Assessment of Apple (*Malus pumila* Mill.) germplasm in Kashmir

III. Cytology of Lal-farashi, Double-Kaseri, Hindwand-rakam, Kichhama-trail, Sabe-alif and Tursh-nawabi

Ranbir Singh, B. A. Wafai and A. K. Koul

Department of Biosciences, University of Jammu,
Jammu-180001, India

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Sixty five triploid varieties have so far been reported in *Malus pumila* (Roscoe 1934, Einset and Imhofe 1947, 1949, Einset and Lamb 1951, Hunter and Walker 1955, Shanti *et al.* 1963, Hathwala 1966, Pratt *et al.* 1978). Recently, Koul *et al.* (in press) and Singh and Wafai (in press) have listed four triploids from Kashmir Valley. Further exploration has brought to light six more. The present communication describes the morphology and pollen mother cell meiosis of these triploids with a view to assess the impact of triploidy on their floral and fruit characteristics and discuss the nature of triploidy.

Material and methods

Six varieties, namely Lal-farashi, Double-kaseri, Hindwandrakam, Kichhama-trail, Sabe-alif and Tursh-nawabi constitute the material for investigation. The observations are based on trees growing in different orchards listed in Table on next. page.

Meiotic studies have been undertaken using Lespinasse *et al.*'s (1976) procedure.

Observations

Morphological descriptions

1.1 Lal-farashi: Tree medium to large sized with widespreading open head; branches drooping; flowers pinkish-white, 4.4-6.0 cm across, in clusters of 3-7; fruit dull yellow, striped in saffron, spherical to oblate, symmetric, sometimes angular, not very uniform, 4.5-6.5 × 5.9-7.2 cm; skin thin, rough; lenticels large, brown, raised, conspicuous, concentrated around the apex of fruit; fruit pedicel greenish-brown, pubescent, 2.4-2.9 cm long, 0.2 cm thick; stem cavity acute or nearly acuminate, occasionally lipped, heavily lined with golden yellow russet, 2.5-3.0 cm wide, 1.4-1.8 cm deep; basin narrow, gradual, regular, symmetric, russeted in brown, 2.4-2.7 cm wide, 0.2-0.3 cm deep; calyx reflexed, flattened, lobes pubescent; eye mostly closed, occasionally open; calyx tube cone shaped, 1.0-1.2 cm deep, 0.6-0.8 cm wide; stamens persistent, placed at the base of calyx tube; pistil point absent; core median or slightly distant, closed, 3.5-4.0 cm wide; core lines clasping; fruit flesh greenish

yellow, hard, juicy, subacidic; seed cavities 5, axile, round or cordate; seeds 1–3 per cavity, 7–10 per fruit, obtuse or nearly acute, $0.8-1.0 \times 0.5-0.6$ cm; fruit yield low to medium; trees neither strict annuals nor strict biennials; fruit production is good in alternate years; blooming period mid April, duration of bloom 6–8 days; fruit ripens within 160–170 days and is harvested in early October.

1.2. Double-kaseri: Trees small, semi erect with open head; flowers in clusters of 4–6, white with pink splashes, petals leathery; flower spread 4.7–5.0 cm; fruit uniformly deep red, oblate, generally lopsided, angular, occasionally symmetric, $4.8-6.2 \times 6.0-7.4$ cm; skin thin, tough, smooth, oily; lenticels small, white with a red ring around, depressed or submerged, concentrated towards fruit apex; fruit pedicel green, pubescent, 0.8–1.0 cm long, 0.2–0.3 cm thick; stem cavity acute to acuminate, heavily russeted, 2.5–3.0 cm wide, 1.3–1.5 cm deep; basin gradual, regular, symmetric, 2.3–2.7 cm wide, 0.4–0.6 cm deep; eye open; calyx tube cone or

