ISSN 0100-2945 DOI: http://dx.doi.org /10.1590/0100-29452018212

Revista Brasileira de Fruticultura

Yellow Passion fruit performance in organic crop under mulch

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Abstract - The aim of this work was to evaluate the effect of mulch on clay loam and sandy loam soils on the start harvest, number of fruits per plant, yield and quality of yellow passion fruits in organic crop. A complete randomized block design with five treatments and four replicates of five plants each was used. Treatments corresponded to different percentages of mulch of the area occupied by the plant (3 x 3 m), extending from the center of the planting line to the planting row in 0% without mulch (T1); 25% (T2); 50% (T3); 75% (T4) and 100% (T5). Mulch anticipated the harvest in comparison to crop in uncovered soil in both types of soil. The number of fruits per plant and yield increased in a quadratic function with maximum point of 38.6 fruits plant^{-1} and 5,182.0 kg ha^{-1} with 75.7% and 78.0% of soil cover, respectively. Mulch on clay loam soil did not provide increase in the average fruit mass and did not change the quality of fruits in relation to control fruits.

Index terms: *Passiflora edulis* f. *flavicarpa* Degener, soil texture, fruit quality, organic fruit crop.

Desempenho do maracujazeiro-amarelo em cultivo orgânico sob cobertura morta

Resumo - O objetivo deste trabalho foi avaliar o efeito da cobertura morta em solo franco-argiloso e franco-arenoso sobre o tempo necessário para início da produção, número de frutos por planta, produtividade e qualidade dos frutos do maracujazeiro-amarelo em cultivo orgânico. Utilizou-se o delineamento experimental de blocos inteiramente casualizados, com cinco tratamentos e quatro repetições de cinco plantas cada. Os tratamentos corresponderam a diferentes porcentagens de cobertura morta da área ocupada pela planta (3 x 3 m) se estendendo do centro da linha de plantio para a rua em 0% sem cobertura (T1); 25% (T2); 50% (T3); 75% (T4) e 100% (T5). A cobertura do solo foi aplicada em faixa contínua na linha de plantio. A cobertura morta antecipou a colheita dos frutos em comparação ao cultivo em solo descoberto, em ambos os solos. O número de frutos por planta e a produtividade aumentaram em função quadrática com ponto de máximo de 38,6 frutos/planta^{-1} e 5.182,0 kg ha^{-1} com 75,7% e 78,0% de cobertura morta no solo, respectivamente. A cobertura morta no solo franco-argiloso não proporcionou incremento na massa média nem alterou a qualidade dos frutos em relação aos frutos provenientes da testemunha.

Termos para indexação: *Passiflora edulis* f. *flavicarpa* Degener, textura do solo, qualidade do fruto. Fruticultura orgânica.

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Received: Janeiro 04, 2017.
Accepted: May 18, 2017.

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Introduction

Yellow passion fruit (*Passiflora edulis* f. *flavicarpa Degener*) is one of the most produced fruit species in Brazil, with production of 703,489 tons in 2016 in an area of 49,889 ha (IBGE, 2016), which has an increasing trend due to the industrialization and demand for fresh fruits in the market.

In Acre, the production of this fruit in 2016 was 736 tons in 89 ha harvested, resulting in a low yield of 8.27 t ha^{-1} (IBGE, 2016). It represents a good planting option in the regional fruit activity for offering quick economic returns and distributed income throughout the year. It is a culture that demands intensive and qualified labor directly related to family agriculture in the control of rural exodus (PETINARI et al., 2008).

Yellow passion fruit in the state of Acre is sown 60 days before planting (September), and field planting is performed at the beginning of the rainy season (November). Flowering takes place 90 days after planting (DAP) (February) and harvesting starts around 180 DAP (April). When there is water deficit in the soil and presence of photoperiod less than 11 h day^{-1}, which stops plant flowering and fruiting (CAMPOS, 2011; COSTA et al., 2009), this period after planting provides an "out-of-season" harvest for presenting low productivity (ANDRADE JÚNIOR et al., 2003), only 2.8 t ha^{-1} in the conditions of dry land organic farming of Acre (ARAÚJO NETO et al., 2009).

