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Genetic studies of morpho-physiological traits of maize (*Zea mays* L.) seedling

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The proposed study was carried out in the glasshouse of the Department of Plant Breeding and Genetics, University of Agriculture Faisalabad, Pakistan to evaluate eighty maize genotypes for seedling traits during the crop season in February 2011. The higher value of genotypic variance was found for chlorophyll contents, photosynthetic rate and sub-stomatal CO_2 concentration. The higher values of heritability and genetic advance were also recorded for chlorophyll contents, photosynthetic rate and sub-stomatal CO_2 concentration for both after 14 and 28 days of seedling emergence. It was concluded that the selection of higher yielding genotypes can be made and may also be used as potential genotypes for higher grain and fodder yields.

Key words: *Zea mays*, genotypic variance, heritability, genetic advance, Pakistan.

INTRODUCTION

Maize (*Zea mays* L.) is world's leading cereal food crop with added importance for countries like Pakistan where rapidly increasing population has already outstripped the available food supplies. Maize is third important cereal in Pakistan after wheat and rice. Maize accounts for 5.67% of the value of agriculture output. It accounts for 950 thousands hectares of total cropped area in Pakistan with annual production of 3487 thousands tons (Anonymous, 2010). Maize is dual purpose crop such as food for human and feed for livestock and also used as industrial raw material for the manufacture of different products. It has highest crude protein 9.9% at early and at full bloom stages which decreases to 7% at milk stage and to 6% at maturity. Maize has highly nutritive value as it contains starch 72%, protein 10%, oil 4.80%, fiber 9.50%, sugar 3.0%, ash 1.70%, endosperm 82%, embryo 12%, bran testa 5% and tip cap 1% (Chaudhary, 1983; Bureau of Chemistry, U.S., 2010). Pakistan have livestock population of 154.7 million heads which produce approximately 43.562 million tons of milk, 1.601 million tons of beef and 0.590 million tons of mutton (Anonymous, 2009-2010). Livestock sector contributes approximately 53.2% of the agriculture value added and 11.4% to national GDP of Pakistan (Anonymous, 2009-2010). Green fodder is the most valuable and cheapest source of food for livestock. It is rich source of cellulose 35 to 40%, hemicelluloses 25.28%, fat 0.30%, crude fiber 28.70%, ADF 37.22%, NDF 70.85% dry matter 40.6%, ash 4%, carbohydrates 48.86%, moisture 9.22%, ether extract 2.84% and crude proteins 11% (Chaudhary, 1983; Bureau of Chemistry, U.S., 2010). With quality nutritional fodder, milk production can be increased up to 100% (Maurice et al., 1985). The present study was conducted to evaluate maize accessions for morpho-physiological

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seedling traits.

MATERIALS AND METHODS

The present study was carried out in the glasshouse of the Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad to evaluate the maize genotypes for seedling traits during the crop season in February 2011. The experimental material was consisting of 80 accessions including ten check varieties namely: F-121, F-128, F-150, F-142, F-151, F-118, F-117, F-130, F-140, F-143, F-113, F-111, F-114, F-136, F-122, F-134, F-147, F-105, F-148, F-146, B-303, B-316, B-306, B-303, B-313, B-314, B-305, B-321, B-326, B-308, B-304, B-312, EV-344, EV-343, EV-310, POP/209, EV-342, EV-347, F-96, EV-324, EV-335, EV-323, EV-334, EV-330, EV-329, EV-338, EV-340, E-349, E-352, E-341, E-351, E-322, E-346, E-336, BF-337 BF-248, BF-212, BF-236, BF-238, F-98, B-96, F-135, VB-06, B-121, B-15, B-11, Sh-213, Sh-139, SWL-2002, Sawan-3, Pak-Afgoee, Gold Isalamabad, Islamabad W, VB-51, EV-1097, EV-7004Q, Raka-Poshi, BS-2 and POP/2007). The seeds were sown in iron trays filled with sand following a randomized complete block design (RCBD) with three replications. The seed were sown at the depth of 2.5 cm. Twenty seedlings of each accession were established in each replication. The data of 5 plants was recorded for Chlorophyll contents, Photosynthetic rate, Stomata conductance, Leaf temperature, Transpiration rate, Sub-stomata CO_2 concentration, fresh root weight and fresh shoot weight after 14 and 28 days of sowing with the help of Chlorophyll Meter and IRGA (Infrared Gas Analyzer). The data was analyzed statistically using analysis of variance technique and Duncan Multiple Range (DMR) test at 1% significance level was used to compare the treatments means (Steel et al., 1997).

RESULTS AND DISCUSSION

Chlorophyll contents (mg g^{-1} fr. wt.)

It persuaded from Table 1a and b that highly significant differences were found among genotypes. The higher mean for chlorophyll contents (4.384±0.022 mg g^{-1} fr. wt.) was recorded for 28 days old seedlings of genotypes while lower for 14 days old seedlings. Table 1 indicated that the genotypic variance, phenotypic variance and environmental variance were 23.068, 23.07 and 0.002, respectively while genotypic coefficient of variance, phenotypic coefficient of variance and environmental coefficient of variance were 110.31, 110.32 and 0.98%, respectively. From Table 1b it is cleared that genotypic, phenotypic and environmental variances were 22.81, 22.81 and 0.0003, respectively while genotypic coefficient of variance, phenotypic coefficient of variance and environmental coefficient of variance were 108.84, 108.84 and 0.42%, respectively. Table 1a and b also indicated that highest estimates of heritability (100%, 100%) and genetic advance were 154.43 and 152.52% for 14 and 28 days old seedlings respectively. The higher values of heritability and genetic advance indicated that selection for chlorophyll contents of seedling may be effective for selecting higher yielding maize genotypes (Moulin et al., 2009; Ali et al., 2011b).

Figure 1a and 1b indicated that the genotypes Raka-Poshi and EV-344 showed higher chlorophyll contents for 14 and 28 days, respectively while lowest chlorophyll contents was found for F-146 and B-316 followed by B-327 and F-134 for 14 and 28 days, respectively. The higher values of chlorophyll contents indicated that the photosynthesis is enhanced due to which the root and shoot fresh/dry weights are increased that increased plant productivity (Moulin et al., 2009).

Photosynthetic rate (µg CO_2 s^{-1})

It persuaded from Table 1a and b that highly significant differences were found among genotypes. The higher mean for photosynthesis rate (7.517±0.084 µg CO_2 s^{-1}) was recorded for 14 days old seedlings of genotypes while lower for 28 days old seedlings. It is indicated from Table 1 that the genotypic variance, phenotypic variance and environmental variance were 35.14, 35.14 and 0.002, respectively while genotypic coefficient of variance, phenotypic coefficient of variance and environmental coefficient of variance were 78.86, 78.86 and 0.57%, respectively. From Table 1a and b it is cleared that genotypic, phenotypic and environmental variances were 36.23, 36.24 and 0.013, respectively while genotypic coefficient of variance, phenotypic coefficient of variance and environmental coefficient of variance were 80.96, 80.98 and 1.55%, respectively.

