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Supplement to the

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The Genetics and Exploitation of Heterosis in Crops

An International Symposium

Heterosis in Crops

17-22 August 1997
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The Genetics and Exploitation of Heterosis in Crops

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Contents

A71 - Advances in Thermo-Photoperiod Sensitive Genic Male Sterility Wheat in China

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Introduction

There are three main methods used in wheat heterosis research: three-line systems (Wilson 1968); chemical hybridizing agents (CHA) (Hoagland 1953 and Chopra et al. 1960); and two-lines systems (Mukai 1979 and Tan et al. 1992). The two-lines system using thermophotoperiod sensitive genic male sterility wheat is a new domain in wheat heterosis research. Chinese researchers have been engaged in this new approach and selected a few thermo-photoperiod sensitive genic male sterility wheat materials, such as C49S-87, C49S-89, C86s, etc. Therefore it is important to provide information about advances in thermo-photoperiod sensitive genic male sterility wheat in China.

Methods

C49S-87, a new thermo-photoperiod sensitive genic male sterility wheat line, was used in this study. The fertility of C49S-87 was tested with different planting phase in 1995, more than 100 plants were observed in each phase. Pollen was examined under a microscope by using I_2-KI staining at heading date; we investigated the bagged setting degree at maturity date. The High-Molecular-Weight (HMW) glutenin subunits of endosperm storage protein of C49S-87 was fractionated by SDS-PAGE technology (Payne 1979), Flour protein and SDS sedimentation of C49S-87 was tested as described by Peña et al (1991). Using as a female parent, C49S-87 was crossed with many advanced lines and varieties, hybrid seeds were then planted to provide F_1 plants and F_2 seeds for selecting and analysis. During low temperature and short day season, the fertility inheritance of C49S-87 was studied with F_1, F_2 populations derived from reciprocal cross between China spring and C49S-87. These populations were planted on the farm of Chengdu Institute of Biology, Chese Academy of Sciences during 1995-1996.

Results

We measured the pollen sterile degree and bagged setting degree for different planting phases (Table 1). Two desirable two-lines hybrid wheats with higher yield potential, wider adaptability, good bread-making quality have been selected (Table 2). Planting in low temperature and short day season, segregation for fertility was found for three in reciprocal cross F_2 populations; the fertile/sterile ratios were 17.3:1 and 18.14:1, respectively (Table 3).

Conclusions

The fertility of C49S-87 under different temperature and photoperiod conditions under different sowing times was controlled by temperature and light duration -- the lower temperature and short day induced sterility, when the seeds were sowed in early season (Oct. 25 to Nov. 15) in Chengdu-China. The plants of C49S-87 were sterile with rates of sterile plants reached to 100% and average seed sterility by bagging and pollen sterility were about 95%. When sowed in late season in Chengdu-China, the plants turned to fertility apparently, the rates of natural seed setting reached 78%. The results showed that the fertility transmission of C49S-87 is clear, making it useful for hybrid wheat production. The protein content and SDS-Sedimentation values of C49S-87 are 15.1% and 55 ml, respectively; its Glu-1D loci genes coded for the HMW glutenin subunits 5 + 10, related to good bread-making quality (Payne et al 1987). The fertility inheritance of C49S-87 was studied with F_1, F_2 populations, the result indicated that its male sterility is controlled by two pairs of recessive major genes with less cytoplasm effect. As a female parent, C49S-87 was crossed with many advanced lines and varieties, some new two-line hybrid wheat combinations with both high yield and good quality have been selected. Therefore, C49S-87 might have potential in two-line hybrid wheat breading.

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Table 1. The fertility expression of C49S-87 with different planting phase (Chengdu-China, 1995)

Sowing date (month-day)	Heading date (month-day)	Sterile degree of pollen (%)	Bagged sterile degree (%)	Bagged setting (%)
Oct.25	Mar.23	100	100	0
Nov.2	Mar.29	96.2	95.3	4.7
Nov.15	Apr.10	97.3	95.1	4.9
Nov.30	Apr.14	49.0	46.9	53.1
Dec.15	Apr.17	18.5	21.4	78.6

Table 2. Values of yield components and quality traits of two desirable combinations of two-lines hybrid wheat

Combination	Plant height	Ears per plant	No. of spikelet	No. of kernel per spike	Grain weight per spike (g)	1000-kernel weight (g)	Grain yield per plant (g)	Protein content (%)	SDS-sedimentation value (ml)
C49S-87X4905	88	6	28	64	3.26	51	19.56	14.5	66
C49S-87X4927	85	10	27	78	3.26	41.8	32.66	16.5	56

Table 3. The fertility segregation in F2 populations of reciprocal cross between China spring and C49S-87

Combination	Total plants	Fertile plants	Sterile plants	Ratio Ferile:sterile
China spring XC49S-87	340	312	18	17.3:1
C49S-87XChina spring	563	534	29	18.4:1

A33 - Utilization of Heterotic Patterns to Develop Maize Hybrids for El Bajio

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Introduction

Maize is one of the most important crops in the subtropical regions of Mexico, judged by the area planted and its yield potential Hybrids are in great demand in this region and their development requires efficient breeding programs. To develop a maize breeding program in El Bajio that makes more efficient use of available germplasm and funds, research was initiated to classify the available inbred lines into two heterotic groups.

Materials and Methods

We crossed a set of inbreds derived from different germplasm sources with testers, PB-1 and PB-2, which are parents of the single cross hybrid H-358. The testcrosses were generated at the experiment station of El Bajio (CEBAJ) during 1993 spring-summer season and evaluated at Acambaro and Celaya Gto., during 1994 and 1995. The data were analyzed by material type and location, and finally across environments. General and specific combining ability effects were estimated for grain yield using adjusted means.

Results

The elite lines from different germplasm were grouped according to their SCA value with both testers. Lines with high GCA values were also identified. Specific combinations with high yield of 19.1 t/ha were also identified.

Conclusions

The results permit grouping of the CEBAJ lines by heterotic patterns for development of superior hybrids by making specific crosses. The lines can be intermated within heterotic patterns to develop populations for improvement in a reciprocal recurrent selection program.

A40 - Incorporación de androesterilidad e identificación de restauradores de la fertilidad masculina en germoplasma de maíz de CIMMYT y la UNAM

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Introducción

El uso de la esterilidad masculina y los genes restauradores de la fertilidad, evitan el desespigamiento de los progenitores hembra de híbridos de maíz por lo tanto reducen los problemas en esa etapa de la producción de semillas, lo que facilita el control de calidad e identidad genética de híbridos. La androesterilidad dejó de emplear a partir de la triste experiencia en U:S:A:, en 1970 con la fuente de esterilidad masculina y los daños causados por el tizón foliar (*Helminthosporium maydis* raza T) en maíz (Besnier, 1989; Jugenheimer, 1990), sin embargo se han identificado diversas fuentes de esterilidad (Grupos S, C-cms_3, P, entre otros), con lo que se evita la dependencia de una sola y limita los problemas generados con la raza T, además en los Valles Altos de México (2200-2600 msnm), las condiciones agroclimáticas podrían limitar el desarrollo del hongo responsable del tizón foliar, por ello en la Universidad Nacional Autónoma de México, desde 1992, se desarrollan diversos trabajos para aprovechar la androesterilidad en la producción de semillas de híbridos de maíz. a partir de una fuente con esta característica, esta se incorporó a diferentes líneas progenitoras tanto del CIMMYT como de la UNAM, en especial en aquellos materiales avanzados que participan en los diferentes híbridos Pumas en proceso de evaluación y/o liberación.

En este trabajo se presenta información sobre el proceso que se ha seguido en la incorporación de la androesterilidad asó como la identificación de líneas restauradoras.

Materiales y Métodos.

Los trabajos se han desarrollado en las parcelas experimentales de la Facultad de Estudios Superiores Cuautitlán - UNAM, donde se captó una fuente de esterilidad masculina de una generación avanzada de un material de maíz comercial, la que se incorporó a diversas líneas, empleando para ello cuatro retrocruzas, paralelamente y con mayor detalle, en 1995, se aplicó la prueba de descendencia con el fin de identificar las líneas restauradoras de la fertilidad masculina (Reyes, 1989), para lo cual se evaluó un número grande de líneas, encontrándose que cuatro de ellas, son restauradoras al 100% y tres tienen capacidad restauradora parcialmente (Solano et al, 1996).

En 1996 nuevamente se verifico la capacidad restauradora, en un ensayo de rendimiento, en el cual se incluyeron, 41 híbridos androestériles que fueron cruzados con las líneas identificadas como restauradoras de la fertilidad masculina, 7 híbridos fértiles experimentales y 2 híbridos comerciales: El H-135 y el PUMA 1157 como testigos. El trabajo se realizó en la Facultad de Estudios Superiores Cuautitlán - UNAM, bajo diseño experimental de bloques completos al azar con tres repeticiones y una densidad de aproximadamente 65,000 plantas por hectárea. Se realizó un análisis de varianza y una prueba de comparación de medias de Tukey al 0.05 de probabilidad para cada una de las variables evaluadas fueron, días a floración femenina y masculina, altura de planta y mazorca, rendimiento. Para la variable de fertilidad masculina la apreciación fue visual anotando su condición: fértil parcialmente fértil o estéril

Resultados

De los híbridos evaluados, diecisiete que tuvieron como progenitor paterno la línea EHT-49-3, resultaron ser totalmente fértiles, por lo que esta línea confirmó su capacidad restauradora de la fertilidad masculina. Lo mismo sucedió con la línea P2-1 progenitora de dos híbridos, los cuales también fueron fértiles, cabe mencionar que uno de estos híbridos el UHS95E123, obtuvo el mejor rendimiento de los híbridos evaluados, superando a los testigos comerciales.

A diferencia de las líneas antes mencionadas, la EHT-11-1, que es línea hermana de una línea identificada como restauradora de la fertilidad, generó híbridos en tres condiciones es decir: Tres híbridos para los cuales fue macho, fueron estériles, dos presentaron fertilidad parcial y dos más recuperaron la fertilidad masculina. En cambio la línea EHT-9-6, que fue identificada como restauradora parcial de la fertilidad, presentó 4 híbridos fértiles y dos híbridos parcialmente fértiles. Lo mismo sucede con la línea EHT-30-5 que igualmente fue identificada como parcialmente restauradora de la fertilidad también tuvo 6 híbridos fértiles y dos parcialmente fértiles. La razón por la que las líneas EHT-11-1,EHT-9-6 y EHT-30-5 presentaron estos resultados, podría deberse a que los genes de la restauración se encontraban en estado heterocigótico y se generó segregación que se vio reflejada en los híbridos resultantes.

En relación a las demás variables se puede decir que, para la variable rendimiento el mejor híbrido fue el UHS95E123 X P2-1, con 11,994 kg/ha. seguido de algunos de los híbridos cuya línea paterna fue la EHT´49-3, lo que indica que además de ser restaurador de la fertilidad masculina, genera híbridos, con buen potencial agronómico, ya que tiene rendimientos que van de 11,362 a 20,230 kg/ha superando a los testigos comerciales PUMA 1157, (que obtuvo un rendimiento de 9,841 kg/ha), y al H-135 que presentó un rendimiento de 7;283 Kg/ha superado por 44 híbridos experimentales incluyendo el testigo PUMA 1157. Los híbridos experimentales también superan a los testigos comerciales para la variable días a floración masculina, el PUMA 1157 y el H-135 tienen 84 y 89 días respectivamente a floración, mientras que los experimentales resultan ser más precoses con 75 a 84 días. Otra buena característica que presentan los híbridos experimentales evaluados es la altura de planta y mazorca que es menor a la presentada por el testigo H-135, lo cual les da cierta resistencia al acame.

