4.62	1.02
81.	19	Pirozpur	23.29609/ 90.82814	Burichong	MLL	Mustard- Boro-F.	6.44	0.22	19.64	0.051	13.00	2.12	3.70	0.44
82.	19	Pirozpur	23.29662/ 90.82749	Burichong	MLL	Mustard- Boro-F.	6.16	0.28	15.75	0.042	14.15	3.00	5.20	0.42
83.	19	Pirozpur	23.29752/ 90.82746	Burichong	MLL	Mustard- Boro-F.	6.19	0.35	18.59	0.051	16.10	3.33	6.35	0.46
84.	19	Pirozpur	23.29723/ 90.82706	Burichong	MLL	Mustard- Boro-F.	6.23	0.33	11.13	0.074	15.10	3.28	7.77	0.82
85.	19	Pirozpur	23.29682/ 90.82575	Burichong	MLL	Mustard- Boro-F.	6.09	0.26	1.05	0.065	15.35	3.04	6.95	0.98
86.	19	Pirozpur	23.29599/ 90.82546	Burichong	MLL	Mustard- Boro-F.	6.02	0.24	15.33	0.051	15.70	2.91	4.12	0.56
87.	19	Pirozpur	23.29512/ 90.82491	Burichong	MLL	Mustard- Boro-F.	6.13	0.26	21.63	0.042	15.50	2.77	4.07	0.42
88.	19	Pirozpur	23.29518/ 90.82562	Burichong	MLL	Mustard- Boro-F.	5.95	0.31	17.12	0.046	15.05	2.81	4.77	0.48
89.	19	Pirozpur	23.29509/ 90.82672	Burichong	MLL	Mustard- Boro-F.	6.11	0.12	9.14	0.065	15.55	3.30	5.23	0.44
90.	19	Pirozpur	23.29565/ 90.82751	Burichong	MLL	Mustard- Boro-F.	6.47	0.22	17.96	0.069	15.50	2.47	3.95	0.14
91.	19	Changini	23.2739/ 0.99114	Chandina	HL, MHL	Boro--Aus - T.Aman	6.03	0.21	54.18	0.056	13.85	1.55	2.61	0.64
92.	19	Changini	23.2741/ 90.99001	Chandina	HL, MHL	Boro--Aus - T.Aman	5.98	0.19	42.32	0.032	13.65	1.62	3.04	0.58
93.	19	Changini	23.27352/ 90.98957	Chandina	HL, MHL	Boro--Aus - T.Aman	5.58	0.08	63.32	0.023	14.25	1.50	1.82	1.56

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94.	19	Changini	23.27349/ 90.98909	Chandina	HL, MHL	Boro--Aus - T.Aman	5.73	0.15	72.14	0.019	15.90	1.14	3.89	0.46
95.	19	Changini	23.27301/ 90.9886	Chandina	HL, MHL	Boro--Aus - T.Aman	5.89	0.14	19.85	0.019	13.45	1.67	2.43	2.38
96.	19	Changini	23.27262/ 90.98914	Chandina	HL, MHL	Boro--Aus - T.Aman	5.61	1.55	19.74	0.019	14.55	1.38	2.32	0.70
97.	19	Changini	23.27265/ 90.98969	Chandina	HL, MHL	Boro--Aus - T.Aman	5.81	0.12	36.23	0.023	14.05	1.50	2.26	0.96
98.	19	Changini	23.27294/ 90.99026	Chandina	HL, MHL	Boro--Aus - T.Aman	5.64	0.10	30.98	0.023	15.20	1.45	2.30	0.52
99.	19	Changini	23.27295/ 90.99088	Chandina	HL, MHL	Boro--Aus - T.Aman	5.64	0.17	35.07	0.023	13.90	1.27	2.95	0.16
100.	19	Changini	23.27319/ 90.99131	Chandina	HL, MHL	Boro--Aus - T.Aman	6.17	0.18	32.76	0.023	13.15	1.37	4.22	1.74
101.	19	Ghagra	23.35949/ 90.8665	Debidhar	MHL,MLL ,LL	Boro-F.-B.Aman	5.78	0.22	31.29	0.056	15.05	2.71	3.46	1.06
102.	19	Ghagra	23.35859/ 90.8666	Debidhar	MHL,MLL ,LL	Boro-F.-B.Aman	6.15	0.17	10.82	0.028	15.30	2.48	4.28	0.66
103.	19	Ghagra	23.35767/ 90.86662	Debidhar	MHL,MLL ,LL	Boro-F.-B.Aman	6.28	0.17	21.42	0.069	16.55	2.57	5.58	1.76
104.	19	Ghagra	23.35702/ 90.86694	Debidhar	MHL,MLL ,LL	Boro-F.-B.Aman	6.45	0.21	30.03	0.065	15.55	2.67	6.27	0.44
105.	19	Ghagra	23.35675/ 90.86684	Debidhar	MHL,MLL ,LL	Boro-F.-B.Aman	6.39	0.25	23.31	0.069	16.30	3.25	4.97	2.24
106.	19	Ghagra	23.35706/ 90.86912	Debidhar	MHL,MLL ,LL	Boro-F.-B.Aman	6.37	0.21	29.72	0.088	18.75	2.84	4.53	1.64
107.	19	Ghagra	23.35739/ 90.86927	Debidhar	MHL,MLL ,LL	Boro-F.-B.Aman	6.44	0.26	8.03	0.097	21.10	2.96	4.16	0.78
108.	19	Ghagra	23.35803/ 90.86859	Debidhar	MHL,MLL ,LL	Boro-F.-B.Aman	6.34	0.18	15.86	0.032	14.95	2.61	4.26	1.10
109.	19	Ghagra	23.35862/ 90.86787	Debidhar	MHL,MLL ,LL	Boro-F.-B.Aman	6.52	0.22	20.58	0.046	15.75	2.70	3.99	1.36
110.	19	Ghagra	23.35897/ 90.86752	Debidhar	MHL,MLL ,LL	Boro-F.-B.Aman	6.36	0.22	16.59	0.060	14.40	2.53	4.72	1.28
111.	19	Budumda	23.41288/ 90.84544	Chandina, Debidhar	MHL,MLL ,LL	Potato-B.-B.Aman	6.08	0.18	55.34	0.102	17.25	2.67	2.03	0.58
112.	19	Budumda	23.41308/ 90.84468	Chandina, Debidhar	MHL,MLL ,LL	Potato-B.-B.Aman	5.95	0.14	56.39	0.120	14.55	2.24	2.41	0.42

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113.	19	Budumda	23.41313/ 90.84343	Chandina, Debidhar	MHL,MLL ,LL	Potato-B.-B.Aman	5.36	0.17	45.05	0.069	19.30	1.93	2.00	0.86
114.	19	Budumda	23.41218/ 90.84324	Chandina, Debidhar	MHL,MLL ,LL	Potato-B.-B.Aman	5.36	0.17	25.73	0.051	14.25	1.96	2.02	0.98
115.	19	Budumda	23.41098/ 90.8432	Chandina, Debidhar	MHL,MLL ,LL	Potato-B.-B.Aman	5.38	0.35	33.71	0.051	34.30	3.30	2.65	0.76
116.	19	Budumda	23.41027/ 90.84389	Chandina, Debidhar	MHL,MLL ,LL	Potato-B.-B.Aman	5.74	0.21	25.20	0.120	14.60	2.23	2.99	0.68
117.	19	Budumda	23.41135/ 90.84464	Chandina, Debidhar	MHL,MLL ,LL	Potato-B.-B.Aman	5.94	0.25	19.53	0.097	14.80	2.44	3.23	0.26
118.	19	Budumda	23.41141/ 90.84539	Chandina, Debidhar	MHL,MLL ,LL	Potato-B.-B.Aman	5.81	0.19	20.69	0.037	15.85	2.49	3.90	0.52
119.	19	Budumda	23.41108/ 90.8454	Chandina, Debidhar	MHL,MLL ,LL	Potato-B.-B.Aman	5.97	0.21	24.36	0.046	15.20	2.67	3.31	0.20
120.	19	Budumda	23.2739/ 0.99114	Chandina, Debidhar	HL, MHL	Boro--Aus - T.Aman	5.92	0.18	50.09	0.032	14.45	2.65	4.12	0.24
121.	20	Gourinogor	25.03363/ 91.81267	Fagu	MLL, LL	Boro-F.-T. Aman	5.54	0.18	1.75	0.085	14.45	1.19	1.14	2.50
122.	20	Gourinogor	25.03349/ 91.81215	Fagu	MLL, LL	Boro-F.-T. Aman	5.35	0.17	1.75	0.085	13.60	1.32	1.32	3.10
123.	20	Gourinogor	25.03375/ 91.81109	Fagu	MLL, LL	Boro-F.-T. Aman	5.05	0.17	3.25	0.078	16.40	1.15	1.02	3.32
124.	20	Gourinogor	25.03314/ 91.81062	Fagu	MLL, LL	Boro-F.-T. Aman	4.99	0.14	2.75	0.078	13.00	1.24	1.24	3.02
125.	20	Gourinogor	25.03267/ 91.81029	Fagu	MLL, LL	Boro-F.-T. Aman	5.91	0.19	2.95	0.097	13.65	1.33	1.20	3.18
126.	20	Gourinogor	25.03202/ 91.80999	Fagu	MLL, LL	Boro-F.-T. Aman	4.97	0.28	1.63	0.085	12.65	1.78	1.72	3.80
127.	20	Gourinogor	25.03132/ 91.80998	Fagu	MLL, LL	Boro-F.-T. Aman	4.22	0.26	0.75	0.085	13.60	1.91	1.83	3.46
128.	20	Gourinogor	25.03094/ 91.81115	Fagu	MLL, LL	Boro-F.-T. Aman	4.92	0.25	0.40	0.097	15.30	2.50	3.04	5.80
129.	20	Gourinogor	25.03141/ 91.8118	Fagu	MLL, LL	Boro-F.-T. Aman	5.02	0.29	1.18	0.139	15.05	2.97	2.91	5.98
130.	20	Gourinogor	25.03211/ 91.8128	Fagu	MLL, LL	Boro-F.-T. Aman	4.96	0.25	0.68	0.115	27.80	2.84	2.89	5.86
131.	20	Khagail	25.02175/ 91.81746	Fagu	MLL, LL	Boro-F.-T. Aman	4.89	0.22	0.60	0.103	18.30	2.27	2.77	5.12

Sl No.	AEZ	Village	GPS (Lat. /Long.)	Soil Series	Land type	Cropping pattern	Soil pH	Total N (%)	Ava. P (ppm)	Ex. K (meq/100g)	Ava. S (ppm)	Ex. Ca (meq/100g)	Ex. Mg (meq/100g)	Ava. Zn (ppm)
132.	20	Khagail	25.02113/ 91.81765	Fagu	MLL, LL	Boro-F.-T. Aman	5.00	0.17	1.23	0.097	14.35	1.83	1.75	3.82
133.	20	Khagail	25.02101/ 91.81706	Fagu	MLL, LL	Boro-F.-T. Aman	4.97	0.19	0.55	0.072	15.70	1.54	1.67	2.46
134.	20	Khagail	25.02034/ 91.81675	Fagu	MLL, LL	Boro-F.-T. Aman	4.88	0.15	0.40	0.060	16.90	1.48	1.53	2.96
135.	20	Khagail	25.01999/ 91.81629	Fagu	MLL, LL	Boro-F.-T. Aman	4.83	0.21	0.15	0.060	15.30	1.42	1.35	3.00
136.	20	Khagail	25.01955/ 91.81577	Fagu	MLL, LL	Boro-F.-T. Aman	5.20	0.21	0.20	0.109	13.80	1.87	2.87	2.52
137.	20	Khagail	25.01882/ 91.81516	Fagu	MLL, LL	Boro-F.-T. Aman	4.76	0.11	0.60	0.175	23.10	2.49	3.56	5.70
138.	20	Khagail	25.0185/ 91.81398	Fagu	MLL, LL	Boro-F.-T. Aman	4.94	0.19	0.58	0.091	15.30	1.36	1.73	1.80
139.	20	Khagail	25.02244/ 91.81845	Fagu	MLL, LL	Boro-F.-T. Aman	4.97	0.15	1.75	0.109	15.35	1.57	2.34	4.06
140.	20	Khagail	25.02259/ 91.81923	Fagu	MLL, LL	Boro-F.-T. Aman	4.95	0.15	1.25	0.097	16.45	2.11	2.74	5.78
141.	20	Dolirgaon purbopara	25.02043/ 91.80702	Fagu	MLL, LL	Boro-F.-T. Aman	4.83	0.17	2.50	0.060	13.10	0.85	0.65	1.56
142.	20	Dolirgaon purbopara	25.02114/ 91.80692	Fagu	MLL, LL	Boro-F.-T. Aman	5.11	0.14	2.00	0.060	13.40	1.04	1.15	1.10
143.	20	Dolirgaon purbopara	25.02215/ 91.80686	Fagu	MLL, LL	Boro-F.-T. Aman	5.22	0.26	1.50	0.048	12.30	0.86	0.74	1.76
144.	20	Dolirgaon purbopara	25.02282/ 91.80675	Fagu	MLL, LL	Boro-F.-T. Aman	5.15	0.17	3.50	0.048	13.00	1.01	1.06	1.78
145.	20	Dolirgaon purbopara	25.02366/ 91.80685	Fagu	MLL, LL	Boro-F.-T. Aman	5.12	0.15	2.50	0.048	11.65	1.04	0.93	2.02
146.	20	Dolirgaon purbopara	25.02388/ 91.80757	Fagu	MLL, LL	Boro-F.-T. Aman	5.05	0.14	2.75	0.048	11.65	0.97	0.83	1.78
147.	20	Dolirgaon purbopara	25.02362/ 91.80781	Fagu	MLL, LL	Boro-F.-T. Aman	5.10	0.14	2.50	0.048	12.75	1.08	1.07	1.68
148.	20	Dolirgaon purbopara	25.02295/ 91.80803	Fagu	MLL, LL	Boro-F.-T. Aman	4.97	0.14	2.50	0.060	11.75	0.86	0.75	1.32
149.	20	Dolirgaon purbopara	25.02226/ 91.80797	Fagu	MLL, LL	Boro-F.-T. Aman	4.97	0.22	4.93	0.054	17.25	0.76	0.57	0.78
150.	20	Dolirgaon purbopara	25.02133/ 91.80796	Fagu	MLL, LL	Boro-F.-T. Aman	4.98	0.28	1.98	0.048	12.65	0.90	0.84	1.28

Sl No.	AEZ	Village	GPS (Lat. /Long.)	Soil Series	Land type	Cropping pattern	Soil pH	Total N (%)	Ava. P (ppm)	Ex. K (meq/100g)	Ava. S (ppm)	Ex. Ca (meq/100g)	Ex. Mg (meq/100g)	Ava. Zn (ppm)
151.	20	Vitorgram	25.06059/ 92.12566	Bijipur	MHL, MLL	F.-F.-T. Aman	5.74	0.25	5.03	0.042	13.45	0.63	0.63	1.20
152.	20	Vitorgram	25.05957/ 92.12549	Bijipur	MHL, MLL	F.-F.-T. Aman	5.78	0.21	2.83	0.060	14.7	0.73	0.95	1.32
153.	20	Vitorgram	25.05889/ 92.12511	Bijipur	MHL, MLL	F.-F.-T. Aman	5.14	0.24	4.00	0.072	16.45	0.81	0.79	2.22
154.	20	Vitorgram	25.05817/ 92.12449	Bijipur	MHL, MLL	F.-F.-T. Aman	5.96	0.25	1.50	0.091	11.95	1.41	3.09	0.58
155.	20	Vitorgram	25.05799/ 92.12355	Bijipur	MHL, MLL	F.-F.-T. Aman	5.41	0.32	3.50	0.066	12.9	1.41	0.81	0.86
156.	20	Vitorgram	25.05875/ 92.12352	Bijipur	MHL, MLL	F.-F.-T. Aman	5.22	0.12	3.50	0.066	12.85	0.73	0.67	1.76
157.	20	Vitorgram	25.05986/ 92.12396	Bijipur	MHL, MLL	F.-F.-T. Aman	5.23	0.42	3.03	0.072	12.55	0.83	1.02	1.22
158.	20	Vitorgram	25.06034/ 92.12471	Bijipur	MHL, MLL	F.-F.-T. Aman	5.26	0.99	2.95	0.078	12.25	0.86	1.36	1.06
159.	20	Vitorgram	25.06109/ 92.12459	Bijipur	MHL, MLL	F.-F.-T. Aman	5.32	0.14	2.50	0.078	12.55	0.87	1.36	1.08
160.	20	Vitorgram	25.0616/ 92.12469	Bijipur	MHL, MLL	F.-F.-T. Aman	5.24	0.17	2.50	0.078	12.7	0.83	1.16	1.24
161.	20	Kholagram	25.06368/ 92.12353	Bijipur	MHL, MLL	F.-F.-T. Aman	5.75	0.25	2.65	0.078	12.55	1.38	3.54	0.62
162.	20	Kholagram	25.06417/ 92.12381	Bijipur	MHL, MLL	F.-F.-T. Aman	5.34	0.15	4.15	0.048	11.65	0.96	0.53	0.80
163.	20	Kholagram	25.06445/ 92.12396	Bijipur	MHL, MLL	F.-F.-T. Aman	5.20	0.15	6.28	0.054	11.9	1.18	0.37	1.24
164.	20	Kholagram	25.06563/ 92.12408	Bijipur	MHL, MLL	F.-F.-T. Aman	5.19	0.14	4.13	0.060	13.05	0.94	0.48	0.80
165.	20	Kholagram	25.06591/ 92.12314	Bijipur	MHL, MLL	F.-F.-T. Aman	5.35	0.14	3.08	0.048	13.4	0.69	1.21	0.64
166.	20	Kholagram	25.06596/ 92.12238	Bijipur	MHL, MLL	F.-F.-T. Aman	6.70	0.29	3.00	0.060	12.5	0.72	0.90	0.80
167.	20	Kholagram	25.06588/ 92.12128	Bijipur	MHL, MLL	F.-F.-T. Aman	5.98	0.24	5.25	0.048	13.6	0.53	0.34	0.78
168.	20	Kholagram	25.06495/ 92.12107	Bijipur	MHL, MLL	F.-F.-T. Aman	5.78	0.21	3.55	0.054	15.05	0.41	0.38	1.02
169.	20	Kholagram	25.06418/ 92.12148	Bijipur	MHL, MLL	F.-F.-T. Aman	5.85	0.22	3.00	0.048	14.9	0.46	0.66	1.06

