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Growth response of Elephant grass (*Pennisetum purpureum*) and *Zea mays* to chilling temperature

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ABSTRACT

Pennisetum purpureum is a fast-growing C_4 crops. During winter, chilling temperature that reaches 12°C represents a major problem for the growth and productivity of *P. purpureum* in AL-Madinah AL-Munawwarah, the western part of Kingdom of Saudi Arabia. The objective of this work is to study the effect of chilling temperature on growth rates of both *P. purpureum* and *Zea mays*. The results obtained indicate that chilling temperature significantly reduces all the growth parameters of *Z. Mays*, but only reduced leaf extension, leaf area, and chlorophyll content of *P. purpureum*. Roots of both *P. purpureum* and *Z. mays* showed higher resistance to the chilling temperature than shoots when compared to the control. This study showed that the growth rate and productivity of *P. purpureum* at chilling temperature were greater than that of *Z. mays*.

Key words: *Zea mays*, Elephant grass, *Pennisetum purpureum*, chilling stress, plant growth.

INTRODUCTION

In cool and temperate regions, chilling temperatures lower the rates of both leaf cell division and the elongation of C_4 plants (Sowinki *et al*., 2005). Chilling temperature is also known to affect all the stages of plant growth (from germination, early seedling growth through to canopy closure) and a wide range of physiological processes (Foyer *et al*., 2002; Tambussi *et al*., 2004; Hund *et al*., 2007). The closure of canopy in the early growing season is an important point for a crop to intercept solar radiation and convert it into biomass energy (Vargas *et al*., 2002; Heaton *et al*., 2004).

Many studies have shown a rapid and sensitive growth response of plants to chilling temperature (Ismail and Hall, 2002; Naidu *et al*., 2003; Tambussi *et al*., 2004; Sowinki *et al*., 2005; Hund *et al*., 2007). Maize is the most cultivated C_4 species in the world (Kim *et al*., 2007). Exposure of *Zea Mays* to low temperatures impairs leaf development and photosynthesis, and breaks down chlorophyll of mature leaves (Long, 1999; Sage, 1999). Milford and Riley (1980) found that the rate of leaf expansion was the major factor determining the differences in rates of leaf growth of nine sugar beet varieties at four different temperatures. This suggests that low temperature is one of the most important factors that affect leaf growth of C_4 plants.

Elephant grass (*P. purpureum*) is a fast-growing C_4 grass (Wang *et al*., 2002), that is cultivated for cattle feeding in AL-Madinah AL-Munawwarah in the western part of Kingdom of Saudi Arabia (AL-Shoaibi and AL-Sobhi, 2004). During winter, chilling temperature drops to 12°C, this might affect its growth and productivity (Presidency of Meteorology and Environment, personal communication).

Since there is a lack of information concerning the chilling resistance of *P. purpureum*, this work was carried out to investigate the growth response of the elephant grass toward chilling temperature. All the growth factors were compared to *Z. mays* pattern.

MATERIAL AND METHODS

Rhizomes of *Pennisetum purpureum* originally derived from Africa and *Zea mays cv.* LG 80 were planted in pots containing a peat-based compost (F2, Levington Horticultural Ltd., Ipswich, UK.) and grown in high-light controlled chambers (Fitotron SGC066. CHX, Sanyo Gallenkamp PLC, Leicester, UK.), at day/night periods with temperatures of 25°C/20°C and 14°C/12°C. Fertilization was carried out once a week by irrigation with Hoagland's nutrient solution (Arnon & Hoagland, 1940). The vapour pressure deficit (VPD) was kept below 1 kPa. Photon flux density at leaf height was 600 µmol $m^{-2}s^{-1}$ and 14 hours photo period .

Leaf extension was measured every day. Growth parameters included shoot length, number of leaves, leaf area and fresh weights of shoots and roots were determined 30 days after planting. To determine the dry weight, shoot and root samples were oven-dried at 70 °C for 48 h. Chlorophyll of leaves was extracted using 80% acetone and its content was determined as described by Arnon (1949), at 645 and 663 nm.

The data obtained from various analyses and measurements were statistically analyzed using analysis of variance (Systat, Inc., Evanston, Illinois. U.S.A).

