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RELATIONSHIPS BETWEEN YIELD AND ASSOCIATED TRAITS OF MAIZE HYBRIDS UNDER DROUGHT STRESS AND NON-DROUGHT ENVIRONMENTS

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Abstract

Grain yield is one of the most important traits in maize breeding programs and depends on the association of different plant traits. Twenty maize hybrids were evaluated to explore the relationships between yield and associated traits, at Agricultural Research and Development Station Simnic. This experiment was conducted under two environmental conditions: 2017 (drought stress) and 2018 (non-drought) and was planted in a randomized block with three replications. Significant differences ($p\leq0.05$) were found for all the studied traits excepting: the days to 75% anthesis, the days to physiological maturity and the protein content under drought stress conditions. In non-drought conditions were found significant differences for all the studied traits, excepting the days to physiological maturity and the shelling percentage. Correlation analysis revealed that grain yield exhibited a significant negative correlation only with hectolitre weight ($r = -0.531^0$) in drought stress conditions, and significant positive correlation only with thousand grains weight ($r = 0.485^*$) in non-drought conditions.

Key words: *correlation, drought, hectolitre weight, maize, thousand grains weight.*

INTRODUCTION

Maize is an important cereal crop of the world holding second position after rice in terms of production. In 2017, maize was produced in 2405 thousand hectare with the production of 14326 thousand tons with average yield of maize is 5.9 tons/ha in Romania (FAO, 2017).

Heat and drought are two factors that influence equally the maize crop evolution in the Romanian region of Oltenia. Water stress and heat lead always to different yield losses levels depending on the constrainer length, its intensity and crop stage (Bonea & Urechean, 2011; Pandia, 2006; Pandia et al., 2013; Urechean & Bonea, 2017). It is known that drought tolerance is a complex trait making the search for efficient selection traits, breeding and screening methods difficult (Petcu et al., 2018).

In cereal breeding programs, grain yield is one of the most important and complex traits and depends upon a combination of different plant traits (Mirosavljevic et al., 2015).

According to Georgieva and Kosev (2018), a new priority in the plant breeding is creating cultivars combining high potential productivity and resistance to stressful environmental factors.

Therefore, an effective breeding program requires a proper understanding of the relationships between grain yield and associated traits. According to Banziger et al. (2000) secondary traits that have a phenotypic correlation with yield under drought conditions can be used as selection traits of drought tolerant maize hybrids.

It is important to know that breeding progress using grain yield and a given secondary trait in selection is greater than progress using grain yield alone.

Correlation coefficient reveals the strength of relationship among the group of traits, thus is one of the important biometrical tools for formulating a selection index. This also helps to decide the dependability of the traits that have little or no importance (Jayakumar et al., 2007). Phenotypic correlation involves both genetic and environmental factors.

The present study was, therefore, conducted to assess the relationships among yield and associated traits, through association analysis for grain yield improvement in different environmental conditions.

MATERIALS AND METHODS

Plant materials

Twenty Romanian maize hybrids were used in this study.

Field evaluation and experimental design

The experiment was conducted under two environmental conditions: 2017 (drought stress) and 2018 (non-drought) and was planted at ARDS Simnic, in a randomized block with three replications. This Station is located at $44^0 19'$ N, $23^0 48'$ E, and 182 m altitude, characterized by preluvosoil. Fertilization was done with 250 kg/ha ($N_{20}P_{20}K_0$) complex fertilizers before sowing and in vegetation (phase 8-10 leaves) with ammonium nitrate 250 kg/ha. Planting was done on April 10^{th} - 2017 and April 24^{th} -2018, respectively. In order to prevent negative effects of weeds, DUAL GOLD 960 - 1.5 l/ha applied immediately after sowing and with EQUIP 1.5 l/ha + BUCTRIL 1.0 l/ha in the growing season (6-8 leaves).Two mechanical and two manuals weeding were applied.

