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PERFORMANCES OF SORGHUM GENOTYPES UNDER DROUGHT STRESS

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ABSTRAK

Cekaman kekurangan air merupakan faktor pembatas dalam produksi sorgum di daerah-daerah dengan musim kemarau panjang. Percobaan pot yang melibatkan lima genotipe sorgum dilakukan untuk menentukan periode-periode kritis dalam pertumbuhan tanaman terhadap cekaman kemarau. Cekaman kemarau selama dua minggu diberikan pada 3 minggu setelah tanam, fase bunting, dan fase pengisian biji. Tanaman tanpa cekaman kemarau digunakan sebagai kontrol. Baik karakter pertumbuhan maupun karakter hasil diamati untuk mengukur respon tanaman terhadap cekaman kemarau. Hasil pengamatan menunjukkan bahwa pertumbuhan dan hasil tanaman mengalami penurunan akibat perlakuan cekaman kemarau pada fase vegetatif maupun fase reproduktif. Diameter batang dan biomassa tanaman mengalami penurunan yang sangat nyata ketika cekaman diberikan pada awal fase vegetatif. Baik fase bunting maupun fase pengisian biji merupakan periode kritis terhadap cekaman kemarau bagi tanaman untuk mengekspresikan potensi hasilnya.

Kata kunci : sorghum, cekaman kekeringan, fase pertumbuhan

INTRODUCTION

Sorghum is considered to be one of the most drought-resistant plants. It has an extensive root system, waxy bloom on the leaves that reduces water loss, and the ability to stop growing in periods of drought, and resume it again when conditions become favorable. Dry climate with short wet season is the common features of main sorghum producing areas, such as Purwodadi, Pati, Demak, Wonogiri (Central Java), Gunung Kidul, Kulon Progo (Yogyakarta), Lamongan, Bojonegoro, Tuban, Probolinggo (East Java) and some parts of East and West Nusa Tenggara (Sirappa, 2003). In these areas, sorghum is grown on dry land or rain fed fields as an alternate crop to rice or legumes during drought season.

Drought is a meteorological phenolmenon by prolonged dry weather sufficient to cause serious moisture depletion in the soil (Gedzelman, 1980). In terms of crop production, drought can be viewed as inadequacy of water supply during the life cycle of the crop plant (Mitra, 2001). Hale and Orcutt (1987) suggested that drought-stress is a condition within the plant when water loss exceeds water absorption. The drought stress can occurs during different stages of plant growth and development, and has the most adverse effect on yield during and after anthesis (Tuinstra et al.,1997). The common symptoms associated with drought stress include stomatal closure, photosynthesis decline, slower leaf expansion, decreases in respiration and biomass production, premature leaf and stem death, accelerated leaf senescence, stalk brittleness or collapse and reduction in seed size (Xu *et al.*, 2000).

Although sorghum has the capability to withstand under drought conditions, it has been an axiomatic that plant under limited water supply would not express its full genetic potential. Degree of severity caused by drought stress has been reported to be growth stage and varietal dependent (Ali *et al.*, 2009). Knowing the critical growth stages on which the drought stress bring about the most substantial reduction on the plant growth and yield would enable of managing the crop production in drought prone areas. Objective of this study was to evaluate the response of five sorghum genotypes to drought stress exposed at three stages of plant development.

MATERIALS AND METHODS

This greenhouse experiment was conducted from June to October 2010 in a completely randomized design with 5 replications and a 5 x 4 factorial arrangement of the treatments. First factor consisted of five sorghum genotypes: (i) Irat 31-1-3, (ii) Mandau, (iii) ICSV 1-40-1-1, (iv) Span 040-17, and (v) ICSV 57-55-52. Second factor consisted of plant growth stages at which the drought stress for 2 weeks was imposed: (i) no drought stress, (ii) 3 week after planting, (iii) boot stage, and (iv) grain filling stage. The planting media was 10 kg mixture of soil and manure (2:1 v/v) filled in a 40 cm x 40 cm plastic pot. Basal fertilizers (equivalent to 100 kg Urea, 100 kg SP-36, and 75 kg KCl hectare^{-1}) and additional 50 kg Urea hectare^{-1} at 42 days after sowing were added to each pot. Two seeds were sown in each pot at 3 cm depth, but thinned to single plant per plot after emergence. Drought stress was made by maintaining soil moisture at 10% of the media weight and monitored daily using soil moisture meter, otherwise soil moisture was kept at field capacity. The observations were made during harvest. Plant height was measured at heading from stem base to highest leaf tip. Stem diameter was measured at second node of stem base. Leaf number was counted at heading to all leaves including the flag leaf. Plant biomass was determined as the total dry weight of the whole plant, excluding panicle and grain, after oven dried at 80 ^oC to constant weight. Maturity date was counted from sowing to harvest (dap). Grain development and maturation period (GDP) length was determined as the difference between maturity date and heading date. Panicle length was measured from first ring of spikelet to panicle tip. Weight of 100 grain and grain yield per plantwere measured using digital balance after sun dried to 13 % seed water content. Analysis of variance (ANOVA) was employed to determine the significance of both main and interaction effects. Mean comparison was made using least significant different (LSD) at a $P \leq 0.05$ significance level. All statistical analyses were carried out using Statistical Analysis Software (SAS v8.2).