Conclusiones

Se verificó y comprobó la capacidad restauradora de la fertilidad masculina de las líneas EHT-49-3 y P2-1, además de que estas líneas generan híbridos con buen potencial agronómico, por los altos rendimientos alcanzados superando a los testigos comerciales PUMA 1157 y H-135.

En cambio las líneas EHT-11-1, EHT-9-6 y EHT-30-5, son líneas que contienen genes de la restauración, pero por estar estos en estado heterocigótico, presentan segregación por lo que deben ser utilizados bajo un esquema especial, sin embargo debido a que producen híbridos con buen potencial agronómico deben ser aprovechados.

Las líneas 64-2, IA49-2, EHT-49-3, P2-1 al poseer probada capacidad restauradora, resultan de importancia, ya que no requieren de un esquema especial de producción para ser utilizados como restauradoras, además de que algunas de estas líneas son progenitoras de excelentes características de los híbridos Puma, dentro de los cuales se incluye al PUMA 1157, entre otros.

Las líneas EHT-49-3, EHT-11-1, EHT-9-6 y EHT-30-5, se desarrollaron a partir de germoplasma de CIMMYT y P2-1, IA49-2, 64-2 de la UNAM, es decir en ambos materiales, se encontraron restauradores de la fertilidad.

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A43 - Development of Narrow-Base Synthetics from Early-Maturing Heterotic Pools and Their Use in Developing Non-Conventional Hybrids of Maize in India

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Introduction

The lack of good productive vigorous inbred lines in early maturing germplasms has been the major hurdle in the development of two-parent (TP) hybrids. To overcome this difficulty use of non-conventional hybrids have been suggested. The hybrids that involve at least one non-inbred (NI) progenitor are called non-conventional hybrids (Vasal, 1986; 1987). The germplasm (like early maturity local germplasm) having less tolerance to inbreeding can be easily exploited in N.C. hybrid breeding. In this breeding approach the major limiting factor has been lack of conscious efforts to develop non-inbred progenitors for their specific use in hybrid breeding. In the present study performance of some non-conventional TP hybrids developed by crossing early maturing narrow base hybrid oriented synthetics, extracted from early maturing heterotic pools have been studied.

Material and Methods

Early maturing heterotic pools viz. Ind. Pool Semi-exotic pool A (SE-A) and semi exotic pool (SE-B) have been synthesized at Punjab Agricultural University (Saxena *et al.*, 1993). Both SE-A and SE-B are heterotic with Ind pool but were synthesized separately to have their correspondence with MS pool and Tux pool synthesized earlier for full season germplasm. Hybrid oriented narrow base synthetics (Syns.) of sub-populations with in each pool were synthesized using 4-6 advance inbred lines possessing high G.C.A.

The details of these synthetics are given below:

Ind. Pool: 1. Syn J663 (Y-2987, P-49, S-51); 2. Syn-JS2 (Y-3417), P-49, S-50); 3. Syn A68 (Y-3119, P-50, S-52); 4. Syn (JS2 x J322) (Y-2612, P-50, S-51); 5. Syn Local (Y-3081, P-50, S-52)

SE Pool A: 6. Syn Tarun (Y-2959, P-51, S-53); 7. Syn MS EP (Y3718, P-51, S-53); 8. Syn JS4 (Y-3778, P-50, S-52)

SE Pool B: 9. Syn Tux EP (Y-3079, P-52, S-54); 10. Syn Pop 31 of CIMMYT (Amarillo Cristalino-2) (Y-3530, P-50, S-52)

Checks: Comp Kiran (Y-3938, P-49, S-51); Comp Kesri (Y-3770, P-52, S-54); Comp Megha (Y-2859, P-51, S-53); L.S.D. at 5% - 513

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* Y=Yield kg/ha, P=Days to 50% pollen shed, S=Days to 50% silk

These synthetics were further made uniform for morphological traits like tassel shape, ear shape, texture and colour of grain through selective sib maturing. Non-conventional two parent (NCTP) hybrids were developed using synthetics of Ind Pool as female parent and synthetics of SE-A and SE-B pools, the heterotic partners as male parent. Twenty three NCTP hybrids alongwith three early maturing check composite varieties (Kesrim Megha and Kiran) were evaluated in three environments during 1993 i.e. Ludh (Irrigated), Lud (Rainfed) and Jal (Irrigated). Five best selected NCTP hybrids were again evaluated in two different all India Coordinated Trials during 1994 alongwith national check varieties Kiran and Tarun.

RESULTS

The level of superiority of these NCTP hybrids in Punjab during *kharif* 1993 and during *kharif* 1994 across the whole country indicated that these hybrids are widely adapted to diverse condition both under irrigated and rainfed conditions. Besides high yield, these hybrids are of comparable maturity as indicated by days to 50% silking.

In India about 80 per cent maize is grown under rainfed condition, hence this approach of breeding N.C. hybrids have tremendous scope due to easy and commercially viable seed production. Subsequently more productive lines can be extracted for developing the conventional single cross hybrid.

Conclusion

The results of this study suggested the scope of NCTP hybrids provided concerted efforts are made to breed parents of NC hybrids. This approach may prove to be highly rewarding particularly with the early maturing germplasm. Subsequently it may be possible to develop productive inbred line for developing a viable single-cross hybrid. The guidelines in producing the seed of NI parents will have to be developed. Vasal *et al.*, (1994) also suggested that synthetic parents and intersynthetic hybrids with high yield can be developed.

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Table 1. Performance of promising early maturing NCTP hybrids in Punjab (Mean of 3 locations) during *kharif* 1993

NCTP hybrids	Grain yield (kg/ha)	Days to 50% pollen shed	Days to 50% silk
Syn local x Syn JS4	4753	54.7	57.0
Syn 663 x Syn Tarun	4372	50.0	53.0
(Syn JS2 x J3022) x (Syn Tux EP)	4350	52.7	54.7
(Syn JS2 x J3022) x (Syn JS4)	4292	53.7	56.3
Syn local x Syn MSEP	4185	55.3	58.0
Syn A68 x Syn JS4	4150	53.3	56.0
Check			
Comp Kesri	3668	53.3	54.7
Comp Megha	3159	53.7	56.0
Comp Kiran	3288	53.0	56.7
L.S.D. at 5%	471		

Table 2. Performance of selected NCTP hybrids in All India Coordinated Trial during *kharif* 1994.

NCTP Hybrid	Mean grain yield (kg/ha)		Days to 50% silking	
	Irr. (14 loc)	RF (13 loc)	Irr. (14 loc)	RF (13 loc)
(Syn J663 x Syn Tarun)	5559 (15.7%)	4579 (31.7%)	51.6	55.9
(Syn A68 x Syn Tux EP)	5490 (14.3)	4212 (21.1)	52.7	57.6
[(Syn JS2xJ3022) x (Syn Tux EP)]	5712 (18.9%)	3792 (9.0%)	53.1	57.1
National check				
Comp. Kiran	4803	3478	52.0	56.3
C.D. at 5%	778			
	(13 loc)	(5 loc)	(13 loc)	(5 loc)
4x10 [Syn (JS2xJ3022)x Syn Pop 31]	5230 (17.9%)	4657 (14.3%)	53.2	52.2
5x9 (Syn Local x Syn Tux EP)	5794	4372	54.3	54.7
National check				
Comp. Kiran	4435	4109	52.2	53.6
C.D. at 5%	685			

B73 - **Heterosis and Combining Ability Studies for Oil Content in Maize**

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Introduction

Viewed in global context, India has the dubious distinction of having the highest acreage under oilseeds (24.0 m ha, 12.5% of cultivable land) and yet showing the lowest yield. The average per capita per annum availability of oils and fats in India is 5.0 kg against the requirement of 11.0 kg/Cap./annum. But when one take a realistic view of the available levels of technology and their productivity potential, there is hardly room for any aceptism about the current capabilities of the country to keep date with the targets. Yield advance through vertical improvement has been marginal. Development of maize for oil content seems to be the answer and efforts are directed towards projected goals. That too, as a by-product of starch industries. High oil strains of corn have a higher biological value than low oil corn (Schucider et al. 1952). Genter et al. (1956); however, observed that while some environmental factors did affect oil quantity and quality, genotypic factors were much more influential. Oil content is partly determined by the parent and partly by the maternal seed genotype in maize (Grami and Stefansson, 1977 b). Genes responsible for oil content are additive in maize Yermanos et al. (1967). Xhepa et al. (1989) observed heterosis in some maize crosses. It would, therefore, be in the interest of nations as a whole to isolate high oil strains (lines) having good combining ability and high heterotic performance.

Methods

The material consisted of all possible 45 crosses excluding reciprocals of a diallel of 10 screened genotypes for oil content. All 56 entries, including parents, crosses and a check, were tested in an RBD with three replications in 7.5 m^2 plots the at Maize Breeding Research Centre Dholi, India. One random sample of 5.0 g seeds from each replication for each treatment was ground and the powder was used for oil estimation by the Soxhlet extraction methods using Petroium Ether (B.P. 40-60°C). The combining ability analysis was carried out using Model-1, Method-2 of Griffing (1956). The estimates of heterosis was worked out by the procedure suggested by Hay et al. (1955).

Results

Variance due to GCA and SCA for oil content were significant. δ GCA: δ SCA was found to be 1.03 (Table 1). Out of 45 crosses studied, 14 crosses exhibited significantly negative SCA effects, 18 crosses exhibited significantly negative SCA effects, 18 crosses exhibited significantly positive SCA effects, and the remaining 13 crosses exhibited non-significantly positive or negative SCA effects, for the trait under reference. The crosses with negative SCA effects contained comparatively low oil. The GCA effects of parents varied from -0.47 to 0.34 and four parents (Phil DMR, Comp-2, M-10, M-18 and M9) showed significantly positive GCA effects. Heterosis over mid-parent, better parent, and check varied from 16.67 to 140.59, 23.57 to 137.10, and -7.69 to 109.74 respectively.

Conclusion

Oil content in maize can be substantially increased either by increasing the frequency of additive genes, through repeated mass selection of hybridization between selected genotypes having varying oil content. Four parents (listed above) proved to be the best general combiners. Two crosses (CM500 X, EC120144 and M9 x Phill DMR Com-2) exhibited high oil content combined with high SCA effects and high economic heterosis, and may be utilized as high oil content varieties.

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Table 1. Analysis of variance for combining ability for oil content

Source	df	Oil content
Gca	9	0.64**
Sca	45	0.62**
Error	108	0.002
δ GCA/ δ SCA		1.03

B2 - Heterosis and Yield in 4 Maize Populations in the Subtropical Zone of Tarija, Bolivia

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Introduction

Since 1992 the "Instituto Boliviano de Tecnologia Agropecuaria" (IBTA) maize program has carried out research in breeding and released improved varieties for the different agroecological zones of the country to slowly replace native varieties. To develop more productive varieties or populations for the subtropical zone, we are using intervarietal hybridization, thus increasing both genetic variability and productivity. These results are most evident when crosses involve unrelated individuals (Paterniani 1974; Marquez, 1988).

Materials and Methods

We crossed improved varieties such as Suwan, CMS-36, P. Compuesto-10, and Cubano Amarillo with IBO-128, an improved local variety as a common tester. After one or two cycles of selection, each intervarietal cross and its progenitors were evaluated at three locations. A randomized complete block design with three replications was used. The traits measured were grain yield, male flowering, plant high and ear aspect. Heterosis and heterotic gain was calculated with respect to the progenitors (Hayman cited by Robles 1986).