The list of trees observed

Name of the variety	Tree number	Orchard
Lal-farashi	LF ₁ , LF ₂ 18*	1. Malik Orchards, Khounmoh, Kashmir
		2. Nehru Memorial Botanical Gardens, Chasma Shahi, Srinagar, Kashmir
Double-kaseri	DK ₁	Malik Orchards, Khounmoh, Kashmir
Hindwand-rakam	2545*	Jyoti Pvt. Ltd; Orchards, Boulevard, Srinagar, Kashmir
Kichhama-trail	27*	1. Nehru Memorial Botanical Gardens, Chasma Shahi, Srinagar, Kashmir
	1525*	2. Jyoti Pvt. Ltd; Orchards, Boulevard, Srinagar, Kashmir
Sabe-alif	34*	Nehru Memorial Botanical Gardens, Chasma Shahi, Srinagar, Kashmir
Tursh-nawabi	20*	1. Nehru Memorial Botanical Gardens, Chasma Shahi, Srinagar, Kashmir
	3884*	2. Jyoti Pvt. Ltd; Orchards, Boulevard, Srinagar, Kashmir
	TN ₁	3. Malik Orchards, Khounmoh, Kashmir

* The numbers have been given to individual trees by the orchardists.

almost funnel shaped, 0.5–0.7 cm wide, 0.5–0.6 cm deep; stamens median in the calyx tube; pistil-point absent; core median, closed, 3.6–4.0 cm wide; corelines clasping or nearly meeting; fruit flesh quite firm, hard, light green, quite juicy, crisp, sweet; seed cavities 5, obcordate, axile; seeds none to one per cell, 3–5 per fruit, mostly aborted, acute, $0.8-0.9 \times 0.5$ cm in size; trees biennial; fruit yield very low; blooming period late April; duration of flowering 10–12 days; fruit ripens within 150–160 days; harvesting period late September or early October.

1.3. Hindwand-rakam: Trees small, semierect with small open head; flowers pinkish white, in clusters of 3–7; flowers 3.2–4.2 cm across; fruit yellow, oblate, compressed, ribbed, oblique, irregular, angular, not uniform, $6.1-6.5 \times 7.2-8.4$ cm; skin thick, smooth, waxy; skin lenticels large, areolar, initially submerged or depressed but brown, raised, open, rough at maturity, concentrated towards the apex

of fruit; fruit pedicel thick, fleshy, dull green, pubescent, clubbed in the cavity; stem cavity obtuse or nearly acute, occasionally lipped, 2.8–3.5 cm wide, 0.8–1.2 cm deep; basin abrupt, obtuse, symmetric, 2.0–2.5 cm wide, 0.4–0.5 cm deep; calyx persistent, connivent, pubescent; eye closed or partly open; calyx tube funnel shaped, 0.5–0.6 cm broad, 1.2–1.4 cm deep; persistent stamens basal; pistil point absent; core median, open, 4.2–4.5 cm wide; corelines clasping; fruit flesh cream coloured, soft, crisp, juicy, subacidic; seed cavities 5, abaxile, obcordate; seeds none to one per cell, none to five per fruit, seed abortion heavy, healthy seeds acute 0.8–0.9 cm long, 0.4 cm broad; fruit yield very low; trees annual bearing bloom in 2nd week of April for 7–10 days; fruit ripens within 100–115 days; harvest time early August.

1.4. Kichhama-trail: Trees medium sized, semierect with extensively branched, round, densely closed crown; flowers pure white, borne in clusters of 5–6; flower spread 4.1–4.5 cm; fruit splashed with red on yellowish background at the time of harvest but blushed or self coloured with bright red on maturity, oblate to nearly spherical, ribbed, irregular, angular, 2.0–2.6 cm long, 2.9–3.5 cm across; skin thin smooth covered with thin white powdery bloom which gets rubbed off easily; lenticels on fruit skin few, sparsely placed, depressed or submerged, not very conspicuous; fruit pedicel slender, green, pubescent, 1.8–2.5 cm long, 0.1 cm thick; stem cavity obtuse, very narrow and shallow, clear, smooth, occasionally lined with thin russet, 0.7–0.9 cm wide, 0.1–0.3 cm deep; basin very small, corrugated or mommiform, frequently compressed, 1.5–1.8 cm wide, 0.1–0.2 cm deep; calyx persistent, connivent; eye closed; calyx tube cone shaped, 0.3–0.4 cm deep, 0.2–0.3 cm wide; persistent stamens placed at the base of calyx tube; pistil point absent; core median or nearly sessile, closed, 1.8–2.0 cm wide; corelines clasping; fruit flesh yellow, soft, quite juicy and crisp, aromatic, subacidic, seed cavities 5, axile, obcordate; seeds 1–2 per cell, 3–5 per fruit, pointed, 0.7–0.8 cm long, 0.3–0.4 cm broad, mostly aborted; fruit-yield quite high; trees strict biennials; bloom in second week of April for 9–12 days; fruit ripens within 170–180 days; harvesting time mid October.

