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Evaluation of NPK doses on the production of papaya 'Caliman 01'[1]

Avaliação de doses de NPK na produção do mamoeiro 'Caliman 01'

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ABSTRACT - The study aimed to evaluate the effect of different NPK doses on the yield components of papaya hybrid 'Caliman 01'. The experiment was carried at the company WG Fruticultura, located in the Chapada do Apodi region. Five nitrogen doses (94, 590, 837, 1088 and 1575 kg N ha^{-1}), five phosphorus doses (10, 72, 96, 133 and 195 kg P_2O_5 ha^{-1}) and five potassium doses (75, 527, 752, 978 and 1429 kg K_2O ha^{-1}), were combined according to the experimental matrix Pan Puebla II, in 16 combinations and distributed in a randomized block design, with five repetitions. The plots consisted of six papaya plants and the four central plants were evaluated. The fertilizers urea, monoammonium phosphate and potassium chloride were used as NPK sources, respectively. The doses of N and K were split into 30 applications, one every two weeks. Phosphorus doses were split into two applications, the first at 75 days after transplantation (DAT) and the second one at 150 DAT. Fruit production was evaluated during eight months. The best results were obtained for NPK doses of 1088, 72 and 527 kg ha^{-1}, respectively. Increasing N doses linearly increased the number of fruits per plant and yield, while increasing P and K doses reduced yield by a quadratic and linear model, respectively. The combination of NPK doses 590-72-75 kg ha^{-1} provided the best economic results with the highest rate of return for papaya production.

Key words: Carica papaya L.. Fertilization. Yield.

RESUMO - O objetivo do trabalho foi avaliar o efeito de diferentes doses de NPK nos componentes de produção do híbrido de mamão papaia 'Caliman 01'. O experimento foi realizado na empresa WG Fruticultura, localizada na região da Chapada do Apodi. Cinco doses de nitrogênio (75, 590, 837, 1088 e 1575 kg N ha^{-1}), cinco doses de fósforo (10, 72, 96, 133 e 195 kg P_2O_5 ha^{-1}) e cinco doses de potássio (527, 752, 978 e 1429 kg K_2O ha^{-1}), foram combinados de acordo com a matriz experimental Pan Puebla II, em 16 combinações e distribuídos em delineamento de blocos ao acaso, com cinco repetições. As parcelas foram constituídas por seis plantas, sendo avaliadas as quatro plantas centrais. Como fontes de N, P e K foram utilizados os fertilizantes ureia, fosfato monoamônico e cloreto de potássio, respectivamente. As doses de N e K foram divididas em trinta aplicações, uma a cada duas semanas. As doses de fósforo foram divididas em duas aplicações, a primeira aos 75 dias após o transplante (DAT) e a segunda aos 150 DAT. A produção de frutos foi avaliada durante oito meses. As doses de NPK que proporcionaram os melhores resultados em termos de produtividade foram 1088, 72 e 527 kg ha^{-1}, respectivamente. O aumento das doses de N aumentou linearmente o número de frutos por planta e a produtividade, enquanto o aumento das doses de P e K reduziu o rendimento segundo modelos quadrático e linear, respectivamente. A combinação de doses de NPK 590, 72, 75 kg ha^{-1} proporcionou os melhores resultados econômicos com maior taxa de retorno na produção de mamão.

Palavras-chave: Carica papaya L.. Fertilização. Produtividade.

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INTRODUCTION

Brazil presents excellent climatic conditions for the cultivation of papaya. In 2016, Brazil produced 1.4 million tons in 30,372 hectares. In 2017, Brazil exported about 39,700 kg year^{-1}, generating USD 40.35 million revenue (BRAZILIAN FRUIT YEARBOOK, 2018).

The papaya cv. Formosa absorbs large amounts of nutrients continuously, especially in the first year (FONTES *et al*., 2010). To obtain the maximum crop yield and fruit quality required by the market there is a need to supply correct amounts of fertilizers (SANTOS *et al*., 2014).