In an attempt to reduce the negative effects found in tropical regions, a form of cultivation that aims to reduce high temperatures and water losses by evapotranspiration using mulch is especially important, especially considering that it is a shallow root crop and of continuous and vigorous growth (PERES et al., 2010).

In addition to the low "out-of-season" harvest productivity, yellow passion fruit can present premature death at the beginning of the second year of cultivation. In one third of soils in the state of Acre, there is predominance of high activity and permanent load clays with significant physical impairments to agricultural use, especially due to the high expansion and contraction capacity (WADT, 2002). This feature is undesirable, affecting the soil physical attributes such as density, porosity reduction, aeration, water infiltration and retention capacity (MÜLLER et al., 2001) and the soil physical characteristics cause direct damages by the rupture of roots during the dry period at the end of the "out-of-season" harvest.

In order to minimize the effects of soil contraction with expansive clays, mulching with vegetal remains is used to reduce the evaporation of water available to plants, obtaining greater conservation of soil moisture and reducing water consumption (FREIRE et al., 2011), in addition to reducing the direct interception of solar rays and promoting low competition for spontaneous plants (HIRATA et al., 2014).

The decomposition of mulch cover turns into soil organic matter (SOM), rich in cementing agents, such as polysaccharides, fungal hyphae and aromatic compounds, which promote particle aggregation, increase the cation exchange capacity, stimulate microbial activity and soil fauna and favors heterotrophic decomposition (FREIRE et al., 2010; MELLONI et al., 2013), which may contribute to crop yield.

Therefore, the aim of this study was to evaluate the effect of mulch on clay loam and sandy loam soils on the start harvest, number of fruits per plant, yield and quality of yellow passion fruits in organic crop.

Material and Methods

Two experiments were carried out on soils with different textures: ARGISSOLO AMARELO alítico plíntico, sandy loam texture, located at Seridó Ecological Site, P.A. Aquiry, Highway AC 10, km 04, Ramal José Rui Lino, Rio Branco, AC, (09º53 '16' 'S and 67º49'11' 'W, and 170 m a.s.l.). ARGISSOLO VERMELHO-AMARELO plíntico distrophico, sandy loam texture, located in P.A. Humaitá, Highway AC 10, km 22, Ramal Flaviano Melo, km 07, in Porto Acre, AC, (09º48'18 "S and 67º39'11" W ans 150 m a.s.l.).

ARGISSOLO AMARELO alítico plíntico soil is located in a gently wavy topography with no apparent erosion, moderate drainage and with the following nutrient contents in the 0 - 20 cm depth layer: pH (H_2O) = 5.0; P = 2 mg dm^{-3}; K = 2.0 $mmol_c$ dm^{-3}; Ca = 17 $mmol_c$ dm^{-3}; Mg = 8mmol dm^{-3}; Al = 3 $mmol_c$ dm^{-3}; H = 39 $mmol_c$, dm^{-3}; OM = 18 g dm^{-3}; sum of bases = 27.0 $mmol_c$ dm^{-3}.

ARGISSOLO VERMELHO-AMARELO plíntico distrophico soil is located in smooth wavy relief, not apparent erosion, imperfect drainage and with the following nutrient contents in the 0-20 cm depth layer: pH (H_2O) = 5.2; P = 2 mg dm^{-3}; K = 1.2 $mmol_c$ dm^{-3}; Ca = 27 $mmol_c$ dm^{-3}; Mg = 11 $mmol_c$ dm^{-3}; Al = 18 $mmol_c$ dm^{-3}; H = 70 $mmol_c$, dm^{-3}; OM = 27 g dm^{-3}; SB = 39.2 $mmol_c$, dm^{-3}.