1.5. Sabe-alif: Trees large with widespreading round densely closed head; flowers white, 4.8–6.2 cm across borne in clusters of 5–7; fruit striped in red against greenish yellow background, oblate, regular, symmetric, occasionally lopsided, uniform, 5.6–6.4 × 7.2–7.6 cm in size; skin thin smooth, waxy, russeted in the cavity; lenticels submerged, areolar, surrounded by a pale halo, conspicuous; fruit pedicel short, thick, dull green with dirty white pubescence 0.6–0.8 cm long, 0.3 cm thick; stem cavity acute, 1.5–1.8 cm deep, 2.4–2.7 cm wide; basin medium to deep, abrupt, rarely gradual, symmetrical, regular, 2.2–2.8 cm wide, 0.5–0.7 cm deep; calyx persistent, reflexed, flat; eye closed; calyx tube cone shaped 0.4–0.5 cm wide, 0.5–0.7 cm deep; core median, open, 2.9–3.9 cm wide; corelines meeting; fruit-flesh white firm with yellow tinge, hard, tough, very juicy, crisp, subacidic; seed cavities 5, ovate, abaxile; seeds acute to acuminate, 2 per cell, 10 per fruit, dark brown, 0.7–0.8 cm long, 0.4 cm wide; blooming period mid April, each tree keeps in bloom for 8–11 days; fruit ripens within 115–125 days; harvest time early to late August.

1.6. Tursh-nawabi: Trees large with round, closed head; branches drooping; flowers white borne in clusters of 5–6, six flowered clusters more frequent, flower

spread 4.9–5.8 cm; fruit oval to conical, irregular, compressed or sometimes even ribbed, angular, not uniform, 5.0–7.0 cm long, 5.0–6.2 cm across, striped or splashed in pinkish red against greenish yellow background; skin thick, smooth, shining, waxy; lenticels on fruit skin very few, small, inconspicuous, depressed; fruit pedicel brown, pubescent, occasionally clubbed in stem cavity, 0.7–1.5 cm long, 0.2 cm thick; stem cavity narrow, acute to acuminate, 1.5–2.0 cm broad, 1.5–1.9 cm deep; basin gradual, symmetric, occasionally compressed, wavy to corrugated or even mommiform, 2.0–2.3 cm wide, 0.3–0.6 cm deep; calyx persistent, reflexed, divergent, nearly flattened; eye closed or partly open; calyx tube cone shaped, 0.4–0.7 cm deep, 0.3–0.5 cm broad; persistent stamens positioned at the middle of calyx tube, protruding through the eye; core median, open, 3.0–3.5 cm wide; corelines meeting; fruit flesh cream-coloured, soft, quite juicy, crisp, subacidic; seed cavities 5, abaxile; seeds none to two per cell, 2–7 per fruit, acute, 0.7–0.9 cm long, 0.3–0.4 cm broad, aborted seeds quite frequent; fruit yield fairly good; trees alternate bearers, blooms in mid April for 6–9 days; fruit ripens within 120–140 days; harvesting period mid August to early September.

Pollen mother cell meiosis

Varieties Lal-farashi, Double-kaseri, Hindwand-rakam, Kichhama-trail, Sabe-alif and Tursh-nawabi bearing 51 chromosomes, are all triploids, based on x , 17. Metaphase-I spreads are well scattered and stained and therefore permit detailed analysis. Data collected on chromosome associations during MI, have been presented in Table 1.

