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HEXAPLOID TRITICALE

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The underlying idea is to obtain a new cereal with the milling and baking qualities of wheat combined with the drought resistence and the ability of rye to grow on poor soils. Such a cereal would be of great value to the Spanish regions were rye or a rye-wheat mixture called "tranquillón" are the main crops.

As a working hypothesis we assume that the number of 56 chromosomes in the Triticale obtained from the cross between common wheat and ryewould be too high and therefore the attainment of 42 chromosome Triticale from crosses between tetraploid wheat and rye would give a polyploid level that could be the optimum for this cereal.

My intention now is to give some data obtained during the last eight years' work of the hexaploid Triticale program at the Estación Experimental de Aula Dei, Zaragoza, Spain.

SOURCE

Our 42-chromosome Triticale have been obtained from crosses between a tetraploid wheat as seed parent and a population or inbred line of rye as pollen parent.

As seed parent we have used indigenous as well as foreing tetraploid wheats from the species Triticum durum, T. turgidum, T.polonicum, T. carthlicum, T. dicoccum, T. dicoccoides and T. timopheevi.

As pollen parent we used at the beginning of our work populations of cultivated rye and later on inbred rye lines selected for vigor and self fertility. We are following the idea of Professor Müntzing that with this selection in the allogamous parent the sterility and lack of vigor due to the presence of the rye genome can be avoided in the autogamous amphiploid.

Some of the inbred lines actually used in our crosses show, in

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their seventh generation of inbreeding, good vigor and high sel-fertility even under bag isolation, reaching values higher than a 90 per cent seed setting.

It may be of interest to point out that the inbred lines isolated in a population cultivated in the S.E. of Spain show the highest self-fertility and also greater uniformity of this character through the seven years of selfing. In table 1 two of the best lines obtained in other Spanish regions are compared with four lines from Villarrobledo (S.E. of Spain) that show the continuity and - high value of their seed setting under selfing.

The pooled results of our crosses between tetraploid wheats and rye made during the years 1950-1957 are shown in table 2. (The figure in brackets is the number of amphiploids lost by freezing damage during the exceptional winter 1955-1956).

The major differences in crossability with rye occur between individual cross combinations. Although the maximun crossability values have been obtained for a Triticum durum genotype, this is not in my opinion an indication of greater crossability of the species as such. It is highly probable that if a greater number of genotypes of the other six tetraploid Triticum species were tried, some of them would give crossability values as high or higher than those found within T. durum.

No relation has been found between self-fertility of the inbred rye lines and their ability to pollinize the tetraploid -- wheats. There are indications, however, about the existence of differences between rye lines regarding such ability.

The results of Pissarev and Vinogradova (1944) confirmed by Hall (1954) indicate an increase in the crossability of rye to hexaploid wheat plants obtained.

TABLE 1.- Successive self-fertilities (per cent) in various inbred rye lines from Spanish populations.

Line nº	I_7	I_6	I_5	I_4	I_3	I_2	Origin
5	48,6	60,7	25,6	20,1	3,1	3,7	Granada (S.)
14	82,6	66,4	78,1	59,9	70,4	67,4	Villarrobledo (S.E.)
25	78,6	75,4	77,4	31,3	38,7	62,0	Villarrobledo (S.E.)
33	91,1	61,5	93,9	47,0	58,3	54,7	Villarrobledo (S.E.)
48	84,7	74,1	91,1	93,9	67,2	47,9	Villarrobledo (S.E.)
75	78,8	75,9	39,9	26,5	16,9	15,4	Biota (N.)

by grafting wheat embryos on rye endosperm. We have tried the same technique with tetraploid wheats using two durum genetypes supposed to be of high and low crossability to rye according to the results of previous years. The two controls were plants obtained after grafting durum wheat embryos on their own endosperms and were compared with the plants obtained by grafting on rye endosperms. All the pollinations were made with the same I_5 rye line. Our results (table 3) seem to indicate a decreasing effect of the graft on the crossability with rye. Howewer, our experiment is too limited to assert that the grafting of tetraploid wheat embryos on rye endosperm is not efficient enough to increase its crossability with rye.

One of the authors already mentioned, in a later publication (Pissarev 1956) indicates that the F_1 between two hexaploid wheats is usually of greater crossability to rye, than both its parents. We have also compared the crossability of several F_1 progenies with that of their parents (table 4) using always the same I_5 rye line. Again our results seem tobe in contradiction to those of previous authors. From 1,347 flowers of the parents pollinated with the rye line, we obtained 12 hybrid plants, but not a single one from the 1,457 F_1 flowers pollinated. Here again I must admit that the experiment is not big enough to affirm that heterozygosity in durum wheat decrease its crossability with rye.