The climate of both sites is hot and humid, Am type, according to the Köppen classification, with annual average temperatures of 24.5 ° C, annual relative humidity of 84% and rainfall of 1,947 mm $year^{-1}$ (INMET, 2015).

Passion fruit seedlings were produced in January 2014 in plastic bags of 10 cm x 20 cm, containing 1.57 L of substrate, based on soil, organic compound, ground straw and ground charcoal at proportion of 3: 3: 3: 1, added 1 kg $m^{-3}$of dolomitic limestone and 1.5 kg m^{-3} of natural thermophosphate. The filling of bags was done manually. Three seeds were sown in each bag. These were kept in a greenhouse, receiving irrigation by micro sprinkler. Thinning was performed 20 days after sowing

when seedlings were 2-3 cm high and two pairs of leaves.

Field planting was carried out in March 2014, in pits with dimensions of 40 cm x 40 cm x 40 cm, fertilized with 500 g of dolomitic limestone and 200 g of thermophosphate.

Experiments were conducted in the period from March 2014 to June 2015. The experimental design was a randomized block with five treatments and four replicates, with experimental plot composed of four useful plants.

Treatments corresponded to different percentages of mulch of the area occupied by the plant (3 x 3 m), extending from the center of the planting line to the planting row in 0% without coverage (T1); 25% (T2); 50% (T3); 75% (T4) and 100% (T5).

The mulch biomass was composed of spontaneous plants of various local species: malva roxa (*Urena lobata* L.), "capim estrela" (*Rynchospora speciosa*), "língua de vaca" (*Symphytum officinale* L.), "joá" (*Solanum viarum*), "trapoeraba" (*Commelina benghalensis* L.), grass (*Paspalum notatum)*, "quebra pedra" (*Phyllanthus niruri*), "betônica" (*Stachys officinalis*), "serralha mirim" (*Emilia sonchifolia* L.), "carrapicho" (*Cenchrus echinatus* L.), "lombrigueira" (*Spigelia anthelmia* L.), "tiririca" (*Cyperus rotundus* L.), "caruru" (*Amaranthus viridis)*, "amendoim bravo" (*Euphorbia heterophylla* L.), "barba de bode" (*Eragrostis curvula)*, "picão branco" (*Galinsoga parviflora*), being *Brachiaria brizantha* the most abundant species, accounting for 90% of the biomass. The height of the cover layer was fixed at 20 cm and renewed every two months after planting.

The passion fruit cultivar used was genotype 232 from the germplasm bank of UFAC. Plants were conducted on vertical vines with a 12-gauge wire, located 2.00 m above the soil surface, trapped and stretched by six-meter spaced posts. Pruning of both lateral branches was performed when they reached 1.5 m away from the main stem.

Pollination of flowers occurred naturally. Harvesting was carried out twice a week, harvesting all fallen fruits and also ripe fruits (with more than 30% of the yellow bark), but still attached to the plant.

The evaluated variables were: beginning of harvest, considering the time from planting to the harvest of the first fruit (days); number of fruits per plant; fruit yield (kg ha^{-1}), estimated by the number of fruits per plant, average fruit mass and planting stand; fresh fruit mass (g / fruit), total soluble solids content (TSS), expressed in ºBRIX, directly determined from the juice using a digital refractometer with automatic temperature control (AOAC, 2012); total titratable acidity (TTA), expressed as percentage (%) of citric acid, as determined by titration with sodium hydroxide (NaOH, 0.1 N) and 0.1% phenolphthalein as indicator; TSS / TTA ratio, obtained by the quotient between TSS and TTA.

After tabulation of data, the presence of outliers was verified by the Grubbs test, normality of errors by the Shapiro-Wilk test and homogeneity of variance by the Bartlett test (1937). When these assumptions were met, analysis of variance was performed and when the F value indicated difference among quantitative treatments, they were submitted to regression analysis. In order to analyze the effect of the type of soil and interaction with mulch, minimum difference between the MS of the residue of both experiments was verified (<7), performing a combined analysis of Zimmermann experiments (2014).