The chromosomes pair in twos or threes; 1–20 chromosomes per cell remain as univalents either because they fail to pair or on account of precocious disjunction. The 220 pollen mother cells scored from the six varieties displayed 50 different patterns of chromosome associations. Frequencies of different associations vary from cell to cell and variety to variety. The most frequently observed patterns are $12III+6II+3I$ in 26.6% cells of Sabe-alif and $12III+5II+5I$ in 25.0% cells of Kichhama-trail (Fig. 1).

It is important to note that in all the six varieties a significant number of pollen mother cells (for frequency see Table 7) has an equal number of univalents and bivalents which creates the possibility that these might have been involved in trivalent associations during early prophase (Figs. 1–6). The frequency of such cells is highest in Kichhama-trail (65.0%) and least in Sabe-alif (10.0%).

The breakup of chromosomes involved in various association is contained in Table 2. The average frequency of different chromosome associations per cell is given in Table 3. The table reveals that univalents, bivalents and trivalents occur in equal proportion in Lal-farashi. The maximum univalent frequency per cell exists in Double-kaseri (Fig. 7); the value is 1.4–1.7 times higher than the number of bi- and trivalents. Trivalent frequency is least in this variety (7.13 ± 3.07 per cell). Kichhama-trail and Tursh-nawabi have the largest number of trivalents ($1\frac{1}{2}$ more than the number of bivalents) per cell (10.17 ± 2.79 and 10.0 ± 2.75). A pollen mother cell of Kichhama-trail contained $16III+1II+1I$ (Fig. 3). This configuration is only slightly different from what would be expected in a true autotriploid (17III).

Table 1. Metaphase I associations in different varieties

I	II	III	Number of pollen mother cells						Total no. of cells
			Lal-farashi	Double-kaseri	Hindwand-rakam	Kichhama-trail	Sabe-alif	Tursh-nawabi	
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)
5	5	12*	—	2	3	10	1	9	25
3	6	12	2	—	—	1	8	3	14
4	7	11	3	1	—	2	4	1	11
5	8	10	3	—	5	2	—	—	10
7	7	10*	—	—	—	2	1	6	9
6	9	9	4	1	—	1	—	3	9
3	3	14*	1	—	2	3	—	3	9
10	13	5	5	—	3	—	—	—	8
10	7	9	6 (Fig. 8)	1	—	1	—	—	8
9	12	6	1	—	3	1	—	3	8
7	13	6	1	—	—	1	2	4	8
7	10	8	3	—	—	2	2	—	7
6	6	11*	2	2	—	2	—	1	7
9	9	8*	—	—	1	2	1	2	6
18	9	5	1	3	—	1	—	—	5
16	10	5	—	2	2	—	—	—	4
15	9	6	—	1	1	—	2	—	4
14	8	7	—	—	4	—	—	—	4
11	11	6*	—	—	1	1	—	2	4
10	10	7*	—	—	1	2	—	1	4
8	11	7	2	1	—	—	—	1	4
7	4	12	1	—	—	1	—	2	4
4	4	13*	2	—	—	1	—	1	4
3	12	8	—	—	—	—	2	2	4
12	15	3	1	1	—	1	—	—	3
12	9	7	—	—	3	—	—	—	3
8	8	9*	—	—	—	2	—	1	3
4	13	7	—	—	2	—	1	—	3
18	12	3	—	1	1	—	—	—	2
13	10	6	—	—	2	—	—	—	2
13	7	8	—	2	—	—	—	—	2
12	3	11	2	—	—	—	—	—	2
4	1	15	—	1	—	—	1	—	2
3	9	10	—	—	—	—	—	2	2
2	5	13	—	—	—	—	—	2	2
20	11	3	—	1	—	—	—	—	1
19	10	4	—	1	—	—	—	—	1
17	14	2	—	—	1	—	—	—	1
17	2	10	—	—	—	—	1	—	1
15	6	8	—	—	1	—	—	—	1
11	8	8	—	—	—	—	1	—	1
9	15	4	—	—	—	—	1	—	1
9	6	10	—	1	—	—	—	—	1
8	14	5	—	—	—	—	1	—	1
6	15	5	—	—	—	—	1	—	1
6	12	7	—	—	1	—	—	—	1
6	3	13	—	—	—	—	—	1	1
5	11	8	—	—	1	—	—	—	1
1	1	16*	—	—	—	1	—	—	1
Total no. of cells scored			40	22	38	40	30	50	220

* PMCs with equal number of uni- and bivalents. Kichhama-trail (65.0%); Tursh-nawabi (42.0%), Hindwand rakam (28.5%), Double-kaseri (18.2%), Lal-farashi (12.5%), Sabe-alif (10.0%).

