Relationship among yield and quality traits in *Sorghum bicolor* L. Moench. for biomass and food utilisation

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**Abstract.** Fifteen genotypes of sorghum derived from four different sources of population were evaluated for quality and yield related components. The experiment was conducted at Field 10, Universiti Putra Malaysia in a Randomized Complete Block Design with three replications. The objectives of this study were to evaluate the performance and genetic variation for eight yield and quality traits on selected genotypes sorghum, to estimate the phenotypic correlation between yield and yield related components in sorghum. Genotypes 1-3-5 and 1-4-4 were identified to have high yield for most of the biomass (904.0 g/plant and 880.7 g/plant respectively) and grain yield components (98.1 g and 88.97g respectively). Genotypes 1-1-1, 1-4-1 and 5-3-6 were found to have total soluble solid of more than 16%, which make them suitable for food purposes. Mean for all genotypes for all measured traits, together with the significant genotypic variance indicated substantial amount of genetic variability towards the improvement for fresh biomass weight, stem diameter and total soluble solid content. Biomass and grain yield traits namely plant height, fresh biomass yield, stem diameter and panicle weight indicated significant positive correlation. Thus, selection on any one of these traits will increase in the other traits, thereby improving biomass and grain yield in sorghum for mentioned purpose.

1. Introduction

*Sorghum* (*Sorghum bicolor* L. Moench) is the world’s fifth most important cereal crop after rice, wheat, maize and barley. It is an important food crop particularly in the area of the poorest countries in the semi-arid tropics of Africa and Asia [1]. It has proven to be a drought tolerant crop due to the ability to recover growth after undergoing some period of water stress. More than 80 % of sorghum plantation area [2] are located in developing countries including in the African and Asian continents, where sorghum is the primary source of grain. The remaining 16–20% of sorghum field is predominantly located in the developed countries such as the USA, where it is especially cultivated by large-scale commercial farms mainly for animal feed [3].

Sorghum plant can be classified into four different types, mainly based on the plant characteristic and their uses. Grain sorghum is typically made into flour for the food industry due to the high grain to forage ratio. Forage sorghum is used for green chop, hay, silage and pasture because of the high tonnage yield performance and high stalk sweetness (sugar content) [4]. Biomass sorghum is primarily for the production of bioenergy crop because it is drought resistant and it has large biomass production potential [5]. Apart from that, sweet sorghum is grown for the production of syrup [6]. The syrup is being used as an alternative sweetener and the utilisation could potentially be extended into biofuel and chemical production [4].
Sorghum has the potential to be introduced to Malaysia due its suitability and potential to be utilized for various purposes, thus it is listed as crop in the future. However, there is still lack in breeding program and to study adaptation of sorghum in tropical climate. In order to address this problem, breeder need to start a breeding program to develop sorghum varieties that can be grown and cultivated locally. There is a need to assess the genetic variation in sorghum as well as the associations among quantitative traits for the purpose of the feasibility of joint selection of two or more traits. Primarily in Malaysia, sorghum utilisation would focus on biomass and food purposes as alternative source of food and potential energy.

The study of correlation among traits helps in evaluating the cause-effect relationship as well as managing and suggesting effective selection criteria for high yielding sorghum can be used to initiate the breeding program of sorghum in our country. Consequently, the evaluation and effect of selection for secondary traits as well as the genetic gain for the primary trait under consideration can be done [7]. Therefore, the present study was aimed to determine variations in selected sorghum genotypes as well as analyze the relationship among biomass and yield traits using the correlation analysis.

2. Materials and Methods

The experiment was conducted at Field 10, Faculty of Agriculture, Universiti Putra Malaysia (UPM), Serdang, Selangor in March-October 2019. Plant materials used in this study were 15 genotypes (Table 1) derived from four populations of Sorghum bicolor. The seeds were obtained from the collection at Agrogene Bank, Faculty of Agriculture, UPM, Serdang, Selangor. The study was conducted in a Randomized Complete Block Design with three replications, each replication consisted of 15 plots that consist 20 plants per plot. Each experimental unit is represented by one genotype. The distance was 0.8 m between rows and 0.2 m between plant. Basal application of N:P:K compound fertilizer at the rate of 120kg/ha were done at seven and 21 days after planting. Irrigation using the sprinkler system were ensured to supply adequate water throughout plant growth.