Table 1a and b also indicated that highest estimates of heritability (100%, 100%) and genetic advance were 110.34 and 110.90% for 14 and 28 days old seedlings respectively. The higher values of heritability and genetic advance indicated that selection for photosynthesis rate of seedling may be effective for selecting higher yielding maize genotypes. It is cleared from the graphs (Figure 2) that the genotypes F-146 and E-341 showed higher photosynthesis rate, followed by EV-343 and BS-2 for 14 and 28 days respectively while lowest photosynthesis rate was found for B-305 and B-313 for 14 and 28 days, respectively. The values of photosynthetic rat indicated that the production and accumulation of food reserves are increased that leads towards the improvement in the crop yield and productivity to increase grain and fodder production in maize (Grzesiak et al., 2007; Wang et al., 2007; Moulin et al., 2009).

Stomatal conductance (mmol m^{-2} s^{-1})

It persuaded from Table 1a and b that highly significant differences were found among genotypes. The higher mean for stomatal conductance (0.376±0.040 mmol m^{-2} s^{-1}) was recorded for 28 days old seedlings of genotypes while lower for 14 days old seedlings. It is indicated from Table 1a that the genotypic variance, phenotypic variance and environmental variance were 0.014, 0.017 and

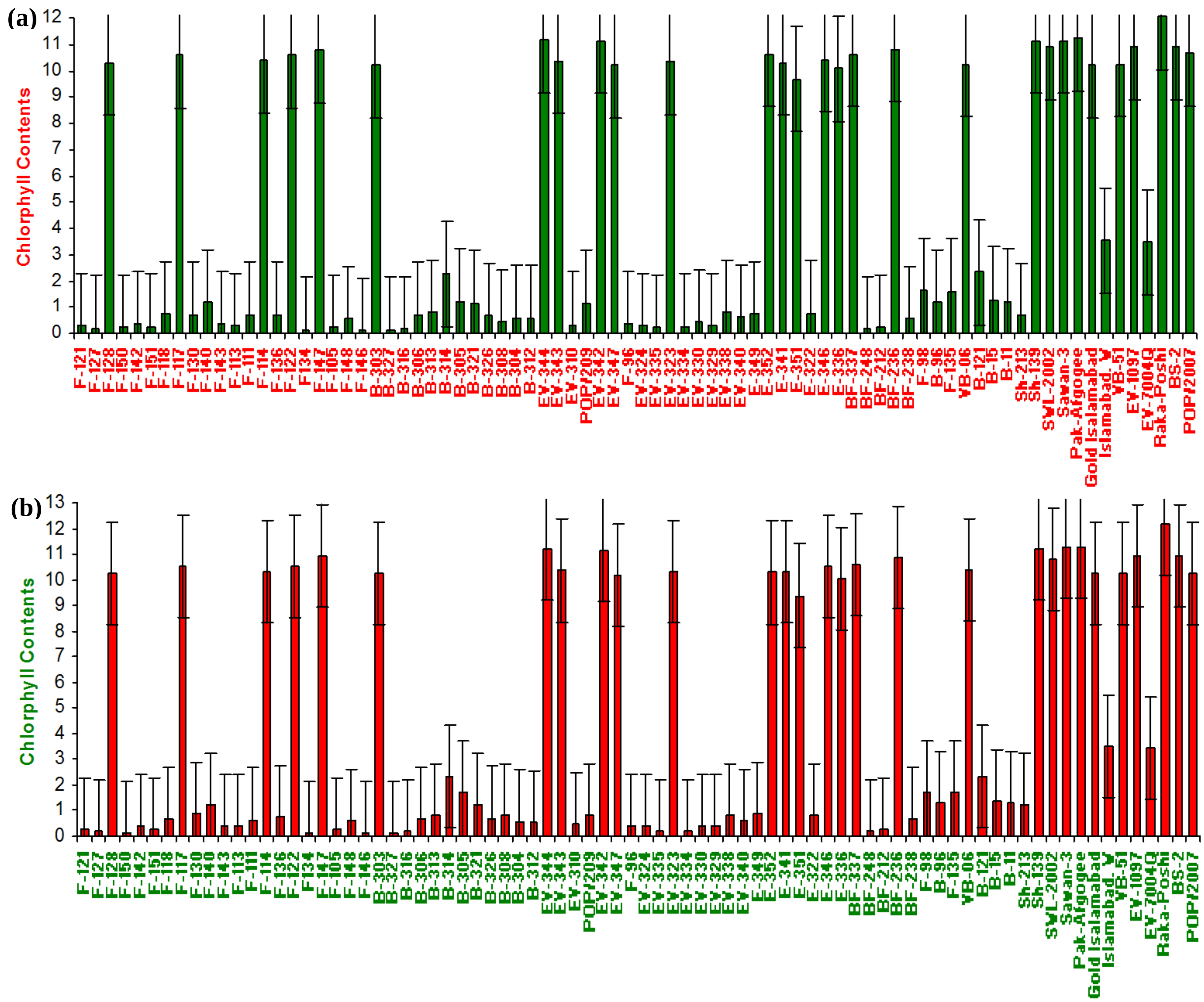

Figure 1. Chlorophyll contents (mg g^{-1} fr. wt.) of (a) 14 days old seedlings; (b) 28 days old seedlings.

Table 1a. Genetic components of 14 days old maize seedlings.

