Bulgarian Journal of Agricultural Science, 28 (No 1) 2022, 76–88

Assessment of yield performance and related attributes of selected soybean (*Glycine max* L. Merrill) genotypes in southwest coastal region of Bangladesh

Bornali Saha and Md. Matiul Islam*

Khulna University, Khulna 9208, Bangladesh
**Corresponding author:* matiul_rubel@ku.ac.bd

Abstract

Saha, Bornali & Matiul Islam, Md. (2022). Assessment of yield performance and related attributes of selected soybean (*Glycine max* L. Merrill) genotypes in southwest coastal region of Bangladesh. *Bulg. J. Agric. Sci., 28 (1)*, 76–88

The experiment was conducted at the Agronomy Laboratory and Field Laboratory of Agrotechnology Discipline, Khulna University, Khulna, during the period of February to May 2021 under the agro-ecological zone: AEZ-13 (Ganges Tidal Flood Plain). Ten soybean genotypes (varieties) have been released in Bangladesh *viz*. BD-4, Sohag, BARI Soybean-5; BARI Soybean-6, BINA Soybean-1, BINA Soybean-2, BINA Soybean-3, BINA Soybean-4, BINA Soybean-5 and BINA Soybean-6. All of them were selected for the study. The Agronomy laboratory experiment was carried out to evaluate the performance of selected soybean varieties under 5 different salinity treatments (0 dS m^{-1}, 2 dS m^{-1}, 4 dS m^{-1}, 8 dS m^{-1} and 16 dS m^{-1}) with 3 replications. In laboratory experiment, conducted following Completely Randomized Design (CRD), BINA Soybean-6 showed highest germination rate (100%), longest root length (19.12±0.91 cm) and highest number of lateral roots per seedling (10.53±0.35), while BINA Soybean-2 produced maximum fresh weight (0.53±0.05 g) and dry weight (in 0 dS m^{-1}, 2 dS m^{-1} and 4 dS m^{-1} treatments) per seedling. The field experiment was laid out in a simple randomized design. Each plot size was (3×2.5) m^2. Significant variation was found among the varieties in respect of observed parameters. BARI Soybean-6 showed the tallest plant height (50.2±1.44 cm) and highest number of nodes (11.8±0.33) per plant while BINA Soybean-3 produced highest number of leaves per plant (22.9±1.02). Highest pod-shell weight (10.09±0.86 g) was recorded in BINA Soybean-5. BINA Soybean-5 also produced highest number of pods (64.1) and seeds (146.4) per plant while the maximum stem dry weight (8.46±1.05 g) was recorded in BINA Soybean-4. The highest number of branches per plant (4.6) and highest 100-seed weight (13.15 g) was recorded in BINA Soybean-2. Highest seed yield per plant was observed in BINA Soybean-5 (14.302 g) followed by BINA Soybean-2 (14.225 g) while BINA Soybean-6 produced the lowest seed yield (8.495 g) and showed inferior yield attributes. BD-4 was the early matured variety and required 101 days to attain maturity while BINA Soybean-2 and BINA Soybean-5 required 106 days to mature fully. Among the selected ten varieties, BINA Soybean-2 and BINA Soybean-5 showed superior performances than other varieties. Moreover, BINA Soybean-2 performed comparatively better than BINA Soybean-5 under different levels of salinity stresses. Hence, BINA Soybean-2 was the most appropriate genotype for better yield and other performances in the salinity affected southwest coastal region of Bangladesh.

Keywords: soybean; genotypes; salinity; yield contributing attributes; performance

Introduction

The Soybean (*Glycine max* L. Merrill) is a species of legume native to East Asia, widely grown for its edible bean that has numerous uses. It is an annual plant of the family Fabaceae which is capable of adding nitrogen into the soil. The UN Food and Agricultural Organization (FAO) classified soybean as an oilseed rather than a pulse. Soybean cultivation is successful in climates with hot summers, with optimum growing conditions in mean temperatures of 20°C to 30°C. They can grow in a wide range of soils, with optimum growth in moist alluvial soils with good organic matter content. It is the most popular oil crops in Bangladesh, however, grown in scanty arable area. Out of the total cropped areas of 38.14 million acres, oil crops occupy about 1.18 million acres land and the total oilseed production of the country stands at 0.97 million tons. Out of total oil copped area, Soybean occupied about 0.151 million acres land and production of soybean was around 0.105 million tons per year (BBS, 2020).

The benefits of soybean are countless. It contains about 42-45% protein and 22% edible oil (Mondal et al., 2001). Moreover, it contains minerals such as Fe, Cu, Mn, Ca, Mg, Zn, Co, P and K. Vitamins B1, B2 and B6 are also available in soybean grains (Messina, 1997). Soybean oil is rich in polyunsaturated fatty acids, including the two essential fatty acids: linoleic and linolenic (Khan et al., 2015). It serves as source of food and feed for human and animal, respectively.

According to the April 2021 projection of the United States Department of Agriculture (USDA), Bangladesh's current yearly demand for soybean oil stands at 1.3 million tons and that of palm oil 1.6 million tons. Bangladesh is heavily dependent on import to meet its oils and fats requirements. With 0.8 million tons of yearly crude soybean oil imports, Bangladesh stands behind only India and China among top oil and oilseed importing countries. Each year, Bangladesh pays a whooping import bill of 2 billion dollars to meet its edible oil needs (Dhaka Tribune, 2021).

Bangladesh is a plain land with little exceptions in the southeast and southwest regions. The Khulna University of Bangladesh is situated in the southwest coastal region adjacent to the Sundarbans: the largest single-stand mangrove forest of the world. The southwest coastal region is featured with soil salinity (range: 2-20 dS m^{-1}) problems and prolonged drought in the dry season. The rice based cropping pattern has been found the most important cropping system in our country. The farmers of this locality grow only transplanted rice (locally known as Aman rice) in the rainy season (subsequent 3-4 months of August/September) and sesame in the following season in the cropping pattern. The land in the winter season remains fallow due to increased soil salinity problem (characterized by lack of soft irrigation water). As a result the cropping intensity of the coastal areas (134%) (BBS, 2018) is far below than the national average (197%) (BBS, 2020). As such condition, short duration crop like soybean can easily be fit as a cash crop between major cropping seasons to increase the cropping intensity of coastal areas. Farmers of southwest coastal region can get more profit through minimal investment from soybean cultivation. It is a short-durated crop and seed sowing can be done after harvesting of Aman rice to mid-February.

Soybean varieties that are released in Bangladesh by Bangladesh Agricultural Research Institute (BARI) and Bangladesh Institute of Nuclear Agriculture (BINA) are salinity tolerant, high yielding, short-durated and to some extent insect-pest and disease resistant. Anybody can find the soybean seeds being sold in the local markets of southwest coastal areas as it is very popular as an ingredient of poultry, fish and ruminant feeds. However, nobody will find a soybean field here in the arable places, though there is ample suitability of soybean cultivation herein. Thus, soybean may be a potential crop for the southwest coastal region to utilize the fallow land during winter and to increase the cropping intensity. However, the research in this line is highly scarce in Bangladesh and the entire released soybean varieties are not yet assessed for yield performance in the salinity affected coastal area. Thus by the outcome of this research, the farmers of southwest coastal area will find a high yielding soybean variety for potential cultivation which will contribute to increase the cropping intensity of this locality, ultimately adding increased production to national target.

Therefore, the specific objectives of the study were:

i. Evaluation of soybean germplasms available in Bangladesh and identification of suitable soybean genotype for salinity affected coastal area.
ii. Yield performance assessment of selected soybean genotypes in the southwest coastal area.

