THE IDENTIFICATION OF FOUR NEW MONOSOMICS IN COMMON OATS *AVENA SATIVA* L.

BY

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ABSTRACT

Eight monosomic lines produced by X-irradiation and one derived spontaneously from a population of common oats of variety Garry were studied to identify the missing chromosome. Enlarged photomicrographs of well-spread mitotic figures of each line provided the basis for critical analysis of the missing chromosome. The chromosomes were cut out from the photographs, matched and mounted on metric paper. A total of four new monosomic lines were added to those already identified by McGinnis in the variety Garry.

Line R 176-376, deficient for chromosome 14, exhibited a distinct phenotype, i.e., white striations in the leaves of seedlings which were more pronounced on nullisomic plants than on monosomics. In addition they were subintermediate fatuoid and had abaxial curling of leaves. A hemizygous ineffective dominant gene (or genes) appeared to condition white striations on leaves, while the genes for subintermediate fatuoid and abaxial curling of leaves acted as complete dominants. One plant monotelosomic for the short arm was similar to nullisomics suggesting that genes conditioning all characteristics were located on the long arm of chromosome 14.

Sister lines R 252-452, -453, -456, and -457 were

deficient for the same chromosome 14, but lines -452, -453, and -456 all had a heterozygous deletion in the upper part of the short arm of chromosome 19, while -457 was homozygous for the deletion. The missing part of the short arm had an effect on the fatuoid expression when chromosome-14 was lost.

R 524-575 was deficient for chromosome 6. Hybrids between this line and R 176-376, had 19 pairs and two univalents. The two univalents were not distributed randomly but were oriented in close proximity to each other, indicating homoeology is probably shared by these two chromosomes.

Line R 364-535, deficient for chromosome 18, displayed a kinky neck phenotype when it was nullisomic. A high frequency of monotelosomics for the long arm seemed to be specific for this line. It is suggested that the gene or genes for normal neck are on the long arm of chromosome 18 since these monotelosomics appeared normal.

In line R 355-508, the critical chromosome was number 4; nullisomics were late in flowering and extremely slow-growing.

R 222-413, R 263-477, and 21-139-136 were all identified as mono-15 and R 267-492 was monosomic-21. Both these lines had been obtained prior to this study.

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INTRODUCTION

Common oats is an allohexaploid comprised of the A, C, and D genomes (24). Because of the polyploid nature of this species, the deficiency of a single chromosome and even a pair of chromosomes is tolerated, so that it should be possible to produce a series of all 21 monosomics. Such a series has been completed by Sears (26) in common wheat which is similar to oats in chromosome number and ploidy level. The value of this monosomic series has been widely recognized.

It is reasonable to assume that a monosomic series in common oats would prove equally useful in cytogenetic studies. Two main sources were found productive by Sears, namely the progeny of a haploid plant pollinated with normal pollen and the progeny of a partially asynaptic nullisomic (3B). Unfortunately such sources have not been so productive in common oats. Only one haploid has been obtained thus far (19) and asynaptic nullisomics are sterile both when selfed and crossed.

As pointed out by Rajhathy (22) the idiogram of hexaploid oats shows considerable variation in chromosome size and in position of centromere, and many of the different monosomics can be identified from karyotype studies. Thus lack of progress in establishing a complete monosomic series has been mainly due to the lack of a promising

source of aneuploids. Recently a large number of monosomics have been produced at this institution by X-irradiation. The present study was conducted on a number of these monosomics in order to identify them.

LITERATURE REVIEW

SPONTANEOUS OCCURRENCE OF ANEUPLOIDS

Huskins (8) in 1927 was the first one to observe a monosomic plant in oats which was characterized by a fatuoid phenotype. He classified the oat fatuoids into three series α, β, r (9). The heterozygous fatuoid of series β was associated with a deficiency for the "C" chromosome. Normal types and heterozygous types were found to segregate in ratios of 1:5 to 1:10 plus a few nullisomics which were homozygous fatuoids. The 40-chromosome fatuoids had irregular meiosis and were dwarf and sterile.

