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杨属派间核型比较研究

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摘 要：对杨属五派代表种的核型进行了分析，各代表种核型公式如下：欧洲山杨（白杨派）2n=2x=38=21m(2SAT)+4sm+13st(1SAT)；小叶杨（青杨派）2n=2x=38=1M+26m(1SAT)+8sm(1SAT)+1st+2t(1SAT)；大叶杨（大叶杨派）2n=2x=38=2M+22m+8sm+6st；胡杨（胡杨派）2n=2x=38=2M+23m+3sm+10st(2SAT)；箭杆杨（黑杨派）2n=2x=38=3M+29m(2SAT)+5sm+1st。杨属派间核型差异主要表现在中部与次中部着丝点（M，m）和近端部与端部着丝点（st，t）染色体数目上。白杨派和胡杨派具较多的 st、t 染色体，核型不对称系数比其它派高。按 Stebbins 理论白杨派和胡杨派属进化类型。

关键词：白杨派；青杨派；大叶杨派；胡杨派；黑杨派；核型比较

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A comparative study on the karyotypes among sections of *Populus*

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Abstract: This paper analyzed the karyotypes of 5 sections of *Populus*. The karyotype formula were as follows: *P. tremula* L. 2n=2x=38=21m(2SAT)+4sm+13st(1SAT); *P. simonii* Carr. 2n=2x=38=1M+26m(1SAT)+8sm(1SAT)+1st+2t(1SAT); *P. lasiocarpa* Oliv. 2n=2x=38=2M+22m+8sm+6st; *P. euphratica* Oliv 2n=2x=38=2M+23m+3sm+10st(2SAT); *P. nigra* L. var. *thevestina* (Dode) Bean 2n=2x=38=3M+29m(2SAT)+5sm+1st. The results of karyotype analysis showed that the karyotype differences among sections of *Populus* were mainly in the change of chromosome number of M and m, st and t. Populus and Turanga had more st and t chromosomes and their Asymmetry index was higher than Aigeiros, Tacamahaca and Leucoides. According to the Stebbins's theory, Populus and Turanga were the evolutional type.

Key words: *Populus*; *Tacamahaca*; *Leucoides*; *Turanga*; Aigeiros; karyotype comparison

杨属（*Populus*）在分类学上又分为五大派（组），即：白杨派（Populus）、大叶杨派（Leucoides）、青杨派（Tacamahaca）、黑杨派（Aigeiros）和胡杨派（Turanga）（王战等，1984）。张绮纹等（1988）从花粉形态的观察结果表明，黑杨派、青杨派、大叶杨派三派之间有较近的亲缘关系。程广有等（2000）对杨属白杨派、黑杨派、青杨派过氧化物同工酶分析表明三派之间差异较大。苏晓华（1989）研究表明黑杨派和青杨派间容易杂交，可以产生许多天然和人工杂种，表明两者亲缘关系相近，而白杨派与青杨派和黑

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杨派间杂交不亲和，通常只得到无生命力的种子或矮小的实生苗，表明这三派间亲缘关系较远，但都没有一个肯定的结论。

由于杨属植物的染色体比较小，许多作者认为染色体形态表现了一定的相似性，染色体呈点状和杆状(康向阳，1996)，因此有关杨属植物的细胞学研究十分薄弱，只有零星报道(Blackburn 等，1924；Meurman，1925；Johnsson，1940；Smith，1943；康向阳，1996)，且都是对染色体数目和倍性方面的研究，关于杨属植物的核型分析研究还未见报道。为了更好地了解和发掘这些种质资源以及为杨属植物的育种提供细胞学的基础资料，作者试图从核型分析角度对杨属派间的进化趋势进行比较研究，为杨属派间基因组结构研究提供参考。

1 材料与方法

本实验材料取自山西、湖北(表 1)，凭证标本存放于中国林科院林业研究所。染色体标本制备采用去壁低渗法(陈瑞阳等，1982)，早春将采集的杨属各派代表树种枝条浸泡在自来水中，每天换水待长出根尖或幼芽后，取根尖或幼芽用饱和对二氯苯溶液 20 ℃下预处理 3 h，用甲醇/冰乙酸(3∶1)固定液固定 2 h 以上，蒸馏水充分冲洗后用 2.5%纤维素酶和果胶酶混合酶液 25 ℃下处理 40 min，蒸馏水洗去酶液后用 0.075M KCl 进行低渗处理 20 min，再用甲醇/冰乙酸(3∶1)固定液固定 30 min，火焰干燥法制片，Giemsa 染色后用 Olympus BX51 显微镜观察并照相。核型分析按李懋学等(1985)方法进行，染色体计数观察 30 个细胞，核型分析取 5 个细胞。染色体相对长度计算采用 Kuo(1972)的标准。核型不对称系数及臂指数计算用 Arano(1963)的方法。核型类型根据 Stebbins(1971)的标准划分。