2.1. Data collection

Days to flowering were recorded from sowing until 50% of the inflorescence in the plot initiated anthesis. Data related to plant agronomic yield and quality traits were collected at time of harvest, including fresh biomass weight (g/plant), plant height (m), number of leaves per plant, stem diameter (mm) and total soluble solid (TSS) content (%), panicle length (cm) and panicle weight (g).

2.2. Data analysis

Descriptive statistics and analysis of variance were executed using Excel and SAS software to summarize the performance and determine the genetic variation among sorghum genotypes. Simple correlation among the traits measured were analysed using the Pearson correlation formula.

3. Results and Discussion

3.1 Descriptive statistics of yield and quality traits among sorghum genotypes

The descriptive statistics and ANOVA (mean, genetic variance and coefficient of variation) for all traits measured on 15 different genotypes of sorghum were presented in Table 1.

Genotype 5-3-6 and 1-2-1 were the earliest genotypes to flowering at 56 days after planting. On average, all the sorghum genotypes in this study were more than 2m tall, with genotype 6-34-7, 1-4-3 and 1-1-6 being among the tallest genotypes recorded (2.71-2.6 m). Number of leaves ranges between 8-15 leaves per plant, with the highest number recorded by genotype 1-3-5 (11.7). Fresh biomass weight and stem diameter of the sorghum genotypes in this study averaged around 762.62 g/plant and 17.5 mm, respectively. Genotype 1-3-5 recorded the highest fresh biomass, panicle weight and the second highest stem diameter. Total soluble solid content taken from the stem of all 15 genotypes ranged between 12.95% - 16.92, whereby genotype 1-4-1 recorded the highest TSS level.
Table 1. Mean for yield and quality traits measured on 15 sorghum genotypes and genotypic variance of all traits obtained from ANOVA.

| Genotypes | Days to flowering (days) | Fresh biomass (g/plant) | Plant height (m) | Number of leaves/plant | Stem diameter (mm) | Panicle weight (g) | Panicle length (cm) | Total Soluble Solid(%) |
|-----------|--------------------------|-------------------------|-----------------|------------------------|-------------------|-------------------|-------------------|------------------------|
| 1-1-1     | 60.83                    | 746.33                  | 2.56            | 11.43                  | 18.30             | 85.19             | 26.10             | 16.36                  |
| 1-1-6     | 57.73                    | 707.33                  | 2.60            | 11.13                  | 16.50             | 78.70             | 28.28             | 12.95                  |
| 1-2-1     | 56.20                    | 696.33                  | 2.28            | 9.40                   | 16.16             | 74.63             | 28.30             | 15.16                  |
| 1-3-1     | 59.93                    | 738.33                  | 2.38            | 10.97                  | 18.83             | 75.14             | 25.27             | 14.89                  |
| 1-3-5     | 61.13                    | 904.00                  | 2.41            | 11.87                  | 19.02             | 98.10             | 25.36             | 13.57                  |
| 1-4-1     | 60.60                    | 772.33                  | 2.39            | 11.30                  | 19.13             | 72.92             | 24.89             | 16.92                  |
| 1-4-3     | 61.67                    | 812.33                  | 2.63            | 11.70                  | 18.02             | 77.67             | 25.22             | 14.40                  |
| 1-4-4     | 59.17                    | 880.67                  | 2.50            | 11.23                  | 18.02             | 88.97             | 28.67             | 15.74                  |
| 2-36-3    | 57.86                    | 671.33                  | 2.46            | 10.60                  | 17.29             | 73.13             | 29.67             | 14.68                  |
| 5-3-6     | 56.17                    | 666.00                  | 2.38            | 10.80                  | 16.36             | 83.33             | 24.39             | 16.25                  |
| 5-8-2     | 57.00                    | 607.00                  | 2.20            | 9.33                   | 17.09             | 89.57             | 28.29             | 13.50                  |
| 5-23-1    | 58.77                    | 738.67                  | 2.57            | 10.97                  | 16.44             | 72.93             | 26.40             | 14.24                  |
| 6-31-1    | 59.60                    | 659.33                  | 2.52            | 10.23                  | 17.52             | 71.73             | 30.10             | 14.16                  |
| 6-34-7    | 59.07                    | 697.67                  | 2.71            | 10.90                  | 16.84             | 65.90             | 29.62             | 15.24                  |
| 6-41-2    | 59.57                    | 620.33                  | 2.24            | 10.27                  | 18.28             | 67.82             | 17.94             | 15.02                  |

| Genotypic variance CV(%) | 9.87** | 22343.66** | 0.06m | 1.33m | 3.06** | 7270.38** | 12.51* | 3.13* |
|-------------------------|--------|------------|-------|-------|--------|-----------|--------|-------|
| CV: Coefficient of variation | 1.92 | 14.13 | 7.51 | 7.57 | 6.00 | 15.30 | 8.22 | 8.01 |

