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Thermal Response of Seedling Growth in Tropical Grasses in Controlled and Field Environments of Northern Kyushu, Japan

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ABSTRACT

Most tropical grasses in the warm southwestern region of Japan are cultivated as annuals and can be sown from May to July, after the harvest of an alternating crop of Italian ryegrass. However, suboptimal thermal conditions in the region may affect the germination and growth of seedlings. The objective of this study was to compare the growth of seedlings of promising tropical grasses in a Controlled Environment Facility (CEF) and in a Field Data (FD) trial. Temperatures in the CEF averaged 17.9, 22.9 and 27.9°C for the low (LT), middle (MT) and high temperature (HT) regimes, respectively, while the temperature in the FD trial was higher in the June-sowing (average 23.7°C, with a range between MT and HT in the CEF) than in the May sowing (average 21.2°C, between LT and MT). Favorable plant growth attributes tended to increase with the increase in air temperature in both trials. The growth rates in Guinea grass and Sudan grass exhibited a linear response to the increase in temperature from LT to HT, whereas the growth rate of Rhodes grass and colored Guinea grass showed saturation between MT and HT. Thus, for early sowing in mid-May, the prominent species judged in terms of high seedling potential were Sudan grass and Rhodes grass and for the late-sowing in early July, Sudan grass and Guinea grass.

Key words: Controlled environment, field trial, thermal response, tropical grasses

INTRODUCTION

Most tropical grasses in the warm southwestern region of Japan are cultivated as annuals and can be sown from May to July, after the harvest of an alternating crop of a temperate species of Italian ryegrass (*Lolium multiflorum* Lam.). The annual forage yield in double cropping of a summer crop of tropical green panic (*Panicum maximum* Jacq. var. *Trichoglume*) (Shen *et al.*, 1994) or Rhodes grass (*Chloris gayana* Kunth) (Fukagawa *et al.*, 2003, 2005) and Italian ryegrass (Fukagawa *et al.*, 2002) in a range of cropping seasons can reach 18-30 Mg ha^{-1} and tends to increase with an increase in the summer cropping periods (Kobayashi, 1982). However, thermal conditions in the region should regulate seed germination and growth of seedlings of tropical grasses due to suboptimal conditions for the grasses, even if the sowing season is delayed early in the summer season (Shimizu *et al.*, 1977). Annual tropical grasses cultivated in the region should possess higher annual dry matter yield accompanied with rapid seedling growth (Shen *et al.*, 1994). Since, tropical grasses usually have a lower germination percentage than temperate grasses

(Hardegree, 2006), especially for perennial species such as Bahia grass (*Paspalum notatum* Flügge), Centipedegrass (*Eremochloa* phiuroides (Munro) Hack.) and Guinea grass (*Panicum maximum* Jacq.), pre-sowing seed priming can enhance rapid germination in response to soaking in concentrated sulfuric acid solution for 30 min (Kijima and Takei, 1971), the mixed solution of gibberellic acid at 100 ppm and thiourea at 0.2% (Kijima and Takei, 1971), gibberellic acid solution (Zheng *et al.*, 2004) or H_2O_2 solution at 3% for 10 min (Chen *et al.*, 1993) and to potassium chloride, priming under salt stress (Dkhil *et al.*, 2014). It is apparent that tropical grass species with rapid seedling growth should be selected and cultivated (Shimizu *et al.*, 1977) so as to compete with summer weeds such as barnyard grass (*Echinochola crus-galli* L.) and Livid amaranth (*Amaranthus lividus* L.). As variation in sowing season affects the thermal conditions of grasses, it is necessary to clarify the thermal response of seedling growth for the major tropical grasses of the region. Thermal condition is considered important factor for the development of tropical grasses, since it is possible to assume that temperature may affect plant phenology in the process of nutrients absorption and translocation (Da Silva *et al.*, 2012). The growth of tropical grasses has already compared for controlled and field environments in Japan (Okada, 1978) and in Thailand (Tudsri *et al.*, 2002). However, since there have been few studies of the effects of sowing season on the thermal responses of seedling growth, it was first necessary to determine the growth characteristics of promising tropical grasses for haymaking in a range of sowing seasons in the region (Yamamoto *et al.*, 2004).