Traits	S.S	G.M±S.E	GV	GCV%	PV	PCV %	EV	ECV %	h^2_{bs} %	S.E h^2_{bs}	GA %
Chl.C	3645.098**	4.354±0.045	23.068	110.31	23.07	110.32	0.002	0.98	100	0.023	154.43
PR	5551.91**	7.517±0.084	35.14	78.86	35.14	78.86	0.002	0.57	100	0.019	110.34
SC	2.75*	0.325±0.054	0.014	36.90	0.017	40.59	0.003	16.92	82.60	0.912	46.95
LT	557.149**	33.22±0.114	3.513	5.64	3.526	5.65	0.013	0.34	99.60	0.059	7.88
TR	22.482*	0.682±0.031	0.141	55.09	0.142	55.31	0.001	4.59	99.20	0.296	76.81
SSCC	7179115**	257.75±3.494	45539.15	82.79	45551.36	82.80	12.21	1.36	100	0.0005	115.89
FRW	3.905*	0.715±0.156	0.024	21.82	0.025	21.99	0.0004	2.75	98.40	0.712	30.30
FSW	4.757*	0.814±0.015	0.029	21.24	0.03	21.32	0.0002	1.85	99.2	0.643	78.99

** = Significance at 5% level, * = significance at 1% level; S.S = Sum of Squares, G.M. = grand mean, S.E. = standard error, GV = genotypic variance, GCV = genotypic coefficient of variance, PV = phenotypic variance, PCV = phenotypic coefficient of variance, EV = environmental variance, ECV = environmental coefficient of variance, h^2_{bs} = broad sense heritability, S.E h^2_{bs} = standard error for broad sense heritability, GA = genetic advance, Chl.C = chlorophyll contents, PR = photosynthetic rate, SC = stomatal conductance, LT = Leaf temperature, TR = transpiration rate, SSCC = sub-stomatal CO_2 concentration, FRW = fresh root weight, FSW = fresh shoot weight.

Table 1b. Genetic components of 28 days old maize seedlings.

Traits	S.S	G.M ±S.E	GV	GCV %	PV	PCV %	EV	ECV %	h^2_{bs}%	S.E h^2_{bs}	GA%
Chl.C	3604.142**	4.384±0.022	22.81	108.94	22.81	108.94	0.0003	0.42	100	0.023	152.52
PR	5725.664**	7.434±0.114	36.23	80.96	36.24	80.98	0.013	1.55	100	0.018	110.90
SC	3.37*	0.376±0.040	0.019	37.33	0.021	38.84	0.002	10.75	92.3	0.789	50.21
LT	533.671**	33.058±0.143	3.357	5.54	3.378	5.56	0.020	0.43	99.40	0.061	7.73
TR	21.808*	0.682±0.013	0.138	54.44	0.138	54.47	0.0002	1.95	99.90	0.299	76.17
SSCC	7074406**	255.438±2.739	44772.89	82.84	44774.72	82.84	1.832	0.53	100	0.0005	115.96
FRW	16.263**	1.07±0.014	0.103	29.96	0.103	29.98	0.0002	1.31	99.80	0.347	41.89
FSW	152.391**	2.53±0.051	0.962	38.77	0.965	38.82	0.0026	2.00	99.70	0.113	54.20

** = Significance at 5% level, * = significance at 1% level; S.S = Sum of Squares, G.M = grand mean, S.E = standard error, GV = genotypic variance, GCV = genotypic coefficient of variance, PV = phenotypic variance, PCV = phenotypic coefficient of variance, EV = environmental variance, ECV = environmental coefficient of variance, h^2_{bs} = broad sense heritability, S.E h^2_{bs} = standard error for broad sense heritability, GA = genetic advance, Chl.C = chlorophyll contents, PR = photosynthetic rate, SC = stomatal conductance, LT = Leaf temperature, TR = transpiration rate, SSCC = sub-stomatal CO_2 concentration, FRW = fresh root weight, FSW = fresh shoot weight.

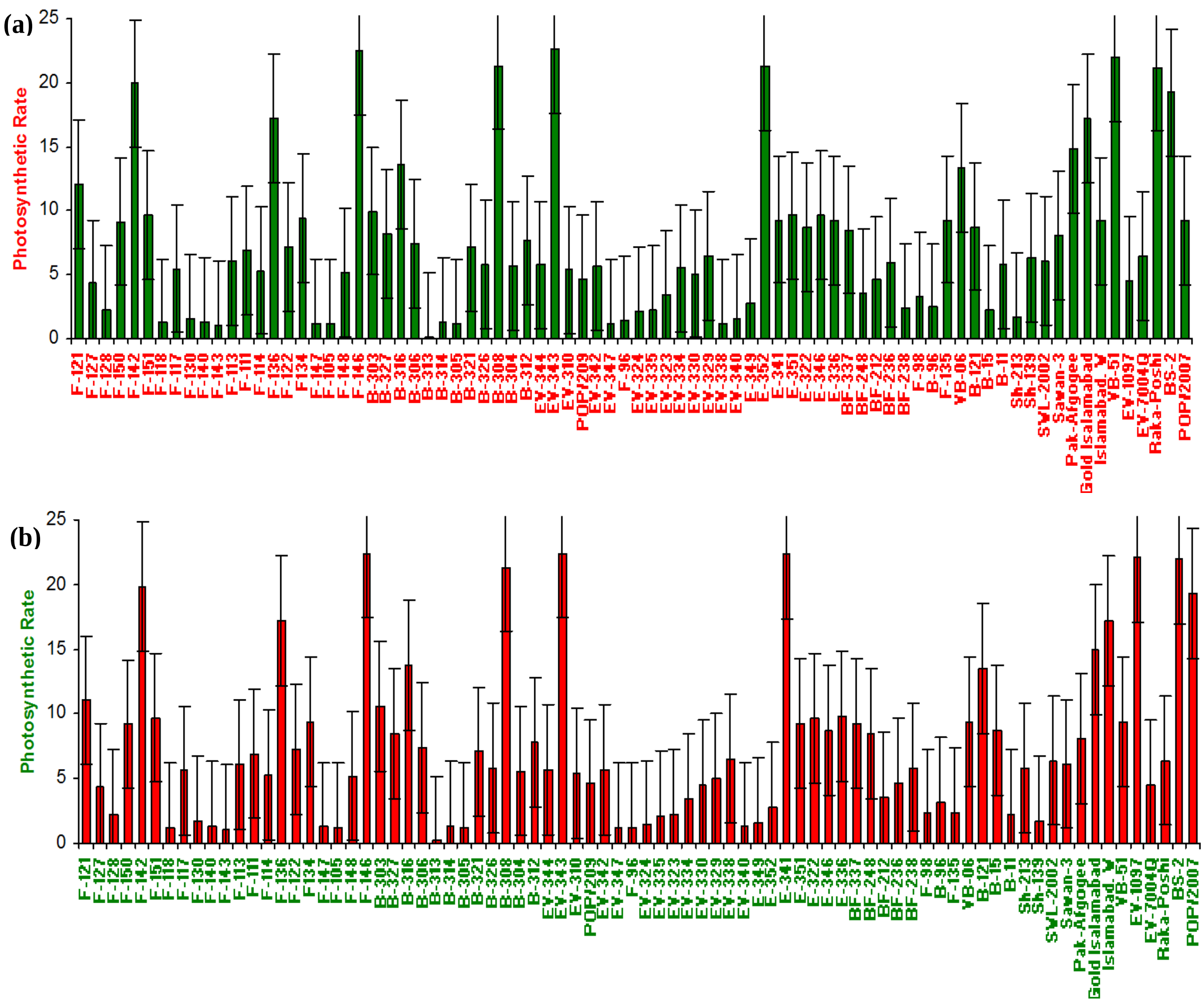

Figure 2. Photosynthesis rate (μg CO_2 s^{-1}) of (a) 14 days old seedlings; (b) 28 days old seedlings.

