Theor. Appl. Genet. 57, 177-180 (1980)

F_1 Hybrid Versus 32 Selected F_7 Lines Performance of Common Winter Wheat (*Triticum aestivum* ssp. vulgare)

M. Jošt
Department of Genetics and Plant Breeding, Faculty of Agriculture, University of Zagreb, Zagreb (Yugoslavia)

C.F. Hayward
Pioneer Hi-Bred International, Inc., Department of Cereal Seed Breeding, Hutchinson, Kansas (USA)

Summary. One F_1 common wheat hybrid ('Zlatna Dolina' × 'Primépi') which had exhibited significant heterosis in a previous study was compared with 32 F_7 lines selected from the same cross. The yield test was planted in the 1976-77 season at two locations: Zagreb, Yugoslavia (optimal environment) and Hutchinson, Kansas, USA (stress environment). The purpose of this experiment was to determine if a homozygous segregant superior to the F_1 hybrid could be obtained from the same cross combination.

Heading date, plant height, disease incidence, grain yield and its components, protein content, and sedimentation value were examined at Zagreb. Germination, winterhardiness and grain yield were determined at Hutchinson.

At Zagreb, the F_1 hybrid exhibited significant heterosis in grain yield, even though two of the three yield components were intermediate to parent values. Heterotic effects were greater in the stress environment (Hutchinson), mainly due to the poor winterhardiness and lower yield of one parent variety. At Zagreb, grain yield of the F_1 hybrid was significantly better than the best F_7 line. However at Hutchinson, the two leading F_7 lines outyielded the F_1 hybrid, but differences were not significant.

It can be concluded that genes involved in heterosis in the hybrid, 'Zlatna Dolina' × 'Primépi', were not fixed in the homozygous lines selected from the same cross.

Key words: Heterosis – Homozygous segregant – Winter wheat

Introduction

After the big upsurge in hybrid wheat research, most public and several private agencies have curtailed their hybrid wheat research efforts, partially due to the belief that yield gains can be achieved as rapidly by the conventional pure line breeding method (Hayward 1975).

A few genetic investigations have suggested that a large proportion of hybrid vigor, resulting from the complementary and cumulative action of dominant genes, can be fixed by conventional selection methods. It has been reported that hybrid vigor resulting from heterozygosity can be fixed or at least partly substituted by homeologous heterosis. According to Mac Key (1970), homozygotes of tetraploid or hexaploid wheat are able to exhibit homeologous overdominance. If interaction between homeologous loci is as effective as between true homologous loci, a considerable part of the heterosis of an autogamous polyploid might be exploited in a conventional breeding program.

So far, only relatively few studies have compared F_1 hybrids with homozygous segregants and reported yields of pure lines as high as that of the F_1 hybrids from which they were derived; namely, in winter wheat by Winhues (1968), in durum wheat by Amaya et al. (1972), and in spring wheat by Busch et al. (1971) and Cregan and Busch (1978).

Mac Key (1973, 1974) considers that the decisive criterion for hybrid wheat will be whether heterozygosity is sufficiently superior to homozygosity in common wheat. In addition to comparing the F_1 with parental mean, best parent or the best available market variety, it should compete with its own homozygous segregants.

The purpose of this study, in hexaploid common wheat, was to determine if a homozygous segregant(s) superior to the corresponding F_1 hybrid could be obtained.

Materials and Methods

'Zlatna Dolina', a high yielding semidwarf bread wheat cultivar well adapted to Yugoslav conditions, was crossed with 'Primépi', a French conventional height bread wheat. 'Primépi' is known as a

0040-5752/80/0057/0177/$ 1.00

valuable source of fertility restorer genes. The consistent heterotic effect exhibited by this hybrid in previous studies was the basis for selection. In a one year diallel cross experiment (Jošt et al. 1976), heterosis in grain yield per plant (spaced planting) was 120%, and 132% for a four year mean in a top-cross experiment (Jŏst et al. unpubl.).

The F_7 lines for this experiment were selected as follows: in 1972, 1250 F_2 plants were grown and strong selection for short straw was applied. The following year, 133 semidwarf F_2 plants were selected and planted. In subsequent years, visual selection for agronomic characters was continued up to the F_6. In 1976, from 260 F_6 lines grown at Zagreb, the 32 best lines in grain yield per row were selected for this test. A total of 4900 F_1 seeds were produced by emasculation and hand pollination.