Climatically data

The years of the investigation, were characterized as follows: 2017 was considered a dry year (drought stress conditions) and 2018 was considered favourable for the growth and development of maize (non-drought conditions). In 2017, the rainfall deficiency was largely pronounced in June and August. The mean monthly temperatures were over the multiannual average in June, July, and August.

For this area, the rainfall from August had a decisive role in defining the production capacity in the draughty years as well as in the favourable years (Urechean et al., 2010).

Field measurements

Grain yield and 10 secondary traits were measured or calculated.

Grain yield per hectare adjusted to 15.5% moisture. In each plot, days to anthesis (DA) and days to silking (DS) were recorded as the number of days from sowing to when 75% of the plants had shed pollen and emerged silks, respectively.

For measurement of physiological maturity, regular sampling of two cobs per plot was done to assess the presence of black layers at the base of the grains.

Plant and ear heights were measured in centimetre as the distance from the base of the plant to the height of the first tassel branch and the node bearing the upper ear, respectively.

Shelling percentage (SP) was calculated by using the following formula:

$$SP = \frac{\text{Grains weight of 10 ears}}{\text{Total weight of 10 ears}} x100$$

Hectolitre weight (HW) was determined using Hectolitre Weight Apparatus.

Thousand grains weight (1000-grain weight/TGW) data was recorded by weighing thousand grains randomly taken, with the help of electronic balance, and then average weight was calculated.

The protein content (PC) and oil content (OC) of the maize grains was determined by Inframatic 9140 (Sweden or Foss Infratec 1241, Denmark).

Statistical analysis

The data collected were subjected to ANOVA: single factor and differences between mean values were tested by F-test and separated using the Least Significant Differences (LSD) at 5% level of probability. The relationships between the yield and associated traits were established using Pearson correlation coefficient (r). The variability presence in the hybrids was estimated by coefficient of variations (CV) using the procedure suggested by Săulescu and Săulescu (1967).

RESULTS AND DISCUSSIONS

Mean performance and analysis of variance

Mean values and significant levels of yield and yield associated traits of twenty maize hybrids were presented in Tables 1 and 2.

The results showed that under drought stress conditions, except for days to anthesis, days to maturity and protein content, and in non-drought conditions, except for days to maturity and shelling percentage, there were significant differences ($p \le 0.05$) between studied hybrids (Tables 1 and 2). Variation in grain yield and associated traits was reported by numerous researchers for different environmental conditions. Raut el al. (2017) observed highly significant variation in grain yield, days to 50% tasseling, days to 50% silking, plant height, ear height and thousand grains weight, while comparing fourteen maize genotypes. Muchie and Fentie (2016) also found highly significant variation for days to 50% anthesis, plant height, ear height and grain yield.

In this study, the mean grain yield per hectare was 5.26 ± 0.13 tons/ha in drought stress and 9.22 ± 0.18 tons/ha in non-drought conditions. Significant differences (0.15 and 0.35) between studied hybrids were found for grain yield in both environmental conditions (Tables 1 and 2).

The mean value for day to 75% anthesis was 82.35 ± 0.36 days under drought stress, and 68.10 ± 0.59 days under non-stress conditions. ANOVA revealed significant difference only in non-drought conditions (2.90) for this trait.

The mean value for days to 75% silking among 20 hybrids was 85.20 ± 0.64 days in drought stress, and 69.95 ± 0.62 days in non-drought conditions. There were highly significant differences (3.56 and 2.95) among hybrids for this trait in both environmental conditions.

The mean value for days to maturity was 124.75 ± 0.73 days in drought stress and 123.45 ± 0.81 days in non-stress conditions. ANOVA revealed non-significant difference among hybrids for this trait in both conditions.

The mean value for plant height among experimented hybrids was 184.15 ± 4.04 cm in drought stress and 243.05 ± 4.46 cm under non-drought conditions. ANOVA revealed significant differences (5.72 and 8.50) among 20 hybrids, in both conditions.

The mean value for ear height was 73.65 ± 2.07 cm in drought stress and 96.95 ± 2.36 cm in non-drought conditions. ANOVA revealed significant difference among hybrids for this trait in both conditions (1.49 and 3.00).

