# Up Scaling Guava Water Balance in the Petrolina/Juazeiro Growing Area, Northeast Brazil

A.H. de C. Teixeira
Embrapa Tropical Semi-arid
Petrolina, PE
Brazil

F.B.T. Hernandez
São Paulo University State
Ilha Solteira, SP
Brazil

**Keywords:** 'Paloma', modelling, crop coefficient, water requirements, water productivity, water resources

**Abstract**

**Weather data for 2011, from a net of 15 automatic agro-meteorological stations and previous field energy balance results, were used together with regression models for modelling the guava water requirement (GWR) in the growing area of Petrolina (Pernambuco state) - Juazeiro (Bahia state), Brazil, considering a 6.5-months average growing season (GS). $GWR_{GS}$ joined with rainfall, allowed the acquirement of the regional water balance and the application of a guava water indicator ($GWI_{GS}$) calculated as the ratio of the total precipitation during a growing season ($P_{GS}$) to $GWR_{GS}$. The variation of the averaged $GWR_{GS}$ values for Petrolina, was from 750±6.9 to 950±10.5 mm, while for Juazeiro, it was from 730±6.2 to 900±9.2 mm, with pruning periods in January and June, respectively. Considering the $GWI_{GS}$ indicator, its values for both municipalities were found similar, which were around 0.38 and 0.08 for pruning done in January and June, respectively. Quantifying the differences between $P_{GS}$ and $GWR_{GS}$, it was evident that a higher amount of irrigation water needed to be applied between September and October for growing cycles starting in June. Additional data from IBGE (Brazilian Geographical and Statistical Institute) allowed the inspection of the guava water productivity (GWP) at the municipality level. The GWP values for Petrolina were 4.1 and 3.3 kg $m^{-3}$, while for Juazeiro they were 1.8 and 1.5 kg $m^{-3}$, for pruning periods in January and June, respectively. It could be concluded that the lower GWP values for Juazeiro was because of a poorer crop management, resulting in lower yield, evidencing scope for improvements. The analyses spatially presented, can subsidize water allocation and irrigation management criteria, when aiming improvements on guava water productivity and yet, avoiding environmental damage by the fast climate and land use changes in the Brazilian semi-arid areas.**

## INTRODUCTION

In Petrolina (Pernambuco state) and Juazeiro (Bahia state), guava is one of the most important commercial crops under irrigation and 'Paluma' the main cultivar grown. According to data from the Brazilian Geographical and Statistical Institute (IBGE), in first municipality, the harvested area, yield and productivity were 2,380 ha, 71,400 t and 30,000 kg $ha^{-1}$, respectively, in 2010, while for Juazeiro the corresponding values were 73 ha, 949 t and 13,000 kg $ha^{-1}$.

Although the Brazilian semi-arid climate being very favourable for the guava crop, the orchards are in conditions of low precipitation and high atmosphere demands, making irrigation an essential input during the growing seasons. Irrigation water has to be applied rationally, based on the guava water requirements (Singh et al., 2007). The capability to predict levels of evapotranspiration (ET) is a valuable asset for water resource managers, as it describes the water consumption from the crop. On the other hand, too much water will result in water logging which might damage the root and limit root water uptake by inhibiting respiration.

The potential evapotranspiration ($ET_p$) is referred as the water flux from the plants growing under optimum soil moisture and achieving full production. The effects of characteristics that distinguish guava crop from grass are integrated into the crop coefficient ($K_c$). $ET_p$ can be estimated by multiplying reference evapotranspiration $ET_0$ by $K_c$ and may be considered as the guava water requirements (GWR) (Allen et al., 1998; Teixeira et al., 2003).

The difficulties to measure large scale water variables prompted the use of models together with the Geographic Information Systems (GIS) to evaluate these variables on this scale (Teixeira and Bassoi, 2009). The use of a GIS excludes the need to quantify complex hydrological processes, being an excellent means for mapping the spatial and temporal structure of the water balance parameters. In this balance the input is precipitation (P), while the output is ET.