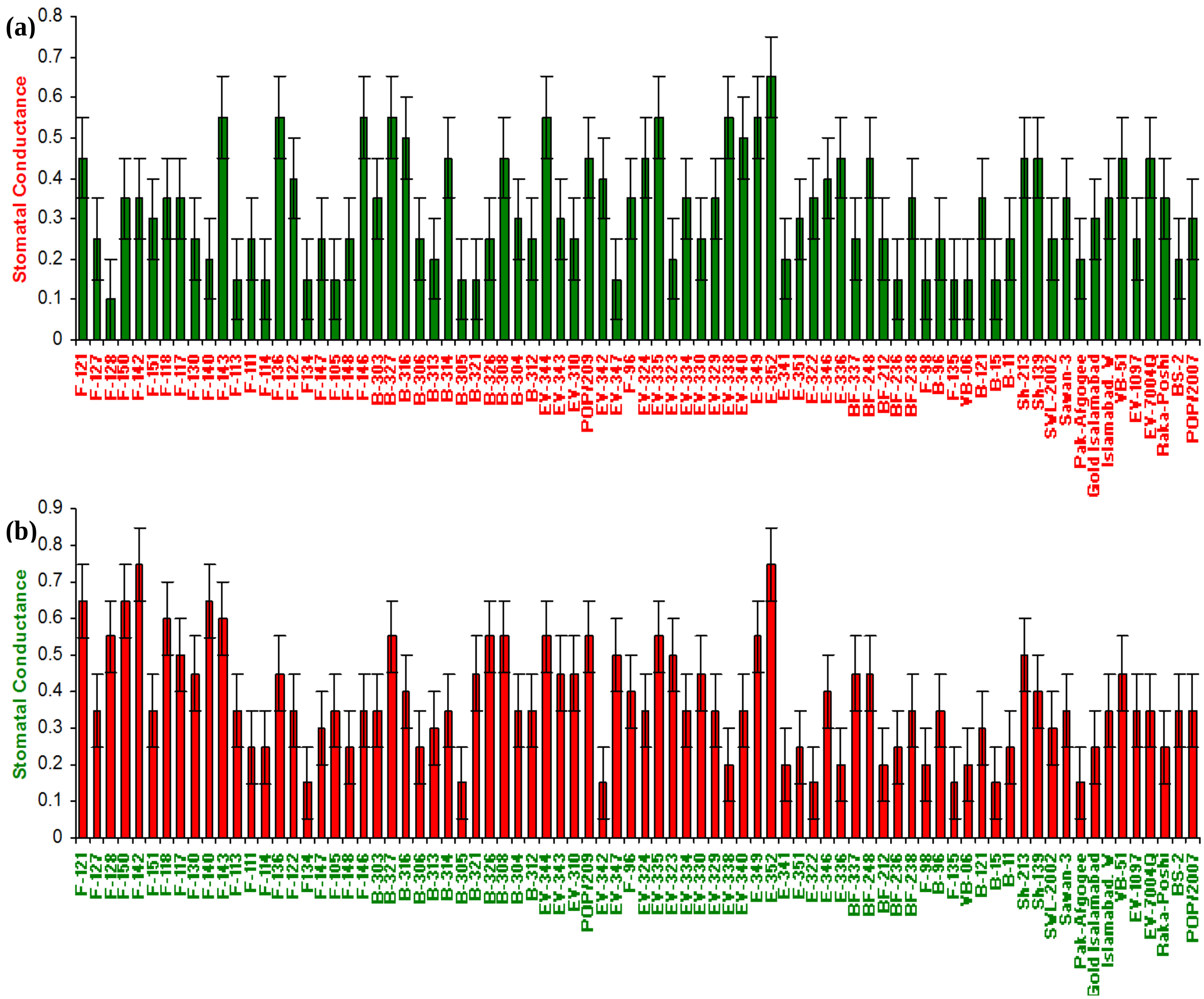

Figure 3. Stomata conductance (mmol m^{-2} s^{-1}) of (a) 14 days old seedlings; (b) 28 days old seedlings.

0.003, respectively while genotypic coefficient of variance, phenotypic coefficient of variance and environmental coefficient of variance were 36.90, 40.59 and 16.92%, respectively. From Table 1a and b it is cleared that genotypic, phenotypic and environmental variances were 0.019, 0.021 and 0.002, respectively while genotypic coefficient of variance, phenotypic coefficient of variance and environmental coefficient of variance were 37.33, 38.84 and 10.75%, respectively. Table 1a and b also indicated that highest estimates of heritability (82.60%, 92.30%) while lower genetic advance were 46.95 and 50.21% for 14 and 28 days old seedlings respectively. The higher values of heritability indicated that selection for stomatal conductance of seedling may be effective for selecting higher yielding maize genotypes. The increased stomatal conductance caused to enhance the CO_2 absorption due to which photosynthetic rate increased that leads towards increase in grain and fodder yield in maize (Grzesiak et al., 2007; Wang et al., 2007; Moulin et al., 2009; Ahsan et al., 2011). It is cleared from the graphs (Figure 3) that the genotypes E-352 and BS-2 showed higher stomatal conductance, followed by E-349 and F-142 for 14 and 28 days respectively while lowest stomatal conductance was found for F-128 and B-305 followed by F-105 and F-134 for 14 and 28 days, respectively.

Leaf temperature (°C)

It persuaded from Table 1a and b that highly significant differences were found among genotypes. The higher

