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HETEROSIS, CORRELATION AND PATH COEFFICIENT ANALYSIS FOR FORAGE YIELD AND ITS CONTRIBUTING TRAITS OF MAIZEX TEOSINTE HYBRIDS IN TWO SEASONS

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ABSTRACT

A local ecotype of teosinte (*Euchlaena mexicana* Schrad.) and eight different maize (*Zea mays* L.) genotypes were crossed to generate eight crosses as well as their eight reciprocals to study the heterosis, nature of associations between dry forage yield and its contributing traits at the phenotypic level in addition to detect the relative importance of each yield component in determining plant dry forage yield variation through path coefficient analysis. The obtained results revealed that the two crosses ((P_6 x P_1 and P_1 x P_7) exhibited the maximum heterosis % over better parent for dry forage yield plant^{-1} in both seasons. These crosses could be considered as promising crosses for teosinte improvement. Correlation coefficients among studied traits indicated that dry forage yield was positively and significantly associated with tillers plant^{-1} and leaf area in both crosses and their reciprocals as well as with plant height in maize x teosinte crosses and with protein content in teosinte x maize crosses in both seasons as well as with stem diameter in 2008 season . The path coefficient analysis indicated that both number of tillers plant^{-1} and plant height had the highest positive direct effects on dry forage yield plant^{-1} in both maize x teosinte and teosinte x maize crosses during both seasons. Thus, dry forage yield improvement can be achieved through selection for more tillers and taller plants.

Keywords: Maize x Teosinte cross, Teosinte x Maize cross, Heterosis, Correlation, Path coefficient analysis, Dry forage yield, Yield components, Seasons.

INTRODUCTION

Maize-Teosinte or Teosinte-Maize hybrids have been of considerable interest to both maize and teosinte breeders. The close genetic relationship between the two subspecies has stimulated interest in enriching the gene pool of maize with useful genes from maize. Likewise, maize-teosinte or teosinte-maize hybrids have also received attention for enhancing the fodder production potential of teosinte by taking advantage of hybrid vigour shown by the hybrids. Crosses between maize (*Zea mays* L.), variety "HGA6" and teosinte (*E. mexicana* Schrad) were evaluated for fodder production by Chaudhuri and Prasad (1968). They indicated that the hybrids could be raised with greater ease when maize is used as the female parent. The F_1 hybrids possessed the characters which contributed toward higher forage yield. They had somewhat longer vegetative period than maize but were much earlier than teosinte in flowering habit and had a profuse number of cobs plant^{-1}. Hybrids grew more quick than either parents and on average had 2-3 tillers plant^{-1} and consequently more leaves plant^{-1} than maize. Fodder from hybrids had much higher content of crude protein and sucrose than either parents and possessed a higher nutritive value. The hybrids were thus considered as a potentially valuable fodder crop.

Heterosis is a special genetic mechanism whereon the distant genotypes are brought together in a specific pattern to express their ability to make a dramatic shift in the magnitude of a particular trait. The presence of sufficient hybrid vigor is an important prerequisite for successful production of hybrid varieties. In this respect, Khan (1957) found an appreciable increase in forage yield of maize x teosinte hybrids, which showed 82.77% and 23.61% increase in dry weight over maize and teosinte parents, respectively. Heterosis for dry matter and protein production plant^{-1} expressed in F_1 hybrids between diploperennial teosinte (*Zea perennis*) and a sweet variety of maize (Ever-green) were studied by Palacios and Magoja (1988). Thirty days after sowing, the hybrids had produced almost twice as much dry weight and protein content plant^{-1} than the better parent (maize) with heterosis values of 60.2 and 57.6%, indicating that the efficiency of vegetative production of maize can be increased by introducing genes from related wild germplasm. Sohoo *et al.* (1993) studied heterosis for some fodder characters in a cross between the inbred line J-1006, which is a released variety of fodder maize and a selected strain of teosinte, TL-1. Positive and significant mid-parent heterosis was observed for plant height (34.79%), leaf length (15.52%), leaf width (11.91%), leaf weight plant^{-1} (36.33%), stem weight plant^{-1} (77.29%) and green fodder plant^{-1} (62.74%).

Forage yield is a complex trait conditioned by the interaction of various growth and physiological processes throughout the plant life cycle. The appropriate knowledge of such interrelationships between forage yield and its contributing components can significantly improve the efficiency of breeding programs. The nature of associations between yield and its components determines the appropriate traits to be used in direct selection for the improvement of forage yield. However, environmental fluctuations influence the phenotypic expression of quantitative characters and consequently different estimates of correlations among characters may have an effect on various characters sensitive to environmental modifications. Furthermore, evaluation of genotypes across different environments comes more important in planning breeding programs for improving yield and would help the teosinte breeder to decide the characters showing consistent correlation with yield under different environmental condition. Such characters should be taken into account, when selection is practiced for superior genotypes.

