Grain Yield and Quality of Semiflint Maize Hybrids at Two Sowing Dates

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Summary

Hybrid selection has an important influence on specific end-use of maize (*Zea mays* L.) grain. Field experiments were conducted to evaluate the grain yield and quality of four recently released (1999-2002) maize hybrids compared to a check hybrid Bc 462 released in 1982. All hybrids were of semiflint type, that belong to the various maturity groups (FAO 200-400). Hybrids were grown over two years at the optimum (around 1 May) and delayed (about two weeks later) sowing dates. Grain yields were significantly higher in the growing season of 2004 averaging 7247 kg ha^{-1} compared to 6114 kg ha^{-1} in 2003. Larger grain yields in 2004 were primarily associated with the heavier 1000-kernel weights. Grain protein and oil contents did not vary across two years and averaged 112 and 43.4 g kg^{-1}, respectively. Hybrids significantly differed in grain yield, yield components and grain quality traits. A new, longer-maturity hybrid Zlatko produced the largest grain yields, which were by 22 % higher than those of the lowest yielding Tvrtko 303, a shorter-season hybrid. Sowing date did not affect grain yield and protein content in any of the tested hybrids, but all hybrids tended to have slightly, yet significantly lower oil content with delayed sowing date. A full-season check hybrid Bc 462 had significantly higher grain protein and oil content than all recently released hybrids, which did not differ among themselves for those quality traits. However, Bc 462 produced significantly smaller protein, oil and starch yield per hectare than Zlatko because of lower grain yields for the former. Positive correlation existed between grain protein and oil content among tested hybrids, whereas these quality traits negatively correlated with grain yield and starch content. Thus, end-users that require high grain quality maize may need to provide incentives to growers to offset the negative correlation of grain yield with protein and oil content.

Key words

yield components; grain protein; grain oil; grain starch

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Introduction

There has been a long-term interest in developing maize hybrids that have enhanced content of starch, protein or oil (Eyherabide et al., 2004). This interest has intensified recently with efforts to develop value-added hybrids for specific dry and wet milling end-use, animal feed and processing applications such as ethanol production. Numerous studies have documented genetic variability for grain composition traits in maize hybrids (e.g. Lang et al., 1956; Gyenes-Hegyi et al., 2001). However, breeding progress for high quality maize grain has been somewhat limited by an apparent inverse genetic relationship between grain yield and protein concentration (Dudley and Lambert, 1992).

Flint and semiflint maize is highly desired because of its better traits for animal feed and industrial uses for food products when compared to dent type hybrids (Eyherabide et al., 2004). However, grain yield potentials for the flint maize hybrids are usually lower than those for the dent ones (Svečnjak et al., 2004). Inverse relationships between yield and important physical and chemical characteristics of grain was found by Ahmadi et al. (1993). The authors pointed out that the emphasis on high yield may result in less desirable grain. No information is available on chemical composition of the grain of recently released semiflint maize hybrids in Croatia.

Maize producers are frequently concerned about the response of crop to sowing date. Farmers who plant maize early are concerned about frost, poor emergence, and early plant growth. Planting full-season hybrids within optimum planting date window in a given environment are highly recommended because the entire growing season can be used. Physiological maturity can be reached before growth stops because of frost, and some field-drying of maize can occur allowing greater profit margin (Gupta, 1985). A full-season hybrid generally produced more grain than a short-season hybrid when planted at optimum sowing date, and growing season length was not a yield-limiting factor (e.g. Gotlin et al., 1969). However, yield of a shorter-season hybrid might be equal to or greater than yields of a full-season hybrid at delayed planting dates (Norwood and Currie, 1996). The optimum planting date window for the full-season hybrids in the main production areas of Croatia typically occurs between April 20th and May 5th. Most maize hybrids of semiflint type commercially available to Croatian farmers have shorter vegetation than the full-season hybrids, which makes them suitable for the delayed sowing dates. Delayed sowing dates are common on wet, cold soils that can be found extensively in Croatia.

Our objective was to evaluate the grain yield and quality responses of the recently released maize hybrids of semiflint type compared to a check hybrid released in 1982 when grown at optimum and delayed sowing dates.