The relationship between the water balance parameters and yield is essential for applying and maintaining good water management practices. The agro-hydrological processes in a guava orchard are only rarely described in the international literature. Despite the economical and nutritious importance of its fruits, little research has been attributed to the guava water productivity (GWP), which can be considered as the ratio of the actual yield ($Y_a$) to the amount of water required during a growing season. Many promised pathways for raising GWP may be available over the continuum from irrigated farming systems (Teixeira, 2009).

The objective of this research was to model the water balance parameters and water productivity of guava crop at the large scale by applying a GIS in the growing region of Petrolina (Pernambuco state) - Juazeiro (Bahia state), aiming to subsidise the water management in the existing commercial irrigated guava crop, as well as its expansion in the semi-arid region of Brazil.

## MATERIAL AND METHODS

Data for 2011 from a net of 15 agro-meteorological stations, are presented in Figure 1, at different locations. These values were used to acquire the large-scale values of reference evapotranspiration ($ET_0$) by the Penman-Monteith method (Allen et al., 1998).

For up scaling the $K_c$ values, first the maps of accumulated degree days ($DD_{ac}$) were elaborated considering a basal temperature of 10°C. For modelling, the $K_c$ values were obtained from a field experiment with the cultivar ‘Paluma’ (Teixeira et al., 2003), allowing the elaboration of the following equation:

$$K_c = aDD_{ac}^{\ 2} + bDD_{ac} + c \qquad (1)$$

where $a=-3\times10^{-8}$, $b=2\times10^{-4}$ and $c=0.63$ are the coefficients found from the experimental data.

The maps of $K_c$ were then multiplied by the corresponding ones of $ET_0$ for the quantification of the guava water requirements (GWR) on a large scale:

$$GWR = K_c ET_0 \qquad (2)$$

After generating the GWR maps, they were coupled with those of precipitation (P) for the quantification of the guava water deficiencies (GWD), giving an idea of the irrigation requirements during the growing seasons, as well the elaboration and application of a guava water indicator (GWI):

$$GWD = P - GWR \qquad (3)$$

$$GWI = \frac{P}{GWR} \qquad (4)$$

With yield data for 2010 from the Brazilian Geographical and Statistical Institute (IBGE), the guava water productivity (GWP) was quantified:

$$GWP = \frac{Y_a}{GWR} \quad (5)$$

After the calculations, for the area shown in the right side of Figure 1, Petrolina and Juazeiro were extracted, aiming the water productivity analyses at the municipality level.

**RESULTS AND DISCUSSION**

The guava water balance components along the crop stages of two growing seasons in a year of the cultivar 'Paluma', in the producing municipalities of Petrolina and Juazeiro, are presented in Figure 2. The annual trends of precipitation are similar for both, presenting small differences, with the rains concentrated from January to May, when large amounts of the guava water requirements can be supplied naturally by the rains. For pruning dates in June, the volumes of irrigation water needs are much higher as a consequence of the coupled effects of the lowest precipitation rates and the highest atmospheric demands. The GWR picks from September to November, above 160 mm month$^{-1}$, represent daily rates around 5.3 mm day$^{-1}$, the largest irrigation water requirements. On the other hand, as a consequence of high P and low GWR, the lowest rates of GWD are verified in May, with the lowest average daily GWR of 3.5 mm day$^{-1}$, meaning that for pruning dates in January, some of the irrigation water can be saved from February to March, increasing the water productivity.

The water use in a micro sprinkler irrigated guava crop from a field experiment in Petrolina, Brazil, showed an average, of 4.5±0.7 mm day$^{-1}$ (Teixeira et al., 2003), similar to the average regional values of the daily GWR in the actual modelling study, however higher than that reported by Singh et al. (2007) of 2.7 mm day$^{-1}$ in West Bengal, India, with the crop under drip irrigation and plastic mulch. With regard to vineyards and other orchards in the same study region, the GWR results were higher than the averaged reported ones of 3.9 and 3.7 mm day$^{-1}$ for grapes and for mango orchards respectively (Teixeira et al., 2007, 2008).