Results

In the three environments evaluated the best crosses (Table 1, Fig. 1) were Suwan x IBO-128 (5.83 t/ha) and CMS-36 x IBO-128 (5.25 t/ha). Plant height decreased compared with the progenitor IBO-128. Heterosis for male flowering was generally negative compared with female progenitors (Suwan, Cubano Amarillo and CMS-36), due probably to the use of heterozigous populations (Marquez 1988). Ear aspect improved considerably. In all cases cycle 2 was superior in yield to initial cycles, except for Suwan x IBO-128 C_1, which showed 82.8% heterosis for grain yield over Suwan and 18.4 % over IBO-128. The genetic gain was 1.77 t/ha, perhaps due to crossing unrelated varieties (Paterniani 1974). For Cubano Amarillo x IBO-128, heterosis was 81.7 % with respect to Cubano and 18.5% with respect to IBO-128. For CMS-36 x IBO-128, heterosis was higher for cycle 2, with 22.3% heterosis with respect to CMS-36 and 6.70% with respect to IBO-128. Genetic gain was 0.65 t/ha. The highest heterosis was observed between Suwan and P.Compuesto-10, 18.9% with respect to Suwan and 200.7% with respect to P. Compuesto-10. The genetic gain was 1.73 t/ha and could be explained by a greater genetic divergence (Arboleda, 1965 cited by Manrique and Robles, 1997).

Conclusions

Reciprocal recurrent selection should be started with Suwan and IBO-128 populations.

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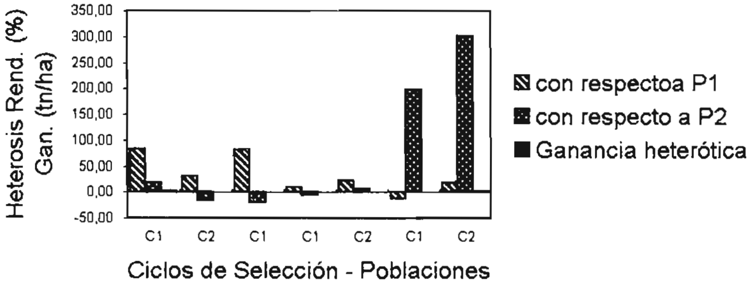
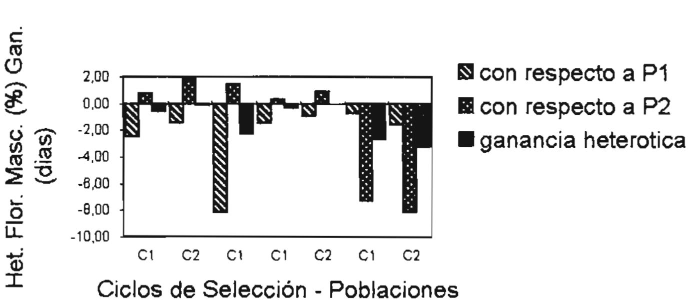
Tabla 1. Heterosis Porcentual y Ganancia Heterótica con respecto a los rogenitores, en 4 poblaciones de Maíz, con 1 y 2 ciclos de selección, para Rendimiento y otros Caracteres Agronómicos en promedio de 3 localidades de la Región Sub Tropical de Tarija (Gestión Agrícola 1994 - 1995).

POBLACION	Ciclos	Rend. (tn/ha)	Rendimiento			Flor. Masc.			Alt. Plta.			Asp. Maz.		
			H1 (%)	H2 (%)	G.H. tn/ha	H1 (%)	H2 (%)	G.H. (dias)	H1 (%)	H2 (%)	G.H (cm)	H1 (%)	H2 (%)	G.H (1-5)*
Suwan x IBO-128	C1	5.834	82.8	18.4	1.7	-2.4	0.7	-0.5	12.4	8.1	20.5	-4.0	14.5	-4.8
	C2	4.191	31.3	-14.8	0.1	-1.4	1.8	-0.1	6.5	2.4	8.9	12.3	0.0	2.9
Cub.Am. x IBO-128	C1	4.011	81.7	-18.5	0.4	-8.1	1.4	-2.2	-1.8	8.7	6.8	-29.6	18.3	14.2
CMS-36 x IBO-128	C1	4.705	9.5	-4.4	0.1	-1.4	0.3	-0.3	-3.9	2.2	-1.8	-27.8	-14.6	-12.0
	C2	5.254	22.6	6.7	0.6	-0.9	0.9	0.0	0.3	6.8	7.3	-18.4	-3.5	-6.8
Suwan x P.Comp-10	C1	2.806	-12.0	196.3	0.7	-0.7	-7.2	-2.6	16.5	-11.8	0.8	28.9	14.8	4.9
	C2	3.795	18.9	200.7	1.7	-1.5	-8.0	-3.2	13.9	-13.7	4.1	32.9	18.4	3.0
TESTIGOS														
IBO-128	CO	4.924												
CMS-36	CO	4.294												
Suwan	CO	3.190												
Cubano Amarillo	CO	2.207												
P. Compuesto 10	CO	0.947												

* Escala transformada a porcentaje y luego arcoseno

Fig.1. Heterosis para rendimiento y floración masculina en 4 poblaciones de maíz con respecto a sus progenitores





B70-Heterosis in two white maize populations with different grain hardness

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Introduction
In Venezuela, maize (*Zea mays* L.) occupies first place among the cereals used for human consumption. Most maize is used as pre-cooked maize flour. This product requires white maize and flint endosperm is preferred. This type of maize is not common in the world market, while Venezualan hybrids with semi-flint grain type fulfill this requirement. Results from different authors indicate that intervarietal hybrids are a good alternative to increase yield, by exploiting heterosis (Lonnquist and Gardner, 1961: Paterniani and Lonnquist, 1963: Paterniani, 1967). The objective of the present study was to evaluate intervarietal hybrids obtained from crosses among cycles of selection of two populations with contrasting grain types.

Materials and Methods
During 1982-1984, half-sib recurrent selection between and within families was used in two white maize populations, one with flint grain (FPX-01B) and the other (FPX-03B) with dent grains, completing three and four cycles of selection, respectively. Fourteen intervarietal hybrids were obtained from crosses among cycles of each population. In the rainy season, the intervarietal hybrids were evaluated at San Javier, Edo. Yaracuy and El Sombrero, Edo. Guárico. A randomized complete block design with 5 replications and 28 treatments (14 intervatietal hybrids, 9 parents and 5 commercial checks) was used. The experimental unit consisted of 2 row-plots, with 5 meters long rows, 0.8 m between rows and 4 plants by lineal meter for a density of 50,000 plants/ha. Yield (kg/ha) was the main trait evaluated.

Results
For yield (kg/ha), no significant differences were detected among intervarietal hybrids, progenitors and commercial checks in both locations. The heterosis observed in each location (Fig.1 and Fig.2) not be consistent but grain texture observed in hybrids to fulfills requirements of the agroindustry.

Conclusions
The intervarietal hybrids were competitive with commercial checks, and also had semi-flint grain type suitable to prepare pre-cooked maize flour. The inconsistency of the results in both locations are due to genotype environment interaction, for which it is recommended to make selection of cultivars in specific environments.

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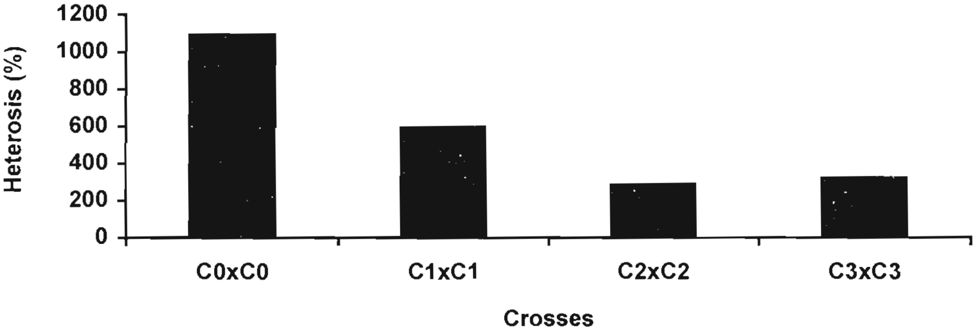

Fig 1. Hetrosis between populations FPX-01B and FX-03B in El Sombrero, State of Guarco, Venezuela

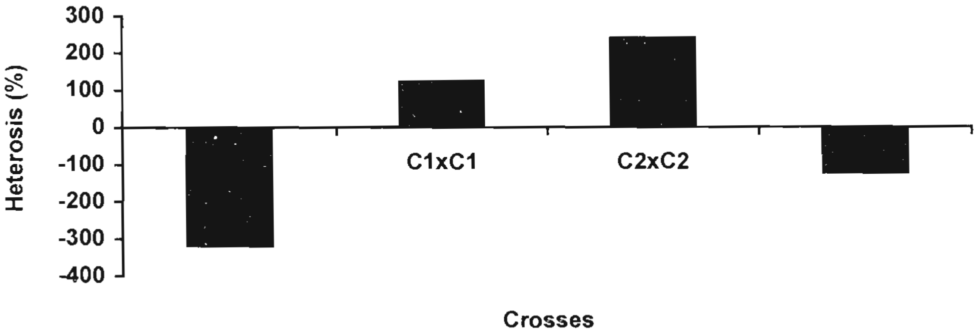

Fig 2. Heterosis between populations FPX-01B y FX-03B in San Javier, State of Yaracuy (Venezuela).

B47 - Environmental Influence on Phenology of Parental Lines of Sunflower Hybrids and Seed Production Planning

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Introduction
Sunflower is an important oilseed crop in India ranking 4th among oilseeds with an area of 3 m ha and 1.8 m t annual production. Photoinsensitivity and tolerance to problematic soil conditions make sunflower more flexible for adoption over a wide range of regions and seasons. In India sunflower is grown round the year as a contingency crop. The demand for hybrid seed has increased in recent years and present seed supply is inadequate to meet the growing need, primarily because hybrid seed production is concentrated in low productive areas in Southern States. Exploratory studies conducted at Indian Agricultural Research Institute (IARI), New Delhi demonstrated that real potential of sunflower lies in Indo-Gangetic belt where hybrid seed productivity is three times higher than traditional areas of Southern States (Virupakshappa, 1996). With this need, a complete package of hybrid seed production technology for Nothern India was visualized. In this endeavour an experiment was designed to study the environmental influence on phenology and yield contributing traits among six parental lines of three sunflower hybrids.

Methods
Parental lines of three hybrids viz. KBSH-1, APSH-11, and LSH-3 as detailed below were planted over six dates of planting (15th Sept., 15th Oct., 15th Nov., 15th Dec., 15th Jan., and 1st March) in a randomized block design experiment. Planting was done in 4 rows of 5 m length keeping 75 cm and 22 cm spacing between rows and plants respectively. The planting months fall in specific seasons: Sept-Oct. (Autumn), Nov., Dec. and Jan. (Winter) and Feb-March (Spring).

Hybrids	Male sterile CMS line	Restorer male line
KBSH-1	CMS 234A	6D-1
APSH-11	CMS 7A-1	RHA-271
LSH-3	CMS 207A	MRHA-1

Observations were recorded for days to emergence, button stage (head visible), flowering initiation 50% flowering, termination of flowering and maturity. Head size and per head yield averaged over 20 randomly chosen plants in each replication were also recorded in each planting.

