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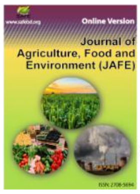

Original Article

Yield of four sugar beet genotypes in acidic soils with various soil amendments

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A B S T R A C T

Soil acidity is one of the crucial abiotic stresses that reduces crop yield. Proper tuning of soil pH is, therefore, utmost importance for successful crop production in acidic soil. A pot experiment was carried out at the experimental field of agronomy, Sylhet Agricultural University, Bangladesh to examine the yield of different sugar beet genotypes in response to various soil amendments in acidic soil. The treatment consists of four sugar beet genotypes viz., HI-0044, HI-0473, KWS-Allanya, and KWS-Serendara, and five soil amendments viz., without lime and fertilizers (T1), lime @ 1 t ha^{-1} $CaCO_3$ + inorganic fertilizer of recommended dose (RD) (T2), lime @ 1 t ha^{-1} $CaCO_3$ + compost @ 10 t ha^{-1} (T3), lime @ of 2 t ha^{-1} $CaCO_3$ + inorganic fertilizer of RD (T4), lime @ 2 t ha^{-1} $CaCO_3$ + compost @ 10 t ha^{-1} (T5). Based on growth pattern and yield performance, the cultivar HI-0044 showed the highest values for all the parameter measured followed by KWS-Allanya, and KWS-Serenada while HI-0473 was the worst performer. Soil amendments, T4 and T2 were found most effective while T1 was less effective in managing acidic soil to grow sugar beet. According to the results of the experiment, the maximum outputs were obtained by the genotype HI-0044 when soil amended with $CaCO_3$ @ both 1 and 2 t ha^{-1} along with the recommended rate of inorganic fertilizers. But $CaCO_3$ @ 1 t ha^{-1} was found the most suitable from an economic point of view.