Nitrogen is the second most required nutrient by the papaya plant and is responsible for vegetative growth (FONTES *et al.*, 2010). Its absorption is continuous and increasing during plant cycle. In an experiment with nitrogen doses of 210, 428.4 and 642 kg ha^{-1} year^{-1} and constant doses of 85.7 kg ha^{-1}of P_2O_5 and 428.4 kg ha^{-1} of K_2O, Marinho *et al.* (2001) observed statistical differences in yield and number of fruits per plant. Silva Junior *et al.* (2016a, b) observed statistical differences in yield of papaya 'Caliman 01' as a function of different doses and sources of nitrogen, as well as for the interaction.

Phosphorus is required in smaller quantities by papaya as compared to N and K, but presents a great importance in the early stage of root development (OLIVEIRA *et al*., 2004). Evaluating combinations of N, P_2O_5 and K_2O for papaya 'Improved Sunrise Solo Line 72/12', Oliveira and Caldas (2004) and Oliveira *et al.* (2007) observed statistical differences in yield, and fruit quality. In Indonesia, Nasution, Noflindawati and Budiyanti (2011) observed a positive correlation between doses of phosphorus and number of fruits per plant, and average fruit weight in five papaya varieties.

Potassium is the most required nutrient by papaya and it is absorbed at a continuous and increasing rate along the plant cycle, with particular importance during the flowering and fruit set stage (OLIVEIRA *et al*., 2004). Testing different doses of K_2O in papaya, Nascimento *et al.* (2009) observed an increase of 36.45% in the number of fruits per plant between the minimum and the maximum rate tested. Viana *et al.* (2008) observed quadratic increases with maximum number of fruits per plant with the dose of 157 kg KNO_3 ha^{-1}month^{-1}.

In a study carried out in five locations in India, Kumar *et al.* (2010) tested the doses 0; 150; 300 and 450 g K_2O plant^{-1} year^{-1}, with fixed doses of N and P_2O_5. The N-P_2O_5-K_2O, combination of 300-300-300 kg ha^{-1}, was recommended to obtain highest yield, number of fruits per plant and fruit weight.

Due to the economic importance of papaya production, its increasing planted area and lack of research on papaya fertilization in the Chapada do Apodi region, this study tested the hypothesis that increasing doses of NPK increase yield of papaya 'Caliman 01', and there is a combination of NPK doses that provides the best economic return for papaya growers. The objective of this work was to study the effects of fertilization with different doses of nitrogen, phosphorus and potassium on yield components of papaya hybrid 'Caliman01', in order to determine the doses with maximum economic return and improve the sustainability of the crop fertilization.

MATERIAL AND METHODS

The experiment was carried in the company WG Fruticultura Ltda., in Baraúna- RN (latitude 05º03'31.1"S and longitude 37º38'58.4" W). The soil was classified as Inceptisols, having the following physical attributes (in g kg^{-1}): 530 sand, 165 silt and 305 clay; and chemical (in $cmol_c$ kg^{-1}): 0.05 Na^+, 0.7 K^+, 17.0 Ca^{++}, 1.8 Mg^{++}, 0.0 H^++Al^{3+}, 10 mg P kg^{-1}, 7.68 g C kg^{-1}and pH 8.4.

Seedlings of papaya hybrid 'Caliman01' were transplanted to the field 30 days after germination, in the spacing 4.0 x 2.0 m, planting three plants per pit. The roughing was done at 90 days after transplanting (DAT), leaving one hermaphrodite plant per pit.

Treatments consisted of sixteen combinations of doses of N, P_2O_5 and K_2O. Five nitrogen doses (94, 590, 837, 1088 and 1575 kg N ha^{-1}), five phosphorus doses (10, 72, 96, 133 and 195 kg P_2O_5 ha^{-1}) and five potassium doses (75, 527, 752, 978 and 1429 kg K_2O ha^{-1}), were combined according to the experimental matrix Pan Puebla II and distributed in a randomized block design, with five repetitions. The plots consisted of six plants and the four central plants were evaluated.

The fertilizers urea, monoammonium phosphate (MAP) and potassium chloride (KCl) were used as NPK sources, respectively. Urea and KCl doses were split in 30 applications, applied every two weeks, with the following distribution along the crop cycle: 83% of the urea and 30% of KCl doses were applied in the vegetative stage (15-120 DAT), 17% of the urea and 70% of KCl doses were applied in the flowering and fruit set stage (120-300 DAT). The MAP doses were split into two applications, 53% of the MAP dosage was applied at 75 DAT and the remainder at 150 DAT. The N added in the MAP applications was discounted from the applied urea doses.

