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Morpho-Physiological Features and Yield Attributes of Soybean Genotypes in Acid Soil

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A B S T R A C T

An experiment was conducted at the experimental field of the Department of Crop Botany and Tea Production Technology, Sylhet Agricultural University, Sylhet, Bangladesh during 10 April to 25 August 2013 to evaluate the morpho-physiological attributes and yield performances of nine advanced genotypes and five varieties of soybean in acidic soil. The advanced genotypes were SBM-9, SBM-15, SBM-17, SBM-18, SBM-20, SBM-22, SBM-73, SBM-78, BAU-S/70 and varieties were Binasoybean-1, Binasoybean-2, Shohag, BARI Soybean-5 and BARI Soybean-6. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The results revealed that the genotypes varied considerably in the morpho-physiological characters at all growth stages and yield also and yield attributing characters. In growth analysis, SBM-78 showed the highest TDM accumulation, AGR, CGR among the genotypes followed by BARI Soybean-5 but variety Shohag had the highest RGR. The highest yield (2.50 t ha^{-1}) was produced by BARI Soybean-5 followed by SBM-78 (2.39 t ha^{-1}), SBM-22 (2.32 t ha^{-1}) and BARI Soybean-6 (2.28 t ha^{-1}) whereas the lowest yield (1.26 t ha^{-1}) was recordrd in genotype SBM-17 but it was statistically similar to SBM-73, SBM-15, Binasoybean-2 and SBM-9. The highest yield of BARI Soybean-5 was contributed by the highest number of branches (9.0), pods $plant^{-1}$(240.4), seeds $plant^{-1}$(430.3). The genotype SBM-78 had the highest seed yield $plant^{-1}$(48.7 g), number of branches (8.5), pods (223.6), seeds (404.7) and 100-seed weight (13.5g). It had also higher crop growth rate. The variety BARI Soybean-5 and the advanced genotype SBM-78 showed better growth performance and produced maximum grain yield due to better adaptability and superiority of yield attributing characters under acid soil condition than those of others.

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INTRODUCTION

Soybean (*Glycine max* (L.) Merrill) belonging to the family Papilionaceae is one of the most important protein and oilseed crops throughout the world. It is enriched in Ca, P, Vitamin A, B, C and D. In Bangladesh, soybean is mostly used as poultry feed and for making nutritious food dishes and confectionary items such as soyadal, soyakhechuri, soyabread, soyamilk and so on (Rahman, 2003). Soybean generally grows well in soil that is neither too acidic nor too alkaline. Bekere *et al*. (2013) noted that nitrogen-fixing bacteria do not function effectively under low soil pH condition of 4.2 and below while the recommended optimum pH is 6-6.5 for proper growth of soybean. Acidic soils are one of the most important limitations to agricultural production worldwide (Kochian *et al*., 2004). Acid-soil involves both nutrient deficiencies and toxicities, the tolerance of plants to soil acidity could take the form of efficient uptake and utilization of those nutrients that are deficient under acid soil conditions or outright tolerance to Al and Mn toxicities. Thus, it is important to select acid tolerant soybean genotypes with the intention of reducing the dependence of small farmers on lime and fertilizer inputs. Foy *et al*. (1992) stated that selection of genotypes with high adaptability to the acid soils is a promising alternative.

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The screening of commonly grown soybean genotypes for low pH tolerance would provide a better understanding of the crops adaptation and the management requirements under low soil pH conditions. Raut *et al*. (2001) reported that acid tolerance in plants is often clearly identifiable through morphological and physiological symptoms. High acidic soil condition greatly influence on the physiological growth and yield contributing characters of soybean (Dong *et al*., 2004; Uguru *et al*., 2012; Kuswantoro *et al*., 2013). A number of researchers have been conducted to develop acid tolerant varieties of soybean through several plant breeding methods, viz. screening technique (Ferrufino *et al*., 2000), segregating population selection (Bertham and Nusantara, 2011) and germplasm screening (Kuswantoro and Zen, 2013). The production and research on soybean cultivation in acidic soil conditions in Sylhet region is almost nill. High and medium lands of the region contain acid soils with pH ranging from 4.8 to 5.7 with high content of iron. The cultivation of oil crop especially soybean is unknown to the farmers in this region due to the lack of local variety. The yield performance of any crops depends on some physiological characteristics. To evaluate the morpho-physiological characteristics responsible for yield differences among the genotypes of soybean are useful in crop improvement. Important morpho-physiological attributes such as crop growth rate (CGR), relative growth rate (RGR), absolute growth rate (AGR) and total dry matter (TDM) can address various constrains of a genotype/variety for increasing its productivity (Tandale and Ubale, 2007; Ruhul Amin, 2009). In the present study an attempt was undertaken to study some genotypes as well as varieties to assess their performances in acid soil of Sylhet region.