Introduction

Sugar beet (*Beta vulgaris L.*) is the second important sugar crop after sugarcane which accounts for about 30% of world sugar production (Iqbal and Saleem, 2015). It is a biennial plant, comprising a period of vegetative growth, cold-induced vernalization and development of upright extended flowering stems for seed production. It develops a large succulent taproot in the first year and a seed stalk in the second year. However, under certain circumstances it can act as an annual crop (Smith, 1987). Typically, sugar beet is planted in spring and harvested in autumn of the same year. Beet root is the storage organ of sugar beet, of which 10% is derived from hypocotyls (Shrivastava *et al.*, 2013). Composition wise, a freshly harvested sugar beet root contains 15-20% sugar, 2.6% non-sugar and 4-6% pulp and the tops with 10% digestible crude protein are rich in carotene (1.4 – 6.2%), vitamin C and E (Brar *et al.*, 2015). Beet roots are processed into white sugar, pulp, and molasses. Byproducts of sugar beet industries are fed to animals, used in the production of yeast, chemicals, pharmaceuticals, polyethylene, methane, and hydrogen (Urbaniec and Grabarczyk, 2014; Tan *et al.*, 2015). In Bangladesh, sugarcane is the main sugar crop but only supply 25% (5% as sugar and 20% as jaggery) of the total demand of the country and the rest 75% are imported from abroad at the expense of foreign currency (Rahman *et al.*, 2016). Despite the government initiative to increase sugarcane production, farmers are gradually shifting from long-duration sugarcane to other short-duration crops for getting higher annual income (Parvez, 2016; Rahman *et al.*, 2016). Hence, the total area and production of sugarcane in Bangladesh are gradually reducing (BBS, 2019). Therefore, the cultivation of sugar beet could be an excellent alternative to ensure sugar production in Bangladesh. Sugar beet is a short-duration crop (5-6 months) that contains a higher amount of sucrose (14- 20%) compared to long-duration sugarcane (12-14 months) with low sucrose content (10-12%) (Ahmad *et al*., 2012). Although sugar beet is considered as a temperate crop, its cultivation is possible in subtropical countries like Egypt, Pakistan, Iran, Iraq, Bangladesh due to the development of new tropical sugar beet (TSB) varieties/genotypes (Islam *et al*., 2012; Brar *et al*., 2015; Bithy *et al*., 2020). In Bangladesh, Bangladesh Sugar Crop Research Institute (BSRI) is working on some tropical genotypes to recommend and cultivation of few of their suitable genotypes have already been confirmed in Bangladesh (Islam *et al*., 2012; Brar *et al*., 2015; Rahman *et al*., 2016; Paul *et al*., 2018; Bithy *et al*., 2020). All sugar beet genotypes are not equally potential in different environment and soil conditions (Babaee *et al*., 2013; Hossain *et al*., 2017a,b). The nitrification of fertilizer and minimizing the Al toxicity enhanced by the decrease of the soil pH associated with nitrification during vegetative growth of sugar beet, which reveals importance to avoid low values for the soil pH (Fueki *et al*., 2004). Soil pH is a master soil variable that influences myriads of soil biogeochemical properties and processes that affect plant growth, development, and biomass yield (Brady *et al*., 2008; Minasny *et al*., 2016). Low soil pH has adverse effects on soil fertility and decrease seedling emergence, root growth and crop yield as it creates toxicity of Al and/or Mn and the deficiency of essential nutrients such as Ca, Mg, P and Mo (Marschner, 2011). In Bangladesh, soil acidity is a major constraint to grow crops and about 30% of the land of the country has been characterize as acidic (BARC, 2018). Soils of Sylhet region are acidic (pH around 4.5) but the climate of the region is suitable for crop productions (Shaheb *et al*., 2014). Farmers in the Sylhet region usually use agricultural lime or dolomite for crop cultivation as liming reduce soil acidity, improves N fixation capacity and overall soil fertility status (Reddy and Subramanian, 2016). It also increases the availability of P, Mo, Ca, and Mg, reduces the toxic effect of Al, Fe and Mn, increase microbial activity (Kanyanjua *et al*., 2002; Rousk *et al*., 2010). Application of lime and organic fertilizer in acidic soil improve the soil properties for crop production by increasing the pH, organic matter, and availability of some essential nutrients (Ferdous, 2018). However, in developing countries for sustainable soil management liming is not economically feasible in a large scale as it increase the cost of production (Dai *et al*., 2017). Besides, high rate of lime application in acidic soil can decrease the availability of micronutrients, especially Fe, Mn, Zn and Cu and makes phosphate insoluble through combining with Ca and Mg (Fageria and Baligar, 2008; Murphy and Sims, 2012). So, an accurate rate of lime application in acidic soil or other alternative way of managing soil acidity is important to ensure proper nutrient availability of plants. Sugar beet is a promising stress tolerant crop against different abiotic stresses like drought, salinity (Babaee et al., 2013; Hossain *et al*., 2017a,b). However, still there is not enough information available on compatibility of sugar beet in acidic soil. So, the present study was undertaken to observe the growth and yield of four sugar beet genotypes (BSRI, Bangladesh recommended) in acidic soils under various soil amendments.

2. Materials and methods

2.1. Experimental site and weather

A pot experiment was conducted during November 2018 to April 2019 at the experimental field of agronomy, Sylhet Agricultural University, Bangladesh (24^{0}89'N, 91^{0}88'E). The area covers the north-eastern part of the country and belong to Agro Ecological Zone-20 named Eastern Surma-Kushiyara Floodplain and is characterized by a sub-tropical climate. Soil type belongs to Non-calcareous Grey Floodplain soils. Organic matter content of the soil is moderate, soil pH ranges from strongly acidic to neutral, levels of CEC and Zn are medium while the status of P, K and B is low (BARC, 2018). During the experimental period, the average maximum and minimum temperature of the area ranges from 27.9 to 32.4°C and from 13.8 to 21.4°C, respectively (Table 1a). The amount of rainfall was very low from November to January and then gradually increased to 326 mm in April. Relative humidity varied between 55 and 71% throughout study period and was the highest in November (71%) (Table 1a).

Table 1a. Weather data during the experimental period

Month	Maximum temperature (°C)	Minimum temperature (°C)	Rainfall (mm)	Relative Humidity (%)
November	30.2	18.5	8.2	70.0
December	28.1	15.4	5.0	70.0
January	27.9	13.8	0.0	57.0
February	28.3	15.7	45.2	57.0
March	31.1	19.1	46.9	55.0
April	32.4	21.4	326.0	62.0

Initial soil status in terms of organic matter and major nutrients are given in the Table 1b.

