

Review article

Gene expression in allergenic pollen

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Abstract

The molecular mechanism of gene expression for pollen specificity is not yet fully known. However, it is an exciting area with great potential and has a wide scope of application in the field of molecular biology, breeding systems, biotechnology etc. The main aim of this write-up is to review some of the interesting achievements made through studies like gene expression in allergic pollen and the research which will make a way towards practical application of pollen molecular biology in identifying and isolating the genes responsible for all allergic disorders reported among various individuals.

Introduction

Pollen grain represents the male portion of the gametophytic stage in the angiospermic life cycle and is only a 3-celled organ after it completes the process like microsporogenesis and microgametogenesis. The pollen grain is certainly a reduced system in the morphological sense, but it contains all the genetic information which are essential for the formation of complete plants.

In recent years voluminous research literature has been published on genetic programme operations in the male gametophytes in comparison to saprophytes and a number of national and international laboratories have started providing information on the genes expressed in the pollen development of a number of plant species.

Pollen development

In angiosperms, microgametophytes display a complex programme during its development; for example, in maize where sporogenous cells in the anther begin to differentiate within the nutritive tissue, the tapetum. So, tapetal tissues are important in normal pollen development and any abnormal development of tapetum leads to the male sterility

(Laughnan and Gabay-Laughnan, 1983; Lonsdale, 1987). These findings are supported by experimental disruption of another function by expression or inhibition specific gene under the control of tapetum specific promoters which can result in a male sterility among plants (Mariani et al., 1990; Vander Meer et al., 1992; Worrall et al., 1992).

Pollen expressed and pollen specific genes

The activity of genes expressed in the pollen, the number of the genes active in the pollen species have been directly estimated, e.g. in maize pollen 24000 mRNA's in comparison to different mRNA's present in shoot tissue is 31000 (Willing et al., 1988). The number of genes expressed in pollen are cellular "House Keeping genes", which are expressed in the sporophytes. The percentage of genes expressed specifically in pollen can also be evaluated by screening of pollen specific clones in a pollen cDNA library.

Timing of pollen gene and expression

The pollen genes complex programmes studied so far have revealed that the expression patterns have been broadly classified into two main classes of genes

Table 1. Pollen specific genes in some allergenic plant species.

Plant species	Genes	Putative function (homology to)	Studied by
<i>Zea mays</i> (maize)	Zm 58	Pectate lyase (lat 56, lat 59, G10, Amb a I.II)	Turcich et al. (1993)
<i>Zea mays</i> (maize)	Zea m I	Allergen (Lol pI)	Boardwater et al. (1993)
<i>Zea mays</i> (maize)	Zm 13	– Ole e I, lat 52, PSI	Stinson et al. (1987); Hanson et al. (1989).
<i>Zea mays</i> (maize)	PGIw2247 (and others)	Polygalacturonase	Niogret et al. (1991); Allen an Lonsdale (1993); Barakate et al. (1993)
<i>Zea mays</i> (maize)	Zm Pro 1,2,3	Profilin	Staiger et.al. (1993).
<i>Ambrosia artemisiifolia</i> (ragweed)	Amb a II-4, Amb a II	Allergens, pectate lyases (Zm 58, lat 56, lat 59, G10)	Rogers et al. (1991); Rafnar et al. (1991).
<i>Lolium perenne</i> (ryegrass)	Lol p II, Lol p Ib	Allergens (Zea m I)	Singh et al. (1991).
<i>Poa pratensis</i> (kentucky bluegrass)	KGB family, Poa p ix	Allergens	Silvanovich et al. (1991).
<i>Olea Sp.</i> (olives)	Ole e I	Allergen (Zm 13), Ole e I, lat 52 PSI	Villalba et al. (1994)
<i>Oryza Stavia</i> (rice)	PSI	– Ole e I, Zm13 lat 52	Zou et al. (1994)
<i>Arabidopsis</i>	TUAI	α -tubulin	Carpenter et al. (1992)

expressed (early and late) during pollen development (Mascarenhas, 1990) with a transition period occurring roughly at microspore mitosis. It is presumed that the early class of genes expression is associated with immature microspore formation and the late class of gene expression with pollen maturation, germination and pollen tube growth. Besides, the late class of genes expression has been identified with several pollen specific clones which sequences are similar to enzymes associated with cell wall metabolism as well as many cytoskeleton genes, the product of which are clearly necessary for pollen tube growth. Recently, several pollen specific genes have been isolated and their promoters are studied in detail which will help in identifying the common element present in allergic pollen (Table 1).

Also, a large group of pollen expressed proteins characterized to date are cytoskeleton related proteins like actin (Thangavelu et al., 1993), α -tubulin (Carpenter et al., 1992), β -tubulin (Rogers et al., 1993) and profilin (Valenta et al., 1991b; Staiger et al., 1993).