The efficiency of a breeding program depends mainly on the direction and magnitude of the association between yield and yield components and also the relative importance of each factor involved in contributing to forage yield. Path analysis is a statistical technique that partitions correlations into direct and indirect effects and distinguishes between correlation and causation, whereas correlation in general measures the extent and direction (positive or negative) of a relationship occurring between two or more variables. The estimates of correlation and path coefficients can help us to understand the role and relative contribution of various plant traits in establishing growth behavior of crop cultivars under given environmental conditions (Shahbaz Akhtar *et al.* 2007).

A number of researchers focused on forage maize tried to explain the relations of yield-related components by using correlation and path coefficient analysis. Kara *et al.* (1999) reported that green forage yield in maize was positively correlated with stem diameter. Zahid *et al* (2002) reported that dry fodder yield is significantly and positively associated with each of tiller plant^{-1} leafiness, leaf area and crude protein. Positive and significant correlations of silage yield with each of leaf area, stem weight and leaf weight were reported by Ergul and Soylu (2009), but they did not determine any significant correlation between silage yield and each of plant height stem ratio, leaf number and leaf ratio. Hunter (1986) and Iptas and Yavuz (2008) reported that plant height and stem diameter were not related to dry matter yield as well as dry matter yield was negatively correlated with stem ratio and leaf ratio. Kumar Srivas and Singh (2004) notified that dry forage yield plant^{-1} was found to be significantly and positively associated with green fodder yield and yield components, viz. plant height, number of leaves plant^{-1} and stem diameter. Thus, the improvements in plant height, number of leaves plant^{-1} and stem diameter will help in improving the fodder yield in maize both directly and indirectly. Icoz and Kara (2009) suggested that to optimize the silage corn yield, the greater priority must be given to ear weight, leaf number and stem diameter. Carpici and Celik (2010) indicated that the relationship between the dry forage yield and each of yield components except for stem ratio was positive and significant.

The main objective of this study was to determine heterosis and interrelationships between dry forage yield and its components, as well as the direct and indirect effects of yield-related components on dry forage yield variation in two seasons.

MATERIALS AND METHODS

The breeding materials used in this study (Table 1) consisted of a local ecotype of teosinte (*Euchlaena mexicana* Schrad.) and eight different maize (*Zea mays* L) genotypes including three groups of maize genotypes, i.e. three inbred lines, two single crosses and one three way-cross as well as two populations obtained from the Maize Research Dept., FCRI, ARC, Giza. These parents were representing a wide range of variability in most of the agronomic characters. The experiments were carried out at the experiment station of the Agricultural Research Center (ARC), Giza, Egypt during three successive growing seasons of 2006, 2007 and 2008.

Table 1: Pedigree and origin of the parental genotypes.

No.	Genotype	Pedigree	Origin
P_1	Local teosinte	Damietta District	Egypt
P_2	Inbred line 60 (white)	Rg-15 g.s. (Syn. Laposta x Ci 64) (S.C.14)	Egypt
P_3	Inbred line170 (yellow)	C.M.103	India
P_4	Inbred line171 (yellow)	C.M.104	India
P_5	SC 10	(Sd 7 x Sd 63)	Egypt
P_6	SC 129	(G. 612 x G. 628)	Egypt
P_7	TWC 310	(SC 10 x Sd 34)	Egypt
p_8	G. 2	A composite population	Egypt
P_9	Laposta	A composite population	CIMMYT

In 2006 summer season, the parental genotypes were crossed to generate eight crosses namely; $P_1 \times P_2$, $P_1 \times P_3$, $P_1 \times P_4$, $P_1 \times P_5$, $P_1 \times P_6$, $P_1 \times P_7$, $P_1 \times P_8$ and $P_1 \times P_9$ as well as their eight reciprocal crosses. The evaluation trials were carried out during 2007 and 2008 seasons involving 8 F_1's and their reciprocals as well as local teosinte, using RCBD with three replications. Each cross from them was grown in a plot representing three ridges. Each ridge was 4 m long and 60 cm wide with single-plant hills spaced 20 cm apart (20 plants row^{-1}). Hills were overseeded then thinned to one plant/hill after complete emergence. Recommended cultural practices for teosinte production were followed.