MATERIALS AND METHODS

Soil and climate:

The experiment was carried out at the experimental field of the Department of Crop Botany and Tea Production Technology, Sylhet Agricultural University, Sylhet, Bangladesh during April to August 2013 to evaluate the morpho-physiological attributes and yield performance of nine advanced genotypes and five released varieties of soybean in acidic soil. The climate and soil of the selected plot was under subtropical climate having heavy rainfall during April to September (Kharif Season) and scanty rainfall during October to March (Rabi Season), high land type, well drained and non-calcareous grey floodplain fertile soils of acidic nature. The soil pH, nutrient status of the soil, monthly air temperature, relative humidity, rainfall and sunshine hours are presented in the table 1 and 2.

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

Elements	Amount
Soil pH	4.83
Organic matter (%)	1.39
Potassium (mili equivalent/ 100g of soil)	0.38
Nitrogen (%N)	0.07
Phosphorus (μg/ g of soil)	9.15
Sulphur (μg/ g of soil)	37.98

Source: Regional Office of SRDI (Soil Resources Development Institute), Sylhet-3100, Bangladesh.

Table 2: Monthly air temperature (ºC), relative humidity, rainfall and sunshine hours/day of the experimental site during the period from April to September 2013.

Month	Temperature (ºC)				Rainfall (mm)		Relative Humidity (%)	Sunshine (hr)
	Max.	Average	Min.	Average	Total	Average		
April	36.2	33.0	17.8	21.9	236.1	13.9	59	5.6
May	36.2	30.4	18.0	21.9	958.2	14.2	78	5.7
June	37.5	33.9	23.3	22.7	727.2	26.9	75	2.5
July	35.8	33.3	24.2	25.8	567.6	18.9	78	4.4
August	35.3	32.6	24.3	26.6	534.1	17.8	80	4.8
September	36.6	32.8	22.8	25.3	337.1	14.0	78	4.6

Source: Sylhet Meteorological Station, Shahi Eidgah, Sylhet-3100, Bangladesh.

Experimental materials and design:

Fourteen genotypes/varieties of soybean were used as experimental materials. Among these Shohag, BARI Soybean-5 and BARI Soybean-6 were collected from Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh and two varieties viz. Binasoybean-1 and Binasoybean-2 were collected from Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh, Bangladesh along with nine advanced mutant lines (SBM-9, SBM-15, SBM-17, SBM-18, SBM-20, SBM-22, SBM-73, SBM-78 and BAU-S/70). The experiment was laid out in a Randomized Complete Bock Design (RCBD) with three replications. The size of each unit plot was 2.5m × 1m. Distances between two plots were 0.35m and the blocks were 0.45m apart. Seeds were sown in 3 to 4 cm soil depth on 25 April 2013 in 30cm apart rows and after germination plants were thinned by maintaining 15cm distance of each plant. The plot were fertilized with a general dose of urea, triple super

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phosphate (TSP), muriate of potash (MOP) and gypsum as sources of nitrogen, phosphorus, potassium and sulphur and were applied @ 30, 90, 80 and 120 kg ha^{-1}, respectively.

Data collection and analysis:

Final harvesting of the crop was done when the foliage turned pale yellow for data collection. Data on morpho-physiological growth parameters like root dry weight, stem dry weight, leaf dry weight, total dry matter (TDM) were recorded with sampling of 6 plants/plot starting from 50 DAS till 110 DAS with an interval of 15 days. From these data absolute growth rate (AGR), relative growth rate (RGR), crop growth rate (CGR) were calculated. After sampling the plant, the plant parts were separated into roots, stems and leaves and the corresponding dry weight were recorded after oven drying at 80 ± 2 ºC for 72 hours and calculated the morpho-physiological growth parameters by the following formulae:

$$\text{AGR (g day}^{-1}) = \frac{(W_2 - W_1)}{(T_2 - T_1)}$$

Where, W_1 = Dry weight of the plant at time 'T_1'; W_2 = Dry weight of the plant at time 'T_2'; T_1 and T_2 = Time interval in days.

$$\text{CGR (g m}^{-2}\text{ day}^{-1}) = \frac{(W_2 - W_1)}{(T_2 - T_1)} \times \frac{1}{A}$$

Where, W_1 = Total dry weight of the plant at time 'T_1'; W_2 = Total dry weight of the plant at time 'T_2'; T_1 and T_2 = Time interval; A = Ground area covered by each plant (m²).

$$\text{RGR (g g}^{-1}\text{ day}^{-1}) = \frac{(\log W_2 - \log W_1)}{(T_2 - T_1)}$$

Where, W_1 = Dry weight of the plant at time 'T_1'; W_2 = Dry weight of the plant at time 'T_2'; T_1 and T_2 = Time interval in days.

At harvest, yield and plant characters like plant height (cm), number of branches $plant^{-1}$, pod length (cm), number of pods $plant^{-1}$, number of seeds pod^{-1}, 100-seed weight (g), seed yield $plant^{-1}$(g) and seed yield (t ha^{-1}) were measured. Besides, days to 50% flowering and days to maturity were recorded. The collected data were analyzed statistically and the mean differences were separated with Duncan's Multiple Range Test (DMRT) at 5% level of significance using the statistical computer package program, MSTATC (Russell, 1986).

RESULTS AND DISCUSSION

Growth analysis:

Growth analysis technique has contribution for understanding the morpho-physiological basis of yield variation in different crops. The AGR, CGR, RGR and TDM etc. are the important growth parameters influencing yield which depend not only on the genotype but also on the environmental and management practices.

