Research Paper

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Inheritance of Fertility Restoration in Sorghum Cytoplasmic Male Sterility Systems

Plant Breeding

KEYWORDS : Fertility restoration, Inheritance, Phenotypic ratio, Sorghum.

PRAVEEN M	Marker-assisted selection Laboratory, ICAR-Indian Institute of Millet Research (IIMR), Rajendranagar, Hyderabad, India 500 030
ANURAG UTTAM G	Marker-assisted selection Laboratory, ICAR-Indian Institute of Millet Research (IIMR), Rajendranagar, Hyderabad, India 500 030
R MADHUSUDHANA	Marker-assisted selection Laboratory, ICAR-Indian Institute of Millet Research (IIMR), Rajendranagar, Hyderabad, India 500 030

ABSTRACT

The inheritance of fertility restoration on four cytoplasmic male sterility (CMS) systems (A_1, A_2, A_3 and A_4) in sorghum was studied in F_1 and F_2 generations. Six hybrids of A_1, two hybrids of A_2 and one each of A_3 and A_4 CMS systems were planted during rainy season of 2012 and were selfed to produce F_2 seeds. Ten F_2 populations of these hybrids were raised during post-rainy season of 2012-13. All plants of each F_2 population were selfed and data on fertility/sterility was collected. In A_1 CMS, fertile and sterile plants in the F_2 involving four hybrids segregated in the ratio of 3 (fertile):1 (sterile), indicating single dominant gene control for fertility restoration. Two other A_1 CMS hybrids however segregated in 13 (fertile): 3 (sterile) indicating control of two genes in restoration of fertility. In A_2 and A_4, segregation of fertile and sterile plants in the F_2 generation was in 3 (fertile):1 (sterile) ratio, specifying single dominant gene control. The segregation of 15 (fertile): 1 (sterile) in F_2 of A_3 suggested operation of two genes in the genetic control of fertility restoration. These results indicate that the genetic control of fertility restoration is not uniform across CMS systems, and varies with the genetic background of the parents involved.

INTRODUCTION

Sorghum (*Sorghum bicolor* (L.) Moench) is one of the important cereal crops cultivated globally for food, fodder, feed and fuel. It is the second cereal crop after maize where cytoplasmic male sterility (CMS) system was successfully exploited for the mass production of F_1 hybrid for increased productivity. CMS in sorghum was first discovered when the nuclear genome of "*kafir*" was moved into an incompatible cytoplasmic background of "*milo*" (Stephens & Holland 1954). Sorghum F_1 hybrids are superior by 50-60% in their grain yield compared to the traditional landraces. Exploitation of CMS in hybrid production has revolutionized sorghum production worldwide. Of the several cytoplasm available in sorghum, only the A_1 (*milo*) CMS system is predominantly used for commercial production of hybrids (Reddy et al. 2007)specific combining ability (sca . In addition to A_1 cytoplasm several other CMS sources like A_2, A_3, A_4, Indian A_4, A_5, A_6, 9E and KS were described in sorghum (Quinby 1981). Utilization of CMS in breeding programme made it easier to incorporate the desired character into hybrid parents (House 1985). Fertility restoration is controlled by single gene or two genes or it may be polygenic based on the type of cytoplasm used (Schertz 1994). In this background, we studied fertility restoration on four (A_1, A_2, A_3 and A_4) CMS systems to determine the number of genes governing their fertility restoration.

