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A Path-Coefficient Analysis of Dry Matter Yield and Some Agronomic Characters in Grain Maize Hybrids When Used for Silage Production

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ABSTRACT

Dry matter yield of grain maize hybrids when used for silage production is influenced by several agronomic characters and also by the ear ratio (ER) and stalk ratio (SR). Path-coefficient analysis were calculated to study the relationships among dry matter (DM) yield and, yield components. Thirteen genotypes of maize being improved for grain production were grown during the year 1996, 1997 and 1998 with two sowing pattern (the first crop and the second crop) at Tokat province in Turkey. There was year-to-year variation among the DM yield and the other traits at both first crop and second crop. Mainly ER and secondly SR have direct or indirect effects on DM yield. The direct and indirect effects of the leaf ratio (LR) and plant height (PH) on DM yield were important in some years. However, the best yield of silage was not obtained from hybrids with a high proportion of ER or SR. Moreover, the relationships between the DM yield and the agronomic characteristics were not adequate to permit reliable selection of hybrids for silage production based on the ER and SR. The findings of this study support the need for separate evaluation trials for corn grown for silage production as opposed to grain production.

Key Words: Silage Maize, Dry Matter Yield, Path Coefficient Analysis

INTRODUCTION

Maize is generally valued as a grain crop; however it has a substantial importance as a forage crop in many livestock production regions. After harvesting of winter cereals and in regions where vegetation period is limited in irrigated area, it is grown for silage as a first and second crop in Turkey. All maize hybrids currently sold in the market are developed for grain production in our country. The approach mentioned above is based on research carried out in the USA during the year 1930 and 1940. Most breeders have concentrated on the development of hybrids for grain production, assuming that the best grain-producing hybrids are also the most suitable for silage production [1, 2]. However, Barriere and Traineau [3] reported that the physiology of a silage maize hybrid was not the same as that of a grain maize. Fairey [4] and Vattikonda and Hunter [1] found that the best yield of silage was not obtained from hybrids with a high proportion of grain. Additionally, Pinter [2] and Allen et al. [5] didn't find, a close relationships between forage and grain hybrids as regards to yield of DM.

The primary objectives in forage maize breeding programmes are to improve the forage quality and yield [6, 7, 8]. DM yield is a complex character as influenced by various agronomic parameters and ecological factors [3, 6, 9, 10]. It is important to examine to contribution of the several components in order to use them in direct selection for DM yield. Simple correlation coefficient alone, did not give complete scheme. These relationships did not reflect the estimation of direct and indirect effects of the characters on DM yield. Therefore, path-coefficient analysis can be used to partition the correlation coefficients obtained in such studies. A path coefficient is a standardized partial-regression coefficient, obtained from equations where all variables have been expressed as deviations from the mean in units of standard deviation. Thus, it provides a measure of the relative importance of each independent variable to the prediction of changes in dependent one [11, 12].

The aim of this study is to determine the relationships among the DM yield and related agronomic characters by correlation and path-coefficient analysis of maize hybrids for silage production that is grown as first and second crop during the years 1996, 1997 and 1998.

MATERIALS AND METHODS

This study was conducted at the Field Crops Department, Gaziosmanpasa University, Faculty of Agriculture, Tokat-Turkey (40º 13ᴵ-40º 22ᴵ N, 36º 1ᴵ-36º 40ᴵ E, elevation 623 m) in the years 1996, 1997 and 1998. In this research, thirteen commercial corn hybrids were used. The hybrids were TTM-813 and LG-60 (early-maturing), LG-55, LG-2777, RX-899, TTM-8119, Karadeniz Yildizi (medium-early maturing), P.3167, P.3163, TTM--815, RX-947 (medium late-maturing) and Arifiye (late-maturing).

Sowings were done on 16^{th} May 1996, 20^{th} May 1997 and 15^{th} May 1998 as first crop, and 15^{th} July 1996, 17^{th} July 1997 and 15^{th} July 1998 as second crop. The experimental design was a randomized complete block with three replicates in the first and second crop growing season. Row spacing was 40 cm, length of the plot was 4 m and number of rows per plot was four. Each plot received 80 kg N ha^{-1} and 100 kg P_2O_5 ha^{-1} at sowing. An additional 80 kg N ha^{-1} was applied as a side dressing when the plants were about 45 cm tall. All genotypes were harvested between 1-20 September for first crop, and 15-22 October for second crop growing season. 8-10 plant samples were taken for dry matter determinations and for separation into ear, leaf and stalk components. Samples were dried at 70 ^oC, and the data reported on an oven-dry basis. For each of the six experiments, simple correlation coefficients between all possible combinations of variables were first calculated and then path-coefficient analysis were made applying these correlation coefficients and a method similar to that described by Wright [12] to partition the relation coefficient into direct and indirect effects. The characteristics used were (i) leaf ratio (%), (ii) stalk ratio (%), (iii) ear ratio (%), (iv) plant height (cm), (v) dry matter yield $t.ha^{-1}$ and (vi) dry matter ratio (%).