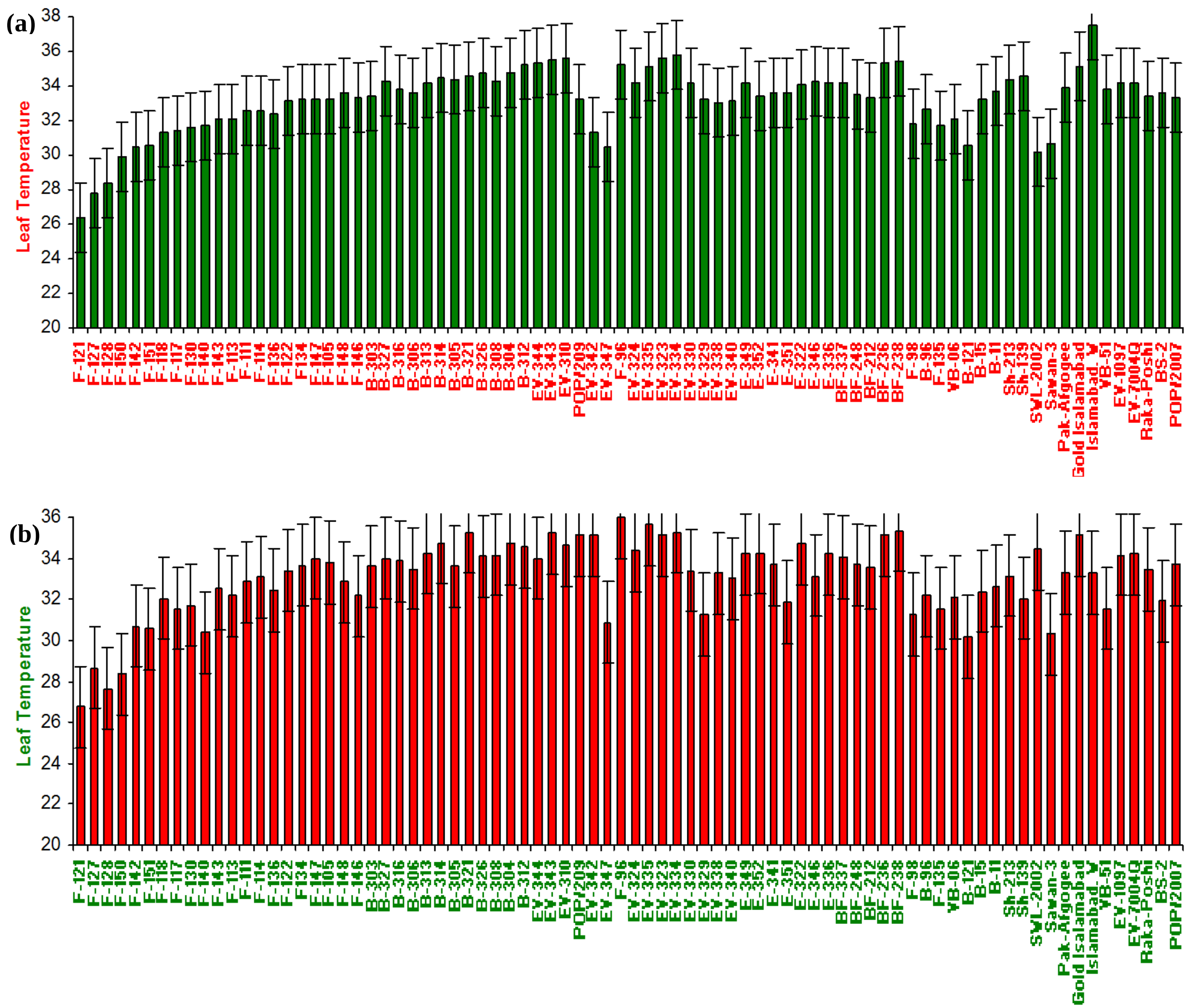

Figure 4. Leaf temperature (°C) of (a) 14 days old seedlings; (b) 28 days old seedlings.

mean for leaf temperature (33.22±0.114°C) was recorded for 14 days old seedlings of genotypes while lower for 28 days old seedlings. It is indicated from Table 1a that the genotypic variance, phenotypic variance and environmental variance were 3.513, 3.526 and 0.013, respectively while genotypic coefficient of variance, phenotypic coefficient of variance and environmental coefficient of variance were 5.64, 5.65 and 0.34%, respectively. From Table 1b it is cleared that genotypic, phenotypic and environmental variances were 3.357, 3.378 and 0.020, respectively while genotypic coefficient of variance, phenotypic coefficient of variance and environmental coefficient of variance were 5.54, 5.56 and 0.43%, respectively. Table 1a and b also indicated that highest estimates of heritability (99.60%, 99.40%) and genetic advance were 7.88 and 7.73% for 14 and 28 days old seedlings respectively. The higher values of heritability and genetic advance indicated that selection for leaf temperature of seedling may be effective for selecting higher yielding maize genotypes. The change in leaf temperature caused change in stomatal conductance, photosynthetic and transpiration rate (Grzesiak et al., 2007; Wang et al., 2007; Moulin et al., 2009; Ahsan et al., 2011; Ali et al., 2011b). It is cleared from the graphs (Figure 4) that the genotypes Islamabad W and F-96 showed higher leaf temperature, for 14 and 28 days respectively while lowest leaf temperature was found for F-121 for 14 and 28 days respectively.