Sl No.	AEZ	Village	GPS (Lat. /Long.)	Soil Series	Land type	Cropping pattern	Soil pH	Total N (%)	Ava. P (ppm)	Ex. K (meq/100g)	Ava. S (ppm)	Ex. Ca (meq/100g)	Ex. Mg (meq/100g)	Ava. Zn (ppm)
170.	20	Kholagram	25.06396/ 92.12231	Bijipur	MHL, MLL	F.-F.-T. Aman	5.64	0.28	5.00	0.066	12.35	0.40	0.32	1.58
171.	20	Vitrikhel	25.11838/ 92.12051	Monu	MHL, MLL	F.-F.-B. Am/ T.Am	5.34	0.28	4.53	0.145	13.95	1.16	0.73	2.70
172.	20	Vitrikhel	25.1177/ 92.12122	Monu	MHL, MLL	F.-F.-B. Am/ T.Am	5.63	0.24	2.38	0.097	18.5	1.03	0.70	1.52
173.	20	Vitrikhel	25.11832/ 92.12228	Monu	MHL, MLL	F.-F.-B. Am/ T.Am	5.16	0.39	4.15	0.121	18.45	1.01	0.68	2.92
174.	20	Vitrikhel	25.11913/ 92.12294	Monu	MHL, MLL	F.-F.-B. Am/ T.Am	5.39	0.67	2.85	0.121	14.2	0.89	0.61	2.00
175.	20	Vitrikhel	25.11971/ 92.1232	Monu	MHL, MLL	F.-F.-B. Am/ T.Am	5.47	0.19	4.33	0.085	14.7	0.66	0.37	1.46
176.	20	Vitrikhel	25.12059/ 92.12324	Monu	MHL, MLL	F.-F.-B. Am/ T.Am	5.44	0.32	3.03	0.091	15.9	0.63	0.42	1.02
177.	20	Vitrikhel	25.12139/ 92.12239	Monu	MHL, MLL	F.-F.-B. Am/ T.Am	5.42	0.22	2.95	0.121	14.35	0.93	0.33	0.64
178.	20	Vitrikhel	25.12164/ 92.12216	Monu	MHL, MLL	F.-F.-B. Am/ T.Am	5.40	0.24	3.40	0.066	18.1	0.58	0.31	1.14
179.	20	Vitrikhel	25.12172/ 92.12067	Monu	MHL, MLL	F.-F.-B. Am/ T.Am	5.49	0.19	5.65	0.097	16.35	0.99	0.55	2.36
180.	20	Vitrikhel	25.06059/ 92.12566	Monu	MHL, MLL	F.-F.-T. Aman	5.30	0.22	5.50	0.121	14.15	1.13	0.88	2.44

BINA Component

Appendix 3. Soil sample analytical data along with baseline information

Sample No.	GPS		Village/Union	Soil series	Land type	pH	OM (%)	Total N (%)	Avail. P (ppm)	Excha. K (meq/ 100g)	Avail. S (ppm)	Avail. B (ppm)	Avail. Zn (ppm)	Excha. Ca (meq/ 100g)	Excha. Mg (meq/ 100g)
	N	E													
Godagari, Rajshahi															
1	24° 29' 9.8″	88° 20 36.6″	Sormongla, Rahi	Nachole	MHL	5.87	1.04	0.144	22.0	0.102	14.5	0.195	1.4	2.99	2.77
2	24° 29' 8.7"	88° 20'35.9"	Sormongla, Rahi	Nachole	HL	6.08	0.72	0.082	9.0	0.073	16.2	0.135	0.72	3.01	1.96
3	24° 29' 6.9"	88° 20'46.8"	Sormongla, Rahi	Amnura	HL	6.24	0.88	0.095	13.3	0.078	8.1	0.180	1.24	3.12	1.91
4	24° 29' 5.7"	88° 20' 49.5"	Sormongla, Rahi	Amnura	HL	6.8	0.76	0.112	19.8	0.042	9.7	0.165	1.21	2.64	1.67
5	24° 29' 13.7"	88° 20' 55.7″	Sormongla, Rahi	Amnura	HL	6.46	0.96	0.125	20.4	0.061	14.5	0.090	1.16	2.86	1.45
6	24° 29' 16.5"	88° 21' 05.2″	Sormongla, Rahi	Atahar	HL	6.58	0.92	0.115	28.1	0.069	12.9	0.255	1.19	3.34	1.55
7	24° 29' 14.2"	88° 21' 06.2″	Sormongla, Rahi	Atahar	MHL	6.53	1.04	0.109	30.5	0.053	8.1	0.135	1 18	2.87	1.41
8	24° 29' 12.3"	88° 21' 07.5"	Sormongla, Rahi	Atahar	MHL	6.54	0.76	0.101	35.9	0.055	8.1	0.180	1.27	2.90	1.58
9	24°29' 11.4"	88° 21' 06.5"	Sormongla, Rahi	Atahar	MHL	6.56	1.16	0.119	22.4	0.062	6.5	0.150	1.55	2.98	1.48
10	24° 29' 11.4"	88° 21' 06.5"	Sormongla, Rahi	Atahar	MHL	6.59	1	0.107	12.9	0.069	9.7	0.135	1.54	2.53	1.69
11	24° 31' 30.7"	88° 22' 31.6"	Digram,mohanpur	Atahar	HL	6.11	1.12	0.136	23.1	0.119	14.5	0.180	1.69	3.41	1.87
12	24° 31' 28.1"	88° 22' 37.5"	Digram, Rahi	Atahar	HL	5.88	1.44	0.144	46.0	0.097	19.4	0.221	1.26	2.79	1.78
13	24° 31' 28.3"	88° 22' 40.1"	Digram,mohanpur	Atahar	HL	5.41	0.76	0.122	47.4	0.119	17.8	0.135	0.97	3.03	0.79
14	24°31' 30.1"	88° 22' 39.3″	Digram,mohanpur	Atahar	HL	5.39	1.12	0.122	47.8	0.086	21.1	0.348	1 14	3.50	1.68
15	24° 32.1' 11.4″	88°22' 37.2"	Digram,mohanpur	Atahar	HL	5.44	0.96	0.1	47.5	0.103	14.5	0.305	1.58	3.81	0.92
16	24° 31' 45.1"	88° 22' 34.1″	Digram,mohanpur	Atahar	MHL	6.32	1.16	0.109	22.9	0.071	9.7	0.285	1.13	3.03	1.48
17	24° 31' 45.1″	88° 22' 34.1"	Digram,mohanpur	Atahar	MHL	6.62	1.28	0.147	25.6	0.068	17.8	0.450	1 04	3.42	2.07
18	24° 31' 46.5″	88° 22' 36.1″	Digram,mohanpur	Atahar	HL	6.43	1.34	0.141	7.8	0.117	9.7	0.435	1.14	3.10	1.59
19	24° 31' 44.4"	88° 22' 41.6"	Digram,mohanpur	Atahar	HL	5.79	1.12	0.124	19.3	0.058	17.8	0.195	1.7	3.61	1.42
20	24° 31' 46.5"	88° 22' 43.4	Digram,mohanpur	Atahar	HL	6.37	1	0.106	11.4	0.084	19.4	0.300	1.24	3.40	1.67
21	24° 32' 52.0"	88° 22' 55.1"	Kazipara,mohanpur	Atahar	MHL	6.44	1.16	0.108	4.3	0.056	8.1	0.255	0.76	4.25	2.65
22	24° 32' 54.0"	88° 22' 56"	Kazipara,mohanpur	Atahar	MHL	6.65	1	0.098	6.5	0.073	9.7	0.165	0.55	3.35	2.33
23	24° 32' 56.3"	88° 22' 55.8″	Kazipara,mohanpur	Atahar	MHL	6.66	1.12	0.109	3.4	0.069	6.5	0.150	0.49	3.50	2.93
24	24° 32' 58.1"	88° 22' 56.2″	Kazipara,mohanpur	Dudnai	MHL	6.44	1.28	0.099	9.7	0.099	8.1	0.270	0.54	3.69	2.69
25	24° 32' 58.6"	88° 22' 57.1"	Kazipara,mohanpur	Dudnai	MHL	6.37	1.2	0.138	5.6	0.12	9.7	0.206	0.55	3.03	3.66
26	24° 32' 58.7"	88° 22' 57"	Kazipara,mohanpur	Dudnai	MHL	6.36	1.23	0.142	6.9	0.118	21.1	0.075	0.57	3.84	2.47
27	24° 32' 57.8"	88° 22' 54.7"	Kazipara,mohanpur	Dudnai	MHL	6.3	1	0.114	3.8	0.163	14.5	0.150	0.61	3.46	4.01
28	24° 32' 57.1"	88° 22' 52.1"	Kazipara,mohanpur	Dudnai	MHL	6.06	1.04	0.115	11.0	0.137	12.9	0.190	0.56	3.34	3. 12
29	24° 32' 56.2"	88° 22' 51.1"	Kazipara,mohanpur	Dudnai	MHL	6.19	0.8	0.073	3.6	0.135	11.3	0.045	0.54	3.97	3.77
30	24° 32' 54.8"	88° 22' 47.9"	Kazipara,mohanpur	Dudnai	MHL	6.16	1	0.082	8.3	0.159	12.9	0.195	0.53	3.01	3.64

Sample No.	GPS		Village/Union	Soil series	Land type	pH	OM (%)	Total N (%)	Avail. P (ppm)	Excha. K (meq/ 100g)	Avail. S (ppm)	Avail. B (ppm)	Avail. Zn (ppm)	Excha. Ca (meq/ 100g)	Excha. Mg (meq/ 100g)
	N	E													
Nachole, Chapai															
31	24° 44' 10.8"	88° 25' 38.8"	W.laxanpur,Nachole	Amnura	MHL	6.81	1.16	0.078	28.5	0.079	13.2	0.286	1.12	3.35	1.35
32	24° 44' 11.2"	88° 25' 40.4"	W.laxanpur,Nachole	Amnura	MHL	7.06	0.96	0.087	6.2	0.064	24.5	0.259	1.24	3.46	1.37
33	24° 44' 11.4"	88° 22' 40.9"	W.laxanpur,Nachole	Amnura	MHL	7.08	1	0.075	5.8	0.062	4.9	0.273	1.08	3.75	1.33
34	24° 44' 11.6"	88° 25' 43.2"	W.laxanpur,Nachole	Amnura	MHL	7.58	0.92	0.086	22.4	0.028	3.3	0.437	1.16	4.23	1.34
35	24° 44' 12.1"	88° 25' 45.0"	W.laxanpur,Nachole	Amnura	MHL	7.12	0.76	0.077	10.8	0.041	6.6	0.273	1.13	4.04	1.22
36	24° 44' 13.1"	88° 25' 45.4"	W.laxanpur,Nachole	Amnura	MHL	7.1	1.04	0.07	10.7	0.064	18.1	0.355	1.08	4.33	1.31
37	24° 44' 15.4"	88° 25' 47.1"	W.laxanpur,Nachole	Atahar	MHL	7.43	1.24	0.084	5.8	0.056	23.0	0.300	0.89	3.50	1.47
38	24° 44' 16.3"	88° 25' 48.5"	W.laxanpur,Nachole	Dudnai	MHL	7.31	1.28	0.086	6.6	0.069	11.5	0.327	0.74	4.48	1.51
39	24° 44' 17.8"	88° 25' 49.9"	W.laxanpur,Nachole	Dudnai	MHL	7.29	1.16	0.122	3.5	0.073	21.4	0.409	0.62	3.97	1.59
40	24° 44' 19.8"	88° 25' 52.2"	W.laxanpur,Nachole	Nachole	MHL	7.13	1.08	0.113	10.8	0.057	11.5	0.245	0.36	3.32	1.62
41	24° 42' 40.7"	88° 25' 26.0"	Hamidpur,Nasirabad	Dudnai	MHL	7.28	1.11	0.157	21.5	0.099	9.9	0.601	0.48	4.22	1.71
42	24° 42' 40.1"	88° 25' 25.3"	Hamidpur,Nasirabad	Dudnai	MHL	7.51	0.88	0.128	23.4	0.088	18.1	0.491	0.59	3.93	1.78
43	24° 42' 40.2"	88° 25' 24.2"	Hamidpur,Nasirabad	Atahar	MHL	7.52	1.08	0.109	17.5	0.06	19.7	0.546	0.48	4.95	1.81
44	24° 42' 39.6"	88° 25' 23.6"	Hamidpur,Nasirabad	Atahar	MHL	7.47	0.88	0.098	3.2	0.055	16.5	0.341	0.89	4.51	2.11
45	24° 42' 40.1"	88° 25' 22.2"	Hamidpur,Nasirabad	Amnura	MHL	7.59	1.56	0.151	34.3	0.077	21.4	0.833	1.4	5.20	2.85
46	24° 42' 40.3"	88° 25' 21.7"	Hamidpur,Nasirabad	Dudnai	MHL	7.95	1.12	0.128	15.9	0.067	26.3	0.683	1.23	5.54	2.23
47	24° 42' 38.8"	88° 25' 21.9"	Hamidpur,Nasirabad	Dudnai	MHL	7.13	1	0.055	13.8	0.057	27.8	0.532	1.36	4.72	2.21
48	24° 42' 38.1"	88° 25' 20.2"	Hamidpur,Nasirabad	Dudnai	MHL	7.1	1.39	0.085	9.7	0.04	4.9	0.327	0.85	4.61	2.14
49	24° 42' 38.0"	88° 25' 18.5"	Hamidpur,Nasirabad	Dudnai	MHL	7.16	0.84	0.074	5.7	0.069	21.4	0.519	0.96	4.30	2.13
50	24° 42' 37.9"	88° 25' 16.9"	Hamidpur,Nasirabad	Dudnai	MHL	7.28	1.11	0.079	35.7	0.049	11.5	0.614	1.4	4.52	2.03
51	24° 41' 03.4"	88° 25' 08.8"	Nijampur	Nachole	MHL	7.22	1.48	0.109	20.0	0.198	8.2	0.587	0.98	2.54	2.14
52	24° 41' 03.7"	88° 25' 06.0"	Nijampur	Nachole	HL	6.51	1.39	0.077	7.6	0.095	11.5	0.163	0.78	3.03	2.24
53	24° 41' 03.4"	88° 25' 06.7"	Nijampur	Nachole	HL	5.88	1.71	0.095	16.0	0.029	9.9	0.425	0.68	3.27	2.36
54	24° 41' 02.4"	88° 25' 06.6"	Nijampur	Nachole	HL	7.44	1	0.08	5.8	0.082	3.3	0.122	0.62	3.03	2.44
55	24° 41' 01.9"	88° 25' 07.5"	Nijampur	Dudnai	HL	6.66	0.88	0.082	3.9	0.059	11.5	0.300	0.5	3.35	2.56
56	24° 41' 01.7"	88° 25' 08.8"	Nijampur	Dudnai	HL	6.44	1.31	0.118	6.7	0.119	4.9	0.259	0.59	3.70	2.65
57	24° 41' 03.5"	88° 25' 10.2"	Nijampur	Atahar	HL	6.65	1.63	0.101	8.4	0.254	3.3	0.218	0.64	2.83	2.74
58	24° 41' 03.9"	88° 25' 10.9"	Nijampur	Dudnai	HL	6.97	1.31	0.084	7.5	0.117	4.9	0.642	1.02	3.06	2.84
59	24° 41' 03.4"	88° 25' 11.6"	Nijampur	Atahar	HL	7.02	0.92	0.079	4.9	0.13	11.5	0.163	1.06	3.16	2.91
60	24° 41' 04.1"	88° 25' 12.9"	Nijampur	Atahar	HL	6.66	1.19	0.077	20.8	0.093	4.9	0.450	1.34	2.98	2.9
Manda, Nagaon															
61	24° 41' 53.1″	88° 40' 30.4"	Fatehipur,Kalikapur	Nijuri	MHL	6.43	0.82	0.086	28.0	0.059	19.3	0.689	1.24	2.25	1.46
62	24° 41' 50.6"	88° 40' 29.5"	Fatehipur,Kalikapur	Nijuri	MHL	6.77	0.94	0.077	31.0	0.048	41.7	0.787	1.15	2.26	1 44
63	24° 41' 50.1"	88° 40' 28.5"	Fatehipur,Kalikapur	Nijuri	MHL	6.74	0.94	0.064	34.7	0.054	36.5	0.872	1.18	2.23	1.48

