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# Evaluation of Drought Tolerance of Corn (*Zea mays* L.) Hybrids and Their Response to Biofertilizer

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## ABSTRACT

Drought is one of the major problems affecting crop production in many parts of Uzbekistan. It is important to select high-yielding corn cultivars, and to improve their growth and development under ecologically stressed conditions. The objective of the present study was to evaluate corn hybrids which had adapted to stressful (salt) conditions and to investigate their response to biofertilizer. Among the studied corn hybrids, Harinoso de Ocho (4.10 t/ha) and Celaja (4.0 t/ha) had the highest yield while Sonora 373 (3.14) and Zapalote chico SRV (3.24) produced the lowest yield under stressed conditions. An analysis of variance showed that the effect of *Pseudomonas putida* TSAU1 (also considered to be a biofertilizer) on grain yield of salt-tolerant corn hybrids Harinoso de Ocho, Celaja and Colorado was significant compared to control plants. These results, in agreement with previous reports in the literature, suggest that by concentrating the breeding objective to select salt-tolerant corn genotypes can result in a more rapid improvement of grain yield under drought stress. The response to bacterial inoculants differed among hybrids. Corn hybrids that benefit from an association with plant growth-promoting bacteria should be selected.

**Keywords:** bacterial inoculants, corn, drought tolerance, hybrids

## INTRODUCTION

Across the globe today, maize (*Zea mays* L.) is a direct staple food for millions of individuals and, through indirect consumption as a feed crop, it is an essential component of global food security (Campos *et al.* 2004). In Uzbekistan, maize is the principal staple food crop produced and consumed by most households, but its production is limited by drought and salt stress. Drought affects maize productivity by restricting seasonal duration required for optimal vegetative growth and through unpredictable stress that can occur at any time during the cropping cycle (Edmeades *et al.* 1994). Thus, the development of drought-tolerant crop varieties is a key step for yield improvement under drought stress (Campos *et al.* 2004; Boomsma and Vyn 2008; Golbashy *et al.* 2010). In Uzbekistan, improvements in drought tolerance of maize hybrids could potentially benefit growers through improved water use efficiency and enhanced productivity during periods of drought. Moghaddam and Hadi-Zadeh (2002) found that stress tolerant index (STI) was useful to select favourable corn cultivars under stressful and stress-free conditions.

Another solution for sustaining plant growth and development under stress is to use plant growth-promoting rhizobacteria (PGPR) containing 1-aminocyclopropane-1-carboxylate (ACC) deaminase activity which reduce stress-induced ethylene production and improve drought stress resistance of plants (Glick *et al.* 2007). The ameliorative effects of PGPR on plant growth under saline conditions have been shown on various plant species, such as tomato, pepper, canola, bean and lettuce (Yildirim and Taylor 2005; Barassi *et al.* 2006; Egamberdieva and Kucharova 2009).

To our knowledge, no corn breeding and physiological research programs have examined the beneficial effects of biofertilizers on maize when developing drought-tolerant varieties. Here, corn hybrids adapted to stressful conditions were evaluated and their response to biofertilizer was investigated.

## MATERIALS AND METHODS

This study was conducted in the northwest of Uzbekistan with a temperate semi-arid region during 2008. The drought tolerance of 11 corn hybrids (Dente Rio, Grandense Rigoso, Harinoso de Ocho, Cateto Sulino Grosso, Sonora 373, Sonora 268, Zapalote chico, Zapalote chico SRV, Zapalote chico J 217413, Celaja, and Colorado) was evaluated in two separate experiments based on a complete randomized block design with four replications under optimal moisture condition and/or drought stress. The hybrids were grown in two-row plots with 3.5 m length and 0.70 cm spacing between rows. Irrigation was applied based on 50 and 80% allowable water depletion for non-stress and stress conditions, respectively. Drought tolerance indices were calculated by the following equations (Fischer and Maurer 1978; Sio-Se Mardeh *et al.* 2006), where Ys and Yp are stress and non-stress yield indices of a given genotype, respectively.

$$\text{Stress Tolerance Index } (STI) = \frac{Yp \times Ys}{(\bar{Y}p)^2}$$

Five plants were randomly selected to measure yield attributes at the maturation stage and final yield was measured in a 9 $m^2$ area from four replicated plots. Data were recorded on 10 plants from each plot for grain yield (kg $ha^{-1}$), which was calculated for the entire plot.

Field experiments for the evaluation of the response of corn hybrids to bacterial inoculation were conducted at the Agricultural Research Station of the Tashkent State University of Agriculture. The experiment was carried out in a randomized complete block design with four replications. The factors were 1) control, without bacterial inoculation; 2) *Pseudomonas putida* TSAU1, a biofertilizer. Each experimental unit contained six plant rows over 5 m with 6 cm row spacing and 16 cm distance between plants. For cultivation of the bacteria, 750-ml flasks containing 100 ml of KB medium (reference required) were inoculated with 5 ml of a *P. putida* TSAU1 suspension and grown in a shaker (220 rpm) at 28°C for 48 h. These flasks were used for inoculation of 5-L

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**Short Communication**

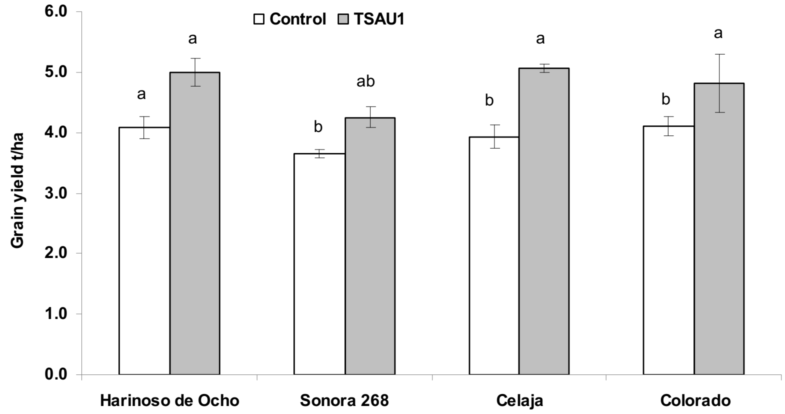


**Fig. 1 Effect of *Pseudomonas putida* TSAU1 on the grain yield of four corn hybrids.** Statistical differences between treatments are indicated with different letters ($P < 0.05$ according to DMRT).

