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Original Research

GENETIC ASSOCIATION AMONG SEEDLING TRAITS OF *ZEA MAYS* UNDER MULTIPLE STRESSES OF SALTS, HEAVY METALS AND DROUGHT

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Abstract: *Maize is highly sensitive for drought, heat, cold, salinity and heavy metals toxicity. The grain yield and quality of grains is highly affected due to abiotic environmental factors. For evaluating maize under drought as well as salts and heavy metals we have conducted an experiment in the greenhouse of IMBB (Institute of Molecular Biology and Biotechnology), University of the Lahore. Four maize genotypes were selected for our research work, viz., B-316, EV-1097Q, Raka-poshi and Sahiwal-2002. The seeds of selected maize genotypes were sown in 72 pots. Each of the pot was in triplicate for each of the maize genotype. The treatments of drought, salt and heavy metals were kept as following: Control, 50% irrigation water, 0.5m Molar NaCl, 0.5m Molar $ZnSO_4$, 0.5m Molar $AlCl_3$ and 0.5m Molar $MgCl_2$. It has been revealed from results the performance of maize genotypes was variable under different treatments of heavy metals, drought and salt stress environments. The treatments of $AlCl_3$ and NaCl were found as the higher toxic treatments for most of the study traits of maize which may decrease the photosynthetic rate and accumulations of organic compounds in maize seedlings and may cause the death of seedlings. Significant and positive correlation was reported between shoot length other studied traits while the higher contribution for shoot length was reported for root length, leaf area and fresh root/shoot weight ratio. It was found from results that the Sahiwal -2002 performed better under all stress treatments for seedling traits as compared with B-316, Raka-poshi and EV-1097Q maize genotypes.*

Keywords: *Zea mays*, salt, heavy metals, root length, shoot length, correlation, regression

Introduction

The Maize (*Zea mays* L.) as one of an important leading cash and food crops in the world occupied a significant role and position among all of the cultivated crop cultivars of cereal plants (Dixon et al., 2009). The cultivation or growing of maize is a symbolic of the green revolution which has played an important and pivotal role for fulfillment of nation food and nutrient requirements. *Zea mays* is an important member of family poaceae which is 95% cross pollinated plant (de Azevedo Neto et al., 2006; Fisher and Byerlee, 1990). It ranks at first among all of the worldwide food crop plants; in terms for its cultivated crop area which is 1097 m ha along with production of grain is 3.13 m tones however it has productivity potential up to 3264 kg ha-1 (Anonymous, 2018). It has ability to be grown as below as sea level up to 4000 m of altitude along with the areas where the rainfall is in the 250-300 mm range. It contributes higher calories up to 20% and also has higher protein contents as compared with other world's foods or diets even from all other food crop plants and species. The grain availability for maize is increasing from 79 g capita-1day-1 up to as higher as 185 g capita-1day-1 however under the increasing population affects since 1960 (Ali et al., 2014a; Sheng et al., 2008). The maize is the 3rd most an important among cereal crops after rice and maize and was the key crop in green revolution. In Pakistan maize was grown on an area up to 1097 m ha along with grain production up to 3.13 million tones while the average grain productivity was 3.07 t ha^{-1} (Anonymous, 2018). The grain yield of maize has been highly affected due to abiotic environmental factors which included drought, salt, alkalinity, heat and cold stress. The world water demands and supply has been affected due to changing climate conditions (Karahara et al., 2004; Rohanipoor et al., 2013). The drought stress caused damage of cell membranes which lead towards the abnormality of cell growth and development in crop plants. The deficiencies of the nutrients in the soil also caused the decrease in the growth of maize. The long drought and heat stress conditions for maize growth in tropical and subtropical regions of the world have been highly affected which may lead towards the famine in those maize growing area of world (Ali et al., 2015; Ali et al., 2016; Nadeem et al., 2006). Therefore, it is the need of hour to take another serious initiative to increase the plant productivity for major cash crops even with lower input to keep the sustainability of crop grain yield and production in maize. The crop productivity of maize is controlled through large number of factors among which mineral salt nutrition especially the nitrogen (N), phosphorus (P) and potassium (K) are the most important nutrients (Shan et al., 2014; Shu and Liu, 2001). The abiotic environmental stress conditions caused damages on maize which highly affect to reduce grain yield and crop productivity of maize. The drought, heavy metals and salt stresses caused the damages in cell membrane, the production of organic toxic chemicals with the accumulation of highly reactive oxygen species (ROS) within the maize plant body parts (Aaliya et al., 2016; Rohanipoor et al., 2013; Zubair et al., 2016). Drought and salt stresses caused un-repairable damages in plant cell membranes, whoever the use of plant growth regulators may be helpful to keep plants healthy and withstand under any type of stress environmental conditions (de Azevedo Neto et al., 2006; Hütsch et al., 2014; Karahara et al., 2004).

