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Heterosis of Vine Decline Disease Resistance Caused by the Fungus *Monosporascus cannonballus* in Melons (*Cucumis melo* L)

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Abstract

Vine decline disease (VDD) constitutes a menace to melons worldwide. Especially, the one caused by the fungus *Monosporascus cannonballus*. Thus, resistant plant material must be released to help growers. Hence, our goal was to develop resistant plant material to VDD. More than 600 melon accessions are expected to be tested for disease resistance in *M. cannonballus* infested soil in Weslaco, Texas, USA, to identify resistance to VDD, and other important traits. So far, at most 7 lines were found to be resistant to VDD and some of them were used to develop elite, muskmelon inbred lines by pedigree breeding following single or double backcrosses. These elite parents were crossed to each other to develop the hybrids M3 and M4. They were also tested in the same infested field in Weslaco. The hybrids were grown using standard commercial practices followed by growers and when their fruits were ready, their roots were sampled as well as scored for disease severity to estimate high and mid-parent heterosis Our results indicate the existence of heterosis regarding resistance to VDD. Thus, resistant plant material can be developed and selection for resistance can be accomplished.

Keywords

Melons, Vine Decline Disease, *Monosporascus cannonballus*, Resistance, Heterosis

1. Introduction

Melon is an important vegetable crop worldwide. Its production was estimated to be $236 million in 2022 [1]. Moreover, melons are a rich source of vitamins and minerals [2]. Nevertheless, melon growers face many challenges. For instance, the production of melons in Texas, USA, has declined drastically over the years, from 11,000 ha to 2000 ha [3]. High costs of production, increased competition from Central America, and quality control problems have been relevant factors contributing to plummeting production in the US. Furthermore, the appearance of soil borne diseases such as vine declines, which are widely spread in areas where melons are grown worldwide, has negatively impacted it, causing yield losses that fluctuate between 20% - 25% and rendering areas unsuitable for growing this crop [4]. Thus, due to the problems previously described, the economic return of the crop must be improved. Furthermore, recent phylogenetic studies locate the origin of the genus *Cucumis* in Asia. Specifically, India. Moreover, in this continent and Africa many species of *Cucumis* can be found, which is important for breeding programs because knowing where the ancestors of melons are found, facilitates the collection of plant material that can be useful for improving important traits of this crop [5].

Vine decline disease caused by the fungus *M. cannonballus* is a damaging disease. This fungus penetrates the roots of melon plants and thrives within them and during the final stages of the disease, it produces perithecium and its spores are found in it. Also, the spores produced by this fungus look like cannonballs (**Figures 1-3**). The symptoms of VDD disease are more evident when the fruits are growing, and the plant requires more water. Such symptoms are noticeable because the leaves of the plant collapse, its fruits do not develop completely and are damaged by the sun. Traditionally, fumigants are used to control VDD, which increases production costs and pollutes the environment [4].

perithecium (black spots)

Figure 1. Root of melon plants affected by vine decline disease caused by *M. Cannonballus*.

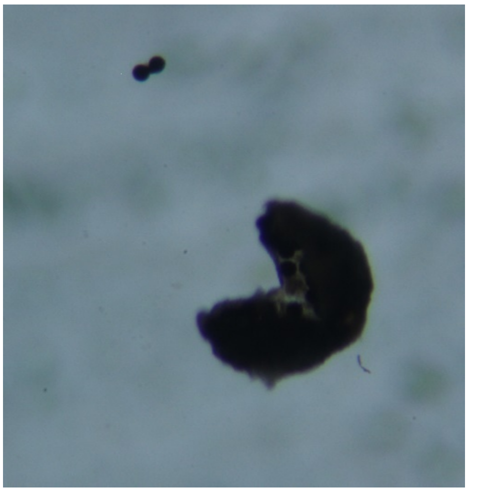

Figure 2. Opened perithecium with spores.

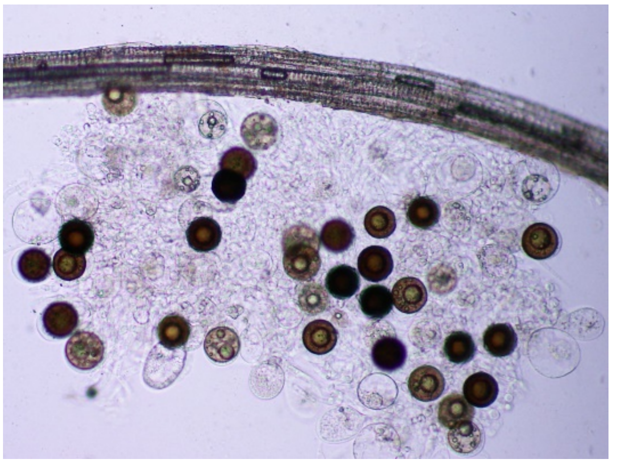

Figure 3. Spores of *M. cannonballus*.