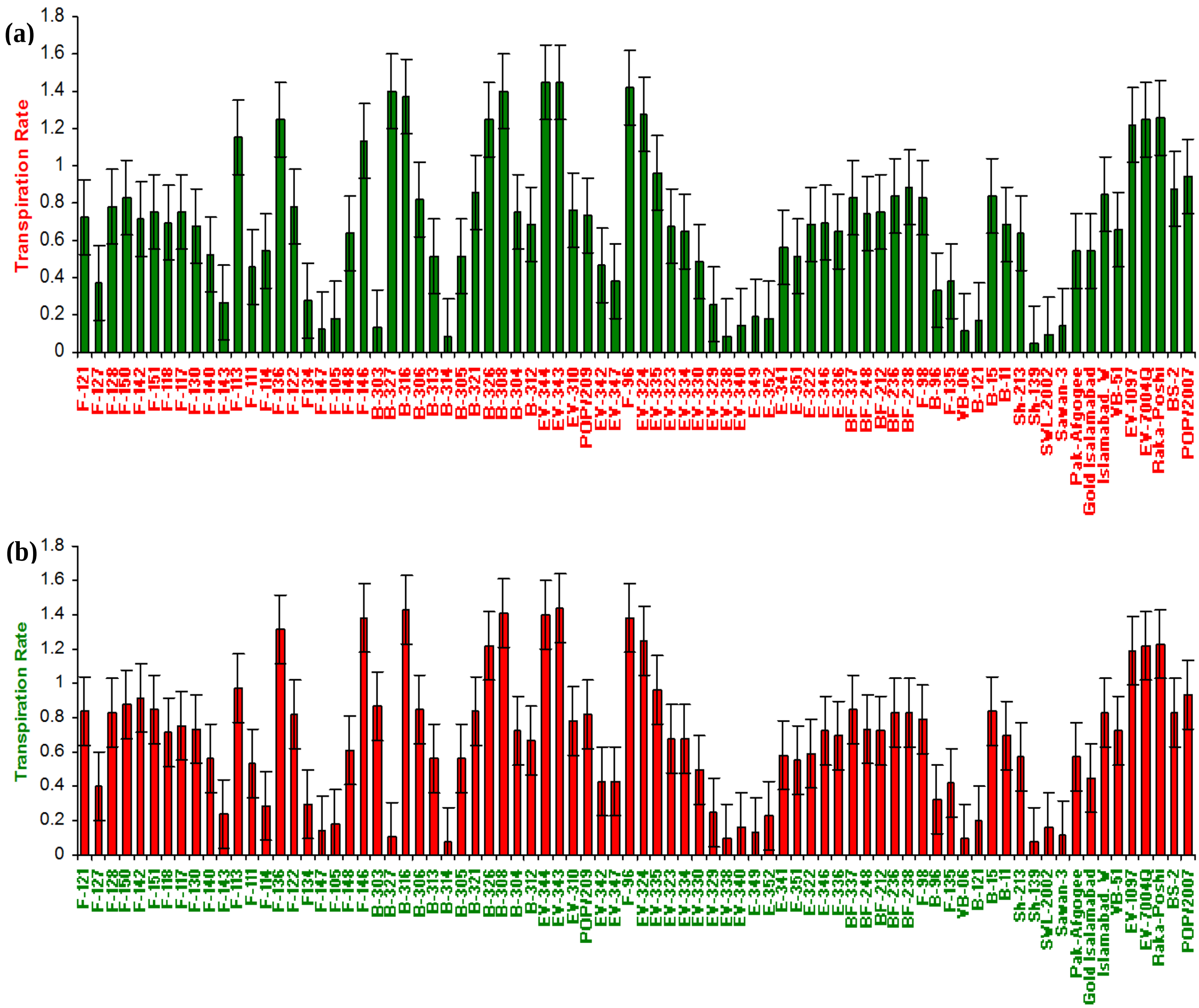

Figure 5. Transpiration rate (mm day^{-1}) of (a) 14 days old seedlings; (b) 28 days old seedlings.

Transpiration rate (mm day^{-1})

It persuaded from Table 1a and b that highly significant differences were found among genotypes. The higher mean for transpiration rate (0.682±0.031 mm day^{-1}) was recorded for 14 days old seedlings of genotypes while lower for 28 days old seedlings. It is indicated from Table 1a that the genotypic variance, phenotypic variance and environmental variance were 0.141, 0.142 and 0.001, respectively while genotypic coefficient of variance, phenotypic coefficient of variance and environmental coefficient of variance were 55.09, 55.31 and 4.59%, respectively. From Table 1b it is cleared that genotypic, phenotypic and environmental variances were 0.138, 0.138 and 0.0002, respectively while genotypic coefficient of variance, phenotypic coefficient of variance and environmental coefficient of variance were 54.44, 54.47 and 1.95%, respectively. Table 1a and 1b also indicated that highest estimates of heritability (99.20%, 99.90%) and moderate genetic advance were 76.81 and 76.17% for 14 and 28 days old seedlings respectively. The higher values of heritability and moderate genetic advance indicated that selection for transpiration rate of seedling may be effective for selecting higher yielding maize genotypes. Higher transpiration rate causes changes in stomatal conductance and photosynthetic rate (Grzesiak et al., 2007; Wang et al., 2007; Moulin et al., 2009; Ahsan et al., 2011). It is cleared from the graphs (Figure 5) that the genotypes EV-343 and B-316 showed higher transpiration rate, followed by EV-344 and EV-343 for 14

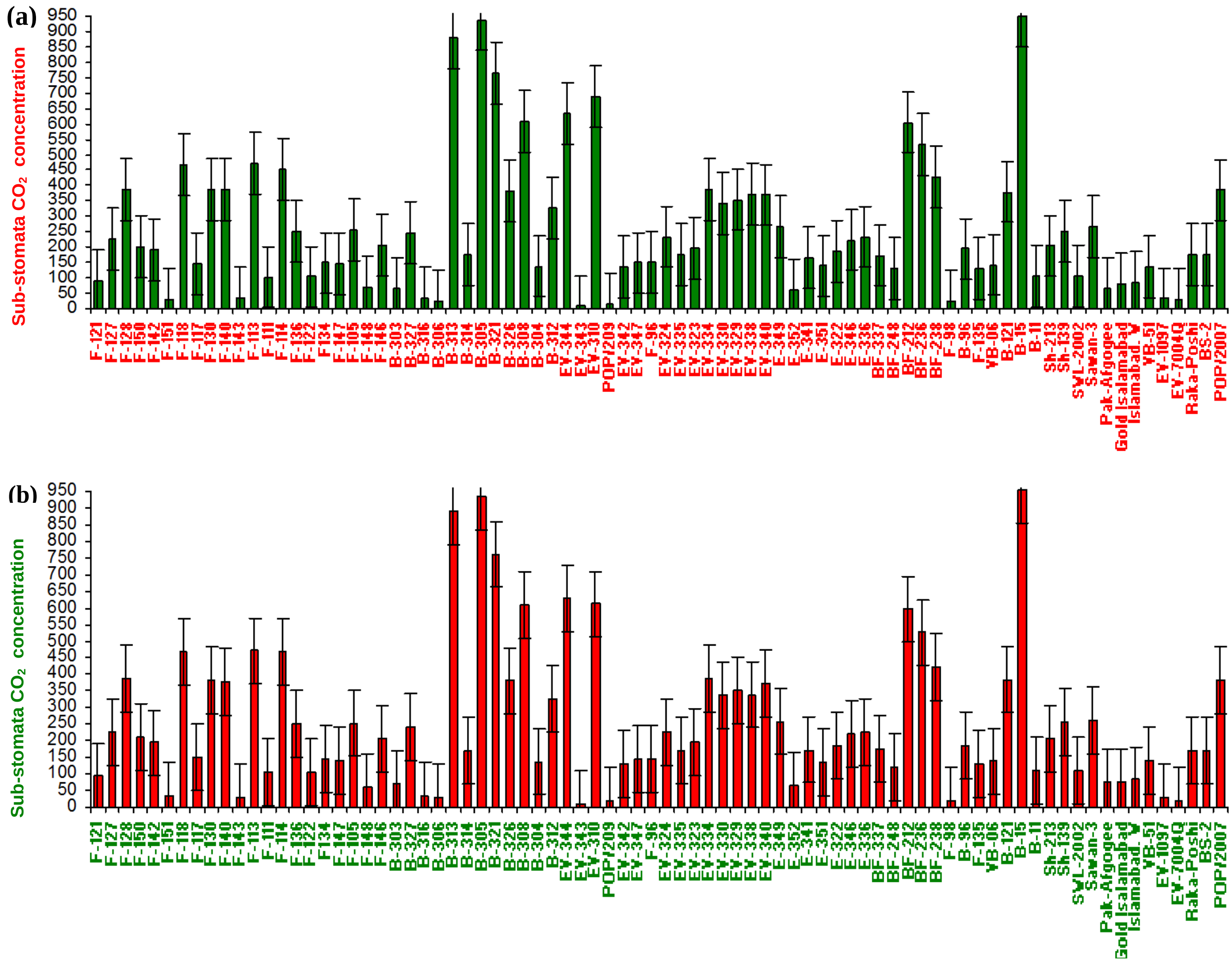

Figure 6. Sub-stomata CO_2 concentration (μmol mol^{-1} CO_2) of (a) 14 days old seedlings; (b) 28 days old seedlings.

and 28 days, respectively while lowest transpiration rate was found for B-314 and Sh-139 for 14 and 28 days, respectively.