The spatial variation of guava water requirements (GWR) and guava water deficiencies (GWD) for the 'Paluma' with pruning dates in January and June in Petrolina and Juazeiro municipalities, respectively are presented in Figure 3. In general, Petrolina presents higher values than Juazeiro of both, GWR and GWD, being 3 to 5% more for pruning dates in January and June, respectively. Also the spatial variation in Petrolina is larger, evidenced by the stand deviation (SD) of 6.9 and 10.5 mm for the GWR values against those for Juazeiro of 6.2 and 9.2 mm for pruning in January and June, respectively. Considering the GWD values, the correspondent SD values are 10.0 and 11.2 mm for Petrolina against 8.6 and 9.5 mm in Juazeiro. Lower values of GWR and GWD are noticed in the south-eastern part of both municipalities.

To see the effective moisture conditions on guava crop in the municipalities of Petrolina and Juazeiro, with different pruning dates, the water indicator described by the Equation 4 and its spatial variation along the crop stages were analysed to infer, besides yield, the effects on water productivity (Fig. 4). Comparing Figure 4a and 4b, the wettest conditions occur when the crop is pruned in January rather than in June. However, the behaviour of GWI for both municipalities is similar along the crop stages considering the two pruning periods, with the averaged growing season values being 0.38 and 0.09 for pruning in January and June, respectively. Even with Petrolina showing a higher spatial variation than Juazeiro, as can be seen by the SD trend, it can be concluded that the overall effect of the natural moisture availability on GWP will be lower than those originated from bad crop and water management during the growing seasons.

The similarity in GWI values between municipalities and pruning dates are also evident when considering the spatial variation of this water indicator (Fig. 5a). However, when including yield data in the analyses throughout the GWP, the differences between Petrolina and Juazeiro become larger (Fig. 5b). To apply the Equation 5, the yield data ($Y_a$) were averaged municipal values from IBGE for the year of 2010, while the guava water consumption was represented by the GWR values calculated with interpolated data for 2011 from the agro-meteorological stations, representing water potential conditions (Allen et al., 1998; Teixeira et al., 2003). The average GWP values were 4.1 and 3.3 kg $m^{-3}$ for Petrolina, while for Juazeiro they were 1.8 and 1.5 kg $m^{-3}$, with pruning done in January and June, respectively.

The GWP histograms for the two pruning dates in Petrolina (Pet) and Juazeiro (Jua) growing regions, considering the cultivar 'Paloma', are shown in Figure 6. With pruning done in January, more than 95% of the GWP_Pet values were from 3.5 to 4.5 kg $m^{-3}$, while the GWP_Jua values stayed between 1.5 and 2.0 kg $ha^{-1}$. When the pruning dates are in June, considering the same percentage threshold, the GWP_Pet values were from 3.0 to and 4.0 kg $m^{-3}$ and those for GWP_Jua between 1,3 and 1.7 kg $m^{-3}$.

It can be concluded that, since the moisture conditions are similar for both municipalities, the lower GWP values for Juazeiro should be a poorer crop management, resulting in lower yield, evidencing ample room for water productivity improvement. Higher GWP values happen in the southern part of the study growing region. For both municipalities the values are generally higher than for those described for arable crops (essentially from 0.5 to 1.5 kg $m^{-3}$ for wheat and rice; see Zwart and Bastiaassen, 2004), comparable with 3.2 kg $m^{-3}$ for grapes (Teixeira et al., 2007) and 3.6 kg $m^{-3}$ for mangos (Teixeira et al., 2008), but much lower than the reported averaged value of 8,3 kg $m^{-3}$ for water melon (Rashid and Gholami, 2008) that contain a very high moisture content of the fresh product.