Nishiyama (17,18) reported that monosomic heterozygous fatuoids segregated into normal types, heterozygotes and dwarf, asynaptic homozygotes. In the progeny of heterozygous fatuoids, some off-types were found which were monotelosomic for either the long arm or the short arm of the submedian "C" chromosome. Plants monotelosomic for the short arm were heterozygous fatuoids, semidwarf, asynaptic and highly sterile. Plants monotelosomic for the long arm were homozygous fatuoids, dwarf, synaptic and partially fertile. Nishiyama concluded that the gene or genes for fatuoid characteristics are located on the short arm and the gene or genes for synapsis are on the long arm of the "C" chromosome.

Philp (20) was able to demonstrate that chlorophyll deficiency is associated with a nullisomic condition. In the advanced generation of a cross between Avena sativa and Avena fatua, one family segregated 1 green: 6 albino seedlings. The green plants were monosomic, whereas the albinos were all nullisomics.

Philp (21) reported on a nullisomic with a narrow leaf width which was found in the progeny of the same interspecific cross between Avena sativa and Avena fatua. Measurements and cytological observations showed that seedlings whose leaf width was less than 3 mm had 40 chromosomes and the others had 41 chromosomes. The ratio was approximately 1 broad: 2 narrow. This indicated that a gene for normal leaf width is located on this chromosome.

McGinnis and Taylor (15) showed that albinism in an intervarietal cross of Avena sativa resulted from the loss of a whole chromosome pair. Monosomic and disomic plants were green. In the progeny of selfed monosomics, a high frequency of nullisomic plants resulted (63.9%) indicating that the deficient pollen grains underwent little or no certation and competed successfully in fertilization. They identified the chromosome as the shortest one of the complement, namely chromosome 21, on the basis of the idiogram prepared by Rajhathy (22). An albino plant monotelosomic for the short arm was later isolated which

indicated that the gene for chlorophyll production is located on the long arm of this chromosome (16).

McGinnis and Andrews (4) identified a second chromosome involved in chlorophyll production. The nullisomic plants derived from a selfed monosomic segregated in a ratio of 3 green: 1 albino. This meant the gene constitution of the monosomic plant was VvV-. The chromosome carrying the gene for chlorophyll production was found to be the second shortest one, namely chromosome 15. One albino was monotelosomic for the short arm making it possible to locate the gene for chlorophyll production on the long arm of this chromosome also.

Joshi and Howard (10) noted that meiosis was not completely regular in Avena sativa, homologous chromosomes occasionally failing to form a bivalent. Riley and Kimber (25) checked the chromosome numbers of 631 seedlings of the variety Sun II, and found seven plants with 41 chromosomes and one with 34 chromosomes. This represented a frequency of spontaneous aneuploids of 1.3%. They suggested that the extraction of a whole monosomic set by selecting spontaneous monosomics might be possible in the cultivated oat. McGinnis (13) in an attempt to produce an aneuploid series in hexaploid oats looked for spontaneous aneuploids in the variety Garry. Out of 4,023 seedlings, he found 24 aneuploids comprised of 2 nullisomics, 17 monosomics, and

5 trisomics. This represented a frequency of spontaneous aneuploids of 0.6%.

In 1963 Hacker and Riley(6) obtained 6 nullisomics, 40 monosomics and 4 trisomics from 3,453 seedlings of the variety Sun II, a frequency of about 1.2%. In a study of the 40 monosomics, Hacker and Riley (7) grouped them into 13 distinct classes based on morphology of their nullisomic progeny and karyotype differences. Three categories of asynaptic nullisomics were also reported.

Lafever and Patterson (11) found a male sterile oat plant in a sib line of Clintland 60, which was analyzed later to be due to a nullisomic condition. From crosses of the nullisomic line with disomics, monosomic F_1 hybrids were obtained. Univalent transmission rate in F_1 hybrids was similar in both the male and female, about 6%. No certation effect for the 20-chromosome gametes was detected.

Gauthier and McGinnis (5) studied a spontaneous monosomic of Garry oats, which exhibited a kinky panicle neck. This character was exaggerated in the nullisomic condition. The chromosome involved was identified as chromosome 20 on the basis of the standard karyotype of Rajhathy (22). Two plants monotelosomic for the short arm exhibiting the exaggerated kinkiness of the nullisomics suggested that the long arm carried a gene for normal neck.