Observations and measurements were recorded on 10 guarded plants chosen at random from each plot for the following characteristics: plant height (cm), number of basal tillers plant^{-1}, stem diameter (cm) at the third internode above soil surface, length and width of the fourth basal leaf (cm), fourth leaf area estimated as maximum blade width x blade length x 0.747 (Stickler *et al.*, 1961), leafiness; leaf weight x 100/ (leaf + stem) weight on dry basis; estimated from a random sub- sample of stem, dry forage yield plant^{-1} (drying at 70°C to a constant weight), and protein content (%) according to A.O.A.C. (1980).

The heterosis % expressed by the F_1 hybrid and better parent (B_P) was calculated according to Mather and Jinks (1982) as follows:

Herterosis % = $[(F_1 - B_P)/ B_P] \times 100$

The significant of heterotic effect for F_1 values from the better parent (teosinte) was tested according to the following formula: LSD = $t_{0.05 or\ 0.01} \times (2MSe/r)^{0.5}$

Where, t is the tabulated t value at significant level of probability for the experimental error degree of freedom, MSe is mean squares of the experimental error and r = No. of replicates.

In this study, the phenotypic correlation coefficients among all possible pairs of the studied traits were computed in the two seasons according to Snedecor and Cochran (1981) . To obtain more information about the relative contribution of a specific character to dry forage yield plant^{-1} and its contributing traits, the path coefficient analysis was performed for maize x teosinte crosses and their reciprocals using the method proposed by Wright (1934) and utilized by Dewey and Lu (1959).

RESULTS AND DISCUSSION

Heterosis effects:

Heterosis expressed as percent increase of F_1 hybrid over the better parent (teosinte for the forage breeder) for all studies traits are presented in Table (2). Maximum heterosis values for maize x teosinte crosses in both seasons were observed for plant height, stem diameter, leaf length, leaf area and dry forage yield plant^{-1} in cross ($P_6 \times P_1$) as well as for protein content in cross ($P_7 \times P_1$) in 2007 seasons only. Likewise, Maximum heterosis for reciprocal F_1 crosses in both seasons were found for stem diameter, leaf length and dry forage yield plant^{-1} in cross ($P_1 \times P_7$), for leaf width and leaf area in cross ($P_1 \times P_3$).

Table 2: Heterosis percentage relative to the teosinte parent for the studied traits of maize x teosinte crosses and their reciprocals after 60-days from planting during 2007 and 2008 seasons.