Materials and Methods

A laboratory experiment was carried out in the Agronomy Laboratory of Agrotechnology Discipline, Khulna University to evaluate the performance of selected ten soybean varieties under 5 different salinity treatments (T1= 0 dS m^{-1}, T2= 2 dS m^{-1}, T3= 4 dS m^{-1}, T4= 8 dS m^{-1}, T5= 16 dS m^{-1}) with 3 replications. Saline solutions were prepared using extra pure NaCl salt. The salinity concentration was adjusted using a conductivity meter. The laboratory experiment was laid out following standard procedure of Complete Randomized Design (CRD). The soybean seeds were placed for ger-

mination test in paper towel method. 20 seeds of each variety were placed in a particular petridish. Total petridish number was 150. The experiment was set on February 4, 2021. Number of seed germination was counted after 3 and 5 days after experiment setting to measure the germination rate of the varieties. Besides root length (cm), number of lateral roots per seedling and fresh weight per seedling (g) were recorded after 10 days of experiment setting. The seedling samples were oven dried at 70ºC for 42 hours to measure the dry weight (g). The collected data were statistically analyzed with the help of Statistix 10.0 software for different statistical measures (i.e., mean, standard deviation, standard error of mean, range, etc.) and for Tukey HSD Test ($P < 0.05$).

The field experiment was conducted at the Field Laboratory of Agrotechnology Discipline, Khulna University, Khulna, Bangladesh during the period of February to May, 2021 (in the late *Rabi* season; October 16 – March 15). The experimental area was located under the agro ecological zone: AEZ-13 (Ganges Tidal Flood Plain) which occupies about 49% of coastal areas and soils of that area are mostly calcareous to non-calcareous, silty clay loam to clay in texture, grey to dark grey in color and salinity affected (Ahsan & Bhuiyan, 2010). In February 2021, during seed sowing of soybean, the average temperature of Khulna varying between 30.7°C to 18.3°C with an average relative humidity of 47%. Whereas during the harvesting period (May 2021), the average temperature varying between 35.5°C to 27.7°C and average relative humidity was 67% (Weather Forecast Khulna, Bangladesh, 2021). On the basis of Soil Resource Development Institute (SRDI) report in 2018, the soils of the experimental site is characterized by pH 6.4-7.9; organic matter content 0.54-2.42%, nitrogen (N) content 0.027-0.121%, phosphorus (P) content 0.13-90.65 ppm, potassium (K) content 0.20-0.42 meq $100g^{-1}$ soil (SRDI, 2018). Besides the salinity range is 0.3-70 dS m^{-1} (SRDI, 2010). Ten soybean varieties released in Bangladesh viz. V1 (BD-4), V2 (Sohag), V3 (BARI Soybean-5); V4 (BARI Soybean-6), V5 (BINA Soybean-3), V6 (BINA Soybean-5), V7 (BINA Soybean-1), V8 (BINA Soybean-2), V9 (BINA Soybean-4), and V10 (BINA Soybean-6) were selected for the study. The experiment was laid out in a simple randomized way. The unit plot size was 3 m × 2.5 m with a distance of 1 m between the plots where the varieties were allotted randomly to the ten particular plots. The land was prepared properly by deep ploughing and cross ploughing followed by laddering. Urea, Triple Super Phosphate (TSP) and Muriate of Potash (MoP) were applied in the field uniformly at the rate of 60-175-120 kg ha^{-1} respectively, in two split doses recommended by BARI *Krishi Projukti Hatboi* (Agricultural Technology Handbook) [2019, 8th edition]. Half of fertilizer was applied during final land preparation and another half was applied during earthing up. The seeds were sown on 2nd February, 2021 with 70 cm distanced lines maintaining 15 cm plant to plant distances (10 plants m^{-2}) (Islam et al., 2016). Seeds were treated with Vitavax [Carboxin 37.5% + Thiram 27.5% DS (antifungal seed treating agent)] before sowing. Seed sowing was done at 5-6 cm soil depth and 4 seeds were sown in each pit. Thinning was done after 22 days after sowing (DAS) when the first trifoliate leaf appeared. Earthing up, weeding, irrigation and other intercultural operations were done properly when required. Ten plants were selected randomly from each plot during the full bloom stage (at 60 and 70 DAS) and at the full seed stage of soybean plants (at 90 and 100 DAS) to measure plant height (cm), number of leaves per plant, number of flowers per plant, number of nodes per plant, number of branches per plant and number of pods per plant. Harvested plants were kept in room temperature for few days to become air dried at room temperature. Yield attribute were measured following Islam et al. (2017). After drying properly, ten plants from each variety were randomly selected to collect data on stem height (cm), stem weight (g), pod-shell weight per plant (g), number of pods per plant, number of seeds per plant, seed yield per plant (g), 100 seed weight (g) [i.e., seed size], number of nodes per plant and number of branches per plant. The collected data were statistically analyzed with the help of Statistics 10.0 software for different statistical measures and for Tukey HSD Test ($P < 0.05$).

A total of 10 soybean varieties have been released in Bangladesh, 4 [(a) to (d)] from Bangladesh Agricultural Research Institute (BARI) and 6 [(e) to (k)] from Bangladesh Institute of Nuclear Agriculture (BINA). Some important features of these selected ten soybean varieties are presented below:

(a) BD-4

This variety was released in 1994 by the Bangladesh Agricultural Research Institute (BARI). Plant height 60-65 cm. Seeds are greenish yellow and smaller in size. 1000 seeds weight: 60-70 g. Seeds have high germination percentage and tolerant to YMV. Crop duration: 85-95 days (in *Kharif* season; March 16 – 15 October) and 120 days (in *Rabi* season; October 16 – March 15). Yield: 1.5-2.2 t ha^{-1}.

(b) Sohag

It was developed by BARI and released in 1991. Plant height: 50-60 cm. Protein: 40-45%; Oil: 21-22%. Tolerant to YMV. 100 seed weight: 11-12 g. Seed color is bright yellow and comparatively large size. Crop duration: 100-110 days (in *Rabi* season) and 90-100 days (in *Kharif* season). Yield: 1.5-2 t ha^{-1}.

(c) BARI Soybean-5

This variety was developed by BARI and released in 2002. Plant height: 40-60 cm. Seed size is slightly smaller than Sohag but larger than BD-4. 100 seeds weight: 9-14 g. Crop duration: 90-100 days. Yield: 1.6-2.0 t ha^{-1}.

(d) BARI Soybean-6

This variety was developed by BARI and released in 2009. Plant height: 50-55 cm. Nor of pods per plant: 50-55, Pod length: 3-3.5 cm, Maximum seeds per pod: 2-3, and 100 seed weight: 10-12 g. Single seed contains about 20-21% oil and 42-44% protein. Crop duration: 100-110 days. Yield: 1.80-2.10 t ha^{-1}.

(e) BINA Soybean-1

This variety was released by the Bangladesh Institute of Nuclear Agriculture (BINA). It can tolerate up to 8 dS m^{-1} salinity and moderately resistant to YMV. Plant height: 48-57 cm; no of primary branches: 3-5 and no of pods per plant: 45-60. Seeds are medium in size and 100 seed weight: 11.5-13.0 g. Protein: 44.5%, Oil: 18% and CHO: 27%. Crop duration: 105-110 days (in *Rabi* season) and 95-105 days (in *Kharif*-2 season; July 1 – 15 October). Yield: 2.4-2.7 t ha^{-1} (in *Rabi* season) and 2.5-3.0 t ha^{-1} (in *Kharif*-2 season).

(f) BINA Soybean-2

This variety can tolerate up to 12 dS m^{-1} salinity and highly resistant to YMV. Plant height: 27-35 cm (in *Rabi* season) and 35-42 cm (in *Kharif*-2 season). No of primary branches: 3-5 and no of pods per plant: 30-60. Seeds are larger in size, yellow in color and 100 seed weight: 13.0-13.8 g. Protein: 43%; Oil: 18% and CHO: 27%. Crop duration: 95-105 days (*Rabi* season) and 110-115 days (*Kharif*-2 season). Yield: 2.4-2.8 t ha^{-1} (in *Rabi* season) and 2.7-3.3 t ha^{-1} (in *Kharif*-2 season).

(g) BINA Soybean-3

It can tolerate up to 6 dS m^{-1} salinity and moderately resistant to YMV. Plant height: 62-70 cm. No of primary branches: 3-5 and no of pods per plant: 50-60. Seeds are medium in size and 100 seed weight: 12-13 g. Protein: 42.5%; Oil: 20% and CHO: 26%. Crop duration: 110-115 days (in *Rabi* season) and 105-110 days (in *Kharif* season). Yield: 2.5-3.2 t ha^{-1} (in *Rabi* season) and 2.4-3 t ha^{-1} (in *Kharif* season).