Magnesium sulfate was applied as a source of sulfur and magnesium at dosage of 1.5 kg ha^{-1}, once a week, by

fertigation. Micronutrients were foliar applied using the commercial product Supra® with the following chemical composition, in g L^{-1}: 130 P_2O_5, 78 K_2O, 26 Ca, 14.3 Zn, 6.5 B, 2.6 de Cu, 1.9 Fe, 1.3 Mo and 78 of total carbon, at a dosage of 0.8 L h^{-1}, once a month.

Irrigation was performed daily, 4 hours per day, using a drip irrigation system. Emitters with flow rate of 4 L h^{-1} were spaced every 0.50 m. During the vegetative phase it was used one drip line per row and in the reproductive phase two drip lines per row. The weed control was carried out using herbicides Glyphosate© and Gramoxone©. Preventively, were applied Oberon©, Abamec© and Ortos© to control mites and Calipso© and Decis© for insect control.

Harvest began at 190 DAT and was performed once a week, for eight months. Fruits were harvested when they presented two or three noticeable yellow stripes at their the base. At harvest the fruits were counted and weighed, obtaining this way, the number of fruits per plant, average fruit weight, production (kg $plant^{-1}$) and yield (t ha^{-1}).

The cost of each combination of NPK was determined taking as a basis the average price (in USD) per kilogram of N, P_2O_5 and K_2O are 0.51, 0.55 e 0.66, respectively. Revenue (benefit) from fruit sales was calculated considering the average price per kilogram (R$ 0.16). The most economical combination of NPK doses was determined by the cost/benefit ratio.

The data were submitted to analysis of variance to evaluate the effect of different combinations of NPK doses and the means were compared by the Tukey test at 5% probability. The effect of doses of N, P_2O_5 and K_2O was assessed by multiple regression analysis, using the statistical software SAEG 9.1 (UNIVERSIDADE FEDERAL DE VIÇOSA, 2007).

RESULTS AND DISCUSSION

The number of fruits per plant, average fruit weight, production and yield of papaya 'Caliman 01' were significantly affected by combinations of NPK doses (Table 1). The largest number of fruit per plant was obtained with the combination of NPK doses 1088-72-527 kg ha^{-1} (combination 5), differing significantly

Table 1 - Production variables obtained in the papaya 'Caliman 01' in function of combinations of rates of N, P_2O_5 and K_2O

Combinations	N	P_2O_5	K_2O	NFrP	AFrW kg	FrP kg $plant^{-1}$	FrY t ha^{-1}
NPK	---------- kg ha^{-1} ----------						
1	590	72	527	15.00	1.46	22.20	27.75
2	590	72	978	18.46	1.66	29.22	36.53
3	590	133	527	19.08	1.57	28.92	36.15
4	590	133	978	18.80	1.56	26.65	33.31
5	1088	72	527	22.87	1.50	37.21	46.51
6	1088	72	978	21.15	1.65	29.98	37.47
7	1088	133	527	15.72	1.48	25.41	31.76
8	1088	133	978	20.87	1.49	31.14	38.92
9	837	96	752	20.73	1.60	30.59	38.24
10	94	72	527	18.15	1.42	27.12	33.91
11	1575	133	978	16.12	1.61	25.29	31.61
12	590	10	527	19.86	1.55	30.58	38.22
13	1088	195	978	20.74	1.53	33.29	41.62
14	590	72	75	22.77	1.45	32.97	41.22
15	1088	133	1429	17.31	1.54	26.28	32.85
16	94	10	75	17.87	1.40	26.49	33.12
Means				19.09	1.53	28.96	36.20
C.V. (%)				11.45	3.43	10.29	10.29
Tukey (5%)				4.95	0.12	6.74	8.43

Number of fruits per plant - NFrP, average fruit weight - AFrW, fruit production - FrP and fruit yield -FrY

from combinations 1, 7, 11, 15 and 16. The highest fruit weight was obtained with the combination of NPK doses of 590-72-978 kg ha^{-1} (combination 2), which was not significantly different from combinations of 3, 4, 6, 9, 11, 12 and 15. The highest fruit production and yield were 37.21 kg $plant^{-1}$ and 46.51 t ha^{-1}, respectively, and were obtained using combination 5 (1088-72-527 kg ha^{-1}), which did not differ significantly from combinations 8, 9, 12, 13 and 14.