Parents, F_1 hybrid and the 32 F_7 lines were planted in a yield test at two locations: (1) Zagreb, Yugoslavia, represented an optimal environment. The seeding rate was 500 seed per m^2. The basic plot of 1 m^2 consisted of two 2.5 m rows, spaced 20 cm apart. Randomized complete block design with four replications was used. The following characters were measured: earliness, plant height, incidence of disease, grain yield and its components, protein content, and sedimentation value. (2) Hutchinson, Kansas, USA, represented a stress environment due to low temperature and moisture stress. Randomized complete block design with four replication and the basic plot area of 3.83 m^2 was used. The seeding rate was 162 seeds per m^2. Germination, winterhardiness and grain yield were determined.

Results

At Zagreb, the 1976-77 growing season deviated from average climatic conditions. A mild, wet winter was followed by a long, cold spring. Excessive vegetative growth resulted from the unusually long growing season. Plant height of all genotypes exceeded the long term average by about 20 cm. However, no lodging was encountered except in the parent variety 'Primépi'. A moderate infestation of powdery mildew and a high incidence of stripe rust were probably the main limiting factors for grain yield in certain wheat lines at Zagreb.

Table 1 presents data of examined characters for the paren, F_1 hybrid, and the high (HL) and low (LL) segregants of the 32 selected genotypes.

The F_1 hybrid headed one day earlier than the early parent. According to Borojević (1966), earliness of a hybrid can serve as an indicator for good combining ability. Earliness is a desirable character for the Zagreb environment and selection pressure resulted in four F_7 lines that were earlier than the F_1 hybrid by one or two days.

Resistance of the F_1 hybrid to powdery mildew was intermediate to parents, while both F_7HL and F_7LL were more susceptible. Both, parents and F_1 hybrid, exhibited good resistance to stripe rust. However, some lines (for example F_7LL) showed complete susceptibility with reduced grain yields. It would appear that each parent carried a different gene(s) for resistance to stripe rust. Because of rare occurrence of the stripe rust attack at Zagreb, there was no selection against this disease.

The F_1 hybrid exhibited significant heterosis in grain yield even though the heterotic effect was only in one yield component – the number of heads per m^2. Two of the three yield components, kernels per head and 1000 kernel weight, were intermediate to parent values. Similar results of the same F_1 hybrid were reported in a recent paper of Jošt et al. (1976). Namely, in crossing parent varieties of very divergent values for certain yield components, the heterotic effect may appear in grain yield of the hybrid even though the yield components have remained intermediate. In this study, 'Zlatna Dolina' with a large number of small kernels per head, crossed with 'Primépi', with low number of very large kernels per head, resulted in the phenomenon of transgressive grain yield increase in the hybrid. According to Mac Key (1974), this type of heterosis may be based on completely independent units of the genetic system, which by themselves might be only intermediate in reaction, as compared to parents. As components, these purely recombinative

Table 1. Heading date, plant height, disease attack, three yield components, grain yield, protein content and sedimentation value of P_1 ('Zlatna Dolina'), P_2 ('Primépi'), F_1 ('Zl. Dolina' X 'Primépi') and the best (F_7HL) and poorest (F_7LL) of 32 F_7 lines selected from the same cross. All grown at Zagreb in 1976/77

Entry	Heading date – May	Plant height (cm)	Disease attack		Yield components			Grain Yield (g/ha)	Protein content %	Sed. value (ccm)
			Powdery mildew 1-9	Stripe rust 1-9	Heads per sq.m	Kernels per head	1000 kernel weight			
P_1	13	95	4	2	563 ab	52.0 a	31.70 c	71.3 b	11.59	26
P_2	18	130	2	1	531 b	30.9 c	51.78 a	52.4 c	12.36	27
F_1	12	130	3	1	608 a	44.8 b	49.88 a	98.5 a	10.87	22
F_7HL	14	105	6	1	569 ab	57.3 a	40.44 b	84.3 b	10.95	21
F_7LL	10	107	4	9	499 b	52.3 a	32.84 c	55.3 c	11.69	21

Values followed by the same letter are not significantly different at 0.01 level based on LSD

units are, however, able to result in heterosis for a complex character of higher hierarchy, owing to their summation effect.

The F_1 hybrid with a grain yield of 98.5 q/ha outyielded the mid- and high-parent by 59% and 38%, respectively (Tables 1, 3). The best homozygous segregant from the same cross, F_7HL, had significantly lower grain yield than the F_1 hybrid.

Frequency distribution for grain yield of selected F_7 lines compared with parents and the F_1 hybrid is shown in Figure 1.

The 1976-77 growing season at Zagreb was unfavorable for good wheat quality characteristics. Protein content and sedimentation value were lower in the F_1 hybrid and F_7HL than either parent or the F_7LL.

At Hutchinson, the 1976-77 growing season was characterized by a dry and cold winter period, a very wet, late spring and early summer (about 270 mm above normal rainfall). A high temperature period at the soft dough stage caused severe kernel shriveling. While soil borne mosaic virus (WSBMV) caused some damage at Hutchinson, ratings were not recorded.