(i) BINA Soybean-4

It can tolerate up to 8 dS m^{-1} salinity and moderately resistant to YMV. Plant height: 35-42 cm. No of primary branches: 3-5 and no of pods per plant: 45-55. Seeds are larger in size and 100 seed weight: 13.8-14.3 g. Protein: 43.5%; Oil: 19% and CHO: 27%. Crop duration: 115-120 days (in *Rabi* season) and 110-115 days (in *Kharif*-2 season). Yield: 2.4-2.7 t ha^{-1} (in *Rabi* season) and 2.5-3.0 t ha^{-1} (in *Kharif*-2 season).

(j) BINA Soybean-5

It can tolerate up to 6 dS m^{-1} salinity and moderately resistant to YMV. Plant height: 55-60 cm. No of primary branches: 3-5 and no of pods per plant: 45-60. Seeds are medium in size and 100 seed weight: 13-13.8 g. Protein: 43.5%; Oil: 16.2% and CHO: 26%. Crop duration: 105-115 days (in *Rabi* season) and 95-108 days (in *Kharif* season). Yield: 2.4-3.0 t ha^{-1} (in *Rabi* season) and 2.5-3.3 t ha^{-1} (in *Kharif* season).

(k) BINA Soybean – 6

It can tolerate up to 12 dS m^{-1} salinity and moderately resistant to YMV. Plant height: 55-63 cm. No of primary branches: 2-4 and no of pods per plant: 46-60. Seeds are medium in size and 100 seed weight: 11-13.5 g. Protein: 44%; Oil: 20% and CHO: 27%. Crop duration: 95-105 days (in *Rabi* season) and 110-115 days (in *Kharif*-2 season). Yield: 2.5-3.1 t ha^{-1} (in *Rabi* season) and 2.6-3.2 t ha^{-1} (in *Kharif*-2 season).

Results and Discussion

(A) Laboratory Experiment Analysis

Germination rate

The seed germination rate of ten soybean varieties at 3 days after experiment setting showed significant variation among them for 5 different salinity treatments (Figure 1). Under T4 (8 dS m^{-1}) the highest seed germination was observed in BINA soybean-6 (20±0) followed by Sohag (19.33±0.66) which was statistically similar to BINA soybean-2 (18.66±0.33). These genotypes also maintained higher germination rate under T1 (0 dS m^{-1}), T2 (2 dS m^{-1}) T3 (4 dS m^{-1}) and T5 (16 dS m^{-1}). The lowest seed germination under T5 (16 dS m^{-1}) was recorded in BINA soybean-1 (11±1.52) followed by BINA Soybean-3 (13.66±0.33) which was statistically similar to with BINA soybean-5 (14.66±0.33). These three varieties didn't perform well under 0 dS m^{-1}, 2 dS m^{-1} and 4 dS m^{-1} and always showed lowest germination rate than other varieties. The dissimilarity in germination rate among varieties might be attributed due to the variations in salinity tolerance and genotypic constituents.

All the varieties attained their maximum germination at 5 days after experiment setting (Figure 2). During this

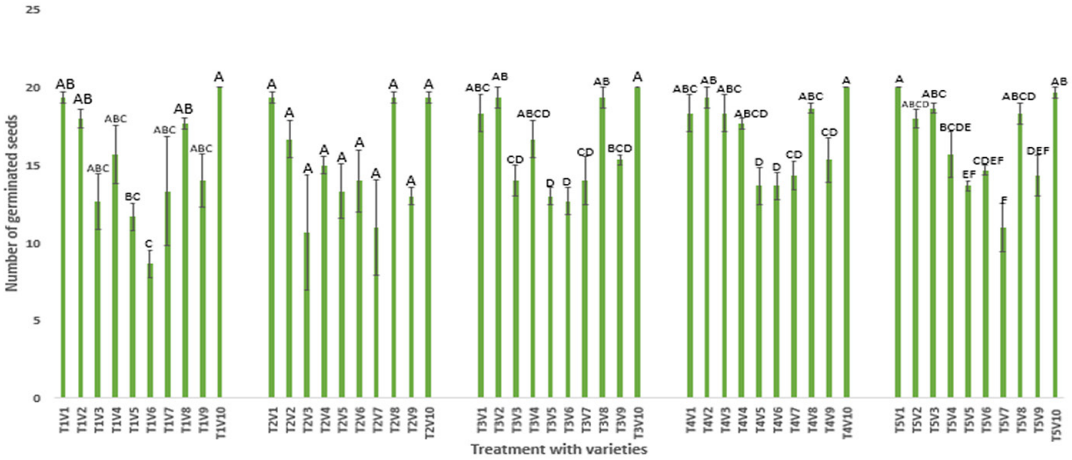

Fig. 1. Variation in germination rate of soybean genotypes at 3 DAS under different salinity level

period the highest seed germination under T1 (0 dS m^{-1}) was observed in BINA soybean-6 (20±0) followed by BD-4 (19.66±0.33) which was statistically similar with BARI Soybean-5 (19.66±0.33) and BARI Soybean-6 (19.66±0.33). On the other hand, the lowest numbers of germinated seeds were counted in BINA Soybean-3 (17±0.57) that was statistically similar with BINA soybean-4 (17.66±0.88). In case of severe salinity T5 (16 dS m^{-1}), the number of seed germination ranged from 20.00 to 16.66. The highest germinated seeds were counted in BD-4 (20±0) and BARI Soybean-5 (20±0) which was statistically similar with BINA soybean-6 (19.66±0.33). In contrast, the lowest seed germination was found in BINA soybean-4 (16.66±0.33); BINA soybean-5 (18±0.57) and BINA Soybean-3 (18.33±0.66). Other varieties showed intermediate results in respect to highest and lowest values for all the salinity treatments.

Root Length

Significant variation was found among different varieties in average root length (cm) under five different salinity levels (Figure 3). Longest roots were produced in all varieties under control environment (0 dS m^{-1}) because the root growth was not affected by salinity. In T1 (0 dS m^{-1}) the average root length ranged from 19.12 cm to 11.07 cm where the longest root length was observed in BINA soybean-6 (19.12±0.91 cm) which was statistically similar with BD-4 (18.68±1.52 cm) and BINA soybean-1 (18.28±5.15 cm). Root growth declined gradually in all the varieties with the increase of saline concentration and produced shortest roots under both T4 (8 dS m^{-1}) and T5 (16 dS m^{-1}). Under severe salinity T5 (16 dS m^{-1}) average root length ranged from 12.907 cm to 6.59 cm. The longest root was produced by BINA soybean-4 (12.90±0.52 cm) which was statistically similar to BINA soybean-2 (12.51± 0.61 cm) and BINA soybean-6 (11.90±0.56 cm). The shortest

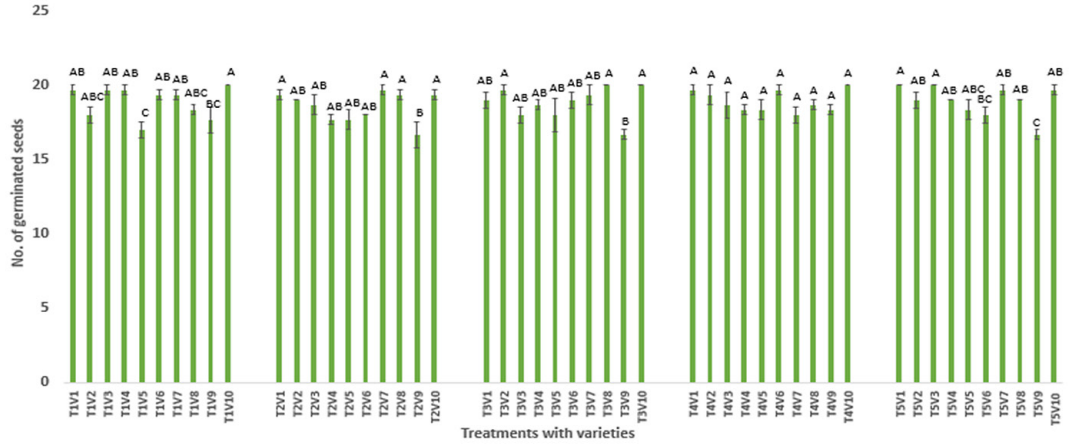

Fig. 2. Variation in germination rate of soybean genotypes at 5 DAS under different salinity level