Silva Júnior *et al.* (2016a) obtained a fruit production of 8.08 kg $plant^{-1}$ and yield of 13.5 t ha^{-1}, when they applied 525 g of polymerized N $plant^{-1}$. Using urea as the source of N, they obtained a fruit production of 6.42 kg $plant^{-1}$ and a yield of 10.7 t ha^{-1} for the maximum N dose (500.9 g $plant^{-1}$). Both yields are smaller than those obtained by Brito Neto *et al.* (2011) and Souza *et al.* (2007) with papayas 'Sunrise Solo' and 'Tainung 01', respectively.

Evaluating combinations of nitrogen source on papaya 'Tainung 01' Souza *et al.* (2007) obtained 13.2 fruits per plant after five months of harvest, applying ammonium sulfate during 25% of the crop cycle and calcium nitrate during the remaining 75% of the crop cycle. Also with the cultivar 'Tainung 01', but working with potassium fertilization, Nascimento *et al.* (2009) obtained 17.37 fruits per plant after nine months of harvest, applying 102 kg ha^{-1} of K_2O before planting and 102 kg ha^{-1} of K_2O during the crop cycle. Viana *et al.* (2008) obtained the maximum of 17.37 fruits per plant applying 72.2 kg ha^{-1} of K_2O per month.

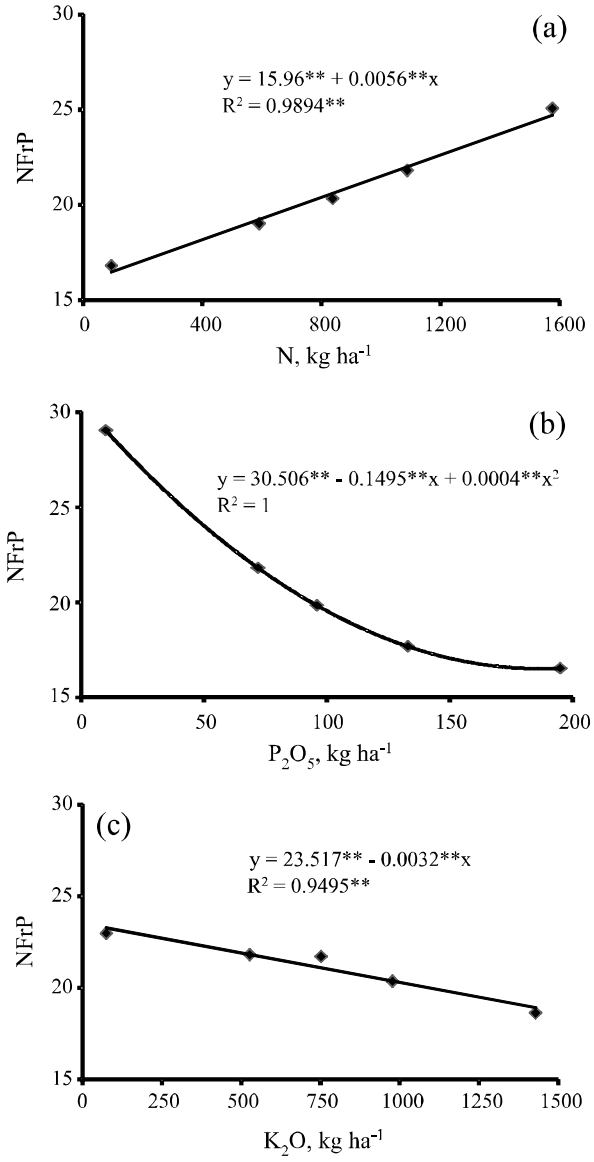
For papaya variety 'Sunrise Solo', Oliveira and Caldas (2004) and Oliveira *et al.* (2007) obtained 102.4 fruits per plant after 12 months of harvest, using a combination of NPK 560-280-560 kg ha^{-1}. Marinho *et al.* (2001), working with the cultivar 'Improved Sunrise Solo Line 72/12' obtained 45.4 fruits per plant, using the combination of NPK 428.4-85.7-428.4 kg ha^{-1}.