Results
All observations recorded on phenology over dates of planting are presented in Table 1. Sunflower requires 8-10° C temperature for satisfactory germination (Cotte A. 1957) but in the present study good germination has been observed in seed beds even during winter months of January and February when atmospheric temperature had gone as low as 0° C. The process of emergence is faster in Autumn months (6 days after planting) in comparison to 15-16 days taken in Winter planting. All the six genotypes behaved identically for field emergence under different planting dates. The button stage (head visible) was attained after 30-39 days of emergence in September-October planting while the November planted crop took 58-68 days, coinciding with very low temperature conditions. The crop planted in March behaved identical to that of September planting. Button to flowering initiation period is important in hybrid seed production from the point of view of roguing. Once the plant starts flowering, its complete phenotype emerges, allowing the discrimination of atypical plants from parental stock. Criteria for roguing at this phase would be plant height, leaf shape, petiole pigmentation and angle and stem colour. This stage is again very important in identifying and roguing out of pollen

shedders in male sterile line. Flowering initiation stage came 15-20 days after button stage in the September planting, which is narrowed down to 9-15 days in the December planting. The 50% flowering stage was reached earliest in the September and March plantings (66 days after planting), while it took 100 days for the winter planting. Simultaneous flowering in male sterile line and restorer parents is essential for high productivity and genetic purity in hybrid seed. It is most relevant where the male sterile line flowers ahead of the respective restorer parent. Hybrid KBSH-1 (CMS 234A x 6D-1) never achieves synchronized flowering at its place of origin (Bangalore). But in this study synchronized flowering was seen in the December, January and March plantings at Delhi. This helps in planning KBSH-1 hybrid seed production at Delhi without the need for staggered sowing. Flowering initiation to completion took 34-40 days for the October sowing, but only 16-17 days for the March planting. This process of maturity is very rapid for the January planting (5-11 days), whereas it is much slower for the November planting (15-23 days). The shortest life span of crop was 90 days for the March planting which is stretched to 127-134 days when planted in November. Winter planting showed the best expression for head size and per capitulum seed yield as compared to other planting dates, lowest being in the March planting (Table 2).

Conclusion

The study reveals the tremendous impact of temperature on the phenology of sunflower at all developmental stages with variable magnitudes. The present study is very important in India, where the season changes every two months. It also provides ample guidance in planning hybrid seed production of sunflower in North-India. By choosing a particular season one may achieve perfect synchrony of flowering between seed and pollen parent. Winter planting has been found very suitable for synchronization, pollination and productivity. Anticipatory planning for roguing, pollination and crop inspection schedules can be precisely worked out. Information so generated can also be utilized for deciding time isolation, as sunflower is cropped round the year in India.

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Table 1. Phenology of parental lines over dates of planting (days).

	KBSH-1											
	CMS 234A						6D-1					
Planting dates	D1	D2	D3	D4	D5	D6	D1	D2	D3	D4	D5	D6
Emergence	5	6	12	15	17	11	5	5	12	12	16	13
Emergence to button	33	39	62	56	45	35	32	41	64	51	45	32
Button to flowering initiation	19	22	16	15	9	13	21	21	14	21	12	15
Flowering initiation to completion	28	35	24	13	28	17	27	37	30	29	31	26
Flowering completion to maturity	21	20	15	16	5	17	19	17	10	10	5	9
	D1	D2	D3	D4	D5	D6						
Crop duration of CMS lines	106	122	129	115	104	93						

	APSH-11											
	CMS 7A-1						RHA-271					
Planting dates	D1	D2	D3	D4	D5	D6	D1	D2	D3	D4	D5	D6
Emergence	4	5	11	11	15	13	5	5	11	11	15	11
Emergence to button	31	34	57	53	42	30	30	34	58	51	45	30
Button to flowering initiation	18	21	21	15	15	15	15	20	20	18	11	14
Flowering initiation to completion	28	40	22	22	21	16	22	41	20	26	25	16
Flowering completion to maturity	11	18	16	13	8	13	17	15	18	6	6	13
	D1	D2	D3	D4	D5	D6						
Crop duration of CMS lines	92	118	127	114	101	87						

	LSH-3											
	CMS 207A						MRHA-1					
Planting dates	D1	D2	D3	D4	D5	D6	D1	D2	D3	D4	D5	D6
Emergence	7	6	12	12	17	11	6	7	12	12	16	11
Emergence to button	39	42	63	56	45	35	36	41	68	60	48	40
Button to flowering initiation	19	22	17	16	13	14	16	20	14	13	11	12
Flowering initiation to completion	33	34	19	17	21	16	37	42	30	35	32	26
Flowering completion to maturity	13	23	23	21	11	20	13	17	12	5	3	14
	D1	D2	D3	D4	D5	D6						
Crop duration of CMS lines	111	127	134	122	107	96						

D1 = 15^{th} Sept., D2 = 15^{th} Oct., D3 = 15^{th} Nov., D4 = 15^{th} Dec., D5 = 15^{th} Jan. D6 = 1^{st} March

Table 2. Head diameter and seed yield of parental lines over dates of planting.

	KBSH-1												APSH-11												LSH-3											
	CMS 234A						6D-1						CMS 7A-1						RHA-271						CMS 207A						MRHA-1					
Planting dates	D1	D2	D3	D4	D5	D6	D1	D2	D3	D4	D5	D6	D1	D2	D3	D4	D5	D6	D1	D2	D3	D4	D5	D6	D1	D2	D3	D4	D5	D6	D1	D2	D3	D4	D5	D6
Head diameter (cm)	13	15	15	19	15	9	10	12	10	9	9	7	15	18	17	15	18	12	8	11	9	9	8	7	14	15	17	16	16	9	11	15	11	11	9	8
Per head seed yield (g)	10	4	4	28	13	6	7	5	15	18	6	4	16	9	21	21	20	10	7	6	13	11	6	5	12	9	23	16	36	12	15	13	21	31	10	11

D1 = 15th Sept., D2 = 15th Oct., D3 = 15th Nov., D4 = 15th Dec., D5 = 15th Jan. D6 = 1st March

B11 - Strategies to Use CIMMYT's Hybrid Schemes in the Bajío Maize Program

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Introduction

Genetic diversity is one of the main components of heterosis in maize. The maize breeding program of INIFAP - Bajío has been using introduced germplasm as the main source of heterosis in crosses with local germplasm to obtain highly productive hybrids. For two decades CIMMYT's germplasm has been an important source to our national programs. At present CIMMYT's hybrid maize program has emphasized the grouping of heterotic patterns of their tropical and subtropical germplasm (Vasal *et al.*, 1992a, b), to enhance the development of inbred lines with excellent combining ability and outstanding agronomic traits. For our program it is crucial to develop strategies to identify which germplasm sources from our program can be use to maximize the heterotic response in crosses with lines derived by CIMMYT. The objective of this work was to outline the use and exploitation of CIMMYT's materials and to detect which local germplasm sources express highest values of heterosis with the heterotic groups used at CIMMYT.

Materials and Methods

The maize breeding program of the Bajío has been using as testers, the progenitor lines from a single cross H-358 to separate our germplasm in two contrasting heterotic groups. These testers were crossed with two groups of lines from CIMMYT: a) subtropical lines from heterotic groups A and B, and b) tropical and subtropical inbred lines (CMLs). Also crosses were made between superior experimental lines from CIMMYT's subtropical maize program with experimental lines and single crosses from INIFAP. The groups of materials above mentioned were evaluated at El Bajío in 1995 and 1996. Additionally a group of 3-way crosses involving lines from CIMMYT and single crosses from INIFAP were evaluated during two years in three locations.

Results

The results of crosses between lines derived from heterotic group A with Bajío (PB1) and (PB2) testers showed a tendency to identify PB1 as a B type; nevertheless, the lines derived from heterotic group B showed important heterotic responses with both testers. In the group of crosses among CML lines with PB1 and PB2, the heterotic combinations CML11 and CML111 x PB1, and CML8 and CML58xPB2 were outstanding. The crosses between INIFAP-Bajío elite lines and subtropical lines showed heterotic responses of high magnitude between germplasm of both institutions. Similar heterotic responses were also expressed in three-way hybrid trials across locations. In these trials the single crosses between lines from Aguascalientes and Bajío crossed with CMLs 311 and 321 were outstanding.

Conclusions

Crosses between CIMMYT and INIFAP germplasm identified valuable heterotic response that can be exploited for the development of new hybrids in a short time. Results from these trials make it possible to design and structure the incorporation of CIMMYT germplasm, without having to carry out parallel and duplicate research.

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B80 - Heterosis and the Genetic Structure of Productivity Components in Fiber Flax

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Introduction

Fiber flax, also called "northern silk", is an important industrial crop in the Republic of Belarus. The results of heterosis studies in flax are rarely reported in the literature (Patiel et al. 1983; Rao et al. 1983; Sorochinskaya et al. 1980; Khotyljova et al. 1987). Though heterosis has not found a wide application in fiber flax, hybrids, where either one of the parents, or both parents have high GCA, can serve as sources of transgressive forms that are important for the self-pollinating species to which fiber flax belongs.

Methods

Heterosis was studied in 30 F_1 hybrids produced by crossing 6 varieties — Leorkovsky (Czech Republic), L-41 (Belarus), K-6307 (USA), Viking (France), Koto (Canada), and K-6659 (Italy) -- with 5 testers — Baltuchai (Lithuania), Laser (Belarus), Svetoch (Russia), Mogilevsky 1 (Belarus), and Belinka (The Netherlands). Heterosis was expressed as a percentage of F_1 hybrid trait value over the best parental form (F1 - Pb) / Pb x 100%. For establishing the possible cause of heterosis, the data on the heterosis effects (%) were compared with the value of the dominance average (a), the effects of general combining ability (GCA), and the specific combining ability (SCA). The combining ability of fiber flax varieties was estimated in the system of line x tester crosses. The model of the experiment II by Comstock, Robinson (5) generalized by Kempthorne (6) was the basis for the analysis.

Results

Heterosis was manifested in all traits studied: plant height at different ontogenesis stages, technical length, number of inflorescence orders, number of capsules, number of seeds per capsule, stem weight, fiber weight, and fiber yield percentage. The average heterosis value for the productivity components is given in Figure 1 and the data for the characteristic average (xij), population average (u), GCA effects of both parental forms (gi, gj), and SCA constants for hybrids exhibiting high heterosis are represented in Table 1.

Conclusions

Having analyzed heterosis and the genetic control of traits, we observed heterosis for plant height (6.7%), technical length (3.7%), and seed number per capsule (7.8%). Inheritance was controlled by additive gene effects and dominance is low and incomplete and directed at decreasing the trait. The percentage of heterosis is higher in the hybrids; additive gene effect are observed at dominance equal to 1 (number of inflorescence branch orders, 18.7%; stem weight, 26.8%; fiber weight, 32.8%). Though the frequency and value of heterosis seem to depend largely on the frequency of favorable genes with additive effects, the overdominance effect in the high heterosis for capsule number (42.9%) in fiber flax is of paramount importance. The analysis of individual hybrids has shown that heterosis is defined by different causes depending on the genotype and the traits studied. Approximately 90% of the hybrids had one of the parental forms with high GCA. Such hybrids can serve as sources of productive transgressive forms, with the following hybrids being recommended for practical breeding: L-41 x Belinka, L-41 x Svetoch, L-41 x Mogilevsky I, Koto x Svetoch, Viking x Laser, Viking x Mogilevsky 1.