Chromosome segregation is highly erratic (Table 4). Seventy nine segregation patterns have been observed in different PMCs of these varieties. The percentage of cells following 26 : 25 (Fig. 9), distribution is 14.2% in Kichhama-trail, 14% in Sabe-alif, 11.0% in Lal-farashi and 11.1% in Tursh-nawabi.

Segregation patterns producing nuclei with full haploid or diploid chromosome complement are very rare (Table 4). Cells that follow 26:25 (Fig. 9), 27:24 and

Figs. 1-8. 1, a PMC of Kichhama-trail at metaphase I showing 12 III+5 II+5 I. Bar=10 μ m. 2, a PMC of Kichhama-trail at metaphase-I showing 6 III+11 II+11 I. Bar=10 μ m. 3, a PMC of Kichhama-trail at metaphase I showing 16 III+1 II+1 I. Bar=10 μ m. 4, a PMC of Tursh-nawabi at metaphase I showing 14 III+3 II+3 I. Bar=10 μ m. 5, a PMC of sabe-alif at metaphase I showing 12 III+5 II+5 I. Bar=10 μ m. 6, a PMC of Hindwand-rakam at metaphase I showing 14 III+3 II+3 I. Bar=10 μ m. 7, a PMC of Double-kaseri at metaphase I showing 8 III+7 II+13 I. Bar=10 μ m. 8, a PMC of Lal-farashi at metaphase I showing 9 III+7 II+10 I. Bar=10 μ m.

Figs. 9-12. 9, a PMC of Lal-farashi at anaphase I showing 25:26 segregation. Bar=10 μ m. 10, a PMC of Kichhama-trail at anaphase I showing 28:23 segregation. Bar=10 μ m. 11, a PMC of Lal-farashi showing at least 6 laggards. Bar=10 μ m. 12, a PMC of Sabe-alif showing 11 laggards. Bar=10 μ m.

28:23 (Fig. 10) patterns of disjunction (and are therefore, without laggards) have highest incidence in all the six varieties.

As a consequence of highly disturbed disjunction, chromosome lagging and differentiation of micronuclei is a regular feature (Figs. 11 and 12). The latter

Table 2. Breakup of chromosomes involved in different associations

Varietal name	No. of PMCs scored	Number of chromosomes involved in different associations at MI		
		I	II	III
Lal-farashi	40	304 (14.90%)	668 (32.74%)	1,068 (52.35%)
Double-kaseri	22	269 (23.97%)	382 (34.04%)	471 (41.97%)
Hindwand-rakam	38	367 (18.93%)	710 (36.63%)	861 (44.42%)
Kichhama-trail	40	259 (12.69%)	560 (27.45%)	1,221 (59.85%)
Sabe-alif	30	194 (12.67%)	526 (34.27%)	810 (52.94%)
Tursh-nawabi	50	294 (11.52%)	756 (29.64%)	1,500 (58.82%)

Table 3. Mean and range of metaphase I chromosome associations in six triploid varieties of apple