Materials and methods

Field experiments were conducted in northwestern Croatia in Glina during the two growing seasons (2003 and 2004). The monthly temperature averages and precipitation during the time of the experiment are given in Table 1. The soil type was a clay loam (Typic Vertisol) with mean organic matter of 2.8 % and pH 5.7 in top 20-cm of the soil profile. Four recently released maize hybrids (Tvrtko 303, PR38F70, PR39N72 and Zlatko) along with a check hybrid Bc 462 were grown at two sowing dates in a randomized split-plot design with four replications. Main plots were devoted to sowing rates, and subplots to hybrids.

All tested hybrids were of semiflint type but belonged to the various (FAO 200–400) maturity groups (Table 2). Hybrids were either introduced (PR38F70 and PR39N72) or home-bred (Bc 462, Tvrtko 303 and Zlatko). At sowing, each plot consisted of 4 rows that were 0.7 m apart and 5.6 m long. Hybrids were sown at recommended planting densities to achieve a stand of 55-60 000 plants per hectare at harvest. For the optimum sowing date, maize was planted on April 29th, 2003 and May 1th, 2004. The delayed sowing date occurred on May 12th, 2003 and May 15th, 2004. The harvest dates were October 4th, 2003 and October 16th, 2004.

Before starting the experiment, soil analysis of a top 20-cm of the soil profile was done to determine the required amount of fertilization rates during the experiment. In October of preceding year, 500 kg ha^{-1} N–P–K fertilizer (7:20:30) combined with 100 kg ha^{-1} of urea [$(NH_2)CO$] (46% N) was broadcast before moldboard ploughing at 25-cm. In the spring next year, 200 kg ha^{-1} of N–P–K fertilizer (15:15:15) was broadcast before seedbed preparation. An additional 40.5 kg N ha^{-1} was applied with interrow cultivations at the growth stages V2 and V5 (Ritchie et al., 1986). Thus, the total fertilization rates involved 192 kg N ha^{-1}, 100 kg P_2O_5 ha^{-1} and 150 kg K_2O ha^{-1}. The herbicides metolachlor {2-chloro-*N*-(2-ethyl-6-methylphenyl)-*N*-(2-methoxy-1-methylethyl)acetamide} at the rate of 1.5 kg a.i. ha^{-1} and atrazine {6-chloro-*N*-ethyl-*N'*-(1-methylethyl)-1,3,5-triazine-2,4-diamine} at 1.0 kg a.i. ha^{-1} were applied preemergence.

At maturity, plots were evaluated for final plant stand, barren plants and stalk lodging. Very few barren and lodged plants occurred in our experiments, and data are omitted from results. After physiological maturity of the latest maturing hybrid, all ears were hand-harvested from the two middle rows of each plot, and the fresh weight and moisture level of shelled grain were used to estimate grain yield. At harvest, ten ears were taken from hand-harvested ear samples to determine grain yield components. Average kernel number per plant was determined by counting all kernels after hand-shelling of each ear. A 1000-kernel weight was calculated as an average grain weight per plant / average kernel number per plant × 1000. Grain samples were weighed and oven dried at 60°C until constant weight to determine moisture content. Thousand-kernel weight and grain yield were adjusted to 14.0 % moisture. Grain yields per hectare were also adjusted to include grain removed in ear samples for yield components analyses. A 100-g subsample of the grain from ears used for yield component analysis was ground, and the concentration of protein, oil and starch in the ground sample was determined with a Dickey-john Instalab 600 near-infrared reflectance analyzer (Dickey-john Corp., Auburn, IL). Protein, oil and starch yield were calculated by multiplying their concentrations in the grain with grain yield per hectare.

All data were analyzed with analysis of variance using a mixed model procedure (SAS Institute, 1997). Mean separation was obtained using a LSD test at the 0.05 probability level when significant F-tests ($P < 0.05$) were observed. Simple correlation coefficients among grain yield, yield components and grain quality traits were obtained from the pooled data.

Results and discussion

Despite similar kernel number per plant in both growing seasons (Table 3), average grain yield in 2004 (7247 kg ha^{-1}) were significantly higher that those in 2003 (6114 kg ha^{-1}). Thus, these higher yields in 2004 were primarily associated with heavier 1000-kernel weights averaging 330 g compared to 260 g in the growing season of 2003. This relatively large difference in kernel weights was mainly due to the prolonged period of dryeness than usual growing conditions during the grain filling period in 2003 (Table 1).