Sample No.	GPS		Village/Union	Soil series	Land type	pH	OM (%)	Total N (%)	Avail. P (ppm)	Excha. K (meq/ 100g)	Avail. S (ppm)	Avail. B (ppm)	Avail. Zn (ppm)	Excha. Ca (meq/ 100g)	Excha. Mg (meq/ 100g)
	N	E													
64	24° 41' 50.5"	88° 40' 25'.5"	Fatehipur,Kalikapur	Nijuri	MHL	6.76	1.06	0.074	37.5	0.111	27.3	0.900	1.17	2.07	1.42
65	24° 41' 51.9"	88° 40' 24.5"	Fatehipur,Kalikapur	Nijuri	MHL	7.13	0.98	0.083	31.8	0.031	34.6	0.801	1.3	2.01	1.31
66	24° 41' 53.5"	88° 40' 25.2"	Fatehipur,Kalikapur	Nijuri	MHL	7.05	0.69	0.112	36.1	0.04	25.7	0.604	1.27	2.09	1.44
67	24° 41' 54.5"	88° 40' 25.7"	Fatehipur,Kalikapur	Nijuri	MHL	6.84	0.86	0.101	31.4	0.044	25.7	0.492	1.08	1.97	1.31
68	24° 41' 57.3"	88° 40' 27.9 "	Fatehipur,Kalikapur	Nijuri	MHL	7.41	1.35	0.119	31.3	0.043	19.3	0.350	1.04	1.96	1.21
69	24° 41' 59.8"	88° 40' 28.6"	Fatehipur,Kalikapur	Nijuri	MHL	7.42	1.27	0.112	30.7	0.026	17.7	0.237	1.19	2.12	1.14
70	24 ° 41' 59.5"	88° 46' 30.6"	Fatehipur,Kalikapur	Nijuri	MHL	7.24	1.18	0.139	29.7	0.027	22.5	0.942	1.16	2.25	1.11
71	24 ° 42' 27.9"	88° 40' 32.6"	kaligram	Nijuri	MHL	7.12	1.35	0.069	16.8	0.045	14.4	0.886	1.28	2.46	1.13
72	24 ° 42' 27.5"	88° 40' 30.6"	kaligram	Nijuri	MHL	7.41	1.39	0.133	22.6	0.033	36.9	0.083	1.12	2.53	1.18
73	24 ° 42' 27.8"	88° 40' 28.6"	kaligram	Nijuri	MHL	7.31	1.27	0.08	34.5	0.052	14.4	0.012	1.32	2.58	1.34
74	24 ° 42' 29.8"	88° 40' 28.1"	kaligram	Nijuri	MHL	7.28	1.26	0.074	26.0	0.065	19.3	0.280	1.09	2.72	1.62
75	24 ° 42' 31.2"	88° 40' 28.5"	kaligram	Nijuri	MHL	7.23	1.39	0.077	11.7	0.037	20.9	0.617	1.02	2.30	1.79
76	24 ° 42' 32.7"	88° 40' 31.5"	kaligram	Nijuri	MHL	7.34	1.26	0.078	9.6	0.043	20.9	0.181	0.89	2.68	1.81
77	24 ° 42' 32.3"	88° 40' 33.8"	kaligram	Amnura	MHL	7.29	1.1	0.081	8.6	0.039	12.8	1.111	0.87	2.45	1.88
78	24 ° 42' 30.2"	88° 40' 37.0"	kaligram	Amnura	MHL	7.05	1.14	0.079	13.6	0.085	20.9	0.928	0.69	2.73	1.78
79	24 ° 42' 29.5"	88° 40' 38.3"	kaligram	Amnura	MHL	7.26	1.14	0.101	26.2	0.046	35.3	0.322	0.59	3.59	1.67
80	24 ° 42' 28.1"	88° 40' 39.0"	kaligram	Amnura	MHL	7.43	1.47	0.071	16.8	0.065	30.5	0.308	1.04	2.74	1.9
81	24 ° 42' 54.0"	88° 40' 32.6"	Kituli, Kusumba	Amnura	MHL	7.12	1.06	0.083	4.9	0.079	28.9	0.696	0.47	2.12	1.89
82	24 ° 42' 52.5"	88° 40' 32.5"	Kituli, Kusumba	Amnura	MHL	7.11	1.35	0.133	6.4	0.11	25.7	0.710	0.56	3.00	1.78
83	24 ° 42' 49.3"	88° 40' 32.9"	Kituli, Kusumba	Amnura	MHL	7.29	1.04	0.107	7.2	0.069	33.7	0.844	0.67	3.33	1.74
84	24 ° 42' 49"	88° 46' 34.5"	Kituli, Kusumba	Amnura	MHL	7.06	1.26	0.128	6.7	0.072	41.7	0.859	0.84	3.28	1.64
85	24 ° 42' 48.7"	88° 40' 85.3"	Kituli, Kusumba	Amnura	MHL	7.31	1.26	0.115	11.0	0.061	33.7	1.110	1.08	3.04	1.55
86	24 ° 42' 48.2"	88° 40' 36.7"	Kituli, Kusumba	Amnura	MHL	7.05	1.14	0.122	5.6	0.131	32.1	0.933	0.99	2.91	1.45
87	24 ° 42' 52.4"	88° 40' 45.6"	Kituli, Kusumba	Amnura	MHL	7.1	1.26	0.13	16.0	0.051	22.5	1.170	0.94	2.77	1.35
88	24 ° 42' 50.9"	88° 40' 45.9"	Kituli, Kusumba	Amnura	MHL	7.31	1.06	0.112	30.9	0.036	30.5	0.947	0.96	2.81	1 23
89	24 ° 42' 49.2"	88° 40' 45.3"	Kituli, Kusumba	Amnura	MHL	7.05	1.1	0.101	10.8	0.072	31.4	0.577	0.82	3.30	1.33
90	24 ° 42' 49.6"	88° 40' 14.6″	Kituli, Kusumba	Amnura	MHL	7.22	1.14	0.108	11.5	0.064	36.9	0.651	0.74	2.47	1.19
Nondigram, Bogura															
91	24 ° 40' 48.5"	89° 17' 45.3"	Shingjani, Burail		MHL	5.45	1.79	0.16	6.7	0.028	12.9	0.073	0.86	1.55	1.64
92	24 ° 40' 47.0"	89° 17' 15.3″	Shingjani, Burail		MHL	5.34	1.55	0.122	9.6	0.059	9.7	0.088	0.75	1.62	1.66
93	24 ° 40' 46.3″	89° 17 ' 1"	Shingjani, Burail	Akdala	MHL	5.23	1.59	0.112	24.9	0.054	16.2	0.176	0.69	1.50	1.74
94	24 ° 40' 46.6″	89° 17' 18.7″	Shingjani, Burail	Akdala	MHL	5.18	1.39	0.133	23.7	0.058	24.3	0.103	0.93	1.14	1.61
95	24 ° 40' 46.6″	89° 17' 18.7"	Shingjani, Burail	Akdala	MHL	5.14	1.63	0.151	35.2	0.057	21.0	0.147	1.24	1.67	1.56
96	4 ° 40' 46.3″	89° 17' 20.4"	Shingjani, Burail	Akdala	MHL	5.12	1.87	0.163	22.0	0.076	16.2	0.117	1.13	1.38	1.56

Sample No.	GPS		Village/Union	Soil series	Land type	pH	OM (%)	Total N (%)	Avail. P (ppm)	Excha. K (meq/ 100g)	Avail. S (ppm)	Avail. B (ppm)	Avail. Zn (ppm)	Excha. Ca (meq/ 100g)	Excha. Mg (meq/ 100g)
	N	E													
97	24 ° 40' 47.0″	89° 17' 21.3"	Shingjani, Burail	Akdala	MHL	5.37	1.63	0.157	30.5	0.052	22.6	0.162	1.09	1.50	1.66
98	4 ° 40' 48.3″	89° 17' 21.3"	Shingjani, Burail	Akdala	MHL	5.02	1.63	0.142	12.4	0.072	21.0	0.147	0.78	1.45	1.67
99	24 ° 40' 48.2"	89° 17' 19.9"	Shingjani, Burail	Akdala	MHL	5.51	1.67	0.122	4.7	0.057	21.0	0.088	0.88	1.27	1.71
100	24 ° 40' 49.5″	89° 17' 19.3"	Shingjani, Burail	Akdala	MHL	5.76	1.59	0.142	7.2	0.155	11.3	0.221	0.61	1.37	1.8
101	24 ° 40' 06.0″	89° 16' 26.0"	Kataham,Bhatgram	Akdala	MHL	5.83	1.35	0.163	33.6	0.065	12.9	0.073	0.66	2.71	1.89
102	24 ° 40' 04.9″	89° 16' 24.0"	Kataham,Bhatgram	Akdala	MHL	5.72	1.67	0.128	23.0	0.055	24.3	0.103	0.95	2.48	1.68
103	24 ° 40' 04.0″	89° 16' 21.0"	Kataham,Bhatgram	Amnura	MHL	5.58	1.47	0.13	39.9	0.061	16.2	0.073	1.12	2.57	0.79
104	24 ° 40' 03'.4″	89° 16' 21.2"	Kataham,Bhatgram	Amnura	MHL	5.42	1.51	0.177	26.6	0.044	14.6	0.088	1.31	2.67	0.81
105	24 ° 40' 05.3"	89° 16' 21.1"	Kataham,Bhatgram	Amnura	MHL	5.26	1.43	0.142	24.7	0.045	14.6	0.073	2.14	3.25	0.58
106	24 ° 40' 07.1"	89° 16' 20.8"	Kataham,Bhatgram	Amnura	MHL	5.35	1.31	0.139	23.3	0.054	8.1	0.103	1.51	2.84	0.62
107	24 ° 40' 11.2"	89° 16' 22.3"	Kataham,Bhatgram	Amnura	MHL	5.27	1.55	0.128	11.1	0.06	11.3	0.103	1.64	2.96	0.58
108	24 ° 40' 11.2"	89° 16' 24.0"	Kataham,Bhatgram	Amnura	MHL	5.48	1.51	0.098	11.3	0.084	19.9	0.088	1.55	2.61	0.66
109	24 ° 40' 11.2″	89° 16' 24.9"	Kataham,Bhatgram	Amnura	MHL	5.39	1.35	0.16	6.3	0.069	6.5	0.073	1.48	2.70	0.63
110	24 ° 40' 10.3″	89° 16' 25.9"	Kataham,Bhatgram	Amnura	MHL	5.47	1.55	0.133	9.5	0.062	11.3	0.221	1.72	2.53	0.61
111	24 ° 38' 56.9″	89° 15' 47.9"	Nandigram	Amnura	HL	5.76	1.47	0.119	26.3	0.052	16.2	0.103	1.64	2.67	0.71
112	24 ° 38' 56.0″	89° 15' 47.7"	Nandigram	Amnura	HL	5.83	1.59	0.122	16.8	0.059	16.2	0.147	1.35	2.24	0.79
113	24 ° 38' 55.2″	89° 15' 46.6"	Nandigram	Amnura	HL	5.91	1.64	0.098	24.7	0.048	12.9	0.088	1.48	1.93	0.91
114	24 ° 38' 55.4"	89° 15' 47.7"	Nandigram	Amnura	HL	5.22	1.47	0.13	21.3	0.056	22.3	0.147	1.56	1.96	0.88
115	24 ° 38' 56.3"	89° 15' 44.5"	Nandigram	Amnura	HL	5.41	1.51	0.13	16.6	0.056	11.3	0.162	2.51	3.30	0.5
116	24 ° 38' 57.8"	89° 15' 44.3"	Nandigram	Amnura	HL	5.53	1.67	0.13	30.3	0.058	6.5	0.044	2.41	2.23	0.55
117	24 ° 38' 59. 0″	89° 15' 44.4"	Nandigram	Amnura	HL	5.26	1.55	0.119	29.0	0.067	11.3	0.176	2.33	2.44	0.59
118	24 ° 38' 59.8"	89° 15' 44.9"	Nandigram	Amnura	HL	5.15	1.23	0.093	17.3	0.047	9.7	0.117	2.62	2.49	0.51
119	24 ° 39' 00.5"	89° 15' 44.4"	Riduil, Boroil	Amnura	HL	5.47	1.47	0.115	36.8	0.065	6.5	0.088	2.55	2.67	0.61
120	24 ° 39' 01.6"	89° 15' 45.1"		Amnura	HL	5.51	1.23	0.154	14.7	0.057	17.8	0.103	2.51	2.65	0.55
Mithapukur, Rangpur															
121	25 ° 31' 38.2″	89° 11' 31.3"	Banderpara,Gopalpur	Nuada	HL	5.56	1.22	0.125	11.7	0.079	23.4	0.145	2.34	1.19	0.57
122	25 ° 31' 39.3″	89° 11' 31.1"	Banderpara,Gopalpur	Nuada	HL	5.47	1.47	0.142	11.1	0.088	21.8	0.130	2.41	1.32	0.61
123	25 ° 31' 39.9″	89° 11' 30.4"	Banderpara,Gopalpur	Nuada	HL	5.44	1.75	0.147	13.6	0.128	28.5	0.217	2.31	1.15	0.68
124	25 ° 31' 40.0"	89° 11' 30.4"	Banderpara,Gopalpur	Nuada	HL	5.37	1.47	0.139	16.5	0.081	25.1	0.203	2.42	1.24	0.59
125	25 ° 31' 41.0"	89° 11' 28.9"	Banderpara,Gopalpur	Nuada	HL	5.66	1.3	0.125	8.1	0.087	13.4	0.217	2.39	1.33	0.5
126	25 ° 31' 40.8"	89° 11' 27.8"	Banderpara,Gopalpur	Nuada	HL	5.42	1.55	0.122	18.7	0.112	21.8	0.217	2.12	1.78	0.51
127	25 ° 31' 40.7"	89° 11' 26.8"	Banderpara,Gopalpur	Nuada	HL	5.51	1.43	0.125	24.0	0.101	8.4	0.130	1.78	1.91	0.55
128	25 ° 31' 42.2"	89° 11' 26.2"	Banderpara,Gopalpur	Nuada	HL	5.38	1.59	0.133	21.4	0.0791	18.4	0.174	1.54	2.50	0.57
129	25 ° 31' 43.0"	89° 11' 26.2"	Banderpara,Gopalpur	Nuada	HL	5.61	1.59	0.142	21.4	0.07	11.7	0.174	1.33	2.97	0.48

Sample No.	GPS		Village/Union	Soil series	Land type	pH	OM (%)	Total N (%)	Avail. P (ppm)	Excha. K (meq/ 100g)	Avail. S (ppm)	Avail. B (ppm)	Avail. Zn (ppm)	Excha. Ca (meq/ 100g)	Excha. Mg (meq/ 100g)
	N	E													
130	25 ° 31' 43.4"	89° 11' 25.3"	Banderpara,Gopalpur	Nuada	HL	5.56	1.75	0.136	17.8	0.064	18.4	0.203	0.97	2.84	0.36
131	25 ° 30' 40.1"	89° 11' 36.1"	Durgamuthi,Gopalpur	Nuada	HL	5.85	1.61	0.093	16.2	0.098	25.1	0.116	1.14	2.27	0.45
132	25 ° 30' 39.5"	89° 11' 35.6"	Durgamuthi,Gopalpur	Nuada	HL	5.95	0.98	0.119	9.9	0.099	28.5	0.101	0.89	1.83	0.46
133	25 ° 30' 39.1"	89° 11' 35.3"	Durgamuthi,Gopalpur	Nuada	HL	5.76	1.31	0.107	14.7	0.109	21.8	0.188	0.96	1.54	0.51
134	25 ° 30' 39.5"	89° 11' 33.1"	Durgamuthi,Gopalpur	Nuada	HL	5.83	1.06	0.104	8.7	0.121	15.1	0.130	1.01	1.48	0.53
135	25 ° 30' 39.7"	89° 11' 32.3"	Durgamuthi,Gopalpur	Nuada	HL	5.75	0.98	0.122	13.5	0.071	26.8	0.232	0.86	1.42	0.49
136	25 ° 30' 39.4"	89° 11' 32.3"	Durgamuthi,Gopalpur	Nuada	HL	5.62	1.23	0.129	14.3	0.114	6.7	0.217	0.92	1.87	0.54
137	25 ° 30' 39.6"	89° 11' 31.9"	Durgamuthi,Gopalpur	Nuada	HL	5.7	1.22	0.112	12.0	0.106	6.7	0.203	1.03	2.49	0.58
138	25 ° 30' 39.2"	89° 11' 31.5"	Durgamuthi,Gopalpur	Nuada	HL	5.82	1.51	0.139	12.5	0.108	11.7	0.232	0.47	1.36	0.62
139	25 ° 30' 39.4"	89° 11' 30.6"	Durgamuthi,Gopalpur	Nuada	HL	5.75	1.63	0.133	25.2	0.115	6.7	0.203	0.58	1.57	0.52
140	25 ° 30' 40.3"	89° 11' 30.9"	Durgamuthi,Gopalpur	Nuada	HL	5.95	1.02	0.101	5.4	0.091	5.3	0.188	0.47	2.11	0.47
141	25 ° 31' 30.7"	89° 09' 58.9"	Baluha, Hamidpur	Belabu	HL	5.72	1.18	0.108	25.0	0.097	20.1	0.174	0.67	0.85	0.48
142	25 ° 31' 24.9"	89° 09' 59.6"	Baluha, Hamidpur	Belabu	HL	5.9	1.31	0.151	10.5	0.107	30.1	0.101	0.49	1.04	0.59
143	25 ° 31' 29.0"	89° 10' 0.2'	Baluha, Hamidpur	Belabu	HL	5.75	1.1	0.109	7.2	0.102	20.1	0.217	0.55	0.86	0.62
144	25 ° 31' 27.6"	89° 10' 0.1'	Baluha, Hamidpur	Belabu	HL	5.86	1.06	0.101	5.9	0.115	31.8	0.159	0.61	1.01	0.66
145	25 ° 31' 25.8"	89° 10' 0.0"	Baluha, Hamidpur	Belabu	HL	6.03	1.06	0.098	7.7	0.083	11.7	0.130	0.54	1.04	0.54
146	25 ° 31' 24.3"	89° 09' 58.7"	Baluha, Hamidpur	Belabu	HL	5.91	1.18	0.13	5.7	0.097	5.0	0.246	0.58	0.97	0.63
147	25 ° 31' 24.5"	89° 09' 56.7"	Baluha, Hamidpur	Belabu	HL	5.65	1.18	0.093	10.6	0.096	18.4	0.087	0.47	1.08	0.64
148	25 ° 31' 24.7"	89° 09' 55.9"	Baluha, Hamidpur	Belabu	HL	5.74	0.66	0.076	5.7	0.065	5.0	0.203	0.62	0.86	0.57
149	25 ° 31' 24.9"	89° 09' 54.8"	Baluha, Hamidpur	Belabu	HL	5.68	0.1	0.09	10.7	0.098	25.1	0.217	0.78	0.76	0.55
150	25 ° 31' 25.1"	89° 09' 53.9"	Baluha, Hamidpur	Belabu	HL	5.47	1.43	0.112	15.6	0.065	8.4	0.290	1.14	0.90	0.32
Hakimpur, Dinajpur															
151	25 ° 18' 58.3"	89° 02' 02.0"	Bhauldar	Amnura	HL	5.76	1.84	0.177	22.3	0.066	13.3	0.129	0.98	0.63	0.45
152	25 ° 18' 57.3″	89° 02' 02.3"	Bhauldar	Amnura	HL	5.58	1.63	0.163	41.4	0.076	16.6	0.142	1.02	0.73	0.46
153	25 ° 18' 55.7″	89° 02' 02.1"	Bhauldar	Amnura	HL	5.63	1.64	0.182	11.2	0.068	21.6	0.099	1.07	0.81	0.57
154	25 ° 18' 54.8"	89° 02' 00.4"	Bhauldar	Amnura	HL	5.58	1.43	0.109	8.0	0.076	13.3	0.085	1.1	1.41	0.51
155	25 ° 18' 52.7"	89° 02' 00.1"	Bhauldar	Amnura	HL	5.8	1.75	0.16	6.9	0.069	18.3	0.171	1.02	1.41	0.49
156	25 ° 18' 52.2"	89° 02' 01.2"	Bhauldar	Amnura	HL	5.78	1.43	0.168	10.3	0.066	26.6	0.114	1.06	0.73	0.47
157	25 ° 18' 51.5"	89° 02' 02.4"	Bhauldar	Amnura	HL	5.62	1.88	0.177	12.1	0.067	18.3	0.099	1.32	0.83	0.46
158	25 ° 18' 52.9"	89° 02' 05.2"	Bhauldar	Amnura	HL	5.65	1.59	0.177	15.1	0.069	13.3	0.071	1.45	0.86	0.53
159	25 ° 18' 54.9"	89° 02′ 05.1"	Bhauldar	Amnura	HL	5.86	1.51	0.144	10.2	0.068	16.6	0.057	1.14	0.87	0.48
160	25 ° 18' 56.7"	89° 02' 05.5"	Bhauldar	Amnura	HL	5.52	1.67	0.179	10.5	0.156	21.6	0.071	2.65	0.83	1.13
161	25 ° 16' 22.9"	89° 03' 10.2"	Hakimpur, Municipulity	Amnura	HL	5.89	1.06	0.139	6.2	0.075	18.3	0.042	2.45	1.38	1.24
162	25 ° 16' 23.9"	89° 03' 11.1"	Hakimpur, Municipulity	Amnura	HL	5.73	0.86	0.095	16.1	0.108	15.0	0.042	2.61	0.96	1.31