Cross	Plant height (cm)		Tillers plant^{-1}		Stem diameter (cm)		Leaf length cm)		Leaf width (cm)		Leaf area (cm^2)		Leafiness (%)		Protein content (%)		Dry forage yield plant^{-1}(g)	
	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008
F_1 Crosses																		
P_2 x P_1	43.2**	34.8**	-62.0**	-63.0**	71.4**	39.0**	1.1	0.5	34.5**	33.0**	35.5**	34.5**	-28.2**	-30.7**	-1.6	-3.3**	96.5**	66.5**
P_3 x P_1	69.3**	78.1**	-56.0**	-55.9**	42.9**	26.8**	1.0	3.8	33.3**	28.4**	32.9**	22.9**	-28.2**	-30.8**	-7.0**	-9.1**	128.5**	92.5**
P_4 x P_1	80.4**	55.7**	-67.0**	-63.0**	71.4**	41.5**	5.6	9.9**	50.6**	54.5**	58.3**	71.8**	-37.1**	-39.4**	-5.7**	-7.4**	120.9**	93.1**
P_5 x P_1	30.5**	21.3**	-70.0**	-67.8**	25.7**	29.3**	-8.3*	-9.2**	8.0	11.4**	-1.9	1.5	-35.1**	-37.4**	-9.6**	-12.4**	114.7**	45.5**
P_6 x P_1	98.1**	99.6**	-53.0**	-56.8**	85.7**	61.0**	33.8**	29.2**	60.9**	52.3**	115.1**	97.1**	-36.0**	-38.3**	-4.7**	-6.3**	168.5**	153.7**
P_7 x P_1	60.2**	38.2**	-70.0**	-63.4**	71.4**	36.6**	5.3	-7.0*	35.6**	17.0**	41.6**	9.6	-27.5**	-30.1**	2.6*	-0.3	163.2**	135.6**
P_8 x P_1	89.1**	78.4**	-66.0**	-56.8**	68.6**	46.3**	19.6**	12.7**	63.2**	50.0**	94.3**	69.8**	-36.1**	-38.4**	-3.9**	-7.4**	145.8**	120.1**
P_9 x P_1	78.0**	66.4**	-61.0**	-53.3**	71.4**	56.1**	29.9**	14.0**	51.7**	30.7**	96.6**	49.7**	-32.9**	-35.3**	-11.4**	-14.0**	124.5**	98.4**
Reciprocal F_1 Crosses																		
P_1 x P_2	60.4**	54.4**	6.5	-15.9**	82.9**	58.5**	14.0**	12.9**	58.6**	51.1**	79.4**	71.0**	-20.2**	-23.0**	-3.9**	-5.8**	342.5**	285.8**
P_1 x P_3	38.4**	39.4**	-12.5*	-33.0**	65.7**	43.9**	22.4**	5.9	83.9**	63.6**	124.0**	74.7**	-16.5**	-19.6**	-8.8**	-14.5**	305.4**	253.4**
P_1 x P_4	34.5**	22.6**	5.0	-16.3**	31.4**	12.2*	5.3	3.3	37.9**	36.4**	44.6**	41.7**	-20.1**	-23.0**	-11.4**	-12.7**	280.9**	232.1**
P_1 x P_5	87.3**	73.3**	-42.0**	-48.9**	80.0**	70.7**	15.5**	13.8**	46.0**	37.5**	68.5**	57.5**	-20.4**	-23.3**	-16.6**	-17.0**	151.0**	118.8**
P_1 x P_6	79.8**	88.6**	-13.5*	-24.7**	88.6**	63.4**	8.0*	3.9	52.9**	43.2**	63.7**	49.1**	-27.5**	-30.1**	-18.2**	-21.3**	313.0**	260.0**
P_1 x P_7	103.8**	72.5**	-3.0	-18.9**	114.3**	78.0**	29.1**	19.2**	49.4**	39.8**	91.9**	68.2**	-24.1**	-28.6**	-11.4**	-12.7**	454.4**	331.3**
P_1 x P_8	96.2**	78.8**	-35.0**	-38.3**	82.9**	56.1**	2.2	0.3	42.5**	40.9**	45.5**	42.2**	-27.2**	-32.3**	-15.6**	-18.0**	261.9**	215.4**
P_1 x P_9	91.1**	60.0**	-30.0**	-41.9**	88.6**	63.4**	16.7**	13.1*	48.3**	29.5**	72.1**	46.5**	-20.4**	-29.6**	-24.4**	-26.4**	239.1**	177.2**
L.S.D.0.05	7.86	7.43	1.07	0.68	0.28	0.21	6.42	5.32	0.43	0.36	52.49	39.62	2.83	0.78	0.39	0.31	38.42	12.38
L.S.D.0.01	10.45	9.88	1.42	0.90	0.37	0.28	8.54	7.08	0.57	0.48	69.82	52.70	3.76	1.04	0.52	0.41	51.10	16.47

Moreover, the cross (P_1 x P_7) gave the highest heterosis values for plant height in 2007 season only. Similar results were reported by Khan (1957), Palacios and Magoja (1988), Corcuera (1991) , Sohoo *et al* (1993), Radwan *et al* (2000), Al-Shazly (2007), who observed positive and significant heterosis relatively to teosinte parent for plant height (243.43%), stem diameter (117.65%), leaf area (140.74%), dry forage yield plant^{-1} (197.23%). Number of stems showed significant negative heterosis (-18.75%).

Correlation among studies traits:

Phenotypic correlation coefficients estimated among all possible pairs of traits including forage dry yield on data of maize x teosinte crosses and their reciprocals in two seasons are presented in Tables (3 and 4). In 2007 season, the dry forage yield plant^{-1} showed significant positive correlations with each of tillers plant^{-1}, leaf width and leaf area in both crosses and their reciprocals. Such results could help the breeder to select high dry forage yield through selection for one or more of these traits.

Significant positive correlations were also detected between dry forage yield plant^{-1} and plant height as well as leaf length in M x T crosses and with protein content in T x M maize crosses. However, no correlations were observed between dry forage yield plant^{-1} and each of protein content in M x T crosses, plant height in T x M crosses. These results are in accordance with the findings of Hunter (1986), Cox *et al.* (1994), Gomaa and Shaheen (1994), Kara *et al.* (1999), Iptas and Yavuz (2008), Ergul and Soylu (2009), Icoz and Kara (2009) and Carpici and Celik (2010) for the studies traits.

Table 3: Phenotypic correlation coefficients among the nine studied traits of maize (M) x teosinte (T) crosses and their reciprocals grown in 2007 season.

