

Molecular markers in sex determination of dioecious angiosperms

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Abstract

Identification of sex in dioecious plants during early stages of development is important for selecting female or male plants for mass cultivation, to conserve time and to reduce cost of production. It is more significant in dioecious perennial tree species with sex specific economic and medicinal values. The literature contains many reports highlighting the use of molecular markers such as RAPD, RFLP, AFLP, SSR, SCAR and others for gender identification in higher plants.

Keywords: *Molecular markers, Sex determination, Dioecious plants*

The methods for sex determination in plants are a popular research topic. Early sex identification in plants is very important for plant breeders. Molecular markers help to analyse the variations between individuals, regardless of their developmental stage, which is very useful in sex determination studies of plants. In dioecious plants, where sex chromosomes have not yet been identified, molecular markers for male or femaleness indicate either the presence of sex chromosomes which have not been distinguished by cytological methods or that the molecular marker is tightly linked to a gene or genes involved in sex determination. DNA based molecular markers have now become a popular means for the identification of the plant genome (Milewicz and Sawicki 2013).

In recent years, various molecular marker systems have been developed and used for the study of sex identification in plants. These methods include RFLP (Restriction Fragment Length Polymorphism), RAPD (Random amplified Polymorphic DNA), AFLP (Amplified Fragment Length Polymorphism), SSR (Simple Sequence Repeats), SCAR (Sequence Characterized Amplified Region).

RFLP is time consuming and labour intensive process. Though AFLP provides a high multiplexing ratio, in this case high DNA quantity is required and this method is complex. SSR is one of the most widely used marker systems because of its extensive disperssion around the genome and because it produces co-dominant markers, but it is expensive to develop. RAPD technique is simple, cheap, less time consuming and requires much smaller DNA samples than RFLP but to obtain a marker linked to a gene or genomic region through RAPD analysis depends to a large extent on chance, because random sequences are used as PCR primers. ISSR is a simple and reproducible method that overcomes many of the limitations noted in RAPD and RFLP. The SCAR was first derived from RAPD fragments and now it has been developed for various identification applications including determination of sex in plants. SCAR markers are sometimes advantageous over RAPD markers because they can detect a single locus and their amplification is less sensitive to reaction conditions. The effectiveness of RAPD is also limited due to its low reproducibility, though it is most widely used molecular marker for sex identification .

In this study we have reported a list of different sex determination methods using molecular tools and the number of identified sex-linked markers for various plant species.

Table-1

SI No.	Plant species	Marker system and other methods	Determined sex and number of discovered markers	References
1	<i>Pistacia vera</i>	RAPD	IF	Hormaza et al., 1994
2	<i>Actinidia chinensis</i>	RAPD	IF, 1M	Harvey et al., 1997
3	<i>Actinidia deliciosa</i> var. <i>deliciosa</i>	RAPD	6F, 2M	Shirkot et. al., 2002
4	<i>Asparagus officinalis</i>	RAPD	2F, 2M	Jiang and Sink, 1997; Gao et al., 2007
5	<i>Distichlis spicata</i>	RAPD	IF	Eppeley et al., 1998
6	<i>Melandrium rubrum</i> (<i>Silene dioica</i>)	RAPD	IF, 1M	Di Stilio et. al., 1998
7	<i>Salix viminalis</i>	RAPD	IF	Alstrom-Rapaport et. al., 1998
8	<i>Hippophae rhamnoides</i>	RAPD	2M	Persson and Nybom, 1998; Sharma et. al., 2010; Jadhav and Sharma, 2014
9	<i>Myristica fragrans</i>	RAPD	IF	Shibu et. al., 2000
10	<i>Piper longum</i>	RAPD	2M	Banerjee et. al., 1999
11	<i>Cannabis sativa</i>	RAPD	5M, 5F	Sakamoto et. al., 1995, 2005
12	<i>Encephalartos natalensis</i>	RAPD	IF	Prakash and Staden, 2006
13	<i>Borassus flabellifer</i>	RAPD	1M	George et. al., 2007 George and Karun, 2011
14	<i>Simmondsia chinensis</i> (Jojoba)	RAPD	IM 3M, 3F 2M, 5F	Agarwal et. al., 2007; Al-Obaidi et. al., 2011 Hosseini et. al., 2011
15	<i>Trichosanthes dioica</i>	RAPD	IF, 1M	Kumar et. al., 2008
16	<i>Phoenix dactylifera</i>	RAPD	3F, 2M 25F, 20M	Younis et al., 2008 Dhawan et. al., 2013

17	<i>Commiphora wightii</i>	RAPD	IF, 1H, 1 for both F and H	Samantaray et. al., 2010
18	<i>Humulus lupulus</i>	RAPD	3M	Seefelder et. al., 2000 Aleksandrov et. al., 2011
19	<i>Pistacia atlantica</i>	RAPD	2M	Esfandiyari et. al., 2011
20	<i>Pistacia khinjuk</i>	RAPD	IF, IM	Esfandiyari et al., 2011
21	<i>Trichosanthes dioica Roxb.</i>	RAPD	5M, 5F	Kumar et. al., 2011
22	<i>Pandanus tectorius</i>	RAPD	7F, 7M	Panda et. al., 2010
23	<i>Humulus japonicus</i>	RAPD		Aleksandrov et. al., 2011
24	<i>Pistacia vera L.</i>	RAPD	3F, 3M	Ehsanpour and Arab, 2009
25	<i>Carica papaya</i>	RAPD	25H, 25F 1M, IF	Deputy et. al. 2002 Reddy et. al., 2012
26	<i>Simarouba glauca</i>	RAPD	1M 1M, 2F, 2H	Baratakke and Patil, 2014 Vaidya and Naik, 2014
27	<i>Momordica charantia</i>	RAPD	IF, IM	Mishra et. al., 2014
28	<i>Populus ciliata wall ex. Royle</i>	RAPD	4M, 4F	Amita Kumari et al., 2014
29	<i>Momordica dioica Roxb. ex. Wild</i>	RAPD	IF	Raju et. al., 2015