Root dry weight varied significantly among the soybean genotypes/varieties (Figure1). There was a higher rate of increase in root dry weight during 50 to 65 DAS and it increased slowly after that upto the physiological maturity at 110 DAS for all fourteen genotypes/varieties. The highest root dry weight was found in the variety Binasoybean-2 (2.23 g $plant^{-1}$) which was closely followed by BARI Soybean-5 (2.22 g) and the lowest was observed in the genotype SBM-15 (1.37 g) which was statistically similar to genotype SBM-73 (1.47 g) and SBM-17 (1.51 g) at 110 DAS. Root growth depends on the genetic characteristics of a plant as well as soil and environment. The increment rate of root dry weight was the highest during 50 to 65 DAS because the vegetative growth rate of the plant. Similar result was reported by Ferrufino *et al*., (2000) and Masud (2010) in soybean.

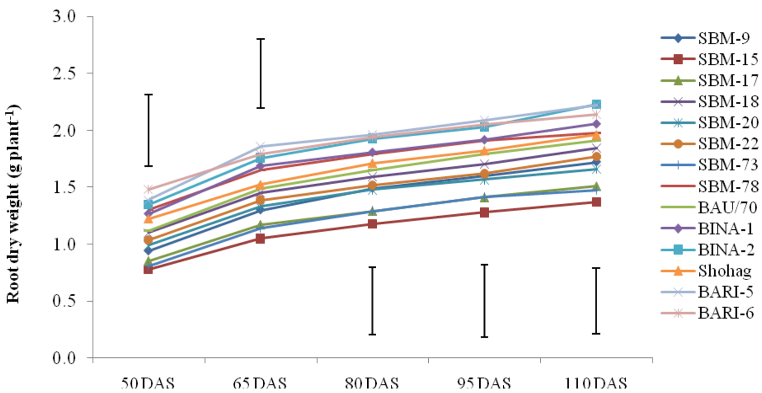

Fig. 1: Root dry weight $plant^{-1}$ in different soybean genotypes/varieties at different days after sowing Vertical bars represent $lsd_{(0.05)}$

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Stem dry weight differed significantly among the genotypes/varieties (Figure 2). There were a similar stem dry weight increments during the period 65 to 95 DAS and declined slightly thereafter till harvest. Among all, BARI Soybean-5 produced significantly the maximum stem dry weight (7.84 g plant^{-1}) which was closely followed by SBM-78(7.45 g plant^{-1}). The increase in stem dry weight could be attributed to increase in stem thickness, increased plant height and number of branches. The lowest stem dry weight (5.68 g plant^{-1}) was found with the genotype SBM-73. After 95 days of sowing, declining in stem dry weight in all soybean genotypes/varieties might be due to translocation of stored photosynthates towards reproductive organs. This result was corroborated with the results found by Ruhul Amin (2009) and Masud (2010).

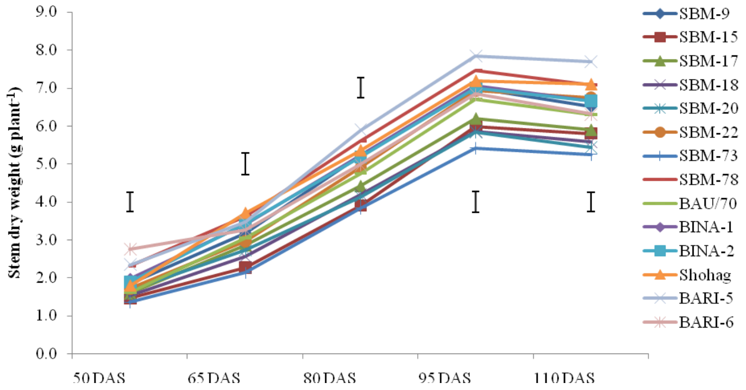

Fig. 2: Stem dry weight plant^{-1} in different soybean genotypes/varieties at different days after sowing Vertical bars represent lsd$_{(0.05)}$

There were significant variations in leaf dry weight of soybean genotypes/varieties (Figure 3). In general irrespective of genotypes or varieties, leaf dry weight increased rapidly up to 80 DAS and after that it increased slowly till 95 DAS and then declined till harvest. This decline in leaf dry weight at later stages of crop might be due to translocation of stored photosynthates towards reproductive organs. At 95 DAS, the highest leaf dry weight was observed in BARI Soybean-5 (7.16 g plant^{-1}) followed by BARI Soybean-6 (6.97 g), SBM-78 (6.77 g) and Shohag (6.74 g) and the lowest were in SBM-73 (4.83 g). Increase in leaf dry weight may be due to increased leaf thickness and increase in number of branches. These results are in agreement with the study of Masud (2010) who reported an increased leaf dry weight in soybean genotypes.