Table 1b. Nutrient status of the soil of experimental field

Characteristics	Value
OM (%)	1.54
N (%)	0.09
K (meq/100 g soil)	0.16
Ca (meq/100 g soil)	4.91
Mg (meq/100 g soil)	1.69
P (Bray) (mg kg^{-1})	0.28
Cu (mg kg^{-1})	0.21
Zn (mg kg^{-1})	0.81
Fe (mg kg^{-1})	1.64
Mn (mg kg^{-1})	0.28
S (mg kg^{-1})	8.5

(Source: SRDI, Sylhet, Bangladesh)

2.2. Treatments and experimental design

Four sugar beet genotypes viz., HI-0044 (G1), HI-0473 (G2), KWS-Allanya (G3), and KWS-Serendara (G4) were used in the experiment and were collected from BSRI, Bangladesh. To manage soil acidity and nutrients, five types of soil amendments viz., without lime and fertilizers (T1), lime @ 1 t ha^{-1} $CaCO_3$ + inorganic fertilizer of recommended dose (RD) (T2), lime @ 1 t ha^{-1} $CaCO_3$ + compost @ 10 t ha^{-1}, lime @ 2 t ha^{-1} $CaCO_3$ + inorganic fertilizer of RD (T4), lime @ 2 t ha^{-1} $CaCO_3$ + compost @ 10 t ha^{-1} were applied in this experiment. The RD of inorganic fertilizer for this region were 120-30-100-12-3.5-1.2 kg ha^{-1} for N-P-K-S-Zn-B, respectively (BARC, 2018). The experiment was laid out following Completely Randomized Design (CRD) with 5 replications. Thus, the total number of pots were 100 and the individual pot size was 24 cm (diameter) × 32 cm (depth). Two third portion of the pots were filled with 8 kg of thoroughly mixed soil. After seed sowing, the pots were relocated once in every week throughout the experiment.

2.3. Crop husbandry

The soil was sandy loam having fertility status low to medium with pH 4.9. To increase the soil pH, $CaCO_3$ @ 1 t ha^{-1} and 2 t ha^{-1} was thoroughly mixed with soil about two weeks before seed sowing. Due to the addition of $CaCO_3$ @ 1 t ha^{-1} and 2 t ha^{-1} the soil pH increased to 5.6 and 6.25, respectively. Fertilizers were applied as basal dose at final soil preparation. After liming soil was mixed thoroughly with compost (10 t ha^{-1}). Urea, Tripple super phos-phate (TSP), Muriate of Potash (MoP), Gypsum, Zinc Sulphate, and Boric acid were used as inorganic fertilizer source and one third of Urea and whole amount of TSP, MoP, Gypsum, Zinc Sulphate and Boric acid were applied as basal dose. The rest of urea was applied in two splits at 60 and 90 days after sowing (DAS). Two seeds were sown in each pot at three cm soil depth from the surface. The first irrigation was done just after seed sowing and the subsequent irrigation were done four times at 45, 70, 95 and 120 DAS. In case of heavy rainfall, the excess water was drained out properly to avoid root damage. To keep one plant per pot, thinning was done if both the seeds were germinated and gap filling were done if both the seeds were failed to germinate within 13 DAS. Sugar beet is susceptible to weeds at earlier stage until the sugar beet leaves provide shade over the ground. Hence, weeds were removed from the pot manually at 15, 30, 45 and 60 DAS. Dithane M 45 at the rate of 2.2 kg ha^{-1} and Score 250 EC 0.5 ml L^{-1} of water were used at 15 days intervals from 30 DAS by hand sprayer to control damping off and sclerotium root rot diseases. Durshban at the rate of 2.5 ml L^{-1} of water was applied for controlling cut warm, tobacco caterpillar and army warm.