RESULTS

There was year-to-year variation among the DM yield and the other characters in first crop. The simple correlation coefficient calculated from the data of 1996 and 1997, indicated that all traits had no significant effect on the DM yield except for dry matter ratio obtained during the year 1997. However, in 1998, dry matter yield was negatively correlated with (r=0.614*) the stalk ratio and positively correlated with (r=0.743**) the ear ratio (Table 2).

Direct effect of LR on DM yield was 49.2 % and 41.6 %, and the indirect effect of LR via SR were 39.9 % and 44.6 % in first and second year. Although the correlation between DM yield and SR was not significant during the years 1996 and 1997, direct effect on DM yield of SR were 50.1 % and 45.0 %, respectively.

The indirect effect of ER on DM yield via SR was 48.3 % in 1996 and 44.0 % in 1997. The indirect effect of the SR on DM yield via plant height was not negligible, but the direct effects of the PH on DM yield was negligible in these relationships. DM yield was most highly related to (r=0.711**) DMR in 1997. However, the same relation was not obtained for path-coefficient analysis. The direct effect of the DMR on DM yield was 25.4 % and indirect effect was 74.6 %. In 1998, the correlation between SR and DM yield was also negatively significant (r=-0.614*). The direct effect of the SR on DM yield was negligible (5.7 %), but indirect effect of the SR on DM yield via ER was not negligible (88.2 %). The correlation between ER and DM yield was positively significant (r=0.743**) and ER had the greatest direct positive effect on DM yield in third year (Table 3). The direct effect of the LR, SR, PH, and DMR on DM yield was negligible in 1998. However, the most indirect determinant of DM yield was ER via SR followed by DMR via PH and LR.

In second crop, the LR was negatively correlated with DM yield (r=-0.731** for the year 1996 and r=-0.731** for the year 1997) and positively correlated with PH (r=0.577* and r=0.609* for the year 1996 and 1997, respectively). The correlation between DM yield and DMR was positively significant (r=0.747**) in 1996. However, in third year, the correlation among DM yield and other traits were not significant. In 1996, the most important direct effect of DM yield was SR (49.8 %) followed by ER (49.7) and followed by LR (49.0 %). The similar results were also obtained at the second year. However, in 1998, the direct effects obtained in the path-coefficient analysis indicated that DM yield in thirteen maize genotypes depended mainly upon DMR (61.4 %) and secondly upon the LR (48.5 %) and thirdly upon the ER (43.1 %). Path-coefficient analysis shows that indirect effect of other traits on DM yield varied from year-to-year (Table 5). Indirect effect on DM yield by PH via ER (49.3 %) and DMR via LR (48.5 %) were the highest in 1996. In second year, indirect effect on DM yield of ER via LR (53.3 %) and of PH (50.6 %), and SR via DMR (45.4 %) was important. In 1998, the highest indirect effect on DM yield of LR via DMR was 29.6 %.

DISCUSSION

Interpretation of the path analysis gives somewhat a different idea than does a simple correlation analysis. For example, a negative correlation coefficient of r=-0.614* was calculated between DM yield and SR, but the direct effect on DM yield by SR was not significant in first crop in 1998. Path analysis reveals that SR exercised only a negligible direct effect on DM yield. Path analysis also indicates that indirect effect was more than the direct effect. None of these relationships were revealed by the simple correlation analysis. Therefore, path analysis could be more useful in establishing direct and indirect interrelationships among the variables affecting DM yield.

One of the primary objectives for silage maize is dry matter production [1, 3, 13]. Dry matter production is a function to come into being, by interaction of various agronomic characters and ecological factors [3, 6, 10]. In this study, there was year-to-year variation among the DM yield and the other variables.