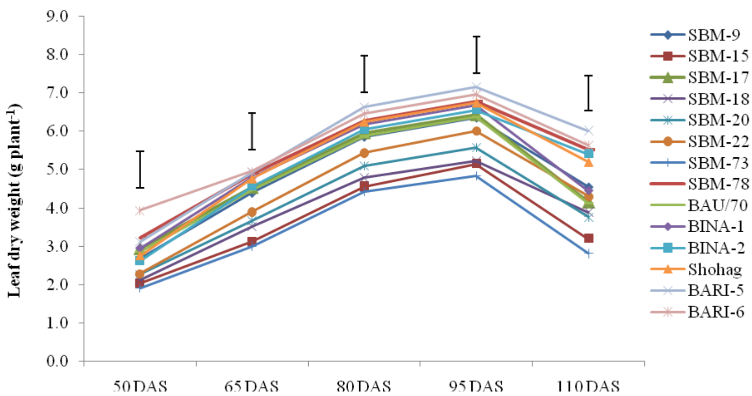

Fig. 3: Leaf dry weight plant^{-1} of different soybean genotypes/varieties at different days after sowing Vertical bars represent lsd$_{(0.05)}$

Result revealed that total dry matter (TDM) production increased with age up to 110 DAS whereas the rapid increases were found from 65 DAS to 95 DAS (Figure 4). The highest TDM (32.82 g plant^{-1}) was produced by the genotype SBM-78 followed by BARI Soybean-5 (30.97 g) whereas the lowest was recorded in SBM-73 (19.01 g) at 110 DAS. The highest TDM were noticed at all growth stages in the variety BARI Soybean-5 and genotype SBM-78. The amount of total dry matter production is an indication of the overall efficiency of utilization of resources and better interception of light. Even if the dry mater production in general is the indication of efficiency of genotypes, the pattern in which it is distributed in different plant parts will give

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a better understanding of genotypes. The result is supported by the result of Yusuf and Idowu (2001) and Tandale and Ubale (2007) in soybean who reported that high yielding genotypes produced greater TDM than low yielding ones.

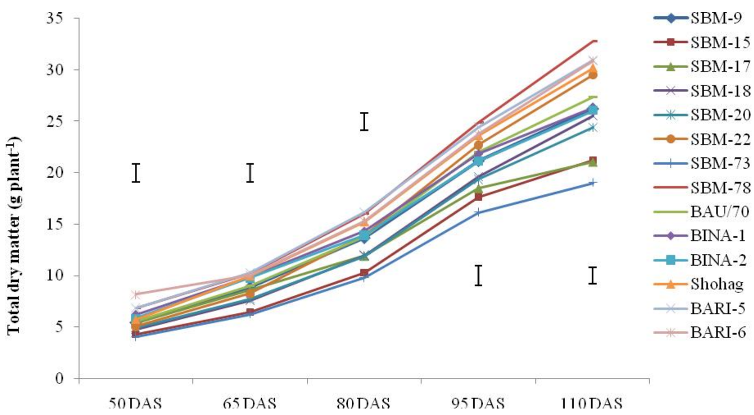

Fig. 4: Total dry matter of soybean genotypes/varieties at different days after sowing Vertical bars represent $lsd_{(0.05)}$

Absolute growth rate (AGR) was calculated in fourteen soybean genotypes/varieties from vegetative stage (50 DAS) to physiological maturity (95 DAS). The results revealed that AGR in all genotypes differed significantly at all growth stages (Figure 5). The AGR was maximum at 80 DAS in all the genotypes/varieties and then decreased towards maturity of the crop. The genotype SBM-78 maintained the highest AGR value at most of the growth stages. In contrast, at early growth stages, SBM-17 had the lowest AGR but considering the overall growth period, SBM-73 showed lower AGR. It is evident that soybean had three distinct growth phases: early slow growth (up to 65 DAS before flowering start) followed by a rapid growth (80 DAS at flowering and pod filling stage, respectively) and then decline growth phase (95 DAS at pod maturity stage). Slow growth rate in early growth stage was associated with lower TDM production. Initial slow growth favors weed growths which hamper development and thus crop ultimately suffer a lot. Result of the present experiment is in agreement with Ruhul Amin (2009) and Raut *et al*. (2001). So selection of genotypes with rapid growth rate in early part of a crop life is therefore desirable. The result revealed that the genotype SBM-78 and BARI Soybean-5 had greater AGR than others indicating their desirable characters.

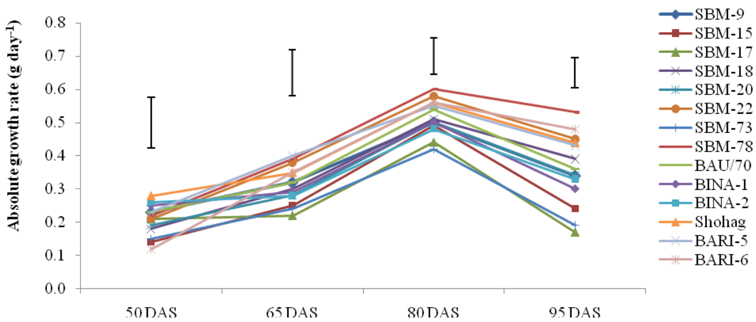

Fig. 5: Absolute growth rate (AGR) at different growth stages of soybean advanced genotypes and varieties in different time.