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Table 1. Dominance average (a), heterosis characteristic (%), indices averages (xij), population average (u), GCA (gi, gj) — and SCA (Sij) effects in parental forms of heterotic hybrids in fiber flax (BES of IGC at BAS 1994).

Crossing combination	% of heterosis	Xij	u	gi	gj	Sij
Plant height (a — 0.58)						
L-41 x Belinka	7.6	77.95	62.81	11.94	-1.95	5.15
Technical length (a — 0.77)						
Viking x Laser	6.2	49.2	46.25	2.76	-3.65	3.84
Number of seeds per capsule (a — 0.89)						
Leorkovsky x Belinka	4.0	7.0	5.79	1.30	0.45	-0.53
Number of capsules (a — 3.67)						
L-41 x Mogilevsky 1	60.6	10.68	9.22	1.09	-0.22	0.59
Stem weight (a — 1.1)						
L-41 x Svetoch	25.7	833.0	541.5	220.10	19.40	51.95
Fiber weight (a — 1.0)						
L-41 x Belinka	50.0	197.7	105.32	53.87	10.15	28.36

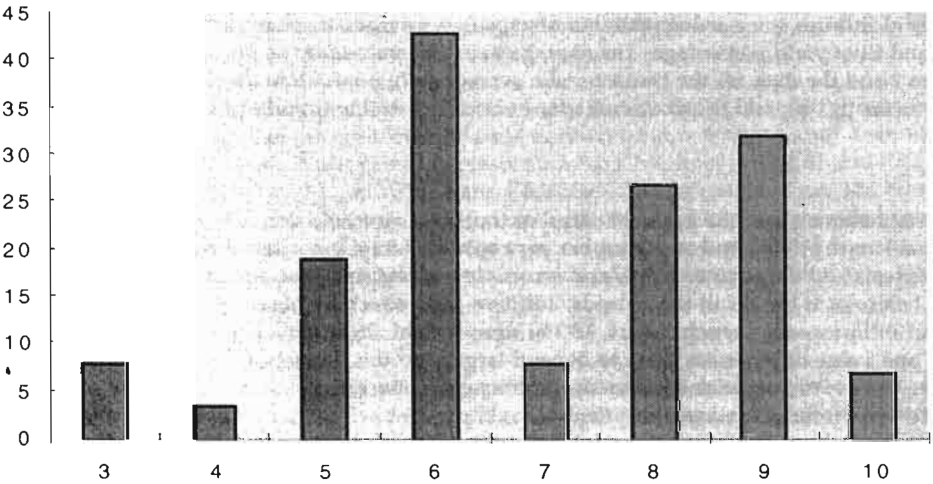

Figure 1. Heterosis for productivity components in fiber flax. Traits: 1) Plant height at early ontogenesis; 2) Plant height at main growth stage; 3) Plant height at maturity; 4) Technical length; 5) Number of inflorescence branch orders; 6) Number of capsules; 7) Number of seeds per capsule; 8) Stem weight; 9) Fiber weight; 10) Percent fiber yield.

A76 - Heterosis in Drought-tolerant Lines Derived from a Direct Cross of Wheat (*Triticum aestivum* L.) with *Triticum tauschii*

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Introduction
Dryland wheat yields are often limited because of drought and it is considered that breeding for increased drought tolerance could enhance yield. Although differences in response to drought amongst wheat cultivars have been detected in many studies, progress in improving drought tolerance is often small and slow. It may be possible to identify superior levels of drought tolerance in diploid and tetraploid ancestors of cultivated wheat. One such ancestor is *Triticum tauschii* which has continental distribution (Central Asia) and adapted in some places where extremes of climate: dry, hot summers and cold winters and poor adaphic conditions occur (Harlan and Zohary 1966). Increased levels of drought tolerance have been found in some accessions of *T. tauschii* under semiarid conditions (Damania and Pecetti 1990). Many researchers were successful in transferring to wheat from *T. tauschii* useful genes because *T. tauschii* is the putative donor of D genome to bread wheat (Kihara 1944). While transferring useful characters from *T. tauschii* to wheat through direct cross, interspecific heterosis were reported in some progenies resulting in higher yields than recurrent wheat parent (Cox et al. 1990). The main objective of the present study was to assess the agronomic potentials in lines derived from a direct cross between wheat and *T. tauschii* that showed different responses to drought at the seedling stage under moisture stress conditions.

Methods
A wheat cultivar Songlen reputed to be drought-tolerant was directly crossed with a *T. tauschii* (accession Tt7) which exhibited higher levels of drought tolerance than Songlen both at the seedling and post-anthesis stages. Two subsequent backcrosses were made with wheat as a recurrent parent. There were 56 backcrossed lines which were evaluated for drought tolerance at the seedling stage. Briefly, seedlings were subjected to drought stress by withholding water and measurements of area of leaf 3, leaf water potential and relative water content were done on leaf 3 which developed under maximum stress. Lines exhibited a wide variation in response to drought stress at the seedling stage. The seedlings of the progenies and Songlen were transferred to bigger pots, rewatered and grown to maturity under well-watered conditions in a controlled environment. At maturity, plants were harvested and dried. Total grain weight and number of grains per plant, kernel weight and harvest index (HI) were determined.

Results
Total grain weight per plant between 56 lines differed significantly and about 14% of the lines which exhibited tolerance to drought at the seedling stage gave higher grain yield than Songlen. The increase in grain yield depended upon both in grain number per plant (Fig. 1) and individual kernel weight (Fig. 2). The harvest index did not increase and ranged from 0.28 to 0.54 in lines which exhibited higher grain yield than Songlen (0.54).

Conclusions

By direct crossing wheat with *T. tauschii*, the AB genomes of wheat remain intact resulting in less disruption in agronomic traits and potential for interspecific heterosis (Cox et al. 1990). This was reflected in the present cross with high yield potential and improved drought tolerance in some of the lines. Because the lines from the direct cross of wheat cultivar Songlen and *T. tauschii* accession Tt7 exhibited a wide variation for yield and yield components, it gives an opportunity to select for desirable genotypes. In drought-prone areas, it is generally considered that grain yield depends on high grain number per plant and cultivars preferred are with small grains as in the case of some lines that gave higher grain number than Songlen (41) (Fig. 1). It appears that there is a potential to increase yield in wheat through wheat/*T. tauschii* crosses possibly through interspecific heterosis.

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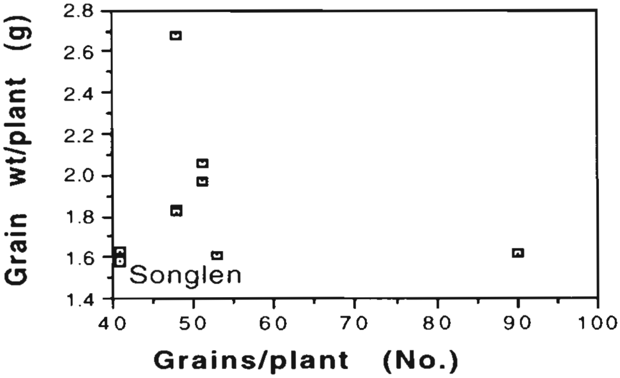

Figure 1. Total grain weight/plant and number of grains/plant of selected drought-tolerant (seedling stage) of lines derived from the cross wheat (Songlen)/*T. tauschii*

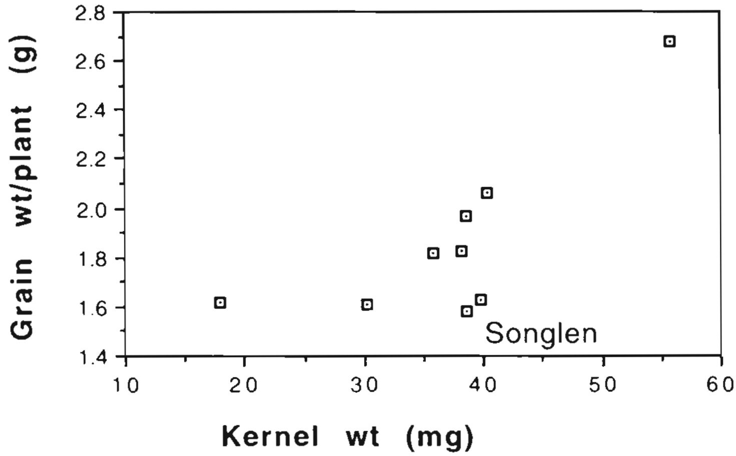

Figure 2. Total grain weight/plant and mean kernel weight of selected drought-tolerant (seedling stage) of lines derived from the cross wheat (Songlen)/*T. tauschii* (Tt7).

B18 - **Commercial Hybrid Wheat in Argentina**

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Introduction
To provide guidelines for future research projects that may include the development of hybrid wheat, our experience is presented here, where the advantages and constrains of this type of breeding is analyzed. Hybrid wheat was considered as a theoretical possibility in breeding for many years, until some research reports demonstrated the possible use of some male sterilization systems, allowing work with this self fertile species as an allogamous plant (Machado 1980). During 1960-1970 several seed companies started wheat breeding programs, focusing efforts on hybrid wheat. In our case, breeding included the coordinated efforts of four countries: USA., Argentina, France and Australia. This presentation describes the most remarkable events about the Argentine experience, started in 1970.

Three major aspects were simultaneously studied:

Sterilization system: Two options were considered: the cms (T. timopheevi cytoplasm), and some chemical hybridazing agents. T. timopheevi system was selected as the best option .
"Producibility": Environmental conditions, and the genetics of the traits related to the outcrossing at commercial level were studied. The program was located in the South East where the conditions and yield levels were more adequate.
Profitability: The whole project had to be profitable for the seed company as well as for the farmer.

Description of the Program
All aspects considered were closely related to breeding methodologies. No previous experience existed in our country or others, and completely new procedures had to be developed. The main concern then was the sterilization system. The *T. timopheevi* system was effective to produce sterile lines but not really efficient on the restorer's side. The best restorers we had were non-adapted germoplasm with many agronomic deficiencies. The restoration capacity of the *T. timopheevi* system was not well known and carried a strong environmental interaction. Full restoration was not accomplished until 1978, when the first full restored hybrids were obtained. The right procedure to ensure full restoration included recurrent selection and an individual plant control for several advanced generations. Before this was obtained, the yield potential of the hybrids was underestimated due to poor seed set. The restoration genetic system was considered to involve three major genes and some modifiers. About 300 to 500 crosses considering restorations and agronomic traits were planned every year. The crosses "restorer/normal lines" produced very few lines, so we accepted partial restorers that were crossed among themselves. Partial restorer/partial restorer finally produced the required full restorers. Once a good number of lines were obtained, the most common cross type was R/B//R. In spite of this, the high selection pressure for restoration reduced the speed of the program because few good lines per year were incorporated as new males.

Two separate programs were run: restorers and A/B lines, like in any other cms system based crops. The A/B program was very similar to any conventional varieties program (in this case modified genealogic) and at F_4 CMS conversion was started, using good CMS sources. To convert a B line into its A version takes at least 2 years, using a greenhouse to make 3 back crosses per year. Once a B line was partially converted, the BC_4 seed was planted in the field for both purposes: A/B increasing and first top-crossing with a group of restorers selected as testers. The following year the experimental hybrids obtained were included in yield trials. Meanwhile, all new selected parental lines were included in a phenological trial to determine days to flowering and estimate outcrossing ability for different lines.

phenotype evaluation, recognizing additive variance as a necessary component in the lines. New experimental hybrids were included in a three-location testing program; the number of locations was increased to 10 in the evaluation. The evaluation criterion was yield expressed in terms of competitiveness with commercial varieties and measured as stability. To be considered an experimental hybrid had to be superior to the average of the three best commercial varieties under different environments, because any commercial hybrids will have to compete with well-known and competitive varieties. Only hybrids and commercial varieties were included in trials; parental lines were not evaluated.