MATERIAL AND METHODS

The experimental material comprised of five male sterile lines ($A_1$296, $A_1$27, A_2N178, A_3N178 and A_4N178) and five restorer lines (M35-1, SPV462, RS647, Mangalweda Maldandi and RSSGV3). Six F_1s on A_1, two on A_2 and one each on A_3 and A_4 CMS were developed during the post-rainy season of 2011 at the experimental farm of the ICAR-IIMR, Hyderabad, Telangana, India. All the F_1 s were grown during rainy season of 2012 and were selfed using paper bags to avoid cross-pollination and to get selfed seed. Selfed seed from each F_1 plants ($F_{2:0}$ seed) of each hybrid cross harvested separately for developing F_2s. Ten F_2 populations (Table 1) were raised separately during post-rainy season of 2012-13 at the experimental farm of the ICAR-IIMR, Hyderabad, Telangana, India. F_2 Plants were grown as a single plant per hill with a spacing of 15 cm between plants and 60 cm between rows. Recommended agronomic practices were followed to raise good crop. Each plant of 10 F_2 populations was labeled and before flowering at about the boot leaf stage when the panicle emerges, panicles were covered with a paper bag to avoid cross-pollination. Around 25-30 days after flowering (around physiological maturity), each panicle was observed visually for seed set under selfing. The F_2 plants were classified as male fertile (full-seed set) or male-sterile (< 10 seeds per panicle) as suggested (Klein et al., 2001). The goodness of fit between the observed and expected segregation for fertility: sterility in F_2 generation of each F_2 cross was tested using chi-square (χ^2) test to determine the number of genes involved in the control of fertility restoration on all the four CMS systems.

RESULTS AND DISCUSSION

Understanding the inheritance of fertility restoration of CMS system is essential as it can enhance the efficiency of selecting good restorer and maintainer parents to develop superior hybrids with yield advantage based on diversified CMS seed parents (Sarkar et al. 2002). The F_1 plants of all the ten crosses of the present study were fully fertile which suggested that fertility restoration was dominant over sterility across four CMS systems.

Fertile and sterile plants in F_2 generations involving four of the six hybrids of A_1 CMS segregated in the ratio of 3 (fertile): 1 (sterile) (Table 1). These results indicate that a single dominant gene controlled fertility restoration in these hybrids. This is in conformity with the earlier findings of (Tripathi et al. 1985). On the other hand, two F_2s involving R647 as restorer parent segregated in 13 (fertile): 3 (sterile) suggesting the involvement of two genes for fertility restoration in these crosses. Both monogenic and di-genic control was observed to operate in the inheritance of fertility restoration on A_1 CMS. However, it differed with the genetic background of the restorer parent used. While SPV462 and M35-1 were observed to carry a single gene for fertility restoration on $A_1$296 and $A_1$27, RS647 was found to carry two genes with its di-genic inheritance in F_2 populations. Both M35-1 and RS647 are post-rainy adapted sorghum restorer lines and they carried different genes for fertility restoration on A_1 CMS. SPV462 is a rainy season adapted line and showed monogenic control of fertility restoration similar to M35-1. The results clearly indicated no relationship between seasonal adaptation of the restorer parent and its genetic control on fertility. In other words, the genetic control of fertility restoration solely depended on the genetic background of CMS and restorer lines used.

(Table 1 should be here)

Both F_2 populations of A_2N178 with M35-1 and Magalweda Maldandi restorer parents segregated in 3:1, which indicated that fertility restoration in these hybrids was controlled by single dominant gene. Studies involving A_2 CMS indicated that the genetics of fertility restoration was complex with involvement of 2-4 genes, (Tripathi et al. 1985; Reddy et al. 2010). These studies indicated that the genetic control of A_2 CMS restoration varied with genetic background. Similar to A_2 CMS, F_2 population of the cross A_4N178 x RSSGV3 segregated in 3 (fertile) and 1(sterile) also suggesting monogenic control of fertility in this hybrid on A_4 CMS system.

Segregation of fertile and sterile plants in F_2 generation involving A_3N178 x Mangalweda Maldandi hybrid was in the 15(fertile): 1 (sterile) ratio, which indicated that fertility restoration in this hybrids was controlled by two dominant genes with duplicate epitasis (Table 1). Mangalweda Maldandi, a post-rainy parent, was a restorer on both A_2 and A_3 CMS lines. However, the inheritance of fertility restoration was different on these CMS systems, with single gene control on A_2 CMS and two-gene control on A_3 CMS.