Materials and methods

Maize is an important cereal crop which has been used by human from last thousands of years as grain crop. Maize is highly sensitive for drought, heat, cold, salinity and heavy metals toxicity. The grain yield and quality of grains is highly affected due to abiotic environmental factors. For evaluating maize for drought as well as salts and heavy metals we have conducted an experiment in the greenhouse of IMBB (Institute of Molecular Biology and Biotechnology), University of the Lahore. Four maize genotypes were selected for our research work, *viz*., Raka-poshi, B-316, EV-1097Q and Sahiwal-2002. The seeds of selected maize genotypes were sown in 72 pots. Each of the pot was in triplicate for each of the maize genotype. The treatments of drought, salt and heavy metals were kept as following: T_0 (Control), T_1 (50% irrigation water), T_2 (0.5mMolar NaCl, T_3 (0.5mMolar $ZnSO_4$), T4 (0.5mMolar $AlCl_3$) and T_5 (0.5mMolar $MgCl_2$). The seeds were sown and after germination, the seedlings were given stress treatments after one week of germination. The drought treatment was carried out through the application of 200ml water to normal or control plants while 100ml to the plants under drought stress. The treatment of NaCl, $ZnSO_4$, $AlCl_3$ and $MgCl_2$ was applied through the irrigation of pots through adding 15ml to each pot. The seedling data was recorded for diverse morphological traits, as given below: leaf area, root/shoot dry weight ratio, roots per plant, root length, shoot length and root/shoot fresh weight ratio and statistical analysis was carried out through using SPSS 23.1 version.

Results and discussions

The results from table 1 revealed that there were significant differences among the maize genotypes under all applied treatments. The performance of all genotypes under control conditions was 100% in sense of survival under heavy metals and salt stress conditions. It was found results that the maize genotype Sahiwal-2002 showed higher performance under affects of all treatments as compared with other maize genotypes. The results from table 2 indicated that there was lower coefficient of variation for all studied traits which showed consistency of results, the average leaf area of maize genotypes under combined effects of all treatments was 6.342±0.0011cm^2, root per plant or seedling 6.945±0.0023, dry root/shoot weight ratio 0.7203±0.0011, fresh root/shoot weight ratio 0.9261±0.0002, root length 23.013±1.0003cm and shoot length 21.602±1.0264cm. The higher root and shoot lengths indicated that the seedlings showed tolerance for all applied treatments of salts and heavy metals. The selection of maize genotypes may be helpful to improve stress tolerance and enhance grain yield under stressful environmental conditions (Ali et al., 2011; Ashraf et al., 2020; Khalil et al., 2020).

Table 1. Survival percentage of maize genotypes under different multi stress conditions

Treatments	B-316	Raka-poshi	EV-1097Q	Sahiwal-2002
Control	100	100	100	100
50% irrigation water (T_1)	76.24	75.34	71.12	77.54
0.5Molar NaCl (T_2)	77.45	72.14	73.82	78.59
0.5Molar $ZnSO_4$ (T_3)	82.45	78.25	76.34	80.23
0.5Molar $AlCl_3$ (T_4)	81.34	80.21	72.24	82.13
0.5Molar $MgCl_2$ (T_5)	80.47	78.23	77.05	81.29

Table 2. Genetic components for morphological traits of maize seedlings

Source	LA	RPP	DRSWR	FRSWR	RL	SL
Replication	0.0001	0.0021	0.0002	0.0001	0.0065	0.0024
Genotypes	8..028*	2.0247*	0.00632*	0.0047*	59.2425*	43.261*
Treatments	7.947*	3.4148*	0.01213*	0.0161*	9.2621*	8.1023*