Sowing date showed no important effect on grain yield and yield components regardless of growing season (Table 3). This indicated that tested maize hybrids may be successfully grown at delayed sowing dates because of their shorter-than-full season maturity characteristics (Table 2). In the western Kansas, Norwood and Currie (1996) also reported small differences in maize grain yield responses to early and mid-May sowing, both of which produced higher grain yield than late May planting.

Table 1.
Monthly mean temperature and total rainfall during experiment, 2003-2004

Month	Mean temperature (°C)		Total rainfall (mm)	
	2003	2004	2003	2004
April	10.8	11.6	39	136
May	19.3	14.8	40	39
June	23.9	19.1	64	102
July	23.0	21.2	62	70
August	25.0	21.1	17	56
September	15.9	16.2	12	81

Table 2.
Agronomic characteristics of semiflint maize hybrids

Hybrid	Release date	FAO group	Origin
Bc 462	1982	460	Bc Institute, Zagreb
Tvrtko 303	1999	300	Agricultural Institute, Osijek
PR38F70	2001	340	Pioneer Sjeme, Zagreb
PR39N72	2002	240	Pioneer Sjeme, Zagreb
Zlatko	2000	440	CT Sjeme, Zagreb

Hybrids significantly differed for grain yield and yield components (Table 3). The absence of the hybrid × year and hybrid × sowing date interactions for grain yield (Table 3) indicated the same rankings across years and similar responses to two sowing dates. Thus, we focused our comparison on the hybrid performance averaged over all other treatments. A new longer-maturity (Table 2) hybrid Zlatko produced the highest grain yield (7411 kg ha^{-1} on average) that were significantly higher than those for all other hybrids (Table 4). In spite of the highest kernel number per plant, the smallest grain yield was observed for a shorter-season hybrid Tvrtko 303, which was on average by 22 % lower than those for Zlatko. The smallest grain yields for Tvrtko 303 were primarily associated with its lightest 1000-kernel weights (271 g on average). Smaller grain yield for the shorter-maturity hybrids compared to those for the longer-maturity ones were demonstrated by many authors (e.g. Svečnjak et al., 2004). However, in our study a short-season (FAO 200) hybrid PR39N72 succeeded to produce grain yield similar to those for a full-season check hybrid Bc 462 (Table 4). Consequently, all new hybrid, except Tvrtko 303, achieved larger grain yield than Bc 462 (Table 4) even though the latter had the heaviest 1000-kernel weights (323 g on average). Similarly to grain yield responses, Zlatko produced the greatest number of kernels per plant (499), whereas Bc 462 produced the lowest number of kernels (average of 472 plant^{-1}). Thus, the yield compo-

Table 3.
Combined analysis of variance for grain yield, yield components and grain quality traits of semiflint maize hybrids

Source of variation	Grain yield	Kernel number per plant	1000–kernel weight	Grain protein content	Grain oil content	Grain starch content	Protein yield	Oil yield	Starch yield
Year (Y)	**	ns	***	ns	ns	ns	**	**	**
Sowing date (S)	ns	ns	ns	ns	*	ns	ns	ns	ns
Y × S	ns	ns	ns	ns	ns	ns	ns	ns	ns
Hybrid (H)	**	***	***	***	***	***	***	***	**
Y × H	ns	ns	ns	ns	ns	ns	ns	ns	ns
S × H	ns	ns	ns	ns	ns	ns	ns	ns	ns
Y × S × H	ns	ns	ns	ns	ns	ns	ns	ns	ns

ns–Not significant; *–Significant at P = 0.05; **–Significant at P = 0.01; ***–Significant at P = 0.001.

Table 4.
Average grain yield, yield components and grain quality traits of semiflint maize hybrids, Glina, 2003-2004

Hybrid	Grain yield (kg ha^{-1})	Kernels per plant	1000–kernel weight (g)	Grain protein content (g kg^{-1} DM)	Grain oil content (g kg^{-1} DM)	Grain starch content (g kg^{-1} DM)	Protein yield (kg ha^{-1})	Oil yield (kg ha^{-1})	Starch yield (kg ha^{-1})
Bc 462	6410	472	323	115	45.2	723	737	290	4634
Tvrtko 303	6078	529	271	111	43.9	731	675	267	4443
PR38F70	6961	516	309	110	41.8	734	766	291	5109
PR39N72	6545	497	301	111	44.0	730	726	288	4778
Zlatko	7411	499	317	110	42.2	735	815	313	5447
LSD (0.05)	394	17	11	1.1	0.7	17	44	17	288