Sample No.	GPS		Village/Union	Soil series	Land type	pH	OM (%)	Total N (%)	Avail. P (ppm)	Excha. K (meq/ 100g)	Avail. S (ppm)	Avail. B (ppm)	Avail. Zn (ppm)	Excha. Ca (meq/ 100g)	Excha. Mg (meq/ 100g)
	N	E													
163	25 ° 16' 25.2"	89° 03' 12.2"	Hakimpur, Municipulity	Amnura	HL	5.62	1.35	0.115	7.9	0.106	11.6	0.099	2.41	1.18	1.34
164	25 ° 16' 24.8"	89° 03' 13.9"	Hakimpur, Municipulity	Amnura	HL	5.61	1.14	0.122	4.2	0.062	11.6	0.085	2.33	0.94	1.38
165	25 ° 16' 24.4″	89° 03' 18.3"	Hakimpur, Municipulity	Amnura	HL	5.78	1.84	0.185	4.4	0.145	13.3	0.142	3.14	0.69	1.46
166	25 ° 16' 23.4"	89° 03' 13.9"	Hakimpur, Municipulity	Amnura	HL	5.75	1.83	0.203	11.1	0.133	10.0	0.128	2.44	0.72	1.41
167	25 ° 16' 22.7"	89° 03' 19.6"	Hakimpur, Municipulity	Amnura	HL	5.62	2.08	0.135	12.0	0.114	11.6	0.142	2.56	0.53	1.31
168	25 ° 16' 21.2"	89° 03' 19.2"	Hakimpur, Municipulity	Amnura	HL	5.66	1.1	0.203	11.2	0.108	10.0	0.114	2.77	0.41	1.43
169	25 ° 16' 20.6"	89° 03' 15.2"	Hakimpur, Municipulity	Amnura	HL	5.7	1.47	0.144	11.8	0.07	28.3	0.114	2.51	0.46	1.44
170	25 ° 16' 21.0"	89° 03' 13.0"	Hakimpur, Municipulity	Amnura	HL	5.82	1.35	0.125	15.0	0.07	30.0	0.057	1.76	0.40	1.4
171	25 ° 18' 05.7"	89° 05' 2.0″	Saturia, Alihat	Nuada	HL	5.66	1.41	0.115	13.6	0.1	15.0	0.142	1.87	1.16	1.33
172	25 ° 16' 45.4"	89° 05' 2.0″	Saturia, Alihat	Nuada	HL	5.71	1.7	0.16	39.1	0.077	10.0	0.114	1.93	1.03	1.41
173	25 ° 16' 45.1″	89° 04' 37.2"	Saturia, Alihat	Nuada	HL	5.81	1.82	0.171	17.9	0.076	8.3	0.105	1.47	1.01	1.14
174	25 ° 16' 44.4"	89° 04' 38.1″	Saturia, Alihat	Nuada	HL	5.66	1.86	0.177	35.7	0.072	25.0	0.185	1.85	0.89	1.13
175	25 ° 16' 43.3"	89° 04' 38.3"	Saturia, Alihat	Nuada	HL	5.76	2.1	0.182	35.8	0.074	11.6	0.171	1.81	0.66	0.66
176	25 ° 16' 42.7"	89° 04' 39.0"	Saturia, Alihat	Nuada	HL	5.6	1.73	0.192	32.4	0.086	6.7	0.171	1.96	0.63	0.82
177	25 ° 16' 42.5"	89° 04' 40.8"	Saturia, Alihat	Nuada	HL	5.74	1.94	0.195	38.6	0.077	15.0	0.185	1.33	0.93	0.86
178	25 ° 16' 44.0"	89° 04' 43.1″	Saturia, Alihat	Nuada	HL	5.78	1.8	0.209	25.1	0.06	10.0	0.171	1.66	0.58	0.94
179	25 ° 16' 45.0"	89° 04' 41.6"	Saturia, Alihat	Nuada	HL	5.72	2.06	0.212	33.1	0.062	20.0	0.057	1.47	0.99	0.91
180	25 ° 16' 46.6"	89° 04' 41.4"	Saturia, Alihat	Nuada	HL	5.68	1.82	0.16	37.3	0.109	18.3	0.228	2.39	1.13	0.87

BAU Component

Appendix 4. Soil sample analytical data along with baseline information

Sl. No.	Address	GPS	Soil Series	Land type	Cropping pattern	pH	OM (%)	P (ppm)	T. N (%)	S (ppm)	K (meq)	P (ppm)	Ca (meq)	Mg (meq)	Zn (ppm)	Cu (ppm)	Fe (ppm)	Mn (ppm)
1.	Muktagacha	N. $24^0 46'$.955, E. $90^0 10'$.177	Silmondi	MHL	Boro-mustard-T.amon	4.95	2.44	11.6	0.12	16	0.12	0.39	3.21	0.83	2.93	3.29	202.48	2.77
2.	do	N. $24^0 47'$.261, E. $90^0 12'$.530	Sonatola	HL	Boro-mustard-T.amon	5.1	2.11	17.8	0.12	23	0.09	0.20	3.72	0.72	6.86	1.97	307.94	21.58
3.	do	N. $24^0 47'$.138, E. $90^0 12'$.491	Sonatola	HL	Boro-Fallow-T.amon	5.08	1.78	15.1	0.10	24	0.12	0.98	2.75	0.81	5.57	1.87	343.11	57.04
4.	do	N. $24^0 47'$.285, E. $90^0 12'$.369	Silmondi	HL	Boro-Fallow-T.amon	5.19	1.52	12.4	0.07	16	0.08	0.39	3.77	1.31	7.85	1.69	301.82	35.04
5.	do	N. $24^0 47'$.716, E. $90^0 12'$.185	Silmondi	HL	Boro-Fallow-T.amon	4.89	1.65	12.7	0.11	23	0.13	0.20	2.98	1.03	4.76	2.21	340.21	11.63
6.	do	N. $24^0 47'$.740, E. $90^0 12'$.324	Silmondi	HL	Boro-mustard-T.amon	5.35	1.58	13.1	0.08	24	0.11	0.79	1.74	0.53	7.10	2.63	273.43	7.3
7.	do	N. $24^0 47'$.184, E. $90^0 11'$.086	Sonatola	HL	Boro-Fallow-T.amon	5.03	1.32	15.4	0.07	14	0.11	0.39	2.51	0.61	6.22	1.12	180.18	15.33
8.	do	N. $24^0 47'$.138, E. $90^0 12'$.597	Sonatola	HL	Boro-Fallow-T.amon	4.99	1.58	12.4	0.09	15	0.09	0.59	2.01	0.43	3.75	0.10	130.85	5.18
9.	do	N. $24^0 47'$.282, E. $90^0 12'$.081	Sonatola	HL	Boro-mustard-T.amon	5.05	1.32	15.4	0.07	22	0.10	0.20	3.03	0.74	8.12	2.16	166.54	10.99
10.	do	N. $24^0 47'$.241, E. $90^0 12'$.944	Sonatola	HL	Boro-mustard-T.amon	5.97	1.58	18.9	0.09	24	0.09	0.39	3.02	0.72	3.83	1.08	176.91	12.02
11.	do	N. $24^0 46'$.616, E. $90^0 10'$.617	Silmondi	HL	Boro-mustard-T.amon	4.99	1.71	7.3	0.09	14	0.10	0.59	2.85	0.71	1.92	2.12	307.12	19.76
12.	do	N. $24^0 46'$.699, E. $90^0 10'$.197	Silmondi	MHL	Boro- fallow -T.amon	5.09	1.38	26.6	0.08	24	0.11	0.39	4.31	1.52	5.41	3.04	197.14	39.13
13.	do	N. $24^0 46'$.288, E. $90^0 10'$.076	Silmondi	HL	Boro- fallow -T.amon	4.85	1.98	8.5	0.10	24	0.11	0.20	4.93	1.51	5.44	2.83	221.01	50.7
14.	do	N. $24^0 46'$.477, E. $90^0 10'$.076	Silmondi	HL	Boro- Mustard -T.amon	5.08	1.52	7.7	0.08	20	0.13	0.59	4.7	0.92	3.91	4.11	248.1	85.66
15.	do	N. $24^0 46'$.951, E. $90^0 10'$.297	Silmondi	HL	Boro- fallow -T.amon	5.24	1.91	9.3	0.10	13	0.10	0.39	4.83	1.33	4.16	2.5	162.2	68.22
16.	do	N. $24^0 46'$.740, E. $90^0 10'$.930	Silmondi	HL	Boro- fallow -T.amon	4.91	1.58	9.3	0.08	15	0.13	0.39	4.12	1.34	4.57	3.2	380.91	71.98
17.	do	N. $24^0 46'$.008, E. $90^0 10'$.148	Silmondi	HL	Boro- fallow -T.amon	4.89	1.45	9.7	0.08	12	0.09	0.59	3.65	1.21	5.53	2.94	216.54	85.42
18.	do	N. $24^0 46'$.321, E. $90^0 10'$.185	Silmondi	HL	Boro- Mustard -T.amon	5.35	1.65	10.8	0.09	21	0.12	0.20	3.51	0.93	2.82	1.36	70.43	16.36
19.	do	N. $24^0 46'$.321, E. $90^0 10'$.090	Silmondi	HL	Boro- Mustard -T.amon	5.2	1.78	7.3	0.08	22	0.10	0.39	5.13	1.84	3.04	2.26	130.47	39.45

Sl. No.	Address	GPS	Soil Series	Land type	Cropping pattern	pH	OM (%)	P (ppm)	T. N (%)	S (ppm)	K (meq)	P (ppm)	Ca (meq)	Mg (meq)	Zn (ppm)	Cu (ppm)	Fe (ppm)	Mn (ppm)
20.	do	N. $24^{0}46^{/}.690$, E. $90^{0}10^{/}.180$	Silmondi	HL	Veg-Jute -T.amon	5.31	1.78	13.5	0.10	23	0.11	0.39	3.52	0.61	3.83	1.29	61.75	22.32
21.	do	N. $24^{0}44^{/}.049$, E. $90^{0}12^{/}.162$	Silmondi	HL	Boro- fallow -T.amon	5.26	1.78	17.4	0.08	15	0.10	0.59	5.84	1.81	4.12	1.85	98.72	36.12
22.	do	N. $24^{0}44^{/}.772$, E. $90^{0}12^{/}.357$	Sonatola	MHL	Boro-mustard-T.amon	5.6	2.37	11.6	0.12	23	0.20	0.20	6.27	2.73	2.52	4.57	246.8	102
23.	do	N. $24^{0}44^{/}.720$, E. $90^{0}12^{/}.341$	Silmondi	HL	Boro-mustard-T.amon	5.5	2.00	12.0	0.11	23	0.10	0.39	7.41	2.63	3.32	2.56	114.27	22.78
24.	do	N. $24^{0}44^{/}.005$, E. $90^{0}12^{/}.949$	Silmondi	HL	Boro-Fallow-T.amon	5.08	1.66	12.4	0.08	15	0.17	0.20	6.2	2.65	4.67	6.24	283.06	42.03
25.	do	N. $24^{0}44^{/}.009$, E. $90^{0}12^{/}.289$	Silmondi	HL	Boro-Fallow-T.amon	5.28	2.33	11.2	0.12	9	0.13	0.39	4.91	1.53	1.37	1.63	103.58	17.61
26.	do	N. $24^{0}44^{/}.251$, E. $90^{0}12^{/}.945$	Silmondi	HL	Boro-Fallow-T.amon	5.35	1.73	9.7	0.11	24	0.09	0.20	6.23	2.21	1.72	2.06	112.6	23.12
27.	do	N. $24^{0}44^{/}.054$, E. $90^{0}12^{/}.557$	Silmondi	HL	Boro-mustard-T.amon	5.43	1.46	10.0	0.07	22	0.11	0.59	4.12	1.31	1.77	1.08	81.53	12.57
28.	do	N. $24^{0}44^{/}.565$, E. $90^{0}12^{/}.750$	Silmondi	HL	Boro-Fallow-T.amon	5.15	2.06	11.2	0.10	15	0.13	0.39	3.72	0.93	3.41	1.19	140.87	25.89
29.	do	N. $24^{0}44^{/}.003$, E. $90^{0}12^{/}.965$	Silmondi	HL	Boro-Fallow-T.amon	5.44	1.66	14.3	0.09	23	0.12	0.20	2.43	0.64	4.09	2.07	143.25	23.46
30.	do	N. $24^{0}44^{/}.328$, E. $90^{0}12^{/}.228$	Silmondi	HL	Boro-mustard-T.amon	5.18	1.73	17.0	0.10	23	0.11	0.20	1.81	0.62	4.23	1.75	160.41	29.32
31.	Mym.Sadar	N. $24^{0}39^{/}.860$, E. $90^{0}27^{/}.823$	Sonatola	HL	Boro-Mustard-T.amon	5.87	2.06	12.74	0.08	10.82	0.13	0.24	5.73	1.35	3.64	4	145.97	30.46
32.	do	N. $24^{0}39^{/}.868$, E. $90^{0}27^{/}.213$	Sonatola	MHL	Boro-fallow-T.amon	5.88	2.00	11.58	0.11	12.31	0.11	0.47	12.64	1.83	3.38	3.69	185.26	77.01
33.	do	N. $24^{0}39^{/}.548$, E. $90^{0}27^{/}.546$	Sonatola	MHL	Boro-Mustard-T.amon	5.7	1.86	11.20	0.09	10.82	0.12	0.24	14.35	1.42	2.01	1.55	106.18	18.72
34.	do	N. $24^{0}39^{/}.738$, E. $90^{0}27^{/}.621$	Sonatola	MHL	Boro-fallow-T.amon	5.67	1.93	12.74	0.10	33.96	0.13	0.24	13.08	1.61	2.82	2.74	127.72	36.25
35.	do	N. $24^{0}39^{/}.153$, E. $90^{0}27^{/}.003$	Sonatola	MHL	Boro-fallow-T.amon	5.88	1.93	10.81	0.11	30.97	0.10	0.47	12.98	1.24	3.70	2.24	105.05	24.98
36.	do	N. $24^{0}39^{/}.628$, E. $90^{0}27^{/}.201$	Sonatola	MHL	Boro-mustard-T.amon	5.95	1.66	8.49	0.08	16.04	0.09	0.24	12.22	1.31	5.54	1.67	223.22	36.67
37.	do	N. $24^{0}39^{/}.514$, E. $90^{0}27^{/}.921$	Sonatola	MHL	Boro-mustard-T.amon	6.02	1.33	17.37	0.08	9.33	0.09	0.71	3.11	1.49	2.23	1.94	161.24	43.51
38.	do	N. $24^{0}39^{/}.836$, E. $90^{0}27^{/}.017$	Sonatola	MHL	Boro-fallow-T.amon	5.63	1.66	11.58	0.09	20.52	0.14	0.47	2.51	0.91	4.07	4.2	197.55	13.81
39.	do	N. $24^{0}39^{/}.057$, E. $90^{0}27^{/}.094$	Sonatola	MHL	Boro-fallow-T.amon	5.56	2.06	12.36	0.11	13.81	0.13	0.24	3.55	1.24	7.36	4.94	231.28	23.59
40.	do	N. $24^{0}39^{/}.570$, E. $90^{0}27^{/}.108$	Sonatola	MHL	Boro-fallow-T.amon	5.64	1.33	11.20	0.07	11.57	0.12	0.47	3.42	1.39	3.54	3.3	196.65	57.24