Results and Discussion

Harvesting in area with sandy loam soil started at 256 days after planting (DAP) in cultivation with 100% mulch. In treatment without mulch, harvest started 74 days later, at 330 DAP. However, in the clay loam soil, harvest started at 214 DAP in soil with 100% mulch, anticipating in 100 days the harvest in relation to treatment without soil mulching, which started at 314 DAP (Figure 1). As mulching increased on the soil surface, the beginning of harvest was anticipated in both types of soil.

It is known that mulching, by protecting the soil from direct solar radiation, tends to contribute to greater soil moisture conservation, also reducing soil temperature oscillations. Moisture, as well as high, air temperatures and longer photoperiod, are factors that influence the flowering and fruiting of yellow passion fruit tree (CAVICHIOLI et al., 2006; COSTA et al., 2008; COSTA et al., 2009). On the other hand, mulch treatments did not favor fresh fruit mass. On the contrary, in clayey soils, there was a tendency to decrease the average fruit mass up to 50% soil coverage, with a reduction of about 12 g in relation to fruits from treatment without soil cover (Figure 2). In general, fruits presented relatively small size and below commercialization standards preferred by consumers, which are fruits with mass equal to or greater than 170 g (CAVICHIOLI et al., 2008). It was observed that the higher number of fruits per plant, the lower availability of photoassimilates for each fruit, reducing the fresh fruit mass (TAKAHASHI; CARDOSO, 2015).

Although mulch is an important source of nutrients, they only become available after organic matter decomposition. Therefore, nutrients may be temporarily unavailable to plants. According to Gama-Rodrigues; Gama-Rodrigues (2008), the availability of nutrients will depend on the physical progress of the edaphic environment and the clay contents present in the soil. According to Walpola and Arunakumara (2010), the decomposition of organic residues is slow in soils with higher clay content.

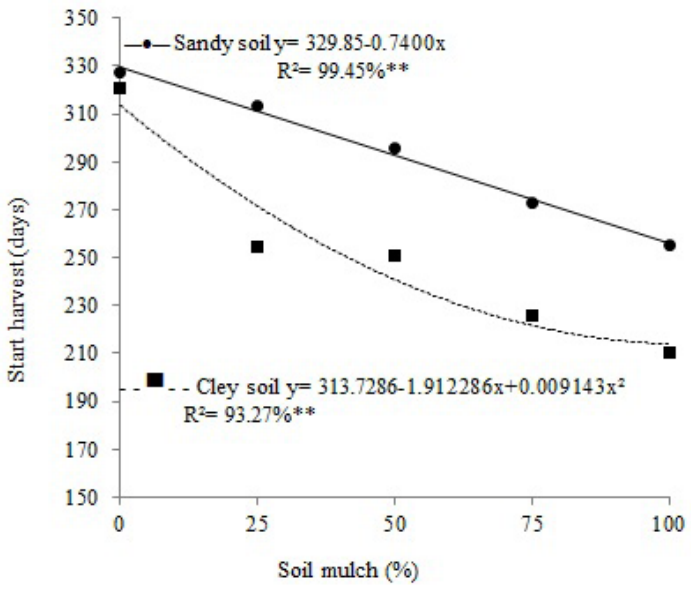

Figure 1 - Start harvest (days) of passion fruits cultivated under mulch in sandy and clay loam soil, Acre, 2015.