Character	Cross	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9
Plant height (X_1)	M x T	0.271*	0.151	0.540**	0.303*	0.537**	-0.117	-0.275*	0.806**
	T x M	-0.336*	0.824**	0.134	-0.229*	-0.108	-0.711**	-0.394**	-0.053
Tillers plant^{-1} (X_2)	M x T		-0.182	-0.092	0.178	0.055	-0.239*	-0.043	0.688**
	T x M		-0.341*	0.010	0.226*	0.215*	0.148	0.643**	0.841**
Stem diameter (X_3)	M x T			-0.215*	0.342*	0.040	-0.165	-0.060	0.047
	T x M			0.624**	-0.128	0.319*	-0.434**	-0.223*	0.022
Leaf length (X_4)	M x T				0.291*	0.846**	0.520**	0.152	0.522**
	T x M				-0.191	0.534**	0.105	0.166	0.129
Leaf width (X_5)	M x T					0.755**	0.357*	0.370*	0.434**
	T x M					0.727**	0.579**	0.509**	0.410**
Leaf area (X_6)	M x T						0.556**	0.316*	0.611**
	T x M						0.575**	0.578**	0.454**
Leafiness (X_7)	M x T							0.893**	0.070
	T x M							0.569**	0.037
Protein content (X_8)	M x T								0.022
	T x M								0.519**
Forage dry yield plant^{-1} (X_9)	M x T								
	T x M								

***, ** denote significant at 0.05 and 0.01 levels of probability, respectively.**

Regarding plant height, significant positive correlations were found with tillers plant^{-1}, leaf length, leaf width and leaf area in M x T crosses as well as with stem diameter in T x M crosses. While, it exhibited negative and significant associations with tillers plant^{-1}, leaf width and leafiness in T x M crosses and with protein content in both M x T and T x M crosses.

Tillers plant^{-1} was significantly and positively correlated with each of leaf area, leaf width and protein content in T x M crosses. Meanwhile, it is significantly and negatively associated with stem diameter in T x M crosses and leafiness in M x T crosses. Previous results of Zahid *et al.* (2002) reported also positive and significant phenotypic correlations between tillers plant^{-1} and each of leaf area and crude protein.

Regarding stem diameter, significant positive correlations were found with leaf width in M x T crosses, and with leaf length and leaf area in T x M crosses. On the other side, significant negative associations were detected between stem diameter and each of leaf length in M x T crosses, and leafiness and protein content in T x M crosses. In contrast, Carpici and Celik (2010) found positive correlations between stem diameter and leafiness in forage maize.

Leaf length exhibited significant and positive associations with each of leaf width, leaf area and leafiness in M x T crosses, and leaf area in T x M crosses. Concerning leaf width, significant positive association coefficients were estimated with each of leaf area, leafiness and protein content in M x T and T x M crosses. Leaf area was significantly and positively correlated with leafiness and protein content in all crosses and their reciprocals. Similar results were obtained by Wernli *et al.* (1988). Leafiness was significantly and positively correlated with protein content in M x T and T x M crosses. The results are in close agreement to those of Muhammad *et al* (1994), Hussain *et al.* (1991) and Zahid *et al.* (2002).

In 2008 season, the dry forage yield plant^{-1} showed significant and positive correlations with each of tillers plant^{-1}, stem diameter, leaf length and leaf area in M x T and T x M crosses. Significant positive correlations were also detected between dry forage yield plant^{-1} and plant height in M x T crosses and with each of leaf width and protein content in T x M crosses. However, no correlations were observed between dry forage yield plant^{-1} and each of protein content in M x T crosses, plant height in T x M crosses. The obtained results are in agreement with the findings of Schmid *et al* (1976), Kumar Srivas and Singh (2004), Iptas and Yavuz (2008), Ergul and Soylu (2009), Icoz and Kara (2009) and Carpici and Celik (2010).

Regarding plant height, significant positive correlations were found with each of leaf length, leafiness and protein content in M x T crosses, and with stem diameter in T x M crosses. While, it was negatively associated with each of tillers plant^{-1}, leafiness and protein content in T x M crosses and with leaf width in M x T and T x M crosses.

Tillers plant^{-1} was significantly and positively correlated with each of stem diameter and leaf length in M x T crosses and with protein content in T x M crosses. Meanwhile, it was significantly and negatively associated with each of leafiness and protein content in M x T crosses and with stem diameter in T x M crosses. Previous results of Zahid *et al.* (2002) also revealed positive phenotypic correlation between tillers plant^{-1} and crude protein.

Regarding stem diameter, significant positive correlations were found with each of leaf length, leaf width and leaf area in M x T crosses, and with each of leaf length, leaf area, leafiness and protein content in T x M crosses. This result is in agreement with the findings obtained by Carpici and Celik (2010) in forage maize. On the other hand, significant negative associations were detected between stem diameter and protein content in M x T crosses.