Sl. No.	Address	GPS	Soil Series	Land type	Cropping pattern	pH	OM (%)	P (ppm)	T. N (%)	S (ppm)	K (meq)	P (ppm)	Ca (meq)	Mg (meq)	Zn (ppm)	Cu (ppm)	Fe (ppm)	Mn (ppm)
41.	do	N. $24^{0}40^{/}.055$, E. $90^{0}26^{/}.089$	Silmondi	MHL	Boro-Aus -T.amon	6.08	1.53	14.29	0.08	36.19	0.09	0.71	8.07	3.81	3.50	4.45	123	20.99
42.	do	N. $24^{0}40^{/}.373$, E. $90^{0}26^{/}.459$	Silmondi	MHL	Boro-fallow-T.amon	5.67	1.80	13.51	0.10	11.73	0.11	0.24	5.54	2.88	4.46	6.71	254.76	70.87
43.	do	N. $24^{0}40^{/}.693$, E. $90^{0}26^{/}.567$	Silmondi	MHL	Boro-Mustard-T.amon	5.9	1.60	12.36	0.07	36.94	0.11	0.94	8.17	4.01	2.43	3.59	115.5	25.32
44.	do	N. $24^{0}40^{/}.945$, E. $90^{0}26^{/}.851$	Silmondi	MHL	Boro-fallow-T.amon	5.85	1.66	11.97	0.08	22.76	0.11	0.24	6.6	3.12	2.06	5.3	182.47	45.49
45.	do	N. $24^{0}40^{/}.554$, E. $90^{0}26^{/}.777$	Silmondi	MHL	Boro-fallow-T.amon	6.33	1.40	18.15	0.07	14.55	0.10	0.47	7.61	3.68	2.75	4.72	153.62	40.19
46.	do	N. $24^{0}40^{/}.489$, E. $90^{0}26^{/}.920$	Silmondi	MHL	Boro-fallow-T.amon	5.84	2.00	13.90	0.10	16.79	0.10	0.47	7.24	3.01	3.46	5.87	338.84	54.14
47.	do	N. $24^{0}40^{/}.471$, E. $90^{0}26^{/}.560$	Silmondi	MHL	Boro-fallow-T.amon	6.03	1.80	15.83	0.08	15.30	0.14	0.24	6.51	3.07	2.17	4.54	166.7	37.69
48.	do	N. $24^{0}40^{/}.061$, E. $90^{0}26^{/}.439$	Silmondi	MHL	Boro-fallow-T.amon	5.83	2.13	12.36	0.11	18.28	0.14	0.47	7.29	3.38	1.82	4.4	151.09	48.3
49.	do	N. $24^{0}40^{/}.914$, E. $90^{0}26^{/}.641$	Silmondi	MHL	Boro-fallow-T.amon	6.16	1.66	10.04	0.08	38.43	0.13	0.24	7.27	3.16	1.48	3.92	129.61	28.45
50.	do	N. $24^{0}40^{/}.623$, E. $90^{0}26^{/}.842$	Silmondi	MHL	Boro-fallow-T.amon	6.11	1.80	9.27	0.09	24.25	0.16	0.47	8.18	3.75	2.04	3.82	119.71	22.72
51.	do	N. $24^{0}40^{/}.224$, E. $90^{0}27^{/}.516$	Sonatola	MHL	Boro-Mustard-T.amon	5.78	1.66	12.74	0.08	13.06	0.10	0.24	4.77	2.04	3.01	5.56	196.3	35.42
52.	do	N. $24^{0}40^{/}.400$, E. $90^{0}27^{/}.271$	Sonatola	MHL	Boro-fallow-T.amon	5.73	1.86	11.20	0.10	24.25	0.13	0.47	6.36	2.92	1.05	5.2	191.82	63.07
53.	do	N. $24^{0}40^{/}.759$, E. $90^{0}27^{/}.765$	Sonatola	MHL	Boro-Mustard-T.amon	5.72	1.60	8.49	0.08	19.03	0.12	0.47	7.45	3.01	2.15	2.77	135.57	21.58
54.	do	N. $24^{0}40^{/}.897$, E. $90^{0}27^{/}.668$	Sonatola	MHL	Boro-Aus-T.amon	5.79	2.13	10.04	0.11	9.33	0.11	0.71	6.28	2.39	3.51	6.15	192.59	22.69
55.	do	N. $24^{0}40^{/}.703$, E. $90^{0}27^{/}.126$	Sonatola	MHL	Boro-fallow-T.amon	5.93	1.86	11.20	0.10	27.24	0.13	0.24	6.93	2.71	1.61	4.89	200.37	20.74
56.	do	N. $24^{0}40^{/}.787$, E. $90^{0}27^{/}.658$	Sonatola	MHL	Boro-mustard-T.amon	6.03	2.00	12.36	0.10	31.72	0.11	0.71	7.57	3.12	1.97	3.25	100.98	21.05
57.	do	N. $24^{0}40^{/}.065$, E. $90^{0}27^{/}.901$	Sonatola	MHL	Boro-mustard-T.amon	5.9	2.33	16.22	0.12	25.75	0.13	0.47	7.65	3.24	2.15	4.68	216.97	26.88
58.	do	N. $24^{0}40^{/}.290$, E. $90^{0}27^{/}.227$	Sonatola	MHL	Boro-fallow-T.amon	5.87	1.66	11.58	0.09	26.49	0.10	0.94	4.97	2.52	1.8	4.65	171.17	28.76
59.	do	N. $24^{0}40^{/}.027$, E. $90^{0}27^{/}.744$	Sonatola	MHL	Boro-fallow-T.amon	5.81	1.86	12.74	0.10	30.22	0.12	0.24	6.81	3.13	1.83	4.5	146.86	13.35
60.	do	N. $24^{0}40^{/}.908$, E. $90^{0}27^{/}.639$	Sonatola	MHL	Boro-Aus-T.amon	5.78	2.13	11.58	0.11	32.46	0.13	0.47	5.37	3.09	1.37	3.03	106.72	41.41
61.	Tetulia	N. $26^{0}28^{/}.729$. E. $88^{0}30^{/}.705$	Baliadangi	HL	Potato-Veg.-T.amon	5.14	1.86	12.96	0.10	16.71	0.14	0.24	6.43	0.8	0.77	0.73	27.76	2.23

Sl. No.	Address	GPS	Soil Series	Land type	Cropping pattern	pH	OM (%)	P (ppm)	T. N (%)	S (ppm)	K (meq)	P (ppm)	Ca (meq)	Mg (meq)	Zn (ppm)	Cu (ppm)	Fe (ppm)	Mn (ppm)
62.	do	N. $26^{0}28^{/}$.364, E. $88^{0}30^{/}$.297	Atoary	HL	Wheat-jute-T.amon	5.09	1.46	25.10	0.07	15.39	0.13	0.24	4.77	0.92	1.81	0.76	35.99	2.42
63.	do	N. $26^{0}28^{/}$.437, E. $88^{0}30^{/}$.533	Atoary	HL	Wheat-jute-T.amon	4.95	2.13	8.91	0.11	17.37	0.15	0.47	4.96	0.74	0.24	1.6	69.35	3.5
64.	do	N. $26^{0}28^{/}$.477, E. $88^{0}30^{/}$.546	Atoary	HL	Wheat-fallow-T.amon	4.57	2.26	21.05	0.12	19.34	0.15	0.47	0.81	0.7	2.29	0.87	33.19	3.06
65.	do	N. $26^{0}28^{/}$.439. E. $88^{0}30^{/}$.546	Atoary	HL	Wheat-fallow-T.amon	4.38	1.80	12.96	0.10	18.03	0.12	0.71	7.56	0.31	2.63	0.9	31.26	12.1
66.	do	N. $26^{0}28^{/}$.496, E. $88^{0}30^{/}$.524	Atoary	HL	Chilli-fallow-T.amon	4.94	2.13	17.00	0.12	19.34	0.15	0.24	5.37	0.56	5.71	1.35	36.64	9.17
67.	do	N. $26^{0}28^{/}$.946, E. $88^{0}30^{/}$.018	Baliadangi	HL	Wheat-fallow-T.amon	4.91	2.46	21.05	0.13	18.68	0.10	0.24	5.03	0.62	1.69	1.12	32.19	5.09
68.	do	N. $26^{0}28^{/}$.538, E. $88^{0}30^{/}$.466	Baliadangi	HL	Wheat-fallow-T.amon	5.09	1.93	17.00	0.10	20.66	0.11	0.71	4.28	0.57	2.17	0.71	37.97	1.72
69.	do	N. $26^{0}28^{/}$.459, E. $88^{0}30^{/}$.893	Baliadangi	HL	Wheat-fallow-T.amon	4.56	1.46	17.00	0.07	15.39	0.13	0.47	4.48	0.69	1.83	0.97	25.13	3.63
70.	do	N. $26^{0}28^{/}$.598. E. $88^{0}30^{/}$.489	Baliadangi	HL	Wheat-fallow-T.amon	4.78	2.46	8.91	0.12	16.71	0.12	0.24	0.27	0.53	3.66	0.81	39.23	2.55
71.	do	N. $26^{0}28^{/}$.468, E. $88^{0}30^{/}$.341	Atoary	HL	Jute-fallow-T.amon	4.85	1.66	21.05	0.08	16.05	0.11	0.47	3.67	0.19	1.93	0.59	23.85	1.6
72.	do	N. $26^{0}28^{/}$.363, E. $88^{0}30^{/}$.343	Pirgacha	HL	Jute-fallow-T.amon	4.89	2.06	29.15	0.11	14.74	0.10	0.28	3.67	0.66	2.9	0.86	38.58	1.63
73.	do	N. $26^{0}28^{/}$.495, E. $88^{0}30^{/}$.288	Atoary	HL	Jute-fallow-T.amon	4.96	1.93	8.91	0.11	16.05	0.11	0.08	3.11	0.42	2.86	1.04	40.89	1.66
74.	do	N. $26^{0}28^{/}$.568, E. $88^{0}30^{/}$.169	Atoary	HL	Wheat-fallow-T.amon	4.94	1.40	21.05	0.07	15.39	0.12	0.48	0.52	0.55	1.29	0.82	24.13	1.34
75.	do	N. $26^{0}28^{/}$.514, E. $88^{0}30^{/}$.289	Atoary	HL	Jute-fallow-T.amon	4.69	2.40	25.10	0.12	15.39	0.13	0.67	3.44	0.002	0.89	0.79	20.44	1.21
76.	do	N. $26^{0}28^{/}$.758, E. $88^{0}30^{/}$.277	Atoary	HL	Til-fallow-T.amon	4.72	2.13	17.00	0.12	16.71	0.12	0.28	5.24	0.5	0.71	1.15	28.9	1.79
77.	do	N. $26^{0}28^{/}$.318, E. $88^{0}30^{/}$.156	Pirgacha	HL	Til-fallow-T.amon	4.91	1.93	25.10	0.11	18.03	0.10	0.48	0.86	0.52	1.09	0.92	21.58	1.53
78.	do	N. $26^{0}28^{/}$.328, E. $88^{0}30^{/}$.433	Pirgacha	HL	Til-fallow-T.amon	5.02	1.46	29.15	0.07	16.71	0.10	0.28	2.93	0.34	1	0.95	24.7	2.55
79.	do	N. $26^{0}28^{/}$.633, E. $88^{0}30^{/}$.154	Atoary	HL	Til-fallow-T.amon	4.63	1.93	25.10	0.11	15.39	0.12	0.48	4.14	0.44	1.42	0.85	25.49	1.85
80.	do	N. $26^{0}28^{/}$.403, E. $88^{0}30^{/}$.229	Atoary	HL	Til-fallow-T.amon	4.45	2.00	21.05	0.10	14.74	0.13	0.28	3.16	0.66	0.17	0.75	23.14	2.1
81.	do	N. $26^{0}28^{/}$.327, E. $88^{0}30^{/}$.676	Baliadangi	HL	Chilli-fallow-T.amon	4.6	1.60	8.91	0.09	16.05	0.13	0.48	0.87	0.7	5.23	0.89	34.77	2.3
82.	do	N. $26^{0}28^{/}$.714, E. $88^{0}30^{/}$.680	Baliadangi	HL	Wheat-fallow-T.amon	5.05	2.26	21.05	0.11	15.39	0.12	0.48	4.3	0.57	2.6	0.77	30.69	2.61

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83.	do	N. $26^0 28'.673$, E. $88^0 30'.018$	Baliadangi	HL	Wheat-fallow-T.amon	5.08	1.73	12.96	0.10	16.71	0.09	0.28	2.57	0.49	2.54	0.53	21.08	0.77
84.	do	N. $26^0 28'.172$, E. $88^0 30'.948$	Baliadangi	HL	Wheat-fallow-T.amon	5.24	2.20	17.00	0.12	18.03	0.10	0.48	3.16	0.66	5.18	0.72	23.28	3.57
85.	do	N. $26^0 28'.172$, E. $88^0 30'.707$	Baliadangi	HL	Potato-fallow-T.amon	4.94	1.73	12.96	0.10	19.34	0.11	0.67	5.1	0.58	2.92	0.67	21.09	6.85
86.	do	N. $26^0 28'.373$, E. $88^0 30'.717$	Baliadangi	HL	Maize-fallow-T.amon	4.9	1.66	25.10	0.09	18.03	0.12	0.08	1.44	0.72	4.41	0.93	24.27	4.52
87.	do	N. $26^0 28'.735$, E. $88^0 30'.471$	Baliadangi	HL	Wheat-fallow-T.amon	5.13	2.40	17.00	0.12	16.05	0.15	0.48	1.96	0.63	4.05	0.78	28.19	4.39
88.	do	N. $26^0 28'.373$, E. $88^0 30'.178$	Baliadangi	HL	Wheat-fallow-T.amon	5.23	1.60	21.05	0.09	18.03	0.09	0.67	1.35	0.71	2.92	0.6	19.38	1.85
89.	do	N. $26^0 28'.237$, E. $88^0 30'.477$	Baliadangi	HL	Wheat-fallow-T.amon	4.98	2.40	17.00	0.13	16.71	0.16	0.28	0.75	0.58	3.52	0.55	28.04	4.14
90.	do	N. $26^0 28'.932$, E. $88^0 30'.756$	Baliadangi	HL	Groundnut-fal-T.amon	5.14	1.86	12.96	0.10	16.71	0.14	0.24	6.43	0.5	0.77	0.73	27.76	2.23
91.	P,Sadar	N. $26^0 28'.806$, E. $88^0 31'.071$	Vojonpur	HL	Chilli-T.amon-g.nut	5.1	2.20	12.55	0.11	10.13	0.13	0.28	1.21	0.54	3.51	1.59	28.54	2.99
92.	do	N. $26^0 28'.824$, E. $88^0 31'.189$	Vojonpur	HL	Chilli-T.amonmugbean	5.24	2.13	8.37	0.11	11.45	0.13	0.48	1.2	0.54	0.26	0.8	30.54	1.47
93.	do	N. $26^0 28'.749$, E. $88^0 31'.288$	Vojonpur	HL	Chilli-T.amon-maize	4.83	2.40	16.74	0.12	10.13	0.14	0.48	0.56	0.54	0.18	1.11	29.26	2.1
94.	do	N. $26^0 28'.449$, E. $88^0 31'.024$	Ruhia	HL	Chilli-T.amon-til	5.23	2.20	12.55	0.12	13.42	0.13	0.10	0.71	0.46	0.26	0.68	24.27	1.53
95.	do	N. $26^0 28'.839$, E. $88^0 31'.016$	Vojonpur	HL	Wheat-T.amon-g.nut	4.48	2.46	20.92	0.13	10.13	0.09	0.48	0.67	0.5	0.18	0.84	24.63	2.04
96.	do	N. $26^0 28'.696$, E. $88^0 31'.029$	Vojonpur	HL	Potato -T.amon-g.nut	4.96	2.00	16.74	0.10	8.82	0.13	0.48	0.65	0.54	0.27	0.72	22.78	2.99
97.	do	N. $26^0 28'.068$, E. $88^0 31'.037$	Ruhia	HL	Onion -T.amon-g.nut	4.86	1.73	12.55	0.10	11.45	0.13	0.28	0.91	0.12	0.13	0.81	23.56	1.85
98.	do	N. $26^0 28'.651$, E. $88^0 31'.040$	Vojonpur	HL	Chilli-T.amon-mustard	4.6	2.33	8.37	0.13	8.16	0.15	0.48	0.75	0.5	0.15	0.8	25.34	1.4
99.	do	N. $26^0 28'.661$, E. $88^0 31'.412$	Vojonpur	HL	Chilli-T.amon-til	5.25	1.46	16.74	0.08	12.76	0.10	0.67	0.81	0.5	0.1	0.88	25.77	1.47
100.	do	N. $26^0 28'.615$, E. $88^0 31'.441$	Vojonpur	HL	Maize -T.amon-til	5.18	1.93	12.55	0.11	11.45	0.12	0.28	0.61	0.5	0.12	0.6	22.14	1.34
101.	do	N. $26^0 28'.663$, E. $88^0 31'.790$	Menanogor	MHL	wheat-jute-T.amon	4.7	2.20	8.37	0.12	10.79	0.15	0.48	1.51	0.54	0.23	1.14	40.97	2.42
102.	do	N. $26^0 28'.686$, E. $88^0 31'.810$	Atoary	MHL	wheat-jute-T.amon	5.11	2.33	12.55	0.12	10.13	0.12	0.28	0.96	0.5	0.36	1.13	33.69	2.55
103.	do	N. $26^0 28'.682$, E. $88^0 31'.869$	Atoary	MHL	Chill – fallow- T.amon	4.61	1.60	8.37	0.08	12.76	0.14	0.48	1.04	0.54	0.28	0.87	31.26	1.15

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104.	do	N. $26^0 28^/.584$, E. $88^0 31^/.913$	Ruhia	MHL	Maize- fallow -T.amon	5.13	2.33	16.74	0.13	9.47	0.13	0.67	0.63	0.13	0.17	0.9	26.48	2.23
105.	do	N. $26^0 28^/.533$, E. $88^0 31^/.952$	Ruhia	MHL	Chill – fallow- T.amon	5.2	2.06	8.37	0.11	12.11	0.11	0.48	0.75	0.14	0.19	1.19	29.54	0.83
106.	do	N. $26^0 28^/.837$, E. $88^0 31^/.650$	Ruhia	MHL	Chill – fallow- T.amon	5.1	1.60	12.55	0.08	10.13	0.10	0.28	1.12	0.19	2.41	0.76	28.97	1.91
107.	do	N. $26^0 28^/.809$, E. $88^0 32^/.229$	Ruhia	MHL	Maize- fallow -T.amon	4.95	2.13	25.10	0.11	14.08	0.11	0.67	0.85	0.19	0.13	0.86	27.26	1.53
108.	do	N. $26^0 28^/.096$, E. $88^0 32^/.087$	Ruhia	MHL	Maize- fallow -T.amon	4.94	1.86	16.74	0.10	11.45	0.10	0.48	0.85	0.15	0.22	0.88	34.63	1.72
109.	do	N. $26^0 28^/.855$, E. $88^0 31^/.149$	Ruhia	MHL	Chill – fallow- T.amon	5.21	1.80	8.37	0.10	15.39	0.12	0.08	1.45	0.23	0.21	1.66	81.5	4.44
110.	do	N. $26^0 28^/.037$, E. $88^0 31^/.902$	Ruhia	MHL	Chill – fallow- T.amon	5.33	2.26	12.55	0.11	12.11	0.10	0.48	0.29	0.08	0.29	0.36	19.81	0.89
111.	do	N. $26^0 27^/.748$, E. $88^0 32^/.954$	Atoary	MHL	g. nut-jute-T.amon	5.2	1.80	20.92	0.10	16.05	0.12	0.48	0.29	0.17	0.13	0.81	30.76	2.49
112.	do	N. $26^0 27^/.248$, E. $88^0 32^/.207$	Ranisonkail	MHL	wheat-fallow-T.amon	4.54	1.26	16.74	0.06	13.42	0.14	0.28	1.03	0.17	0.14	1.1	35.56	1.98
113.	do	N. $26^0 27^/.126$, E. $88^0 32^/.259$	Ranisonkail	MHL	wheat-fallow-T.amon	4.55	2.00	20.92	0.11	12.11	0.13	0.67	0.66	0.1	0.21	1.17	44.88	6.1
114.	do	N. $26^0 27^/.822$, E. $88^0 32^/.748$	Atoary	MHL	wheat-fallow-T.amon	4.96	1.93	8.37	0.11	11.45	0.12	0.48	1.05	0.19	0.16	0.98	28.54	1.59
115.	do	N. $26^0 27^/.821$, E. $88^0 32^/.144$	Atoary	MHL	wheat-fallow-T.amon	5.08	1.46	12.55	0.07	14.08	0.12	0.67	1.43	0.29	0.34	1.19	34.99	3.69
116.	do	N. $26^0 27^/.368$, E. $88^0 32^/.666$	Ranisonkail	MHL	wheat-fallow-T.amon	4.85	2.46	8.37	0.12	12.76	0.14	0.48	0.65	0.09	0.25	0.9	33.26	3.37
117.	do	N. $26^0 27^/.326$, E. $88^0 32^/.832$	Ranisonkail	MHL	Jute-T.amon-fallow	4.96	1.33	20.92	0.08	14.74	0.12	0.67	0.35	0.07	0.11	0.55	29.54	1.15
118.	do	N. $26^0 27^/.140$, E. $88^0 33^/.588$	Ranisonkail	MHL	g. nut-jute-T.amon	5.39	1.80	16.74	0.10	13.42	0.14	0.28	1.05	0.13	0.26	0.95	31.62	2.93
119.	do	N. $26^0 27^/.681$, E. $88^0 33^/.573$	Atoary	MHL	Potato- jute-T.amon	4.32	2.00	20.92	0.11	11.45	0.12	0.28	0.65	0.1	0.21	0.68	31.26	1.66
120.	do	N. $26^0 27^/.482$, E. $88^0 33^/.345$	Ranisonkail	MHL	Potato-jute-T.amon	4.8	2.13	16.74	0.11	12.11	0.12	0.48	0.72	0.11	0.12	0.76	37.43	1.63
121.	Taragonj	N. $25^0 48^/.430$, E. $89^0 05^/.139$	Kaunia	MHL	Boro-Mustard-T.amon	5.1	2.46	14.88	0.12	6.84	0.13	0.36	1.16	0.27	0.1	1.25	69.95	3.44
122.	do	N. $25^0 48^/.540$, E. $89^0 05^/.669$	Kaunia	MHL	Boro-fallow-T.amon	5.02	1.26	39.67	0.07	12.52	0.10	0.71	0.42	0.07	0.11	0.43	22.93	0.89
123.	do	N. $25^0 41^/.410$, E. $89^0 04^/.697$	Kaunia	MHL	Boro-Mustard-T.amon	5.29	1.13	31.40	0.06	11.64	0.11	0.36	1.16	0.13	0.12	1.11	104.85	4.22
124.	do	N. $25^0 48^/.079$, E. $89^0 04^/.501$	Kaunia	MHL	Boro-fallow-T.amon	4.86	2.00	23.14	0.11	10.75	0.14	0.36	0.86	0.41	0.24	1.4	182.25	9.43

