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Evaluation of purple passion fruit grafted onto a fusarium wilt-tolerant rootstock

Abstract – The objective of this work was to evaluate the vegetative growth, yield, fruit quality, and survival of purple passion fruit grafted onto a rootstock tolerant to fusarium wilt in an area with a history of this disease. The treatments were the combination of three elite accessions of purple passion fruit (PutEdu01, TesEdu11, and a commercial accession as the control) and three rootstocks (ungrafted, autografted, and grafted onto *Passiflora maliformis*). TesEdu11 grafted onto *P. maliformis* shows the highest estimated yield at 307 days after transplanting in areas with fusarium wilt incidence.

Index terms: *Fusarium oxysporum*, *Passiflora edulis*, bioprospecting, disease resistance, grafting.

Avaliação de maracujá-roxo em porta-enxerto tolerante à fusariose

Resumo – O objetivo deste trabalho foi avaliar o desenvolvimento vegetativo, a produção, a qualidade do fruto e a sobrevivência do maracujá-roxo enxertado em um porta-enxerto tolerante à fusariose, em uma área com histórico de ocorrência da doença. Os tratamentos foram combinações de três acessos elite de maracujá-roxo (PutEdu01, TesEdu11 e um acesso comercial como controle) e três porta-enxertos (pé-franco, autoenxerto e enxerto em *Passiflora maliformis*). TesEdu11 enxertada em *P. maliformis* apresenta a maior produção estimada aos 307 dias após transplante em áreas com incidência de fusariose.

Termos para indexação: *Fusarium oxysporum*, *Passiflora edulis*, bioprospecção, resistência a doenças, enxertia.

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Economically, purple passion fruit (*Passiflora edulis* Sims) is the second most important species of the genus *Passiflora* (Ocampo et al., 2021). Currently, Colombia is the world's largest producer, followed by Kenya and Zimbabwe, with about 1,500 planted hectares and an approximate production of 2,500 tons (Agronet, 2021), with average yields varying from 20 to 30 Mg ha^{-1} (Hurtado Salazar et al., 2021). However, phytosanitary problems related to bacteria, fungi, viruses, and pests have prevented purple passion fruit crops from reaching their potential (Ocampo et al., 2021).

Despite the scarce reports in the literature, Gil et al. (2017) found considerable economic losses in purple passion fruit due to pathogen incidence. Ángel-Coca et al. (2011) observed economic losses from 90 to 100% in yellow passion fruit (*Passiflora edulis* sims f. *edulis*) crops attacked by fusarium wilt. This has led farmers to abandon infected areas (Guerrero et al., 2016), impacting production costs. In this scenario, short and long-term strategies to improve fruit yield and quality are being sought. New agronomic practices, such as semi-covers, for example, have been adopted to improve yield (Lima et al., 2017). In breeding programs, strategies include screening of new purple passion fruit genotypes and studying the resistance to diseases in wild species of *Passifloracea*, such as *Passiflora maliformis* L., in the search for rootstocks tolerant to *Fusarium* spp. (Lima et al., 2017).

The objective of this work was to evaluate the vegetative growth, yield, fruit quality, and survival of purple passion fruit grafted onto a rootstock tolerant to fusarium wilt in an area with a history of this disease.

The experiment was carried out between August 2019 and October 2021 in the municipality of Manizales, Colombia (5°01'42"N, 75°26'7"W, at 2,280 m above sea level), in an area with a known history of fusarium wilt (Gil et al., 2017). The region presents an average temperature of 17ºC, a relative humidity of 78%, and an average annual rainfall of 1,800 mm (Cenicafé, 2022). The registered solar brightness was 2,010 hours per year, with solar radiation between 320 and 350 calories per centimeter per day (Herrera et al., 2015). According to Köppen's classification, the climate subtype is Af, tropical rainforest. The soils are volcanic in origin, with a loamy texture, and topography has undulating and sloping areas (Obando et al., 2006).

Three elite accessions of purple passion fruit (PutEdu01, TesEdu11, and a commercial accession) and three rootstocks (ungrafted, autografted, and grafted onto *Passiflora maliformis*) were used in the experiment. The PutEdu01 and TesEdu11 purple passion fruit accessions were obtained from Universidad Nacional de Colombia, and the commercial accession, as well as the *P. maliformis* rootstock, from the germplasm bank of Universidad de Caldas. To obtain the plants, seeds of each genotype were sown in plastic trays (54 cm long x 28 cm wide), containing grade-three sphagnum peat substrate. The exception was the commercial accession, which was delivered by an exporting company to the experimental field in ideal conditions for transplanting.