Variety	Range			Ratios I: II: III
	I	Mean $\pm$ S.D II	III	
Lal-farashi	3-18 7.6 $\pm$ 3.19	3-15 8.35 $\pm$ 3.17	3-14 8.9 $\pm$ 2.65	1: 1.09: 1.17
Double-kaseri	4-20* 12.22 $\pm$ 5.35	5-15 8.68 $\pm$ 2.51	3-12 7.13 $\pm$ 3.07	1: 0.71: 0.58
Hindwand-rakam	3-18 9.65 $\pm$ 4.77	3-14** 9.34 $\pm$ 2.83	2-14 7.55 $\pm$ 2.73	1: 0.96: 0.78
Kichhama-trail	1-18 6.47 $\pm$ 3.07	1-15 7.00 $\pm$ 2.96	3-16*** 10.17 $\pm$ 2.79	1: 1.08: 1.57
Sabe-alif	3-17 6.46 $\pm$ 4.16	2-15 8.76 $\pm$ 3.34	4-12 9.00 $\pm$ 2.74	1: 1.35: 1.39
Tursh-nawabi	2-11 5.88 $\pm$ 2.34	3-13 7.56 $\pm$ 3.12	6-14*** 10.00 $\pm$ 2.75	1: 1.28: 1.70

* Note maximum frequency of univalents in this variety.

** Note maximum frequency of bivalents in this variety.

*** Note maximum frequency of trivalents in this variety.

separate out as micro-pollen grains. Cytokinesis leads to the differentiation of 4-8 microspores per pollen mother cell.

Data on pollen stainability and dimensions are given in Table 5.

Table 4. Anaphase disjunction patterns in six triploid varieties

Patterns of segregation (a)	Number of pollen mother cells						Total no. of cells (h)
	Lal-farashi (b)	Double-kasari (c)	Hind-wand-rakam (d)	Kichh-ama-trail (e)	Sabe-alif (f)	Tursh-nawabi (g)	
26: 25	4	—	1	4	4	4	17
27: 24	4	—	2	4	2	4	16
28: 23	1	—	6	4	3	1	15
25: 2: 24	1	1	1	2	2	—	7
24: 6: 21	—	2	1	2	—	1	6
25: 5: 21	2	—	1	2	—	—	5
25: 1: 25	2	1	1	—	—	1	5
31: 20	—	—	—	1	2	2	5
27: 3: 21	—	—	1	1	—	3	5
24: 8: 19	1	2	1	—	—	1	5
29: 2: 20	—	1	—	—	1	2	4
24: 5: 22	—	—	—	—	1	3	4
23: 6: 22	1	—	—	—	1	2	4
30: 7: 14	—	2	—	—	1	—	3
29: 4: 18	—	2	—	1	—	—	3
33: 1: 17*	1	2	—	—	—	—	3
30: 21	—	—	—	—	2	1	3
28: 4: 19	1	—	1	—	—	1	3
29: 22	3	—	—	—	—	—	3
25: 4: 22	—	1	1	—	—	1	3
23: 8: 20	1	1	—	—	1	—	3
23: 5: 23	—	1	1	—	1	—	3
26: 1: 24	1	1	1	—	—	—	3
21: 10: 20	1	—	—	—	1	1	3
30: 3: 18	—	—	1	—	1	—	2
33: 18	1	—	1	—	—	—	2
27: 4: 20	1	—	—	—	—	1	2
26: 3: 22	—	—	—	1	1	—	2
26: 2: 23	—	—	1	1	—	—	2
24: 4: 23	—	1	—	1	—	—	2
25: 7: 19	—	—	—	—	1	1	2
27: 1: 23	—	—	—	—	1	1	2
28: 5: 18	—	—	2	—	—	—	2
26: 6: 19	—	1	1	—	—	—	2
24: 7: 20	1	1	—	—	—	—	2
27: 2: 22	—	—	1	1	—	—	2
23: 9: 19	1	1	—	—	—	—	2
22: 8: 21	—	—	2	—	—	—	2
36: 5: 10	—	1	—	—	—	—	1
35: 4: 12	—	1	—	—	—	—	1
34: 8: 9*	—	1	—	—	—	—	1
34: 7: 10*	—	—	1	—	—	—	1
32: 1: 18	—	1	—	—	—	—	1
32: 2: 17*	—	—	—	—	1	—	1
32: 19	—	—	—	—	1	—	1
31: 4: 16	—	—	—	—	—	1	1
31: 9: 11	1	—	—	—	—	—	1

Table 4. (continued)