RESULTS

The effect of temperature on leaf extension of both *P. purpureum* and *Z. mays* are illustrated in Fig. 1. Leaf extension rates of the two species varied greatly between the two temperature regimes. *Z. mays* showed greater rate of leaf extension at 25°C, while *P. purpureum* showed greater rate of

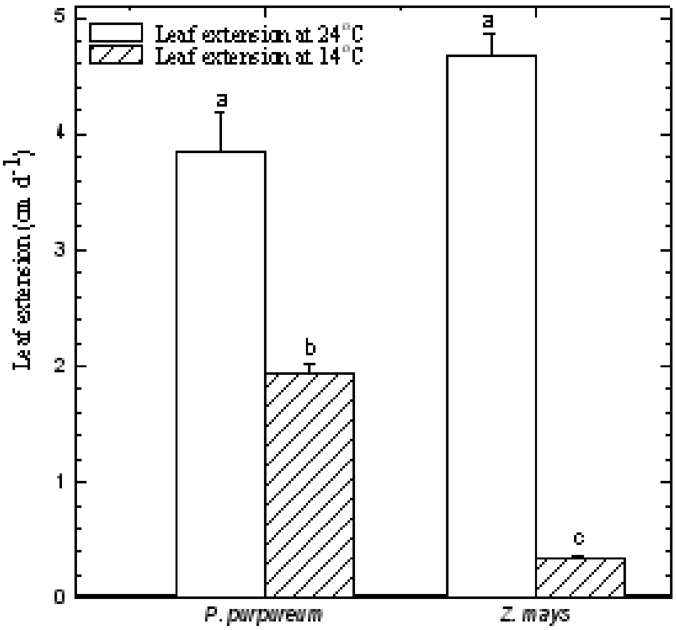

Fig. 1. The effect of chilling temperature on leaf extension of *Pennisetum prpureum* and *Zea mays* Values shown are the mean of n =3 replicate plots (±SE). Different letters show significant differences between chilling treatments (P<0.05)

leaf extension at 14°C. However, both species had a significant lower rate of leaf extension at 14°C compared to 25°C ($P<0.05$). The results also showed that leaf extension rate of *P. purpureum* at 14°C were significantly greater than that of *Z. mays* Fig. 1.

Chilling temperature 14°C significantly reduced plant height, number of leaves and the leaf area of *Z. mays* compared to the control 25°C Table 1. In contrast, plant height and number of leaves of *P. purpureum* were not significantly affected by the chilling temperature Table 1. A comparison of these responses of the three growth parameters of the two species indicated that leaf area was the most sensitive parameter to the chilling temperature compared to control. The reductions in leaf area were amounted to 78.9% for *Z. mays* and to 18.5% for *P. purpureum* compared to control Table 1.

In *Z. mays*, fresh and dry weight of shoots and roots significantly decreased by chilling temperature compared to control Table 2. On the other hand, chilling temperature did not significantly affected the fresh and dry weight of shoots and roots *P. purpureum* Table 2. The results also showed that shoots of both species were more sensitive to chilling temperature than roots.

Table 1: Mean number of leaves, plant height and leaf area of *P. purpureum* and *Z. mays* grown under different temperature

Parameter	Plant	Growth temperature (°C)	
		25/20	14/12
No. of leaves per plant	*P. purpureum*	6.67 ± 033 [a]	5.67 ± 0.37 [a]
	Z. mays	5.33 ± 0.27 [a]	3 ± 0.01 [b]
Plant height (cm)	*P. purpureum*	42 ± 1.22 [a]	34.5 ± 1.02 [a]
	Z. mays	56.67 ± 1.63 [b]	13.5 ± 1.04 [c]
Leaf area per plant (cm^2)	*P. purpureum*	135.9 ± 1.73 [a]	110.8 ± 1.06 [b]
	Z. mays	148.5 ± 2.4 [a]	31.25 ± 0.94 [c]

The means within each row of the same letter do not differ significantly at 5% level of probability according to Scheffe's Test. Values shown are the mean of 3 replicates (± SE).

Table 2: Mean fresh and dry weights of shoot, and root of both *P. purpureum* and *Z. mays* grown under different temperatures

Parameter	Plant	Growth temperature (°C)	
		25/20	14/12
Fresh weight of shoot	*P. purpureum*	6.04 ± 0.23 [a]	5.2 ± 0.41 [a]
(g $plant^{-1}$)	*Z. mays*	7.92 ± 0.41 [b]	1.08 ± 0.02 [c]
Dry weight of shoot	*P. purpureum*	1.41 ± 0.04 [a]	1.06 ± 0.02 [a]
(g $plant^{-1}$)	*Z. mays*	1.18 ± 0.02 [a]	0.17 ± 0.01 [c]
Fresh weight of root	*P. purpureum*	4.85 ± 0.24 [a]	5.28 ± 0.05 [a]
(g $plant^{-1}$)	*Z. mays*	4.97 ± 0.36 [a]	1.43 ± 0.03 [b]
Dry weight of root	*P. purpureum*	0.23 ± 0.01 [a]	0.33 ± 0.02 [b]
(g $plant^{-1}$)	*Z. mays*	0.27 ± 0.05 [a]	0.08 ± 0.01 [c]

The means within each row of the same letter do not differ significantly at 5% level of probability according to Scheffe's Test. Values shown are the mean of 3 replicates (± SE).