INDUCED ANEUPLOIDS

(a) X-irradiation

Costa-Rodrigues (4) facilitated the production of monosomics by X-irradiating young oat panicles at a dose of 300 r. He obtained 20 monosomics out of 279 progeny analysed. Such a high frequency of monosomics (7.2%) indicated that irradiation is an efficient method of inducing them. McGinnis (1962, unpublished) irradiated the variety Garry and obtained 41 monosomics out of 506 progeny analysed (8.1%). Costa-Rodrigues (4) suggested that X-irradiation induces a break in the two chromatids of a chromosome which by illegitimate reunion would form a dicentric chromosome. Such a chromosome is eventually lost in subsequent chromosome divisions.

In view of the success realized by the earlier investigations, a project to determine the most efficient level of X-irradiation was conducted by Andrews and McGinnis (1). Preflowering panicles of the varieties Garry and Rodney of Avena sativa were X-irradiated at 75 r, 150 r, 300 r, and 600 r. They found the frequency of aneuploids increased with the level of irradiation. The 600 r treatment produced the most aneuploids, but the greatest degree of chromosome damage as well. As a result the monosomic frequency was not increased above that obtained from the

300 r dose. The 150 r treatment produced fewer aneuploids than the higher doses, but all were normal monosomics. It was concluded that the most effective level was from 150 r to 300 r. A total of 53 monosomics were produced in Garry and 60 in Rodney by this method.

Rajhathy and Dyck (23) using low doses of X-irradiation to treat preflowering panicles of oats, found 15.5% aneuploids from irradiated panicles. They suggested the use of X-irradiation is the most efficient way to produce oat monosomics.

Chang and Sadanaga (3) obtained six monosomics (A to F) in the variety Cherokee by X-irradiating at 600 r. The breeding behaviour, morphology, karyotype, and intercrossing results were studied. They failed to differentiate the 6 monosomes by karyotype analysis. However, morphologically, monosomes C and F were obviously different from others, while A, B, D, and E differed less obviously as far as morphology was concerned.

(b) Haploids

Rajhathy and Dyck (23) attempted to screen haploids from a large population of common oats. From 672,000 seedlings in three oat varieties they found 148 twins but no haploid was found.

In a similar study in Kanota, a variety of Avena

byzantina which produced a high frequency of twin seedlings, Nishiyama (19) found a haploid. By pollinating the haploid with normal pollen, six monosomic lines were obtained.

(c) Interspecific Hybridization

Rajhathy and Dyck (23) found that late generations of backcrossed pentaploid hybrids produce a high frequency of aneuploids. The authors suggested that because of the high degree of heterozygosity and heterogeneity in these lines, this method is unsatisfactory. In addition, since the A genome is common to all species of Avena, theoretically only 14 different monosomics could be produced.

(d) Transmission Rate

The production and maintenance of monosomic lines depends largely on the behaviour of the univalent chromosomes. Lin (12) carried out an investigation of the influence of genotype and environment on univalent transmission in two monosomics, mono-15 and mono-21 of Avena sativa. It was shown that when meiosis and fertilization occurred under the lowest temperature level tested (50°F), the influence of seed source and variety on the univalent transmission rate of three different lines of mono-21 was not obvious, but at 60, 70, and 80°F the transmission rate showed a positive difference among them. The difference was especially manifest at 80°F. In general the monosomic

lines obtained from X-irradiation had a higher transmission rate than the same monosomics obtained spontaneously.

MATERIALS AND METHODS

The variety Garry was developed at the Canada Department of Agriculture Research station, Winnipeg, Manitoba, from the cross Victoria X (Hajira X Banner) X Victory. This variety was distributed widely in Manitoba and North Eastern United States.

The monosomic lines used in this study were produced by X-irradiation at a rate of 300 r (McGinnis, 1962, unpublished). Karyotype analysis was conducted on eight of them in order to identify the deficient chromosome. In addition, one monosomic, 21-139-156, obtained spontaneously was also studied. These monosomics were grown in a growth cabinet in 1962 and in the field in 1963 and 1964. The irradiated monosomic lines employed are as follows:

Monosomic	Origin
R 176-376	Garry, X-irradiation 300 r (McGinnis, 1962, unpublished)
R 222-413	"
R 252-452	"
-453	
-456	
-457	
R 263-477	"
R 267-492	"
R 355-508	"
R 364-535	"
R 524-575	"
21-139-156	Garry, Spontaneous (McGinnis, 1961)

Seeds of each monosomic line were treated with Arason, put in plastic containers in vermiculite saturated with water