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125.	do	N. $25^{0}48^{/}.852$, E. $89^{0}05^{/}.792$	Kaunia	MHL	Boro-fallow-T.amon	4.92	2.13	39.67	0.11	10.75	0.21	0.71	1.51	0.3	0.35	1.34	192.98	4.34
126.	do	N. $25^{0}48^{/}.343$, E. $89^{0}04^{/}.753$	Kaunia	MHL	Boro-fallow-T.amon	5	1.33	23.14	0.08	11.19	0.16	0.36	1.51	0.67	0.38	1.19	123	1.53
127.	do	N. $25^{0}48^{/}.414$, E. $89^{0}04^{/}.311$	Kaunia	MHL	Boro-fallow-T.amon	4.93	1.20	10.74	0.07	16.06	0.13	0.71	1.5	0.38	0.41	0.99	107.77	2.5
128.	do	N. $25^{0}48^{/}.197$, E. $89^{0}05^{/}.319$	Kaunia	MHL	Boro-fallow-T.amon	5.17	2.00	14.88	0.10	10.31	0.12	0.36	1.32	0.26	0.19	1.02	112.77	2.01
129.	do	N. $25^{0}48^{/}.607$, E. $89^{0}05^{/}.874$	Kaunia	MHL	Boro-fallow-T.amon	5.01	2.00	10.74	0.11	11.19	0.16	0.36	1.05	0.2	0.26	1.12	124.04	2.06
130.	do	N. $25^{0}48^{/}.262$, E. $89^{0}05^{/}.864$	Kaunia	MHL	Boro-fallow-T.amon	4.99	2.13	19.01	0.11	12.96	0.18	0.71	0.16	0.16	0.24	1.07	165.2	2.22
131.	do	N. $25^{0}48^{/}.923$, E. $89^{0}04^{/}.075$	Polashbari	MHL	Boro-fallow-T.amon	5.01	1.60	23.14	0.08	14.73	0.21	0.36	0.63	0.21	0.27	0.9	104.57	2.34
132.	do	N. $25^{0}48^{/}.037$, E. $89^{0}04^{/}.139$	Jamun	MHL	Boro-fallow-T.amon	5.21	2.13	19.01	0.12	12.52	0.14	0.71	0.71	0.3	0.36	1.07	102.59	2.99
133.	do	N. $25^{0}48^{/}.638$, E. $89^{0}04^{/}.725$	Polashbari	MHL	Boro-fallow-T.amon	4.97	1.33	23.14	0.07	14.73	0.15	0.36	0.75	0.14	0.22	1.05	93.11	1.29
134.	do	N. $25^{0}48^{/}.041$, E. $89^{0}04^{/}.664$	Jamun	MHL	Boro-fallow-T.amon	5.35	1.33	27.27	0.08	10.75	0.12	0.36	1.12	0.08	0.14	1.14	117.4	0.72
135.	do	N. $25^{0}48^{/}.930$, E. $89^{0}04^{/}.922$	Polashbari	MHL	Boro-fallow-T.amon	5.1	2.06	14.88	0.11	11.19	0.13	0.71	1.1	0.21	0.28	1.32	122.14	1.08
136.	do	N. $25^{0}48^{/}.942$, E. $89^{0}04^{/}.227$	Polashbari	MHL	Boro-fallow-T.amon	4.61	1.86	35.54	0.10	9.87	0.14	0.36	1.1	0.17	0.11	1.39	128.6	0.84
137.	do	N. $25^{0}48^{/}.009$, E. $89^{0}04^{/}.582$	Jamun	MHL	Boro-fallow-T.amon	5.24	1.33	14.88	0.08	13.41	0.12	0.71	1.05	0.13	0.2	1.79	91.99	2.54
138.	do	N. $25^{0}48^{/}.547$, E. $89^{0}04^{/}.117$	Polashbari	MHL	Boro-fallow-T.amon	4.97	1.80	19.01	0.09	19.16	0.11	0.36	0.65	0.29	0.12	1.67	79.1	1.33
139.	do	N. $25^{0}48^{/}.702$, E. $89^{0}04^{/}.188$	Polashbari	MHL	Boro-fallow-T.amon	5	1.86	10.74	0.10	11.64	0.13	0.36	1.51	0.29	0.14	1.42	42.4	2.66
140.	do	N. $25^{0}48^{/}.159$, E. $89^{0}04^{/}.644$	Jamun	MHL	Boro-fallow-T.amon	5.1	1.53	19.01	0.08	11.64	0.13	0.71	1.21	0.17	0.24	1.49	137.27	1.77
141.	do	N. $25^{0}48^{/}.398$, E. $89^{0}05^{/}.376$	Polashbari	MHL	Boro-fallow-T.amon	5.14	2.33	23.14	0.12	14.73	0.13	0.36	1.85	0.21	0.37	1.02	96.11	2.75
142.	do	N. $25^{0}48^{/}.256$, E. $89^{0}04^{/}.989$	Sonatola	MHL	Boro-fallow-T.amon	5.39	1.86	23.14	0.10	28.45	0.13	0.36	1.91	0.33	0.07	0.71	86.38	1.04
143.	do	N. $25^{0}48^{/}.354$, E. $89^{0}04^{/}.059$	Kaunia	MHL	Boro-mustard-T.amon	5.21	2.00	19.01	0.10	13.85	0.17	0.71	0.95	0.21	1.42	1.43	82.84	3.4
144.	do	N. $25^{0}48^{/}.463$, E. $89^{0}04^{/}.846$	Polashbari	MHL	Boro-fallow-T.amon	4.77	2.40	27.27	0.12	14.73	0.13	0.36	0.95	0.21	2.17	1.71	124.02	1.16
145.	do	N. $25^{0}48^{/}.280$, E. $89^{0}04^{/}.725$	Polashbari	MHL	Boro-fallow-T.amon	5.13	1.86	19.01	0.08	17.83	0.11	0.36	2.4	0.21	0.18	1.15	109.28	2.34

Sl. No.	Address	GPS	Soil Series	Land type	Cropping pattern	pH	OM (%)	P (ppm)	T. N (%)	S (ppm)	K (meq)	P (ppm)	Ca (meq)	Mg (meq)	Zn (ppm)	Cu (ppm)	Fe (ppm)	Mn (ppm)
146.	do	N. 25^{0}48$^{/}$.476, E. 89^{0}04$^{/}$.220	Kaunia	MHL	Boro-fallow-T.amon	5.26	2.46	23.14	0.12	16.95	0.12	0.36	1.6	0.29	2.94	1.59	139.94	1.89
147.	do	N. 25^{0}48$^{/}$.578, E. 89^{0}04$^{/}$.339	Kaunia	MHL	Boro-fallow-T.amon	5.44	2.13	39.67	0.12	15.62	0.13	0.71	1.15	0.12	0.34	1.41	116.46	1.45
148.	do	N. 25^{0}48$^{/}$.437, E. 89^{0}04$^{/}$.120	Kaunia	MHL	Boro-mustard-T.amon	5.01	2.13	27.27	0.11	17.83	0.12	0.71	1.41	0.3	5.15	2.28	139.94	3.36
149.	do	N. 25^{0}48$^{/}$.567, E. 89^{0}04$^{/}$.635	Polashbari	MHL	Boro-fallow-T.amon	5.12	1.66	39.67	0.09	16.06	0.12	0.36	1.21	0.25	0.2	1.08	116.46	2.06
150.	do	N. 25^{0}48$^{/}$.419, E. 89^{0}04$^{/}$.576	Polashbari	MHL	Boro-fallow-T.amon	5.16	1.40	23.14	0.07	15.18	0.14	0.71	1.6	0.28	3.64	1.09	198.07	1.49
151.	R. Sadar	N. 25^{0}48$^{/}$.629, E. 89^{0}08$^{/}$.648	Pirgacha	MHL	Maize-fallow-T.amon	4.83	2.00	14.34	0.11	20.62	0.12	0.40	1.64	0.25	0.19	1.29	80.68	1.57
152.	do	N. 25^{0}48$^{/}$.417, E. 89^{0}08$^{/}$.536	Pirgacha	MHL	Boro-fallow-T.amon	4.99	2.00	18.33	0.10	15.00	0.13	0.15	1.79	0.3	1.17	1.46	102.31	1.65
153.	do	N. 25^{0}48$^{/}$.216, E. 89^{0}08$^{/}$.389	Pirgacha	MHL	Maize-fallow-T.amon	4.75	1.46	14.34	0.08	17.25	0.13	0.40	1.85	0.38	0.34	1.56	149.51	2.66
154.	do	N. 25^{0}48$^{/}$.041, E. 89^{0}08$^{/}$.774	Pirgacha	MHL	Boro-Aus-T.amon	5.13	2.00	18.33	0.11	12.75	0.13	0.65	1.52	0.27	2.54	2.02	131.64	1.73
155.	do	N. 25^{0}48$^{/}$.445, E. 89^{0}08$^{/}$.201	Pirgacha	MHL	Boro-fallow-T.amon	5.1	2.40	22.31	0.12	13.88	0.14	0.40	1.83	0.39	1.1	1.16	98.08	1.45
156.	do	N. 25^{0}48$^{/}$.548, E. 89^{0}07$^{/}$.896	Menanogor	MHL	Maize-fallow-T.amon	4.82	2.13	14.34	0.11	16.12	0.15	0.65	1.12	0.2	0.36	0.43	76.12	1.41
157.	do	N. 25^{0}48$^{/}$.755, E. 89^{0}07$^{/}$.137	Menanogor	MHL	Boro-mustard-T.amon	4.52	1.73	18.33	0.09	18.93	0.13	0.13	0.64	0.13	1.59	1.078	211.42	1.61
158.	do	N. 25^{0}48$^{/}$.106, E. 89^{0}07$^{/}$.685	Menanogor	MHL	Boro-fallow-T.amon	5.17	1.80	26.29	0.10	12.75	0.18	0.65	1.52	0.28	0.36	0.78	114.38	1.45
159.	do	N. 25^{0}48$^{/}$.522, E. 89^{0}07$^{/}$.346	Menanogor	MHL	Boro-fallow-T.amon	5.33	1.66	22.31	0.09	22.87	0.18	0.40	2.28	0.45	1.92	1.29	121	3.24
160.	do	N. 25^{0}48$^{/}$.324, E. 89^{0}07$^{/}$.855	Menanogor	MHL	Boro-fallow-T.amon	5.56	1.40	18.33	0.08	18.37	0.15	0.65	2.76	0.6	1.09	1.68	91.14	2.42
161.	do	N. 25^{0}48$^{/}$.209, E. 89^{0}07$^{/}$.129	Gongachora	MHL	Boro-Mustard-T.amon	5.13	2.00	14.34	0.11	23.99	0.14	0.06	1.22	0.25	0.23	1.6	117.69	1.17
162.	do	N. 25^{0}48$^{/}$.382, E. 89^{0}07$^{/}$.512	Gongachora	MHL	Boro-fallow-T.amon	5.28	2.00	26.29	0.11	13.31	0.12	0.40	0.79	0.35	2.7	1.55	93.2	1.97
163.	do	N. 25^{0}48$^{/}$.921, E. 89^{0}07$^{/}$.295	Gongachora	MHL	Boro-Mustard-T.amon	5.15	1.66	22.31	0.08	18.37	0.14	0.65	1.95	0.35	0.3	1.15	80.31	1.93
164.	do	N. 25^{0}48$^{/}$.282, E. 89^{0}07$^{/}$.921	Gongachora	MHL	Boro-fallow-T.amon	4.71	2.13	18.33	0.12	19.49	0.11	0.40	1.98	0.3	2.1	1.3	100.71	1.41
165.	do	N. 25^{0}48$^{/}$.657, E. 89^{0}07$^{/}$.097	Gongachora	MHL	Boro-fallow-T.amon	4.22	1.86	18.33	0.11	15.56	0.12	0.40	0.51	0.14	0.22	0.96	89.55	0.96
166.	do	N. 25^{0}48$^{/}$.864, E. 89^{0}07$^{/}$.772	Gongachora	MHL	Boro-mustard-T.amon	5.51	1.66	14.34	0.09	25.67	0.11	0.65	1.5	0.21	0.34	1.69	135.17	2.38

Sl. No.	Address	GPS	Soil Series	Land type	Cropping pattern	pH	OM (%)	P (ppm)	T. N (%)	S (ppm)	K (meq)	P (ppm)	Ca (meq)	Mg (meq)	Zn (ppm)	Cu (ppm)	Fe (ppm)	Mn (ppm)
167.	do	N. $25^0 48^/.120$, E. $89^0 07^/.591$	Gongachora	MHL	Boro-fallow-T.amon	4.91	1.93	26.29	0.11	17.81	0.11	0.40	1.9	0.28	2	1.59	133.36	3.56
168.	do	N. $25^0 48^/.418$, E. $89^0 07^/.138$	Gongachora	MHL	Boro-fallow-T.amon	5.03	1.93	14.34	0.10	12.19	0.12	0.15	1.39	0.25	0.12	0.74	95.27	0.84
169.	do	N. $25^0 48^/.352$, E. $89^0 07^/.568$	Gongachora	MHL	Boro-fallow-T.amon	5.16	2.00	26.29	0.11	17.81	0.14	0.15	16	0.28	0.11	1.21	112.2	2.42
170.	do	N. $25^0 48^/.113$, E. $89^0 07^/.679$	Gongachora	MHL	Boro-fallow-T.amon	5.34	1.93	14.34	0.12	15.56	0.12	0.40	1.67	0.31	1.9	0.18	60.27	1.37
171.	do	N. $25^0 48^/.908$, E. $89^0 07^/.340$	Pirgacha	MHL	Boro-Mustard-T.amon	4.81	2.00	30.28	0.11	17.81	0.11	0.65	0.78	0.25	0.24	1.64	115.66	2.83
172.	do	N. $25^0 48^/.165$, E. $89^0 08^/.107$	Pirgacha	MHL	Boro-fallow-T.amon	5	1.80	26.29	0.11	13.31	0.17	0.40	1.68	0.34	1.93	1.75	117.17	1.45
173.	do	N. $25^0 48^/.193$, E. $89^0 07^/.051$	Pirgacha	MHL	Boro-Mustard-T.amon	5.34	2.00	26.29	0.12	20.06	0.14	0.15	1.53	0.07	0.1	1.59	133.17	1.85
174.	do	N. $25^0 48^/.165$, E. $89^0 08^/.170$	Pirgacha	MHL	Boro-fallow-T.amon	5.13	1.86	22.31	0.10	16.69	0.16	0.40	0.36	0.19	2	1.47	99.21	2.14
175.	do	N. $25^0 48^/.349$, E. $89^0 07^/.283$	Pirgacha	MHL	Boro-fallow-T.amon	4.67	1.86	18.33	0.12	18.37	0.15	0.15	1.23	0.32	0.13	1.65	165.39	3.81
176.	do	N. $25^0 48^/.380$, E. $89^0 07^/.209$	Pirgacha	MHL	Boro-mustard-T.amon	5.56	2.00	26.29	0.11	13.88	0.14	0.40	0.59	0.14	0.29	1.2	178.95	6.12
177.	do	N. $25^0 48^/.538$, E. $89^0 07^/.152$	Pirgacha	MHL	Boro-fallow-T.amon	5.02	1.86	18.33	0.10	13.88	0.11	0.65	1.05	0.24	1.7	1.5	125.74	2.46
178.	do	N. $25^0 48^/.277$, E. $89^0 08^/.188$	Pirgacha	MHL	Boro-fallow-T.amon	4.36	1.73	14.34	0.12	18.37	0.12	0.40	1.96	0.33	0.34	1.16	126.03	1.81
179.	do	N. $25^0 48^/.527$, E. $89^0 07^/.189$	Pirgacha	MHL	Boro-fallow-T.amon	5.12	2.06	38.25	0.10	12.19	0.13	0.15	2.26	0.39	2.68	1.19	91.81	1.37
180.	do	N. $25^0 48^/.184$, E. $89^0 08^/.175$	Pirgacha	MHL	Boro-mustard-T.amon	4.43	2.00	46.22	0.11	13.88	0.14	0.40	1.5	0.26	0.2	2.07	110.85	1.53

Appendix-5:

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Evaluation of Critical Limit of Sulphur in Soils for Wheat (*Triticum aestivum* L.) and Mustard (*Brassica napus* L.)

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Abstract: The conception of critical limit (CL) of a nutrient element distinguishes its deficiency from sufficiency, which could advise fertilizer application. A pot culture experiment was conducted during Rabi season (2019–2020) to study the CL of sulphur (S) in soil and plant. A total of 20 soil samples collected from intensive cropping areas of three agroecological zones (AEZs) of Bangladesh were used in the experiment. The 0.15% $CaCl_2$ extractable S (expressed as available S) contents of the test soils ranged from 6.84 mg/kg to 38 mg/kg. Wheat (*Triticum aestivum* L.) cv. BARI gom 30 and mustard (*Brassica napus* L.) cv. BINA sorisha 9 were used as test crops in this study. There were two rates of S application to soil-0 and 15 mg/kg for wheat and 0 and 18 mg/kg for mustard from gypsum ($CaSO_4.2H_2O$). Each S treatment was replicated thrice. Dry matter yield, S content and S uptake by the crops increased with added S. For mustard, the CL of soil S was estimated to be 14 mg/kg by graphical procedure and 11 mg/kg in statistical method while plant tissue concentration showed the CL of 0.35% in both methods. The CL of soil S for wheat was found to be 14 mg/kg and 11 mg/kg in graphical and statistical methods, respectively, and the CL of plant tissue concentration was recorded as 0.14%, in both methods. It is expected that mustard and wheat crops would respond to S fertilization in soils containing S at or below the CL. The results would be useful for predicting crop (wheat and mustard) response to S fertilizer and developing efficient S fertilizer management to promote sustainable crop production.