2 结果与讨论

所观察的杨属五派材料的染色体数目、形态及核型如图版Ⅰ所示，五派间的染色体分析参数见表 2，核型特征比较见表 3。

所观察的杨属五派代表种的染色体数目均为 2n＝2x＝38，这与 Blackburn 等 (1924)，康向阳(1996)报道的染色体数目一致。在白杨派和黑杨派中还发现有天然三倍体的植株存在(另文报道)，大叶杨派、小叶杨派和胡杨派中均未发现三倍体植株。天然三倍体植株的发现对研究杨属的遗传变异、起源进化以及杨属的三倍体育种均具重要意义。

表 1 供试材料的名称及来源

Table 1 The name and origin of experimental materials

派 Section	种名 Species	凭证标本 Voucher	来源 Origin
白杨派 Populus	欧洲山杨 *Populus tremula*	齐力旺 L. W. Qi 03-5	山西、大同 Datong, Shanxi
大叶杨派 Leucoides	大叶杨 *P. lasiocarpa*	齐力旺 L. W. Qi 03-47	湖北、建始 Jianshi, Hubei
青杨派 Tacamahaca	小叶杨 *P. simonii*	齐力旺 L. W. Qi 03-56	山西、大同 Datong, Shanxi
黑杨派 Aigeiros	箭杆杨 *P. nigra* var. *thevestina*	齐力旺 L. W. Qi 03-97	山西、大同 Datong, Shanxi
胡杨派 Turanga	胡杨 *P. euphratica*	齐力旺 L. W. Qi 03-132	山西、大同 Datong, Shanxi

根据 Stebbins(1971)所阐明的植物核型进化的一般规律，即由对称核型向不对称核型发展。由表 3 可以看出杨属五派之间核型基本结构是相当类似的，都具有较不对称的 2B 核型。杨属派间核型差异主要表现在中部与次中部着丝点(M，m)和近端部与端部着丝点(st，t)染色体数目上。白杨派和胡杨派具有较多的 st、t 染色体，核型不对称系数比其它派高分别为 65.97 和 63.03，属较进化的类型。

在核型分析的同时作者还发现不同派之间染色体结构有较大的变异。大叶杨派第二对染色体较其它 4 派的染色体大(图版Ⅰ：B)，也就是说在杨属植物中存在一对较大的染色体，而大叶杨派具有两对较大染色体，这是随体的融合还是易位产生的还有待进一步地研究。在青杨派染色体中的第一对同源染色体为异形染色体，两个成员的长度相差十分显著(图版Ⅰ：C)，这种异形同源染色体可能是由于缺失造成的结果。