Average fruit weight varied from 1.40 to 1.66 kg (Table 1) which was higher than those observed by Marinho *et al.* (2002) for cultivars of the 'Taiwan' group, 'Tainung 01/781' and 'Tainung 02/785', with average fruit weight of 1.35 and 1.11 kg, respectively, while for cultivar 'Know You 01/784 ', the average fruit weight was 2.01 kg, therefore, higher than those obtained in this work.

Production and fruit yield obtained in this study (Table 1) were lower than those obtained by Marinho *et al.* (2002), with cultivars 'Tainung 01/781'; 'You Know 01/784' and 'Tainung 02/785' (36.8 kg $plant^{-1}$ and 45.8 t ha^{-1}, 36.1 kg $plant^{-1}$ and 44.4 t ha^{-1}; 24.5 kg $plant^{-1}$ and 43.7 t ha^{-1}, respectively). That difference in production and yield may be attributed to plant density and harvest period, since in this experiment we used 1,250 plants ha^{-1} and the harvest season lasted eight months. Marinho *et al.* (2002) used 1.785 plants ha^{-1}, which were harvested for nine months.

The number of fruits per plant increased linearly as N doses increased (Figure 1a), while P and K reduced according to quadratic and linear trends, respectively (Figures 1b and 1c). Marinho *et al.* (2001) also observed a linear increase in the number of fruit with increases in nitrogen levels in papaya 'Sunrise Solo Line 72/12', while Oliveira and Caldas (2004) observed quadratic

Figure 1 - Numbers of fruits per plant (NFrP) of papaya 'Caliman 01' in function of N rates combined with 72 kg ha^{-1} P_2O_5 plus 527 kg ha^{-1} K_2O (a); in function of P_2O_5 rates combined with 1088 kg ha^{-1} N plus 527 kg ha^{-1} K_2O (b) and in function of K_2O rates combined with 1088 kg ha^{-1} N plus 72 kg ha^{-1} P_2O_5 (c)

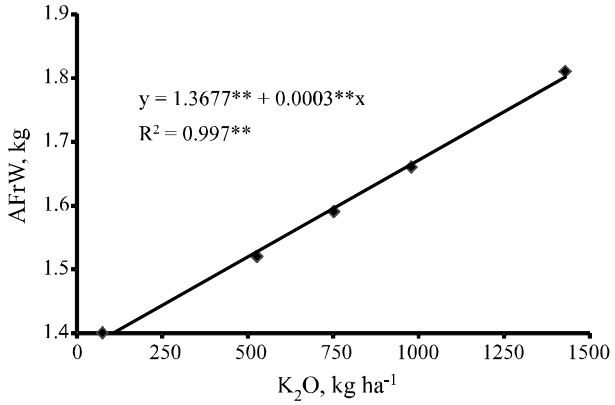


increases with the doses of N and K. Brito Neto *et al.* (2011) obtained a quadratic effect of N doses on the number of fruits, up to 15 fruits plant^{-1} for an estimated dose of 253 g plant^{-1}. Anjos *et al*. (2015) reported a linear effect of K doses on the number of fruits, within a range of 30 to 53 fruits per plant.

Silva Júnior *et al.* (2016 a,b) reported a quadratic response in the production per plant and yield when N doses increased. Maximum yield values of 14,30 and 8.70 t ha^{-1}, were obtained with the doses of 498 and 460 g per plant for coated and conventional urea, respectively. The yield was 39.2% higher when the polymerized urea was used over conventional urea application. Brito Neto *et al.* (2011) reported that the production of fruits per plant presented an increasing linear behavior with increasing N doses, with the highest production of 7.8 kg plant^{-1} obtained with the dose 400 g plant^{-1}. The average fruit weight increased in a quadratic manner as a result of increasing of N doses, with a maximum value of 387 g obtained with the dose of 288.9 g plant^{-1}.