The variation in RGR among the genotypes/varieties was assessed from 50 DAS to 95 DAS and the results were observed that there was an inverse relationship between RGR and plant age (Figure 6). In the early stages of growth at 50 DAS, RGR was maximum and gradually declined with the advancement of crop age. At 50 DAS, RGR was higher in Shohag which was the fourth maximum dry matter producing genotype and the lowest RGR was recorded in BARI Soybean-6 which was the fourth maximum yielding genotype. Results indicate that there was no relation between RGR and seed yield. The results of the study are in agreement with the results of Yusuf and Idowu (2001). However, the RGR declined at later growth stages (reproductive stage) which may be attributed to excessive mutual shading of leaves during this period and increased number of old leaves could have lowered the photosynthetic efficiency (Tandale and Ubale, 2007).

Crop growth rate (CGR) significantly varied among the genotypes/varieties (Figure 7). The maximum CGR (12.97 g $m^{-2}d^{-1}$) was recorded in the genotype SBM-78 which was closely followed by the variety BARI

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Soybean-5 (12.86 g $m^{-2}d^{-1}$). On the other hand, the minimum (9.34 g $m^{-2}d^{-1}$) was found in the genotype SBM-73 which was statistically similar to the genotype SBM-17 (9.67 g $m^{-2}d^{-1}$) during 80-95 DAS. For all the genotypes, crop growth rate increased at the beginning and then showed down and later increased maximum at 80-95 DAS with the advancement of crop growth period and started declining gradually thereafter towards maturity. Such a decline could be attributed to decrease in the rate of dry matter production due to senescence and shading. The increase of CGR up to reproductive stage may due to maximum use of photosynthetic ability in the vegetative parts of the plant. The results of CGR values corroborates with findings of Tandale and Ubale (2007) and Ruhul Amin (2009).

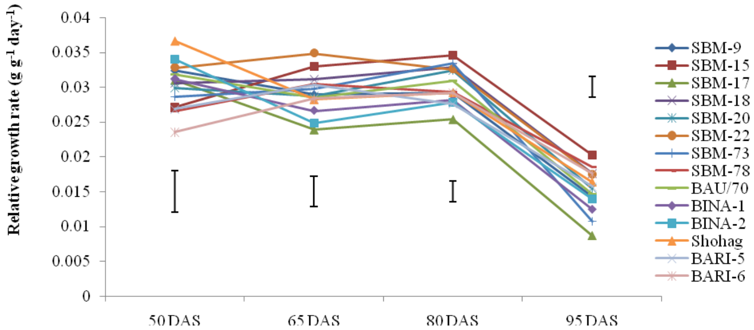

Fig. 6: Relative growth rate (RGR) at different growth stages of advanced genotypes/varieties of soybean.

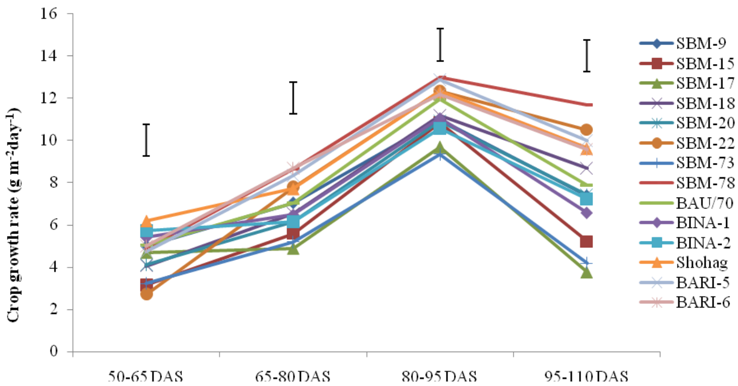

Fig. 7: Crop growth rate (CGR) at different growth stages of advanced genotypes/varieties of soybean.

Yield and yield attributes of soybean genotypes:

Plant height among soybean genotypes/varieties showed significant variation (Table 3). The rate of increase in plant height was higher from 50 DAS to 65 DAS, after that the values of plant height increased slowly upto 95 DAS and then the highest plant height was attained at 110 DAS for all the fourteen genotypes/varieties. The genotype BAU-S/70 showed the tallest (81.71 cm) plant at all growth stage which was statistically similar to SBM-18 (77.02 cm) and SBM-22 (75.87 cm). The shortest (52.25 cm) plant was recorded in Binasoybean-2 which was statistically similar to SBM-17 (57.27 cm) and SBM-15 (59.36 cm). One of the selection criteria for acid tolerance soybean lines is plant height. It is due to the vegetative growth of stressed plants which will be hampered by micro nutrient toxicity as well as macro nutrients deficiency (Kuswantoro *et al*., 2013).