The objective of this study was to compare the growth of seedlings of promising tropical grasses in a Controlled Environment Facility (CEF) under three temperature regimes and in a Field Data (FD) environment after two sowing dates. Based on these data, the thermal response of seedling growth was determined that allowed coordinated high dry matter accumulation and rapid growth.

MATERIALS AND METHODS

CEF experiment (experiment 1): The CEF was located at the National Agricultural Research Center for the Kyushu Okinawa Region (32°53' N, 130° 44' E), where experiment 1 was conducted from December 19, 2001 to January 28, 2002. Four tropical grasses, Rhodes grass (*Chloris gayana* Kunth cv. Asatsuyu), Guinea grass (*Panicum maximum* Jacq. cv. Natsukomaki), colored Guinea grass (*Panicum coloratum* L. cv. Tamidori) and Sudan grass (*Sorghum sudanense* (Piper) Stapf cv. Sugarslim) were selected due to being the major cultivated species in the region. They were sown at three seedlings per pot with a 200 cm^2 base area (1/5000-a sized Wagner pot). Day/night temperatures in the CEF were regulated at three levels, 20/15°C (LT), 25/20°C (MT) and 30/25°C (HT) and the relative humidity was maintained at 80%. Day length was regulated to 14 h under 10 h of natural light, supplemented with 4 h of three incandescent lights at 0.4 kW at the canopy height. Plants were sampled 40 days after sowing at three replications per species per treatment to investigate tiller number and Top Dry Matter Weight (TDW). Mean Tiller Weight (MTW) was calculated as TDW divided by tiller number and plant Growth Rate (GR) as TDW divided by growth days.

The germination percentage was monitored with three replications of each grass species. Fifty seeds were placed in a Petri dish on two layers of filter paper that had been dipped with distilled water and the dishes were transferred to the CEF. The germinated seeds were counted and any that germinated was discarded every day for the 14 days of the experiment. Based on the germination percentage and mean days to germination, the germination coefficient was calculated as germination percentage divided by mean days to germination.

FD experiment (experiment 2): The FD experiment was conducted in a field of the Nagasaki Prefectural Livestock Experiment Station (32°14' N, 130°20' E) from 14 May to 18 July, 2002. As early June was judged the deadline in this region of Japan for sowing tropical grasses in order to double crop with Italian ryegrass, the sowing dates of the same four tropical species used in experiment 1 were fixed on 14 May (MS) and 7 June (JS). The sowing rate for Sudan grass was 3 g m^{-2} and for the other three grasses was 1 g m^{-2} at a row spacing of 40 cm, plotted under three replications. The plants were sampled 44-46 days after sowing to determine plant growth attributes and to calculate Crop Growth Rate (CGR).

The mean air temperatures in the 45 days after sowing on the first day of May, June and July were calculated from the data of a normal year observed by the Nagasaki Local Meteorological Observatory (32°44´N, 129°52´E) which is 43 km southwest from the experimental site.

Statistical analysis: The experiments 1 and 2 were arranged according to a completely randomized design with three replications. Analyses of variance were carried out using Stat-View for windows ver. 5.0, by one-way analyses procedures. Differences among treatment means were tested using the Least of Significance Difference (LSD) at 5% probability level.

RESULTS

Daily mean temperature and days of growth: Temperature conditions in the CEF averaged 17.9, 22.9 and 27.9°C for the LT, MT and HT regimes. The temperature in the FD trial was higher in JS (average 23.7°C, with a range between MT and HT in the CEF) than MS (average 21.2°C, between LT and MT). The days of growth after sowing in the FD were 44 days for MS and 46 days for JS and in the CEF, consistently 40 days for each plot.

Thermal response of TDW, MTW and GR in the four grass species: Plant growth attributes, such as TDW and MTW, tended to increase with an increase in daily mean temperature in both the CEF and FD trials (Fig. 1a and b, respectively). Changes in MTW were somewhat correlated with TDW, suggesting that dry matter accumulation in each tiller may be a major determinant of seedling growth. The relationship of daily mean temperature with GR and CGR in both the CEF and FD trials are shown in Fig. 2. The variations of GR in the CEF trial among grasses were larger than those of CGR in the FD trial due to the wider thermal regimes. The GR of Guinea grass and Sudan grass exhibited a linear response to the increase in temperature from LT to HT, whereas the GR of Rhodes grass and colored Guinea grass showed saturation between MT and HT. The high GR of Sudan grass and Rhodes grass at LT in the CEF trial was most directly related to the high germination coefficient for the two species and secondarily to the highest thousand seed weight (13.2 g) of Sudan grass, as shown in Table 1.