Sub-stomata CO_2 concentration (μmol mol^{-1} CO_2)

It persuaded from Table 1a and b that highly significant differences were found among genotypes. The higher mean for Sub-stomata CO_2 concentration (257.75±3.494 μmol mol^{-1} CO_2) was recorded for 14 days old seedlings of genotypes while lower for 28 days old seedlings. It is indicated from Table 1 that the genotypic variance, phenotypic variance and environmental variance were 45539.15, 45551.36 and 12.21, respectively while genotypic coefficient of variance, phenotypic coefficient of variance and environmental coefficient of variance were 82.79, 82.80 and 1.36%, respectively. From Table 1b it is cleared that genotypic, phenotypic and environmental variances were 44772.89, 44774.72 and 1.832, respectively while genotypic coefficient of variance, phenotypic coefficient of variance and environmental coefficient of variance were 82.84, 82.84 and 0.53%, respectively. Table 1a and b also indicated that highest estimates of heritability (100%, 100%) and genetic advance were 115.89 and 115.96% for 14 and 28 days old seedlings respectively. The higher values of heritability and genetic advance indicated that selection for Sub-stomata CO_2 concentration of seedling may be effective for selecting higher yielding maize genotypes. Higher Sub-stomata CO_2 concentration increased CO_2 absorption that caused an increase in the stomatal conductance, photosynthetic and transpiration rate (Grzesiak et al., 2007; Wang et al., 2007). It is cleared from Figure 6 that the genotypes B-15 showed higher while EV-343 showed lowest Sub-stomata CO_2

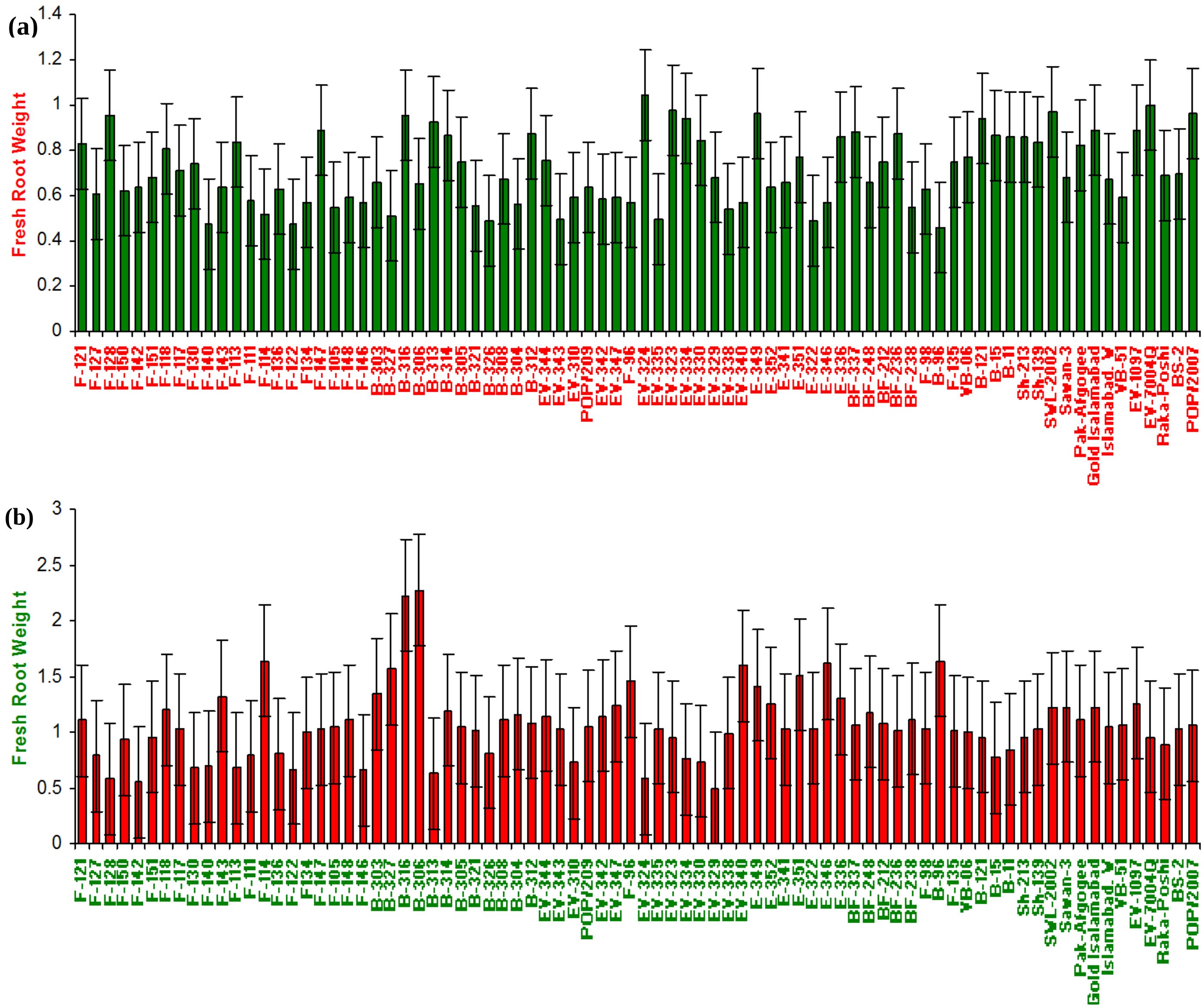

Figure 7. Fresh root weight (g) of (a) 14 days old seedlings; (b) 28 days old seedlings.

concentration for 14 and 28 days.