TABLE 2 - Crossability of 4n wheat species with cultivated rye

Species	Nº of Genotypes		Total Number of Pollinated Flowers	Total Number of F_1 Plants	Crossability Percent			Number of F1 Types Giving the Amphiploid
	Crossed	Giving F_1			Average	Maximum for a Wheat Genotype	Maximum for a Cross Combination	
T. durum	40	22	15,215	136	0,9	15,3	36,7	7 (4 lost)
T. turgidum	13	7	5,527	19	0,3	1,0	5,3	0
T. Polonicum	3	1	874	3	0,3	0,7	4,5	0
T. carthlicum	4	3	3,376	6	0,2	0,6	5,0	0
T. dicoccum	6	3	1,847	8	0,4	5,4	10,7	3
T. dicoccoides	3	1	1,261	2	0,2	0,3	2,5	1
T. timopheevi	3	2	1,904	4	0,2	0,6	1,6	0
	72	39	30,004	178	0,6	15,3	36,7	11 (4 lost)

TABLE 3 - Effect of grafting wheat embryos on rye endosperm on crossability to rye.

Graft: Embryo / Endosperm	Nº of Pollinated Flowers	Nº of F_1 Plants
Durum L.C. / Durum L. C.	780	2
Durum H.C. / Durum H. C.	528	3
Total Wheat / Wheat	1,308	5
Durum L.C. / Rye	659	1
Durum H.C. / Rye	780	0
Total Weat / Rye	1,439	1

L.C. = Low crossability
H.C. = High crossability

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TABLE 4 - Crossability to rye of F_1 progenies and their parents in durum wheat

	F_1	
(161 - 0) Enano de Jaén	(200-0)	D(195 - 1)
	(230-0)	
(178 - 1) Senatore Capelli..	(411-0)	...Andalucia 344-57(219-8)
	(199-0)	
		..Andalucia 344-56(204-0)
(191 - 1) Lebrija	(200-0)	
	(217-0)	...Andalucia 344-58(199-1)

Total parents .... (1347 - 12)

Total F_1 .... (1457 - 0)

In the brackets the first figure gives the number of pollinated floers and the second the number of F_1 plants obtained.

CHROMOSOME DOUBLING OF THE F_1 PLANTS

For the doubling of the chromosome number of the intergeneric hybrids, a colchicine technique recommended by Bell (1950) has been applied. One to three tillers are cut back when the F_1 plants have from four to eight tillers. These are then capped with an inverted glass phial filled with 0.2 to 0.3 per cent colchicine solution for 72 hours. The technique proved to be effective in producing amphiploids. Out of 150 plants treated, 69 have produced fertile **ears** or ear sectors, thus giving an efficiency of 46 per cent.

MORPHOLOGICAL AND PHYSIOLOGICAL CHARACTERS

In the descriptions that follow, only the first three 42-chromosome Triticale types obtained have been used. These three Triticales come from three different wheat species: Triticum durum, T. dicoccum and T. dicoccoides.

Morphological and physiological traits are given in tables 5 to 7, comparing the amphiploids with their wheat and rye parents. All the amphiploids look much more like the wheat than like the rye parent.

From table 5 can be seen that the anthocyanin colors, when present in the wheat parent, are manifested in the amphiploid. The neck hairiness from the rye parent is always present in the Triticale, and in some cases, with greater intensity than in the rye. The characteristics of rachis-fracture and glume-covering of the kernel from dicoccum and dicoccoides wheats, behave in a different way in the amphiploid, as this shows naked grain similar to the rye-parent and rachis-fracture like the wheat one.

In table 6 the averages of certain morphological traits are given. These averages were obtained from 100 measurements in plants taken at random.