RESULT AND DISCUSSION

The average effects of two weeks drought stress imposed on five sorghum genotypes at different growth stages were presented in Table 1. Drought stress imposed at 3 wap had reduced stem diameter, plant biomass, and grain yield.Vanderlip (1993) noted that at 3 wap sorghum plant has five leave fully expanded and enters grand period of growth that constantly accumulate dry matter at nearly a constant rate until maturity. Any disturbance during this period would inhibit the vegetative growth process. Theoretically, early drought stress cause leaf water potential declines progressively with the advance in severity of the stress to meet evapotranspiration demand, leaving less water for dry matter accumulation process. Effects of early drought stress on the reduction growth characteristics of sorghum plant were reported by various workers, e.g. net assimilation rate (NAR) by Inuyama *et al.* (1976), photosynthetic rate by Morrrisset (1979), crop growth rate (CGR) and relative growth rate (RGR) by Ramu *et al.* (1991). However, as the early stress was discontinued, sorghum leaf water potential returned to normal and stomata reopen promptly (Sanchez-Diaz and Kramer, 1971) and the plant continues to elongate (Inuyama at al., 1976). Blum *et al* (1994) noted that sorghum stem plays an important role as food storage which is genetically linked to assimilate partitioning during stem elongation and the developmental characteristics of the stem. This implies that reductions in stem diameter, plant biomass, and grain yield were resulted as the compensatory effect of maintaining stem elongation and leaf number.

Decreasing plant performances were also observed when the drought stress was imposed at boot stage. However, the reductions on the vegetative growth ware not as intensive as they occurred in earlier stress, where only plant biomass was significantly reduced by the stress. In this study, plant biomass was measured as the whole plant basis and no attempt was made to separate between shoot and root dry weight. It seemed that the biomass reduction was mainly due to the decreasing root growth, as plant height, leaf number, and stem diameter were not affected by drought stress in this period. The severe effects of the stress imposed at boot stage were pronounced on panicle length, grain size, and grain yield. This indicates that assimilate production occurred during and following stress was mostly allocated for shoot growth and leaved less for the growth of root and yield components. In addition, drought stress at grain filling stage produced effects similar to same stress at boot stage, except that the reduction in grain yield was not so substantial.

Heading date was not affected by drought stress, but differential responses among genotypes to the stress were found on maturity date. Consequently, the grain development period (GDP) among the genotypes was varied accordingly (Table 2). This means that drought stress does not necessarily shorten the grain filling period as suggested by Younesi and Moradi (2009), but it is genotypic dependence and the growth stage in which the drought stress occurred. In this case, the GDP of ICSV 1-40-1-1 was not affected by two weeks stress at any growth stage, Span 040-17 shortened its GDP when the stress occurred during grain filling period, whereas other genotypes tended to prolong their GDP when the stress was imposed at early growth stage.

Table 1. Mean plant height, leaf number, stem diameter, panicle length, weight of 100 grain, and grain yield of sorghum as affected by two week drought stress.

Drought stress	Plant height (cm)	Leaf number	Stem diameter (mm)	Plant biomass (g)	Heading date (dap)	Panicle length (cm)	Weight of 100 grain (g)	Grain yield (g)
Control (no stress)	**145.52**	**10.5**	**14.02 a**	**80.32 a**	**62.0**	**24.48 a**	**2.30 a**	**33.97 a**
3 weeks after planting	**145.17**	**9.7**	**10.79 b**	**53.15 c**	**61.4**	**23.50 ab**	**2.30 a**	**28.41 b**
Boot stage	**140.64**	**10.0**	**14.66 a**	**66.16 b**	**61.8**	**21.32 b**	**1.29 b**	**10.02 d**
Grain filling stage	**142.60**	**10.4**	**13.54 a**	**63.01 b**	**62.8**	**25.28 a**	**1.33 b**	**13.46 c**

Note: Means in a column having the same letter do not different at the 0.05 probability level

Tabel 2. Mean grain development period (GDP) of five sorghum genotypes as affected by two weeks drought stress

Drought stress	Irat 31-1-3	Mandau	ICSV 1-40-1-1	Span 040-17	ICSV 57-55-52
	day				
Control	**36.4 b**	**44.8 ab**	**33.8 a**	**40.4 a**	**33.8 ab**
3 weeks after planting	**47.5 a**	**48.8 a**	**38.8 a**	**42.4 a**	**34.8 a**
Boot stage	**41.0 ab**	**42.4 ab**	**34.8 a**	**40.2 a**	**31.4 ab**
Grain filling stage	**36.0 b**	**38.2 b**	**41.6 a**	**27.4 b**	**28.6 b**

Note: Means in a column having the same letter do not different at the 0.05 probability level

CONCLUSION

The growth and yield of sorghum plant are reduced by two weeks drought stress occurred during either vegetative or reproductive stages. Stem diameter and plant biomass are substantially reduced by the stress during early vegetative stage. Both boot stage and grain filling stage are the critical periods of sorghum plant to produce higher yield under drought stress. Genotypes vary their grain development period in response to drought stress. The results presented here can bring the implication to the grain sorghum grower in determining the planting date to minimize the grain yield reduction due to drought stress.

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