Table 2 presents the data of examined characters of parents, F_1 hybrid and the highest (F_7HL) and lowest (F_7LL) yielding selections from the homozygous segregants. The F_7HL and F_7LL were not the same at Zagreb and Hutchinson.

Table 2. Germination, winter-killing and grain yield of P_1 ('Zlatna Dolina'), P_2 ('Primépi'), F_1 ('Zl. Dolina' × 'Primépi') and the best (F_7 HL) and poorest (F_7 LL) of 32 homozygous segregants from the same cross. All grown at Hutchinson in 1976/77

Entry	Germination %	Winter-killing %	Grain yield (q/ha)
P_1	74.5 b	13.7 a	22.5 b
P_2	44.8 c	76.2 b	8.4 c
F_1	96.4 a	26.2 a	29.7 a
F_7HL	90.0 a	15.0 a	32.3 a
F_7LL	71.4 b	96.0 c	5.4 c

Values followed by the same letter are not significantly different at 0.01 level based on LSD

Table 3. Grain yield of F_1 hybrid expressed in percent of midparent (heterosis), high parent (heterobeltiosis) and high line (HL heterosis) at two test sites

Grain yield in percent of		Zagreb	Hutchinson
Mid parent	(Heterosis)	159d	192d
High parent	(Heterobeltiosis)	138d	132d
High line	(High line heterosis)	117d	92

d = significant at 0.01 level

A surprisingly low seed germination was noted in the parent variety 'Primépi' (44.8%). The F_1 hybrid with 96.4% seed germination was superior to the mid-parent, better parent, and the best homozygous segregant F_7HL.

As these wheats are not adapted to Kansas environment, it was anticipated that winter-killing would be the most serious hazard at Hutchinson. The female parent, 'Zlatna Dolina', and the male parent, 'Primépi', had 13.7 and 76.2% winter-killing, respectively. The F_1 hybrid showed an intermediate value of 26.2% winter-killing while the F_7LL exhibited 96.0% winter-killing. The F_7HL with 90.0% germination and only 15.0% winter-killed plants exhibited the highest grain yield. These data substantiate that winterhardiness was the limiting factor for grain yield at Hutchinson.

The F_1 hybrid with a grain yield of 29.7 q/ha significantly outyielded the mid-parent by 32% (Table 3). Two F_7 lines with the best winterhardiness were numerically better in grain yield than the F_1 hybrid, but differences were not significant.

Frequency distribution for grain yield of selected F_7 lines compared with the F_1 hybrid and corresponding parent varieties is presented in Figure 1.

While the F_1 hybrid has been compared with a limited number of corresponding homozygous lines, we can conclude that genes involved in heterosis in the hybrid, 'Zlatna Dolina' × 'Prinépi', were not fixed in the homozygous lines selected from the same cross.

Discussion

Other investigators have reported results that differed from this study. Busch et al. (1971) compared the performance of three F_1 hybrids with ramdomly derived F_5 lines in three crosses of spring wheat. In each cross there were F_5 lines which performed significantly better than the F_1 hybrid. In this test one F_1 hybrid failed to exceed the yield of its high parent. The two other hybrids outyielded their high parents, but not significantly. Perhaps these results were due to insufficient heterosis present in the three hybrids selected for this experiment. Amaya et al. (1972) examined four crosses of durum wheat. Although grain yield of the F_1 hybrids exceeded their high-yielding parents by an average of about 25%, some F_3 lines from all crosses were not significantly different from their corresponding F_1's. Probably some degree of heterozygosity remained in these F_3 lines of durum wheat and should not be called homozygous segregants or pure lines. Probably the most extensive research in this field has been reported by Cregan and Busch (1978). These researchers compared grain yield of the F_1 versus F_5 lines of 28 hybrid populations of spring wheat. The F_1 yields, compared to the high parent, ranged from 83 to 141%. The

