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Glycinebetaine, an osmolyte of interest to improve water stress tolerance in sunflower (*Helianthus annuus* L.): water relations and yield

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Abstract

Two sunflower lines, namely, Gulshan-98 (dwarf) and Suncross (tall) were subjected to water stress environment at the vegetative or reproductive growth stage. Three levels (0, 50 and 100 m*M*) of glycinebetaine (GB) were applied before sowing (seed treatments) or at the start of water deficit treatments (foliar application) at the vegetative or reproductive growth stage. Water stress significantly decreased leaf water contents, osmotic and turgor potentials in both sunflower lines. Pre-treatment of seeds with both levels of GB did not affect above mentioned water relation parameters under both control (normal irrigation) and water stress environments. Foliar application of GB at the vegetative or reproductive growth stage, however, increased leaf water and turgor potentials to some extent in both sunflower lines when grown under water stress. The leaf osmotic potential was not affected by exogenous supply of GB at either growth stage. However, water stress induced decline in achene yield/plant was significantly reduced by the foliar application of GB. Foliar spray of 100 m*M* GB was found to be more beneficial in preventing the effects of water stress on above mentioned attributes as compared with 50 m*M* GB.

Keywords: Achene yield; Glycinebetaine; Osmotic potential; Sunflower; Water potential; Water stress

1. Introduction

Shortage of water, the most important component of life, limits plant growth and crop productivity, particularly in arid regions more than any other single environmental factor (Boyer, 1982). Reduced precipitation together with the higher evapotranspiration is expected to subject natural and agricultural vegetation to a greater risk of drought in those areas (Samarakoon and Gifford, 1995). Even a short term drought can cause substantial losses in crop yield (Ashraf and Mehmood, 1990). Decreasing water supply either temporarily or permanently affects morphological and physiological processes in plants adversely. Differences in water relation characteristics reflect the differences between the species and lines, and are considered as an indicator of drought resistance or tolerance (Sobrado and Turner, 1983). Particularly, osmotic adjustment (active lowering of osmotic potential in response to drought) is a mechanism that significantly contributes towards drought resistance (Blum and Sullivan, 1986; Ludlow and Muchow, 1990).

Water deficit has been shown to decrease leaf water potential in various sunflower lines (Ashraf and O'Leary, 1996). In sunflower, leaf water potential usually ranges from −0.48 to −1.74 MPa under different agro-climatic conditions (Prasad et al., 1985; Rachidi et al., 1993), although under water deficit, it can drop as below as −3.0 MPa (Wise et al., 1990). Moreover, it is reported that dwarf sunflower lines are more drought tolerant than tall lines, showing a smaller decrease in leaf osmotic potential in response to drought stress (Angadi and Entz, 2002a). Turgor maintenance plays a very important role in stress tolerance of plants and this may be due to its role in stomatal regulation, and hence photosynthesis (Ludlow et al., 1985). Sunflower cultivars showing higher turgor potential under water stress showed a smaller decrease in yield (Angadi and Entz,

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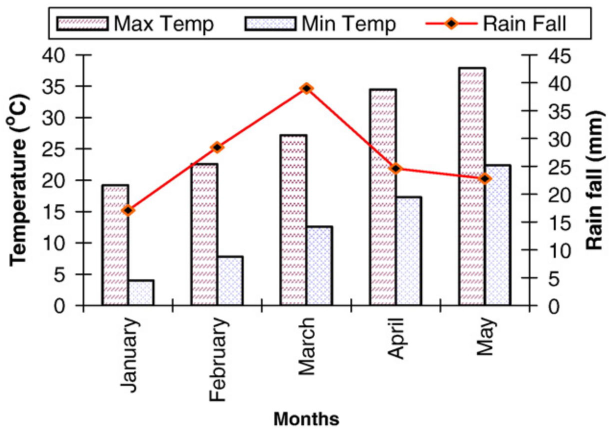

Fig. 1. Meteorological data recorded during the entire growth season of the crop.

2002b). However, some evidence indicated that stress tolerance is not associated with leaf turgor potential (Ashraf and O'Leary, 1996).