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Genotypes × treatments	19.302*	2.6024*	0.00418*	0.00133*	3.0231*	2.7425*
Error	0.0024	0.0032	0.00021	0.0002	0.0007	0.0302
Grand Mean	6.342	6.945	0.7203	0.9261	23.013	21.602
Coefficient of variance (%)	9.402	7.103	7.120	9.022	11.026	9.422
Standard Error	0.0011	0.0023	0.0011	0.0002	1.0003	1.0264
Genetic advance	23.024	17.189	13.142	21.821	23.232	23.032
Broad sense heritability	85.190	84.244	81.325	86.102	92.220	94.508

* = Significant at 5% probability level, DRSWR = dry root/shoot weight ratio, FRSWR = fresh root/shoot weight ratio, RL= root length, SL = shoot length, RPP = roots per plant, LA = leaf area

The figure 1 showed that the genotype EV-1097Q and Sahiwal-2002 showed better performance for leaf area as compared with B-316 and Raka-poshi under all different treatments of salts and heavy metals. The maize genotypes showed almost nearly similar number of root per seedling under all types of treatments (Figure 2). The root and shoot length of genotype EV-1097Q and Sahiwal-2002 was found higher as compared with B-316 and Raka-poshi under all different treatments of salts and heavy metals (Figures 3, 4). The higher fresh root/shoot weight ratio was found for B-316, and higher dry root/shoot weight ratio was found higher for Sahiwal-2002 as compared with other genotypes under all of the applied treatments (Figures 5, 6 respectively). The higher root length, shoot length, fresh root/shoot weight ratio and dry root/shoot weight ratio indicated that the genotypes showed tolerance for salt and heavy metal stress conditions. The selection of maize genotypes for these traits may be useful for improving stress tolerance in maize genotypes to improve grain yield and production under varying environmental conditions (Masood et al., 2015; Mazhar et al., 2020; Saif-ul-malook et al., 2014).