The mean value for shelling percentage was 82.05 ± 0.69% in drought stress and 84.25 ± 0.42% in non-drought conditions. There were significant differences only in drought stress (3.41) among hybrids for this trait.

The mean value of hectolitre weight for the studied hybrids was 69.35 ± 0.46 kg/hl in drought stress and 71.15 ± 0.48 kg/hl in non-drought conditions, revealed significant differences were found among hybrids for this trait in both conditions (3.06 and 3.21).

The mean value of thousand grains weight for the experimented hybrids was 236.60 ± 6.42 g in drought stress and 319.80 ± 10.52 g in non-drought conditions, revealed significant differences were found among hybrids for this trait in both conditions (6.20 and 6.30).

The mean value for protein content of maize hybrids was 14.55 ± 0.15% in drought stress and 13.66 ± 0.18% in non-drought conditions. ANOVA revealed non-significant difference among 20 hybrids for this trait in drought stress and significant difference (0.54) in non-drought conditions.

For oil content, the mean value was 5.11 ± 0.09% in drought stress and 4.80 ± 0.1% in non-drought conditions. ANOVA revealed significant differences were found among hybrids for this trait in both conditions (0.19 and 0.13).

The differences in CV% values for different traits has been observed (Tables 1 and 2), indicating environmental conditions influence over these traits. Among the studied traits, moderate CV values (10-20%) were observed for grain yield, ear height and thousand grains weight in drought stress, and for ear height, thousand grains weight and oil content in non-drought conditions.

The other traits had low CV (0-10%) values in both conditions (Tables 1 and 2).

Correlation Coefficient Analysis

Analysis of correlation coefficient of yield related traits revealed some fundamental basis (Tables 2 and 4).

Under drought stress conditions, correlation coefficients of studied traits indicated that the grain yield has been correlated significant negative only with hectolitre weight ($r = -0.531^0$) (Table 3). The result is contradictory where Shiri et al. (2013) that found non-significant correlation of grain yield and hectolitre weight in thirty-six new late maturity maize hybrids under drought stress.

Thus, our findings suggested that the selection of hybrids having lower hectolitre weight should be the priority of breeders to achieve higher yield in drought stress conditions.

As well were significant negative correlations between days to 75% anthesis and oil content ($r = -0.530^0$), days to 75% silking and protein content ($r = -0.521^0$), plant height and oil content ($r = -0.501^0$), ear height and oil content ($r = -0.497^0$), shelling percentage and oil content ($r = -0.487^0$).

Table 1. Mean ± SEd, F test, CV% and LSD (at p≤0.05) of yield and associated traits at 20 maize hybrids under drought stress (2017)

Hybrid	GY	DA	DS	DM	PH	EH	SP	HW	TGW	PC	OC
H1	5.71	83	85	128	200	77	81	68	176	15.1	5.6
H2	4.47	82	84	128	188	75	85	69	190	15.4	5.0
H3	5.56	84	86	128	193	73	84	70	262	15.2	5.3
H4	6.20	84	86	128	210	78	82	67	254	14.6	4.6
H5	6.52	85	87	128	195	75	81	67	290	13.9	4.5
H6	5.87	83	95	128	183	70	83	68	210	12.9	4.9
H7	4.59	85	86	118	190	73	86	69	248	13.3	4.6
H8	5.52	81	83	125	190	70	80	67	254	14.4	4.9
H9	5.21	83	85	125	183	83	82	74	210	15.0	5.1
H10	5.81	82	83	118	175	78	86	66	212	13.6	4.9
H11	5.01	82	84	125	177	73	81	68	204	15.2	4.7
H12	4.40	82	84	125	169	75	85	69	246	14.4	4.9
H13	5.31	83	85	125	170	70	86	70	262	15.1	5.4
H14	5.10	81	83	125	200	65	78	69	258	15.1	5.5
H15	5.18	79	81	125	160	70	81	73	262	14.2	5.7
H16	4.66	81	85	125	185	75	83	70	252	14.7	5.1
H17	4.72	83	87	125	230	105	82	71	244	14.7	4.7
H18	4.77	83	87	125	160	63	82	72	224	14.3	5.4
H19	4.80	79	82	118	162	60	80	71	226	15.3	5.5
H20	4.97	82	86	123	163	65	73	69	248	14.6	5.9
Mean	5.26	82.35		124.75	184.15	73.65	82.05	69.35	236.60	14.55	5.11
± SEd	0.13	0.36	0.64	0.73	4.05	2.07	0.69	0.46	6.42	0.15	0.09
F test	*	ns	*	ns	*	*	*	*	*	ns	*
LSD5%	0.15		3.56		5.72	1.49	3.41	3.06	6.20	-	0.19
CV%	10.83	1.98	3.36	2.62	9.83	12.57	3.76	2.99	12.15	4.74	8.02