Table 5.
Simple correlation coefficients among the grain yield, yield components and grain quality traits of semiflint maize hybrids (n = 80)

	GY	KN	TKW	P	O	S
Grain yield (GY)	—					
Kernel number per plant (KN)	0.60*	—				
1000–kernel weight (TKW)	0.63*	0.19	—			
Grain protein content (P)	−0.23*	−0.26*	0.12	—		
Grain oil content (O)	−0.30*	−0.26*	−0.22*	0.54*	—	
Grain starch content (S)	0.35*	0.35*	0.05	−0.71*	−0.70*	—

*–Significant at P = 0.05

nent that best described differences in grain yield among tested hybrids (except Tvrtko 303) was kernel number per plant (Table 4).

In contrast to grain yield responses (Table 3), growing season showed no significant effect on grain chemical composition, which averaged 112 g kg^{-1} for protein content, 43.4 g kg^{-1} for oil content and 731 g kg^{-1} for starch content. Gyenes-Hegyi et al. (2001) also reported no significant effect of growing season on the oil content of the 12 single-cross maize hybrids studied in their two-year research, whereas other authors (Jellum and Marion, 1966; Zhang et al., 1993) reported significant variations in protein and/or oil contents across years.

Small, but significant (Table 3) decrease in oil content was found with delayed sowing date (42.9 g kg^{-1}) when compared to optimum sowing date (43.8 g kg^{-1}). Moreover, these responses to sowing date for grain oil content were similar in all hybrids tested, as indicated by the absence of hybrid × sowing rate interaction (Table 3). For sunflower (*Helianthus annuus* L.), Bhatti et al. (1999) also found that crop sown on 25 May resulted in 2% higher oil content then sunflower sown on 28 June.

Tested hybrids differed significantly for grain quality traits (Table 3). Similarly to grain yield responses, these genotypic specific responses were consistent in both growing seasons and unaffected by sowing date (Table 3). The highest average grain protein content had a check hybrid Bc 462 (115 g kg^{-1}). In contrast, the two highest yielding hybrids (Zlatko and PR38F70) had significantly lower grain protein content than Bc 462 (Table 4). Correlation coefficients showed weak positive correlation between protein content and 1000-kernel weight (Table 5), as also reported by Gyenes-Hegyi et al. (2001).

Hybrid differences in grain oil content were similar to those found for protein concentration (Table 4), with a check hybrid having the highest oil content averaging 45.2 g kg^{-1}. Consequently, a strong positive correlation between protein and oil content existed among tested hybrids in our study (Table 5). Differences in oil content among hybrids are usually associated with differences in the proportion of the kernel constituted by the embryo. Recent findings of Uribelarrea et al. (2004) showed that hybrids with the highest proportion of embryo in their kernels had the highest oil concentrations and vice versa. Their findings may be supported by a negative correlation between 1000-kernel weight and oil content found in our research (Table 5), as also reported by Kereliuk and Sosulski (1995). The negative association between oil concentration and kernel weight can be partially explained by differences in the structural components (i.e., the weight of the endosperm and the embryo) of the kernel. Hybrids with small kernels would have a higher proportion of their kernels as embryo and endosperm aleurone layer, which contain almost all of the total grain oil (Kereliuk and Sosulski, 1995). In contrast, Gyenes-Hegyi et al. (2001) reported that the correlation between 1000-kernel weight and oil content in their study was positive.

Hybrid differences in grain starch concentration were essentially inverse to those observed for protein concentration, and consequently, reflected relative yield differences among the tested hybrids (Table 4). The two highest yielding hybrids had the highest grain starch content, which averaged 735 g kg^{-1} for Zlatko and 734 g kg^{-1} for PR38F70. A check hybrid Bc 462 exhibited the lowest grain starch concentration averaging 723 g kg^{-1}. These results indicated the inverse relationship between grain protein and both starch concentration and grain yield (Table 5). This negative correlation has been reported previously by Dudley and Lambert (1992), as well as in other maize selection programs for high grain protein (e.g. Pollmer et al., 1978).

