CYTOLOGICAL STUDY OF HYBRIDS OF *SORGHUM HALEPENSE* (L.) PERS.[1]

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Hybrid combinations of cytoplasmic-genetic, male-sterile varieties of cultivated diploid sorghum, namely Combine Kafir-60, Dwarf Redlan, Martin, Redlan and Wheatland, with tetraploid *S. halepense* were studied for chromosome number and associations. Results showed a range of 0-22% male-sterile triploids and 78-100% tetraploids with 0-7% male fertility. Complete and semi-asynaptic cells were observed in Dwarf Redlan X *S. halepense* and Redlan X *S. halepense*. Syncytes were observed in all hybrid combinations ranging from 12 to 40% of the plants examined and the chromosome numbers varied including $2n = 60$, 80, 120, 150, and 160. These were considered to be fusion syncytes.

Price (1) used the term "syncytes" for polyploid microsporocytes which he observed in F_1 hybrids of Saccharum species. A high frequency of polyploid microsporocytes in F_1 hybrids of Sorghum species was observed by Endrizzi (2), Hadley (3), and McClure (4). They found a higher proportion of tetraploid than triploid F_1 hybrids in crosses between diploid sorghum (*Sorghum bicolor* L., Moench, the common sorghum previously known as *S. vulgare*) and tetraploid sorghum (*S. halepense* L., Pers.). Casady and Anderson (5) studied caryopsis development and mature F_1 hybrids of diploid and tetraploid sorghums. From the chromosome associations, they concluded that *S. halepense* was probably an autotetraploid of some variety of *S. bicolor*. Duara and Stebbins (6) saw less quadrivalent pairing and were of the opinion that *S. halepense* originated as a segmental allopolyploid containing two genomes derived from *S. bicolor* and two genomes derived from some related species with chromosomes partly homologous to those of *S. bicolor*. Bhatti, Endrizzi, and Reeves (7) suggested that *S. halepense* was established as a result of the spontaneous doubling of a natural hybrid between *S. bicolor* and *S. virgatum*, since they observed rhizomes in both *S. virgatum* and its F_1 hybrids with common sorghum. Mouftah and Smith (8) studied the cytological behavior of hybrids of *S. bicolor* X *S. virgatum* and bicolor-virgatum X *S. halepense*. They concluded that the high frequency of bivalents and quadrivalents, which suggested a high degree of similarity between the two chromosome complements of *S. halepense* and those of the 40 chromosome bicolor-virgatum hybrid, should prove that *S. bicolor* and *S. virgatum* were diploid progenitors of *S. halepense*.

This report deals with the chromosome numbers of about 80 hybrids involving cytoplasmic-genetic male-sterile diploid sorghum and tetraploid *S. halepense* and their cytological behavior.

METHODS

Studied were F_1 generation hybrids involving diploid cytoplasmic-genetic male-sterile varieties of grain sorghum, namely Combine Kafir-60, Dwarf Redlan, Martin, Redlan, and Wheatland, as female parents and tetraploid *S. halepense* as male parent. Cytological observations were made of acetocarmine-stained microsporocytes.

RESULTS AND DISCUSSION

The combination Wheatland X *S. halepense* yielded only tetraploid F_1 hybrids, while F_1 hybrids from all other combinations were both triploids and tetraploids (Table 1).

Triploids with chromosome numbers of $2n = 30$ were all male-sterile, mostly with laggards in Anaphase I (Fig. 3) and some produced syncytes having chromosome numbers of $2n = 60$ (Fig. 7) and $2n = 150$. The range of chromosome associations for triploids showed 0 - 6.0 univalents, 6.0 - 15.0 bivalents, 0 - 2.0 trivalents, and 0 - 2.0 quadrivalents.

In comparing these results for triploid hybrids with those obtained from an earlier

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study of hybrids between common sorghums and *S. almum* by Sengupta and Weibel (9), it was observed that no triploids occurred with Martin in that study, while none occurred with Wheatland in the present study. Also the frequency of bivalent pairing was higher in hybrids with *S. halepense* than with *S. almum*. This would seem to indicate either slightly more homology between common sorghum chromosomes and *S. halepense* chromosomes than between common sorghum chromosomes and *S. almum* chromosomes, or some difference in the genetic control of pairing.

The tetraploids were mostly male-sterile, but a few were male-fertile, with fertility ranging from 0 to 7.1%. Anaphase I was mostly normal (Fig. 4), but some had laggards (Fig. 5). Chromosome associations for tetraploids showed ranges of 0 - 40.0 univalents, 0 - 20.0 bivalents, 0 - 4.0 trivalents, 0 - 5.0 quadrivalents, and very rarely a sexivalent. Hybrid combinations of Wheatland and Dwarf Redlan showed 2 univalents, 15 bivalents, and 2 quadrivalents (Fig. 1), and 10 bivalents and 5 quadrivalents (Fig. 2), respectively. Hybrid combinations with Combine Kafir-60, Martin, and Redlan showed generally similar types of chromosome associations. One completely asynaptic cell with 40 univalents (Fig. 6), and semiasynaptic cells were observed in each of two hybrid combinations of Dwarf Redlan and Redlan. Syncytes with varying chromosome numbers were observed in all hybrid combinations. Examples can be seen in Figure 8 with a chromosome number of $2n = 80$, in Figure 9 with a chromosome number of approximately $2n = 160$, and in Figure 10 with a chromosome number of approximately $2n = 120$.