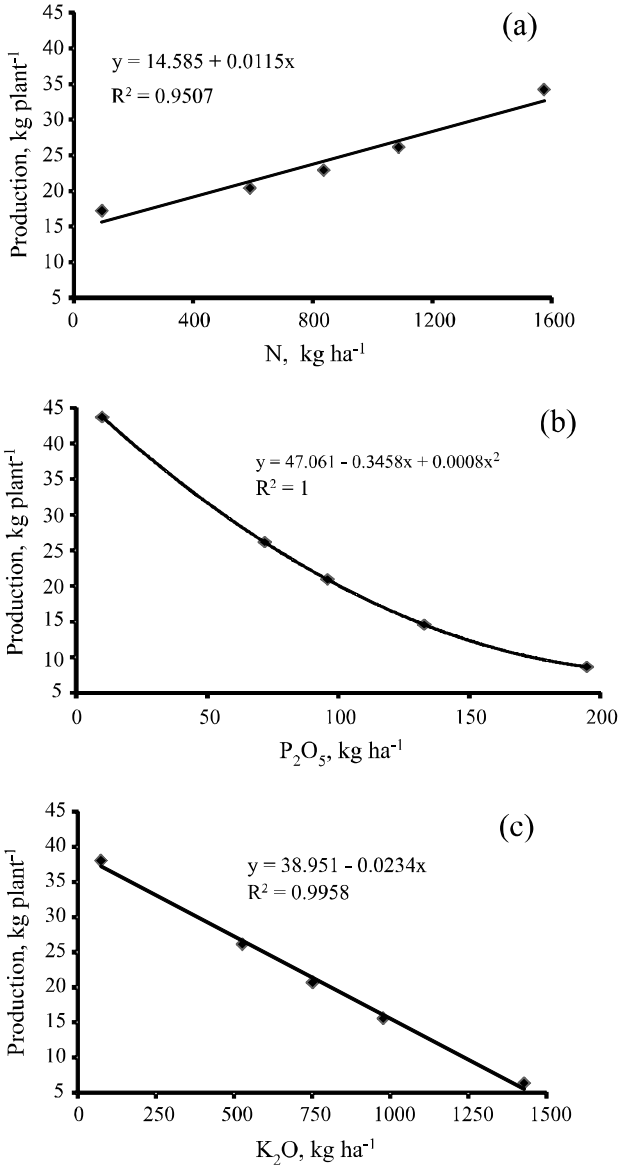
Increasing N levels did not significantly affect average fruit weight of papaya 'Caliman 01'. Marinho *et al.* (2001) also observed no effect of N rates on average fruit weight of cultivar Sunrise Solo Line 72/12. Doses of K showed a positive linear effect on average fruit weight (Figure 2), with an estimated increase of 29.3%.

Figure 2 - Average fruit weight (AFrW) of the papaya 'Caliman 01' in function of K_2O rates combined with 1088 kg ha^{-1} N plus 72 kg ha^{-1} P_2O_5



N doses linearly increased production of fruits per plant, providing estimated increase of 1.15 kg of fruits per plant per 100 kg N ha^{-1} (Figure 3a). Brito Neto *et al.* (2009) also observed positive linear behavior of N rates in the production of papaya 'Sunrise Solo' (increase of 0.96 kg of fruits per plant per 100 kg N ha^{-1}). However,

Figure 3 - Fruits production of the papaya 'Caliman 01' in function of N rates combined with 72 kg ha^{-1} P_2O_5 plus 527 kg ha^{-1} K_2O (a); 01' in function of P_2O_5 rates combined with 1088 kg ha^{-1} N plus 527 kg ha^{-1} K_2O (b) and in function of K_2O rates combined with 1088 kg ha^{-1} N plus 72 kg ha^{-1} P_2O_5 (c)



increasing P and K doses reduced fruit production of papaya 'Caliman 01' by 80.1% and 83.3%, between the highest and lowest doses of these nutrients, respectively (Figures 3b and 3c). Anjos *et al.* (2015) observed positive linear behavior of K rates in the production of papaya 'Tainung 01' with yield varying from 100 to 142 kg of fruits per plant. Allam, Taylor and Dicks (2000) evaluated the fertilization with NPK in papaya 'Solo' and did not detect effects of N, P and K on fruit quality. Fruit weight presented significant quadratic responses for N and P

applications, but there was a significant negative NK interaction, with higher levels of K, resulting in reduced fruit weight.