2.4. Data collection

The data were collected on different growth and yield contributing characters viz. number of leaves (no. per plant), leaf chlorophyll content (relative unit), shoot length (cm), shoot dry weight (g), beet length (cm), beet girth (cm), beet dry weight (g), total dry matter (g) and total soluble solid (TSS) in beet (%). Data on plant growth behavior, yield contributing characters and yield were recorded following the guidelines described in tropical sugar beet production technology in Bangladesh (BSRI, 2013). Sugar beets attain the highest vegetative growth at 120 days after emergence (DAE) and provide the maximum yield at 165 DAE (Ferdous *et al*., 2015). So, all data were recorded at 165 DAE.

2.4.1. Physiological traits

2.4.1.1. Leaf chlorophyll content

Leaf chlorophyll content was determined using portable Soil Plant Analysis Development (SPAD) meter (SPAD-502, Minolta Camera, Tokyo, Japan) at five different points of eight fully expanded leaves in between 10:00 am to 12.00 pm.

2.4.1.2. Total soluble solid (TSS) of beet root (%)

TSS in beet roots were determined on a blended composite using a portable hand-held refractometer (ATAGO, MASTER-53α, Japan) at harvest from every beet root. The outer skin of sugar beet root was removed and sliced into small pieces by using a sharp knife. Then a drop of juice was extracted by using mortar and pestle and the juice was transferred into the prism of the refractometer. After closing the lid of the refractometer, measurement of TSS (%) was taken through observing by eyepiece.

2.4.2. Yield contributing characters

2.4.2.1. Total number of leaves plant^{-1}

Total number of leaves plant^{-1} were counted in every pot at 165 DAS.

2.4.2.2. Shoot length (cm)

Shoot (the petiole and leaf blade) length (cm) of every plant was measured from the base to the top of the leaf by a measuring scale.

2.4.2.3. Beet root length (cm) and girth (cm)

Beet root length (cm) and girth of every pot was measured by using a measuring scale and slide calipers. For beet root girth, three measurements were taken at the basal part, middle part and top part of the beet root and the average were recorded.

2.4.2.4. Dry matter at harvest

Shoot of each plants were separated, sun dried for several days and then oven-dried at 70º C for 24 hours to determine the dry weight (g plant^{-1}). Beet root of each plants was harvested, cleaned, cut into small pieces and sun dried for several days. After that, oven-dried to till constant weight at 70º C to determine the dry weight of beet root (g plant^{-1}). Total dry matter (g plant^{-1}) was computed by adding sugar beet shoot and root dry weight.

2.5. Statistical Analysis

Variation among the genotypes and fertilizer treatments were analyzed through two-way ANOVA. In case of significant effect, means were separated through post hoc test (using LSD value). Values were reported as significant at p-values <0.05. All the analysis was performed in R (R Core Team, 2014).

3. Results

3.1. Variation among the sugar beet genotypes

The sugar beet genotypes significantly varied for number of leaves plant^{-1}, leaf chlorophyll content, shoot length, shoot dry weight, beet root length, beet girth, beet root dry weight, total dry matter and TSS in beet root (Table 2). The highest values for leaf number (16.1), chlorophyll content (24.5) and beet root length (12.0) were found in the genotype HI-0044 (G1) while shoot length, shoot dry weight, beet root girth were highest but similar among the genotypes HI-0044 (G1), KWS-Allanya (G3) and KWS-Serenada (G4). Genotype HI-0044 (G1) and KWS-Allanya (G3) found better for beet root dry weight, total dry weight and TSS content in beet root (Table 2). Overall, the genotype HI-0473 (G2) gave lower values for all the parameters.

3.2. Effect of soil amendments on sugar beet performance in acidic soil

Different soil amendments significantly affected all the variables measured (Table 3). Soil amendments T4 and T2 gave highest chlorophyll content, shoot length, shoot dry weight, beet root length and girth, beet root dry weight and total dry matter content while number of leaves an TSS content of beet root were higher in T4 than others (Table 3). Overall, liming along with inorganic fertilizer showed better performance than liming along with organic fertilizer and without any fertilizer.