Number of branches significantly differed among the genotypes/varieties at all growth stages in soybean (Figure 8). Result revealed that the number of branches increased abruptly from 50 to 65 DAS then gradually increased with time up to 95 DAS and after that remained stable in all soybean genotypes/varieties till maturity. The maximum number of branches (9.00) was found in the variety BARI Soybean-5 which was similar with the genotype SBM-78 (8.54) and the minimum number of branches (5.13) was recorded in SBM-15 followed by Binasoybean-2 (5.40) and SBM-17 (5.54) at 110 DAS. The results showed that the genotype BARI Soybean-5 produced the highest branches in all growth stage except at 50 DAS. On the other hand, Binasoybean-2 and SBM-15 maintained the lowest branches number over their growth period. Similar to the results were reported by De-bruin and Pedersen (2009) who reported that number of branches increased with increasing plant age up to physiological maturity in soybean. According to Wirnas *et al*. (2006) the number of branches was one of the agronomic traits that had positive and highly significant correlation with seed yield per plant in soybean.

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Table 3: Plant height of soybean genotypes/varieties at different days after sowing.

Genotypes	50 DAS	65 DAS	80 DAS	95 DAS	110 DAS
SBM-9	42.16 cd	60.55 b-e	66.83 b-d	70.38 b-d	71.66 b-e
SBM-15	33.67 g-i	51.69 e-g	54.82 fg	58.51 gh	59.36 gh
SBM-17	31.43 hi	50.09 fg	54.60 fg	57.00 gh	57.27 gh
SBM-18	47.53 b	67.92 ab	72.77 ab	75.16 ab	77.02 ab
SBM-20	38.96 c-g	58.99 b-f	62.47 d-f	66.89 c-f	67.43 d-f
SBM-22	44.31 bc	63.71 b-d	70.62 a-c	74.33 a-c	75.87 a-c
SBM-73	35.23 f-h	52.40 ef	57.13 e-g	60.52 e-g	60.98 fg
SBM-78	40.74 c-e	60.26 b-e	64.59 c-e	67.75 b-e	68.39 c-f
BAU-S/70	54.35 a	72.82 a	77.45 a	80.82 a	81.71 a
BINA-1	36.12 e-h	53.90 ef	57.79 ef	59.88 fg	60.58 fg
BINA-2	28.39 i	43.32 g	49.65 g	51.89 h	52.25 h
Shohag	37.72 d-g	65.57 abc	68.03 b-d	71.39 b-d	73.52 b-d
BARI-5	39.81 c-f	58.10 c-f	61.44 d-f	63.68 d-g	65.32 e-g
BARI-6	34.38 gh	56.48 d-f	60.23 d-f	61.93 e-g	64.02 e-g
CV (%)	8.35	9.50	7.82	7.36	7.41

Values having same letter(s) in a column do not differ significantly at 5% level of significance

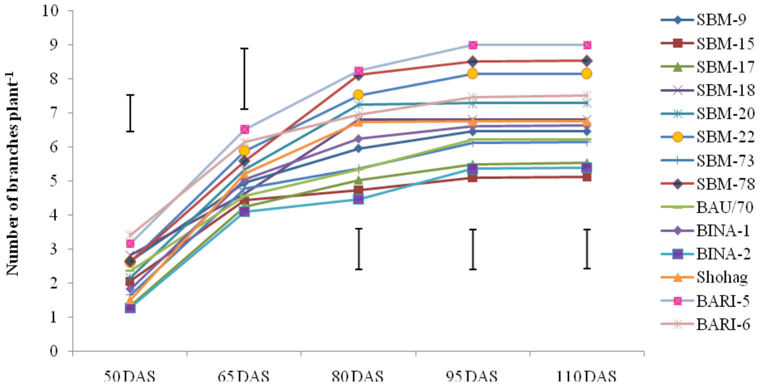

Fig. 8: Number of branches plant^{-1} of different soybean genotypes/varieties at different days after sowing Vertical bars represent $lsd_{(0.05)}$

There were significant differences among the genotypes/varieties in respect of days to 50% flowering and it varied from 53.00 days to 74.00 days (Table 4). The average days taken by the genotypes for 50% flowering were 64.03. The genotype SBM-9 (73.61 days) took maximum days to 50% flowering which were closely followed by the variety BARI Soybean-5 (70.41 days). The least number of days were recorded in SBM-73 (53.51 days) and Binasoybean-1 (54.23 days). Soybeans are at 50% bloom when an open flower can be found on every other plant in a row. Flowering on soybeans, begins from the bottom of the plant and then progress upward. As all the genotypes of soybean were planted during kharif-2 season, initiation of flower in most of the genotypes was delayed because of heavy rainfall. Uguru *et al*. (2012) and Kuswantoro *et al*. (2014) stated that acidity stress at pre and post flowering stage significantly affected soybean growth and yield attributes.

Table 4: Days to 50% flowering and maturity of soybean genotypes.