Plant height of Triticale is always greater than in its wheat parent, and in Triticale dicoccoides it is also greater than in its rye parent. Spikelet number per ear is between the two, and the tillering, measured by the ear number per mature plant, is smaller in Triticale than in both parents. Internode length is grea-

TABLE 5 - Morphological traits of hexaploid TRITICALE and their parents

	Triticale Durum			Triticale Dicoccum			Triticale Dicoccoides		
	Triticum	Triticale	Secale	Triticum	Triticale	Secale	Triticum	Triticale	Secale
Habit of Growth	Erect	Erect	Prostrate	Erect	Intermediate	Prostrate	Intermediate	Intermediate	Intermediate
Auricle Hairiness	Smooth	Smooth	Smooth	Strongly-hairy	Hairy	Smooth	Strongly hairy	Strongly-hairy	Smooth
Auricle Color .	Purple	Purple	Pale Purple	Purple	Purple	Green	Purple	Purple	Green
Hairiness of Upper Node	Smooth	Smooth	Smooth	Hairy	Smooth	Smooth	Smooth	Smooth	Smooth
Neck Hairiness.	Smooth	Strongly-hairy	Hairy	Smooth	Hairy	Hairy	Smooth	Strongly-hairy	Strongly hairy
Rachis Strength	Tough	Tough	Tough	Dicocc. Type	Dicocc. Type	Tough	Dicocc. Type	Dicocc. Type	Tough
Glume Covering of Kernel	Naked	Naked	Naked	Covered	Naked	Naked	Covered	Naked	Naked

TABLE 6 - Averages of 100 measurements in TRITICALES and their parents

	Triticale Durum			Triticale Dicoccum			Triticale Dicoccoides		
	Triticum	Triticale	Secale	Triticum	Triticale	Secale	Triticum	Triticale	Secale
Plant Height, cm.	113.8 ± 4.4	134.3 ± 1.4	135.4 ± 2.8	123.9 ± 7.2	126.3 ± 1.7	146.6 ± 8.9	131.4 ± 2.8	154.9 ± 1.7	138.8 ± 0.1
Number of Ears per Plant	8.9 ± 0.2	6.0 ± 0.1	12.6 ± 0.3	12.6 ± 1.5	8.1 ± 0.2	14.8 ± 1.4	12.2 ± 0.5	9.8 ± 0.2	13.3 ± 0.7
Number of Spikelets per Ear	20.5 ± 0.1	27.2 ± 0.2	43.4 ± 0.5	24.5 ± 0.2	29.2 ± 0.5	38.7 ± 0.7	23.7 ± 0.2	31.7 ± 0.2	37.3 ± 0.4
Rachis Lenght, mm.	79.8 ± 1.7	127.7 ± 3.9	130.0 ± 5.4	110.2 ± 4.5	146.7 ± 9.4	136.0 ± 18.8	91.3 ± 3.7	150.6 ± 4.3	107.4 ± 4.0
Lenght of Sterile Segment of Rachis mm.	5.8 ± 0.1	3.2 ± 0.3	3.7 ± 0.2	10.5 ± 0.3	10.3 ± 0.7	2.8 ± 0.2	5.9 ± 0.1	7.5 ± 0.3	2.7 ± 0.2
Internode Lenght of Rachis, mm. ..	3.69 ± 0.02	4.52 ± 0.02	2.92 ± 0.01	4.04 ± 0.01	4.66 ± 0.01	3.39 ± 0.01	3.55 ± 0.01	4.54 ± 0.01	2.83 ± 0.01
Grain Weight per Plant, gr.	22.0 ± 3.9	13.9 ± 4.0	18.8 ± 1.2	27.2 ± 6.4	10.0 ± 0.5	12.9 ± 2.8	17.7 ± 2.0	29.7 ± 2.3	8.3 ± 0.3
1.000 Kernels - Weight, gr.	57.9 ± 3.0	56.3 ± 1.1	29.7 ± 0.3	52.0 ± 2.1	40.5 ± 1.0	22.1 ± 0.7	34.6 ± 0.4	58.1 ± 0.6	16.1 ± 0.2

TABLE 7 - Disease resistances, earliness and fertility in TRITICALES and their parents

	Triticale Durum			Triticale Dicoccum			Triticale Dicoccoides		
	Triticum	Triticale	Secale	Triticum	Triticale	Secale	Triticum	Triticale	Secale
Resistance to:									
Erysiphe graminis	MR	R	R	MR	R	R	S	MR	R
Puccinia dispersa	0	0	VS	0	0	VS	0	0	S
Puccinia glumarum	R	R	0	R	R	0	VS	R	0
Puccinia rubigo-vera	MS	R	0	MS	MS	0	MS	R	0
Puccinia graminis	R	0	S	VS	MS	VS	S	MS	MS
Date of Earing	May 7	May 7	April 22	May 13	May 14	April 22	May 7	May 7	April 22
Date of Maturity	July 2	July 8	June 28	July 2	July 8	July 2	July 2	July 8	July 2
Maximum Flower Fertility	132%	110%	93%	152%	74%	77%	177%	103%	73%
Minimum Flower Fertility	48%	5%	8%	0%	1%	1%	49%	39%	30%
Average Flower Fertility	105%	75%	60%	87%	52%	49%	97%	85%	55%

M = Moderately; V = Very; R = Resistant; S = Susceptible; 0 = No visible infection

ter in Triticale.