本文仅提供了杨属五派之间的核型基本资料，要深入探明它们的起源和亲缘关系，还有待应用更新的技术手段。

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表 2 五种杨属植物的染色体参数

Table 2 The parameters of chromosomes in 5 species of *Populus*

序号 No.	欧洲山杨 *P. tremula* 相对长度 Relative length S+L=T(%)	臂比 Arm ratio	类型 Type	大叶杨 *P. lasiocarpa* 相对长度 Relation length S+L=T(%)	臂比 Arm ratio	类型 Type	小叶杨 *P. simonii* 相对长度 Relative length S+L=T(%)	臂比 Arm ratio	类型 Type	箭杆杨 *P. nigra* var. *thevestina* 相对长度 Relative length S+L=T(%)	臂比 Arm ratio	类型 Type	胡杨 *P. euphratica* 相对长度 Relative length S+L=T(%)	臂比 Arm ratio	类型 Type
1	2.155+2.928=5.083	1.359	m	1.763+2.925=4.688	1.659	m	2.302+3.377=5.679	1.467	m	2.405+3.224=5.629	1.341	m	1.886+3.086=4.972	1.636	m
2	2.210+2.762=4.972	1.250	m	1.634+3.183=4.817	1.948	sm	1.727+2.609=4.336	1.511	m	2.149+3.071=5.220	1.429	m	2.171+2.857=5.028	1.316	m
3	0.552+3.094=3.646	5.605	st*	1.634+3.011=4.645	1.843	sm	1.113+2.648=3.761	2.379	sm	1.638+2.201=3.839	1.344	m*	0.571+2.857=3.428	5.004	st
4	1.657+2.044=3.701	1.234	m*	1.634+2.581=4.215	1.580	m	1.151+2.302=3.453	2.000	sm	1.535+2.047=3.582	1.334	m*	0.571+2.286=2.857	4.004	st
5	1.215+1.492=2.707	1.228	m	1.247+2.151=3.398	1.725	sm	1.497+1.919=3.416	1.282	m	1.228+2.047=3.275	1.667	m	1.429+1.714=3.143	1.199	m
6	1.215+1.657=2.872	1.364	m	1.075+2.022=3.097	1.881	sm	1.535+1.919=3.454	1.250	m	1.331+2.047=3.378	1.538	m	1.371+1.714=3.085	1.250	m
7	0.552+2.210=2.762	4.004	st	1.290+1.634=2.924	1.267	m	1.228+2.494=3.722	2.031	sm*	1.484+1.791=3.275	1.207	m	1.257+1.714=2.971	1.364	m
8	0.552+2.099=2.651	3.803	st	1.290+1.677=2.967	1.300	m	1.113+1.842=2.955	1.655	m*	1.382+1.535=2.917	1.111	m	1.143+1.714=2.857	1.500	m
9	1.160+1.436=2.596	1.238	m*	0.817+1.892=2.709	2.316	sm	0.921+2.379=3.300	2.583	sm	1.279+1.894=3.173	1.481	m	0.971+1.943=2.914	2.001	sm
10	1.105+1.657=2.762	1.500	m	0.860+1.892=2.752	2.200	sm	1.036+1.919=2.955	1.852	sm	1.484+1.535=3.019	1.034	m	0.800+2.057=2.857	2.571	sm
11	1.105+1.492=2.597	1.350	m	0.430+2.151=2.581	5.002	st	0.844+2.264=3.108	2.682	sm	0.972+2.047=3.019	2.106	sm	0.571+2.286=2.857	4.004	st
12	1.050+1.602=2.652	1.526	m	0.344+2.366=2.710	6.878	st	1.074+1.727=2.801	1.608	m	1.024+1.740=2.764	1.699	m	0.571+2.229=2.800	3.904	st
13	0.552+2.210=2.762	4.004	st	1.290+1.290=2.580	1.000	M	1.151+1.612=2.763	1.401	m	1.024+1.945=2.969	1.899	sm	0.457+2.457=2.914	5.376	st
14	0.552+1.934=2.486	3.504	st	1.290+1.333=2.623	1.033	m	1.228+1.612=2.840	1.313	m	0.870+1.689=2.559	1.941	sm	0.457+2.286=2.743	5.002	st
15	0.552+2.099=2.651	3.803	st	0.645+1.978=2.623	3.067	st	0.307+2.341=2.648	7.625	t*	1.177+1.535=2.712	1.304	m	1.200+1.543=2.743	1.286	m
16	0.552+2.044=2.596	3.703	st	0.430+2.151=2.581	5.002	st	0.384+0.230=0.614	0.599	m	1.024+1.586=2.610	1.549	m	1.200+1.371=2.571	1.143	m
17	1.050+1.492=2.542	1.421	m	0.946+1.591=2.537	1.682	m	0.307+2.494=2.801	8.124	t	0.870+1.894=2.764	2.177	sm	0.571+1.886=2.457	3.303	st