3.3. Genotypes performance in different soil amendments

The effects of soil amendments did not vary among the genotypes except leaf chlorophyll content, shoot dry weight, beet root dry weight and total dry matter (Table 4). Leaf chlorophyll content was highest in the combination of G1T2 which was statistically similar with the combination of T2G4, T4G1 and T4G4. The combinations of T2G1, T2G4 and T4G3 produced higher shoot dry weight than others while beet root dry weight was higher in the combinations of T2G1, T2G3, T4G1, T4G2 and T4G3. The total dry matter production was higher in the combination of T2G1, T2G3, T2G4 and T4G2 (Table 4). On the other hand, the lowest values for all the parameters were obtained in sugar beet genotype HI 0473 in combination with without lime and fertilizers (T1G1).

Table 2. Variation in crop characters, yield components, yield and quality of sugar beet in acidic soil among different genotypes (Here, G1*:* HI-0044, G2*:* HI-0473, G3: KWS-Allanya, G4: KWS-Serenada)

Genotypes	No. of leaves plant^{-1}	Chlorophyll content (r.u.)	Shoot length (cm)	Shoot dry weight (g plant^{-1})	Beet root length (cm)	Beet root girth (cm)	Beet root dry weight (g plant^{-1})	Total dry matter (g plant^{-1})	TSS (%) in beet root
G1	16.1±1.8a	24.5±2.1a	22.9±2.2a	66.9±8.9a	12.0±1.3a	9.6±0.9a	286.2±42.5a	353.1±51.1a	15.0±1.0a
G2	12.3±1.6c	17.2±1.3d	18.9±1.7b	60.1±10.1b	9.5±1.0c	8.8±0.9b	266.6±42.4c	326.7±52.1c	12.0±0.7c
G3	14.0±7.7b	21.6±2.4c	21.7±2.0a	67.2±9.9a	11.7±1.3ab	9.7±0.8a	285.5±42.6a	352.7±52.2a	14.2±1.0ab
G4	14.1±1.9b	22.8±2.5b	22±2.2a	66.4±8.1a	10.3±1.4b	9.5±0.9a	277.1±34.4b	343.5±41.0b	13.8±0.9bc
p-value	<0.001	<0.001	<0.001	<0.001	<0.001	0.017	<0.001	<0.001	<0.001

Table 3. Effect of soil amendments on the crop characters, yield components, yield and quality of sugar beet in acidic soil (Here, T1: Without lime and fertilizers, T2: Lime @ 1 t h^{-1} $CaCO_3$ + inorganic fertilizer, T3: Lime @ 1 t h^{-1} $CaCO_3$ + compost @ 10 t h^{-1}, T4: Lime @ 2 t h^{-1} $CaCO_3$ + inorganic fertilizer, and T5: Lime @ 2 t h^{-1} $CaCO_3$ + compost @ 10 t h^{-1})

Soil amendments	No. of leaves plant^{-1}	Chlorophyll content (r.u.)	Shoot length (cm)	Shoot dry weight (g plant^{-1})	Beet root length (cm)	Beet root girth (cm)	Beet root dry weight (g plant^{-1})	Total dry matter (g plant^{-1})	TSS(%) in beet root
T1	8.6±0.8e	15.3±1.4e	14.8±1.1c	39.1±5.6d	7.4±0.4c	7.1±0.4c	143.5±12.1d	182.5±16.4d	11.6±0.7c
T2	16.5±1.1b	26.2±2.0a	25.4±1.3a	85.8±4.7a	13.4±0.9a	11.2±0.4a	361.2±20.4a	445±24.7a	14.0±1.0b
T3	12.3±0.8d	21.2±1.1b	20.5±1.1b	47.0±2.5c	9.5±0.8b	8.6±0.6b	242.1±16.3c	289.1±18.3c	14.4±1.1ab
T4	18.6±0.9a	25.9±1.9a	25.5±1.4a	83.7±2.5a	13.9±0.7a	11.4±0.4a	365.8±19.6a	451.5±21.6a	15.1±1.0a
T5	15.4±1.0c	19.0±1.3c	20.7±1.0b	70.2±1.4b	10.2±0.9b	8.8±0.6b	281.6±5.6b	351.8±5.7b	13.6±0.6b
p-value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Table 4. Interaction effect of soil amendments and sugar beet genotypes on the crop characters, yield components, yield and quality of sugar beet in acidic soil (Here, G1: HI-0044, G2: HI-0473, G3: KWS-Allanya, G4: KWS-Serenada, T1: Without lime and fertilizers, T2: Lime @ 1 t h^{-1} $CaCO_3$ + inorganic fertilizer, T3: Lime @ 1 t h^{-1} $CaCO_3$ + compost @ 10 t h^{-1}, T4: Lime @ 2 t h^{-1} $CaCO_3$ + inorganic fertilizer, and T5: Lime @ 2 t h^{-1} $CaCO_3$ + compost @ 10 t h^{-1})