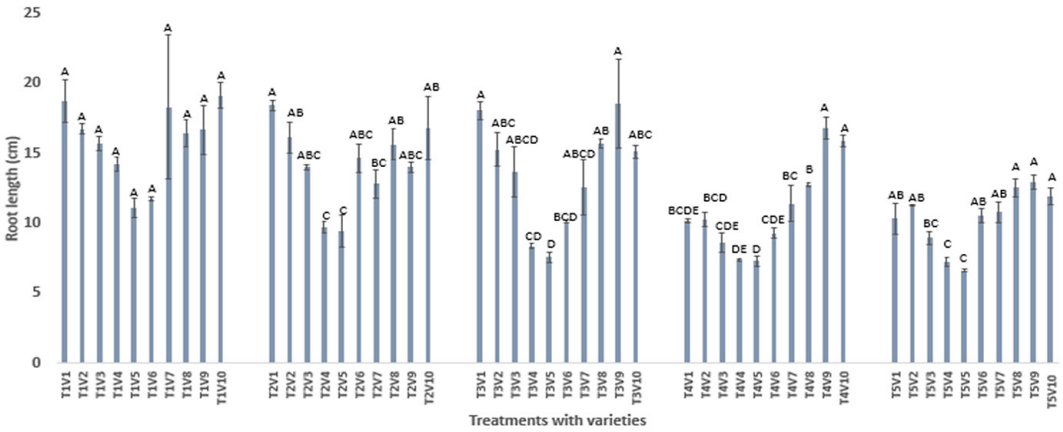

Fig. 3. Variation in root length (cm) of soybean genotypes under different salinity level

root length was observed in BINA Soybean-3 (6.59±0.08 cm) and BARI Soybean-6 (7.24±0.31 cm). Both BINA Soybean-3 and BARI Soybean-6 produced shortest roots under all the treatments. Slightly better performance of soybean varieties in root growth was observed under T2 and T3 than T4.

Number of lateral roots per seedling

The number of lateral roots seedling^{-1}varied among the soybean genotypes at different salinity treatments (Figure 4). Under T1 (0 dS m^{-1}) the highest no of lateral roots seedling^{-1}was observed in BD-4 (15.88±1.33) which was statistically similar with BARI Soybean-5 (13.31± 0.43) and Sohag (12.98±0.49) whereas the lowest no of lateral roots seedling^{-1}was recorded in BINA Soybean-3 (9.06±0.43). The lateral roots production gradually decreased in T2, T3, T4 and T5 due to the increase of salinity. Under severe salinity T5 (16 dS m^{-1}), the highest number of lateral roots were produced by BINA soybean-4 (10.86±1.09) which was statistically similar with BINA soybean-6 (10.53±0.35) and BINA soybean-2 (9±0.69). Similar type of results for these varieties also observed under (2 dS m^{-1}, 4 dS m^{-1}, 8 dS m^{-1}). BINA Soybean-3 and BARI Soybean-6 produced significantly lowest number of lateral roots under all the treatments.

Fresh weight per seedling

Significant variation on average fresh weight (g) per seedling was observed among the soybean genotypes under different salinity conditions (Figure 5). Under T1 (0 dS m^{-1}) the average fresh weight (g) per seedling ranged from 0.53 g to 0.307 g. The highest and the lowest fresh weight per seedling were observed in BINA soybean-2 (0.53±0.05 g) and BD-4 (0.307±0.05 g) respectively. Other 8 varieties showed intermediate fresh weight in respect to highest and lowest values. Under severe saline condition T5 (16 dS m^{-1}) average

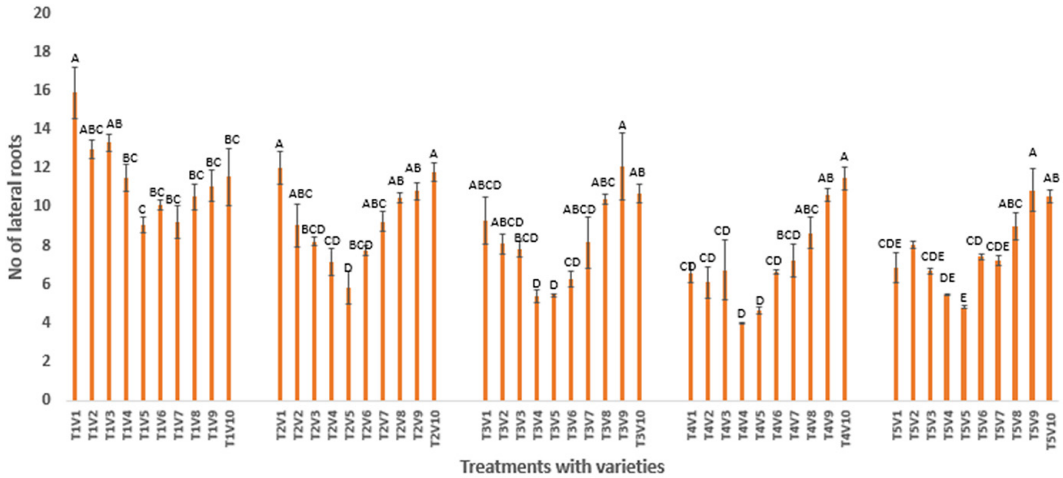

Fig. 4. Variation in number of lateral roots of soybean genotypes under different salinity level

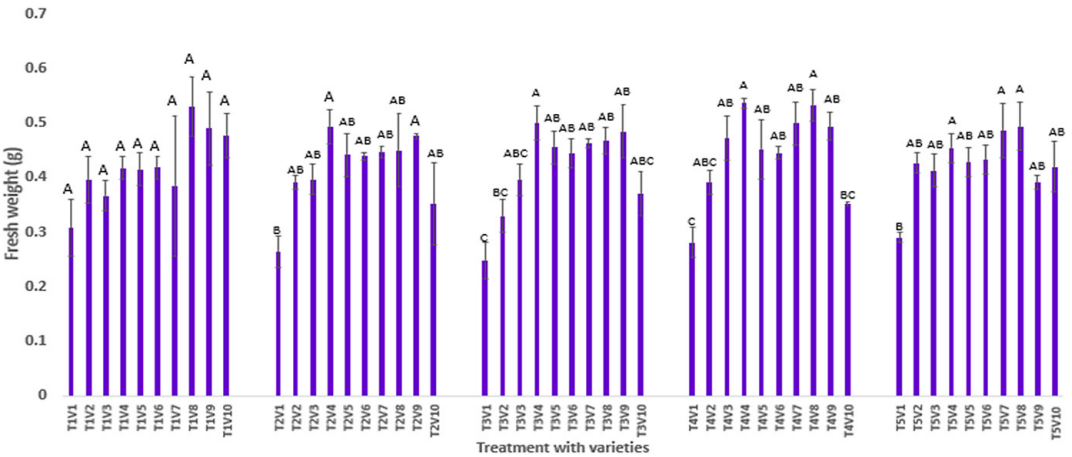

Fig. 5. Average fresh weight (g) of soybean genotypes under different salinity level

fresh weight ranged from 0.494 g to 0.29 g. Highest fresh weight (g) per seedling was recorded in BINA soybean-2 (0.494± 0.04 g) which was statistically similar with BINA soybean-1 (0.485±0.04 g) and BARI Soybean-6 (0.454±0.02 g). These varieties also produced highest fresh weight under T2, T3and T4. Among all varieties, BD-4 produced the lowest fresh weight per seedling under all the salinity treatments.

