MONOSOMIC ANALYSIS IN WHEAT *

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1. INTRODUCTION

CERTAIN aneuploids, particularly nullisomics, monosomics and trisomics, find a place in plant breeding because of their value in locating genes on different chromosomes. The method is particularly useful in polyploids, where monosomics and nullisomics are viable. The use of monosomic series has made it possible to locate both genes with major and those with minor effects. The value of aneuploid analysis in determining the mode of inheritance of different characters, particularly awning and growth habit in some varieties of bread wheat has already been demonstrated (Unrau, 1950; Heyne and Livers, 1953; Sears, 1953, 1954; Sikka *et al.*, 1956; Kuspira and Unrau, 1957; Tsunewaki and Jenkins, 1961; Tsunewaki, 1966, etc.). The present studies were designed to study the genetics of these characters in the wheat variety Yaqui-53.

2. MATERIALS AND METHODS

Yaqui-53 is a derivative of New Thatcher $\times$ Kenya. It is short tipped, medium height and early in maturity. Chinese Spring is "hooded beardless", medium-tall and matures late. Using monosomics as the female parent, each of the 21 monosomic lines of Chinese Spring was crossed with Yaqui-53. A cross between normal Chinese Spring and Yaqui-53 was also attempted. The chromosome number of all the F_1 hybrids was determined in *p.m.c.'s* and seeds from cytologically confirmed monosomics were collected separately. F_2 progenies of all the 21 monosomic lines were screened for awnedness and classified as fully awned or half awned, tipped or awnless. The first two and latter two types were grouped together for statistical analyses. The heading dates of all the plants were noted and mean values obtained when a minimum of 75 per cent. of plants eared in each F_2 progeny. The mean heading days of all the 21 monosomic F_2 lines were compared with disomic hybrids and the departure in each case was recorded separately. Analysis of variance followed by a "t" test was applied in order to find the difference between monosomic and disomic line and also to mark the "critical" monosomic lines.

3. OBSERVATIONS

Growth habit

The heading dates of different monosomic crosses, the normal disomic cross and both the parents, Yaqui-53, and Chinese Spring are shown in table 1. The mean heading dates of the normal cross were

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compared with other monosomic crosses and the deviation observed is summarised in table 1. The observations indicated that Yaqui-53 is early in earing (92 days) and Chinese Spring late by 11-12 days. Most of the monosomic lines were intermediate in earing. F_1 's monosomics for chromosome 5D (XVIII) showed later heading and in mono-5B (V) cross earing was hastened by 6-7 days. Analyses of

TABLE 1
Days to heading
(Chinese monosomics $\times$ Yaqui-53)

Material	Total No. of plants	% of plants eared	Mean No. of days to heading	Deviation from disomic cross
Chinese Spring	203	75.72	104.4	...
Yaqui-53	239	84.17	92.2	...
Chinese Normal $\times$ Yaqui-53	167	78.44	99.6	Disomic cross
1A $\times$ Yaqui-53	150	82.67	101.4	-1.8
2A $\times$ Yaqui-53	162	82.10	102.2	-2.6
3A $\times$ Yaqui-53	150	86.00	101.4	-1.8
4A $\times$ Yaqui-53	157	76.43	102.6	-3.0
5A $\times$ Yaqui-53	147	76.87	102.4	-1.8
6A $\times$ Yaqui-53	151	82.11	101.3	-1.7
7A $\times$ Yaqui-53	157	80.89	99.0	+0.6
1B $\times$ Yaqui-53	151	75.50	102.3	-2.7
2B $\times$ Yaqui-53	107	73.65	99.0	+0.6
3B $\times$ Yaqui-53	150	82.00	102.4	-2.8
4B $\times$ Yaqui-53	164	78.05	101.6	-2.0
5B $\times$ Yaqui-53	136	91.18	93.0	+6.6*
6B $\times$ Yaqui-53	170	74.94	102.1	-2.5
7B $\times$ Yaqui-53	146	80.14	99.3	+0.3
1D $\times$ Yaqui-53	157	78.34	101.4	-1.8
2D $\times$ Yaqui-53	159	80.50	100.8	-1.2
3D $\times$ Yaqui-53	162	82.00	100.1	-0.5
4D $\times$ Yaqui-53	150	81.33	99.2	+0.4
5D $\times$ Yaqui-53	160	72.63	106.4	-6.8*
6D $\times$ Yaqui-53	146	86.98	100.6	-1.0
7D $\times$ Yaqui-53	156	81.41	100.6	-1.0

* "Critical" lines showing maximum deviation. Significant at 1 per cent. level.
(-) indicates later heading and (+) earlier heading when compared to disomic.

the data from F_2 observations indicated the presence of some factors for early maturity on chromosome 5B (V) of Yaqui-53. The heading date was significantly delayed in mono-5D. The delay in heading in mono-5D was maximum, here the plants were still green, while in other lines they were ready for harvesting.