Despite having the highest grain protein and oil contents, a check hybrid Bc 462 failed to produce the largest protein and oil yield per ha due to its relatively low grain yield potentials (Table 4). As expected, the highest starch (5447 kg ha^{-1}) but also protein (815 kg ha^{-1}) and oil (313 kg ha^{-1}) yields were produced by the highest yielding hybrid Zlatko. However, the second largest yielding hybrid PR38F70 failed to produce significantly larger oil and protein yield than a check hybrid Bc 462 primarily because of its lowest concentrations for these grain quality traits (Table 4). The smallest protein, oil and starch yield per hectare were produced by the lowest yielding hybrid Tvrtko 303.

Conclusions

Maize hybrids of semiflint type commercially available in Croatia can be successfully grown at delayed (two weeks later than optimum) sowing date because of their shorter-than-full season maturity characteristics. All recently released hybrids, studied in our investigation, except Tvrtko 303 produced higher grain yields than a check hybrid Bc 462. In contrast, Bc 462 had significantly higher grain protein and oil concentrations than all new hybrids. Thus, end-users that require high grain quality maize may need to provide incentives to growers to offset the negative correlation of grain yield with protein and oil contents.

References

Ahmadi, M., W.J. Wiebold, and J.E. Beuerlein. 1993. Grain-yield and mineral-composition of corn as influenced by endosperm type and nitrogen. Commun. Soil Sci. Plant Anal. 24:2409–2426.

Bhatti, M.H., L.A. Nelson, D.D. Baltensperger, D.J. Lyon, S.D. Kachman, and G.E. Frickel. 1999. Influence of planting dates and populations on seed yield and plant characteristics of sunflower in the high plains. Journal of Production Agriculture 12:38-42.

Dudley, J.W., and R.J. Lambert. 1992. Ninety generations of selection for oil and protein in maize. Maydica 37:81–87.

Eyherabide, G.H., J.L. Robutti, N.M. Percibaldi, D.A. Presello, and M.D. Alvarez. 2004. Association between grain yield and endosperm hardness in maize cultivars. Maydica 49:319–326.

Gotlin, J., A. Pucarić, and B. Mesing. 1969. Reakcija novih hibrida kukuruza na gustoću sklopa i gnojidbu dušikom. Agronomski glasnik 9:633–645.

Gupta, S.C. 1985. Predicting corn planting dates for moldboard and no-tillage systems in the Corn Belt. Agron. J. 77:446–455.

Gyenes-Hegyi, Z., L. Kizmus, S. Zaborszky, and L.C. Marton. 2001. Trends in the protein and oil contents and thousand kernel mass of maize under various ecological conditions. Novenytermeles 50:385–394.

Jellum. M.D., and J.E. Marion. 1966. Factors affecting oil content and oil composition of corn (*Zea mays* L) grain. Crop Sci. 6:41–42.

Kereliuk, G.R., and F.W. Sosulski. 1995. Properties of corn samples varying in percentage of dent and flint kernels. Lebensmittel-Wissenschaft und-Technologie 28:589–597.

Lang, A.L., J.W. Pendleton, and G.H. Dungan. 1956. Influence of population and nitrogen level on yield and protein and oil contents of nine corn hybrids. Agron. J. 48:284–289.

Norwood, C.A., and R.S. Currie. 1996. Tillage, planting date, and plant population effects on dryland corn. J. Prod. Agric. 9:119–122.

Pollmer, W.G., D. Eberhard, and D. Klein. 1978. Inheritance of protein and yield of grain and stover in maize. Crop Sci. 18:757–759.

Ritchie, S.W., J.J. Hanway, and G.O. Benson. 1986. How a corn plant develops. Spec. Rep. 48. Iowa State Univ. of Sci. and Technol. Coop. Ext. Serv., Ames.

SAS Institute. 1997. SAS/STAT Software: Changes and enhancements through Rel. 6.12. SAS Inst., Cary, NC.

Svečnjak, Z., B. Varga, A. Pospišil, Z. Jukić, and J. Leto. 2004. Maize hybrid performance as affected by production systems in Croatia. Bodenkultur 55:37–44.

Uribelarrea, M., F.E. Below, and S.P. Moose. 2004. Grain composition and productivity of maize hybrids derived from the Illinois protein strains in response to variable nitrogen supply. Crop Science 44:1593-1600.

Zhang, F., A. F. Mackenzie, D.L. Smith, 1993. Corn yield and shifts among corn quality constituents following application of different nitrogen fertilizer sources at several times during corn development. Journal of Plant Nutrition 16:1317–1337.

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