## CONCLUSIONS

A regression model, based on the relation between the crop coefficient and the accumulated degree days in guava crop, allowed the up scaling of the guava water balance parameters and the guava water productivity, considering the cultivar 'Paloma' as reference in the growing region of Petrolina (Pernambuco state) - Juazeiro (Bahia state), Brazil. Better crop performance was found for first municipality than for the second, evidencing ample room for improvements in guava water and cultural management in Juazeiro. The modelling described in this paper is useful when using applying with a GIS environment, helping agricultural managers to use less water resources giving ways to increase the productivity in equilibrium with the possible water use restrictions among different users in the near future under the semi-arid conditions of Brazil.

## ACKNOWLEDGEMENTS

The research herein was supported by FACEPE (Science and Technology Foundation of Pernambuco state, Brazil), which is acknowledged for the financial support to the actual project on Water Productivity

### Literature Cited

Allen, R.G., Pereira, L.S. and Smith, M. 1998. Crop evapotranspiration, guidelines for computing crop water requirements, Irrigation and Drainage, Paper No. 56, FAO, Rome, Italy, 300p.

Rashidi, M. and Gholami, M. 2008. Review of crop water productivity values for tomato, potato, melon, watermelon and cantaloupe in Iran. Int. J. Agr. Biol. 10:432-436.

Singh, B.K., Tiwari, K.N., Chourasia, S.K. and Mandal, S. 2007. Crop water requirement of guava (*Psidium guajava* L.) cv. KG/KAJI under drip irrigation and plastic mulch. Acta Hort. 735:399-406.

Teixeira, A.H. de C., Bassoi, L.H., Reis, V.C. da S., Silva, T.G.F. da, Ferreira, M. de N. L. and Maia, J.L.T. 2003. Evaluation of water consumption of guava crop by using automatic and conventional agrometeorological stations. Rev. Bras. de Frut. 25:457-

460 (in Portuguese).
Teixeira, A.H. de C., Bastiaanssen, W.G.M. and Bassoi, L.H. 2007. Crop water parameters of irrigated wine and table grapes to support water productivity analysis in Sao Francisco River basin, Brazil. Agr. Water Manage. 94:31-42.
Teixeira, A.H. de C., W.G.M., Bastiaanssen, Moura, M.S.B., Soares, J.M., Ahmad, M-ud-D. and Bos, M.G. 2008. Energy and water balance measurements for water productivity analysis in irrigated mango trees, Northeast Brazil. Agr. For. Meteorol. 148:1524-1537.
Teixeira, A.H. de C. 2009. Water productivity assessments from field to large scale: a case study in the Brazilian semi-arid region. LAP Lambert Academic Publishing, Saarbrücken, Germany.
Teixeira, A.H. de C. and Bassoi, L.H. 2009. Crop water productivity in semi-arid regions: from field to large scales. Ann. Arid Zone 48:1-13.
Zwart, S. and Bastiaanssen, W.G.M. 2007. SEBAL for detecting spatial variation of water productivity and scope for improvement in eight irrigated wheat systems. Agr. Water Manage. 89:287-296.