Dry weight

The average dry weight (g) was significantly influenced by different varieties under different level of salinity (Figure 6). Highest dry weight (g) was obtained in BINA soybean-2 under T1 (0.0947±0.006 g), T2 (0.0982±0.0002 g) and T3 (0.1019±0.0014 g) followed by BINA soybean-1. In case of severe salinity T5 (16 dS m^{-1}) the highest dry weight (g) was recorded in BINA soybean-1 (0.1003±0.01 g) which was statistically similar to BARI Soybean-6 (0.0959±0.008 g). In contrast, BD-4 showed lowest dry weight (g) under all the treatments as it had lowest fresh weight among all the genotypes. The dissimilarity in dry weight might be attributed due to the variations in inherent characters.

(B) Morphological Characters

Plant height

Plant height of different soybean varieties showed significant variation among them at different growth stages (Figure 7). The tallest plant was observed in BARI Soybean-6 (50.2±1.44 cm) at 60 DAS followed by BINA Soybean-4 (49.5±1.744 cm) that was statistically similar with BINA Soybean-5 (48.7±1.43 cm); BINA Soybean-6 (47.2±1.37 cm) and BINA Soybean-3 (46.9±2.04 cm). These genotypes also maintained increasing trend of height up to 100 DAS. The shortest plant height was found in BINA Soybean-2

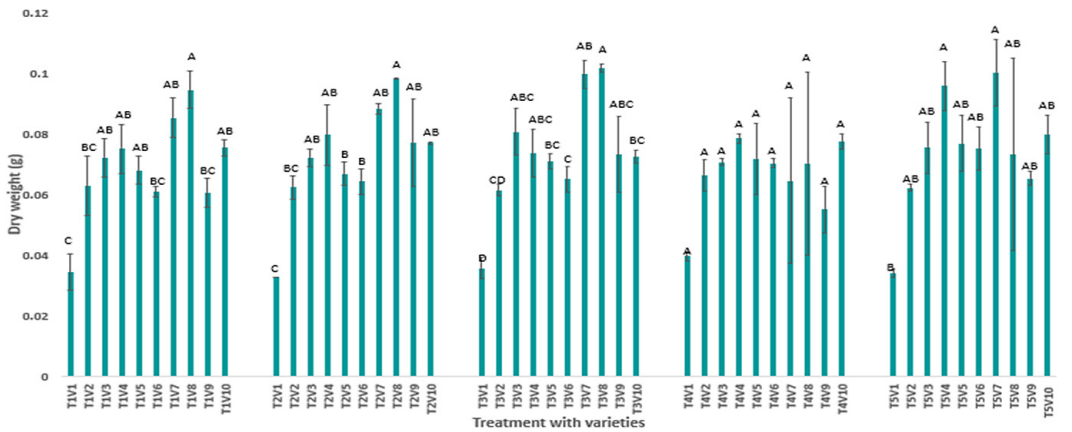

Fig. 6. Average dry weight (g) of soybean genotypes under different salinity level

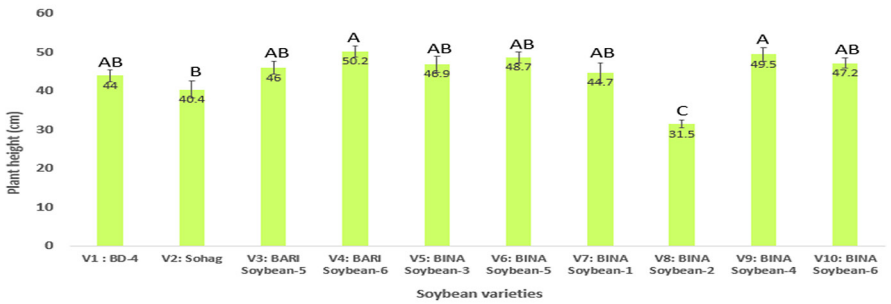

Fig.7a. Plant height of soybean varieties at 60 DAS

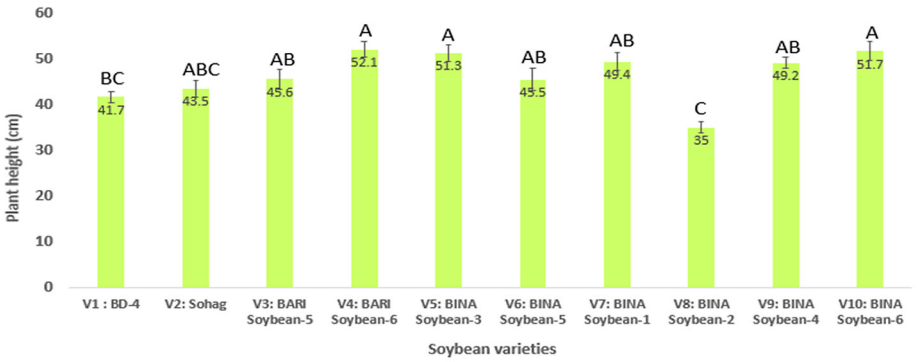

Fig.7b: Plant height of soybean varieties at 70 DAS

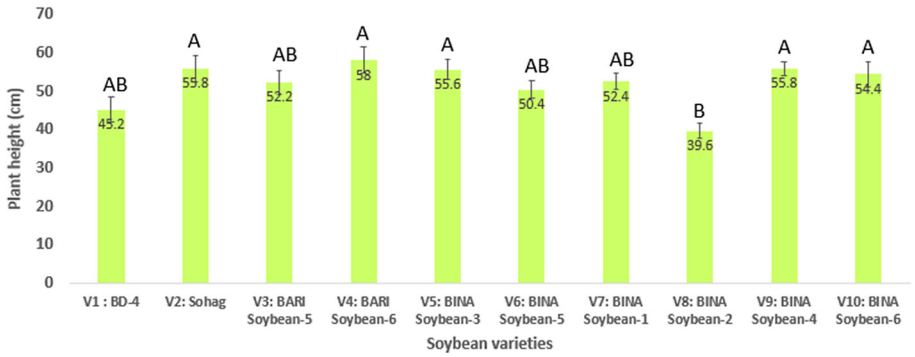

Fig. 7c. Plant height of soybean varieties at 90 DAS

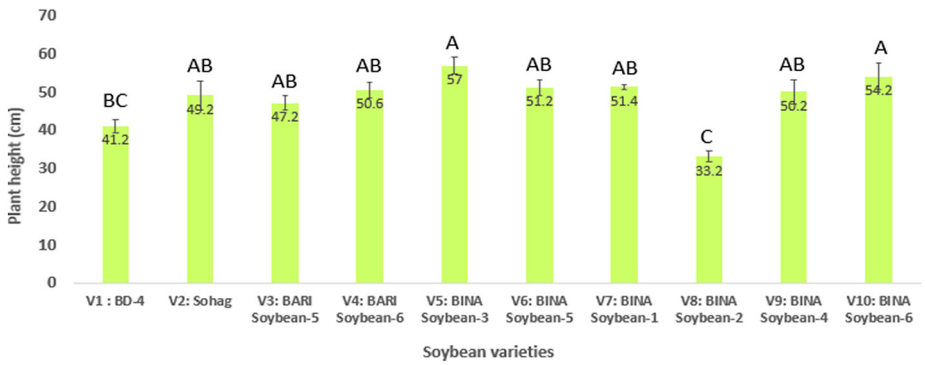

Fig. 7d. Plant height of soybean varieties at 100 DAS

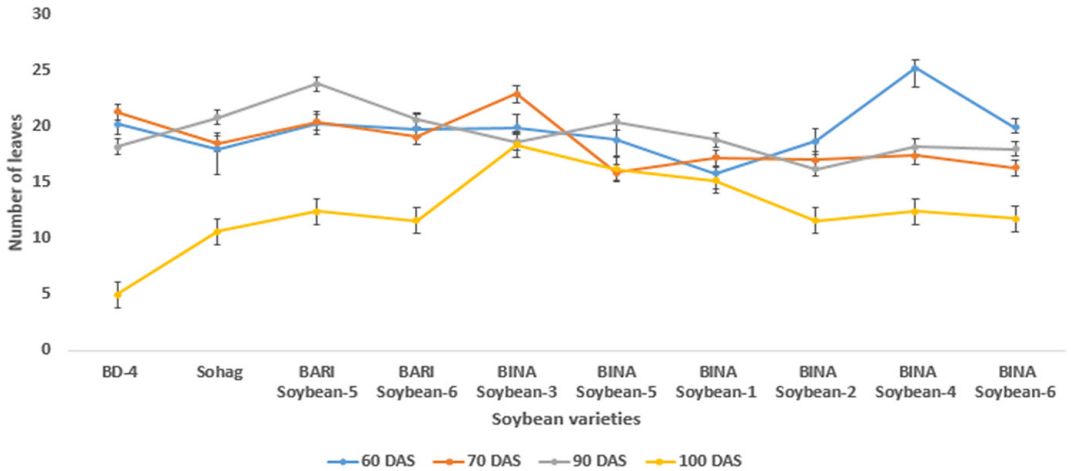

Fig. 8. Variation in total leaf number among varieties during different growth stage

(33.2±1.36 cm) at 100 DAS that was constant throughout all the growth stages. The dissimilarity in plant tallness might be attributed due to variations in genotypic constituents. Khan et al. (2015) and Sultana et al. (2015) have reported high variability in plant height of different soybean varieties.