Genotypes x amendments	No. of leaves plant^{-1}	Chlorophyll content (r.u.)	Shoot length (cm)	Shoot dry weight (g plant^{-1})	Beet root length (cm)	Beet root girth (cm)	Beet root dry weight (g plant^{-1})	Total dry matter (g plant^{-1})	TSS (%) in beet root
T1G1	10.0±0.7	18.3±0.5fgh	16.9±1.1	45.9±0.4k	7.7±0.5	7.2±0.3	160.8±4.3e	206.7±4.1g	12.9±0.8
T1G2	7.0±0.4	12.3±0.7fgh	12.8±0.6	21.2±0.4m	7.0±0.3	6.2±0.3	101.0±0.7f	122.2±1.0h	10.2±0.5
T1G3	9.0±0.7	15.7±1.8k	14.9±0.5	42.8±0.8kl	7.3±0.3	7.6±0.2	158.8±4.6e	201.6±5.3g	11.3±0.6
T1G4	8.3±0.8	14.7±0.5ij	14.7±1.4	46.4±6.2jk	7.7±0.3	7.5±0.5	153.3±6.4e	199.6±3.2g	12.0±0.6
T2G1	18.7±0.9	30.0±0.9a	27.0±1.8	93.9±0.9a	14.3±0.8	11.5±0.7	391.5±1.5a	485.4±0.7a	15.0±0.9
T2G2	14.0±1.1	19.3±0.5efg	22.3±0.8	68.7±0.5gh	11.2±0.9	10.8±0.2	291.1±3.8b	359.8±3.7cd	11.7±0.6
T2G3	16.0±0.4	27.3±0.5b	26.1±0.8	88.3±0.5bc	13.8±0.4	11.1±0.4	391.8±2.7a	480.1±2.9ab	14.7±0.8
T2G4	17.3±1.0	28.3±0.6ab	26.2±0.7	92.1±1.0ab	14.4±0.7	11.5±0.5	386.5±10.3a	478.6±9.8ab	14.7±1.1
T3G1	14.0±0.4	23.7±0.8c	21.3±1.6	44.2±1.4kl	11.1±0.9	8.6±0.5	207.6±4.8d	251.7±5.6f	16.3±1.0
T3G2	10.7±0.9	18.3±0.4fgh	18.5±0.3	52.5±1.0i	8.5±0.2	7.8±0.6	275.8±7.6c	328.3±6.6e	12.1±0.8
T3G3	11.7±0.7	20.3±0.7def	20.6±1.0	40.8±0.6l	9.1±0.7	8.8±0.6	208.5±1.3d	249.2±1.3f	15.3±0.9
T3G4	12.7±0.5	22.3±0.7cd	21.4±0.8	50.7±1.8ij	9.3±0.8	9.1±0.6	276.6±4.5c	327.3±4.0e	14.0±0.6
T4G1	20.3±0.7	29.0±0.6ab	27.7±1.6	81.2±0.6d	14.7±0.6	11.8±0.6	386.1±4.7a	467.4±4.9b	16.7±0.6
T4G2	16.0±0.4	19.3±0.2efg	22.1±0.7	86.0±0.5c	12.3±0.3	10.9±0.3	386.5±1.1a	472.5±1.4ab	13.3±0.5
T4G3	19.0±0.5	27.0±1.4b	26.2±0.7	90.9±0.5ab	13.9±0.3	11.3±0.3	386.1±1.7a	477.0±2.2ab	15.3±1.1
T4G4	19.0±0.8	28.3±0.6ab	26.2±1.3	76.7±0.7e	14.5±0.9	11.5±0.5	288.6±4.2bc	365.3±4.0c	15.0±1.0
T5G1	17.3±0.4	21.3±0.6cde	21.7±0.5	69.1±0.7fgh	12.0±0.7	9.1±0.6	285.2±5.0bc	354.3±5.4cd	14.3±0.5
T5G2	13.7±0.7	16.7±0.7hij	18.8±1.2	71.9±0.6fg	8.6±0.5	8.3±0.6	278.6±6.9bc	350.5±7.0d	12.8±0.3
T5G3	14.3±1.0	17.7±1ghi	20.7±0.6	73.3±0.7ef	9.5±0.7	8.8±0.6	282.3±4.1bc	355.5±4.5cd	14.2±0.3
T5G4	16.3±0.7	20.3±1.4def	21.6±1.2	66.4±0.7h	10.6±0.8	9.0±0.6	280.6±7.2bc	346.9±6.8d	13.2±0.9
p-value	0.82	<0.001	0.97	<0.001	0.37	0.99	<0.001	<0.001	0.82