The simple correlations show that the relationship among the DM yields and LR, SR and DMR were not significant in 1996 and 1997, except for DMR in 1997. However, path-coefficient analysis indicated that the direct effect of each of SR, ER and LR on DM yield was more than 40.0 %. The indirect effects of the SR via LR, ER via PH and DMR, ER via SR and DMR on DM yield were more important in 1996 and 1997. However, DM yield was negatively correlated with (r=-0.614*) the SR and positively correlated with (r=0.743**) the ER for the year 1998. The direct effect of the SR on DM yield was negligible (5.7 %), but indirect effect was not negligible (94.3 %). In 1998, the direct effect of the ER on DM yield was 84.0 % and indirect effect was 16.0 %. The ER of maize genotypes in first crop were 35.3 %, 34.0 %, and 40.1 % during the year 1996, 1997 and 1998, respectively (Table 1). Schmid et al. [14] reported that the correlation between DM yield and ER was not significant (r=-0.04). However, Vattikonda and Hunter [1] observed a positive relationship between grain yield and DM yield of hybrids developed for grain yield. This relationship has not been shown to be strong enough to justify selecting hybrids for silage production based solely on grain yield performance. Coors et al. [8] reported that grain was highly digestible and typically accounts for about 50 % of total dry matter under good conditions. Similar results were also reported by Wolf et al. [7]. However, dry matter yield and quality were highly related to genotype, ecological factors and cultural treatments [6]. In this research, the relationship between DM yield and PH was not significant at first crop. However, path analysis indicated that while the direct effect of PH on DM yield was small, indirect effect was more important in 1996, 1997 and 1998. Schmid et al. [14] reported that the correlation between the PH and DM yield was positive and significant (r=0.76). Similar results were observed by Gallais et al. [15]. In 1996 and 1997, there was positive relationship between DM yield and DMR, but this relationship was not significant (r=0.272 and r=0.429). Increasing DMR increased DM yield in 1997 (r=0.711**). Path-coefficient analysis indicated that the direct effect of DMR on DM yield was 25.4 % and indirect effect was 74.6 % in second year of the first crop (Table 3). In third year, a highest indirect effect on DM yield was obtained with ER via DMR (81.4 %).

LR had a significant negative influence on the DM yield of the second crop in 1996 and 1997 (r=-0.715** and r=-0.731**, respectively). The direct effect of LR was 49.2 % in 1996, and 41.6 % in 1997. Indirect effects of SR via LR on DM yield were significant (Table 5). Gallais et al. [15] reported that the relationship between DM yield and LR was significant, but Schmid et al. [14] observed that the correlation between DM yield and LR was slight (r=-0.08).

Barriere and Traineau [3] reported that increased leaf number per plant of late-maturing hybrids increased the DM yield also increased. Rutger [16] reported that in regions where the duration of the vegetation limited, dry matter concentration and nutritive value were lower for the late-maturing hybrids than for early-maturing hybrids. Consequently, greater dry matter storage losses would also be expected from silage made from the late hybrids. Te Velde [17] noted that the lower the dry matter content at ensilage, the greater will be the loss. In this study, dry matter concentration of the maize varieties were 22.7 %, 17.0 % and 18.3 % for the year 1996, 1997 and 1998, respectively, at the second crop (Table 1). Increased PH increased the DM yield in 1996 and 1997 of the second grown crop (Table 4). Path analysis also indicated that the direct effect of the PH was not more, but indirect effect was more important. In third year, the direct effect of PH was small (29.5 %), but indirect effect of PH via ER was more (70.5 %). Schmid et al. [14] concluded that the correlation between PH and DM yield was positive and significant (r=0.76). This is in agreement with results of Gallais et al. [15] for silage maize. The correlation coefficient between DMR and SR were r=0.195, r=0.034 and r=-0.114 for the year 1996, 1997 and 1998, respectively, (Table 4). The direct effects of SR on DM yield were 49.8 %, 48.3 % and 24.9 %, in first, second and third year. The correlation coefficient indicated that ER had no significant effect on DM yield in 1996, 1997 and 1998. However, path analysis reveals that the direct effect of ER on DM yield was more important (Table 5). The effect of temperature and light intensities are various on the agronomic characters of silage maize growing after harvesting of winter cereals. For example; in the month of september, the mean temperatures were 14.2 ^{o}C, 17.8 ^{o}C, and 18.4 ^{o}C for the year 1996, 1997 and 1998, respectively. Especially, SR and ER of the maize varieties showed that the temperature was most important for the growth of plant. Similar results have been reported that by Barriere and Traineau [3], Coors et al. [8], Struik [18]. In this study, the ER of maize hybrids were 26.2 % in 1996, 11.6 % 1997 and 24.8 % in 1998 for the second crop (Table 1). Russell et al. [19] reported that late-maturing genotypes may have greater dry matter yields but lower grain yield or grain-to-stalk ratio. Consequently, late-maturing genotypes show higher whole-plant fiber and lower whole-plant digestibility as compared to early-maturing genotypes harvested on the same date [8]. However, within narrower maturity groups, these relationships may not be true.

