Cytomorphological Behaviour of Primary Trisomics in Pearl Millet (*Pennisetum americanum* (L.) Leeke)

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The usefulness of trisomic series in cytogenetic and breeding researches of diploid species is well known and has been adequately discussed by Burnham (1965), Hermesen (1970) and Khush (1973). Since the initial discovery of trisomics in *Datura* (Blakeslee 1922), trisomic sets have been produced in several diploid species (for reference see Khush *loc cit*). Gill *et al.* (1970b) reported complete set of trisomics in pearl millet inbred Bil-4. Detailed study on cytogenetics of aneuploids and translocations in pearl millet is also being carried out by Singh and coworkers (Tyagi and Singh 1975, Tyagi 1976 and Nameeta 1973). The present study was undertaken with the objective of isolation, identification and characterization of cytomorphological behaviour of certain trisomics in pearl millet.

Materials and methods

Of the sixteen primary trisomics, six primary trisomic plants were isolated in the progeny of a single partial desynaptic line, nine in the progeny of crosses of triploid with standard normal and one in the progeny of interchange heterozygote. The important meiotic figures were photographed with the help of an Olympus camera with PM 6 attachment using $15\times$ ocular and $100\times$ oil immersion objective. Cinematographic 55 NP ORWO films were used for taking the photographs.

Pollen sterility was expressed as percentage of sterile pollen grains to the total pollen grains counted. On an average 400-500 pollen grains per plant were counted. The morphological characters of each trisomic plant were noted. The trisomics were classified according to Gill *et al.* (1970b) and Nameeta (1973).

Results

Morphological Behaviour of the Primary Simple Trisomics

The primary simple trisomics were distinguishable from their diploid sibs by their poor seedling vigour, significantly shorter stature and narrower grassy leaf and stem. The data on certain morphological characters are presented in Table 1. On the basis of their morphology they were classified into following five types:

Bushy: It was characterised by its bushy habit, profuse tillering, narrow and somewhat linear leaves. There were six plants in this class.

Awned: Characterised by awned ears a single plant in this group was tallest among the trisomics and in other characteristics resembled normal.

Slender: Three plants in this class showed significantly reduced vigour and were extremely poor in tillering.

Dark Green: This group consisted of four plants which had dark green leaves and particularly the upper ones were very small and narrow. The plant height was only slightly reduced but with poor tillering.

Tiny: The plants (two in number) were extremely weak and dwarf among the trisomics and possessed lowest number of leaves and tillers per plant.

Table 1. Morphological characteristics of the five trisomics as compared to the Normal diploid *Pennisetum typhoides*

Type of trisomics	Height (cm)	No. of leaves	Tiller number	Leaf length (cm)	Leaf width (cm)	Pollen sterility
Normal diploid	112.5	37	7	39.6	2.2	16.0
Bushy	45.6	18	3	24.4	1.4	50.5
Awned	62.0	19	2	27.6	1.2	42.5
Slender	28.7	9	2	20.3	1.5	62.0
Dark green	36.5	11	3	15.0	0.9	65.5
Tiny	27.5	8	3	17.7	1.0	70.0
			Ear length	Ear girth	Awns character	
Normal diploid			24.6	4.3	Awnless	
Awned			18.7	3.6	Awns are present	

Table 2. Frequency of different chromosome associations at diakinesis and metaphase I in the five trisomics of *Pennisetum typhoides*.

Type of trisomics	No. of cells analysed		Chromosome Associations					
			6 ^{II} + 1 ^{III}		7 ^{II} + 1 ^I		Others	
	Dia-	Meta-I	Dia-	Meta-I	Dia-	Meta-I	Dia-	Meta-I
Bushy	118	151	72	81	44	69	2	1
Awned	128	91	78	54	50	35	—	2
Slender	89	92	64	56	22	36	3	—
Dark green	92	89	61	64	31	24	—	1
Tiny	173	87	125	66	48	21	—	—
Total	600	510	400	321	195	185	5	4
Mean per cent			66.7	62.9	32.5	36.3	0.8	0.8

Meiotic Behaviour of the Primary Trisomics

Meiotic chromosome associations and trivalent types at diakinesis and metaphase I and chromosome separation at anaphase I were studied in the five groups of primary trisomics (Figs. 1 to 23).