Genotypes	Days to 50% flowering	Days to maturity
SBM-9	73.61 a	127.3 a
SBM-15	62.62 d	115.7 ef
SBM-17	63.63 d	115 f
SBM-18	67.15 c	115.29 ef
SBM-20	66.72 c	118 c-f
SBM-22	58.48 e	117.3 d-f
SBM-73	53.51 f	122 a-d
SBM-78	66.5 c	124 ab
BAU-S/70	69.5 b	121.67 a-d
BINA-1	54.23 f	123.33 a-c
BINA-2	57.5 e	124.33 ab
Shohag	70.14 b	126.67 ab
BARI-5	70.41 b	125.67 ab
BARI-6	62.38 d	121 b-e
CV (%)	2.18	2.91

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Maturity of soybean occurs when the accumulation of dry weight ceases and plants lost completely all the green leaves and stem. If a crop is harvested earlier than physiological maturity yield will be reduced owing to low grain weights. On the other hand, if harvesting is delayed after physiological maturity, the yield may be reduced owing to shattering of grains or a large percentage of grains falling occurred due to delayed harvesting. The difference of days to maturity among the genotypes/varieties was significant (Table 4). Results revealed that the maximum days required for maturity of the genotype SBM-9 (127.3 days) because of the flowering behavior and duration of flowering. Similar result was also found in Shohag (126.7 days), BARI Soybean-5 (125.7 days), Binasoybean-2 (124.3 days) and SBM-78 (124.0 days). The shortest duration was found in the genotype SBM-17 (115.0 days) which was more or less similar to that of genotypes SBM-18 (115.3 days), SBM-15 (115.7 days), SBM-22 (117.3 days) and SBM-20 (118.0 days). Soybean genotypes/varieties were planted during kharif-2 season, and all plants showed over vegetative growth due to the excessive rainfall that were why all genotypes needed more time to mature. Variation in maturity was reported by Debruin and Pedersen (2009) and Kuswantoro and Zen (2013).

Pod length had significant differences among the soybean genotypes/varieties (Table 5). The maximum pod length (3.81 cm) was observed in SBM-73 which was statistically similar to BARI Soybean-5 (3.78 cm) and Binasoybean-2 (3.74 cm). On the other hand, the minimum pod length (2.72 cm) was recorded in Shohag followed by BAU-S/70 (2.84 cm) and Binasoybean-1 (2.91 cm). The genotypes/varieties which produced the maximum pod length influence the production of the highest seeds pod^{-1}, seeds plant^{-1} as well as total yield. Liu (2004) stated that pod length is one of the most important characters for yield improvement.

Table 5: Yield and yield components of soybean genotypes/varieties at harvest.

Genotypes	Pod length (cm)	No. of pods plant^{-1}	No. of seeds pod^{-1}	No. of seeds plant^{-1}	100-seed weight (g)	Seed yield plant^{-1} (g)	Yield (t ha^{-1})
SBM-9	3.56 ab	135.30 f	1.86 cd	248.55 g	12.57 b	31.23 e	1.40 e-g
SBM-15	3.40 bc	102.97 h	1.85 cd	190.49 i	10.98 cd	20.92 fg	1.33 fg
SBM-17	3.10 de	86.85 i	1.73 ef	150.26 k	11.48 c	17.25 h	1.26 g
SBM-18	3.35 b-d	149.41 e	1.83 cd	273.43 f	13.11 ab	35.86 d	1.66 d
SBM-20	3.33 b-d	136.56 f	1.82 cd	248.55 g	12.83 ab	31.88 e	1.49 e
SBM-22	3.11 c-e	182.21 d	1.80 de	327.98 e	13.65 a	41.13 c	2.32 b
SBM-73	3.81 a	86.07 i	2.10 a	180.75 j	10.01 de	18.09 gh	1.29 g
SBM-78	3.23 cd	223.58 b	1.81 cd	404.69 b	13.51 ab	48.68 a	2.39 ab
BAU/S-70	2.84 ef	212.70 c	1.66 fg	353.09 d	10.56 c-e	37.28 d	1.74 d
BINA-1	2.91 ef	187.72 d	1.70 f	319.12 e	9.84 e	31.41 e	1.47 ef
BINA-2	3.74 a	116.50 g	1.99 b	231.84 h	10.42 c-e	24.14 f	1.35 e-g
Shohag	2.72 f	213.93 c	1.59 g	382.24 c	11.40 c	43.60 bc	1.98 c
BARI-5	3.78 a	240.40 a	1.79 de	430.32 a	10.96 cd	44.78 b	2.50 a
BARI-6	3.60 ab	210.68 c	1.88 c	396.07 b	11.02 cd	43.63 bc	2.28 b
CV (%)	5.32	2.61	2.51	1.87	5.65	6.13	5.24

Values having same letter (s) in a column do not differ significantly at 5% level of significance as per DMRT.

Character of number of pods is a supporting character to the yield per plant and it differed significantly among the soybean genotypes/varieties (Table 5). BARI Soybean-5 demonstrated the highest number of pods plant^{-1} (240.4) resulting in the highest seed yields. The result showed that pod numbers were positively correlated with number of seeds plant^{-1}, 100-seed weight and seed yield plant^{-1} as well as total yield (Table 6). According to Sumarno and Zuraida (2006), the total number of pods was positively correlated to seed weight per plant. The variety SBM-73 produced the least number of pods plant^{-1} (86.07) with the second lowest grain yield. The smaller number of pods was due to the acidity of the soil as well as less availability of water and this condition is common in acid soil (Kuswantoro and Zen, 2013).