Path-coefficient analysis is a more useful technique than simple correlation analysis when the aim is to establish relationships among many variables affecting DM yield at the first crop and the second crop. The data presented here reveal the SR and ER as one of the most important factors in determining silage maize DM yield, and the direct or indirect effects of the LR and PH were also important under Tokat, Turkey conditions. The best yield of silage was not obtained from hybrids with a high proportion of ear ratio or stalk ratio, because the physiology of the silage maize hybrid was not same as that of a grain hybrid.

In conclusion, this study supports the need for specific varieties to evaluate hybrids for silage production in Turkey. In addition to this, the fermentation characteristics and the nutritive value must be determined in selecting material for silage production.

Table 1. Mean values of dry matter yield and the other characters of thirteen maize hybrids grown in Tokat, Turkey, in 1996, 1997 and 1998

Sowing date	Year	LR (%)	SR (%)	ER (%)	PH (cm)	DMY (t.ha^{-1})	DMR (%)
First crop	1996	16.8	47.9	35.3	223.3	2.34	30.5
	1997	17.2	48.7	34.0	254.6	1.64	21.3
	1998	16.8	43.1	40.1	251.4	2.18	28.1
Second crop	1996	18.1	55.6	26.2	261.5	1.89	22.8
	1997	18.6	69.8	11.6	223.9	1.62	17.0
	1998	17.7	57.4	24.8	267.9	1.64	18.3

LR: Leaf ratio, SR: Stalk ratio, ER: Ear ratio, PH: Plant height, DMY: Dry matter yield, DMR: Dry matter ratio

Table 2. Correlation coefficients among dry matter yield and related characteristics of thirteen maize hybrid genotypes grown in the first crop season, Tokat, Turkey, in 1996, 1997 and 1998 (n=13).

	LR	SR	ER	PH	DMY
SR	-0.341 [1]	-			
	-0.448 [2]	-			
	0.021 [3]	-			
ER	-0.082	-0.909**	-		
	0.034	-0.909**	-		
	-0.480	-0.887**	-		
PH	-0.566*	0.383	-0.155	-	
	-0.509	0.336	-0.138	-	
	0.170	0.256	-0.303	-	
DMY	-0.051	-0.171	0.204	0.058	-
	-0.214	-0.284	0.417	0.089	-
	-0.442	-0.614*	0.743**	-0.198	-
DMR	-0.115	-0.485	0.457	0.212	0.272
	-0.442	-0.485	0.607*	-0.171	0.711**
	-0.123	-0.675*	0.649	-0.450	0.429

1; 1996, 2; 1997; 3;1998, *, ** significant at P=0.05 and 0.01, respectively. LR: Leaf ratio, SR: Stalk ratio, ER: Ear ratio, PH: Plant height, DMY: Dry matter yield, DMR: Dry matter ratio

Table 3. Correlation coefficients among dry matter yield and related characteristics of thirteen maize hybrid genotypes grown in the second crop season, Tokat, Turkey, in 1996, 1997 and 1998 (n=13).

	LR	SR	ER	PH	DMY
SR	0.213 [1]	-			
	0.075 [2]	-			
	-0.423 [3]	-			
ER	-0.655*	-0.599*	-		
	-0.646*	-0.810**	-		
	-0.174	-0.797**	-		
PH	-0.692**	-0.042	0.598*	-	
	-0.673*	-0.112	0.482	-	
	0.276	-0.237	0.146	-	
DMY	-0.715**	0.195	0.434	0.577**	-
	-0.731**	0.034	0.404	0.609*	-
	-0.269	-0.114	0.307	0.138	-
DMR	-0.641*	0.335	0.267	0.141	0.747**
	-0.008	-0.779**	0.647*	0.165	0.301
	0.435	-0.439	0.186	0.214	0.382

1:1996, 2:1997, 3:1998, *, ** significant at P=0.05 and 0.01, respectively. LR: Leaf ratio, SR: Stalk ratio, ER: Ear ratio, PH: Plant height, DMY: Dry matter yield, DMR: Dry matter ratio

Table 4. Path coefficient (P) analysis of dry matter yield of thirteen maize genotypes grown in first crop, Turkey, in 1996, 1997 and 1998.