Pollen allergens

Presently it has become clear that several of the highly expressed proteins in pollen are human allergen. Sequence homology research indicates that there is a substantial homology between the pectate lyase proteins and proteins identified from the pollen of short ragweed, *Ambrosia artemisiifolia* (McCormick, 1991; Rogers et al., 1991). Of the seasonal allergens which may cause hay fever, asthma, and hives, pollen from the short ragweed has been implicated

as being among the most clinically important (King, 1976; Rafnar et al., 1991). Many prominent allergenic proteins from this pollen have been immunologically characterized, revealing that the Amb a I (formerly Allergen E) protein can account for at least 90 per cent of the allergenicity of ragweed pollen (Rafnar et al., 1991). This protein is one of a multi-gene family of very similar proteins, including Amb a I.1, I.2, I.3, I.4, and II. The Amb a II protein is interesting because it shows only approximately 65% homology with members of the Amb a I family, yet it demonstrates similar allergenic potential (Rogers et al., 1991). All the pollen-specific pectate lyase genes compared have homologies to Amb a I on the order of 46 to 48% amino acid identity and may share similar epitopes. There is also homology between these genes and the partial protein sequence of the major allergen of Japanese cedar pollen. Cry j I (Taniai et al., 1988; McCormick, 1991).

Similarly, many pollen-expressed proteins responsible for IgE binding in allergic patients have been shown to profilins. The first protein recognized as such was identified as one of the major allergens from birch pollen (Valenta et al., 1991b). It has since been shown that pollen profilins represent a common class of immuno-reactive agents and have been found in pollen of several species, including timothy grass, *Phleum pratense* (Valenta et al., 1994). Another allergen that has been shown to exhibit high levels of expression in birch pollen is Bet v I (Breiteneder et al., 1989). Proteins homologous to Bet v I have been shown to be allergens in pollen from many trees in the order Fagales, for example, birch, alder, hazel, and horn-

beam (Valenta et al., 1991a; Ebner et al., 1993). No known plant function has yet been assigned to Bet v I, but it does appear to have homology to plant disease resistance response genes (Breiteneder et al., 1989). There are several other pollen expressed proteins that have been identified as human allergens, but which function in pollen is yet unknown.

Several of the allergenic proteins present in pollen appear to have important functions in pollen tube growth. Attempts to engineer plants with lowered levels of these allergens might thus be problematic from an environmental point of view because male sterility might result.

Conclusions

Characterization of genes and promoters particularly involved in key regulatory processes in allergic pollen will provide insights into the nature of haploid gene expression in relation to that of the diploid plants. All such relevant findings will make a way towards practical application of pollen molecular biology in the areas like plant breeding, biotechnology and allergy.