Leaf length exhibited significant positive associations with each of leaf width, leaf area and leafiness in M x T and T x M crosses. Regarding leaf width, significant positive associations were exhibited with leaf area, leafiness and protein content in crosses and their reciprocals. Leaf area was significantly and positively correlated with leafiness and protein content in crosses and their reciprocals. In this connection, Wernli *et al.* (1988) obtained similar association for leaf area in both maize and sorghum genotypes. Leafiness was significantly and positively correlated with protein content in crosses and their reciprocals. This result is in agreement with the results obtained by Zahid *et al.* (2002).

In general, the existence of positive associations in the present study between dry forage yield plant^{-1} and each of number of tillers plant^{-1}, leaf length, leaf width and plant height suggests that an increment of production may be achieved upon improving either one or more of these yield contributing traits under target conditions.

Table 4: Phenotypic correlation coefficients among the nine studied traits of maize (M) x teosinte (T) crosses and their reciprocals grown in 2008 season.

Character	Cross	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9
Plant height (X_1)	M x T	0.167	-0.040	0.327*	-0.340*	-0.079	0.466**	0.241*	0.583**
	T x M	-0.472**	0.312*	0.175	-0.370*	-0.180	-0.787**	-0.470**	-0101
Tillers plant^{-1} (X_2)	M x T		0.436**	0.298*	0.076	0.198	-0.241*	-0.303*	0.820**
	T x M		-0.271*	0.052	0.181	0.155	0.164	0.686**	0.727**
Stem diameter (X_3)	M x T			0.312*	0.290*	0.339*	-0.174	-0.263*	0.501**
	T x M			0.723**	0.168	0.533**	0.260*	0.308*	0.254*
Leaf length (X_4)	M x T				0.366*	0.745**	0.274*	0.195	0.522**
	T x M				0.208*	0.707**	0.291*	0.151	0.521**
Leaf width (X_5)	M x T					0.893**	0.339*	0.348*	0.121
	T x M					0.838**	0.540**	0.446**	0.355*
Leaf area (X_6)	M x T						0.383**	0.351*	0.339*
	T x M						0.561**	0.413**	0.551**
Leafiness (X_7)	M x T							0.953**	0.033
	T x M							0.487**	0.078
Protein content (X_8)	M x T								-0.173
	T x M								0.635**
Dry forage yield plant^{-1} (X_9)	M x T								
	T x M								

***, ** denote significant at 0.05 and 0.01 levels of probability, respectively.**

Path coefficient analysis:

Path coefficient analysis was performed to assess magnitude of contributions of yield contributing traits to dry forage yield in the form of cause and effect. From path analysis, it was possible to rank plant characteristics according to magnitude of their effects on dry forage yield. In this analysis, dry forage yield plant^{-1} was considered as a resultant variable and plant height, tillers plant^{-1}, stem diameter and leaf area as causal variables. The direct and indirect effects of the four traits related to the yield for F_1 maize x teosinte crosses and their reciprocals in two seasons are shown in Table (5). In 2007 season, tillers plant^{-1} had the highest positive direct effect on the dry forage yield (55.4% for M x T and 86.8% for T x M crosses). Moreover, its indirect effect through plant height in M x T or leaf area in T x M were positive and higher in magnitude than those of via other traits .

Plant height proved to have either moderate direct effect (47.2%) in M x T crosses or low (26.8%) in T x M crosses on dry forage yield plant^{-1}. The indirect effects of this trait through other traits were very low or negative.

Table 5: Partitioning of phenotypic correlation coefficient between dry forage yield plant^{-1}and its contributing traits in maize x teosinte (T x M) crosses and their reciprocals (T x M) grown during 2007 and 2008 seasons.

Source of variation	Effects			
	2007		2008	
	M x T	T x M	M x T	T x M
1-Plant height vs. forage dry yield plant^{-1}				
Direct effect	0.4720	0.2680	0.5030	0.3150
Indirect effect *via* tillers plant^{-1}	0.1501	-0.2916	0.1030	-0.4115
Indirect effect *via* stem diameter	0.0095	0.0016	-0.0074	0.0611
Indirect effect *via* leaf area	0.1745	-0.0314	-0.0153	-0.0660
Total	0.8061	-0.0534	0.5833	-0.1014
2- Tillers plant^{-1} vs. forage dry yield plant^{-1}				
Direct effect	0.5540	0.8680	0.6170	0.8720
Indirect effect *via* plant height	0.1279	-0.0900	0.0840	-0.1487
Indirect effect *via* stem diameter	-0.0115	-0.0007	0.0810	-0.0531
Indirect effect *via* leaf area	0.0179	0.0636	0.0384	0.0570
Total	0.6883	0.8409	0.8204	0.7272
3- Stem diameter vs. forage dry yield plant^{-1}				
Direct effect	0.0630	0.0025	0.1860	0.1960
Indirect effect via plant height	0.0713	0.2208	-0.0201	0.0983
Indirect effect via tillers plant^{-1}	-0.1008	-0.2960	0.2690	-0.2363
Indirect effect via leaf area	0.0130	0.0945	0.0658	0.1961
Total	0.0465	0.0218	0.5007	0.2541
4- Leaf area vs. forage dry yield plant^{-1}				
Direct effect	0.3250	0.2960	0.1940	0.3680
Indirect effect via plant height	0.2535	-0.0289	-0.0397	-0.0567
Indirect effect via tillers plant^{-1}	0.0305	0.1866	0.1221	0.1352
Indirect effect via stem diameter	0.0025	0.0006	0.0631	0.1045
Total	0.6115	0.4543	0.3394	0.5509