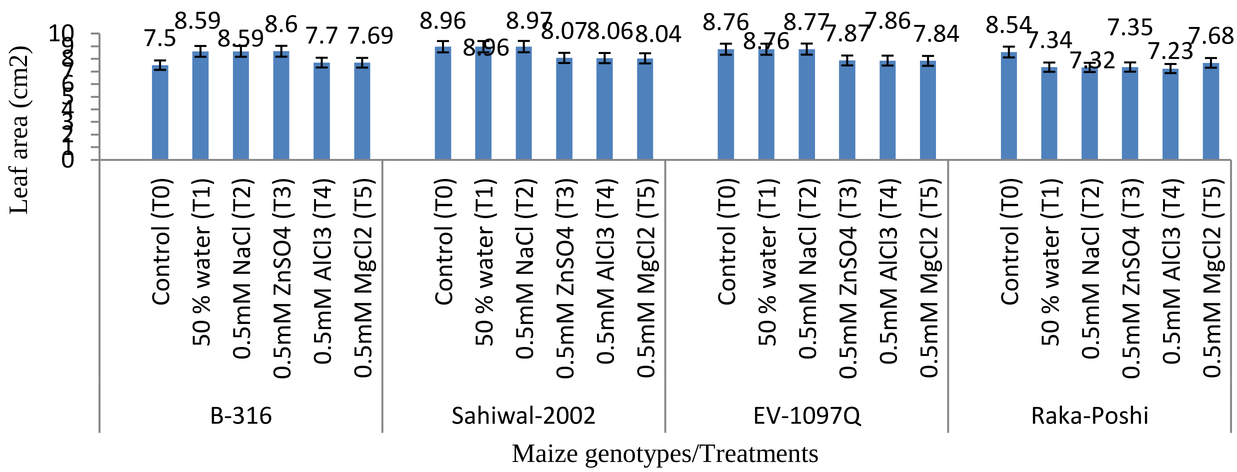

Figure 1. Comparison of maize genotypes for leaf area under different treatments

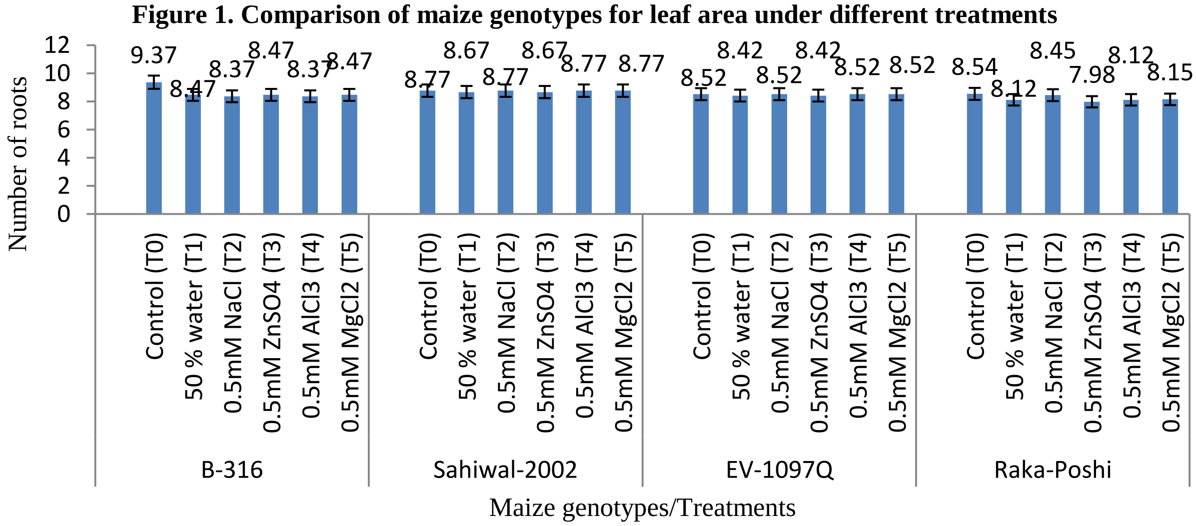

Figure 2. Comparison of maize genotypes for number of roots under different treatments

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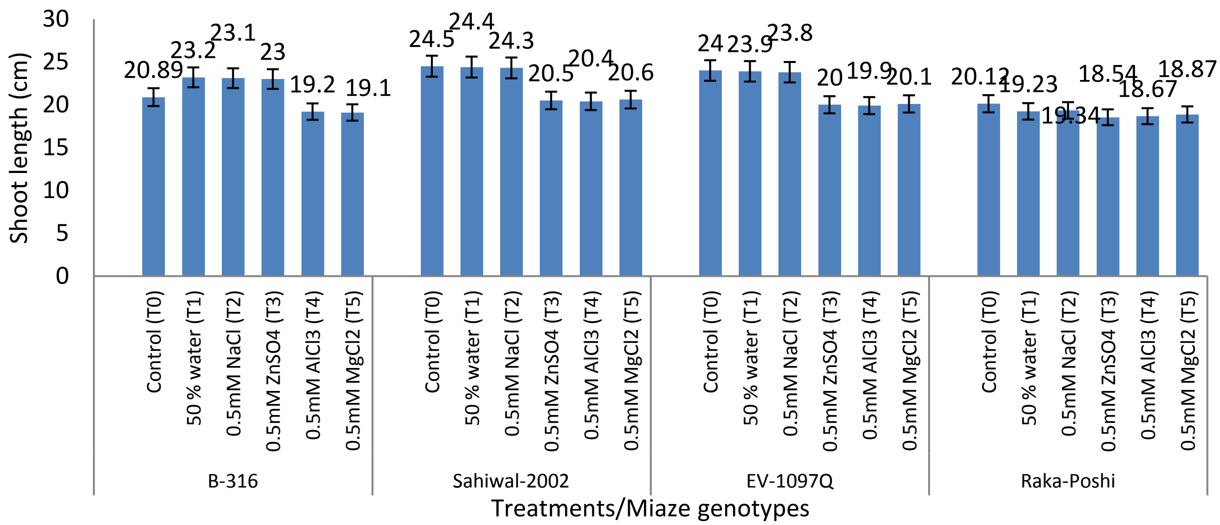

Figure 3. Comparison of maize genotypes for shoot length under different treatments