All the primary trisomics showed one trivalent and six bivalents or seven bivalents and one univalent at diakinesis and metaphase I. Tables 2 and 3 give the frequency of chromosome associations and types of trivalents at diakinesis and metaphase I. It may be noted that the frequency of cells showing 1^{III} + 6^{II} at diakinesis (Figs. 2 to 9) was 66.7 per cent and at metaphase I (Figs. 11, 13, 14 and 16) it was 62.9 per cent. The frequency of cells exhibiting 7^{II} + 1^I at diakinesis

and metaphase I (Fig. 12) was 32.5 per cent and 36.3 per cent, respectively. Other types of chromosome associations at diakinesis such as $6^{II}+3^I$ and $5^{II}+1^{III}+2^I$ were observed in 0.8 per cent of the cells.

The three homologous chromosomes of a trisomic showed V-, inverted S-, L-, Y-, frying pan-, S- and J-shape configurations. The chain of three (Fig. 14) was

Figs. 1-9. Different trivalent types at diakinesis. Magnification. $\times 500$. 1, diplotene, $5^{II}+1^{IV}$. 2, diakinesis, $6^{II}+1^{III}$, V-shaped. 3, diakinesis, $6^{II}+1^{III}$, inverted S-shaped. 4, diakinesis, $6^{II}+1^{III}$, L-shaped. 5, diakinesis, $6^{II}+1^{III}$, Y-shaped. 6, diakinesis, $6^{II}+1^{III}$, 4-shaped. 7, diakinesis, $6^{II}+1^{III}$, Frying pan-shaped. 8, diakinesis, $6^{II}+1^{III}$, S-shaped. 9, diakinesis, $6^{II}+1^{III}$, J-shaped.

the most frequent configuration, being 65 per cent at diakinesis and 63 per cent at metaphase I followed by frying pan (Fig. 7, approx. 19 per cent both at diakinesis and metaphase I). Other types of configurations (Figs. 2 to 9) at diakinesis were observed in about 8 per cent of the cells. At metaphase I frequency of V-shape (Fig. 16) trivalents increased (12 per cent), whereas, other types of configurations decreased (6 per cent). Chromosome length influenced the frequency of different

configurations. Shorter chromosomes had the higher frequency of chain trivalents and lower frequency of Y-shape and frying pan trivalents at diakinesis and metaphase I.

Separation of chromosomes at anaphase I is clearly seen in Figs. 17 to 23. In primary trisomics eight vs. seven chromosomes separation was most frequent (Fig. 17 and Table 4). Certain abnormalities such as 8-1-6 separation of chromosomes (Fig. 19), late disjunction of one bivalent (Figs. 18 and 22), laggards (Fig. 20) and splitting of laggards (Fig. 21) at anaphase I were also observed.

Table 3. Configurations of trivalents at diakinesis and metaphase I in the five trisomics of *Pennisetum typhoides*

Type of Trisomics	Cells analysed		Chromosome associations							
			Chain		V-shaped		Frying-pan		Others Y, J and S-shaped	
	Dia-	Meta-I	Dia-	Meta-I	Dia-	Meta-I	Dia-	Meta-I	Dia-	Meta-I
Bushy	76	63	48	32	6	9	16	16	6	6
Awned	109	70	91	50	6	8	10	8	2	4
Slender	64	56	40	30	4	8	12	14	8	4
Dark green	73	66	38	42	7	9	22	10	6	5
Tiny	78	66	46	48	10	6	14	11	8	1
Total	400	321	263	202	33	40	74	59	30	20
Mean			64.65	62.58	8.74	12.67	18.58	18.49	8.03	6.26

Table 4. Anaphase I separation of chromosomes in the five trisomics of *Pennisetum typhoides*

Type of Trisomic	Cells analysed	Anaphase separations			
		7-8	7-1-7	8-1-6	9-6
Bushy	92	89	2	—	1
Awned	78	76	1	1	1
Slender	84	82	1	—	1
Dark green	88	85	1	1	1
Tiny	98	94	2	—	2
Total	440	426	7	2	5

Though the additional chromosome in the various trisomics was not identified karyotypically the relative frequencies of the bivalents+univalents and trivalents gave some indication regarding the size of the additional chromosome (Table 2). A comparison of morphological characters and pollen sterility of different primary trisomics indicated a relationship between the size of the additional chromosome and morphological characteristics of the trisomic. The larger chromosomes affected the morphology and pollen sterility drastically while the shorter chromosomes had minor effect. Probably tiny trisomic involved the largest chromosome which had negative effect on the different morphological traits (Table 1).