3.4. Root-shoot ratio (RSR)

The sugar beet root dry weight was more than 4 times higher than shoot dry weight across all the treatments (Table 2). However, the RSR varied significantly ($p<0.05$) among the genotypes and soil amendments (Figure 1). Overall, genotypes and soil amendment T3 (1 t ha^{-1} and 10 t compost ha^{-1}) showed higher RSR (Figure 1). Considering the RSR data along with shoot dry weigh and beet root dry weight data, it was revealed that the biomass translocation was higher in genotypes and soil amendments which produced lower total dry matter (Table 2, 3 and Figure 1).

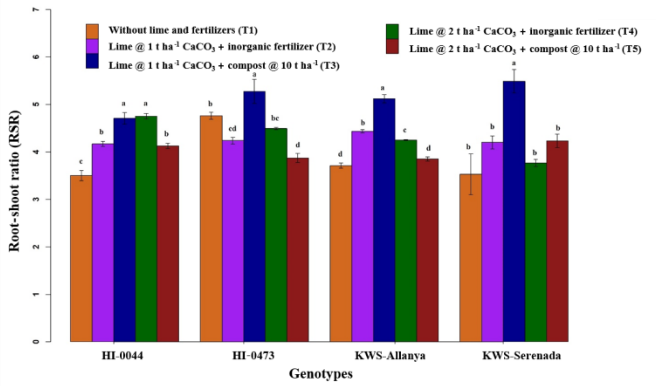

Figure 1: Variation in root-shoot ratio (RSR) of sugar beet among the genotypes and soil amendments

5. Discussion

Considering the growth and yield attributes, all the sugar beet genotypes highly responded to inorganic fertilizers than organic fertilizers. Among the sugar beet genotypes, HI-0044 showed the highest performance (Table 2). Similar reflection was also observed in the case of the soil amendments in T4 (lime @ 2 t ha^{-1} $CaCO_3$ with inorganic fertilizer) followed by T2 (liming @ 1t ha^{-1} $CaCO_3$ with inorganic fertilizer) (Table 3), and interaction in T2G1 (Table 4). So, the recommended rate of inorganic fertilization was found more effective to the productive growth and yield of the sugar beet genotypes. Kashem *et al*. (2015) explained that the combination of 150 kg N ha^{-1} and 180 kg K ha^{-1} was found beneficial to increase photosynthesis, metabolites translocation efficiency from leaves to developing roots and to attain the maximum total dry matter production. In addition, Monreal *et al*. (2007) reported that K plays a vital role in enhancing root length, diameter as well as root fresh weight of sugar beet by enhancing metabolites and activation of carbohydrate accumulating enzymes. Few studies opined that recommended rate of P fertilizer effectively increased photosynthesis while S fertilizer was found to control soil pH, improving soil properties to absorb more nutrients for maximum root growth (Ferweez *et al*., 2011; Awad *et al*., 2012; Awad *et al*., 2013). Foliar application of micronutrients especially, Zn is effective to increase root weight which attributes to increasing photosynthesis and cell division (Kashem *et al*., 2015). All the findings agree with the result of the present experiment where soil amendment with inorganic fertilizer was found more effective to both vegetative growth and reproductive yield of the sugar beet genotypes. In the contrary, compost releases different nutrients in variable amounts in a slower rate compare to inorganic fertilizer (Pan *et al*., 2009; Geng *et al*., 2019). Hence, the yield of sugar beet might be less with organic fertilizer.