Grain weight per plant is higher in Triticale dicoccoides than in its parents, but smaller in the other two Triticales. A thousand kernel weight resulted between the two in Triticale durum and dicoccum, and bigger than in their parents in dicoccoides.

Summing up we can say that the three Triticale types studied show good vegetative vigor, a kind of intergenomic vegetative heterosis, when compared with their parents.

The most unfavorable character in the three Triticale types is the bad quality of the grain, which is very shriveled and lacks density. The shriveling will result in a low flour yield.

Table 7 summarizes the results of three years of observations about disease resistances, earliness and flower fertility. It is interesting to point out that the Triticale usually shows, to a given disease, the same degree of resistance as the more resistant parent.

The Triticales are later maturing than their parents and their average fertility is half way between the two.

The durum and dicoccum Triticales are autogamous, but the dicoccoides type shows a great tendency towards allogamy, as proved by the high proportion of spontaneous hybrids that appear in the progenies of plots of this Triticale grown in close vicinity with other types.

CYTOLOGY

Cytological observations were made on the number of univalents and the chiasma frequency at the first meiotic metaphase. The results of the observations are given in table 8 including, for the purpose of comparison, a 56-chromosome Triticale obtained from a dry-land variety of common Spanish wheat and one of our rye lines. From this table, I should like to emphasize two points:

Firstly, the average number of univalents per P.M.C. is of the same order-between 1.9 and 2.3- for the hexaploid and for the octoploid Triticale; and in second place, adding together the average number of chiasmata per P.M.C. of the two parents, and subtracting from this total the average number of chiasmata of the corresponding amphiploid, figures of the same order -between 4.5 and 5.2- are obtained for the hexaploid and octoploid Triticales.

TABLE 8 - Frequency of univalents and number of chiasmata at first metaphase in Triticale and their parents

	2n	Nº of PMC Observed	Per cent of PMC with the Given Number of Univalents							Average Nº. of Univalents per PMC	Average Nº of Xta per PMC
			0	2	4	6	8	10	12		
Secale	14	300	95.3	4.7	...	...	...	...	...	0.1	12.6 = a
Triticale durum	42	300	21.0	53.7	16.7	7.3	1.0	0.3	...	2.3	35.1 = b
Triticum	28	100	100.0	...	...	...	...	...	...	0.0	27.0 = c
											a+c-b = 4.5
Secale	14	400	98.2	1.8	...	...	...	...	...	0.04	13.2 = a
Triticale dicoccum	42	300	31.3	40.3	20.0	4.7	3.0	0.7	...	2.2	36.4 = b
Triticum	28	100	100.0	...	...	...	...	...	...	0.0	27.7 = c
											a+c-b = 4.5
Secale	14	200	100.0	...	...	...	...	...	...	0.0	13.5 = a
Triticale dicoccoides	42	200	31.5	43.5	43.5	19.5	5.5	...	...	2.0	35.7 = b
Triticum	28	100	100.0	...	...	...	...	...	...	0.0	27.4 = c
											a+c-b = 5.2
Secale	14	200	96.5	3.5	...	...	...	...	...	...	13.0 = a
Triticale aestivum	56	200	40.0	34.5	18.0		2.0	0.5	0.5	1.9	48.6 = b
Triticum	42	100	98.0	2.0	...	...	...	...	...	0.04	40.5 = c
											a+c-b = 4.9

This is in accordance with the observations of Professor Müntzing that the univalents in Triticale are predominantly rye chromosomes. It is also and indication that the mechanism interfering with the formation of seven bivalents from the 14 rye chromosomes, works with the same strength in the amphiploid with two or three wheat genomes being present.

BREEDING

It as already been mentioned, that the most unfavorable character in the hexaploid Triticale is the bad formation of the grain, which is always shriveled. This shriveling appears in the late stages of seed formation, the milky and waxy stages of this formation being normal. Boron treatments of the plants, as recommended by Pissarev (1956) as a means of improving the grain quality, have not been effective with our material.

With the Triticale types already obtained, we have started a breeding program with the main objective of obtaining good grain quality.