Purple passion fruit seedlings at 120 days after sowing (DAS) and at a height from 10 to 13 cm were used for grafting on 150-day-old *P. maliformis* rootstocks. Grafting was performed when stem diameter was 0.5 cm, using the top wedging technique, in which the stem of the rootstock was cut in a V-shaped slit to receive the scion, a small shoot segment from the apex containing two or three buds. The support system was established in semi-cover, using a single wire strung to bamboos, with a distance of 4.0 m between them and of 2.0 m between rows. When the purple passion fruit plants were transplanted, the used spacing was 2.0 m between plants and 2.0 m between rows. Manual weeding was done in the rows, and scythe was used for mechanical control between rows.

Fertilization was carried out following the recommendations of Ocampo & Wyckhuys (2012), using 30 g ammonium nitrate at 30 DAS, 45 g ammonium nitrate at 60 DAS, 100 g of the 05-20-20 NPK formula at 90 DAS, and 150 g of the 20-05-20 NPK formula at 120 DAS. In the reproductive stage, 100 kg ha^{-1} N, 100 kg ha^{-1} P_2O_5, and 200 kg ha^{-1} K_2O were split in eight applications, between May 2020 and February 2021.

Infected 14-month-old purple passion fruit plants from the experimental area were used for the monosporic isolation of *Fusarium oxysporum* f. sp. *passiflorae*, cultivated in papa-dextrose-agar medium (Gil et al., 2017). To identify the disease in the field, 135 plants were classified as dead, symptomatic, or asymptomatic, according to the observed symptoms: wilted leaves, yellow leaves, dead leaves, root cortex with lesions, and wilted stems. Two plants with typical symptoms of fusarium wilt (yellow leaves and necrosis of the main stem), observed at 307 days after transplanting (DAT), were extracted for confirmation of the causal agent. Root samples were taken to the Phytopathology Laboratory of Universidad de Caldas for analysis, and the assays confirmed that the causal agent was, in fact, *F. oxysporum* f. sp. *passiflorae*.

The treatments were combinations of the three scions (TesEdu11, PutEdu01, and a commercial accession as the control) and rootstocks (ungrafted, autografted, and grafted onto the *P. maliformis* rootstock). The experimental unit was one plant. The experimental design was a randomized complete block, using two factors (genotype and grafting), with three levels each, and 15 replicates.

To determine rootstock and graft compatibility, stem diameter 5.0 cm below and 2.0 cm above the graft union was measured, using a digital caliper, every 15 days up to 139 DAT. The evaluation of the reproductive stage began when most of the plants had 50% of flower buds in the pre-anthesis stage. Flowers and fruits were counted at 198 DAT, and fruit set number per plant, at 307 DAT, considered the peak of production. Fifty flowers per plant were marked using a tag identifying flower-opening date. In addition, fruit set percentage, fruits per plant, and yield (grams per plant) were evaluated at 198 DAT. Estimated yield, for the first productive cycle, was calculated at 307 DAT as the average weight of the fruit multiplied by the number of fruits per plant. After the first flowering and fruit formation at 198 DAT, harvesting was carried out three times a week over four months.

The effect of the incidence of *F. oxysporum* f. sp. *passiflorae* on plant yield was estimated as $EY_f = EY \times (1 - I_f)$, where EY_f is the estimated yield with fusarium incidence; EY is the estimated yield without fusarium incidence; and I_f is the percentage incidence of fusarium.

The data set was checked for assumptions for normality, independence of errors, and homoscedasticity using the tests of Shapiro-Wilk, Durbin-Watson, and Bartlett, respectively. Yield per plant was considered as the independent variable. The used model met the assumptions of normal distribution and independence of errors, but did not of homoscedasticity. No parametric analyzes were performed.

Scheirer-Ray-Hare's two-way test was used to verify the effects of grafting, genotype, and the genotype x grafting interaction over yield per plant. Depending on the results, Dunn's test was carried out to analyze the significant factor. The R software, version 4.2.3, was used (R Core Team, 2023).

The stem diameters of all scion and rootstock combinations were between 1.0 and 1.3, representing a positive compatibility. Between wild rootstocks and yellow passion fruit, Lima et al. (2017) found partial incompatibility since parenchyma cells did not fill the spaces in the graft region and phenolic compounds were still being produced 60 days after grafting.

The results of Scheirer-Ray-Hare's test for fruits per plant, yield at 198 DAT, and estimated yield at 307 DAT are presented in Table 1. This test showed that the genotype factor did not influence these three variables, the grafting factor affected all variables, and the genotype x grafting interaction only influenced fruits per plant and estimated yield at 307 DAT; however, since the genotype x grafting interaction is multifactorial, the interpretation of its result is difficult.

Since grafting influenced all studied variables, this factor was subjected to Dunn's test (Table 2). Ungrafted plants showed a higher yield at 198 DAT and estimated yield at 307 DAT than the plants that were autografted or grafted onto *P. maliformis* (Table 3). Grafted plants had a lower number of fruits than the ungrafted and

Table 1. Results of Scheirer-Ray-Hare's test for fruits per plant, yield at 198 after transplanting (DAT), and estimated yield at 307 DAT for purple passion fruit (*Passiflora edulis*) genotypes subjected to grafting treatments.