Yields of papaya 'Caliman 01' did not statistically differ from each other for NPK combinations 5, 8, 9, 12, 13 and 14 (Table 1). Combinations 12 and 14 were those that had the lowest fertilization cost (Table 2). Fertilization costs of treatments 12 and 14 were 36.7% and 53.3% lower than treatment 5, respectively, but their yields were only 17.8% and 11.4% lower, respectively (Table 3).

The combinations of NPK doses 12 and 14 showed the best benefit/cost ratios for production of papaya 'Caliman 01' (Table 3). There was an increase of the benefit/cost ratio for combinations 12 and 14 compared to combination 5, which means a financial return rate of 113% and 212%, respectively, considering only the economic aspect of the papaya fertilization. That return allows to infer that the combination of NPK doses 14 is the best option for the production of papaya 'Caliman 01' at the edaphic and climatic conditions of the site.

Marinho *et al*. (2008) studied the effects of five irrigation depths and four K doses on yield and fruit quality of papaya cv. Golden ('Solo' group). During eleven months of harvest, the average yield was 79.4 t ha^{-1} and there were no significant differences among the treatments. However, in absolute values, the highest yield (96.4 t ha^{-1}) was obtained with the combination of an accumulated irrigation depth of 1,525 mm and fertilization with 42 g K_2O per plant per month. Silva *et al.* (2001) obtained a maximum yield of 30.9 t $ha^{-1}$for the papaya cv. Sunrise (six months of harvest) when they applied an irrigation depth of 2,731 mm. Oliveira and Caldas (2004) obtained, in twelve months of harvest, a maximum yield of 99.53 t ha^{-1} for papaya cv. Sunrise Solo, with fertilization doses of 272; 136 and 272 g $plant^{-1}$ of N, P_2O_5 and K_2O, respectively.

Table 2 - Total fertilization costs of the papaya 'Caliman 01' related to the best combination of rates of N, P_2O_5 and K_2O. (Exchange: USD 1 = R$ 1,74in 2009)

Combinations NPK	N	P_2O_5	K_2O	N	P_2O_5	K_2O	Total cost[1]
	---------- kg ha^{-1} ----------			---------- USD ha^{-1} ----------			
5	1088	72	527	1,938.50	81.90	585,55	2,605.95
8	1088	133	978	1,938.50	154.46	1,086.67	3,179.63
9	837	96	752	1,491,20	111.50	835,55	2,438.25
12	590	10	527	1,051.15	11.61	585,55	1,648.31
13	1088	195	978	1,938.50	226.47	1,086.67	2,535.66
14	590	72	75	1,051.15	81.90	83.33	1,216.38

[1]Based on the average price of N, P and K sources commercialized in Brazil, in 2009

Table 3 - Marginal revenue (MR), benefít/cost ratio (BCR) and relative production (RP) of the papaya 'Caliman 01' obtained with the best combination of rates of N, P_2O_5 and K_2O. (Exchange rate: USD 1 = R$ 1,74 in 2009)

Combinations NPK	Yield kg ha^{-1}	MR USD ha^{-1}	BCR	RP %
5	46,513	4,277.00	1.64	100.00
8	38,925	3,579.30	1.13	83.69
9	38,238	3,516.10	1.44	82.21
12	38,225	3,514.95	2.13	82.18
13	41,613	3,826.45	1.18	89.47
14	41,213	3,789.65	3.12	88.61

CONCLUSIONS

1. Under the conditions of the study, the increase of the nitrogen doses increased the yield of the papaya' Caliman 01', while the increase of the phosphorus and potassium doses reduced fruit yield;
2. The combination of 590-72-75 kg ha^{-1} of N, P_2O_5 and K_2O provided the best economic results for papaya production.

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