The higher yield in soil amendments with inorganic fertilizer might be attributed to the rapid dissociation of inorganic fertilizer into available plant nutrients to which sugar beet is highly sensitive (Prasad *et al*., 2016). The result might be described as, dolomite is effective in alleviating soil acidity with the presence of basic cations (Ca^{2+} and Mg^{2+}) and anions (CO_3^{2-}). The ions are able to exchange H^+ from exchange sites and form H_2O + CO_2. The cations are also involved in improving CEC, nitrogen fixation, availability of essential nutrients (Ca, P, Mo) and decreasing the solubility of toxic elements viz. Al, Mn etc. which are highly beneficial for growth and development of sugar beet(Cifu *et al*., 2004; Caires *et al*., 2008). In spite that liming the soil at the rate of 2 t ha^{-1} (both in organic and inorganic fertilization) was found comparatively less effective on beet root yield than liming the soil at the rate of 1 t ha^{-1}. It might be due to Zn and P deficiency induced by excessive liming of acid soil which affected leaf chlorophyll content and beet root yield of sugar beet (Buni, 2014). However, the increased cation content through higher rate of lime application might be associated with the increase in water content of roots as well as the reduction of sucrose concentration and dry weight of beet root (Follett, 1991; Hilal, 2005). Although beet root development started at the same time in all genotypes, the highest beet root yield was obtained by HI-0044. It might be attributed to the higher chlorophyll content in HI-0044 as reported in other studies. Sanghera *et al*. (2016) and Özbay and Yildirim (2018) confirmed that higher leaf chlorophyll content and carbohydrate accumulation results in enhancing length, diameter, TSS% as well as fresh weight and dry weight of beet root. Here, the higher TSS content was recorded in genotype HI-0044 and T4 which was associated with lime and inorganic fertilizer. Hamed and Soliman (2016)found that application of organic manure significantly affected sucrose percentage of sugar beet but Dubas *et al*. (1970)concluded that organic manure did not influence sugar percentage of beet root. The result of the experiment indicated that the lowest growth and yield attributes were obtained from the sugar beet genotypes grown in a plot without lime and fertilizers. It might be due to poor root penetration in strongly acidic soil with the sign of discolored, fibrous lateral roots (Meyer and Wood, 1976). While liming of the soil was found effective in increasing the growth and yield attributes of the sugar beet genotypes.

6. Conclusion

This study has shown that tropical sugar beet genotypes viz. HI-0044, HI-0473, KWS-Allanya, KWS-Serenada can be grown in Sylhet. The cultivar, HI-0044 was the best performer in all cases of growth and yield attributes. While the lowest performance was recorded in HI-0473. Among the soil amendments, liming @ 2 t ha^{-1} with the recommended rate of inorganic fertilizer had the best positive effect on most of the growth and yield contributing characteristics of the sugar beet genotypes. The interaction effect among the sugar beet genotypes and soil amendments indicated that, HI-0044 along with liming @ 1 t ha^{-1} with the recommended rate of inorganic fertilizer was the best combination for production purpose and was the most suitable from an economic point of view**.**

Author contributions

SA and MSH conceptualized the idea, developed the experimental design, and supervised the whole experiment. SA conducted the experiment, did all measurements, and collected data. MR analyzed the data and prepared the figure. MSH, MR, PM and SA wrote the manuscript. MH, MNHM, MMI and MKH helped in experimentation. All authors read, edited and approved the final version of the manuscript. MSH contributed as team leader throughout the work.

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of interest. The author and co-authors fully declare that we have duly followed the journal's criteria in the instructions for authors and confirmed to all ethical standards.

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