Leaf area seemed to have low direct effect on dry forage yield plant^{-1} in both M x T and T x M crosses. Its indirect effects through plant height in

M x T crosses and number of tillers plant^{-1} in T x M crosses were low. Whereas, its indirect effects through other traits in both crosses were very low or negative.

The components of the dry forage yield plant^{-1} variation determined directly and jointly by each factor are given in Table (6). The data showed that in 2007 season, the highest main sources of dry forage yield variation in order of relative importance in M x T crosses were the direct effects of both tillers plant^{-1} and plant height followed by the joint effects of both plant height with leaf area and plant height with tillers plant^{-1}. For T x M crosses, the rank of contribution was the direct effect of tillers plant^{-1} followed by the joint effects of both plant height with tillers plant^{-1} and tillers plant^{-1} with leaf area. The total contributions of these four mentioned traits directly and jointly were 72.99 and 70.83 %, while the residual effects were 27.01 and 29.17 % of the total variation for the M x T and T x M crosses, respectively. In this connection, Kara *et al.* (1999) reported that plant height was the character having the highest direct effect on fresh forage in corn. These results are in agreement with those obtained by Jatimliansky *et al.* (1988), Gomaa and Shaheen (1994), Salama *et al.* (1994), Ibrahim (2004) and Carpici and Celik (2010).

In 2008 season, the results showed that tillers plant^{-1} in both M x T and T x M crosses had the maximum positive direct effects on dry forage yield plant^{-1} variation (Table 5). Its indirect effects through either plant height in M x T crosses or leaf area in T x M crosses were high in magnitude.

Table 6: The components (direct and joint effects) in percent of contribution due to plant yield and its contributing traits in maize x teosinte (M x T) crosses and their reciprocals (T x M) during 2007 and 2008 seasons.

Sources of variation	2007				2008			
	M x T		T x M		M x T		T x M	
	CD	RI%	CD	RI%	CD	RI%	CD	RI%
Plant height (X_1)	0.2228	16.44	0.0718	5.46	0.2030	20.00	0.0992	5.82
Tillers plant^{-1} (X_2)	0.3069	22.65	0.4834	36.76	0.2939	28.96	0.5604	32.89
Stem diameter (X_3)	0.0040	0.29	0.0022	0.17	0.0346	3.41	0.0384	2.25
Leaf area (X_4)	0.1056	7.8	0.0876	6.66	0.0376	3.71	0.1354	7.95
(X_1) x (X_2)	0.1417	10.46	-0.1563	11.89	0.1037	10.21	-0.2593	15.22
(X_1) x (X_3)	0.0090	0.66	0.0009	0.07	-0.0075	0.74	0.0385	2.26
(X_1) x (X_4)	-0.1648	12.16	0.0171	1.30	0.0154	1.52	0.0417	2.45
(X_2) x (X_3)	-0.0127	0.94	-0.0012	0.09	0.1001	9.86	-0.0926	5.44
(X_2) x (X_4)	0.0198	1.46	0.1105	8.40	0.0474	4.67	0.0995	5.84
(X_3) x (X_4)	0.0016	0.12	0.0004	0.03	0.0245	2.41	0.0769	4.51
Residual effect	0.3660	27.01	0.3836	29.17	0.1473	14.52	0.2619	15.37
Total	1.0000	100.00	1.0000	100.00	1.0000	100.00	1.0000	100.00

CD: Coefficient of determination and RI%: Relative importance.