'significant at p<0.05, **significant at p<0.01, mnot significant

3.2 Genetic variation among sorghum genotypes
Table 1 also indicates that there were significant difference among sorghum genotypes (at p<0.05) for days to flowering, fresh biomass yield, stem diameter, panicle weight, panicle length and total soluble solid content. The coefficient of variation for fresh biomass yield and panicle weight were high indicating environmental influence for the expression of these traits [9]. Additionally, ANOVA indicated substantial amount of genetic variability of genetic improvement for fresh biomass weight, stem diameter and total soluble solid content.

3.3 Correlation among yield traits in sorghum
Results on phenotypic correlation among traits measured on the 15 different genotypes of sorghum are presented in Table 2.

Days to flowering was found to have positive correlation with plant height (r = 0.317), number of leaf (r = 0.303), stem diameter (r = 0.252) and plant fresh weight (r = 0.236), indicating the late maturing genotypes produces higher biomass. All biomass yield components namely plant height fresh biomass yield, stem diameter and number of leaves were significantly correlated (at p<0.05). From these results it was shown that these traits were related with grain yield and therefore, improvement of these traits would lead to increase in grain yield as well [8-9].

Number of leaf was found to have significant positive correlation (at p<0.05) with plant height (r=0.585), fresh biomass weight (r=0.546) and stem diameter (0.478). Plants with high number of leaves have higher photosynthetic activities that could contribute to having higher biomass yield [9].
Table 2. Correlation coefficient among yield and quality traits on 15 sorghum genotypes.

|       | DTF    | PH     | FB     | NOL    | SD     | TSS    | PL     |
|-------|--------|--------|--------|--------|--------|--------|--------|
| PH    |        | 0.317* |        |        |        |        |        |
| FB    | 0.236**|        | 0.568**|        |        |        |        |
| NOL   | 0.303* | 0.585**| 0.546**|        |        |        |        |
| SD    | 0.252**| 0.411**| 0.767**| 0.478**|        |        |        |
| TSS   | -0.118ns | -0.173ns | -0.216ns | -0.132ns | -0.276* |        |        |
| PL    | -0.074ns | 0.095ns | 0.104ns | -0.236ns | 0.083ns | -0.146ns |        |
| PW    | 0.164** | 0.316* | 0.586** | 0.229ns | 0.573** | -0.295* | 0.276* |

DTF: days to flowering, PH: plant height, FB: fresh biomass, NOL: number of leaves, SD: stem diameter, TSS: total soluble solid, PL: panicle length, PW: panicle weight

*significant at p<0.05, ** significant at p<0.01 ns not significant

Traits related to grain yield, namely panicle weight and panicle length, were positively correlated (significant at p<0.05). However these traits were not significantly correlated with other traits with the exception of fresh biomass yield and panicle weight (r=0.586). Plants with high biomass would tend to produce more high grain yield as well.

Stem diameter was found to have positive strong correlation with plant fresh weight (r = 0.767), while had positive correlation with panicle weight (r = 0.573), all significant at p ≤ 0.01. On the other hand, stem diameter had negative correlation with total soluble solids content (r = -0.276), indicating that plants with thinner stalk tends to produce higher TSS content.

4. Conclusion

Evaluation of the 15 different genotypes of sorghum showed adequate genetic variation for days to flowering, number of leaves per plant, stem diameter, total soluble solids content, panicle length which is suitable for further sorghum breeding. However, the performance of these genotypes was quite similar for plant height and number of leaves. From these results it is evident that these traits were associated with yield and were correlated. Thus, selection by any one of these traits will increase in the performance of the other traits Hence, in order to improve biomass and grain yield, selection for traits like number of leaves per plant, plant height and panicle weight may also be given importance. Genotypes 5-3-6 and 1-2-1 were found to be superior for earliness. Genotypes 1-3-5 and 1-4-4 were found to have highest biomass yield and grain yield. Therefore these genotypes should be utilized in further breeding program for developing high yielding sorghum varieties.

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