GY - Grain yield per hectare (t), DA- Days to 75% anthesis , DS - Days to 75% silking, DM -Days to maturity, PH - Plant height (cm), EH - Ear height (cm), SP - Shelling percentage (%), HW - Hectolitre weight (kg/hl), TGW - Thousand grains weight (g), PC - Protein content (%), OC - Oil content (%), SEd - Standard error of mean of differences; * = Significant at p≤0.05

Table 2. Mean ± SEd, F test, CV% and LSD (at p≤0.05) of yield and associated traits at 20 maize hybrids under non-drought conditions (2018)

Hybrid	GY	DA	DS	DM	PH	EH	SP	HW	TGW	PC	OC
H1	8.27	69	71	118	235	93	85	71	302	13.5	5.1
H2	8.08	71	73	126	218	85	84	68	217	14.6	4.9
H3	8.03	73	75	128	230	95	81	71	304	14.2	4.9
H4	9.89	69	70	126	240	98	85	69	321	12.8	4.6
H5	9.05	65	66	118	255	78	86	70	338	11.8	3.8
H6	9.81	66	67	127	213	85	84	72	374	12.1	3.6
H7	9.44	66	68	118	245	98	82	75	289	13.6	5.3
H8	10.16	67	68	125	230	103	84	70	303	13.8	4.8
H9	7.98	66	68	125	240	103	86	75	290	13.5	4.8
H10	8.85	64	66	118	215	95	86	71	362	12.4	4.8
H11	8.90	67	70	125	275	100	86	73	323	13.6	4.4
H12	10.43	66	68	122	235	80	86	69	325	13.5	4.8
H13	9.74	68	70	126	235	80	85	74	344	14.5	5.3
H14	8.30	72	74	118	250	108	84	69	268	14.6	4.7
H15	9.88	69	71	128	270	105	85	67	375	14.0	4.9
H16	9.78	69	71	126	265	110	81	72	258	13.8	5.9
H17	8.48	66	68	122	230	100	83	73	274	13.8	4.9
H18	9.91	70	72	126	285	115	80	71	410	14.6	4.8
H19	8.84	66	68	122	235	103	86	72	370	14.5	4.8
H20	10.60	73	75	125	260	105	86	71	349	14.0	5.0
Mean	9.22	68.10	69.95	123.45	243.05	96.95	84.25	71.15	319.80	13.66	4.80
± SEd	0.18	0.59	0.62	0.81	4.46	2.36	0.42	0.48	10.52	0.18	0.1
F test	*	*	*	ns	*	*	ns	*	*	*	*
LSD5%	0.35	2.90	2.95		8.50	3.00		3.21	6.30	0.54	0.13
CV%	9.16	3.89	3.97	2.94	8.22	10.89	2.27	3.07	14.71	6.04	10.17

* = Significant at p≤0.05

Table 3. Pearson's correlation coefficient among yield and yield associated traits of 20 hybrids of maize under drought stress