Keywords: critical limit; MUSTARD; S content; S uptake; wheat

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1. Introduction

Sulphur (S) is one of the essential plant nutrients, ranked as the fourth most important plant nutrient after nitrogen (N), phosphorus (P) and potassium (K) [1]. It is a major component of S-containing amino acids and plays a vital role in forming chlorophyll, oils, etc., and enzyme activation. Optimum supply of S can increase the nutritional value and yield, whereas S deficiency may cause an approximately 50% decrease in crop yield [2]. The intensive agricultural system and cultivation of high yielding crops coupled with the limited supply of S fertilizers have accelerated S deficiency in arable lands [3], and S deficiency has become prominent in crop agriculture across the globe [4,5]. In Bangladesh, as in other parts of the world, crop production is limited by S deficiency in the soil [6]. At present, approximately 3.31 million hectares of land have been categorized as S deficient soil in Bangladesh with an application rate of 8–12 kg/ha [7]. Therefore, it is crucial to supply an adequate amount of S for maintaining better plant growth, development and yield.

Sulphur deficiency significantly affects the growth and development of crops, such as wheat [8–10] and mustard [11]. Wheat (*Triticum aestivum*) is one of the major three cereal crops in terms of global production, and the second most important cereal crop in Bangladesh after rice. Mustard (*Brassica napus*) is a major oilseed crop as well as a popular culinary herb of Bangladesh. Applying S fertilizers can increase wheat yield [12] and oil content of mustard [13]. For wheat, inadequate S content limits nitrogen use efficiency [14], decreases grain size [8,9] and degrades baking quality [15]. In the case of mustard, S is involved in increasing oil synthesis [16] and S is an important constituent of proteins, vitamins (biotin, thiamine) and S containing amino acids, i.e., cystine and methionine [17]. It is essential to apply the S containing fertilizers to address the S deficiency in plants and avoid production loss when the S content in soil goes below a certain level, i.e., critical limit. Therefore, it is crucial to identify an indicator that helps to know the time of fertilizer application to maintain crop growth and productivity.

Critical limit (CL) is an important indicator to determine the optimum fertilizer requirement for a crop. It is the level at or below which crops respond to the added particular nutrient. It separates a group of soils that give a significant yield response to fertilizers from that of soils that do not respond [18]. The CL or level is quite often employed for a wide variety of soils and crops, even though these CL may be different not only for soils, crop species but also for different varieties of the given crop [19,20]. Different critical values of available S in a particular soil for mustard are reported for different extractants [21]. Moreover, these limits varied with the soil as well as the extractants used within the same soil [22]. It is important to identify a CL for S in soil to enable the farmers to maintain plant growth and productivity by applying S containing fertilizers when the S content in soils goes below the critical limit of specific soil and crops.

The main aim of this study was to determine the CL of S in soils for efficient application of S fertilizer for wheat and mustard, predominantly grown in different agroecological zones of Bangladesh. There is not comparative report available regarding the approaches for determining the CL of S. Therefore, this study will also compare the graphical and statistical approaches used for determining the CL of S in soils of Bangladesh for wheat and mustard cultivation.

2. Materials and Methods

2.1. Soil Sampling, Analysis and Test Crops

The soil samples (0–15 cm soil depth) were collected from 20 different locations of three agroecological zones (AEZs) of Bangladesh; namely Old Himalayan Piedmont Plain (AEZ 1), Tista Meander Floodplain (AEZ 3) and Old Brahmaputra Floodplain (AEZ 9) comprising the districts Panchagarh, Rangpur and Mymensingh. The AEZs were developed mainly based on the soil characteristics and climatic condition, and Bangladesh has been divided into 30 AEZs, where the above mentioned AEZs have the highest cropping intensity. Due to the variation among the AEZs, the crop suitability is also different in different AEZs. The geographical positions and general features of the soil collection sites are presented in Table 1. The sampling location map has also been included in Figure 1. All soils were air-dried, sieved ($\leq$2 mm) and mixed until homogenous. The collected soil samples were analysed to determine different physico-chemical properties of soil such as texture, pH, organic matter and soil nutrients status following standard methods. The physico-chemical properties of the collected soil samples before starting the experiments are presented in Table 2. The non-draining plastic pots (4 kg capacity) were filled with 3 kg of soil. Wheat (*Triticum aestivum*) var. BARI gom 30 and mustard (*Brassica napus* L.) var. BINA sorisha 9 were used in this study as test crops.

Table 1. Geographical position and general features of the soil samples collected from intensive cropping area of three agroecological zones.

Sample ID	Locations (Upazillas)	AEZ No.	Soil Series	Geographical Location	Land Type	Major Cropping Pattern
S1	Taraganj, Rangpur	3	Kawnia	25.48° N 89.05° E	MHL	Mustard-Boro-T. aman
S2	Sadar, Panchagarh	1	Vojonpur	26.28° N 88.31° E	HL	Mustard-Boro-T. aman
S3	Sadar, Panchagarh	1	Vojonpur	26.28° N 88.31° E	HL	Potato-T. aman-G. nut
S4	Sadar, Mymensingh	9	Sonatola	24.39° N 90.27° E	MHL	Boro-Fellow-T. aman
S5	Taraganj, Rangpur	3	Polashbari	25.48° N 89.04° E	MHL	Boro-Fellow-T. aman
S6	Taraganj, Rangpur	3	Sonatola	25.48° N 89.05° E	MHL	Boro-Fellow-T. aman
S7	Sadar, Mymensingh	9	Sonatola	24.39° N 90.27° E	HL	Mustard-Boro-T. aman
S8	Sadar, Panchagarh	1	Atoary	26.27° N 88.33° E	MHL	Potato-Jute-T. aman
S9	Sadar, Rangpur	3	Gongachora	25.48° N 89.07° E	MHL	Boro-Fellow-T. aman
S10	Sadar, Mymensingh	9	Sonatola	24.40° N 90.27° E	MHL	Mustard-Boro-T. aman
S11	Muktagacha, Mymensingh	9	Sonatola	24.47° N 90.12° E	HL	Mustard-Boro-T. aman
S12	Sadar, Mymensingh	9	Silmondi	24.40° N 90.26° E	MHL	Boro-Fellow-T. aman
S13	Tetulia, Panchagarh	1	Pirgacha	26.28° N 88.30° E	HL	Mustard-Jute-T. aman
S14	Muktagacha, Mymensingh	9	Silmondi	24.44° N 90.12° E	MHL	Mustard-Boro-T. aman
S15	Sadar, Rangpur	3	Menanogor	25.48° N 89.07° E	MHL	Tobacco-Aus-T. aman
S16	Sadar, Mymensingh	9	Silmondi	24.40° N 90.26° E	MHL	Boro-Fellow-T. aman
S17	Sadar, Mymensingh	9	Sonatola	24.40° N 90.27° E	MHL	Mustard-Boro-T. aman
S18	Sadar, Mymensingh	9	Silmondi	24.40° N 90.26° E	MHL	Mustard-Boro-T. aman
S19	Sadar, Mymensingh	9	Silmondi	24.40° N 90.26° E	MHL	Mustard-Boro-T. aman
S20	Sadar, Mymensingh	9	Silmondi	24.40° N 90.26° E	MHL	Boro-Fellow-T. aman

AEZ, agroecological zone; MHL, medium high land; HL, high land; T. aman, transplanted aman rice; G. nut, ground nut.

Table 2. Soil physico-chemical properties of the collected soil samples before starting the experiments.

Sample ID	Textural-Class	pH_{CaCl2}	Total OM (%)	Avail. P (mg/kg)	Total N (%)	S (mg/kg)	K (cmolc/kg Soil)	Ca (cmolc/kg Soil)	Mg (cmolc/kg Soil)
S1	Sandy Loam	5.10	2.46	14.88	0.12	6.84	0.13	1.16	0.27
S2	Sandy Loam	4.60	2.33	8.37	0.13	8.16	0.15	0.75	0.5
S3	Sandy Loam	4.96	2.00	16.74	0.10	8.82	0.13	0.65	0.54
S4	Clay loam	6.02	1.33	17.37	0.08	9.33	0.09	3.11	1.49
S5	Sandy Loam	4.61	1.86	35.54	0.10	9.87	0.14	1.1	0.17
S6	Sandy Loam	5.17	2.00	14.88	0.10	10.31	0.12	1.32	0.26
S7	Loam	5.87	2.06	12.74	0.08	10.82	0.13	5.73	1.35
S8	Sandy Loam	4.32	2.00	20.92	0.11	11.45	0.12	0.65	0.1
S9	Sandy loam	5.03	1.93	14.34	0.10	12.19	0.12	1.39	0.25
S10	Clay loam	5.78	1.66	12.74	0.08	13.06	0.10	4.77	2.04
S11	Loam	4.99	1.58	12.36	0.09	15.14	0.09	2.01	0.43
S12	Clay	6.03	1.80	15.83	0.08	15.30	0.14	6.51	3.07
S13	Loam	4.85	1.66	21.05	0.08	16.00	0.11	3.67	0.66
S14	Loam	5.43	1.46	10.04	0.07	22.08	0.11	4.12	1.31
S15	Loam	5.33	1.66	22.31	0.09	22.87	0.18	2.28	0.45
S16	Clay loam	6.11	1.80	9.27	0.09	24.25	0.16	8.18	3.75
S17	Clay loam	6.03	2.00	12.36	0.10	31.72	0.11	7.57	3.12
S18	Clay Loam	6.08	1.53	14.29	0.08	36.19	0.09	8.07	3.81
S19	Clay	5.90	1.60	12.36	0.07	36.94	0.11	8.17	4.01
S20	Clay loam	6.16	1.66	10.04	0.08	38.43	0.13	7.27	3.16

OM, organic matter; P, phosphorus; N, nitrogen; S, sulphur; K, potassium; Ca, calcium; Mg, magnesium Note: Soil pH measured in water using a glass electrode and 1:2.5 soil-to-$CaCl_2$ solution ratio [23]. Mechanical analysis of soils was done by hydrometer method [24] and the textural class was determined from Marshall's triangular co-ordinate following USDA system. Organic matter was determined by wet oxidation method [25], total N by micro-Kjeldahl method [26], available P for neutral and alkaline soil by Olsen method [27], available P for acidic soil by Bray and Kurtz method [28], and exchangeable bases (K, Ca and Mg) were extracted with 1 M NH_4OAc solution (pH = 7) [29]. Available S was determined by extracting the soil sample with 0.15% $CaCl_2$ solution as described by Page et al. [30].

This experiment was conducted in early winter (November to December 2019) with an average day length of 11 h and an average day/night temperature of 22 °C. Initially, 10 seeds were sown in each pot, and then after thinning six uniform plants were allowed to grow until harvesting. The pots were watered as per requirement, weeding and other intercultural operations were carried out as and when required. The plants were harvested 49 days after sowing (DAS) by cutting the shoots just above the soil surface. The plants were washed to removed dirt with running tap water followed by distilled water and were dried in an oven at 65 °C for 48 h, and the dry matter yield was recorded. The dried plant samples were ground and sieved through 2 mm sieve and kept for analysing plant nutrient content. Plant tissue concentration of S was determined following the turbidimetric method [31].

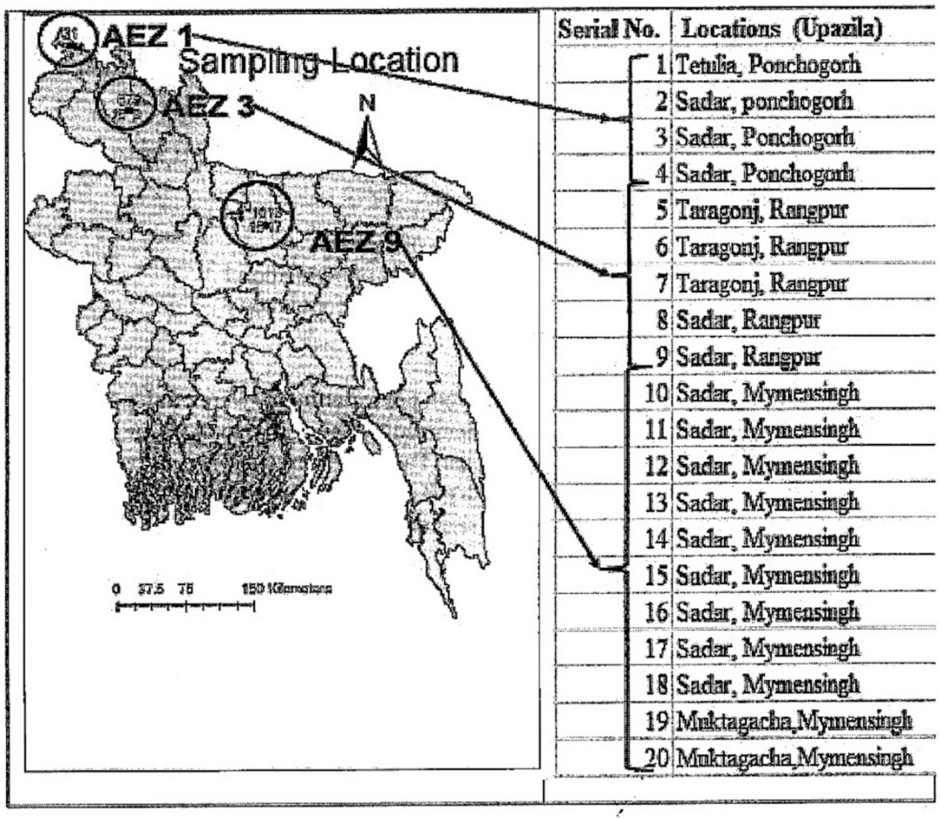

Figure 1. Soil sampling locations from three agroecological zones of Bangladesh.

2.2. Experimental Design and Approach

This study was conducted in the net house of the Soil Science Department of the Bangladesh Agricultural University (BAU) (Mymensingh, Bangladesh). The two-factorial experiment consisted of two levels of S for each plant species (0 and 15 mg/kg soil or 32 kg/ha for wheat and 0 and 18 mg/kg soil or 38 kg/ha for mustard) and 20 soil samples collected from different AEZs with varying available S (ranging from 6.84 to 38.43 mg/kg), and was replicated three times using completely randomized design (six pots (2 sulphur rates × 3 replication) for each soil and 120 pots (6 pots × 20 soils) for each crop). All soils were amended with the following basal nutrients (in mg/kg soil) mixed through the entire soil volume in each pot before sowing: N (70) from urea, P (20) from triple superphosphate and K (40) from muriate of potash. Reagent grade calcium sulphate ($CaSO_4.2H_2O$) was used as the source of S for soil application.

2.3. Critical Limit Determination by Graphical Method

The CL of S was determined by the graphical method as described by Cate and Nelson [32]. A scatter diagram of the relative yields (Bray's percent dry matter yield) as Y-axis versus soil test values as X-axis was plotted. Bray's percent yield was calculated as follows:

$$\% \text{ Relative yield} = (\text{Yield without nutrient addition}/\text{Yield with nutrient addition}) \times 100$$

2.4. Critical Limit Determination by Statistical Method

In the statistical technique of determining critical level of S, coefficient of determination (R^2) was calculated as described by Waugh [33]. In this technique, the data are ordered in an array-based upon rankings of soil test values. The pairs of soil test value and relative yield were maintained in this order throughout the analyses. The procedure amounts to splitting the data into two groups, using successive tentative critical levels to determine the particular critical value. Accordingly, the predictability value (R^2) was computed from the following relationship:

$$R^2 = \{TCSS - (CSS^1 + CSS^2)\}/TCSS$$

where,

TCSS = Total Corrected Sum of Squares
CSS^1 = Corrected Sum of Squares of population 1
CSS^2 = Corrected Sum of Squares of population 2

2.5. Statistical Analysis

The raw data observed from pot experiments were put for statistical analysis using two factorial Complete Randomized Design (CRD) to draw the valid differences among the treatments as well as soils. The data were subjected to two-way ANOVA and the significance of treatment on dry matter yield, concentration and uptake of S by wheat and mustard plant was tested as described by Gomez and Gomez [34].

3. Results

The soils were analysed for physicochemical parameters presented in Table 2. Textural classes of the soils show that 7 soils were sandy loam, 6 soils were clay loam, 5 soils were loam and 2 soils were clay following the USDA system; which indicates a wide variation from relatively coarse to fine texture. Soil pH of the 20 test soils ranged from 4.32 (very strongly acidic: <4.5) to 6.16 (slightly acidic: 5.6–6.5). The soil organic matter content of the soils varied from 1.33% (low) to 2.46% (high). Sulphur content in the soils varied from 6.84 to 38.43 mg/kg; it was the basis for selecting the soils. The S content in a set of 12 soils varied from very low to low (6–15 mg/kg), 4 soils were medium (16–24 mg/kg) and 4 soils were high (25–40 mg/kg). Other major soil nutrient contents were also analysed to support the effect of S content in soil and its application on the growth of wheat and mustard. Nitrogen content between the soils varied from 0.07 to 0.13%; P content from 8.37 to 35.54 mg/kg and K content from 0.09 to 0.14 cmol/kg soil. The range of B, Ca, Mg, Zn, Cu, Fe and Mn of the 20 test soils were 0.15 to 0.94 mg/kg, 0.65 to 8.18 mg/kg, 0.54 to 3.75 mg/kg, 0.27 to 2.04 mg/kg, 0.72 to 3.82 mg/kg, 23 to 120 mg/kg and 2.99 to 22.72 mg/kg, respectively.

3.1. Shoot Dry Matter Yield of Wheat and Mustard

Sulphur application in soil (15 mg/kg soil) significantly increased shoot dry weight of wheat irrespective of initial S status in the soils ($p \leq 0.05$; Table 3a). The shoot dry weight varied from 2.67 to 3.63 g/pot (mean 3.12 g/pot) in the soil without S amendment, whereas amending the soil with S (15 mg/kg soil) exhibited a significant increase in shoot dry weight varied from 3.05 to 4.11 g/pot (mean 3.54 g/pot). In control plants (0 kg S/ha), the lowest dry matter yield was recorded in soil with very low concentration of inherent soil S (6.84 mg/kg; S1: Taraganj), and the highest dry matter yield was obtained in soils having inherent soil S of 11.45 mg/kg (S8: Panchagarh). Notably, the highest shoot dry matter yield of wheat was also observed in the soils of Panchagarh Sadar Upazila (AEZ 1) by applying S to soil (15 mg S/kg soil), and the lowest was also in the soils of Taraganj (AEZ 3). The Bray's percent S yield of wheat ranged from 78 to 93% (mean 88.5%) depending on the soils.