## Figures

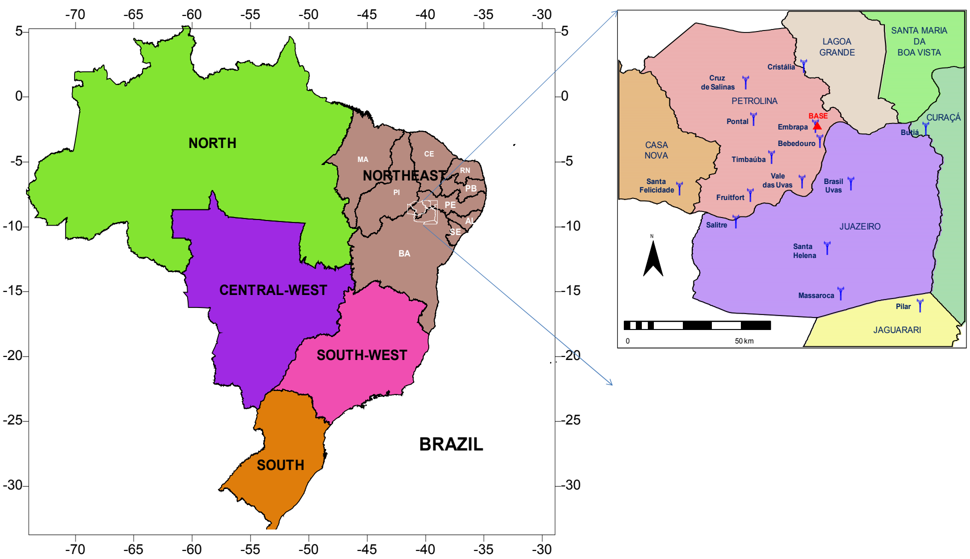


Fig. 1. Brazilian regions and location of the agro-meteorological stations in the semi-arid Brazilian northeastern area.

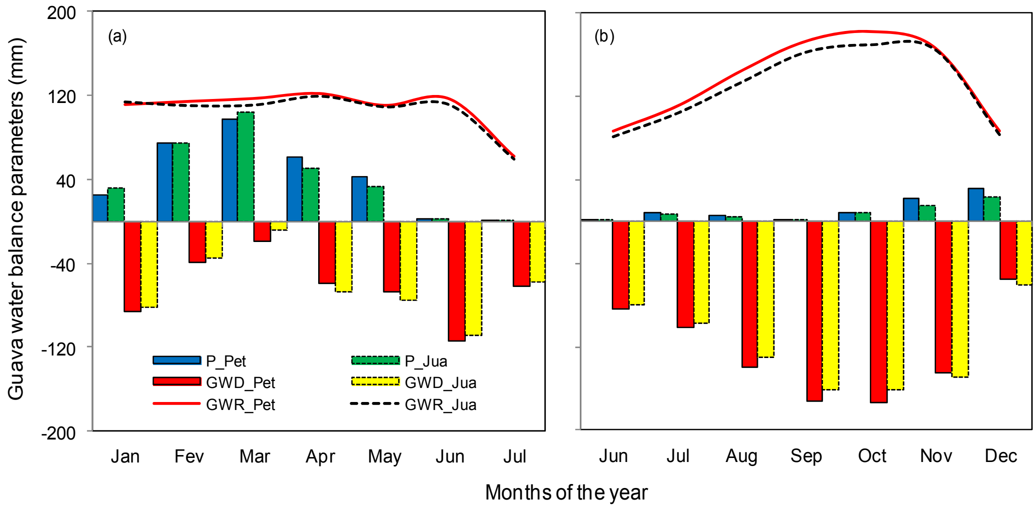


Fig. 2. Monthly averaged guava water balance components during different crop stages of the cultivar ‘Paloma’ with pruning dates in January (a) and June (b) in Petrolina (Pet) and Juazeiro (Jua) growing regions: precipitation (P); guava water deficiencies (GWD) and guava water requirements (GWR).