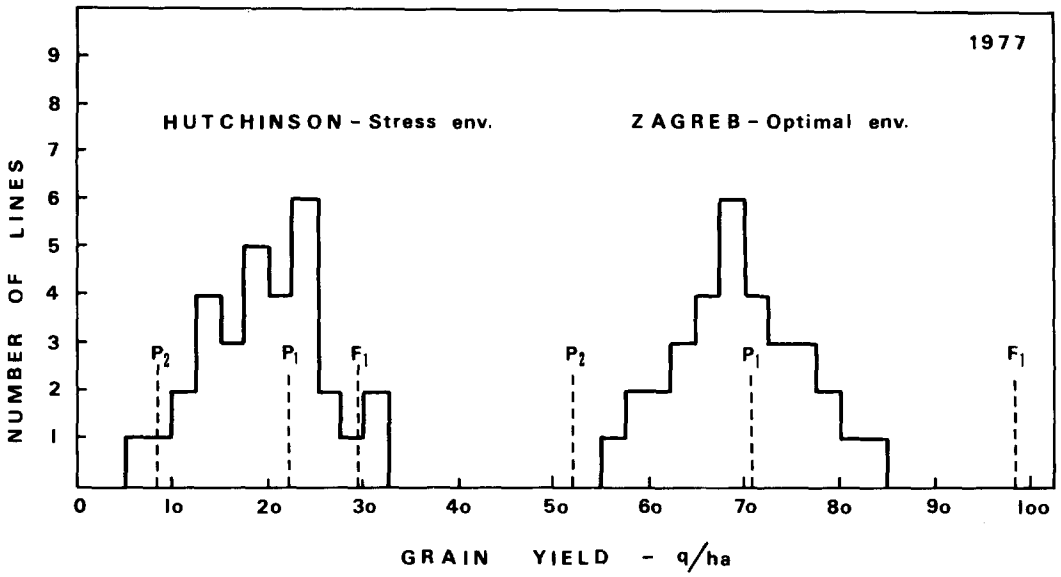

Fig. 1. Frequency distribution for grain yield of selected F_7 lines from cross 'Zlatna Dolina' × 'Primépi', in comparison with F_1, P_1, P_2, all grown at Zagreb (optimal environment) and Hutchinson (stress environment)

three highest yielding entries were F_1's, even though the average HL and F_1 were similar in all crosses.

The superiority of either F_1 hybrids or the best homozygous segregants from the same cross remains contradictory. Data that show F_1 hybrid superiority do not eliminate the possibility that the best homozygous segregant(s) was lost in the selection process. On the other hand, higher yielding segregants might be expected when minimal heterosis is expressed in the F_1 hybrid counterpart. Grain yield heterosis is not always evident in the F_1 hybrid, varying greatly with the genotypes of the inbred parents.

It would appear that more comparative studies are needed. Such studies should include newer hybrids that express maximum heterosis and higher populations of homozygous segregants. Hybrids exhibiting the highest percent heterosis, and especially heterobeltiosis, might serve as good indicators of crosses that should produce the best homozygous segregants for the conventional breeder.

Acknowledgements

This research was supported in part by research grants from IREX and Pioneer Hi-Bred International, Inc. The authors express appreciation to the Pioneer wheat breeders who assisted in conducting the field experiments.

Literature

Arnaldo Amaya, A.; Busch, R.H.; Lebsock, K.L. (1972): Estimates of genetic effects of heading date, plant height and grain yield in durum wheat. Crop Sci. 12, 478-481

Borojević, S. (1966): Combining ability in wheat crosses. Proc. 2nd Int. Wheat Genetic Symp – Lund, Hereditas 2, 102-118

Busch, R.H.; Lucken, K.A.; Frohberg, R.C. (1971): F_1 hybrids versus random F_5 line performance and estimates of genetic effects in spring wheat. Crop Sci. 11, 357-361

Cregan, P.B.; Busch, R.H. (1978): Heterosis, inbreeding, and line performance in crosses of adapted spring wheats. Crop Sci. 18, 247-251

Hayward, C.F. (1975): The status and prospects for hybrid winter wheat. Proc. 2nd Int. Winter Wheat Conference, Zagreb. pp. 84-104

Jošt, M.; Hrust, V.; Milohnić, J. (1976): Hybrid vigour in a twelve-parent diallel cross of common winter wheat, in Hybrid wheat – Research in Yugoslavia, Poljoprivredna znanstvena smotra 38 (48), 131-140

Mac Key, J. (1970): Significance of mating systems for chromosomes and gametes in polyploids. Hereditas 66, 165-176

Mac Key, J. (1973): Possibility and potential of hybrid wheat. Cereal Res. Comm. 1 (3), 50-52

Mac Key, J. (1974): Genetic and evolutionary principles of heterosis. Proc. 7th Congr. Eucarpia, Budapest

Winhues, E. (1968): Long term yield analyses of heterosis in wheat and barley: Variability of heterosis, fixation of heterosis. Euphytica Suppl. 1, 49-62

Received February 3, 1980
Communicated by J. Mac Key

Dr. M. Jošt
Faculty of Agriculture
University of Zagreb
Šimunska c. 25
41000 Zagreb (Yugoslavia)

Dr. C.F. Hayward
Pioneer Hi-Bred International, Inc.
Department of Cereal Seed Breeding
Route 2
Hutchinson, Kansas 67501 (USA)