	Years	Corelation coefficients	Direct Effects	Indirect effects				
				LR	SR	ER	PH	DMR
LR	1996	-0.051	-0.89		0.72	0.16	-0.02	-0.02
			49.2		39.9	8.6	0.9	1.4
	1997	-0.214	-0.84		0.90	-0.06	-0.12	-0.10
			41.6		44.6	3.1	5.5	5.2
	1998	-0.442	-0.12		-0.01	-0.33	0.03	0.01
			26.0		0.2	71.8	0.6	1.4
SR	1996	-0.171	-2.12	0.30		1.72	0.01	-0.08
			50.1	7.1		40.5	0.3	2.0
	1997	-0.284	-2.01	0.38		1.64	0.07	-0.37
			45.0	8.4		36.8	1.6	8.2
	1998	-0.614*	-0.04	-0.01		-0.61	0.01	0.04
			5.7	0.4		88.2	0.6	5.1
ER	1996	0.204	-1.89	0.07	1.93		-0.01	0.10
			47.3	1.8	48.3		0.1	2.5
	1997	0.417	-1.81	-0.03	1.82		-0.03	0.46
			43.6	0.7	44.0		0.7	11.0
	1998	0.743**	0.69	0.06	0.04		-0.01	-0.03
			84.0	7.0	4.3		0.6	4.1
PH	1996	0.058	0.03	0.50	-0.81	0.29		0.05
			1.7	29.9	48.3	17.4		2.7
	1997	0.089	0.22	0.43	-0.68	0.25		-0.13
			12.8	25.1	39.8	14.7		7.6
	1998	-0.198	0.02	-0.02	-0.01	-0.21		0.02
			6.3	7.2	3.6	74.5		8.4
DMR	1996	0.272	0.22	0.10	0.81	-0.86	0.01	
			10.8	5.1	40.6	43.2	0.3	
	1997	0.711**	0.75	0.12	0.97	-1.10	-0.04	
			25.4	3.9	32.7	36.8	1.2	
	1998	0.429	-0.05	0.01	0.03	0.45	-0.01	
			9.5	2.7	5.0	81.4	1.4	

*, ** significant at P=0.05 and 0.01, respectively.

LR: Leaf ratio, SR: Stalk ratio, ER: Ear ratio, PH: Plant height, DMY: Dry matter yield, DMR: Dry matter ratio

Table 5. Path coefficient (P) analysis of dry matter yield of thirteen maize genotypes grown in second crop, Turkey, in 1996, 1997 and 1998.

	Years	Corelation coefficients	Direct Effects	Indirect effects				
				LR	SR	ER	PH	DMR
LR	1996	-0.715**	-30.17		6.12	24.31	-0.41	-0.57
			49.0		9.9	39.5	0.7	0.9
	1997	-0.731**	2.30		0.34	-3.20	-0.10	-0.07
			38.3		5.6	53.3	1.7	1.1
	1998	-0.269	-0.41		-0.10	-0.05	0.04	0.25
			48.5		11.4	6.0	4.5	29.6
SR	1996	0.195	-28.74	6.43		22.24	-0.03	0.30
			49.8	11.1		38.5	0.1	6.5
	1997	0.034	4.49	0.17		-4.01	-0.02	-0.60
			48.3	1.9		43.1	0.2	6.5
	1998	-0.114	0.23	0.17		-0.23	-0.03	-0.25
			24.9	18.9		25.1	3.6	27.5
ER	1996	0.434	-37.13	19.75	17.21		0.36	0.24
			49.7	26.4	23.0		0.5	0.3
	1997	0.404	4.95	-1.48	-3.63		0.07	0.50
			46.5	13.9	34.2		0.7	4.7
	1998	0.096	0.29	0.07	-0.18		0.02	0.11
			43.1	10.6	27.2		3.1	16.0
PH	1996	0.577*	0.60	20.87	1.20	-22.22		0.13
			1.3	46.4	2.7	49.3		0.3
	1997	0.609*	0.15	-1.55	-0.51	2.38		0.13
			3.1	32.8	10.8	50.6		2.7
	1998	0.138	0.14	-0.11	-0.06	0.04		0.12
			29.5	23.9	11.5	8.9		26.1
DRM	1996	0.747**	0.89	19.33	-9.64	-9.93	0.08	
			2.2	48.5	24.2	24.9	0.2	
	1997	0.301	0.77	-0.20	-3.50	3.20	0.02	
			10.0	2.6	45.4	41.6	0.3	
	1998	0.382	0.58	-0.18	-0.10	0.05	0.03	
			61.4	19.0	10.7	5.7	3.2	

*, ** significant at P=0.05 and 0.01, respectively.

LR: Leaf ratio, SR: Stalk ratio, ER: Ear ratio, PH: Plant height, DMY: Dry matter yield, DMR: Dry matter ratio

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