The first crosses between different types of hexaploid Triticale were made last year with an average of 32 per cent success (F_1 plants) between durum types. The F_1 generations grown this year, show very little heterosis. Next year we hope to obtain segregates with better grain quality.

Some crosses have also been made between hexaploid and octaploid Triticale, with a 46 per cent success in the direction octoploid x hexaploid, and only 0.9 per cent in the reciprocal cross. Crosses between hexaploid Triticale and common wheat have also been made this year, but figures will not be given until next year.

Mutagenic treatments have been given to samples of dry seeds of Triticale durum. X-ray doses between 5,000r and 20,000r were given in the laboratories of the Swedish Seed Association at Svalöf, Sweden. As preliminary information, I can only give the percentages of surviving plants in relation to control (table 9). The figures are comparable with those usually obtained with hexaploid wheat (cf. MacKey 1954).

TABLE 9 - Relative per cent of surviving plants of TRITICALE DURUM with different irradiation doses

	Per cent
Control	100.0
5,000 r	101.2
10,000 r	62,9
15,000 r	13,2
20,000 r	9.1

CONCLUSION

In my opinion hexaploid Triticale is a raw material that will be necessary to breed, but for the moment we can't say if the practical results we are looking for will be reached in the near future.

In the meantime, hexaploid Triticale can be used to transfer desirable rye genes into common wheat, by crossing. Such transferability is quite possible, and my experience in this regard with the "Terminillo" wheat will be the subject of a report to the next International Genetics Congress in Montreal.

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DISCUSSION

SHEBESKI: I would like to ask Dr. Sánchez-Monge how many scientists are working in Spain on the hexaploid Triticales.

SANCHEZ-MONGE: I'm the only one.

UNRAU: I think Professor Shebeski could rest his case here because if there were more people working on hexaploid Triticales we would be faced with greater problems of over-production than we have now.

MUNTZING: I think the results obtained by Sánchez-Monge and here at Winnipeg by Professor Shebeski are actually very encouraging for the poor people trying to make something out of Triticales. This material is quite promising I must say and if you can get rid of this seed shrivelling which is the main weakness you will have a new and perhaps important species of cultivated plant. We therefore wish you success in your future attempts to improve seed qualities and yield in this important material

UNRAU: I should like to know exactly by what means Dr. Sánchez-Monge expects to transfer genes from the rye complement to the wheat complement? Does he visualize that it is going to be a case of gene interchange based on homologous sections that will result in homologous pairing and therefore a normal type of gene interchange?.

SANCHEZ-MONGE: I would say that in some cases exceptional gene interchange happens. I. have one example with "Terminillo" wheat which, as you probably know, was obtained by an Italian breeder, Strampelli, crossing Rieti wheat with rye and then backcrossing with Rieti and he obtained a wheat which is very suitable to our mountain conditions in Spain. The differences between Terminillo wheat and Rieti wheat can be explained as an introgression of rye genes into the Rieti wheat. The transfer of rye genes into wheat does really happen but how it happens I do not know.

SHANDS: I would like to ask a question regarding the fertility and seed set in later generations of your hexaploid Triticales.

SANCHEZ-MONGE: Probably you have seen in one of the tables that the fertility of the hexaploid Triticales is between the individual rye lines selected and the wheat. Some of the plants selected have a higher fertility than the average, of course, and the number of instances of this is quite small.
The highest fertility I would say would be about 80 or 90 per cent in the present material.

MUNTZING: It is quite evident that this hexaploid Triticale has higher fertility on the average than the octoploid Triticales. I think you have seen that, Dr. Sánchez-Monge.

SANCHEZ-MONGE: This is probably due to the selection of the inbred rye lines.

RILEY: I would like to ask Dr. Sánchez-Monge what he thinks the agricultural position of this new crop would be. Someone earlier asked me this questionWoult it occupy more or less marginal positions or would it occupy existing areas of cereal cultivation?.

SANCHEZ-MONGE: The main object of our work is to get a plant that will occupy marginal areas of crop production. If I can get some types with good grain quality I am sure that they can occupy the rye lands of Spain.

MACKEY: I understand that the material that you discussed in your paper is to be considered more or less as raw material for future breeding work. I am interested to Know ehether your continued program will include straight crosses only or convergent crosses as well. I would guess that the latter method would be very helpful. By convergent crossing the various genes will be brought together in a melting pot, from which well-balanced genotypes are more likely to come out.

SANCHEZ-MONGE: Yes, you are right.

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