Traits	GY	DA	DS	DM	PH	EH	SP	HW	TGW	PC	OC
GY	1	0.371	0.275	0.375	0.213	0.032	0.007	-0.531^{0}	0.224	-0.323	-0.271
DA		1	0.571**	0.283	0.458*	0.343	0.320	-0.286	0.099	-0.291	-0.530^{0}
DS			1	0.371	0.233	0.142	0.082	-0.154	-0.085	-0.521^{0}	-0.287
DM				1	0.367	0.183	-0.061	-0.048	0.017	0.219	-0.061
PH					1	0.714**	0.073	-0.275	0.068	0.068	-0.501^{0}
EH						1	0.279	0.045	-0.073	0.001	-0.497^{0}
SP							1	-0.052	-0.125	-0.215	-0.487^{0}
HW								1	0.007	0.293	0.437*
TGW									1	0.224	-0.088
PC										1	0.376
PO											1

$*;^{0}$ and $**;^{00}$ - significant at 0.05 and 0.01 level of probability, respectively

Table 4. Pearson's correlation coefficient among yield and yield associated traits of 20 hybrids of maize under non-drought conditions

Traits	GY	DA	DS	DM	PH	EH	SP	HW	TGW	PC	OC
GY	1	-0.042	-0.093	0.274	0.302	0.041	0.018	-0.165	0.485*	-0.118	0.036
DA		1	0.985**	0.383	0.270	0.327	-0.367	-0.366	-0.214	0.595**	0.296
DS			1	0.362	0.320	0.360	-0.353	-0.302	-0.226	0.662**	0.361
DM				1	0.148	0.151	-0.251	-0.108	0.132	0.278	0.049
PH					1	0.549*	-0.207	-0.036	0.262	0.255	0.167
EH						1	-0.395	0.053	0.058	0.435	0.381
SP							1	-0.110	0.163	-0.343	-0.361
HW								1	-0.018	-0.032	0.182
TGW									1	-0.216	-0.369
PC										1	0.600**
OC											1

$*;^{0}$ and $**;^{00}$ - significant at 0.05 and 0.01 level of probability, respectively

In addition, there were significant and positive correlation between days to 75% anthesis and, days to 75% silking (r = 0.571**) and plant height (r = 0.458*).

The correlation between plant height and ear height in drought stress was significant positive (r = 0.714**), this finding being in agreement with the results of Beiragi et al. (2011).

In this study, simple correlation coefficients of studied traits in non-stress conditions indicated that grain yield was correlated significant positive only with 1000-grains weight (r = 0.485*) (Table 4).

The result is in agreement with findings of Rahman et al. (2017) that found positive significant correlation of grain yield with thousand grains weight in 15 maize genotypes experimented under normal conditions.

Thus, our findings suggested that the selection of hybrids having high thousand grains weight should be the priority of breeders to achieve higher yield in non-drought conditions.

There were positive and significant correlation between days to 75% anthesis and days to 75% silking (r = 0.985**), days to 75% anthesis and protein content (r = 0.595**), days to 75% silking and protein content (r = 0.662**), plant height and ear height (r = 0.549*), protein content and oil content (r = 0.600**) (Table 4).

The results are partial contradictory where Sharma et al. (2016) found significant negative correlation of protein content and oil content in 81 genotypes of maize.

Mehri (2015) found that in both environments (normal conditions and water scarcity during grain filling stage) there was a significant positive correlation between grain yield and, thousand grain weight and hectolitre weight.

CONCLUSIONS

The relationships between grain yield and associated traits are the primary important data in maize breeding programs. Selection for high yielding hybrids should focus on the strongly positively associated traits of maize plant with its yield.

The results of this study revealed that grain yield exhibited a significant negative correlation only with hectolitre weight (r = -0.531^0) in drought conditions, and a significant positive correlation only with thousand grains weight (r = 0.485*) in non-drought conditions. Therefore, for yield improvement in maize hybrids as per the findings of the plant traits association studied, it is necessary selection based on plant with lower hectolitre weight under drought stress, and high thousand grains weight in non-drought conditions.

The research emphasized that yield and the relationships between grain yield and other associated traits are influenced by genotypes and environmental conditions studied.

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