Number of seeds pod^{-1} varied significantly among the soybean genotypes/varieties (Table 5). The results indicated that the maximum number of seeds pod^{-1} (2.10) was produced from the genotype SBM-73 and the second highest (1.99) was observed in the variety BINAsoybean-2. The minimum number of seeds pod^{-1} (1.59) was observed in the variety Shohag which was statistically similar to that of genotypes BAU- S/70 (1.66). The results indicated the maximum seeds pod^{-1} was found in the longest pod length that ultimately influenced the yield of soybean. The result corroborates with findings of Pedersen and Lauer (2004) and Kuswantoro *et al*. (2014).

Recorded data on the number of seeds plant^{-1} of fourteen genotypes/varieties had presented in the Table 5. Results indicated that there were significant differences among the soybean genotypes/varieties. The variety BARI Soybean-5 produced the highest number of seeds plant^{-1} (430.32) and it was followed by the genotype SBM-78(404.69). The least number of seeds plant^{-1} (150.26) was obtained in the genotype SBM-17. Variation in the number of seeds plant^{-1} might be due to the pods plant^{-1} and also seeds pod^{-1}. Although these are the genetical characteristics of plant but growing environment also influenced it. These results are in agreement with the findings of Kuswantoro *et al*. (2010) and Uguru *et al*. (2012) who stated that high yielding soybean

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genotype produced high number of seeds plant^{-1} and number of seeds plant^{-1} which has strong positive correlation with the seed yield.

100-seed weight is the most important yield attributes in soybean as well as other growing crops and it influenced by seed size. The 100-seed weight was recorded at final harvest and the result is presented in Table 5. There was significant variation in 100-seed weight among the genotypes/varieties. The results indicated that the highest seed weight (13.65 g) was produced by the genotype SBM-22 and similar weight was noticed in SBM-78 (13.51 g), SBM-18 (13.11 g) and SBM-20 (12.83 g). The lowest seed weight (9.84 g) was produced in BINAsoybean-1 which was statistically identical to SBM-73 (10.01 g), Binasoybean-2 (10.42 g) and BAU-S/70 (10.56 g). It was observed that the bold seeded genotype produced high 100-seed weight than that of small seeded genotypes/varieties. According to Adie and Krisnawati (2007) soybean was categorized as large (greater than 14 g per 100 seeds) medium (10-14 g per 100 seeds), and small (less than 10 g per 100 seeds). Therefore, the variety BINAsoybean-1 was classified as small seeded and other thirteen were classified as medium seeded genotypes/varieties. These results were consistent with the result of Ojo *et al*. (2010) who stated that there were varietal differences in 100-seed weight.

There was a remarkable significant difference in respect of seed yield plant^{-1} among all the genotypes/varieties (Table 5). The results indicated that the genotype SBM-78 had produced the highest seed yield plant^{-1} (48.68 g) followed by the variety BARI Soybean-5 (44.78 g) while the least seed yield plant^{-1} (17.25 g) was found in the genotype SBM-17 which was statistically similar to the genotype SBM-73 (18.09 g). The present results are positively correlated with the number of pods plant^{-1} and number of seeds plant^{-1}. The results indicated that the maximum seed yield plant^{-1} producing genotypes also produced higher yield and can be classified as high yielding ones. This variation in seed yield plant^{-1} might be due to difference in genetic makeup of the genotypes completed with growth environment. Khandit *et al*. (2001) and Jandong *et al*. (2011) reported similar results.

The data on seed yields of fourteen soybean genotypes/varieties presented in Table 5 showed statistical significant variations. The highest yield (2.50 t ha^{-1}) was produced by the variety BARI Soybean-5 followed by SBM-78 (2.39 t ha^{-1}), SBM-22 (2.32 t ha^{-1}) and BARI Soybean-6 (2.28 t ha^{-1}). The lowest yield (1.26 t ha^{-1}) was found in the genotype SBM-17 which was statistically similar to SBM-73 (1.29 t ha^{-1}), SBM-15 (1.33 t ha^{-1}), Binasoybean-2 (1.35 t ha^{-1}) and SBM-9 (1.40 t ha^{-1}). These results indicated that the highest yield producing genotype/variety had better yield attributing characters like number of pods plant^{-1}, number of seeds plant^{-1},100 seed weight and seed yield plant^{-1}. Pod number per plant and seeds per pod and individual seed size might be considered as the major and effective characters influencing the seed yield in soybean. Seed yield and its related parameters also depend on the accumulation of photo-assimilates and its distribution in grain during the reproductive growing period of plant. Variations in yield among the genotypes were also reported by Dong *et al*., 2004; Ojo *et al*., 2010; Kuswantoro and Zen, 2013. Uguru *et al*. (2012) found significant correlation between yield and crop growth rate under acidic soil condition at early reproductive growth; and stated that a key for high seed yield under acidic condition was the maintenance of a high crop growth rate.

Conclusion:

It can be concluded that among the studied genotypes/varieties, BARI Soybean-5 and advanced line SBM-78 performed the best among all in respect of growth analysis, yield and yield attributing characters. Both the genotype/variety showed good growth performance and the highest yield in acidic soil conditions. So, BARI Soybean-5 and the advanced genotype SBM-78 could be preferred as acid tolerant genotypes than the others.

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