18	1.105+1.492=2.597	1.350	m	0.946+1.634=2.580	1.727	sm	0.460+2.149=2.609	4.672	st	0.870+1.535=2.405	1.764	sm	0.571+2.000=2.571	3.503	st
19	0.939+1.602=2.541	1.706	sm	1.290+1.290=2.580	1.000	M	1.151+1.343=2.494	1.167	m	0.972+1.433=2.405	1.474	m	1.143+1.257=2.400	1.100	m
20	0.718+1.713=2.431	2.386	sm	1.032+1.118=2.150	1.083	m	1.074+1.151=2.225	1.072	m	0.921+1.279=2.200	1.389	m	1.143+1.429=2.572	1.250	m
21	1.105+1.436=2.541	1.300	m	1.075+1.204=2.279	1.120	m	1.113+1.113=2.226	1.000	M	1.024+1.177=2.201	1.149	m	1.143+1.143=2.286	1.000	M
22	1.105+1.326=2.431	1.200	m	1.161+1.247=2.408	1.074	m	1.113+1.190=2.303	1.069	m	1.024+1.075=2.099	1.050	m	1.143+1.257=2.400	1.100	m
23	0.773+1.657=2.430	2.144	sm	1.075+1.161=2.236	1.080	m	1.113+1.151=2.264	1.034	m	1.024+1.126=2.150	1.100	m	1.200+1.200=2.400	1.000	M
24	0.773+1.602=2.375	2.072	sm	1.075+1.290=2.365	1.200	m	1.036+1.113=2.149	1.074	m	0.921+1.177=2.098	1.278	m	1.029+1.143=2.172	1.111	m
25	0.939+1.215=2.154	1.294	m	1.075+1.204=2.279	1.120	m	0.767+1.458=2.225	1.901	sm	0.921+1.228=2.149	1.333	m	1.086+1.200=2.286	1.105	m
26	0.884+1.492=2.376	1.688	m	1.032+1.204=2.236	1.167	m	0.767+1.420=2.187	1.851	sm	0.921+1.126=2.047	1.223	m	1.029+1.143=2.172	1.111	m
27	0.552+1.657=2.209	3.002	st	0.430+1.892=2.322	4.400	st	1.074+1.151=2.225	1.072	m	0.972+1.126=2.098	1.158	m	0.457+1.829=2.286	4.002	st*
28	0.552+1.768=2.320	3.203	st	0.430+1.720=2.150	4.000	st	1.036+1.113=2.149	1.074	m	1.024+1.024=2.048	1.000	M	0.457+1.714=2.171	3.751	st*
29	0.939+1.326=2.265	1.412	m	0.860+1.376=2.236	1.600	m	0.844+1.266=2.110	1.500	m	1.024+1.024=2.048	1.000	M	1.029+1.143=2.172	1.111	m
30	0.994+1.215=2.209	1.222	m	0.860+1.333=2.193	1.550	m	1.036+1.151=2.187	1.111	m	1.024+1.024=2.048	1.000	M	1.086+1.143=2.229	1.052	m
31	0.442+1.823=2.265	4.124	st	0.860+1.247=2.107	1.450	m	0.998+1.151=2.149	1.153	m	1.024+1.075=2.099	1.050	m	0.971+1.143=2.114	1.177	m
32	0.331+1.878=2.209	5.674	st	0.860+1.290=2.150	1.500	m	0.883+1.228=2.111	1.391	m	0.972+1.024=1.996	1.053	m	1.086+1.143=2.229	1.052	m
33	0.331+2.044=2.375	6.175	st	0.946+1.118=2.064	1.182	m	0.959+1.151=2.110	1.200	m	0.921+1.075=1.996	1.167	m	1.029+1.143=2.172	1.111	m
34	0.331+1.768=2.099	5.341	st	0.989+1.161=2.150	1.174	m	0.921+1.151=2.072	1.250	m	0.972+1.075=2.047	1.106	m	1.029+1.143=2.172	1.111	m
35	0.994+1.215=2.209	1.222	m	0.860+0.903=1.763	1.050	m	0.767+1.151=1.918	1.501	m	0.716+1.075=1.791	1.501	m	0.743+1.314=2.057	1.769	sm
36	0.773+1.215=1.988	1.572	m	0.860+0.989=1.849	1.150	m	0.844+1.113=1.957	1.319	m	0.409+1.586=1.995	3.878	st	0.800+1.200=2.000	1.500	m
37	0.829+1.105=1.934	1.333	m	0.817+0.946=1.763	1.158	m	0.921+1.036=1.957	1.125	m	0.716+1.024=1.740	1.430	m	0.800+1.143=1.943	1.429	m
38	0.829+1.160=1.989	1.399	m	0.516+1.161=1.677	2.250	sm	0.844+0.921=1.765	1.091	m	0.614+1.024=1.638	1.668	m	0.800+1.200=2.000	1.500	m

