Isozyme polymorphism at the Mdh1 locus in peach has been described by various authors. Arulasekar et al. (1986) and Durham et al. (1987) demonstrated that the variability observed for MDH in peach could be explained by the presence of two alleles (S and F) interacting at a single locus, designated Mgh1. Mowrey et al. (1991) reported the presence of a third allele (Mdh1-3) at the Mdh1 locus, and proposed the designation of Mdh1-1 and Mdh1-2 for the F and S alleles, respectively. Characterization of peach cultivars, breeding lines, and plant introductions for MDH has shown that Mdh1-1/Mdh1-1 homozygotes are very rare. Of 290 cultivars tested by Arulasekar et al. (1986), only six were Mdh1-1/Mdh1-1. Durham et al. (1987) found only one Mdh1-1/Mdh1-1 homozygote among 59 cultivars and breeding lines surveyed. Mowrey et al. (1990) found only one Mdh1-1/Mdh1-1 homozygote among 56 peach plant introductions. This is noteworthy, because the cultivar 'Chinese Cling', introduced into the United States in 1850 (Scorza et al., 1985), is homozygous Mdh1-1/Mdh1-1 (Arulasekar et al., 1986). This cultivar served as the base for cultivar improvement in most state and federal peach breeding programs. Most commercial peach cultivars grown today in the eastern United States can be traced back to 'Chinese Cling' (Scorza et al., 1985). Thus, the Mdh1-1 allele has been rapidly eliminated from breeding populations.

Arulasekar et al. (1986) and Mowrey et al. (1990) have suggested that the Mdh1-1 allele in the homozygous state may have some selective disadvantage, or is clearly linked to an undesirable character.

During routine electrophoretic analysis of various F1 populations in support of our gene linkage studies in peach, an apparent association between MDH isozyme genotype and plant vigor was observed. This study was initiated to determine the relationship between MDH isozyme genotype and plant vigor in peach using two F1 populations segregating at the Mdh1 locus.
Homozygous Mdh1-2/Mdh1-2 individuals showed the greatest vigor and were significantly different from Mdh1-1/Mdh1-1 homozygotes in both populations and from Mdh1-1/Mdh1-2 heterozygotes in the 'Belle of Georgia' population. The association between MDH genotype and plant vigor was greater in the 'Belle of Georgia' population than in 'Cresthaven', as shown by the frequency distribution data (Figs. 1 and 2). The additive effect [calculated as: (Mdh1-2/Mdh1-2 mean height - Mdh1-1/Mdh1-1 mean height)/2] associated with the Mdh1-2 allele was 19.9 and 7.8 cm in the 'Belle of Georgia' and 'Cresthaven' populations, respectively. Mean height of Mdh1-1/Mdh1-1 homozygotes was 27% and 12% less than that of Mdh1-2/Mdh1-2 homozygotes in the 'Belle of Georgia' and 'Cresthaven' populations, respectively (Table 1). A significant deviation from the expected 1 Mdh1-1/Mdh1-1 : 2 Mdh1-1/Mdh1-2 : 1 Mdh1-2/Mdh1-2 ratio was observed in the 'Belle of Georgia' population ($\chi^2 = 10.6, P < 0.01$), but not in the 'Cresthaven' population ($\chi^2 = 2.08, P = 0.25 – 0.50$) (Table 2). This result suggests that moderate lethality of Mdh1-1/Mdh1-1 homozygotes may occur in certain genetic backgrounds and may explain partially the rarity of this genotype.

It is noteworthy that other homozygous Mdh1-1/Mdh1-1 peach cultivars exhibit low vigor. 'Chinese Cling' and 'Siberian-C', both Mdh1-1/Mdh1-1 (Arulsekar et al., 1986), are low to moderate in vigor (characterization of 'Siberian C' by R.E.C. Layne, personal communication). As early as 1932, Blake (1932) characterized the cultivar J.H. Hale (Mdh1-1/Mdh1-2) as "slightly dwarf" in habit. Blake (1933) further reported that 'Elberta' (heterozygous Mdh1-1/Mdh1-2), a seedling of 'Chinese Cling' (Hedrick, 1917), produced numerous "semi-dwarf” and “full dwarf" seedlings. These reports further support the relationship between the homozygous Mdh1-1/Mdh1-1 genotype and low vigor in peach.

Our results clearly show that Mdh1-1/Mdh1-1 homozygotes are low in vigor, and that the relationship was greater in the 'Belle of Georgia' population as compared to 'Cresthaven'. 'Belle of Georgia' is a direct descendent of 'Chinese Cling', having originated as an open-pollinated seedling from it (Hedrick, 1917). Conversely, 'Cresthaven' has a more complex pedigree (Brooks and Olmo, 1972), and is about four generations removed from 'Chinese Cling'. Differences in the two populations regarding the relative effect of the Mdh1 allele on plant vigor may be attributed to differences in genetic backgrounds. It is possible that other genes affecting vigor, either in unlinked regions of the genome or in the region near the Mdh1 locus, also are segregating in the F$_2$ population of 'Cresthaven', thus obscuring the relationship between vigor and MDH genotype.

We propose that one explanation for the rarity of homozygous Mdh1-1/Mdh1-1 genotypes among commercial peach cultivars and breeding lines is due to the marked reduction in vigor of these individuals, and their subsequent loss through natural competition in seedling rows and through culling by breeders during selection. Moderate lethality of Mdh1-1/Mdh1-1 homozygotes further reduces their numbers in breeding populations. Peach breeders have long lamented the production problems faced due to the undesirably high vigor of most commercial peach cultivars, and the lack of appropriate dwarfing rootstock and appropriate dwarf and semi-dwarf scion cultivars to address this concern. This study suggests that a full range in plant vigor can be obtained in young seedling populations segregating at the Mdh1 locus, and that this association between vigor and MDH genotype provides a convenient marker that can be characterized as early as the seed stage, if desired.

The basis for the relationship between MDH genotype and plant vigor cannot be determined from these data. Low vigor of Mdh1-1/Mdh1-1 homozygotes could be due directly to the kinetics and cellular function of the actual variant isozyme itself. Alternatively, the Mdh1 locus may be closely linked to a gene with a major influence on plant vigor, and this gene may have been introduced with the Mdh1-1 allele into current commercial germplasm from 'Chinese Cling'. The existence of some Mdh1-1/Mdh1-1 homozygotes exhibiting normal vigor in these populations examined in this study lends support to the gene linkage association between MDH genotype and plant vigor.
hypothesis. Also, the presence of $\text{Mdhl}_1-2/\text{Mdhl}_1-2$ homozygotes showing low vigor supports this hypothesis, in that such individuals may represent recombinant. These alternatives warrant further investigation.

**Literature Cited**