Factor	Fruits per plant		Yield at 198 DAT (g per plant)		Estimated yield at 307 DAT (g per plant)	
	H	p-value	H	p-value	H	p-value
Genotype (GE)	0.2250	0.8936^{ns}	1.6668	0.4342^{ns}	1.3702	0.5040^{ns}
Grafting (GR)	17.0269	0.0002*	21.4520	<0.0001*	18.1418	0.0001*
GE x GR	47.7650	< 0.0001*	1,0538	0.9015^{ns}	46.4072	<0.0001*

*Significant at 5% probability. ^{ns}Nonsignificant.

Table 2. Results of Dunn's test for the grafting factor for fruits per plant, yield at 198 after transplanting (DAT), and estimated yield at 307 DAT for purple passion fruit (*Passiflora edulis*) plants ungrafted (VS), autografted (AG), and grafted onto *Passiflora maliformis* (GR).

Factor	Pairwise[(1)]	Fruits per plant	Yield at 198 DAT	Estimated yield at 307 DAT
Grafting	VS - AG	ns	*	*
	VS - GR	*	*	*
	AG - GR	*	ns	ns

*Significant at 5% probability. ^{ns}Nonsignificant.

Table 3. Medians of fruits per plant, yield at 198 days after transplanting (DAT), estimated yield at 307 DAT, estimated yield at 307 DAT with the incidence of fusarium wilt, and percentage disease incidence for each treatment of purple passion fruit (*Passiflora edulis*) genotypes.

Treatment[(1)]	Fruits per plant	Yield at 198 DAT (g per plant)	Estimated yield at 307 DAT (g per plant)	Estimated yield at 307 DAT in infected area (g per plant)	Incidence of fusarium wilt (%)
TesEduVS	208.0	10,192.5	39,201.5	10,584.4	73
TesEduGR	140.5	6,808.0	26,184.0	24,351.1	7
TesEduAG	162.0	8,170.5	31,425.0	12,570.0	60
PutEduVS	210.0	10,563.0	40,627.0	16,250.8	60
PutEduGR	113.0	4,437.0	19,109.0	13,949.6	27
PutEduAG	159.5	6,768.5	26,033.5	8,591.1	67
CommercialVS	215.0	14,208.5	54,648.0	18,033.8	67
CommercialGR	110.0	5,976.0	22,986.0	15,400.6	33
CommercialAG	241.0	10,189.0	39,190.0	7,838.0	80

[(1)]TesEduVS, TesEduGR, and TesEduAG, scion TesEdu11 ungrafted (propagated using seeds), autografted, and grafted onto *Passiflora maliformis*, respectively; PutEduVS, PutEduGR, and PutEduAG, scion PutEdu01 ungrafted (propagated using seeds), autografted, and grafted onto *Passiflora maliformis*, respectively; and CommercialVS, CommercialGR, and CommercialAG, commercial scion ungrafted (propagated using seeds), autografted, and grafted onto *Passiflora maliformis*, respectively.

autografted ones. Therefore, overall, ungrafted plants had a higher yield per plant at 198 DAT and grafted plants produced less fruits. However, these results still must take into account the incidence of fusarium.

All ungrafted plants presented the highest estimated yield at 307 DAT without and even with the incidence of fusarium wilt, despite the higher occurrence of the disease (Table 3). The grafted genotypes presented the lowest estimated yield at 307 DAT without the incidence of fusarium wilt, with no significant improvement with the incidence of this disease despite the resistance of the used rootstock. Therefore, in general, the ungrafted and autografted plants showed higher values for this variable than the grafted plants when infected by fusarium wilt. The exception was genotype TestEdu11 grafted onto *P. maliformis*, which showed the highest estimated yield at 307 DAT with the incidence of fusarium wilt and the lowest infection caused by the disease.

Evaluating the impact of fusarium wilt on plant yield, Lima et al. (2018) did not find any improvement when comparing ungrafted plants of yellow passion fruit with those grafted onto *Passiflora gibertii* N.E.Br. resistant to the disease. For the grafted plants, the authors found a yield 39% lower than the national average in Brazil, in the first productive cycle, and a low average life expectancy of 168 days on the graft, in the second cycle, suggesting that this rootstock should only be used in areas infected with *Fusarium* spp., since the vigor and yield of the scion plant could be affected when the disease is not present.

The obtained results are an indicative that the evaluated purple passion fruit scions are compatible with the *P. maliformis* rootstock, although special attention should be given to estimated yield at 307 DAT, which was the lowest in the grafted genotypes. The exception that stood out was TestEdu11 grafted onto *P. maliformis*, which showed the highest values for this variable in areas infected with fusarium wilt.

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