Number of leaves per plant

Significant variation was found among the varieties for number of leaves per plant at different growth stages (Figure 8). Number of leaves per plant increased sharply from early seedling stage to 60 DAS and reached maximum at 70 DAS and then declined gradually. At 70 DAS BINA Soybean-3 (22.9±1.02) produced the highest number of leaves per plant followed by BD-4 (21.3±1.56) that was statistically similar with BARI Soybean-5 (20.4±1.18); BARI Soybean-6 (19.1±1.17); Sohag (18.5±1.10) and BINA Soybean-4 (17.4±0.55). On the other hand the lowest no. of leaves per plant was observed in BINA Soybean-5 (15.9±1.45) during this time followed by BINA Soybean-6 (16.3±1.45) and BINA Soybean-2 (17±0.97). The decrease in number of leaves after 70 DAS may be attributed due to the senescence and dropping of older leaves. At 100 DAS the highest no. of leaves plant^{-1}was counted in BINA Soybean-3 (18.4±0.456) that was statistically similar with BINA Soybean-5 (16.2±1.58) and BINA Soybean-1 (15.2±1.39) whereas the lowest number of leaves per plant was observed in BD-4 (5±0.93) followed by Sohag (10.6±2.27), BINA Soybean-2 (11.6±1.25); BARI Soybean-6 (11.6±0.72) and BINA Soybean-6 (11.8±0.52). Genotypic variation in total number of leaves per plant during different growth stages was also reported by (Amin, 2009). Sultana et al. (2015) and Khan et al. (2015) have reported that variation in leaf number among soybean varieties was responsible for the dissimilarity in Leaf Area Index (LAI) at different growth stages.

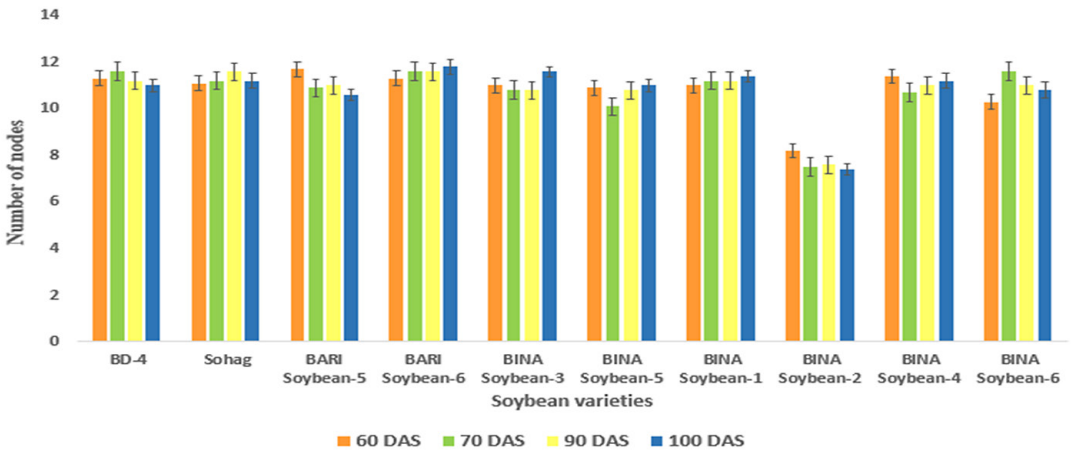

Fig. 9. Variation in no. of nodes among varieties during different growth stages

Number of nodes per plant

The number of nodes per plant varied among the soybean genotypes at different growth stages (Figure 9). Significantly the highest number of nodes per plant was found in BARI Soybean-6 (11.8±0.33) at 100 DAS that was statistically similar with other 8 varieties viz. BINA Soybean-3 (11.6±0.21); BINA Soybean-1 (11.4±0.21); BINA Soybean-4 (11.2±0.33); Sohag (11.2±0.33); BD-4 (11±0.28); BINA Soybean-5 (11±0.28); BINA Soybean-6 (10.8±0.33) and BARI Soybean-5 (10.6±0.21). The lowest number of nodes per plant was observed in BINA Soybean-2 (7.4±0.21) due to its extremely short plant height. This maybe happened due to variation in genetic makeup of the varieties. All the nine soybean varieties except BINA Soybean-2 have similarities with each other in node number throughout all the growing season.

Dry weight of stem

Variation in the dry weight of stem (g) was observed among the soybean genotypes (Figure 10). The average stem weight per plant ranged from 4.50 g to 8.46 g. The highest stem dry weight was observed in BINA Soybean-4 (8.46±1.05 g) and the lowest stem dry weight was found in BINA Soybean-2 (4.50±0.47 g). Other 8 varieties showed intermediate stem weight in respect to highest and lowest values. The values for these varieties are: BINA Soybean-3 (7.87±0.58 g); BARI Soybean-6 (7.03±0.95 g); Sohag (6.81±0.60 g); BINA Soybean-1 (6.51±0.43 g); BARI Soybean-5 (6.10±0.18 g); BINA Soybean-5 (5.55±0.76 g); BINA Soybean-6 (5.64±0.73 g) and BD-4 (5.19±0.54 g). This finding was in close conformity with the finding of (Amin et al., 2009) and (Khan, 2015) where they have reported significant differences in total dry matter among soybean varieties.

(C) Yield and yield contributing factors

Number of branches per plant

The number of branches per plant varied significantly among the soybean genotypes (Table 1). The average number of branches per plant of ten varieties ranged from 2.3 to 4.6. The highest number of branches per plant was found in BINA Soybean-2 (4.6 ± 0.20) followed by BD-4 (3.8±0.41) that was statistically similar with BINA Soybean-3 (3.8±0.27); BARI Soybean-6 (3.4±0.15); BINA Soybean-4 (3.4±0.40) and Sohag (3.3±0.34). The lowest branches per plant was recorded in BINA Soybean-6 (2.3±0.34) that was statistically similar with BINA Soybean-5 (3.1±0.22); BINA Soybean-1 (3.1±0.17) and BARI Soybean-5 (3.1±0.26). The similar findings about number of branches per plant were also observed by Malek et al. (2013) and (Pankaj, 2013).