Table 3. Effect of sulphur (S) application on dry matter yield, S concentration and its uptake by wheat and mustard plants.

(a). Wheat

Sample ID	Soil Available S (mg/kg)	Dry Matter (g/pot) S Level (mg/kg)		Bray's % S Yield	S Concentration in Plants (%) S Level (mg/kg)		S Uptake (mg/pot) S Level (mg/kg)	
		0	15		0	15	0	15
S1	6.84	2.67	3.43	78	0.11	0.14	3.05	4.83
S2	8.16	3.30	4.00	83	0.12	0.15	4.03	5.80
S3	8.82	2.90	3.43	85	0.12	0.14	3.57	4.82
S4	9.33	3.50	4.04	87	0.14	0.16	4.90	6.58
S5	9.87	3.40	3.98	86	0.13	0.15	4.65	6.06
S6	10.31	2.94	3.49	84	0.13	0.15	3.92	5.31
S7	10.82	3.17	3.57	89	0.14	0.16	4.55	5.68
S8	11.45	3.63	4.11	88	0.14	0.16	5.07	6.56
S9	12.19	2.63	3.05	86	0.17	0.20	4.53	5.98
S10	13.06	2.83	3.13	90	0.16	0.18	4.50	5.52
S11	15.14	3.16	3.51	90	0.15	0.17	4.84	6.02
S12	15.30	3.11	3.54	92	0.17	0.19	5.37	6.87
S13	16.00	2.70	3.10	90	0.15	0.17	4.07	5.38
S14	22.08	2.86	3.13	91	0.15	0.16	4.40	5.12
S15	22.87	3.23	3.47	93	0.16	0.17	5.16	5.92
S16	24.25	3.15	3.45	91	0.18	0.20	5.79	6.79
S17	31.72	3.40	3.76	91	0.15	0.17	5.03	6.23
S18	36.19	3.38	3.68	92	0.16	0.17	5.39	6.36
S19	36.94	3.21	3.48	92	0.17	0.19	5.21	6.42
S20	38.43	3.14	3.37	93	0.17	0.18	5.37	6.22
Mean	17.98	3.11	3.54	88.5	0.15	0.17	4.67	5.92
P at 5%	LSD [S (0.45); Soil (0.38)]				LSD [S (0.002); Soil (0.002)]		LSD [S (0.27); Soil (0.22)]	

(b). Mustard

Sample ID	Soil Available S (mg/kg)	Dry Matter (g/pot) S Level (mg/kg)		Bray's % S Yield	S Concentration in Plants (%) S Level (mg/kg)		S Uptake (mg/pot) S Level (mg/kg)	
		0	18		0	18	0	18
S1	6.84	2.82	3.60	76	0.26	0.34	7.3	12.3
S2	8.16	3.03	3.97	80	0.28	0.35	8.4	14.1
S3	8.82	3.23	4.08	79	0.29	0.37	8.9	15.0
S4	9.33	3.17	3.91	81	0.30	0.37	9.7	14.4
S5	9.87	3.95	4.73	83	0.34	0.41	11.7	19.6
S6	10.31	3.21	3.82	84	0.34	0.41	11	15.5
S7	10.82	2.94	3.41	86	0.35	0.41	10	14.2
S8	11.45	3.06	3.62	85	0.35	0.41	10.9	15.0
S9	12.19	3.29	3.76	85	0.34	0.4	11.5	14.9
S10	13.06	3.80	4.39	87	0.35	0.4	13.5	18.2
S11	15.14	3.37	3.83	88	0.38	0.43	12.9	16.4
S12	15.30	3.24	3.63	89	0.38	0.42	12.1	15.2

Table 3. *Cont.*

(b). Mustard								
Sample ID	Soil Available S (mg/kg)	Dry Matter (g/pot) S Level (mg/kg)		Bray's % S Yield	S Concentration in Plants (%) S Level (mg/kg)		S Uptake (mg/pot) S Level (mg/kg)	
		0	18		0	18	0	18
S13	16.00	2.91	3.24	90	0.37	0.41	10.8	13.1
S14	22.08	3.47	3.82	91	0.41	0.45	13.4	17.2
S15	22.87	3.06	3.34	92	0.39	0.42	11.9	14.2
S16	24.25	3.23	3.50	92	0.41	0.44	13.1	15.3
S17	31.72	3.31	3.61	92	0.40	0.43	13.1	15.6
S18	36.19	3.77	4.04	93	0.39	0.42	14.6	16.9
S19	36.94	3.28	3.57	92	0.38	0.41	12.4	14.8
S20	38.43	3.33	3.59	93	0.37	0.40	12.3	14.3
Mean	17.98	3.27	3.77	86.9	0.35	0.41	11.5	15.3
P at 5%	LSD [S (0.24); Soil (0.23)]			LSD [S (0.03); Soil (0.03)]			LSD [S (2.8); Soil (1.4)]	

The shoot dry matter yield of mustard was significantly increased by S application to soils ($p \leq 0.05$; Table 3b). The shoot dry weight varied from 2.82 to 3.95 g/pot (mean 3.27 g/pot) in the soil without S amendment, whereas amending the soil with S (18 mg/kg soil) exhibited a significant increase in shoot dry weight varied from 3.60 to 4.73 g/pot (mean 3.77 g/pot). In control, the lowest shoot dry matter yield was observed in the soil with a deficient concentration of inherent soil S (6.84 mg/kg), and the highest dry matter yield was obtained in the soils having inherent soil S of 9.87 mg/kg. In S amended soil (18 mg S/kg soil), the highest dry matter yield (4.73 g/pot) was recorded in the soils of Taraganj Upazila and the lowest (3.24 g/pot) was observed in the soils of Tetulia Upazila of AEZ 1, irrespective of the nature of soils. The Bray's percent S yield of mustard ranged from 76 to 93% (mean 86.9%) depending on the soils.

3.2. Sulphur Concentration and Uptake by Plants

Applying S to soil (15 mg/kg soil) significantly increased plant S concentration and uptake of wheat plants growing in different soils ($p \leq 0.05$; Table 3a). In control plants (0 kg S/ha), S concentration in wheat plants ranged from 0.11 to 0.18% (mean 0.15%), and in S amended soils (15 mg S/kg soil) the concentration varied from 0.14 to 0.20% (mean 0.16%). In control plants, S uptake by wheat varied from 3.05 to 5.79 mg/plant (mean 4.67 mg/plant) and 4.82 to 6.87 mg/plant with an average of 5.92 mg/plant in S amended soil treatments.

In mustard, application of S (at 18 mg/kg soil) significantly increased plant S concentration and uptake of plants growing in different soils ($p \leq 0.05$; Table 3b). In control plants (0 kg S/ha), S concentration in wheat plants ranged from 0.26 to 0.41% (mean 0.35%), and in S amended soils (18 mg S/kg soil) the concentration varied from 0.34 to 0.45% (mean 0.41%). In control plants, S uptake by wheat varied from 7.3 to 14.6 mg/plant (mean 11.5 mg/plant) and 12.3 to 19.6 mg/plant with an average of 15.3 mg/plant in S amended soil treatments.

3.3. Critical Limit of S for Wheat and Mustard

The CL of S concentration for wheat (49 DAS) was 0.14% (Figure 2a) using the graphical approach. In statistical procedure, the results also showed the same CL of S concentration (0.14%, see Table S1), below which a plant will be regarded as S deficient at the specified growth period. Hence, it would require an external S application. Similar to wheat, the critical S concentration of mustard plants (49 DAS) was found to be 0.35% both in graphical

(Figure 2b) and statistical approaches (Table S2), below which a plant will be regarded as S deficient at the specified growth period, and hence it would require an external S application.

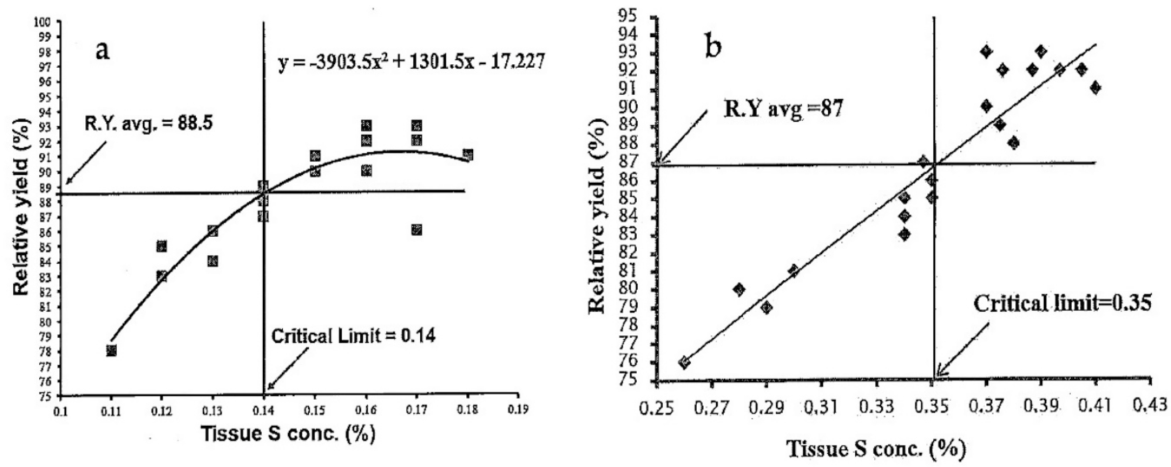

Figure 2. Scatter diagram showing relationship between Bray's per cent yield and tissue sulphur (S) concentration in (**a**) wheat and (**b**) mustard plants for determining critical limit of S for wheat and mustard cultivation.

3.4. *Critical Limit of Soil S Concentration for Wheat and Mustard*

The CL of available S in the present study was found to be 13.5 mg/kg (Figure 3a). It is expected that wheat plants will respond to S application when the soils contain less than 13.5 mg/kg ($CaCl_2$ extractable S). In statistical method, the CL of S in soil for wheat was 11.45 mg/kg (Table S3). From the critical level of S in soils, it is evident that S application rate below 15 mg/kg of soil cannot be helpful for the crop to alleviate the deficiency stress.

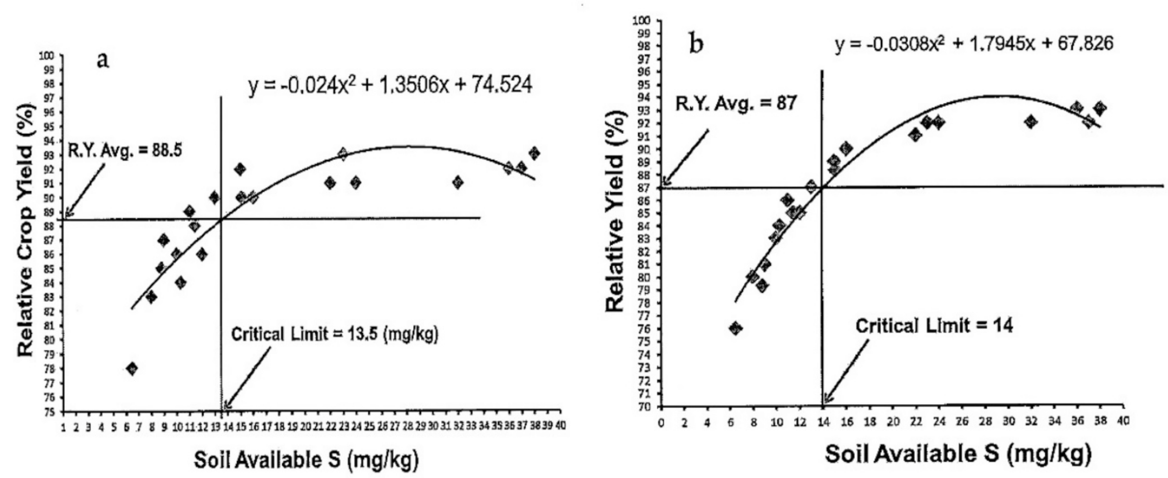

Figure 3. Scatter diagram showing the relationship between Bray's per cent yield of (**a**) wheat and (**b**) mustard for determining critical limit of sulphur for wheat and mustard cultivation.

The CL of available S in the present study was 14 mg/kg (Figure 3b). The CL of S increased because of the intensive cropping system and limited application of organic matter in soil; thus, the soil remains deficient in S content in soil. It is expected that mustard plants will respond to S application when the soils contain less than 14 mg/kg ($CaCl_2$ extractable S). In statistical method the CL of S for mustard soil was 11.45 mg/kg (Table S4). From the critical level of S in soils, it can be précised that S application rate below 18 mg/kg of soil cannot be helpful for the crop to alleviate the deficiency stress.

4. Discussion

The present study has determined the S level in soil below which wheat and mustard might respond to the added S containing fertilizers. For example, the results from this study demonstrated that the CL of S for wheat and mustard was 13.5 and 14 mg/kg soil, respectively. At present, all versions of the fertilizer recommendation guide employed in Bangladesh for fertilizer rate use 10 mg S/kg soil as critical level [35]. The mentioned CL of S in this present study is higher than the current value for fertiliser recommendation. This increase in CL of S can be explained by the intensive cropping system and limited application of organic matter in soil (i.e., compost, farmyard manure etc.). Considering the critical level of S in soils, it is evident that S application rate below 14 mg/kg of soil cannot alleviate the S deficiency of plants. The CL of S in plant tissue can also be used as an indicator to determine the time and requirement of S application instead of soil test values. Based on the present study, the tissue S concentration was 0.14% for wheat and 0.35% for mustard. It is already established that after S application, S becomes available to make it more effective when applied at optimum dose and right time [36]. The CL of a nutrient in soil varies according to crops, soil and extraction methods. Concerning soil factors, what is important here is the soil type (S deficiency occur most often in sandy soil), soil pH (available at low soil pH) and soil organic matter, as they influence the S availability in soil. Limited organic matter content in soil also triggers the deficiency of S in soil, as it serves as a source of S in soil. Hence, this situation justifies the need to determine and update the CL of different plant nutrients to formulate an optimum dose of deficient nutrients for different crops and soils. The basic objective is to achieve a satisfactory crop yield. However, the CL will remain changing due to the current farming practices and frequent monitoring is essential to maximize the fertilizer use efficiency and maintain a sustainable production system.

The CL of S may vary among the graphical and statistical approaches for determining the critical level. The results from this present study highlighted that the CL for wheat and mustard was 13.5 and 14 mg/kg soil, in graphical method. In contrast, the CL of S was lower (11.45 mg/kg soil) for both crops in statistical method. The lower value in the statistical approach might occur due to available soil S corresponding to a corrected sum of squares for the population in this study to calculate predictability value (R^2). However, this dispute requires further investigation to know why the CL is lower in statistical method than the graphical method. It has already been reported that the statistical approach for determining CL provides a lower value than the graphical approach [35]. As the CL value is closer to each other, researchers can use any methods of determining the CL of nutrients in soil. We recommend using the highest critical value derived from the graphical and statistical approach to ensure higher crop yield as the larger percentage of soils will fail to comply with the CL. However, further research work is required to validate the findings from this present study. A good method should be able to predict the amount of plant-available nutrient and the fertilizer responsiveness of crops growing on a wide range of soils. In this regard, the determination of CL using two different approaches is essential to determine an average crop's optimum fertilizer requirement [35].

A set of 20 representative soil was selected from 720 soils collected from throughout Bangladesh covering a wide range in texture, AEZ, general soil type, cropping pattern and land type. Among the 20 soils, six soils were collected from each of Sonatala and Silmondi soil series. Another eight soils included two from Vojonpur and one sample from Kawnia, Polashbari, Atoary, Gonggachora, Pirgacha, and Menanagar soil series. Of the representative soils, 14 were medium high land (MHL), and the remaining six were high land (HL) in their land types. The soils were dominated by rice-based cropping patterns and belong to subtropical monsoon climates with a wide variation in rainfall pattern, temperature and humidity. T. Aman rice was common in all the cropping patterns. Mustard was grown in 10 cropping patterns while wheat was not present in any of the patterns, though AEZ 1 and AEZ 3 are popular as wheat-growing areas in Bangladesh [7]. As the soil samples were collected from diversified regions of Bangladesh, the soil analysis showed variation in S content and other physico-chemical properties of soil. The diversified sampling approach might be the underlying reason for varying critical value of S for wheat and maize [7]. This dispute has also been supported by Murthy [21], who also described that variation among the sampling sites produces significant variation in CL of nutrients.

Applying S to soil significantly increased the shoot dry biomass of crops grown in different soils. For example, application of S to soil exhibited an approximately 12% increase in shoot dry biomass (averaged across wheat and mustard) compared to when no S was applied to soil. The accumulation of dry matter is a vital crop growth index commonly used to determine the economic returns influenced by the effects of different treatments. Sulphur is often considered a limiting factor for shoot biomass yield in crop ecosystems [37]. The results agree with Huda et al. [38], who reported that application of S containing fertilizers based on the critical limit of S increases shoot biomass of rice. The improvements in shoot biomass yield obtained in this study might have resulted from the efficient uptake and metabolism of available S [39]. Thus, the application of S to soil at or above the CL will help to increase crop growth and productivity across the different soil types.

5. Conclusions

We conclude that application of S significantly increased shoot dry matter yield and S uptake of wheat over mustard irrespective of soils. Using the graphical method, the CL of available S for soil in wheat was found to be 13.5 mg/kg and for mustard 14 mg/kg. In the statistical method it was found 11.45 mg/kg for soil of both wheat and mustard, which was higher than the present CL (10 mg/kg soil). Critical plant tissue concentration of S was 0.14% for wheat and 0.35% for mustard at the specified growth period (i.e., 7 weeks) both in graphical and statistical approaches. The findings from this study can be used for updating fertilizer recommendation guides for efficient fertilizer application in Bangladesh. This study may also ensure that S fertilization would be crucial for getting a higher economic yield of mustard and sustainable soil S management below the specified level. However, future research should focus on validating the results from the present study in the actual field condition.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/su13158325/s1, Table S1. Soil available S, Bray's % yield and predictability values (R^2) of wheat plant, Table S2. Soil available S, Bray's % yield and predictability values (R^2) of mustard plant, Table S3. Soil available S, Bray's per cent yield and predictability values (R^2) of soil used for wheat cultivation, Table S4. Soil available S, Bray's percent yield and predictability values (R^2) of soil used for mustard cultivation.

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