Awning

Yaqui-53 is an apically tipped variety which shows "tipped 1" type of awn expression, according to the classification of Watkins and Ellerton (1940). In all the monosomic lines, F_1 plants were almost awnless, except mono-4B and 6B, where somewhat more tipping was present. The F_2 population, grown from seeds collected from F_1

monosomics, showed a complete range of awn types, with fully awned, half-awned, awnletted and awnless plants. A similar type of segregation was observed in the normal cross of Yaqui-53 and Chinese Spring. The number of awned plants was high in monosomic line 4B and 6B.

TABLE 2
Genetics of awning
(Chinese monosomics $\times$ Yaqui-53)
 F_2

Material	Total No. of plants	Tipped types	Awned types	χ^2 (Mode: 15:1)	P value
Chinese Normal $\times$ Yaqui-53	167	158	9	0.2112	0.70-0.50
1A $\times$ Yaqui-53	150	141	9	0.0160	0.90-0.80
2A $\times$ Yaqui-53	162	153	9	0.1333	0.80-0.70
3A $\times$ Yaqui-53	150	139	11	0.3005	0.70-0.50
4A $\times$ Yaqui-53	157	149	8	0.3571	0.70-0.50
5A $\times$ Yaqui-53	147	147	...	...	All tipped types*
6A $\times$ Yaqui-53	151	142	9	0.0216	0.90-0.80
7A $\times$ Yaqui-53	157	149	8	0.3571	0.70-0.50
1B $\times$ Yaqui-53	151	143	8	0.2336	0.70-0.50
2B $\times$ Yaqui-53	167	159	8	0.6071	0.50-0.30
3B $\times$ Yaqui-53	150	143	7	0.6418	0.50-0.30
4B $\times$ Yaqui-53	164	139	25	22.6406	*
5B $\times$ Yaqui-53	136	127	9	0.03137	0.90-0.80
6B $\times$ Yaqui-53	170	132	38	75.2329	*
7B $\times$ Yaqui-53	146	139	7	0.5279	0.70-0.50
1D $\times$ Yaqui-53	157	147	10	0.0038	0.98-0.95
2D $\times$ Yaqui-53	159	139	20	10.8684	*
3D $\times$ Yaqui-53	149	142	7	0.6071	0.50-0.30
4D $\times$ Yaqui-53	150	141	9	0.0160	0.90-0.80
5D $\times$ Yaqui-53	160	151	9	0.1067	0.70-0.50
6D $\times$ Yaqui-53	146	135	11	0.4110	0.70-0.50
7D $\times$ Yaqui-53	156	148	8	0.3350	0.70-0.50

* Monosomic lines showing high deviation from the normal cross.

Not a single awned plant was recorded in monosomic line 5A. Different segregation ratios were tried, but only 15 awnless: 1 awned gave a satisfactory fit. The data thus obtained are presented in table 2.

4. DISCUSSION

Growth habit

Among the 21 F_2 monosomic lines of Yaqui-53, mono-5D (XVIII) showed significant later heading than the disomic. As reviewed by Tsunewaki and Jenkins (1961, 1962) the growth habit of common wheat is mainly controlled by genes belonging to three allelic series Sg_1 , Sg_2 and Sg_3 located on chromosome 5D (XVIII), 5A (IX) and 2A (XIII). But Chapman and Riley (1966) have redesignated Chromosome XIII as 2B and II as 2A. All winter varieties carry winter habit alleles Sg_1 , Sg_2 and Sg_3 . They suggested that some late spring varieties carry the semi-winter habit alleles Sg_1^c , Sg_2^c and Sg_3 .

Yaqui-53 is an early maturing variety and Chinese Spring is semi-winter type. Among the 21 F_2 lines of Yaqui-53 cross, mono-5D (XVIII) showed significant later heading than the disomic. The delay in heading caused by chromosome 5D (XVIII) of Yaqui-53 in Chinese Spring could be due to presence of gene for lateness, which might be ineffective in hemizygous condition or due to the absence of semi-winter gene Sg_1^c of Chinese Spring. The significant early heading date observed in 5B (V) cross could be due to presence of dominant gene for spring habit and this may be epistatic in its action (table 1).

The haploid genotype proposed by Tsunewaki (1966) for variety Chinese Spring is: Sg_1^c , Sg_2^c and Sg_3 . Taking into consideration this genotype, normal segregation pattern and deviation in critical monosomic lines, it is evident that Chinese Spring differs from Yaqui-53 in two major genes of Spring growth habit, located on chromosome 5B and 5D. The analyses of F_1 and F_2 data indicated that even hemizygous condition in 5B cross did not cause any delay in heading. If this gene on chromosome 5B of Yaqui-53 is designated as Sg_5 , then the probable haploid genotype for growth habit will be: Sg_1 (5D), Sg_2^c (5A), Sg_3 (2A), Sg_5 (5B). It is interesting to note that all the three members of homoeologous group No. 5 (5A, 5B, 5D) affect time of maturity, though with different intensity. Driscoll and Jensen (1964) also reported that chromosome 5B of selection 5075-aB-2B-21 possesses a gene for earliness. Sears (1944, 1954) reported gene for earliness on chromosome 5B, but it is evident that the gene carried by Yaqui-53 on the same chromosome is more effective than the gene present in Chinese Spring.