注：* 随体长度未计算在内。Note: The length of satellite is not included in the chromosome length.

表 3 杨属派间核型特征

Table 3 The karyotype characteristics among sections of *Populus*

种名 Species	核型公式 Karyotype formula	染色体相对长度组成 Constitution of relative length	类型 Type	臂指数 N. F.	核型不对称系数 Index of the karyotype asymmetry
欧洲山杨 *P. tremula*	K(2n)=38=21m(2SAT)+4sm+13st(1SAT)	4L+8M2+23M1+3S	2B	63	65.97
小叶杨 *P. simonii*	K(2n)=38=1M+26m(1SAT)+8sm(1SAT)+1st+2t(1SAT)	8L+8M2+17M1+5S	2B	73	61.36
大叶杨 *P. lasiocarpa*	K(2n)=38=2M+22m+8sm+6st	5L+6M2+23M1+4S	2B	70	62.33
箭杆杨 *P. nigra* var. *thevestina*	K(2n)=38=3M+29m(2SAT)+5sm+1st	5L+10M2+17M1+6S	2B	75	58.14
胡杨 *P. euphratica*	K(2n)=38=2M+23m+3sm+10st(2SAT)	3L+12M2+22M1+1S	2B	66	63.03

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transfer of *AtPSK3* gene into *Roselle* cell is a potential method to stimulate the proliferation of *Roselle* cell in low density. In this paper, we have successfully isolated the *AtPSK3* gene from *Arabidopsis* genomic DNA by PCR, and the sequence analysis revealed that the obtained *AtPSK3* gene is identical to that in *Arabidopsis* genome database. We hope it could be the first step towards constructing a transgenic *Roselle* cell line with rapid proliferation.

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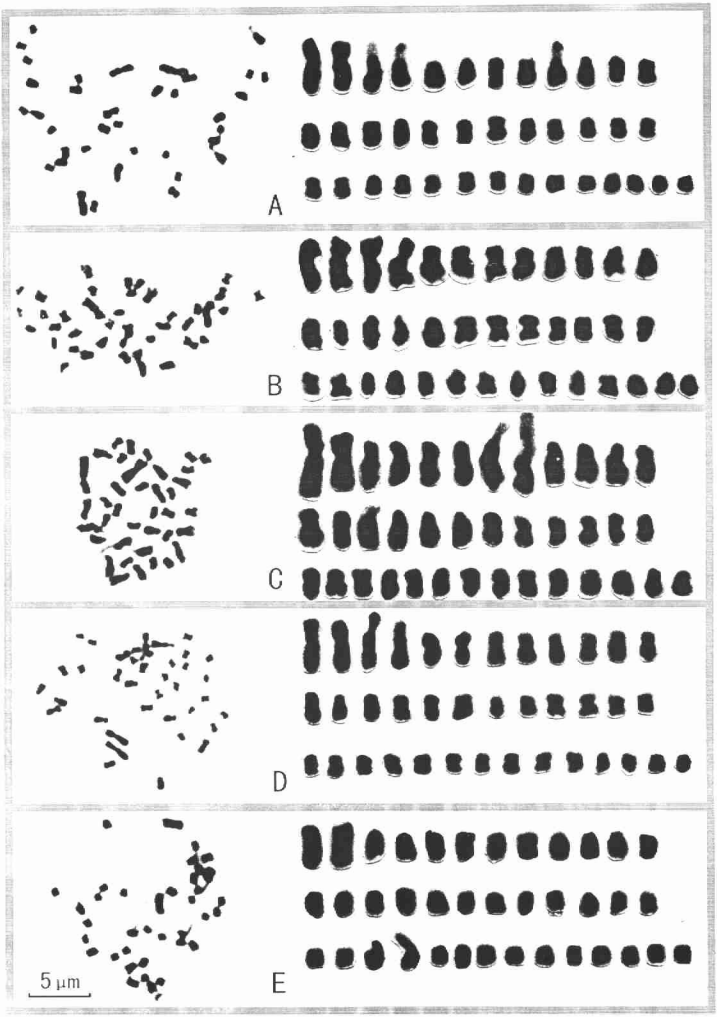

A. 欧洲山杨核型；B. 大叶杨核型；C. 小叶杨核型；D. 箭杆杨核型；E. 胡杨核型。
A. Karyotype of *Populus tremula* L.; B. Karyotype of *P. lasiocarpa* Oliv.; C. Karyotype of *P. simonii* Carr.; D. Karyotype of *P. nigra* var. *thevestina*; E. Karyotype of *P. euphratica* Oliv..