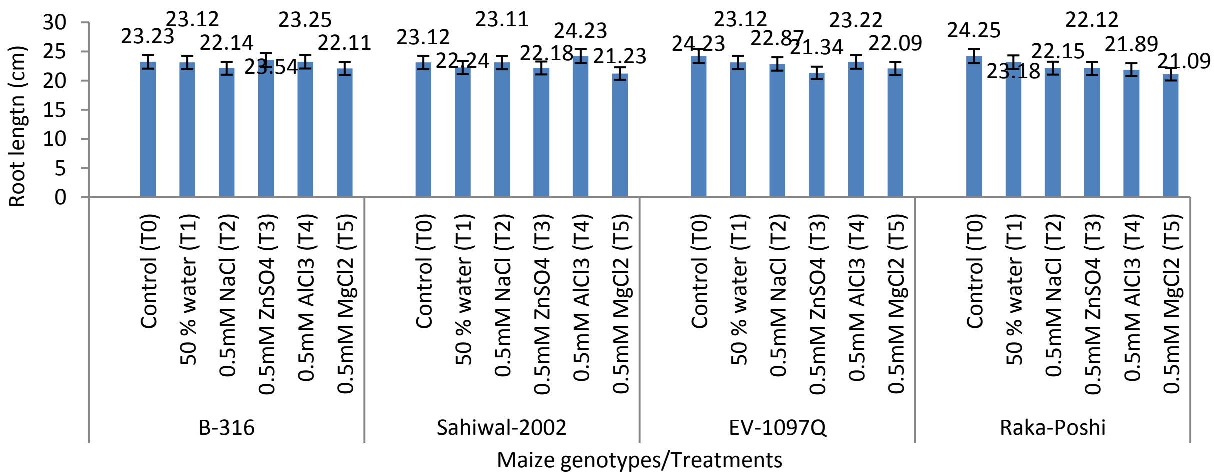

Figure 4. Comparison of maize genotypes for root length under different treatments

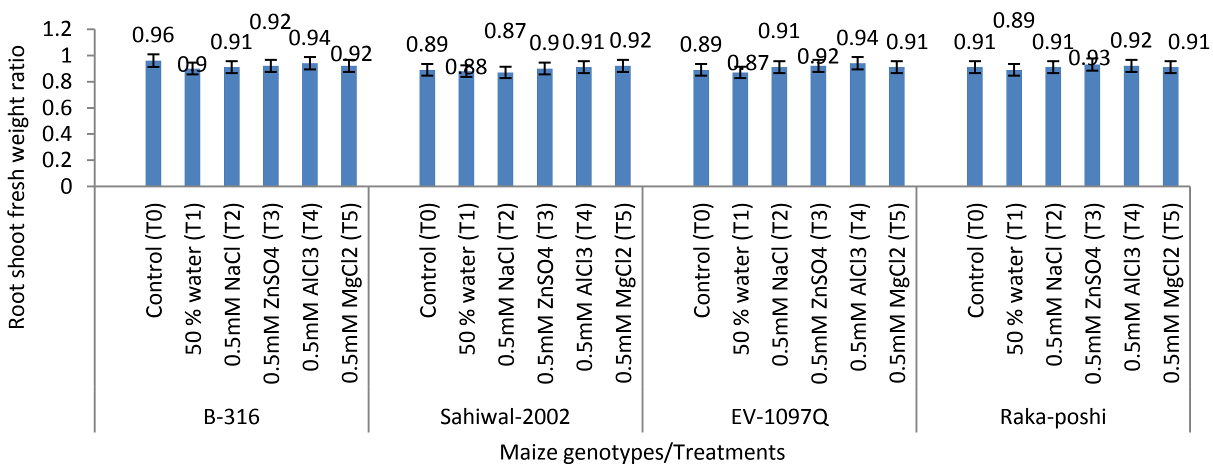

Figure 5. Comparison of maize genotypes for fresh root/shoot weight ratio under different treatments