Number of pods per plant

Number of pods per plant varied significantly among the varieties (Table 1). The average number of pods per plant ranged from 64.1 to 44.8. The highest number of pods plant^{-1}was recorded in BINA Soybean-5 (64.1 ± 4.89) and the lowest number of pods per plant was found in BINA Soybean-6 (44.8 ± 4.79). Other 8 varieties showed intermediate number of pods in respect to highest and lowest values. The values for these varieties were: BD-4 (55.5 ± 8.29); BARI Soybean-5 (53.8 ± 4.07); BARI Soybean-6 (53.7 ± 3.78); BINA Soybean-4 (51.6 ± 5.60); Sohag (51.3 ± 5.31); BINA Soybean-2 (50.4 ± 2.25); BINA Soybean-3 (49.6 ± 4.16) and

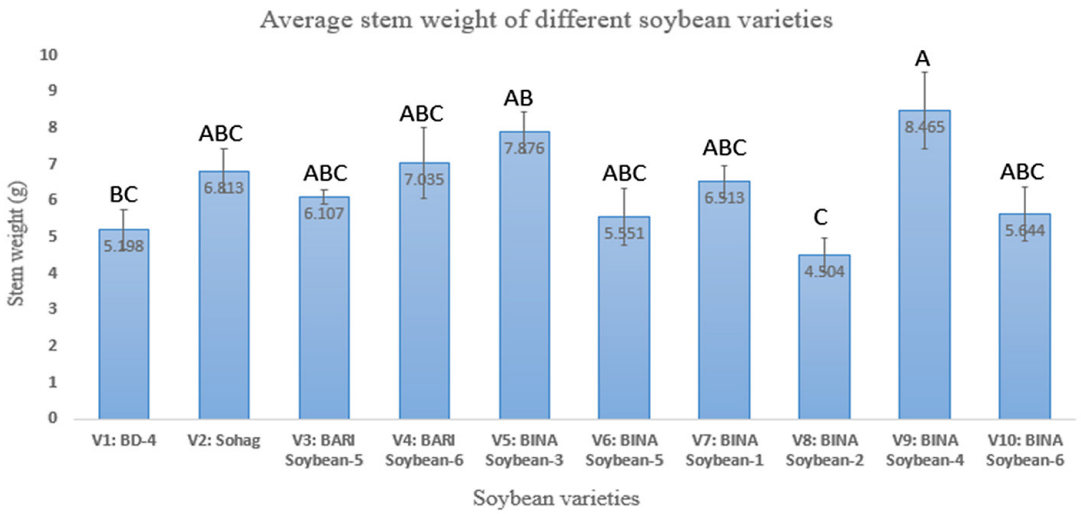

Fig. 10. Effect of different varieties on stem dry weight of soybean

Table 1. Yield and yield contributing factors of different soybean varieties

Varieties	No. of branches per plant	No. of pods per plant	Pod-shell weight, g	No. of seeds per plant	Seed yield per plant, g	100 seed weight, g
BD-4	3.8 ab	55.5	5.492 b	115.9 ab	8.650 ab	8.39
Sohag	3.3 abc	51.3	8.135 ab	101.3 ab	11.419 ab	9.17
BARI Soybean-5	3.1 bc	53.8	7.711 ab	108.4 ab	11.630 ab	11.47
BARI Soybean-6	3.4 abc	53.7	7.939 ab	104.6 ab	11.440 ab	10.39
BINA Soybean-3	3.8 ab	49.6	7.993 ab	100.3 ab	11.262 ab	10.85
BINA Soybean-5	3.1 bc	64.1	10.099 a	146.4 a	14.302 a	9.24
BINA Soybean-1	3.1 bc	49.1	6.888 ab	99.5 ab	10.100 ab	11.23
BINA Soybean-2	4.6 a	50.4	8.250 ab	119.5 ab	14.225 a	13.15
BINA Soybean-4	3.4 abc	51.6	7.788 ab	108.6 ab	12.012 ab	11.25
BINA Soybean-6	2.3 c	44.8	6.465 b	85.7 b	8.495 b	10.46

**Values followed by different letters within a column indicate significant variation at 5% level of significance

BINA Soybean-1 (49.1 ± 2.67). Wide variation in number of pods per plant among varieties was also reported by Khanam et al. (2016), Malek and Rahman (2013) and Sultana et al. (2015). The similar findings on number of pods per plant were also supported by Ali et al. (2008).

Pod-shell weight

Pod-shell weight differed among the soybean varieties (Table 1). The average pod-shell weight (g) per plant of different soybean varieties ranged from 10.09 g to 5.49 g. The highest pod-shell weight per plant was recorded in BINA Soybean-5 (10.09 ± 0.86 g) followed by BINA Soybean-2 (8.25 ± 0.68 g) which was statistically similar with Sohag (8.13 ± 0.90 g); BINA Soybean-3 (7.99 ± 0.60 g); BARI Soybean-6 (7.93 ± 0.81 g); BINA Soybean-4 (7.78 ± 0.84 g); BARI Soybean-5 (7.71 ± 0.39 g) and BINA Soybean-1 (6.88 ± 0.20 g). The lowest pod-shell weight per plant was observed in BD-4 (5.49 ± 0.89 g) that was statistically similar with BINA Soybean-6 (6.46 ± 0.64 g). The probable reason of this variation may be the genetic constituents of the varieties.

Number of seeds per plant

The soybean varieties differed from each other in number of seeds per plant (Table 1).The average number of seeds per plant ranged from 146.4 to 85.7. Highest number of seeds plant^{-1}was recorded in BINA Soybean-5 (146.4 ± 12.98) and the lowest number of seeds per plant was found in BINA Soybean-6 (85.7 ± 9.28). Other 8 varieties showed intermediate number of seeds in respect to highest and lowest values. The values for these varieties were: BINA Soybean-2 (119.5 ± 6.98); BD-4 (115.9 ± 18.52); BINA Soybean-4 (108.6 ± 13.52); BARI Soybean-5 (108.4 ± 5.96); BARI Soybean-6 (104.6 ± 9.45); Sohag (101.3 ± 11.19); BINA Soybean-3 (100.3 ± 8.64) and BINA Soybean-1 (99.5 ± 4.77). There was a positive relationship between pods per plant and total number of seed per plant (Table 1). Higher seed yield might be produced due to higher no. of pods per plant.

Seed yield per plant

Seed yield differed significantly among the genotypes (Table 1). The average seed yield per plant ranged from 14.30 g to 8.49 g. The highest seed yield per plant was recorded in BINA Soybean-5 (14.30±1.37 g) and BINA Soybean-2 (14.22±1.24 g) whereas the lowest seed yield per plant was found in BINA Soybean-6 (8.49±0.78 g). On the basis of plant density m^{-2}, we found 10 actively growing plants in each m^2. Thus, the yield of BINA Soybean-2 could be obtained as 1.422 t ha^{-1}. However, this yield is far below the yield potential (2.4-2.8 t ha^{-1}) claimed by BINA (http://bina.gov.bd/site/page/220c886d-fe3f-4f69-b4f0-bd71241f0240/-). Other 7 varieties showed intermediate seed yield in respect to highest and lowest values. The values for these varieties were: BINA Soybean-4 (12.01±1.50 g); BARI Soybean-5 (11.63±0.58 g); BARI Soybean-6 (11.44±1.39 g); Sohag (11.41±1.38 g); BINA Soybean-3 (11.26±1.10g); BINA Soybean-1 (10.1±0.41 g) and BD-4 (8.65±1.41 g). This findings was supported by (Awal, 2014) who stated that seed yield of soybean varied among varieties for their difference in genetic makeup. (Sultana, 2015) also reported significant differences on seed yield among soybean varieties.

100 seed weight (g)

Considerable genotypic variation in 100-seed weight was found in this study. The 100-seed weight of ten soybean varieties varied from 8.39 g to 13.15 g (Table 1). The highest 100-seed weight was recorded in BINA Soybean-2 (13.15 g) [i.e., the seed size is the highest among the 10 varieties], followed by BARI Soybean-5 (11.47 g) that was statistically similar with BINA Soybean-4 (11.25 g) and BINA Soybean-1 (11.23

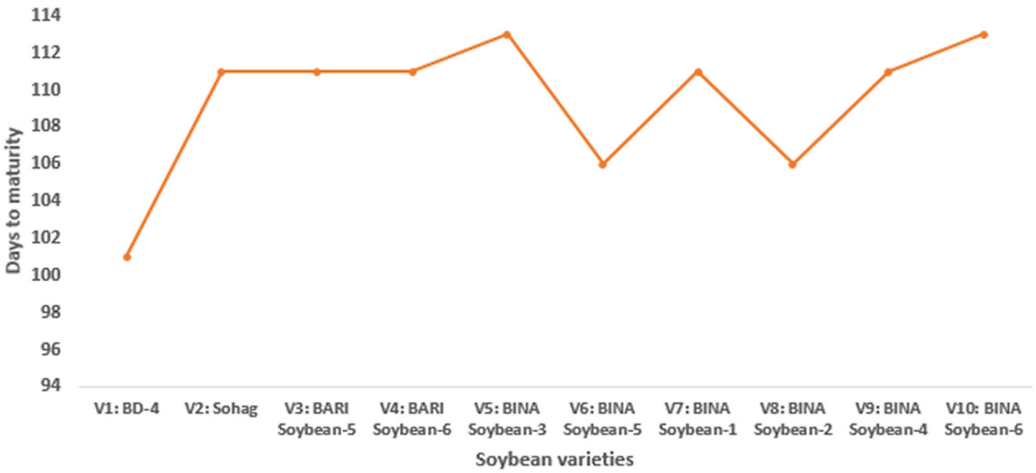

Fig. 11. Variation in days to maturity among soybean varieties

g). The lowest 100 seed weight was found in BD-4 (8.39 g) followed by Sohag (9.17 g) which was statistically similar with BINA Soybean-5 (9.24 g); BARI Soybean-6 (10.39 g) and BINA Soybean-6 (10.46 g). These findings have close conformity with the findings of (Pankaj, 2013) who stated that 100 seed weight among varieties ranged from 10.55 g to 16.34 g. Ali et al. (2008) also found significant variation for 100 seed weight among soybean genotypes.