**Table 1** Average yield of corn hybrids under optimal (Yp) and stress (Ys) conditions, and calculated different drought tolerance indices.

| Genotype | Grain yield, t/ha | | Stress tolerance index (STI) |
|---|---|---|---|
| | Stress condition | Optimal condition | |
| Dente Rio Grandense Rigoso | 3.47 abc | 7.97 ab | 0.53 |
| Harinoso de Ocho | 4.10 a | 8.24 a | 0.65 |
| Cateto Sulino Grosso | 3.56 abc | 7.41 ab | 0.51 |
| Sonora 373 | 3.14 bc | 7.95 ab | 0.48 |
| Sonora 268 | 3.75 ab | 7.40 ab | 0.54 |
| Zapalote chico | 3.57 abc | 6.25 b | 0.43 |
| Zapalote chico SRV | 3.24 bc | 5.58 bc | 0.35 |
| Zapalote chico J 217413 | 3.50 abc | 5.93 b | 0.40 |
| Celaja | 4.00 a | 6.81 abc | 0.53 |
| Colorado | 3.81 ab | 8.66 a | 0.64 |

Statistical differences between treatments are indicated by different; $P < 0.05$ according to DMRT.

bottles, each containing 1 L of growth medium. After cultivation in a shaker (220 rpm) at 28°C for 48 h, the cell suspensions were aseptically transferred into sterile 10-L canisters and stored at 5°C. Seeds of maize genotypes were mixed with a slurry in bacterial suspension. All trays were kept for 4 h at room temperature, allowing the bacteria to coat the seed so as to ensure colonization during germination. Inoculation of seeds and sowing were performed at the beginning of the day. The plants were harvested at maturity (120 days after sowing) from the middle rows of each plot and were weighed for yield measurements.

Data were statistically analyzed using analysis of variance (ANOVA) appropriate for RCBD with SAS ver. 9.1. Means were compared using Duncan's multiple range test at $P \leq 0.05$ (Steel and Torrie 1984).

## RESULTS AND DISCUSSION

There were significant differences among genotypes with respect to crop yield (**Table 1**), which demonstrated the existence of high diversity among genotypes that enabled drought-tolerant hybrids to be screened. Among all hybrids, in stressed conditions, Harinoso de Ocho (4.10 t/ha) and Celaja (4.0 t/ha) had the highest productivity while Sonora 373 (3.14 t/ha) and Zapalote chico SRV (3.24 t/ha) produced the lowest crop yield (**Table 1**).

Low grain yields of Sonora 373 were likely attributable to factors other than drought, probably a combination of low inherent soil fertility and possibly damage by plant pathogens. Drought stress declined seed yield and its components in corn, mainly due to reduction of kernel number per row (Golbashy *et al*. 2010). Genetic variance and broad sense heritability of grain yield often decline with increasing moisture stress (Bolaños and Edmeades 1996; Jafari *et al*. 2009).

The ANOVA showed that the effect of *P. putida* TSAU1 on grain yield of salt-tolerant corn hybrids Harinoso de Ocho, Celaja and Colorado was significant compared to control plants (**Fig. 1**). There was no significant growth stimulation for Sonora 268. The bacterial inoculants increased grain yield of corn hybrids Harinoso de Ocho (22%), Sonora 268 (16%), Celaja (28%) and Colorado (17%). The extent of the positive effect of the bacteria on plant growth varies with the species or variety of the host plant (Chanway *et al.* 1988; Egamberdieva 2010). Alam *et al.* (2003) also found cultivar variation in the stimulation of rice growth inoculated with PGPR. Unfavourable environmental factors such as salinity and drought lead to sharp changes in the balance of phytohormones, associated with a decline in the level of growth activating hormones such as indole-3-acetic acid (IAA) (Frankenberger and Arshad 1995; Sakhabutdinova *et al.* 2003). Egamberdieva (2009) proposed that bacteria which are able to produce IAA under stressed conditions may supply additional phytohormones to the plant, thus may help stimulate root growth and reverse the growth-inhibiting effect of stress to a certain extent in both shoot and root growth. Furthermore, plant stress can be reduced by ACC deaminase-producing bacteria which can lower the level of the plant stress hormone ethylene (Glick *et al*. 2007; Belimov *et al.* 2009). Hamidi *et al*. (2007) reported an increase of grain yield when corn seeds were inoculated with rhizobacteria. Faramarzi *et al*. (2012) observed an increase in corn yield due to combined inoculation of seeds with *Azospirillum lipoferum*, *Pseudomonas putida* and *Azotobacter chroococcum*. In this study, *P. putida* TSAU1 produces the enzyme ACC deaminase, and its colonization of the seed coat of a developing seedling may decrease the ethylene level thus preventing the inhibition of the root growth by ethylene (Glick *et al.* 2007).

These results suggest that corn breeding should select salt-tolerant genotypes that result in improved grain yield under drought stress and since the response of corn to bacterial inoculants differs among hybrids, it is recommend corn hybrids that benefit from an association with PGPR be selected.

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