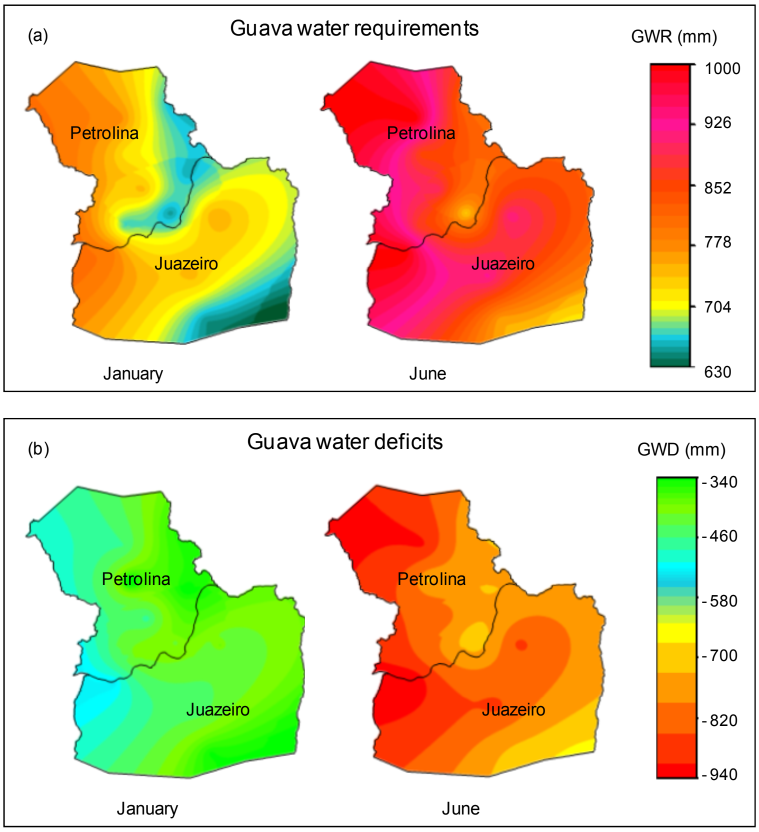


Fig. 3. Large scale growing season values of guava water requirements (GWR) (a) and guava water deficiencies (GWD) (b) for the cultivar ‘Paloma’ and pruning dates in January and June in Petrolina and Juazeiro growing municipalities.

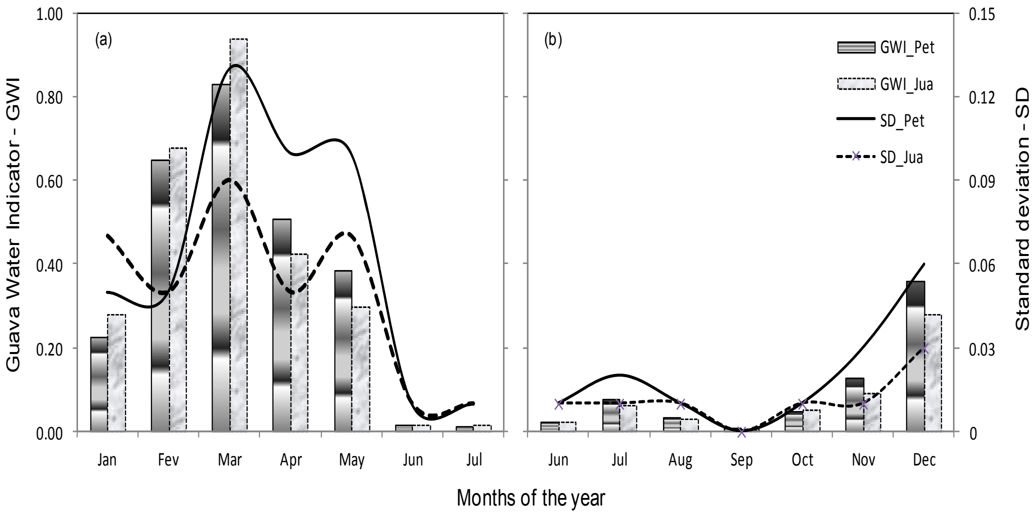


Fig. 4. Monthly averaged values of the guava water indicator (GWI) and its standard deviations (SD) for the cultivar 'Paloma' with pruning dates in January (a) and June (b) in the Petrolina (Pet) and Juazeiro (Jua) municipalities.

