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

S. P. Sengupta and D. E. Weibel

Department of Agronomy, Oklahoma State University, Stillwater, Oklahoma

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. Syn- 
cytes 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 F1 hybrids of Saccharum species. A high frequency of polyploid microsporocytes in F1 hybrids of Sorghum species was observed by Endrizzi (2), Hadley (3), and McClure (4). They found a higher proportion of tetraploid than triploid F1 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 F1 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 F1 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.

METHODS

Studied were F1 generation hybrids involving diploid cytoplasmic-genetic male-sterile diploid sorghum and tetraploid S. halepense and their cytological behavior.

RESULTS AND DISCUSSION

The combination Wheatland X S. halepense yielded only tetraploid F1 hybrids, while F1 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 synecytes 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 1 Journal article 2165 of the Agricultural Experiment Station, Oklahoma State University, Stillwater, Oklahoma.

study of hybrids between common sorghums and \textit{S. altum} 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 \textit{S. halepense} than with \textit{S. altum}. This would seem to indicate either slightly more homology between common sorghum chromosomes and \textit{S. halepense} chromosomes than between common sorghum chromosomes and \textit{S. altum} 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 \(\times\) \textit{S. halepense}, showed one cell with one sexivalent. The occurrence of sexivalent chromosomes in hybrids of \textit{S. bicolor} \(\times\) \textit{S. virgatum} and \textit{bicolor-virgatum} \(\times\) \textit{S. halepense} was reported by Mouftah and Smith (8). Sengupta and Weibel (9) did not show any sexivalent chromosomes in hybrids of \textit{S. bicolor} \(\times\) \textit{S. altum}. Endrizzi (2), however, reported 0.01 sexivalent chromosome associations in one cell of a hybrid combination of Kafir \(\times\) \textit{S. altum}. Hadley (3)

\begin{table}[h!]
\centering
\caption{Chromosome associations and fertility of hybrids between cytoplasmic-genetic male-sterile sorghum and tetraploid Sorghum halepense.}
\begin{tabular}{|c|c|c|c|c|c|c|c|c|c|c|c|}
\hline
Female parent: common sorghum var. & No. hybrids & Ploidy & Average chromosome association per cell and range & Total plants (\%) & Tetraploids male-fertile (\%) \\
\hline
Combine Kafir-60 & 12 & 4x & 0.7 & 17.2 & 0.1 & 1.2 & 0 & 0 & 20 & 80 & 0 & 0 & 20 & 0.0 \\
& 3 & 3x & 2.2 & 12.6 & 0.3 & 0.4 & 0 & 0 & 0 & 0 & 0 & 0 & 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 \\
& 4 & 3x & 1.1 & 12.0 & 0.3 & 1.0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
Martin & 13 & 4x & 1.9 & 17.2 & 0.1 & 0.8 & 0 & 0 & 7.1 & 92.9 & 0 & 0 & 28.6 & 0.0 \\
& 1 & 3x & 2.0 & 13.9 & 0.7 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
Redlan & 15 & 4x & 1.2 & 17.4 & 0.1 & 0.9 & 0 & 0 & 1.8 & 88.2 & 5.9 & 5.9 & 11.8 & 6.7 \\
& 2 & 3x & 0.8 & 13.4 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
Wheatland & 15 & 4x & 0.9 & 18.1 & 0.1 & 0.7 & 0 & 0 & 0 & 100 & 6.7 & 0 & 40 & 6.7 \\
\hline
\end{tabular}
\end{table}
found one hybrid between a cytoplasmic-genetic male-sterile line and Israel Johnson's grass 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. balepense*, 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. balepense* 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. balepense*. Doggett (11) considered that *S. almum*, being a segregate from the hybrids of diploid sorghum and ancient tetraploid *S. balepense*, inherited the high seed set properties (presumably accumulated mutations) of *S. balepense*. The chromosome associations, particularly more bivalent pairing, some quadrivalent, and, occasionally, sexivalent pairing in hybrids of *S. balepense* agreed to some extent with the analysis done by Mouftah and Smith (8). They proposed an affinity of *S. balepense* for one diploid progenitor, namely *S. virgatum*, as did Duara and Stebbins (6). These workers suggested that *S. balepense* originated as a segmental allopolyploid from *S. bicolor* and another diploid progenitor.

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

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

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

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

**FIGURE 4.** Anaphase I with chromosome $2n = 40$ in hybrid of cultivated sorghum var. CK-60 X *S. balepense*. 
FIGURE 5. Anaphase I with chromosome 2n = 40 showing laggards in hybrid of cultivated sorghum var. Wheatland X S. balepense.

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

FIGURE 7. Synocyte with chromosome 2n = 60 at metaphase in hybrid of cultivated sorghum var. CK-60 X S. balepense.

FIGURE 8. Synocyte with chromosome 2n = 80 at Anaphase I in hybrid of cultivated sorghum var. Wheatland X S. balepense.

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

FIGURE 10. Synocyte with chromosome 2n = 120 (approximately) at metaphase in hybrid of cultivated sorghum var. Wheatland X S. balepense.

FIGURES 11 and 12. Same hybrid as in Fig. 10 showing one large synocyte with premeiotic fusion of two cells and two normal microsporocytes (Fig. 11) and one larger synocyte 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 syacites. The hybrid combinations of Dwarf Redlan and Combine Kafir-60 showed the highest percentage of triploids and an intermediate percentage of syacites. Dwarf Redlan had the highest percentage of plants with asynaptic cells and male fertility. The incidence of asynaptic cells with syacites 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.

REFERENCES