Fresh root weight (g)

It persuaded from Table 1a and b that highly significant differences were found among genotypes. The higher mean for fresh root weight (1.07±0.014 g) was recorded for 28 days old seedlings of genotypes while lower for 14 days old seedlings. It is indicated from Table 1 that the genotypic variance, phenotypic variance and environmental variance were 0.024, 0.025 and 0.0004, respectively while genotypic coefficient of variance, phenotypic coefficient of variance and environmental coefficient of variance were 21.82, 21.99 and 2.75%, respectively. From Table 1b it is cleared that genotypic, phenotypic and environmental variances were 0.103, 0.103 and 0.0002, respectively while genotypic coefficient of variance, phenotypic coefficient of variance and environmental coefficient of variance were 29.96, 29.98 and 1.31%, respectively. Table 1a and b also indicated that highest estimates of heritability (98.40%, 99.80%) and low and moderate values of genetic advance were 30.30 and 41.89% for 14 and 28 days old seedlings, respectively. The higher and moderate values of heritability and genetic advance indicated that selection for fresh root weight of seedling may be less effective for selecting higher yielding maize genotypes (Mehdi and Ahsan, 2000a; Ali et al., 2011a, b). It is cleared from the graphs (Figure 7) that the genotypes EV-324 and B-306 showed

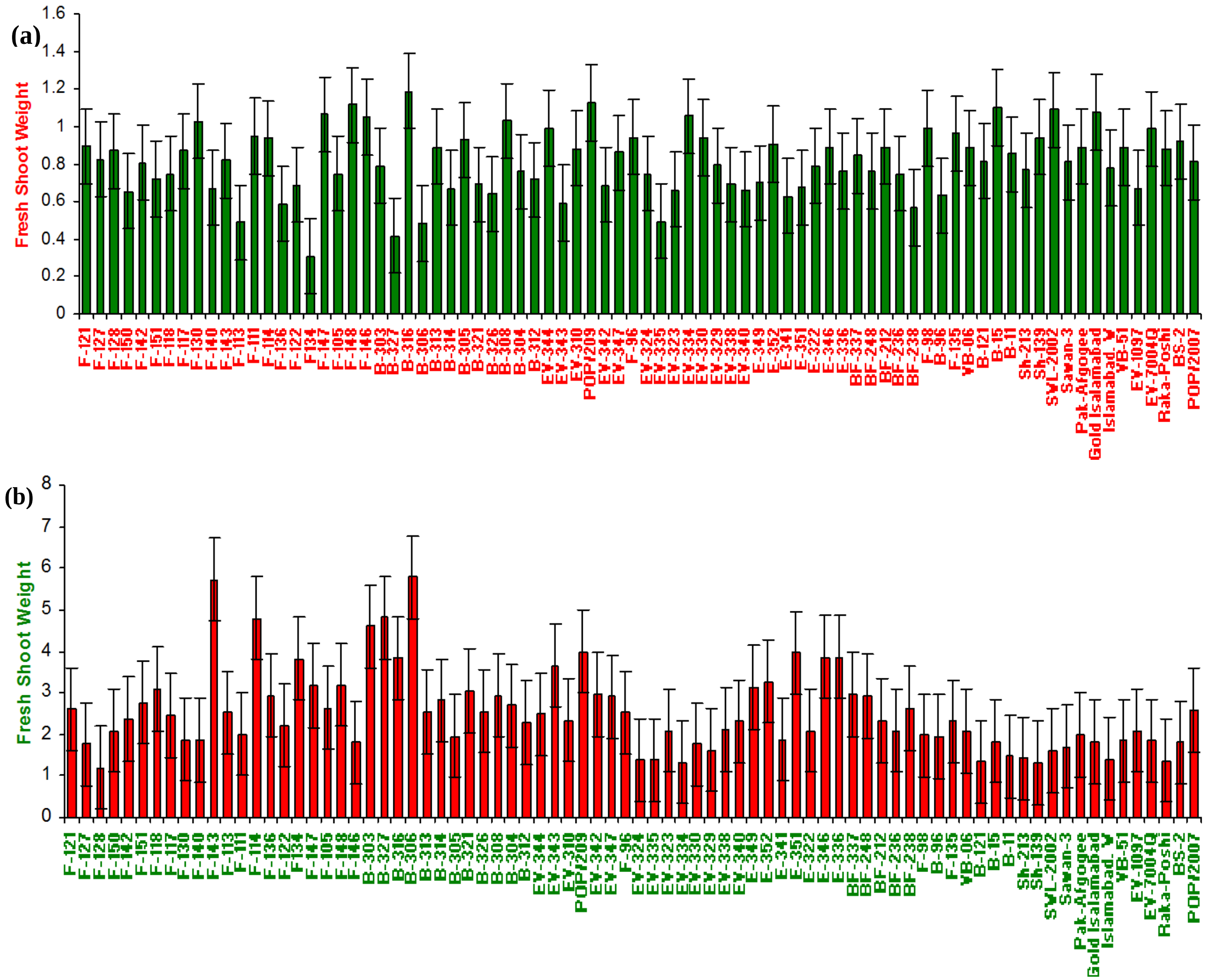

Figure 8. Fresh shoot weight (g) of (a) 14 days old seedlings; (b) 28 days old seedlings.

higher fresh root weight, followed by EV-7004Q and B-316 for 14 and 28 days respectively while lowest fresh root weight was found for F-140 and F-142 followed by B-96 and EV-329 for 14 and 28 days, respectively.

Fresh shoot weight (g)

It persuaded from Table 1a and b that highly significant differences were found among genotypes. The higher mean for fresh shoot weight (2.53±0.051 g) was recorded for 28 days old seedlings of genotypes while lower for 14 days old seedlings. It is indicated from Table 1b that the genotypic variance, phenotypic variance and environmental variance were 0.029, 0.03 and 0.0002, respectively while genotypic coefficient of variance, phenotypic coefficient of variance (PCV) and environmental coefficient of variance were 21.24, 21.32 and 1.85%, respectively. From Table 1b it is cleared that genotypic, phenotypic and environmental variances were 0.962, 0.965 and 0.0026, respectively while genotypic coefficient of variance, phenotypic coefficient of variance and environmental coefficient of variance were 38.77, 38.82 and 2.00%, respectively. Table 1a and b also indicated that highest estimates of heritability (99.20%, 99.70%) and low and higher values of genetic advance were 78.99 and 54.20% for 14 and 28 days old seedlings respectively. The higher values of heritability and genetic advance indicated that selection for fresh shoot weight of seedling may be effective for selecting higher yielding maize genotypes (Hussain et al., 1995; Akhtar, 2002; Mehdi and Ahsan, 2000a, b; Ali et al., 2011a, b). It is cleared from the graphs (Figure 8) that the genotypes B-316 and B-306 showed higher fresh shoot weight, followed by POP/209 and F-143 for 14 and 28 days respectively while lowest fresh shoot weight was found for B-327 and EV-324 followed by F-134 and F-128 for 14 and 28 days, respectively.

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