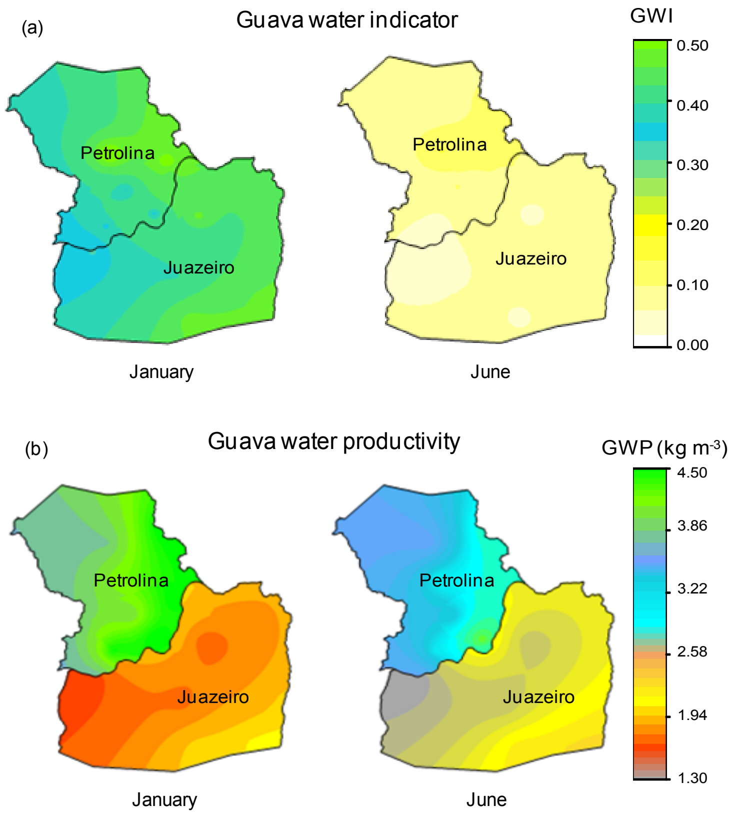


Fig. 5. Large scale growing season values of the guava water indicator (GWI) (a) and the guava water productivity (GWP) (b) for the cultivar 'Paloma' and pruning dates in January and June in the Petrolina and Juazeiro municipalities.

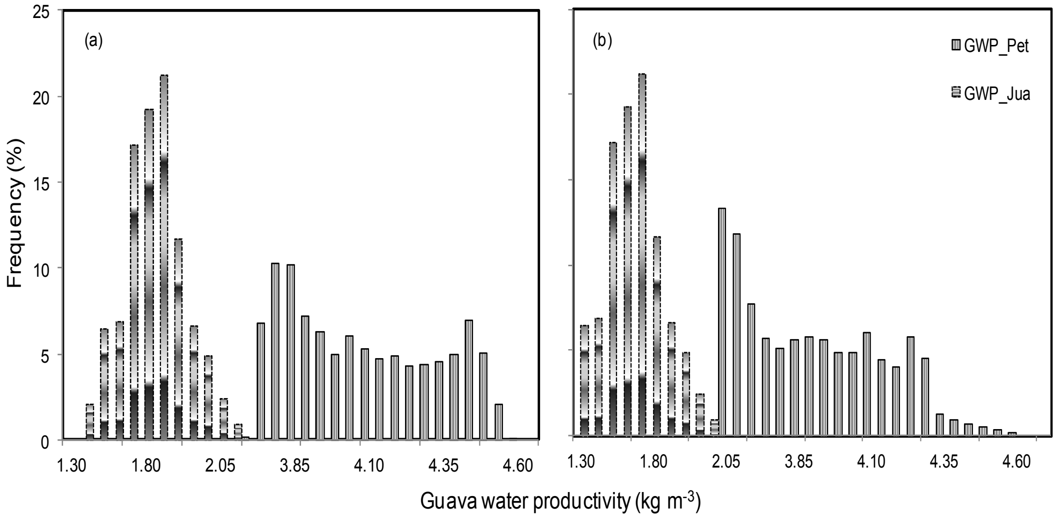


Fig. 6. Histograms of guava water productivity (GWP) in Petrolina-PE (Pet) and Juazeiro-BA (Jua) municipalities for the cultivar ‘Paloma’ and pruning dates in January (a) and June (b).