Table 1: Thousnd seed weight and germination coefficient

	¶Rhodes grass			Guinea grass			Colored guinea grass			Sudan grass		
Measurement	LT†	MT	HT	LT	MT	HT	LT	MT	HT	LT	MT	HT
Thousand seed weight (g)		0.256^{c}			0.953^{b}			1.21^{b}			13.2^{a}	
Germination coefficient ‡(%/day)	21.9^{az}	38.8^{by}	54.6^{bx}	4.21^{cy}	6.81^{dxy}	8.4^{dx}	7.95^{by}	13.6^{cx}	17.6^{cx}	26.5^{az}	44.7^{ax}	71.1^{ax}

†LT, MT and HT: Day and night temperature were 20/15°C and 30/25°C, respectively, ‡Germination coefficient was calculated by germination percentage/mean germination days×100, §: Mean within columns with different superscipts among species (a-d) and plots (x-z) are significantly different at 5% level, ¶: Naked seed of Rhodes grass was set in germination test

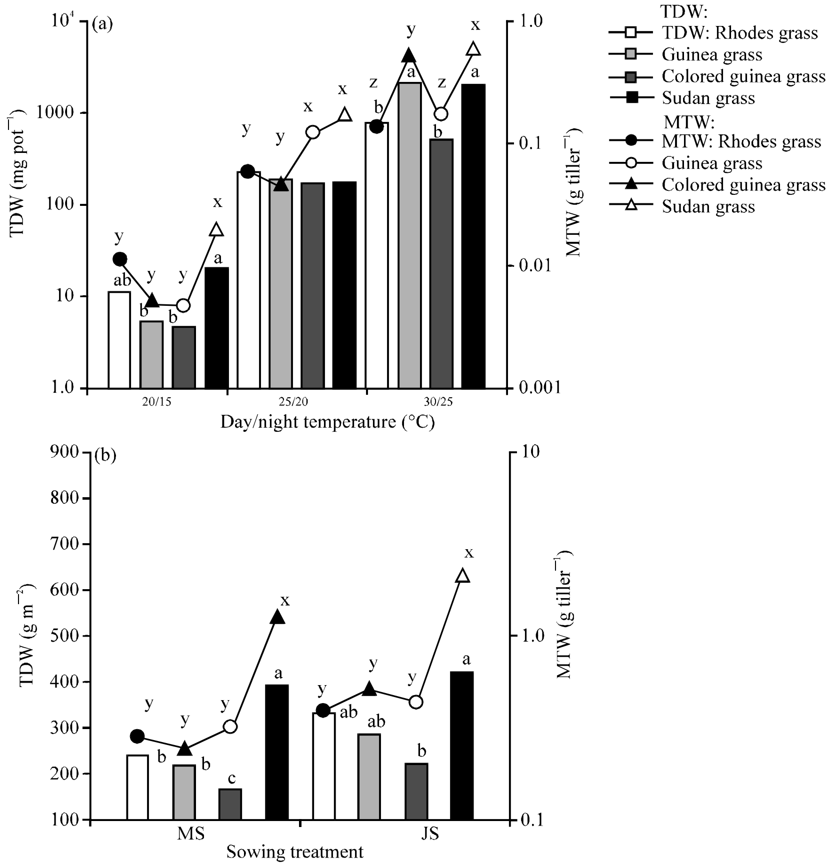

Fig. 1(a-b): Effect of temperature on Top Dry Matter Weight (TDW) and Mean Tiller Weight (MTW) of tropical grasses in (a) Controlled Environment Facility (CEF) and (b) Field. Different letters among same plots denote significant difference at the 5% level (TDW: a-c, MTW: x-z)