The direct and joint effects for plant height, tillers plant^{-1}, stem diameter and leaf area on dry forage yield plant^{-1} variation are given in Table (6). The data showed that the main sources of dry yield variation in order of relative importance were the direct effect of both tillers plant^{-1} and plant height followed by the joint effects of both plant height with tillers plant^{-1} and tillers plant^{-1} with stem diameter in M x T crosses. While, the rank contribution of the traits was the direct effect of tillers plant^{-1} followed by the joint effects of plant height with tillers plant^{-1} in T x M crosses. The total contributions of these mentioned traits directly and jointly were 85.48 and 84.63 %, while the residual effects were 14.52 and 15.37 % of the total variation for the M x T and T x M, respectively.

Conclusion

The two F_1 crosses (P_6 x P_1 and P_1 x P_7) exhibited the maximum heterosis % over better parents for dry forage yield plant^{-1} during two grown seasons. These crosses could be considered as promising crosses for teosinte improvement. Tillers plant^{-1}and Plant height could be used as selection criteria for forage yield improvement in teosinte breeding programs in target environmental conditions.

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قوة الهجين والارتباط و معامل المرور لمحصول العلف والصفات المساهمة فيـــه لهجن الذرة الشامية x الذرة الريانة في موسمين زراعيين

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أجريت هذه الدراسة بمحطة البحوث الزراعية بالجيزة خلال ثلاثة مواسم زراعية (٢٠٠٦ ، ٢٠٠٧، ٢٠٠٨) وذلك بهدف دراسة قوة الهجين والارتباطات المظهرية بين المحصول ومكوناته في ثمانية هجن بين الذرة الشامية والريانة وهجنها العكسية من جهة وبين مكونات المحصول وبعضها البعض من جهة أخرى وكذلك تحديد مدى مساهمة الصفات المختلفة في تباين محصول العلف على المستوى المظهري باستعمال تحليل معامل المرور للوقوف على انسب معايير الانتخاب التي يمكن استخدامها في برنامج تربية الذرة الريانة. وقد اشتملت مادة الدراسة على تركيب وراثي واحد من الذرة الريانة (P1) و ثمانية تراكيب وراثية من الذرة الشامية : السلالة ٦٠ (P2)، السلالة ١٧٠ (P3)، السلالة ١٧١ (P4)، الهجين الفردي ١٠ (P5)، الهجين الفردى ١٢٩ (P6)، الهجين الثلاثي ٣١٠ (P7)، الصنف التركيبي جيزة ٢ (P8)، الصنف التركيبي Laposta (P9). وتم تهجين أباء الذرة الشامية مع صنف الذرة الريانة لإنتاج هجن الجيل الأول وهجنها العكسية فى موسم (٢٠٠٦). وفى موسمي ٢٠٠٧ و ٢٠٠٨ تمت زراعة ١٧ تركيب وراثي (٨ هجن F_1's و٨ هجن عكسية وصنف الذرة الريانة) فى تصميم قطاعات كاملة العشوائية في ثلاثة مكررات

ويمكن تلخيص أهم النتائج فيما يلي:

١. أظهر الهجين (P6 X P1) عند استخدام الذرة الشامية كأم قوة هجين موجبة ومعنوية بالنسبة لصنف الذرة الريانة لصفة طول النبات (٩٨.١، ٩٩.٦%)، قطر الساق (٨٥.٧ ، ٦١.٠%)، طول الورقة (٣٣.٨ ، ٢٩.٢%)، مساحة الورقة (١١٥.١، ٩٧.١%) ومحصول العلف الجاف (١٦٨.٥، ١٥٣.٧%) في موسمي ٢٠٠٧ و ٢٠٠٨ على التوالي. كما أظهر الهجين (P1 X P7) عند استخدام الذرة الريانة كأم قوة هجين موجبة ومعنوية بالنسبة لصنف الذرة الريانة لصفة طول النبات (١٠٣.٨، ٧٢.٥%)، قطر الساق (١١٤.٣ ، ٧٨.٠%)، طول الورقة (٢٩.١ ، ١٩.٢%) ومحصول العلف الجاف (٤٥٤.٤، ٣٣١.٣%) في موسمي ٢٠٠٧ و ٢٠٠٨ على التوالي.
٢. سيادة الارتباطات المعنوية بين المحصول ومكوناته وكذلك بين مكونات المحصول وبعضها البعض مما يشير إلى إمكانية تحسين المحصول من خلال الانتخاب لأي من هذه المكونات كما أن الانتخاب لأي من مكونات المحصول لن يترتب علية الانخفاض في المكون الآخر.
٣. تشير نتائج تحليل معامل المرور إلى أهمية كل من صفتي عدد الأفرع للنبات وارتفاع النبات في المساهمة في تباين محصول العلف خلال موسمي الزراعة وبالتالي يمكن للمربى استخدامهما كمعايير لانتخاب تراكيب وراثية متفوقة في برامج تربية الذرة الريانة.

قام بتحكيم البحث

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