Thus from the segregation pattern of fertility/sterility in the F_2 populations of A_1, A_2, A_3 and A_4 CMS studied, it was apparent that the fertility restoration was under the control of 1-2 genes. In addition, the genetic control of fertility restoration is not uniform across CMS systems, and varied with the genetic background of the parents involved. The genetic architecture of fertility restoration in sorghum has been studied with molecular markers in the recent past, and six major *Rf* genes (*Rf1, Rf2, Rf3, Rf4, Rf5* and *Rf6*) have been described (Praveen et al. 2015). It would be interesting to map the genetic loci of *Rf* genes using the crosses of the present study to validate whether any reported *Rf* locus or a new *Rf* locus is operating in fertility restoration.

Table 1: Details of F_2 crosses used and their segregation for fertility restoration

S.no	F_2 cross	Total no. of plants	No. of fertile plants	No. of sterile plants	Genetic Ratio	χ^2 **Value**	P value
A_1 CMS							
1.	$A_1$296 x M35-1	231	172	59	3:1	0.04	0.85
2.	$A_1$296 x SPV462	213	160	53	3:1	0.001	0.97
4.	$A_1$27 x M35-1	851	650	201	3:1	0.87	0.35
5.	$A_1$27 x SPV462	245	173	72	3:1	2.52	0.11
3.	$A_1$296 x RS647	237	193	44	13:3	0.01	0.94
6.	$A_1$27 x RS647	201	172	29	13:3	2.47	0.12
A_2 CMS							
1.	A_2N178 x M. Maldandi	196	141	55	3:1	0.98	0.32
2.	A_2 x M35-1	246	189	57	3:1	0.44	0.51
A_3 CMS							
1.	A_3 x M. Maldandi	224	208	16	15:1	0.31	0.58
A_4 CMS							
1.	A_4 x RSSGV3	186	143	43	3:1	0.35	0.55

REFERENCE

House LR, 1985. A guide to sorghum breeding (No. SB191. S7. H68 1982). Patancheru, India: International Crops Research Institute for the Semi-Arid Tropics. | Klein RR, Klein PE, Chhabra K, Dong J, Pammi S, Childs KL, and Schertz KF, 2001. Molecular mapping of the rf1 gene for pollen fertility restoration in sorghum (Sorghum bicolor L.). Theoretical and Applied Genetics 102(8): 1206–1212. | Praveen M, Suneetha N , Av U, Patil JV, and Madhusudhana R, 2015. Inheritance and molecular mapping of Rf6 locus with pollen fertility restoration ability on A1 and A2 cytoplasms in sorghum. Plant Science 238: 73-80. | Quinby J, 1981. Interaction of genes and cytoplasms in male sterility in sorghum, in: Proceedings of the annual corn and sorghum industry research conference American Seed Trade Association, Corn and Sorghum Division, Corn and Sorghum Research Conference. | Reddy BVS, Ramesh S, Reddy PS, and Ramaiah B, 2007. Combining ability and heterosis as influenced by male-sterility inducing cytoplasms in sorghum [Sorghum bicolor (L.) Moench]. Euphytica 154(1-2): 153–164. | Reddy PS, Rao D, Reddy BVS, and Kumar A, 2010. Inheritance of male-fertility restoration in A1, A2, A3 and A4 (M) cytoplasmic male-sterility systems of sorghum [Sorghum bicolor (L.) Moench]. Indian Journal of Genetics and Plant Breeding 70(3): 240–246. | Sarkar CK, Zaman FU, and Singh AK, 2002. Genetics of fertility restoration of 'WA'based cytoplasmic male sterility system in rice (Oryza sativa L.) using basmati restorer lines. The Indian Journal of Genetics and Plant Breeding 62(4): 305-308. | Schertz KF, 1994. Male-sterility in sorghum: its characteristics and importance. In Use of molecular markers in sorghum and pearl millet breeding for developing countries: proceedings of an ODA Plant Sciences Research Programme Conference on Genetic Improvement 29: 35-37. | Stephens JC, and Holland RF, 1954. Cytoplasmic Male-Sterility For Hybrid Sorghum Seed Production. Agronomy Journal 46(1): 20. | Tripathi D, Rana BS, and Rao NGB, 1985. Genetics of fertility restoration in sorghum, Indian Journal of Genetics and Plant Breeding 45: 292–301.