Fig. 2 shows that both species had significant lower chlorophyll content at chilling temperature compared to control. The percentages of reduction for *Z. mays* and *P. purpureum* were 27.4% and 76.5%, respectively. Moreover, the chlorophyll content of *P. purpureum* at chilling temperature was significantly higher than that of *Z. mays*.

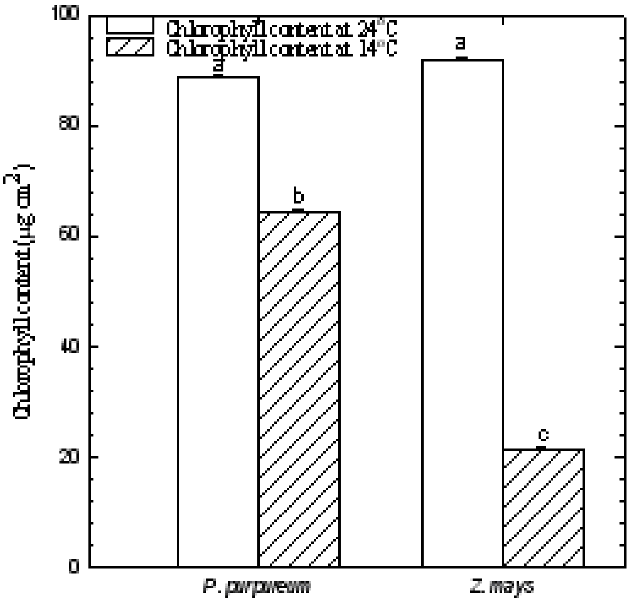

Fig. 2. The effect of chilling temperature on chlorophyll contect of *Pennisetum prpureum* and *Zea mays* values shown are the mean of n =3 replicate plots (±SE). Different letters show significant differences between chilling treatments (P<0.05)

DISCUSSION

The ability to extend leaves rapidly at chilling temperature is one of the two variables that affect the productivity of C_4 species in cold climates (Clifton-Brown and Jones, 1997). The results reported in Figure 1 showed that reduction of temperature from 25°C to 14°C reduced leaf extension rate of *P. purpureum* and *Z. mays* to about 49.6 and 92.4%, respectively. However, *P. purpureum* showed a significantly greater rate of leaf extension at chilling temperature compared to *Z. mays*. This extension rate was grater than *Cyperus longus* (1.1 cm d-1) and *Lolium perenne* (0.75 cm d-1) grown at the same temperature condition (Jones *et al*., 1981; Pollock and Eagles, 1988), but, it was 10.2% lower than that of *Miscanthus giganteus* (2.16 cm d-1) grown at the same temperature (Farage *et al*., 1998).

Results of this study indicate that the speed of leaf elongation at 25°C is not a guide to the speed of leaf elongation at 14°C (Figure 1). At 25°C, the leaf extension rate of *Z. mays* was 17.6% greater than that of *P. purpureum* while the leaf extension rate of *P. purpureum* at 14°C was 81.8% grater than that of *Z. mays* grown at the same temperature. This agrees with the findings of Clifton-Brown and Jones (1997) for one genotype of *Miscanthus* which showed high rates of leaf extension at 20°C but another genotype of the same genus showed the highest leaf extension rates at 5°C.

All the growth parameters of *P. purpureum* were not affected by chilling temperature except leaf extension and leaf area. On the other hand, chilling temperature significantly reduced all the growth parameters of *Z. mays* Table 1-2. Collins and Jones (1986) reported that roots of *Cyperus longus* are more resistant to chilling temperature than shoots. The present results confirmed the earlier observations of higher roots resistant to chilling temperature than shoots for both species compared to control Table 2.

A decrease in chlorophyll contents was reported in many crops that had different responses to chilling temperature (Haldimann, 1998; Kao *et al*., 1998; Haldimann, 1999). In the same way, the results in Fig. 2 showed that chlorophyll contents of both species decreased at chilling temperature. This decrease could be due to the chlorophyll breakdown at this particular chilling temperature (Kao *et al*., 1998). Another possibility to this decrease in chlorophyll contents could be attributed to the irregular development of chloroplasts (Haldimann, 1998; Sowinski *et al*., 2005).

In conclusion, this study showed that the growth rate and productivity of *P. purpureum* at chilling temperature were greater than that of *Z. mays*.

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