It is well reported that exogenous application of glycinebetaine improves stress tolerance in different plant species including both GB-accumulators and non-accumulators (Harinasut et al., 1996; Hayashi et al., 1998; Allard et al., 1998). Application of glycinebetaine significantly alleviates the adverse effects of salinity and water stress on growth of rice (Harinasut et al., 1996; Rahman et al., 2002). However, other evidence suggests that exogenous application of GB is not effective for all crops (Sulpice et al., 1998; WeiBing and Rajashekar, 1999). Furthermore, even toxic effects of exogenously supplied glycinebetaine have been reported in rape plants (Gibon et al., 1997), suggesting that it is not a compatible solute for all plants. Diaz-Zarita et al. (2001) found that foliar application of glycinebetaine at the vegetative stage enhances grain yield by increasing number of grains per spike in water stressed wheat plants. Exogenous application of glycinebetaine also increases grain yield in some other crop plants like maize and sorghum (Agboma et al., 1997a) under varying levels of water stress. However, the rate and timing of glycinebetaine application affect the outcome, and different crop species respond differentially to soil water status and glycinebetaine application (Agboma et al., 1997a,b,c). Glycinebetaine application to the foliage is readily absorbed but the concentrations in the leaves make a negligible contribution to the total leaf sap osmotic potential (Makela et al., 1998).

Although a lot of literature is available about water stress effects on sunflower (Wise et al., 1990; Tahir et al., 2002; Angadi and Entz, 2002a), information regarding the influence of exogenous glycinebetaine on physiological aspects of sunflower under normally irrigated and water deficit environment is scare. The present study was conducted to determine whether and how glycinebetaine application ameliorates the effects of water deficit on water relation parameters and yield of sunflower. The secondary objective of the study was to find out the appropriate application time at which exogenous glycinebetaine could be more beneficial to alleviate the water stress effects on sunflower plants.

2. Materials and methods

Two sunflower lines, namely, Gulshan-98 (dwarf) and Suncross (tall) were used in the present study. The seeds of both lines were obtained from the Regional Office of the Pakistan Seed Council, Faisalabad. The studies were conducted at the Research Area, Department of Botany, University of Agriculture, Faisalabad, Pakistan. Meteorological data were recorded at the University of Agriculture, Faisalabad, Pakistan (about 200 m from the experimental area) for the entire crop growth season. The mean maximum/minimum temperatures and rainfall have been presented in Fig. 1. The soil used was clay. The soil texture was determined with the hygrometer method (Dewis and Freitas, 1970). The physiochemical characteristics are presented in Table 1. Electrical conductivity, pH and ions of saturation extract were determined according to Jackson (1962). The available phosphorous was determined from saturated paste extract (Olsen and Sommers, 1982). The nitrate and ammonium was estimated by acid digested material (Bremner and Mulvaney, 1982) and organic matter through sulphuric acid using the Walkley–Black Method (Sahrawat, 1982). The experiment was laid out in a split plot design with four replications of each experimental unit.

The pre-planting irrigation was applied 15 days before sowing. When the soil came into condition, the field was well ploughed for sowing. Seeds (10 kg/ha) were hand drilled on January 18, 2003 with row to row distance of 75 cm. Thinning the plants was done 15 days after germination to keep plants at a distance of 30 cm. Each replication was allotted two rows containing six plants in each row. Water deficit treatments were applied at the vegetative and reproductive stages of plant growth with a control (normal irrigation) for each application time. First irrigation was applied 15 days after the emergence to all the three main plots. The second irrigation was applied 25 days after the first irrigation except the plants subjected to water stress at the vegetative stage. The third irrigation was applied at the time of head formation (twenty five days after the second one) except the plants subjected to water stress at the reproductive stage. The last irrigation was applied to all the plants at the seed filling stage.

Table 1
Soil characteristics of experimental site

Physiochemical properties	Results
Soil texture	Clay
Sand (%)	22
Silt (%)	13
Clay (%)	65
Saturation percentage	31
Organic matter (%)	0.78
NO_3–N (mg/kg dry soil)	6.5
NH_4–N (mg/kg dry soil)	3.00
Available phosphorus (mg/kg of dry soil)	5.6
Potassium (mg/kg of dry soil)	187
Calcium (mg/kg of dry soil)	109
Soil pH	8.1
Electrical conductivity (dSm^{-1})	2.1