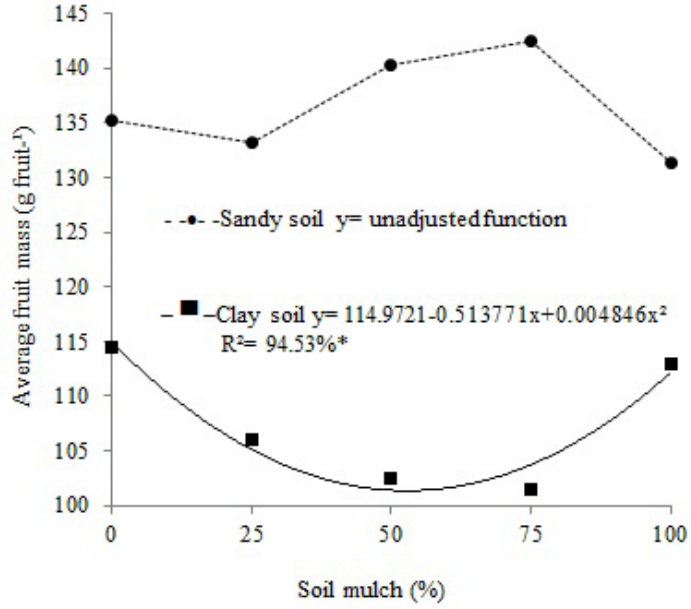

Figure 2 - Average fruit mass (g) per passion fruit plant cultivated under mulch in sandy and clay loam soil, Acre, 2015.

Mulch determined an increase in fruit yield in both types of soils. The number of fruits per plant grew in a quadratic function with maximum point of 38.64 fruits per plant in 75.74% coverage (Figure 3), for both types of soils. In the absence of mulch on the soil surface, evapotranspiration and water consumption of plants increase, decreasing soil moisture (Freire et al., 2011). Thus, the technique should be implemented in tropical regions because it becomes a conditioner for high temperatures and humidity.

The productivity of yellow passion fruits increased in a quadratic function with maximum point of 5.182,00 kg ha^{-1}, with 78% coverage, for both types of soils. The average yield was 4,289.52 kg ha^{-1} (Figure 3). This value is low when compared to the average value for the state of Acre, which is 8,270 kg ha^{-1} and national average of 14,101 kg ha^{-1} (IBGE, 2016), and the productive potential of the crop can reach up to 45,000 kg ha^{-1} (MELETTI et al. 2002). However, in organic crops, yield is low, 5.03 kg ha^{-1} (ARAÚJO NETO et al., 2009).

The lower productivity in uncovered soil may be associated to higher water loss through evaporation, percolation and volatilization, as well as lower nutrient cycling and lower organic matter contents (RODRIGUES et al., 2012). Passion fruit is highly demanding in nutrients and this is one of the factors that most contributes to fruit productivity and quality (COSTA et al., 2008), mainly in tropical soils.

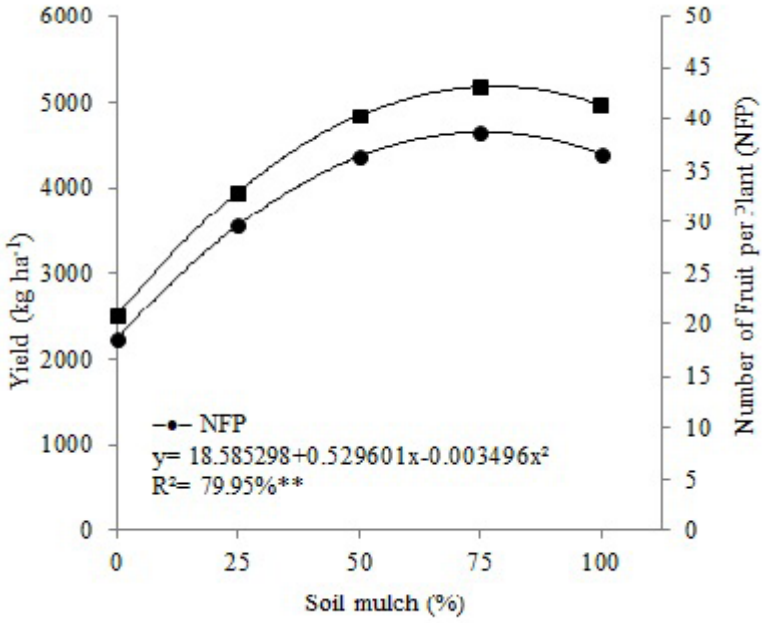

Figure 3 - Number of fruits per plant (NFP) and yield (kg ha^{-1}) of passion fruits cultivated under mulch cover in sandy and clay loam soil, Acre, 2015.