In the present study, one hybrid combination, namely Martin X *S. halepense*, showed one cell with one sexivalent. The occurrence of sexivalent chromosomes in hybrids of *S. bicolor* X *S. virgatum* and bicolor-virgatum X *S. halepense* was reported by Mouftah and Smith (8). Sengupta and Weibel (9) did not show any sexivalent chromosomes in hybrids of *S. bicolor* X *S. almum*. Endrizzi (2), however, reported 0.01 sexivalent chromosome associations in one cell of a hybrid combination of Kafir X *S. almum*. Hadley (3)

TABLE 1. *Chromosome associations and fertility of hybrids between cytoplasmic-genetic male-sterile sorghum and tetraploid* Sorghum halepense.

Female parent: common sorghum var.	No. hybrids	Ploidy	Average chromosome association per cell and range: I	II	III	IV	V	VI	Total plants (%): Tri-ploid	Tetra-ploid	Male fertile	Asyn-aptic	Syn-cytes	Tetra-ploids male-fertile (%)
Combine Kafir-60	12	4x	0.7	17.2	0.1	1.2	0	0	20	80	0	0	20	0.0
			0-4	12-20	0-1	0-3	0	0						
	3	3x	2.2	12.6	0.3	0.4	0	0						
			0-6	10-15	0-2	0-2	0	0						
Dwarf Redlan	14	4x	1.3	17.0	0.3	0.8	0	0	22.2	77.8	5.6	11.1	16.7	7.1
			0-40	0-20	0-4	0-5	0	0						
	4	3x	1.1	12.0	0.3	1.0	0	0						
			0-4	6-15	0-2	0-2	0	0						
Martin	13	4x	1.9	17.2	0.1	0.8	0	.01	7.1	92.9	0	0	28.6	0.0
			0-8	12-20	0-2	0-4	0	0-1						
	1	3x	2.0	13.0	0.7	0	0	0						
			1-3	12-14	0-1	0	0	0						
Redlan	15	4x	1.2	17.4	0.1	0.9	0	0	11.8	88.2	5.9	5.9	11.8	6.7
			0-24	5-20	0-2	0-3	0	0						
	2	3x	0.8	13.4	0	0.6	0	0						
			0-6	12-15	0	0-1	0	0						
Wheatland	15	4x	0.9	18.1	0.1	0.7	0	0	0	100	6.7	0	40	6.7
			0-4	12-20	0-4	0-4	0	0						

found one hybrid between a cytoplasmic-genetic male-sterile line and Israel johnsongrass to be either asynaptic or desynaptic. In this hybrid, syncytes of varying chromosome numbers, $2n = 60, 90, 120, 240$, and 480, and chromosome associations of numerous II's, III's, IV's, V's and VI's rarely were observed. In the present investigation of the hybrids of *S. halepense,* the syncytes were more frequent and more bivalent pairing was observed as compared to the hybrids of *S. almum.* In this study, the syncytes observed had chromosome numbers of $2n = 60, 80, 120, 150$, and 160. These were considered to be fusion syncytes, *i.e.,* fusion of microsporocytes or proto-microsporocytes in any combination. The nuclear components of different cells could be seen in large syncytes (Figs. 11 and 12). Hadley's (3) finding of 90 chromosome cells could be explained under this perspective.

More irregularity of Anaphase I in hybrids of diploid sorghum and *S. halepense* than in hybrids of diploid sorghum and *S. almum* (9) was observed. Male fertility was comparatively low. In the hybrid combinations of Martin and Combine Kafir-60, male fertility was observed to be *nil.* All these facts confirmed the views of other workers. Endrizzi and Morgan (10) concluded that *S. bicolor* and *S. almum* were more closely related in chromosome constitution to one another than either was to *S. halepense.* Doggett (11) considered that *S. almum,* being a segregate from the hybrids of diploid sorghum and ancient tetraploid *S. halepense,* inherited the high seed set properties (presumably accumulated mutations) of *S. halepense.* The chromosome associations, particularly more bivalent pairing, some quadrivalent, and, occasionally, sexivalent pairing in hybrids of *S. halepense* agreed to some extent with the analysis done by Mouftah and Smith (8). They proposed an affinity of *S. halepense* for one diploid progenitor, namely *S. virgatum,* as did Duara and Stebbins (6). These workers suggested that *S. halepense* originated as a segmental allopolyploid from *S. bicolor* and another diploid progenitor.