References

- Barakate A., Martin W., Quigley F. and Mache R.: 1993 Characterization of a multigene family encoding an exopolysaccharuronase in maize. *J Mol Biol* **229**, 797–801.
- Breiteneder H., Pettenburger K., Bito A., Valenta R., Kraft D., Rumpold H., Scheiner O. and Breitenbach M.: 1989, The gene coding for the major birch pollen allergen *Bet v I*, is highly homologous to a pea disease resistance response gene. *EMBO J* **8**, 1935–1938.
- Broadwater A.H., Rubinstein A.L., Chay C.H. Klapper D.G. and Bedinger P.A.: 1993, Zea-mI, the maize homolog of the allergen-encoding Lol-pl gene of rye grass. *Gene* **1331**, 227–230.
- Carpenter J.L., Ploense S.E., Snustad D.P. and Silflow C.: 1992, Preferential expression of an α -tubulin gene of *Arabidopsis* in pollen. *Plant Cell* **4**, 557–571.
- Ebner C., Ferreira F., Hoffmann K., Hirschwehr R., Schenk S., Szepefalusi Z., Breiteneder H., Parronchi P., Romagnani S., Scheiner O. and Kraft D.: 1993, T cell clones specific for Bet v I, the major birch pollen allergen crossreact with major allergens of hazel, Cor A I, and alder, Aln G I. *Mol Immunol* **30**, 1223–1229.
- King T.P.: 1976, Chemical and biological properties of some atopic allergens. *Adv Immunol* **23**, 77–105.
- Laughnan J.R. and Gabay-Laughnan S.: 1983, Cytoplasmic male sterility in maize. *Annu Rev Genet* **117**, 27–48.
- Lonsdale D.M.: 1987, Cytoplasmic male sterility: A molecular perspective. *Plant Physiol Biochem* **25**: 265–271.
- Mariani C., DeBeuckeleer M., Truettner J., Leemans J. and Goldberg R.B.: 1990, Induction of male sterility in plants by a ribonuclease gene. *Nature* **347**, 737–741.
- Mascarenhas J.P.: 1989, The male gametophyte of flowering plants. *Plant Cell* **1**, 657–664.
- Mascarenhas J.P.: 1990, Gene activity during pollen development. *Ann Rev Plant Physiol Plant Mol Biol* **41**, 317–338.
- Mascarenhas J.P.: 1993, Molecular mechanisms of pollen tube growth and differentiation. *Plant Cell* **5**, 1303–1314.
- McCormick S.: 1991, Molecular analysis of male gametogenesis in plants. *Trends Genet* **7**, 298–303.
- Niogret M.F., Dubald M., Mandaron P. and Mache R.: 1991, Characterization of pollen Polygalacturonase encoded by several cDNA clones in maize. *Plant Mol Biol* **17**, 1155–1164.
- Rafnar T., Griffith I.J., Kuo M., Bond J.F., Rogers B.L. and Klapper D.G.: 1991, Cloning of Amb a I (antigen E), the major allergen family of short ragweed pollen. *J Biol Chem* **266**, 1229–1236.
- Rogers B.L., Morgenstern J.P., Griffith I.J., Yu X.B., Counsell C.M., Brauer A.W., King T.P., Garman R.D. and Kuo M.C.: 1991, Complete sequence of the allergen *Amb a II*. *J Immunol* **147**, 2547–2552.
- Rogers H.J., Greenland A.J. and Hussey P.J.: 1993, Four members of the maize β -tubulin gene family are expressed in the male gametophyte. *Plant J* **4**, 875–882.
- Silvanovich A., Astwood J., Zhang L., Olsen E., Kisil F., Sehon A., Mohapatra S. and Hill R.: 1991, Nucleotide sequence analysis of three cDNA coding for Poa p IX isoallergens of Kentucky bluegrass pollen. *J Biol Chem* **266**, 1204–1210.
- Singh M.B., Hough T., Theerakulpisut P., Avjioglu A., Davies S., Smith P.M., Taylor P., Simpson R.J., Ward L.D. McCluskey J., Puy R. and Knox R.B.: 1991, Isolation of cDNA encoding a newly identified major allergenic protein of rye-grass pollen: Intracellular targeting to the amyloplast. *Proc Watt Acad Sci USA* **88**, 1384–1388.
- Staiger C.J., Goodbody K.C., Hussey P.J., Valenta R., Drobak B. and Lloyd C.W.: 1993, The profilin multigene family of maize: Differential expression of three isoforms. *Plant J* **4**, 631–641.
- Stinson J.R., Eisenberg A.J., Willing R.P., Pe M.E., Hanson D.D. and Mascarenhas J.P.: 1987, Genes expressed in the male gametophyte of flowering plants and their isolation. *Plant Physiol* **83**, 442–447.
- Taniai M., Ando S., Usui M., Kurimoto M., Sakaguchi M., Inouye S. and Matuhasi T.: 1988, N-terminal amino acid sequence of major pollen allergen of Japanese cedar pollen (*Cry. j I*). *FEBS Lett* **239**, 329–332.
- Thangavelu M., Belostotsky D., Bevan M.W., Flavell R.B., Roger H.J. and Lonsdale D.M.: 1993, Partial characterization of the *Nicotiana tabacum* acin gene family: Evidence for pollen-specific expression of one of the gene family members. *Mol Gen Genet* **240**, 290–295.
- Turcich M.P., Hamilton D.A. and Mascarenhas J.P.: 1993, Isolation and characterization of pollen-specific maize genes with sequence homology to ragweed allergens and pectate lyases. *Plant Mol Biol* **23**, 1061–1065.
- Valenta R., Ball T., Vrtala S., Duchene M., Kraft D. and Scheiner O.: 1994, cDNA cloning and expression of timothy grass (*Phelum pratense*) pollen profilin in *Escherichia coli*: Comparison with birch pollen profilin. *Biochem. Biophys Res Commun* **199**, 106–118.
- Valenta R., Duchene M., Pettenburger K., Sillaber C., Valent P., Bettelheim P., Breitenbach M., Rumpold H., Kraft D. and Scheiner O.: 1991b, Identification of profilin as a novel pollen allergen; IgE autoreactivity in sensitized individuals. *Science* **253**: 557–560.

- Van der Meer I.M., Stam M.E., Van Tunen A.J., Mol J.N.M. and Stuitje A.R.: 1992, Antisense inhibition of flavonoid biosynthesis in petunia anthers results in male sterility. *Plant Cell* **4**, 253–262.
- Villalba M. Batanero F., Monsalve R.I., Gonzalez de la pena M.A., Lahoz C. and Rodriges R.: 1994, Cloning and pollen expression of Ole e I the major allergen from olive tree pollen. *J Biol Chem* **269**, 15217–15222.
- Willing R.P., Bashe D. and Mascarenhas J.P.: 1988, An analysis of the quantity and diversity of messenger RNAs from pollen and shoots of *Zea mays*. *Theor Appl Genet* **75**, 751–753.
- Worrall D., Hird D.L. Hodge R., Paul W., Draper J. and Scott R.: 1992, Premature dissolution of the microsporocyte callose wall causes male sterility in transgenic tobacco. *Plant Cell* **4**, 759–771.
- Zou J.T., Zham X.Y., Wu H.M., Wang H. and Cheung A.Y.: 1994, Characterization of a rice pollen-specific gene and its expression. *Amer J Bot* **81**, 552–561.