A simple PCR-based method to follow and genotype alleles with single nucleotide changes

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Figure 1A

**mab-9**

<table>
<thead>
<tr>
<th>primer sequence</th>
<th>WT allele</th>
<th>mutant allele e2410</th>
</tr>
</thead>
<tbody>
<tr>
<td>gttccagagaacctttttggt</td>
<td>wild type</td>
<td>358pb fragment</td>
</tr>
<tr>
<td>gttccagagaacctttttggt</td>
<td>mutant e2410</td>
<td>279pb fragment after Acc65I digestion</td>
</tr>
</tbody>
</table>

No digestion by Acc65I : 358pb fragment

Figure 1B

Representative analysis on a 2.5% agarose gel. Lane L: ladder, the 500pb band is indicated; lanes 1: WT allele; lanes 2: mutant allele; lane 3: heterozygote animal. The **mab-9** fragment amplified from the WT allele is left undigested by Acc65I with a size of 358pb (white star), while the PCR fragment length obtained from mutant e2410 allele is 279pb after Acc65I digestion (red star, the remaining 79pb fragment is not visible here).

Description

Mutant analysis and the building of complex strains bearing several mutant alleles and/or transgenes are precious tools routinely used in studies using genetic models such as *C. elegans*. Crossing, strain building and genotyping necessitate to follow the various alleles to be combined during the crosses, some of which may not exhibit any easily detectable phenotype. Phenotypic markers (usually associated with an obvious phenotype: e.g. *dpy, unc, rol, lon*, etc) have been used as balancers in trans to follow a mutation of interest. This strategy is best used when the marker gene is located close enough to the mutation that one wishes to follow, to avoid crossing overs and recombinations during the several crosses and homozygosing steps. In recent years, using MosSCI insertions, Christian Frokjær-Jensen et al. have generated a set of strains bearing fluorescent markers inserted at specific chromosomal locations that can also be used as dominant genetic markers (Frokjaer-Jensen et al. 2014).

However, depending on the location of the mutation of interest on a chromosome, there might not be any close genetic marker that can be used. In addition, the use of genetic markers to follow a mutation of interest imposes to first build one or several intermediate strains to associate two or more mutant alleles. To introduce a chromosome-integrated transgene in the background of a mutant, strategies using genetic markers can also be limited: the phenotypes of different genetic markers are not all compatible, and the fluorescent expression in MosSCI strains can preclude detection of other transgenes needed in the strain of interest. Finally, other species, from other worms to vertebrates, may not have the same tools such as the extensive *C. elegans* genetic markers and mutant strains library.

Here, we describe a simple and quick method to follow mutations through the several crossing steps. This method is particularly handy when the mutation of interest does not create or modify a restriction site, and avoids having to resort to a multi-step process involving the individual sequencing of multiple animals, after amplification of the genomic region of interest. It is based on the creation of a restriction site by PCR specifically in the amplicon for one of the alleles only, using specific oligonucleotides to amplify a small DNA fragment around the mutation to be followed, and can be applied...
to several mutations in parallel. This method which uses only two primers for a given gene, one round of PCR and just one PCR product for each allele is also simpler and more robust than the tetra primer ARMS-PCR previously described (Ye et al., 2001).

To date, we have applied this method to the genotyping of 116 mutant alleles, including daf-2(e1370), ceh-6(gk665), sem-4(n1971, n2654 & n1378), mab-9(e2410), eri-1(mg366), egl-5(n945), egr-1(ku285), jmjd-3.1(fp15), wdr-5.1(ok1417). The results for mab-9(e2410) are shown in figure 1 and have been repeated 5 times.

mab-9 is a T-box transcription factor well studied for its role in hindgut and tail development. Unfortunately, this gene is in a genomic region poor in phenotypic balancer genes, and shows a subtle mutant phenotype under dissecting microscope (https://wormbase.org/species/c_elegans/gene/WBGene000310640-9f-3). The mab-9(e2410) allele exhibits two point mutations (TA to GT) in the 4th intron, that cause a splice defect (Woolhard & Hodgkin 2000, Figure 1A). The WT sequence is gtaact and the mab-9(e2410) sequence gGTact. To follow this mutant allele during crosses, it is possible to modify one nucleotide by PCR and specifically create an Acc65I site (G/GTACC) in the amplicon from the mutant allele: By replacing in the mab9R reverse primer the last T of the mutant gGTact sequence by a C, an Acc65I gGTacc site is created in the mutant amplicon only (Figure 1A). Primers mab9F and mab9R allow amplification of a 358 bp PCR fragment. After Acc65I digestion, the PCR product from mab-9(e2410) is digested into a 279bp and a 79bp fragments, while the WT version remains 358pb, and heterozygous animals exhibit three bands at 358bp, 279bp, and 79bp (Figure 1B). Using this method, genotyping is achieved in a couple of hours enabling to pick the desired animals the same day. Since it bypasses the need to build genetically balanced strains, the time to obtain the final strain is considerably reduced. This PCR-based strategy is widely adaptable to many other organisms than C. elegans, from well-known genetic models such as drosophila, zebrafish or other worms to models lacking a full genetic tool box.

Methods

This method typically allows the amplification of a short fragment (around 350 pb +/-50bp) with the mutation of interest. Here is a brief description of the workflow:

1. **Design oligonucleotides:** locate the SNP between the wild type and the mutant alleles on the locus sequence. Design a pair of amplifying primers with one of them ending its 3’ extremity just before the SNP. By changing a single nucleotide (or two) close to the mutation of interest directly on this primer, it is possible to create a restriction site. For example, in the sequence nnGTTAAnnn (were the last A would be the point mutation in the mutant allele to follow), it is possible to create a palindromic sequence in changing the G by a T. Like most of the 6 nucleotides palindromic sequences, TTTAAA corresponds to a restriction site: the DraI site here. Thus, if the WT has the sequence nnGTTAA

2. **Prepare worms lysates:** we have used this method to follow mutations during crosses, and thus have routinely used single worm lysates (http://www.wormbook.org/chapters/www_SNPsintrotwopointmap/SNPsintrotwopointmap.html#d0e185)) for our PCRs, picking adults after they have laid eggs for 2-3 days. It is recommended to run PCRs on WT and mutant samples in parallel, as well as on a mix of a mutant and a wild type worm to visualise heterozygote animals.

3. **Digest the PCRs** using the restriction enzyme which site is created when amplifying one of the alleles.

**Run a 2% to 3% agarose gel** (the exact concentration will depend on the size of the two fragments to detect: full length PCR, versus full length PCR minus the length of the oligonucleotide including the restriction site).

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References


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