In the present investigation of hybrids of *S. halepense,* the syncytes were more frequent and more bivalent pairing was

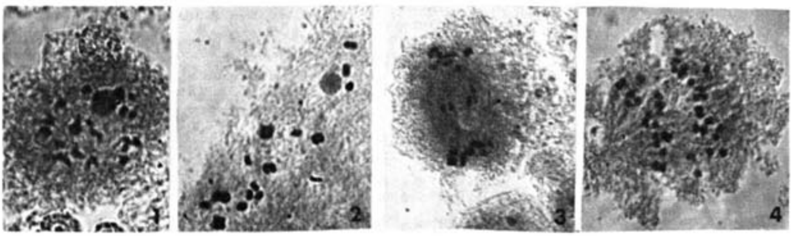

FIGURE 1. Diakinesis with 2 univalents, 15 bivalents and 2 tetravalents in hybrid of cultivated diploid sorghum var. Wheatland X *S. halepense.*

FIGURE 2. Late diakinesis with chromosome association 10 bivalents and 5 tetravalents in hybrid of cultivated sorghum var. Dwarf Redlan X *S. halepense.*

FIGURE 3. Anaphase I with chromosome $2n = 30$ showing 5 laggard bivalents in hybrid of cultivated sorghum var. Combine Kafir-60 X *S. halepense.*

FIGURE 4. Anaphase I with chromosome $2n = 40$ in hybrid of cultivated sorghum var. CK-60 X *S. halepense.*

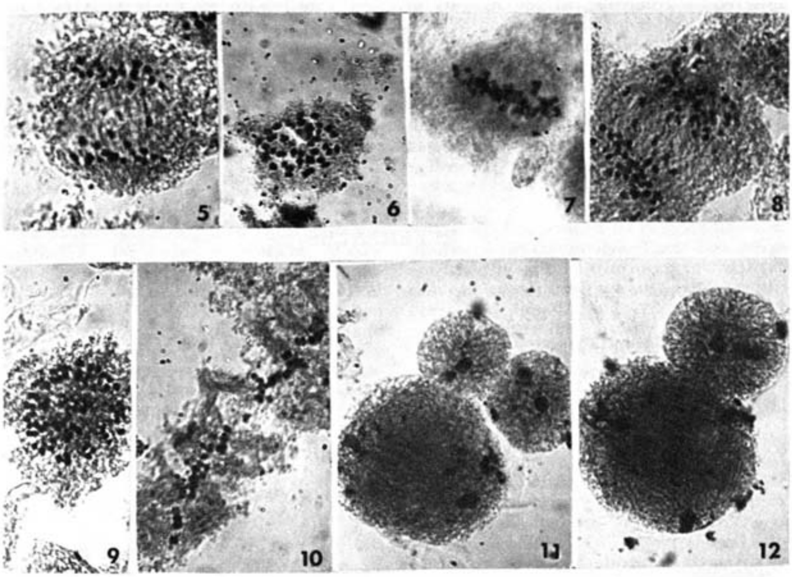

FIGURE 5. Anaphase I with chromosome $2n = 40$ showing laggards in hybrid of cultivated sorghum var. Wheatland X *S. halepense.*

FIGURE 6. Asynaptic cell with 40 univalents in hybrid of cultivated sorghum var. Dwarf Redlan X *S. halepense.*

FIGURE 7. Syncyte with chromosome $2n = 60$ at metaphase in hybrid of cultivated sorghum var. CK-60 X *S. halepense.*

FIGURE 8. Syncyte with chromosome $2n = 80$ at Anaphase I in hybrid of cultivated sorghum var. Wheatland X *S. halepense.*

FIGURE 9. Syncyte with chromosome $2n = 160$ (approximately) at metaphase (polar view) in hybrid of cultivated sorghum var. Dwarf Redlan X *S. halepense.*

FIGURE 10. Syncyte with chromosome $2n = 120$ (approximately) at metaphase in hybrid of cultivated sorghum var. Wheatland X *S. halepense.*

FIGURES 11 and 12. Same hybrid as in Fig. 10 showing one large syncyte with premeiotic fusion of two cells and two normal microsporocytes (Fig. 11) and one larger syncyte with premeiotic fusion of three cells and one normal microsporocyte (Fig. 12).

observed as compared to the hybrids of *S. almum*. The hybrid combination Wheatland X *S. halepense* had 100% tetraploid plants and the highest percentage of plants with syncytes. The hybrid combinations of Dwarf Redlan and Combine Kafir-60 showed the highest percentage of triploids and an intermediate percentage of syncytes. Dwarf Redlan had the highest percentage of plants with asynaptic cells and male fertility. The incidence of asynaptic cells with syncytes in certain balanced proportions may favor higher male fertility and seed fertility. This may be comparable to the hybrids of *S. almum*, where male fertility and seed fertility was much higher and could indicate more chromosome homology.

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