Patterns of segregation	Number of pollen mother cells						Total no. of cells (h)
	Lal-farashi (b)	Double-kaseri (c)	Hind-wand-rakam (d)	Kichh-ama-trail (e)	Sabe-alif (f)	Tursh-nawabi (g)	
31:2:18	—	—	—	—	1	—	1
31:3:17*	—	1	—	—	—	—	1
30:5:16	—	—	1	—	—	—	1
30:2:19	1	—	—	—	—	—	1
29:5:17*	—	—	—	—	1	—	1
29:1:21	—	—	—	—	1	—	1
29:7:15	—	1	—	—	—	—	1
28:9:14	—	1	—	—	—	—	1
28:12:11	—	1	—	—	—	—	1
28:6:17*	—	—	1	—	—	—	1
28:3:20	—	—	—	—	—	1	1
28:7:16	—	—	—	—	—	1	1
28:2:21	—	—	—	1	—	—	1
28:1:22	1	—	—	—	—	—	1
26:7:18	—	—	—	—	1	—	1
26:5:20	—	—	—	1	—	—	1
26:4:21	—	—	—	1	—	—	1
25:3:23	—	—	1	—	—	—	1
24:12:15	—	1	—	—	—	—	1
24:13:14	—	1	—	—	—	—	1
24:3:24	—	—	—	—	1	—	1
24:6:21	1	—	—	—	—	—	1
23:7:21	1	—	—	—	—	—	1
22:7:22	1	—	—	—	—	—	1
22:11:18	—	—	—	—	1	—	1
22:9:20	—	—	—	—	—	1	1
21:13:17*	1	—	—	—	—	—	1
21:15:15	—	1	—	—	—	—	1
20:12:19	1	—	—	—	—	—	1
20:11:20	—	—	—	—	—	1	1
Total no. of pMCs	36	32	32	28	34	36	198

* Nuclei with full haploid or diploid complement of 17 or 34 chromosomes.

Table 5. Pollen stainability and dimensions

Variety	Stainable pollen (%)	Average length of the equatorial axis of stainable pollen (in μm)
Tursh-nawabi	68.24	42.17
Dundwand-rakam	60.42	41.86
Sabe-alif	51.05	39.13
Double-kaseri	41.25	42.25
Lal-farashi	40.08	42.05
Kichhama-trail*	14.20	40.63

* More than 85% pollen of this variety is inviable.

Discussion

In apple it is customary to assess the impact of polyploidy on fruit characteristics through intervarietal comparisons (see Singh and Wafai, in press). In our previous publication (Koul *et al.* in press) which deals with triploid varieties, Rikhal-saharanpuri, Kharoo and Acc. 1877, it was pointed out that triploids do not have any edge over the diploids but they are certainly superior to the tetraploids. In order to see whether this holds true even for the six triploids studied now, comparisons have been drawn between these and some diploid and tetraploid cultivars.

Table 6 reveals that some diploid varieties bear larger and more tasteful fruits than these triploids. The triploid fruit is generally subacidic. Nevertheless, they outshine the tetraploid Khatoon-trail. Kichhama-trail represents an exception. Despite its triploid nature, the fruit is less than half the fruit size of 4x Khatoon-trail. Smaller size notwithstanding, Kichhama-trail maintains its superiority over Khatoon-trail in taste.

Table 6. Comparison of the tree, floral and fruit characteristics of diploid and polyplod cultivars of apple grown in Kashmir Valley

Character	Diploid ⁺	Triploid ⁺⁺	Tetraploid ⁺⁺⁺
Tree size	medium	small to large	medium
Blooming period: (days)	5-13	6-12	4-8
Spread of flower: (cm)	3.0-6.5	3.2-6.0	3.0-4.5
Diameter of the fruit (cm)	2.0-11.0	3.0-8.5	5.0-5.9
Height of the fruit (cm)	2.0-10.0	2.0-7.5	4.2-5.0
Taste of the fruit	subacidic or sweet	subacidic	subacidic
No. of days required for harvest	65-190	100-180	85-95
Bearing quality	annual or biennial	binennial	biennial

⁺ Data represent an average of 60 diploid varieties.

⁺⁺ Triploid varieties under reference.

⁺⁺⁺ Data pertaining to Khatoon-trail.