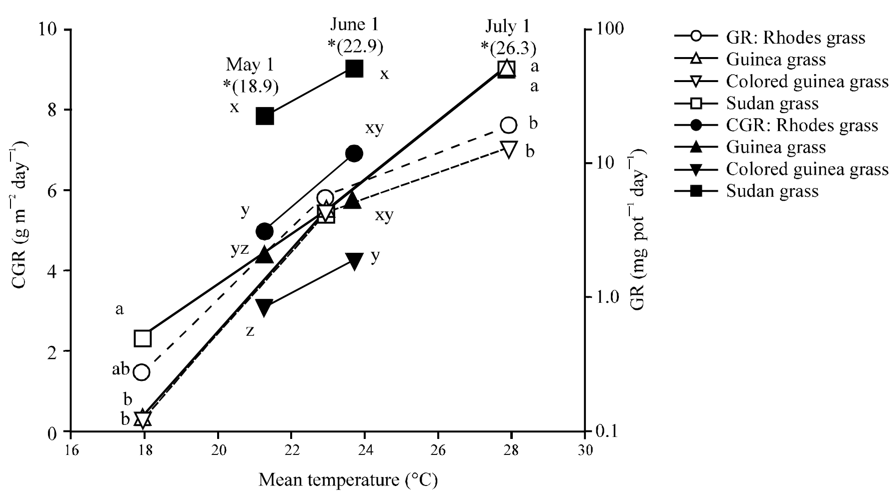

Fig. 2: Relationship of mean temperature to Growth Rate (GR) in CEF and Crop Growth Rate (CGR) in FD trial. Different letters among same plots denote significant difference at the 5% level (GR: a-b, CGR: x-z)

DISCUSSION

The thermal conditions of the CEF trial in the current study (20/15, 25/20 and 30/25°C) were higher than the base temperatures for growth of tropical grasses which were determined to be 12.4-13.4°C in two cultivars of *P. maximum* (Da Silva *et al.*, 2012).

Sweeney and Hopkinson (1975) compared vegetative growth in tropical grasses at 8 day/night temperature regimes, rising at 3°C intervals from 15/10 to 36/31°C, resulting in the notably lowest growth at 15/10°C. These findings were in line with the thermal responses observed in the current study of the seedling growth rate of tropical grasses, although at narrower temperature regimes. Leaf appearance rate (Kobayashi *et al.*, 1977) and individual leaf area (Kobayashi *et al.*, 1979) in some tropical grasses are lower in growing temperature regimes below 20°C than in those above 25°C which presumably led to the lowest TDW and MTW at LT in the CEF trial among the three temperature regimes.

Therefore, dry matter accumulation of tropical grasses is linearly correlated with the thermal sum in field trials, while the regression coefficient was higher in *P. maximum* cv. Mombaca than cv. Tanzania (Da Silva *et al.*, 2012). Optimum temperatures for early seedling growth have been observed to vary in tropical species (Wilson and Ford, 1971; Kobayashi *et al.*, 1977). Sweeney and Hopkinson (1975) classified tropical grasses into two thermal response types which includes those with growth depressed above 30/25°C (Type 1, i.e. *C. gayana*) as well as those in a previous study for *C. gayana* (Fukagawa *et al.*, 2005) and those with no demonstrable high temperature depression (Type 2, i.e., *P. maximum*), in accordance with the current study of thermal response in Rhodes grass (Type 1) and Guinea grass (Type 2).

A high germination coefficient should be an essential characteristic for tropical grasses, especially under low temperature conditions or in the early sowing season, to compete with summer weedy species for establishment (Masters and Mitchell, 2007). The lowest seed weight of Rhodes grass hardly hindered its germination coefficient, probably due to the lack of seed dormancy in the species (Fukagawa *et al.*, 2002). Dormancy release of *Sorghum halpense* which is a relative of Sudan grass, was determined by the observed increase in germination temperature (Arnold *et al.*, 1990). The highest germination percentage, around 25% per day for both Rhodes grass and Sudan grass, was recorded even under the 20/15°C regime, suggesting that these are suitablefor the early sowing season.

CONCLUSION

Based on the these research findings, the effect of air temperature on early seedling growth in the CEF tended to be similar to those in the FD trial and the temperature regimes examined in the CEF corresponded closely to the sowing period of tropical grasses, from 1 May to 1 July, in Nagasaki Prefecture of northern Kyushu. These results suggested that the adoption of cultivation of tropical grasses in the warm southwestern region of Japan would be practical. Thus, for the four cultivated tropical grasses examined, for early sowing in mid-May, the prominent tropical grasses in terms of high seedling potential were Sudan grass and Rhodes grass and for late- sowing in early July, Sudan grass and Guinea grass.

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