"Producibility" was considered a must during the selection process. All agronomic traits related to cross pollination were considered. In F_2 populations, for instance, at flowering all plants showing outstanding anther extrusion were selected. An acceptable genetic correlation with the character was found and was incorporated as a descriptor in the mating crossing blocks every year. Cross pollination in wheat has a strong environmental interaction. Humid, moderate winds and temperate temperatures at flowering are the most convenient conditions. The Southeast or ecological wheat region named Subregion IV in Argentina has optimal conditions for wheat cross pollination. In this area it is also possible to plant wheat with very good results from late May up to mid-August; useful when a split planting is required. Table 1 shows some yield data obtained in some field production plots.

The profitability for the farmer is mainly based on yield advantage over varieties. The above described testing program allowed us to define a group of competitive hybrids followed by a good number of experimental hybrids. After making and testing about 2,000 hybrids, a set of germoplasm showing superior heterosis was identified. The concepts related to heterotic grouping commonly used in allogamous plant hybridization were used, and two different genetic pools were obtained. Both winter and spring types were used in both crossing blocks, combining agronomic traits, diseases resistance and baking quality. The yield differences when compared to new pure line varieties were statistically significant, but not always measured by farmers. After some experiences with hybrid seed, what farmers appreciated the most were yield components such as initial vigor, stress tolerance and disease resistance -- in fact, present in most commercial hybrids. Good results were obtained using low seeding rates. Usually 100 kilos or more per hectare were used, but 60 kilos provided equal yields. Some leading farmers, using precision planters, used about 30 kilos of hybrid seed per hectare with excellent results.

Achievements

In Table 2, the performance of some commercial and precommercial hybrids tested between 1990, 1991 and 1992 are summarized. Table 3 summarizes the total 40 kilos bags sales among 1986 to 1993. Many other data sources show performances and stability (Machado et al. 1990).

Suggestions for future hybrids wheat programs

According to this extensive experience, hybrid wheat may be an interesting option as a breeding tool. Some conditions should be considered to make certain commercial results:

- Genetic diversity for both parental lines must be as broad as possible. Limited conditions (some diseases or grain color or quality traits) may reduce diversity and consequently the possibilities for heterosis. Areas where both winter and spring types may be used and combined are the best.
- Farm businesses must be able to afford the added expense of hybrid seed.
- Technology and environmental conditions must allow low seeding rates both for production and commercial plantings.
- High seed prices must be related to high yield expression, generally closely related to high technology. These technologies must be well-known in the target area.
- The use of gametocides will surely be an important for wheat hybridization, provided an active breeding program is producing lines that are well-adapted, with good crossing ability and good combining ability. It may be used also as a breeding tool for combining ability studies.

- For production, environmental conditions must be good for cross pollination in an area where physical isolation is also feasible.
- An outstanding pure line variety commonly is not a good hybrid parent. Specific breeding procedures must be applied and lines must be evaluated through hybrids

Good yields and stability may be obtained with hybrid wheat as well as good stress tolerance, good disease resistance and initial vigor. The possible yield increase over varieties is not well defined and perhaps pure line varieties and hybrid cultivars will share the market in some wheat growing regions.

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B38 - **Present Progress of Maize Breeding for Sustainable Agriculture and Cropping Systems for the Paddy Lowland and Upland in South Korea**

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Introduction

Maize (*Zea mays* L.) has been one of the most important food, feed, and medicinal and industrial material crops in Korean peninsula, and is planted on about 800,000 ha, second only to rice in cropping area in the peninsula. Waxy corn and sweet corn have been cultivated in the southern part of Korea as a cash and health food crop, and also double-cropped with rice and soybeans for the paddy lowland and upland fields.

Current maize breeding strategies for biotic and abiotic resistance and higher yield

Sweet corn inbreds and waxy corn inbreds have been introgressed with superior insect and disease resistant field corn inbreds and hybrids with higher grain yields.

Current status of maize breeding for achieving for high quality and high yield

Maize grain, fresh ear and green fodder yields have increased in Korea since 1960s. Agronomic trait improvements also occurred for cold tolerance, disease and insect resistance, resistance to barrenness, resistance to lodging, pollen production, grain and seed yields and eating quality. Average maize yields in Korea have increased continuously from the 1970s to date because of improved hybrids (Tables 1-3), increased N fertilizer use, increased plant population, improved management along with effective weed and pest control, and polyethylene field house and tunnel and mulching technologies.

Field corn hybrids developed at the National Crops Experiment Station, Suwon, Korea, 1996

Sweet corn and or waxy corn-rice cropping systems have been practiced for rotation cropping and double cropping in the paddy lowland of the southern part of Korea. Rice yields also increased after rotation with corn. Maize and soybean would be the best upland crops in rotation with rice for lowland paddy, in view of physical and chemical soil properties and of socioconomic factors.

Table 1. Sweet corn hybrids developed at the National Crops Experiment Station, Suwon, Korea, 1996.

					Ear		Seed		Yield	
Hybrid	Days to silking	Tillers/ plant	Stem length	Lodging disease (1-9)	Length (cm)	Seed set (%)	coat diameter (mm)	Ears/ 100 plants	Ears (ears/ha)	Ears wt. (t/ha)
Danok 2 (check)	61	1.5	132	4	1	90	54.7	50	31,480	5.7
KSS36/ KSS37	52	3	126	6	1	96	49.2	74	47,220	8.1

Table 2. Super sweet corn hybrids developed at the National Crops Experiment Station, Suwon, Korea.

				Ear		Seed		Yield	
Hybrid	Days to silking	Tillers / plant	Stem length	Length (cm)	Seed set (%)	coat diameter (um)	Ears/ 100 plants	Ears (ears/ha)	Ears wt. (t/ha)
Chodangok 1	67	1.6	113	15	87	61	69	44,440	7.1
KH9/KH4	68	1.4	127	18.2	95	52	96	63,890	11.8

Table 3. Waxy corn hybrids developed at the National Crops Experiment Station, Suwon, Korea.

Hybrid	Days to silking	Stem length (cm)	Lodging (1-9)	Ear Length (cm)	Ear Seed set (%)	Seed coat diameter (um)	Yield index Ears (ears/ha)	Yield index Ears wt. (t/ha)
Chalok 1	68	168	7	15.4	97	79	100 (48,150)	100 (6.6)
Chalok 2	72	154	3	17.5	96	68	115	118
KW7/KW10	74	179	5	17.7	100	60	117	118
CW/KW13	77	189	5	19.3	94	53	101	121

Table 4. New hybrid Suwon 118 developed and released at the National Crops Experiment Station, Suwon, Korea 1996.

Hybrid	Days to silking	Stem length (cm)	Ear (cm) Length	Ear (cm) Diameter	Grain weight (g)	Stay green (1-9)	Yield (t/ha) Green fodder	Yield (t/ha) Grain
Suown 118	95	262	20.1	4.2	30.4	2.6	19.73	7.72
Female KS7rhm	88	164	13.0	4.0	25.0	3.0	-	-
Male KS 117	97	184	11.0	3.6	27.0	2.3	-	-
Kwanganok	94	247	17.6	4.6	29.0	3.9	19.06	7.42

A56b - **Is Heterosis a Form of Stress Tolerance?**

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Introduction

A maize hybrid normally performs better than its parental lines, both under optimal and nitrogen and water-limited growth conditions. However, comparison with its genetically related open-pollinated variety is needed from an agronomic perspective. This study compares the performance of a bulk of topcrosses of a random set of lines with two testers, the performance of the lines, and the performance of the populations from which the lines were extracted. We also evaluate whether the difference between hybrid and population performance is influenced by the breeding environment of the source populations.

Materials and Methods

The comparison was based on four groups of populations, hybrids and lines, from TS6 C_2 (white, hereafter named TS6, derived from Tuxpeño Sequía C_6, itself derived from CIMMYT maize Population 21), Population 21 MRRS C_2 (white, Pop21), Pool 26 Sequía C_3 (yellow, P26Seq) and Pool 26 C_{23} (yellow, P26). TS6 and P26Seq have been improved for yield under mid-season drought stress, while maintaining grain yield under good conditions. Pop21 and P26 are respective counterpart populations that have been bred conventionally; i.e., without evaluation under drought. About 100 randomly selected S_2 lines from each population were crossed in 1994 with the conventional inbred testers lines: CML247 and CML254 for the white lines and CML287 and CL00331 for the yellow lines. The F_2 of the populations and bulks of the 100 S_2 lines and of the 200 topcrosses were evaluated in the dry 97A cycle at Tlaltizapán, Mexico, under mid-season drought conditions and at Poza Rica, Mexico, under low nitrogen. The 12 entries were sown in an RCBD with 4 replications, in 4-row plots of 5.25 m. Within and between-row plant distances were 0.25 and 0.75 m, respectively. Days to 50% anthesis and silking were recorded. The anthesis-silking interval (ASI), which is negatively correlated with stress tolerance, was computed as the difference between both flowering dates. At final harvest, number of ears per plant (EPP), total above-ground biomass (BIOM) and grain yield (GY) were determined for a bordered area of 7.1 m^2. Averages and correlation coefficients were computed. Two fixed main effects and their interaction were considered in the analysis of variance: germplasm group (GROUP; i.e., TS6, Pop21, P26Seq and P26) and germplasm type (TYPE; i.e., population, hybrid and line).

Results

Correlations. BIOM and GY were closely related. Correlations between EPP and GY were 0.86** and 0.65** under drought and low nitrogen, and between ASI and GY -0.53** and -0.31*.
Significance of effects (Table 1). TYPE explained lower line BIOM and GY under drought (Table 2). Both GERM and TYPE and their interaction effect were significant in the case of GY, ASI and EPP. Both GERM and TYPE effects were significant for BIOM under low nitrogen (Table 2). TYPE was significant for GY and EPP, and GERM for ASI.
Biomass (Table 2). Hybrid BIOM was 11.93 and 6.84 t ha^{-1} under drought and low nitrogen. Population BIOM was not significantly different from hybrid BIOM under drought, but 24% lower under low nitrogen. Line BIOM was significantly the lowest in both environments. BIOM under low nitrogen of TS6 was 68% of the BIOM of Pop21. The bulk of hybrids of Pop21 produced the most BIOM in both environments.
Grain yield. Hybrid GY yielded 3.32 and 2.87 t ha^{-1} under drought and low nitrogen. Population GY was not significantly different from hybrid GY under drought, but 35% lower under low nitrogen. Line GY was significantly lower in both environments. The GY under drought of germplasm based on selection under drought was 144% of that of conventionally bred germplasm. The drought selected

populations had on average 84% more GY under drought than the conventionally selected populations. Hybrid GY of Pop21 under low nitrogen was significantly greater than that of TS6.
ASI and EPP. On the whole, differences in GY reflected differences in ASI and EPP.