Table-2

SI No.	Plant species	Marker system and other methods	Determined sex and number of discovered markers	References
1	1. <i>Rumex acetosa</i>	RFLP	1M	Ruiz et. al., 1994
2	2. <i>Asparagus officinalis</i>	RFLP	IF, 1M	Biffi et. al., 1995

Table-3

SI No.	Plant species	Marker system and other methods	Determined sex and number of discovered markers	References
1	<i>Bryonia dioica</i>	SCAR	20M, 7F	Oyama et. al., 2009
2	<i>Piper betle</i>	SCAR	2M, 1F	Khadke et. al., 2012
3	<i>Phoenix dactylifera L.</i>	SCAR	20M, 25F	Dhawan et. al., 2013
4	<i>Carica papaya</i>	SCAR	6D, 8GD	Chaturvedi et al., 2014
5	<i>Piper longum L.</i>	SCAR	96F, 40M	Manoj et. al., 2014
6	<i>Simarouba glauca</i>	SCAR	20F, 20M	Baratakke and Patil, 2014
7	<i>Idesia polycarpa Maxim</i>	SCAR	30F, 22M	Wang et. al., 2015

Table-4

SI No.	Plant species	Marker system and other methods	Determined sex and number of discovered markers	References
1	<i>Humulus lupulus</i>	AFLP	10M	Polley et. al., 1997
2	1. <i>Asparagus officinalis</i>	AFLP	1M 1M, 1F	Spada et. al., 1998 Reamon-Büttner et. al., 1998
3	2. <i>Dioscorea tokoro</i>	AFLP	1M	Terauchi et al., 1999
4	3. <i>Ficus fulwa</i>	AFLP	1M	Tracey et. al., 2004
5	4. <i>Rumex acetosa</i>	AFLP	4M	Rahman and Ainsworth, 2004
6	<i>Poa archnifera Torr.</i>	AFLP	2M	Renganayaki et. al., 2005
7	<i>Diospyros lotus</i>	AFLP	-	Akagi et. al., 2014

Table-5

SI No.	Plant species	Marker system and other methods	Determined sex and number of discovered markers	References
1	<i>Carica papaya</i>	ISSR	1 for both M and H, 1 for both F and H	Parasnis et. al., 1999; Gangopadhyay et al., 2007
2	<i>Humulus lupulus</i>	ISSR	2M	Danilova and Karlov, 2006
3	<i>Simmondsia chinensis</i>	ISSR	1M	Sharma et. al., 2008
4	<i>Phoenix dactylifera</i>	ISSR	5M	Younis et. al., 2008
5	<i>Humulus japonicus</i>	ISSR		Aleksandrov et. al., 2011

Table-6

SI No.	Plant species	Marker system and other methods	Determined sex and number of discovered markers	References
1	1.. <i>Rumex nivalis</i>	AFLP-SCAR	1M	Stehlik and Blattner, 2004
2	2. <i>Eucommia ulmoides</i>	AFLP-SCAR	1M	Wang et al., 2004; Wang et. al., 2011

Table-7

SI No.	Plant species	Marker system and other methods	Determined sex and number of discovered markers	References
1	<i>Cannabis saliva</i>	RAPD-SCAR	2M	Sakamoto, 1995; Mandoline et al., 1999
2	<i>Asparagus officinalis</i>	RAPD-SCAR	IF, 1M	Jiang and Sink, 1997; Gao et. al., 2007
3	<i>Atriplex garrettii</i>	RAPD-SCAR	1M	Ruas et. al., 1998
4	<i>Melandrium album</i> (<i>Silene latifolia</i>)	RAPD-SCAR	5M	Zhang et. al., 1998
5	<i>Carica papaya</i>	RAPD-SCAR	1M	Parasnis et. al., 2000
6	<i>Salix viminalis</i>	RAPD-SCAR	2F	Gunter et al., 2003
7	<i>Eucommia ulmoides</i>	RAPD-SCAR	IF	Xu et al., 2004
8	<i>Piper longum</i>	RAPD-SCAR	1M	Manoj et al., 2005
9	<i>Pistacia vera</i> sub sp. <i>Sarakhs</i>	RAPD-SCAR	1M, IF	Esfandiyari et al., 2011

Table-8

SI No.	Plant species	Marker system and other methods	Determined sex and number of discovered markers	References
1	<i>Phoenix dactylifera</i> L.	SSR	117F, 12M	Elmeer and Mattat, 2012
2	<i>Pistacia vera</i> L.	SNP		Kafkas et. al., 2015

Conclusion :

In the absence of information on genetic basis of sex determination, molecular based investigation of genetic differences between male and female genotypes is considered worthy. Sex linked markers alone do not explain the molecular mechanism of sex determination in dioecious plants, but the number of markers, their sequence structure and homology between sequences characteristic of males and females, provide an important means for studies into sex determination mechanism. Molecular markers linked with sex in dioecious angiosperms help in identification of genders in early growth stages of plants, which facilitates classifying the genotype and its utilisation in crop improvement. Moreover, sexual dimorphism is linked to many economically important traits such as resistance to different diseases, quality of leaf and others. Finding out the relationship between sex linked markers and desirable characters will assist targeted genetic improvement in future.

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