Singh and Wafai (in press) have convincingly proved that impact of polyploidy on fruit characteristics can be estimated better through intravarietal rather than intervarietal comparisons because in the latter procedure it is difficult to resolve whether size difference is an index of polyploidy or varietal difference. Our observations (Singh and Wafai in press) on variety Hazratbali indicate that triploidy improves fruit quality even at intravarietal level. Triploid Hazratbali II excels its diploid counterpart Hazratbali I, in almost all qualities of the fruit including colour and taste.

Nature of triploidy: The usefulness of pairing behaviour in unravelling the origin and ancestry of polyploids is too well known (Moffett 1931, Roscoe 1934). PMC meiosis of triploid apple is characterised by high frequency of trivalents. Moreover, every variety has a significant number of PMC's carrying an equal number of uni- and bivalents (Table 7) which raises the possibility that they might have been

involved in trivalent associations during prophase. In that case the actual frequency of trivalents will exceed the observed frequency. Formation of so many trivalents speaks of sufficient homology between the constituent genomes and suggests auto- or at best segmental allotriploid nature of these varieties.

Comparison of the data on meiotic pairing of the four triploid varieties studied earlier (Koul *et al.* in press and Singh and Wafai in press), as also the six varieties constituting the present test material reveals that they vary a good deal in the degree of homology among their constituent genomes (Table 7). Hazratbali II, Rikhal-saharanpuri and Kichhama-trail bear as many as 17 or 16 trivalents per cell (Fig. 3) which is the maximum theoretically expected in autotriploids. Average trivalent frequency per cell is 10.77 ± 3.66 (Rikhal-saharanpuri), 10.17 ± 2.79 (Kichhama-trail), 9.88 ± 3.64 (Hazratbali II) and 10.00 ± 2.75 (Tursh-nawabi). Such pairing behaviour testifies the strong homology among the three genomes of these varieties. Acc. 1877 also falls in this very category; although the maximum number of trivalents formed per cell does not exceed thirteen (Koul *et al.* in press), the average trivalent

Table 7. Comparisons of pairing of various varieties

Variety	Maximum number of trivalents per cell	% cells bearing uni- and bivalents in equal number	Authority
Hazratbali II	17	32.0	Singh and Wafai in press
Rikhal-saharanpuri	17	18.6	Koul <i>et al.</i> in press
Kichhama trail	16	65.0	Present work
Tursh-nawabi	14	42.0	Present work
Hindwand-rakam	14	28.5	Present work
Lal-farashi	14	12.5	Present work
Acc. 1877	13	62.5	Koul <i>et al.</i> in press
Sabe-alif	12	10.0	Present work
Double kaseri	12	18.2	Present work
Kharoo	8	8.0	Koul <i>et al.</i> in press

frequency (10.31 ± 1.52) overlaps that of Rikhal-saharanpuri and Kichhama-trail. That, the maximum number of trivalent associations may be even more than 13 in this variety is indicated by the fact that over 62% PMCs bear uni- and bivalents in equal numbers which might have been involved as trivalents during prophase. Double-kaseri and Kharoo differ from other triploids in this respect. In Double-kaseri univalents outnumber other chromosome associations (12.22 ± 5.35 per cell), and in Kharoo bivalents represent the dominant association (13.21 ± 2.4 per cell). Nevertheless both forms have some trivalents as well; 7.13 ± 3.07 and 5.88 ± 1.45 respectively. These facts speak for weak intergenomal homology.

The remaining varieties, namely Lal-farashi, Hindwand-rakam and Sabe-alif seem to lie in between these two categories in respect of the degree of differentiation between their genomes.

Summary

Six triploid varieties of cultivated apple (*Malus pumila* Mill.) namely Lal-

farashi, Double-kaseri, Hindwand-rakam, Kichhama trail, Sabe-alif and Tursh-nawabi having $2n=51$ have been recovered from different orchards of Kashmir Valley. Although not as good as the diploids, they are far superior to the tetraploid variety Khatoon-trail in their fruit quality. Data on the chromosome pairing reveals intergenomal homology suggesting their auto- or segmental allotriploid nature. The six triploids exhibit varying degrees of intergenomal differentiation.

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