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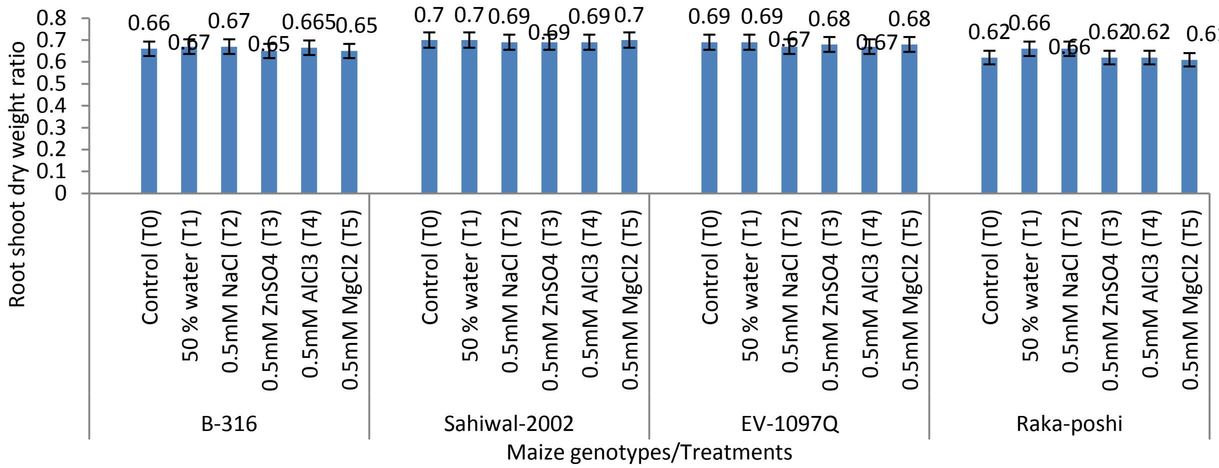

Figure 6. Comparison of maize genotypes for dry root/shoot weight ratio under different treatment

The results from table 3 indicated correlation among studied traits, there was significant and positive correlation among root length, shoot length, dry root/shoot weight ratio, fresh root/shoot weight, roots per plant and leaf area. The significant correlation between rot and shoot length indicated that the selection on the basis of these traits may be helpful to induce stress tolerance in maize genotypes. From regression analysis it was found that root length was higher contributor towards shoot length was reported as 7.6031 followed by leaf area (4.4012), fresh root/shoot weight ratio (4.3022) while negative contribution was found for root per plant (-1.0172) and dry root/shoot weight ratio (-3.020). The higher and positive contribution of root length and leaf area indicated that there was higher photosynthetic rate under stress conditions and absorption of inorganic mineral salts and water from soil which leads to improve plant growth and development (Abbas et al., 2016; Ali et al., 2017; Ali et al., 2014b; Boomsma et al., 2009; Saif-ul-malook et al., 2014; Tahir et al., 2020). The predicted regression equation was Y = 1.217 + 7.6031(RL) + 4.4012(LA) – 3.020(DRSWR) +4.3022(FRSWR) – 1.0172(RPP)

Table 3. Correlation among morphological traits of maize

Traits	LA	RPP	DRSWR	FRSWR	RL
RPP	0.4234*				
DRSWR	-0.0092	0.1294			
FRSWR	0.1923	0.2120	0.5012*		
RL	0.5674*	0.2925*	-0.6624*	-0.1002	
SL	0.8421*	0.6304*	0.8724*	0.9101*	0.7972*

* = Significant at 5% probability level, DRSWR = dry root/shoot weight ratio, FRSWR = fresh root/shoot weight ratio, RL= root length, SL = shoot length, RPP = roots per plant, LA = leaf area

Table 4. Regression analysis for shoot length among morphological traits of maize

Traits	Coefficients	Standard Error	t Stat	Partial R^2	Lower 95%	Upper 95%
RL	7.6031	0.001	-0.0132	0.6712	0.0313	0.0412
LA	4.4012	0.1202	0.0028	0.4602	0.0012	0.2901
DRSWR	-3.020	0.0029	-1.0018	0.1502	-0.0342	0.4205
FRSWR	4.3022	0.0167	4.0128	0.0421	-1.1082	1.3202
RPP	-1.0172	0.0108	0.2012	0.0322	-0.0245	0.0116

Y = 1.217, Multiple R^2= 0.8534, R^2 = 0.6823, Adjusted R^2 = 0.6424, Standard Error = 0.0231 DRSWR = dry root/shoot weight ratio, FRSWR = fresh root/shoot weight ratio, RL= root length, SL = shoot length, RPP = roots per plant, LA = leaf area

Conflict of interest

The authors have declared absence of any type of conflict of interest.

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