Taking into consideration what was previously stated, it is evident that studies to generate resistant plant material to VDD are needed. Hence, this study was conducted with the objective of developing resistant plant material to vine decline disease (VDD) caused by the fungus *Monosporascus cannonballus*.

2. Materials and Methods

2.1. Location

A preliminary study to evaluate the performance of melon hybrids and their parents regarding VDD resistance was conducted during summer of 2022 in Weslaco, Texas, at the Texas A & M AgriLife Research Center.

2.2. Plant Material

The hybrids of melons labeled M3, M4 and their parents were tested for disease resistance. Additionally, the information regarding the background of their parents can be seen in Table 1 and Table 2.

Table 1. Background of the parents used to develop the hybrids M3 and M4.

Female Parent	Male Parent	Off-Spring
Dulce	USDA PI 124104	M1 (Parent)
Ames 20608	Dulce	M2 (Parent)
TAM-Uvalde × MF126 (1405 PMR × USDA PI 124104)	1405 (Deltex × Perlita F12)	M7 (Parent)
Dulce	USDA PI 124104	M8 (Parent)

Table 2. Parents used to develop the hybrids M3 and M4.

Female Parent	Male Parent	Off-Spring
M1	M2	M3 (Hybrid)
M7	M8	M4 (Hybrid)

2.3. Experimental Design

Four replications of 20-plant plots were direct seeded on black plastic mulch with subsurface drip irrigation. All fertilizer and pesticide applications followed standard commercial practices. In addition, the soil in the field plot was highly infested with *M. cannonballus* after continuous crops of melons for over 30 years. Moreover, inoculum prepared with roots obtained in this field produced 1.22×10^7 colony forming units of M. *cannonballus* per gram of medium [6]. Lastly, when fruits were ready to be harvested, the roots of their plants were carefully pulled out of the soil and the damage caused by the pathogen was scored using the following symptom severity scale proposed by Crosby [7]:

1 = plants with no visible symptoms were scored; 2 = slight necrosis of fine roots, few tan lesions; 3 = slight necrosis of all roots, moderate tan lesions; 4 = severe necrosis of all roots; and 5 = only tap root remaining, necrotic and completely tan to brown (**Figure 4**).

Mid and high parent heterosis were calculated using the following equations [8]:

$$\text{Mid-parent heterosis (\%)} = (F_1 - MP/MP) \times 100$$

$$\text{High-parent heterosis (\%)} = (F_1 - HP/HP) \times 100$$

where: F_1 = performance of the hybrid;

MP = average performance of parents;

HP = performance of best parent.

Figure 4. The symptom severity scale used in this study to evaluate root damage of melon plants caused by the fungus *M. cannonballus*. The numbers indicate the severity of the damage according to the scale proposed by Crosby [7].

3. Results and Discussion

The results of high and mid-parent heterosis regarding hybrids M3 and M4 are shown in **Table 3**. It is important to note that the negative values of the heterosis estimates obtained in this study are due to the scale used. The lower values in the scale indicate more resistance. For example, high and mid-parent heterosis of hybrid M3 were −42% and −38%, respectively. That is, such values of heterosis contribute with −42% and 38% reduction of root damage. That is, heterosis augments their resistance.

Parents Attributes

Hybrid M3 was developed by crossing parents M1 and M2 (**Table 2**). It has the variety Dulce and TAM-Uvalde in its background (**Table 1**). The varieties Dulce and TAM-Uvalde are cantaloupes, muskmelons [9]. Moreover, this hybrid presents the variety Ames 20608 (**Table 1**), which belongs to the sub-specie agrestis, which exhibits a high degree of resistance to VDD [7]. Lastly, the variety USDA PI 124104, which is resistant to VDD and originated in India, is present in its background [10].

Hybrid M4 was developed by crossing parents M7 and M8 (**Table 2**). It presents in its background the variety 1405 (**Table 1**), which is the F1 progeny of the cross between Deltex and Perlita, which exhibits a high degree of resistance to VDD [11]. Also, parent M8 has in its background the resistant variety USDA PI 124104 and on the other hand, it has the variety TAM-Uvalde in its background (**Table 1**). Thus, the presence of resistant varieties in the parents used to develop this hybrid may have been key for this hybrid to exhibiting a heterotic response regarding the resistance to VDD. It is important to remark that the varieties Dulce, Deltex and TAM-Uvalde were used to impart good fruit characteristics such as high sugar and carotenoid content, flavor, as well as rounded shape [9]

Table 3. High and mid-parent heterosis of hybrids M3 and M4.

Hybrids	Heterosis	
	High-parent (%)	Mid-parent (%)
M3	−38	−42
M4	−46	−50

[12] [13]. Finally, yield could not be measured in this experiment due to the presence of downy mildew.

4. Conclusion

The results of this study indicate that variability regarding VDD resistance exists and can be exploited to develop resistant plant material. Also, selection for resistance can be accomplished using phenotypic selection on visual assessments of root damage. Lastly, further research is needed to test these hybrids in the same location to measure their yield, and in different locations.

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Conflicts of Interest

The authors declare no conflict of interest.

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