Days to maturity

Different soybean varieties required different number of days to attain maturity (Figure 11). Among these varieties BD-4 was the early mature type which required 101 days for harvesting. BINA Soybean-2 and BINA Soybean-5 required 106 days to mature fully. Another five varieties *viz.* Sohag, BARI Soybean-5, BARI Soybean-6, BINA Soybean-1 and BINA Soybean-4 required 111 days to gain maturity. BINA Soybean-3 and BINA Soybean-6 were the late mature type variety which required 113 days for harvesting. Similar findings on days to plant maturity were obtained by Malek & Rahman (2013).

Conclusion

According to the findings of the study, it was observed that ten soybean varieties influenced significantly in respect to morphological characters, yield and yield contributing attributes. From this study, it was accomplished that BINA Soybean-2 and BINA Soybean-5 showed superior performance than other varieties. Moreover, BINA Soybean-2 showed comparatively better potentiality than BINA Soybean-5 under different levels of salinity. Hence BINA Soybean-2 was the most suitable and advantageous genotype for better yield and other performances in the salinity affected southwest coastal region of Bangladesh.

Acknowledgements

The authors are grateful to the Khulna University Research Cell, Khulna University, Bangladesh for financial support to complete this piece of research work. [Grant# KU/ResCell-04/2000-80, Dated: June 23, 2019]. The authors are also delighted to express their gratitude to the concerned authority of Bangladesh Institute of Nuclear Agriculture (BINA) and Bangladesh Agricultural Research Institute (BARI) for providing the plant propagation materials for the conducted experiments.

Conflict of Interest

The authors declare that there is no conflict of interests regarding the publication of this article.

References

Ahsan, M. & Bhuiyan, M. M. (2010). Soil and water salinity, their management in relation to climate changes in coastal areas of Bangladesh. *Khulna University Studies (Special Issue)*, SESB 2010, 31-42.

Ali, R., Kader, M. A. & Hasan, A. K. (2008). Yield performance of soybean as influenced by phosphorus. *Journal of Agroforestry and Environment, 7(1),* 45-48.

Amin, A. R., Jahan, S. & Hasanuzzaman, M. K. (2009). Growth dynamics of soybean (*Glycine max* L.) as affected by varieties and timing of irrigation. *American-Eurasian Journal of Agronomy*, *2(2),* 95-103.

Awal, A. M. (2014). Grain yield and seed quality of early maturing

dwarf soybean genotypes as influenced by planting time and spacing. PhD Dessertation, Dept. of Agronomy, BSMRAU, Gazipur, Bangladesh, 10-45.

BBS (2018). Statistical Yearbook of Bangladesh, Bangladesh Bureau of Statistics, Statistics Division, Ministry of Planning, Govt. of the People's Republic of Bangladesh. Dhaka.

BBS (2020). Yearbook of Agricultural Statistics-2020, Bangladesh Bureau of Statistics, Statistics and informatics Division, Ministry of Planning, Government of People's Republic of Bangladesh, Dhaka.

Dhaka Tribune (2021). Edible oil: How Bangladesh can cut import dependency. Retrieved from: https://www.dhakatribune.com/bangladesh/agriculture (Accessed May 28, 2021)

Islam, K., Khan, M., Islam, M. & Latif, M. U. (2020). Performance of different cultivars of mungbean in coastal region of Bangladesh. *SAARC Journal of Agriculture, 18(1),* 161-172.

Islam, M. M., Ishibashi, Y., Nakagawa, A. C. S., Tomita, Y., Inoue-Iwaya, M., Arima, S. & Zheng, S.-H. (2016). Nitrogen redistribution and its relationship with the expression of *GmAT-G8c* during seed filling in soybean. *Journal of Plant Physiology, 192,* 71-74. DOI: 10.1016/j.jplph.2016.01.007

Islam, M. M., Ishibashi, Y., Nakagawa, A. C. S., Tomita, Y., Zhao, X., Inoue-Iwaya, M., Arima, S. & Zheng, S.–H. (2017). Nitrogen manipulation affects leaf senescence during late seed filling in soybean. *Acta Physiologiae Plantarum, 39,* 42. DOI: 10.1007/s11738-016-2334-0

Khan, M. S., Karim, M. A., Haque, M. M. & Miab, A. J. (2015). Growth and dry matter partitioning in selected soybean (*Glycine max* L.) genotypes. *Bangladesh Journal of Agricultural Research, 40(3),* 333-345.

Khanam, M., Islam, S., Ali, M. H., Chowdhury, I. F. & Masum, S. M. (2016). Performance of soybean under different levels of phosphorus and potassium. *Bangladesh Agronomy Journal, 19(1),* 99-108.

Malek, M. A. & Rahman, L. (2013). Selection of a high yielding soybean variety : Binasoybean-1. *Research on Crops, 14(4),* 1197-1201.

Malek, M. A., Rahman, L. & Salam, M. Y. (2013). Selection of a high yielding soybean variety, BINA Soybean-2 from collected germplasms. *Journal of Food, Agriculture & Environment, 11(2),* 545-547.

Messina, M. J. (1997). Soyfoods: Their role in disease prevention and treatment. In: Liu, K. *Soybeans: chemistry, technology and utilization*. New York: Chapman and Hall, 442-477.

Mondal, M. R. I. & Wahhab, A. M. (2001). Production technology of oilcrops. Oilseed Reaserch Center, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur, Bangladesh.

Pankaj, B. (2013). Plant Characterization and seed quality of some dwarf soybean genotypes. PhD Dessertation, Dept. of Agronomy, BSMRAU, Gazipur, Bangladesh, 24-53.

SRDI (2010). Saline Soils of Bangladesh (SRMAF project report), Soil Resource Development Institute (SRDI), Ministry of Agriculture, Govt. of the People's Republic of Bangladesh. Dhaka. Retrieved from: http://srdi.portal.gov.bd/sites/default/files/files/srdi.portal.gov.bd/publications/bc598e7a_df21_49ee_882e_0302c974015f/Soil%20salinity%20report-Nov%202010.pdf (accessed September 15, 2021)

SRDI (2018). Annual Report, Soil Resource Development Institute (SRDI), Ministry of Agriculture, Govt. of the People's Republic of Bangladesh. Dhaka. Retrieved from: http://www.srdi.gov.bd/sites/default/files/files/srdi.portal.gov.bd/annual_reports/93bcb3bd_2c85_4bda_9180_b24068febbfb/Annual%20Report%202017-18.pdf (accessed September 15, 2021)

Sultana, D., Bari, M. N., Karim, M. A. & Sarker, M. A. (2015). Variation in morphological characters and yield attributes of five selected soybean genotypes. *Journal of Environmental Science and Natural Resources, 8(2),* 93-96.

Weather Forecast Khulna, Bangladesh (2021). Retrieved from: https://www.weather-atlas.com/en/bangladesh/khulna (accessed May 28, 2021)

Received: May 29, 2021; *Accepted:* December 14, 2021; *Published:* February, 2022