Kuspira and Unrau (1957) suggested that two types of earliness genes are apparently operating (a) those differentiating summer and winter growth habit as on chromosome 2A (XIII) and 5D (XVIII), and (b) those that modify the expression of genes to a greater or lesser extent. A chromosome 5B and 3A of Thatcher, Hope and Timstein carry genes for hastening earliness. Thatcher is one of the donor parents in Yaqui-53, hence it is reasonable to assume that the same gene on chromosome 5B is influencing the maturity. Another important point which emerges from the data is that the growth habit of bread wheat is governed by more than three loci. Critical monosomic analysis in more varieties of winter, semi-winter and spring types of wheat may further confirm the present results.

Awning

From the extensive studies of Watkins and Ellerton (1940) using conventional methods, and those of Sears (1944) using monosomic and nullisomic techniques, it is now clear that awn development in wheat is controlled by a series of recessive genes, designated a_1 , a_2 , a_3 , etc., controlling awn promotion, and a set of dominant awn inhibitors B_1 , B_2 and H_a located respectively in chromosome 5A, 6B and 4B. Heyne and Livers (1953) have proposed a series of A genes to explain awn

development in different wheat varieties. A single recessive gene a in the homozygous condition theoretically could produce full awns, if not inhibited by epistatic genes.

In the present monosomic studies, the F_2 disomic populations, in crosses between Chinese Spring and Yaqui-53, segregated in a 15:1 ratio of awnless or awnletted to awned and half bearded. However, the F_2 population derived from mono-4B and 6B F_1 plants gave comparatively higher proportion of awned-plants, which indicated that tipped variety Yaqui-53 carries recessive alleles of awn inhibitors located on chromosome 4B (H_d) and 6B (B_2). There was no half-bearded or fully bearded plant in the progeny of mono-5A F_1 plants, which indicates that Yaqui-53 carries a dominant awn inhibitory B_1 on this chromosome (table 2). The similarity in non-existence of awns, both in mono-5A and disomic F_1 plants, suggests the dominant nature of the B_1 factor.

Unrau (1950), O'Mara (1948) and Knott (1959) ascribed awnlettedness of Hymar, Marquis and Gabo respectively to the B_1 gene. Campbell and McGinnis (1958) reported that Redman carries another dominant awn inhibitor on chromosome 1D (XVII), in addition to B_1 . Okamoto (1960) has identified one awn suppressor on chromosome 5B. Tsunewaki and Jenkins (1961) through monosomic and conventional gene analysis in common wheat, reported that the awnlettedness of wheat varieties Elgin and Jones Fife is controlled by the B_1 gene in chromosome 5A. They also obtained similar results in mono-4B and 6B cross where maximum deviation was recorded.

Excess of awned plants observed in 2D (XX) cross, allows an inference that some gene for awn development may be present. The digenic segregation obtained in the normal cross, does not explain the observations recorded in monosomic analysis, where four lines (4B, 5A, 6B and 2D) showed significant departure from the expected ratio. It is probable that there are four factor pairs involved in segregation of awn types, which has not expressed due to complex interaction and small progeny size, so a tetragenic F_2 ratio of 240:16 has changed to 15:1. Hence the proposed genotype for awning for Yaqui-53 will be:

$$\begin{array}{ll} \text{Gene} & \rightarrow hd\ hd : B_1\ B_1 : b_2\ b_2 : a_2\ a_2 \\ \text{Chromosome} & \rightarrow 4B\ (\text{VIII}) : 5A\ (\text{IX}) : 6B\ (\text{X}) : 2D\ (\text{XX}) \end{array}$$

5. SUMMARY

1. Yaqui-53 as the male parent, was crossed with all the 21 identified monosomic lines of Chinese Spring.

2. Delayed heading in the mono-5D (XVIII) hybrid and significantly early heading in the mono-5B (V) hybrid indicated the presence of the recessive gene sg_1 and dominant gene Sg_5 for growth habit on these chromosomes respectively.

3. The genotype for growth habit in Yaqui-53 may be: sg_1 (5D), Sg_2^c (5A), Sg_3 (2A) and Sg_5 (5B).

4. In addition to the recessive alleles of, or absence of, the awn inhibitors H_a and B_2 on chromosome, 4B (VIII) and 6B (X), Yaqui-53 has the dominant awn inhibitor B_1 and recessive awn promoter a_2 located on chromosome 5A (IX) and 2D (XX).

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