Conclusions

Differences in BIOM and GY under intermediate drought stress at flowering can be attributed to the germplasm type: hybrids and populations do better in this respect than lines. Differences in partitioning of assimilates to the grain depend also on the germplasm group. The drought-selected populations yield better than the conventionally selected populations, and this is reflected in a greater EPP and in case of TS6 in an ASI of 0. Although differences were not always significant, populations that were improved for drought tolerance gave greater GY than their respective bulks of hybrids, and populations that were not improved for drought tolerance gave lower GY that their respective bulks of hybrids. The fact that hybrid GY is less than population GY for drought-selected materials may be a consequence of the specific combining ability of the tester lines with the four populations under drought. This points to careful use of standard testers for developing drought tolerant material. In summary, heterosis may a form of drought tolerance depending on the background of the source populations and the SCA of the tester lines. Under low nitrogen, which is a condition for which none of the germplasm has been developed, hybrids gave on average greater GY than populations. Here it can be concluded that indeed heterosis is a form of low nitrogen tolerance, though, a comparison with germplasm developed under low nitrogen conditions would be desirable.

Table 1. Significance of effects of germplasm group (GROUP) and type (TYPE) on crop characters under intermediate drought stress around flowering and under low nitrogen growing conditions. ***: $p < 0.001$; **: $p < 0.01$; *: $p < 0.05$

	Drought			Low nitrogen		
Character	GERM	TYPE	GERM*TYPE	GERM	TYPE	GERM*TYPE
Biomass		***		**	***	
Grain yield	***	***	**		***	
Harvest index	***	***	**		***	
Anthesis-silking interval	***	*	**	*		
Ears per plant	***	***	***		***	*

Table 2. Total above-ground biomass (t ha^{-1}) and grain yield (t ha^{-1}) of populations, hybrids and lines developed from 4 sources of germplasm (see text for details).

Biomass	Drought (LSD=1.46)				Low nitrogen (LSD=1.56)			
	Pop.	Hyb.	Line	*Av.*	Pop.	Hyb.	Line	*Av.*
TS6	11.45	11.85	6.96	*10.08^a*	4.35	5.64	2.53	*4.17^b*
Pop21	10.53	13.61	7.28	*10.48^a*	5.07	9.14	4.19	*6.13^a*
P26 Seq	11.20	11.01	6.43	*9.55^a*	5.72	5.83	3.62	*5.06^{ab}*
P26	10.11	11.25	6.19	*9.18^a*	5.76	6.73	4.97	*5.82^a*
Av.	*10.82^a*	*11.93^a*	*6.72^b*	*9.82*	*5.22^b*	*6.84^a*	*3.83^c*	*5.30*

Grain yield	Drought (LSD=0.66)				Low nitrogen (LSD=0.88)			
	Pop.	Hyb.	Line	*Av.*	Pop.	Hyb.	Line	*Av.*
TS6	4.21	3.56	1.49	*3.09^a*	1.69	2.34	0.71	*1.58^a*
Pop21	1.99	3.92	0.81	*2.24^{bc}*	1.70	4.18	1.21	*2.36^a*
P26 Seq	3.75	3.04	1.71	*2.83^{ab}*	2.13	2.25	1.14	*1.84^a*
P26	2.41	2.74	0.53	*1.89^c*	1.97	2.72	1.48	*2.05^a*
Av.	*3.09^a*	*3.32^a*	*1.13^b*	*2.51*	*1.87^b*	*2.87^a*	*1.14^c*	*1.96*

A77- Heterochromatic Knob DNA in Relation to Heterosis in Maize

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Introduction
Heterosis in maize is the most widely exploited biological phenomenon. However, its genetical, physiological and bio-chemical bases still remain largely unexplained. For the last several years, we have been trying to elucidate the role of heterochromatic knob DNA in maize heterosis (Chughtai et al., 1993, 1994, 1995). Highly repetitive (heterochromatic) DNA in maize and its close relatives in Maydeae is present in the form of knobs at fixed locations on the chromosomes. Knob DNA is composed of 180 bp repeat arranged in a tandom array (Peacock et al., 1981). The racial (or varietal/inbred) knob composition is not random (McClintock et al., 1981). Also, the geographic distribution of knobs is non-random. The high-knob genotypes are restricted to the lowlands while low knob genotypes are restricted to the highlands. Knob frequency is also negatively correlated with latitude. In short, the amount of knob DNA is related to the effective growing season and thus adaptation of maize to its environment (Rayburn and Auger, 1990; Bullock and Rayburn, 1991).

Methods
Crossa et al., (1990) published extensive data on hybrids among 25 Mexican races of maize (Arrocillo Amarillo, Bolita, Cacahuacintle, Celaya, Chalqueño, Chapalote, Comiteco, Conico, Conico Norteño, Harinoso de Ocho, Jala, Maize Dulce, Nal-Tel, Olotillo, Oloton, Polomero, Toluqueño, Vandeno, Zapalote Chico and Zapalote Grande). Between 1962 and 1964, over 300 racial hybrids were evaluated in Mexico at three different sites varying in altitudes (Tepalcingo 1962, 1300 meters; Rooque and Juventino Rosas 1964, 1800 meters; Chapingo 1963 and 1964, 2249 meters). Dr. J. Crossa from CIMMYT was kind enough to give us accession to these data on grain yield, days to pollen shedding and ears per plant. Similarly, extensive data on the knob composition of maize from the Americas have been published by McClintock et al. (1981). We have combined these yield and knob data to see how knob constitution is related to heterosis and combining ability in maize.

Results
For comparison, the knob constitution and agronomic performance of the 20 highest yielding and the 20 lowest yielding hybrids is given (Table 1). At high altitude, the top 20 hybrids have a significantly higher number of heterozygous (6.55) than homozygous (3.5) knobs, while the reverse is true for the bottom 20 hybrids (8.9 homozygous and 3.8 heterozygous knobs). At low and medium elevations, the top 20 hybrids have a significantly higher number of homozygous (7.8 and 7.4) than heterozygous (3.95 and 2.8) knobs, while the reverse is true for the bottom 20 hybrids (1.7 and 3.15 homozygous, and 3.8 and 3.95 heterozygous knobs, respectively). Thus it is very important to note that the relationship between knob DNA and combining ability for yield and maturity largely depends on the environment and that it is knob condition (heterozygous or homozygous) which determines the performance of the hybrids rather than the frequency of knobs per se as has been generally believed of the DNA content as has been recently shown Rayburn et al., 1993; Biradar and Rayburn, 1993).

The racial composition of the top and bottom 20 hybrids (Table 2) given some significant insights for hybrid breeding especially what to combine and what not to combine in a given environment. Among the top 20, the most frequent crosses were LXM (45%) at low, MXM (45%) and LXM (40%) at medium, and MXH (80%) at high elevations. These data indicate the significance of the local maize germplasm for hybrid development in any location. For example, at low, medium and high elevations 75%, 95% and 100% of the top 20 hybrids involved low, midland, and highland races, respectively. It is, however, important to notice that the local material has to be crossed to the exotic germplasm adapted to other environments.

Our explanation of the relatioship between knob composition and hybrid vigor or heterosis (Chughtai, 1988; Chughtai and Steffensen, 1987, 1989; Chughtai et al., 1993, 1995) was that in the temperate environments, knob heterozygotes (like knobless genotypes) are early in maturity and thus well adapted to the cooler climates. Since knob homozygosity delayed plant development in cooler climates (Chughtai, 1988), it probably did so through the cis-acting position effect. The data presented in this communication strongly support this contention. The correlations between yield, maturity and prolificacy on the 300 hybrids among 25 Mexican races are presented (Table 3). Prolificacy is negatively associated with maturity but positively associated with yield at all the altitudes. However, maturity and yield show different relationships at different altitudes (environments). They are positively but non-significantly associated at low, positively and significantly associated at medium, but negatively at highly significantly associated at high altitudes.

In order to explain the position effect of the knobs, we (Chughtai, 1988; Chughtai and Steffensen, 1987, 1989) have proposed the existence of a DNA binding protein which specifically binds to the knob DNA and alters the expression of the neighboring genes. The effect of this punitive knob DNA binding protein is temperature dependent. Knob DNA is highly condensed at low temperatures. The spreading or position effect is pronounced in temperate (cool) climate but not in subtropical and tropical (warmer) climates. In warmer climates, knob homozygotes are better adapted than the knob heterozygotes though they have similar maturities (Table 1, top 20 versus bottom 20). It is important that knob composition plays a significant role in the heterosis of maize hybrids and their adaptation to the environmental conditions. Consideration of this factor for breeding of hybrid maize for different target environments and purposes will ensure more success than random mating and selection procedures generally adopted. For example, breeding for cold tolerance in the highlands must ensure knob heterozygosity by crossing a low-knob with a high knob genotype. This would result in early maturing and high yielding hybrids, thus breaking the strong linkage between yield and maturity.

Conclusions

It is concluded that in cool environments knob heterozygosity while in warmer climates knob homosygosity is directly related to heterosis in maize. Knob DNA plays an important and active role in adaptation of maize to its environment. Consideration of this factor will not only make hybrid maize development easy and less time consuming but also more effective and productive.

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Table 1. Number of knobs, days to pollen shedding, ears per plant and grain yield in hybrids among Mexican races of maize grow at different altitudes

Test Site	Hybrid Ranking	Number of Knobs		Pollen Shedding (Days)	Ears per Plant	Grain Yield (t/ha)
		Homozygous	Heterozygous			
Low Altitude (1300 m)						
	Top 20	7.80	3.95	76	1.40	6.24
	Bottom 20	1.70	3.80	75	1.11	2.14
Medium Altitude (1800 m)						
	Top 20	7.40	2.80	88	1.58	8.14
	Bottom 20	3.15	3.95	79	1.40	2.92
High Altitude (2249 m)						
	Top 20	3.50	6.55	91	1.75	6.41
	Bottom 20	8.90	3.80	104	1.03	1.26

Table 2. Racial composition of hybrids among Mexican races of maize grown at different altitudes.

Test Site Altitude	Hybrid Ranking		Racial Composition (%) of Hybrids*					
			LXL	LXM	MXM	LXH	MXH	HXH
Low (1300 m)	Top	20	20	45	15	10	10	0
	Bottom	20	0	0	0	0	50	50
Medium (1800 m)	Top	20	0	40	45	5	10	0
	Bottom	20	10	10	0	5	25	50
High (2249 m)	Top	20	0	0	0	20	80	0
	Bottom	20	60	35	5	0	0	0

* The races were classified as lowland (L), midland (M) and highland (H) on the bases of the highest yield obtained at a location (Crossa _et al_., 1990).

A75 - Origin of Northwestern Dent, Persistent Variety of U.S. Corn

A. Forrest Troyer

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La Salle traveled from Kingston, Ontario through Lakes Ontario, Erie, Huron, and Michigan then down the Kankakee, Illinois, and Mississippi Rivers to the Gulf. He claimed all land drained by the Mississippi for France in 1682. Pierre Verendrye and sons explored Dakota and central Canada in 1738. Lewis and Clark went up and down the Missouri River to explore the Northwest Territory and Oregon. They built Fort Mandan and overwintered (1804-1805) across the river from the present site of Bismarck; they obtained corn from the Mandan and Hidatsa Indians. Bismarck was founded in 1872 mainly with German, Scandinavian, Irish and New England immigrants. The railroad from Fargo to Bismarck was completed in 1873.

Bismarck, in 1880, was described as follows: "On the slopes of bare hills with short grass, a number of bleak homes and false store fronts perched like a flock of transient bird ready to wing away at the least disturbance". Oscar H. Will came to Bismarck in 1881. He had worked as a nurseryman in New York with his older brother, W.F. Will, who had served in the Civil War with E.M. fuller --- they kept in touch. Fuller wrote that he needed an assistant nurseryman; Captain Will recommend his younger brother. Will saw the sharp contrast to his New York home and began planting trees and shrubs, first native plants, then favorites from New York. Encouragement inspired other inhabitants; the new waterworks helped establish plantings. Will leased the green house from Fuller in 1884 and started a nursery and seed business. It was first called Will's Pioneer Seed House in 1901. (The present Pioneer Hi-Bred purchased the rights to the Pioneer name in 1959.)