Discussion

In the present investigation trisomics were produced from three different sources i.e., desynaptic plant, triploid and translocation heterozygote. The desynaptic plant showed univalents ranging from 0 to 13 at diakinesis and metaphase I. In triploid plant 36% of the cells showed eight chromosome separation to one pole at anaphase I. Of the three sources as reported in this case, trisomics were most

Figs. 10-16. Different chromosome associations and types of trivalents at metaphases I. Magnification. $\times 500$. 10, $5^{II} + 1^V$, chain of five. 11, $6^{II} + 1^{III}$, chain type. 12, $7^{II} + 1^I$. 13, $6^{II} + 1^{III}$, L-shaped. 14, $6^{II} + 1^{III}$, rod shaped, early disjunction of one bivalent. 15, $6^{II} + 1^{III}$, early disjunction of trivalent. 16, $6^{II} + 1^{III}$, V-shaped.

frequent in the progeny of triploids.

The chromosome associations at diakinesis and metaphase I were usually $6^{II}+1^{III}$ or $7^{II}+1^I$, whereas $6^{II}+3^I$ were low in frequency. The trivalents exhibited different configurations, viz., chain, frying pan, Y-, J-, S- and 4-shaped. There was no characteristic meiotic configuration of the specific trisomics. In trisomics three homologues of one chromosome are available for pairing. If pairing initiates at a single point only a bivalent and a univalent will be formed. In the present

Figs. 17–23. Different types of chromosomes distribution to the opposite poles at anaphase I. Magnification, $\times 500$. 17, anaphase I, 8: 7 separation of chromosomes. 18, anaphase I, late disjunction of one bivalent and one lagging chromosome. 19, anaphase I, 8: 1: 6 separation of chromosomes. 20, anaphase I, 7: 1: 7 separation chromosomes. 21, anaphase I, 7: 1: 7 separation of chromosomes, splitting of laggard chromosome. 22, mid anaphase I, late disjunction of one bivalent. 23, anaphase I, 9: 6 separation of chromosomes.

study the frequency of trivalents was high suggesting that there were more points for initiation of pairing scattered all over the chromosomes. Higher number of chiasmata would result in large number of trivalents and fewer bivalents.

When chiasmata occur in all available segments the metaphase configuration reflects the pairing relations. The bivalent is usually a ring plus one univalent and the trivalent is a frying pan (Fig. 7). If interstitial chiasmata are few the trivalent will appear as chain (Fig. 14). but an occasional interstitial chiasma alongwith a distal

chiasma in the same arm will result in a Y-shape configuration (Fig. 5) and in absence of chiasma the chromosomes will appear as three univalents. In the present investigation chain trivalent was observed in most of the cases, whereas Y and frying pan configurations were observed only in few cells suggesting that in pearl millet usually the chiasmata are terminally localized.

Anaphase chromosome separations were 7-8, 7-1-7 and 9-6 (Figs. 17, 20 and 23), the first category being most frequent (Table 4). It suggests that on selfing as well as on crossing with normal diploids the trisomics are likely to throw out good proportion of trisomics.

The five trisomics were distinguishable morphologically from diploids as well as from one another. The distinguishing features constituted general vigour, height, leaf width, stem thickness and panicle size. All trisomics had reduced vigour, shorter height, narrower leaves, thinner stem and smaller panicles.

Trisomics morphologically distinguishable from diploids have been reported in *Datura* (Blakeslee 1922), tomato (Rick and Barton 1954), barely (Tsuchiya 1967), sorghum (Schertz 1966), rice (Hu 1968), pearl millet (Gill *et al.* 1970b, Nameeta 1973). However, the trisomics were indistinguishable from the diploid sibs in *Hyacinthus* (Darlington *et al.* 1951), maize (Rhoades 1955). The phenotypic effect of the extra chromosome of a trisomic will obviously depend upon its gene content. The effect of additional chromosome in trisomics is expected to be in proportion to the length of the genome and the importance and vitality of the added genes. In general the trisomics showed reduction in important characters, the magnitude of which increased with increasing size of extra chromosome.

Each of the seven possible trisomics with specific diagnostic characteristics have been described by Gill *et al.* (1970b) and Nameeta (1973), which are consistent regardless of the varietal source. Though different genetic backgrounds may effect the expression of the extra chromosome to a certain extent, the main morphological traits remained similar.

Summary

The desynaptic plant showed univalents ranging from 0 to 13 at diakinesis and metaphase I. In triploid plant 36 per cent of the cells showed eight chromosomes separating to one pole at anaphase I. The morphology, cytology and sterility studies were conducted in all the trisomics isolated. All the primary trisomics showed $6^{II}+1^{III}$ or $7^{II}+1^I$ at diakinesis and metaphase I. The frequency of trivalents was reduced at metaphase I. The trivalent resumed in chain of 3, V-, Y-, frying pan, S-, J- and 4-shape configurations. Based on cytomorphological distinction, the 16 trisomics were grouped in five classes as bushy, awned, slender, dark green and tiny.

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