Mulch and soil texture did not change the quality of fruits evaluated by total soluble solids, total titratable acidity and ratio (Table 1).

The mean total soluble solids content (TSS) was 13.95 ° Brix (Table 2). The higher the soluble solids content in the fruit, the greater the sweetness and the lower the acidity, being the preference of consumers. However, these values are below those required by consumers, which are levels above 15 º Brix (AGUIAR et al., 2015; MELETTI et al., 2002). When fruits are aimed at industrialization, there is preference for fruits with TSS higher than 13 º Brix (MANIWARA et al., 2014), but the majority of yellow passion fruits produced in Brazil have levels below this value (DIAS et al., 2011).

The total titratable acidity of yellow passion fruits in organic farming did not vary between soils, reaching value higher than 4% (Table 2). Possibly, the use of mulch resulted in higher soil moisture content and organic acid production, resulting in higher pulp acidity (FREIRE et al., 2010). High levels of acids in the juice reveal important characteristics for processing by providing longer post-harvest life (ABREU et al., 2009) and difficult deterioration by microorganisms (FLORES et al., 2011). For fresh consumption, less acid and sweeter fruits are preferred. These values exceeded the requirement of Brazilian legislation establishing minimum value of 2.5% for pulp (BRASIL, 2000), similar ($p > 0.05$) to results found by (HURTADO-SALAZAR et al., 2015), which varied from 4.43% to 5.11%.

The total soluble solids and total titratable acidity ratio (Table 2), which defines the sweet-acid nature and fruit flavor, was also not significantly influenced by the factors evaluated. This differs from results obtained by Freire et al. (2010), who observed higher sugar contents in fruit from treatments without mulch than in those with mulch.

Table 1 - Summary of the analysis of variance of the number of fruits per plant (NFP) and yield of yellow passion fruits in sandy and clay loam soil, Acre, 2015.

Source of Variation	DF	Mean Square	
		NFP	Yield
Soil	1	167,895103^{ns}	2212911,660144^{ns}
Block x Soil	6	152,564314**	3184315,093975**
Treatment	4	673,575803**	11503793,627764**
Soil x Treatment	4	47,549389^{ns}	1698636,305168^{ns}
Residue	24	43,074174	838167,254985
Total	39	-	
VC (%)	-	20,54	21,34

^{ns} not differ significantly; ** differ significantly by the F test at 5% error probability.

Table 2 - Total soluble solids (TSS), total titratable acidity (TTA), TSS / TTA ratio of yellow passion fruits cultivated under mulch cover in sandy and clay loam soil, Acre, 2015.

Soil Texture	Total Soluble Solid	Total Titratable Acidity	*Ratio* (TSS/TTA)
Clay loam	13.75	4.10	3.40
Sandy loam	14.15	4.10	3.46
F Test $_{clay}$	2.97^{ns}	1.41^{ns}	0.83^{ns}
F Test $_{sandy}$	0.27^{ns}	1.65^{ns}	2.78^{ns}
V C (%)	8.28	9.14	12.19
Mean	13.95	4.10	3.43

^{ns}Means do not differ significantly by the F test at 5% error probability.

Conclusions

Under the environmental conditions of the state of Acre, the use of mulching with biomass of spontaneous plants anticipated the harvest of yellow passion fruits in up to 74 days in sandy loam soil and in up to 100 days in clay loam soil.

The use of mulch increased number of fruit per plant and yield, with maximum values obtained for coverage of 75.7% and 78% of the soil surface, respectively.

Soil texture and mulch levels did not significantly influence total soluble solids (TSS), total titratable acidity ratio (TTA) and TSS/TTA ratio of fruits.

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