Northwestern Dent was developed and introduced by Will. Bloody Butcher variety was brought to Bismarck by J.W. Burch in 1891 from Bloomington (10 miles north on the White River), Indiana. Will selected 15 or 20 better developed ears from earlier plants before frost killed the rest of Burch's first crop. Will selected for earliness the next two years. Burch then raised a considerable crop of seed. It was offered as Northwestern Dent in 1896 by Will and Quickly became very popular. It was maintained and selected ON THE Will's Seed Co. farm (Atkinson and Wilson 1915).

The Will's Seed Co. farm was in Section 4 of Lincoln Township (now part of Bismarck) in Burleigh County, North Dakota. The land is presently bordered by the Bismarck Expressway on the south and by 10th Street on the east. The Civic Center is near the center of Section 4; the farm lies to the south and to the east. The farm was predominately Havrelon silty clay loam consisting of deep, nearly level, moderately well drained soil that formed on the flood plain along the Missouri River. Available water capacity is high, organic-matter content is low, and fertility is medium. Havrelon is one of the more productive soils in North Dakota.

Burleigh County, North Dakota is part of the Missouri Plateau. Annual precipitation averages q6 to 18" annually with 13 to 15' during the growing season. A moisture deficit occurs from May to September. Average July temperature is 69 to 72°F. Over a 96 year period the high was 114°F and the low -45°F at Bismarck; elevations is 1664 feet. The farm was near the 47th parallel. Natural selection for earliness and for heat and drought tolerance occurred along with human selection for earliness and for yield.

Northwestern Dent is mid-early to early (80RM). It is distinctly earlier than Minnesota 13. Plants grow 4.5 to 6 feet tall. White-cobbed ears are 6 to 8 inches long borne at an average height of 20 inches above the ground. Kernel rows number 10 to 16. The semi-dent kernels are red in color (pericarp) with white or yellow in the indentations.

Northwestern dent was the most popular variety in the northwest—recommended by nine states (ID,MI,MN,MT,ND,SD,UT,WI,WY) in the 1936 USDA Yearbook. Northwestern Dent inbreds were developed at Minnesota (A26, A48, A78, A90, A96, A188, and A509), Montana (D2 and D4) and Wisconsin (CC15, CC16, W83, and W703). Most of the Northwestern Dent in today's hybrids trace back through A509 to A78 and to A48 (aka 64) as A509 derivatives and as one source of earliness for Early Iodent. About %% of present U.S. hybrid corn traces back to Northwestern Dent (Smith et al. 1990) (Troyer 1994).

O.H. Will died in 1917 (influenza epidemic). He was a very productive plant breeeder. His son George F. Will took over the company. G.F. Will was an accomplished anthropologist and author; he wrote Cron for the Northerst and co-authored *Corn Among the Indians of the Upper Missouri* with G.E. Hyde.

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A74 - Diversification of Male Sterile Cytoplasm with the Aid of Embryo Rescue Technique in Inter-Specific Hybridization for Rice

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Introduction

Cytoplasmic male sterility (CMS) has been found to be the most effective genetic tool to develop F_1 rice hybrids (Lin and Yuan, 1980; Virmani et al, 1981). About 95 percent of the commercial hybrids in China and hybrid else where are based on one only cyto-sterility system viz. "WA" source (Virmani, 1990). Any technology based on such narrow genetic base can lead to two kinds of problems viz. (i) restricted adaptability and (ii) genetic vulnerability to sudden outbreaks of diseases and insect pests. The limitations and danger associated with the single source of WA, necessitate therefore diversification of cytoplasmic male sterility not only to sustain the technology but to exploit it across the tropical and subtropical rice growing countries as well.

Methods

1. Inducing new sources of cytoplasmic: with the aid of embryo rescue technique 132 interspecific crosses involving cultivated rice (*O.sativa, O.glaberrima*) and wild species of A genome (*O.rufipogon, O.nivara, O.barthii* and *O.longistaminata*) were effected. Species possessing sterile cytoplasm were detected by reciprocal and sterile F_2 back-cross methods. Combinations exhibiting cytoplasmic genetic interaction for male sterility were chosen for developing usable cytoplasmic male sterile lines by substitution backcrossing.

2. Search for restorer gene sources: for two highly stable and widely adapted CMS lines viz. MS577A and IR64A for which there is no restorer, was made by crossing them respectively with 53 and 15 accessions of wild/weedy species closely related to the cultivated rice to develop iso cytoplasm restorer lines.

Result and Discussion

In all nine CMS lines from six male sterility sources involving sterile cytoplasm of either *O.rufipogon* or *O.nivara* have been developed. Based on the shape and staining pattern of their pollen as well as their nature of reaction to a set of restorers and maintainers of known CMS (WA), they were classified in to the four groups as in the Table 1.

For developing iso-cytoplasmic restorer lines while none of the wild accessions had restorer gene for IR64A, five accessions comprising three *O.rufipogon* (VN2, DRW22016, DRW22017-5) and one each of *O.sativa .f. spotanea* (RPW20001) and *O.glaberrima* (DRGL30030) were found to possess restorer genes for MS577A. Among them an iso-cytoplasmic restorer line based on RPW20001 is promising with strong restoring ability and desiable agronomic characteristics. Study of combinations revealed two dominant genes acting in additive fashion to restorer fertility (table 2).

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Table 1. Characterization of newly identified cytoplasmic male sterile lines.

Source/(CMS line)	Based on pattern of stained pollen or seedset in F_2	Maintainer/restorer reaction: Restorer	Maintainer	Remarks
RPM S1-1 (VN1/V20B,	Gametophytic	?	IRBB7, IR66, IR70, PMS2B, IR62829B	G1* New-Stable
RPM S1-2 (VN1/PMS 2B)	Gametophytic	?	IRBB7, IR66, IR70, PMS2B, IR62829B	G1* New-Stable
RPM S1-3 (VN1/IR70)	Gametophytic	?	IRBB7, IR66, IR70, PMS2B, IR62829B	G1* New-Stable
RPM S1-4 (VN1/IR66)	Gametophytic	?	IRBB7, IR66, IR70, PMS2B, IR62829B	G1* New-Stable
RPM S2 (DRW 21039/IR66)	Gametophytic	?	IR66, IR70, PMS2B, IR62829B	G1 New-Stable
RPM S3 (DRW 21030/PMS 9B)	Stained pollen	IR887	PMS2B, IR62829B	G2 New-?
RPM S4 (DRW 21018/IR66	Sporophytic	?	IR66, IR70, PMS2B, IR62929B	G3 New-?
RPM S5 (RPW 21111/PMS 6B)	Sporophytic	IR887, IR66, IR70	PMS2B, IR62829B	G4 A-non-stable
RPM S6 (RPW 21001/IR62829B)	Sporophytic	IR887	IR62829B	G4 WA-non-stable
WA	Sporophytic	IR887, IR66 IR70, RPW20001	PMS2B, IR62829B	G4 WA-Stable
IR 64A (IR66707A)	Sporophytic	?	Several cultivated varieties	G5-IR64A-Stable
MS577A	Sporophytic (Stained pollen)	RPW20001, VN2 DRW22016, DRW22017-5 DRW30090	Several cultivatied varieties	G6-MS577A-Stable

CMS sources having similar cytoplasm are classified into same group (G*)

Table 2. Relative restoring ability of highly fertile F_2 segregants isolated in different interspecific crosses for MS577A and IR64A (all figures are percentages).

Fertile F_2 segregant	Pushpa A		Mangala		IR64A	
	Stained pollen	Spikelet fertility	Stained pollen	Spikelet fertility	Stained pollen	Spikelet fertility
PushpaA/RPW20001*						
1. Plant $87^{(10)}$	-	-	70	72.3	-	-
2. Plant $87^{(14)}$	-	-	95	81.7	-	-
3. Plant $87^{(15)}$	100	90	97	85.2	5.0	0
PushpaA/DRW22016						
1. Plant $88^{(1)}$	-	-	95	65.0	0	0
2. Plant $88^{(3)}$	96	80	-	-	0	0
Pushpa A/DRGL30090						
1. Plant $89^{(3)}$	92	82.5	-	-	0	0
Pushpa A/DRW22017-5						
1. Plant $90^{(2)}$	85	85	70	35.0	10.0	0
Pushpa A/VN2 (O.rufipogon)						
1. Plant $48^{(1)}$	95	84	-	-	-	-
2. Plant $48^{(3)}$	97	87	90	75.0	0	0
3. Plant $48^{(7)}$	98	83	92	82.0	0	0

* Looking more like a primilive land race.

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ERRATUM:

Please note the following corrected version of the table on p. 155:

Table 1. Ten top-yielding hybrids, their yields and heterosis, and combining abilities of the respective inbreds from a 12X12 diallel cross evaluated at two locations. BP, MP: better-parent, mid-parent; *,: sig. at $p \leq 0.05$, $p \leq 0.01$.**

Hybrid (and inbreds $P_1 \times P_2$)	Grain yield (kg/ha)	Heterosis(%)		SCA effects		GCA effects (kg/ha)
		BP	MP	P_1	P_2	
At Field 2:						
Hy-51 (S-9 x SM5-5)	4763	383	436	1855.6**	304.9**	-40.1
Hy-59 (M-13 x SM5-4)	3941	54	131	962.5*	264.6*	71.0
Hy-20 (SM7-6 x TW-12)	3867	66	122	1050.8**	339.8**	-166.6**
Hy-76 (S-9 x S-2)	3800	277	289	844.5*	304.9**	8.1
Hy-57 (S-2 x SM5-4)	3741	271	289	1019.1**	8.0	71.0
Hy-44 (M-13 x SM5-9)	3733	45	134	1223.3**	264.6*	-397.3**
Hy-43 (S-9 x SM5-9)	3719	277	313	1168.3**	304.9**	-397.3**
Hy-58 (S-9 x SM5-4)	3704	276	289	885.2*	304.9**	71.0
Hy-79 (M-13 x S-9)	3644	42	111	432.3	264.6*	304.9**
Hy-60 (M-5 x SM5-4)	3452	276	295	858.2*	-120.0	71.0
At Share Farm:						
Hy-60 (M-5 x SM5-4)	5948	255	288	1934.0**	-138.6*	130.2*
Hy-59 (M-13 x SM5-4)	5730	117	165	1319.7**	253.4**	130.2*
Hy-58 (S-9 x SM5-4)	5659	237	303	1374.7**	131.8*	130.2*
Hy-45 (M-5 x SM5-9)	5511	198	240	1582.1**	-138.6*	45.0
Hy-73 (S-9 x SM7-11)	5393	314	344	1395.4**	131.8*	-161.9**
Hy-79 (M-13 x S-9)	5378	104	187	970.0**	253.4**	131.8*
Hy-43 (S-9 x SM5-9)	5296	187	260	1100.0**	131.8*	45.0
Hy-53 (M-5 x SM5-5)	5259	215	244	1503.3**	-138.6*	-132.8*
Hy-23 (S-2 x TW-12)	5259	333	372	1400.1**	-108.5	-55.0
Hy-66 (M-5 x SM7-6)	5244	71	135	1934.0**	-138.6*	200.0**

We regret the error.

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