NITROGEN AND POTASSIUM FERTILIZATION AFFECTING THE PLUM POSTHARVEST QUALITY[1]

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ABSTRACT - The goal of this research was evaluated the effects of potassium and nitrogen fertilization on the plum (*Prunus salicina*) fresh fruit quality and after cold storage. The experiment was carried out in a five year-old plum orchard 'Reubennel', located at Araucaria County, Parana State, Southern Brazil, in a Haplumbrept Soil. Potassium fertilizer was applied at 55 and 110 kg/ha/year of K_2O, as KCl. Nitrogen fertilizer was applied at 40, 80, 120, 160 and 200 kg/ha/year of N, as urea. It was used a split-plot design in a factorial scheme (2x5). One hundred plum fruits were harvested from each plot, in the same day, when 25 to 50% of the peel presented yellow-reddish color. At harvest and after 17, 27 and 37 days of storage at 0 ± 0.5 ºC, the flesh firmness, the total soluble solids, and the titratable acidity were assessed. Fresh fruit quality was affected by N application, with the best results obtained by applying 40 kg/ha/year of N. The N and K rate of 40 and 110 kg/ha/year, respectively, kept superior fruit quality during the storage. 'Reubennel' cold storage can not exceed 27 days. Fresh and stored 'Reubennel' plum fruit qualities depend on the N and K fertilizer rates.
Index terms: *Prunus salicina*, stone fruit, storage, nutrition, fertilizer.

ADUBAÇÃO COM NITROGÊNIO E POTÁSSIO AFETA A QUALIDADE PÓS-COLHEITA DE AMEIXA

RESUMO - O objetivo foi analisar o efeito da adubação com nitrogênio e potássio na qualidade pós--colheita de frutos de ameixa (*Prunus salicina*) armazenados sob baixa temperatura, durante 37 dias. Este experimento foi desenvolvido em um pomar com cinco anos de idade da cultivar 'Reubennel', situado no Município de Araucária, Paraná, Brasil, num Cambissolo Húmico. Foram aplicados 55 e 110 kg/ha/ano de K_2O, na forma de cloreto de potássio e nitrogênio, nas doses de 40; 80; 120; 160 e 200 kg/ha/ano, na forma de ureia, em esquema fatorial (2x5), em parcelas subdivididas. Cem frutos de cada parcela foram colhidos no mesmo dia, quando de 25 a 50% da casca apresentava coloração amarelo-avermelhada. Os parâmetros avaliados foram: firmeza de polpa, sólidos solúveis totais e acidez titulável na colheita e depois de 17; 27 e 37 dias de armazenamento a 0 ± 0,5 ºC. A qualidade dos frutos na colheita foi afetada somente pela aplicação de N, com os melhores resultados na dose de 40 kg/ha/ano. A aplicação de 40 kg/ha/ano de N e 110 kg/ha/ano de K permitiram que os frutos permanecessem com melhor qualidade durante o armazenamento. O armazenamento refrigerado não deve exceder a 27 dias. A qualidade dos frutos de ameixa 'Reubennel' depende das doses de N e K.
Termos para indexação: *Prunus salicina*, fruta de caroço, armazenamento, nutrição, fertilizante

INTRODUCTION

Fertilizer is an important tool used by the most farmers in order to boost crop yield. However, excessive fertilization has been verified, especially on the horticultural enterprises, where the fertilizer costs represented less than 10% of the variable crop costs (HUETT; DIROU, 2000). Besides of the economic aspects, excessive fertilization has been associated to ground and stream water contamination (EPPA, 2005), as well as causing an increment of pest (MARSCHNER, 1995) and diseases occurrence (TRATCH et al., 2010). The increasing of the public concern about environment aspects caused by over fertilization renew the interest on evaluating the adequate fertilization recommended on field to maintain productivity and fruit quality with less environment impact.

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It is well known that the fertilizer amount applied by farmers influences the fruit quality. Plant nutrition has been reported affecting fruit appearance (KAYS, 1999), texture (SAM, 1999), and taste (MATTHEIS; FELLMAN, 1999). Postharvest fruit properties which control storage potential have been also affected by fertilization (EMONGOR et al., 1994; SAMS, 1999; HUNSCHE et al., 2003), because they affect fruits susceptibility to mechanical damage, physiological disorders, and decay (KADER; ROLLE, 2004).

Nitrogen and potassium are among the principal nutrients needed by plants (MARSCHNER, 1995). However, excessive nitrogen supply can cause negative impact on the stone fruits quality by reducing flesh firmness and sweetness (RETTKE et al., 2006), diminishing red color appearance (CRISOSTO et al., 1997), and increasing susceptibility to postharvest diseases (DAANE et al., 1995). Otherwise, nitrogen deficiency was reported leading to small fruits with poor flavor (TAYLOR, 2009). Even though, nitrogen application did not affect the stone fruit quality in Brazil (DOLINSKI et al., 2005; BRUNETTO et al, 2007).

Stone fruit trees nitrogen deficient can provide low yield (TAYLOR, 2009) as result shorter period of leaves maintenance, resulting in shorter reserves accumulation for the posterior cycle (MONTE-SERRAT et al., 2004, TRATCH et al., 2010). Under potassium deficiency, stone fruit productivity, quality (CHATZITHEODOROU et al., 2004), and storage potential (RUIZ, 2006) are negatively affected. Johnson and Uriu (1989) reported that poor fruit color, either lacking color or having dirty looking was observed under potassium deficiency for peaches. High potassium level increases the fruit acidity (KADER; ROLLE, 2004). In many cases, the interaction between nutrients at plant and balanced supply by fertilizer application is more important than to analyzed isolated rates. For example, the fruit red color development showed to be strongly affected by balance between nitrogen and potassium (TAYLOR, 2009). N and K levels for stone fruit trees depend on factors such as cultivar (TAYLOR, 2009), tree status (VITANOVA, 1990), soil characteristic (VITANOVA, 1990), ground cover, and irrigation method (JOHNSON; URIU, 1989). N rate from 112 to 168 kg/ha/year is usually considered adequate for stone fruits (JOHNSON; URIU, 1989).

Stored plum (*Prunus salicina*) fruits quality and acceptability depends on the cultivars, such as was verified on a research developed on Polish (PLICH, 1998). 'Reubennel' is one of the main plum cultivars growths in south of Brazil (MALGARIM et al., 2007). The influence of fertilization over the 'Reubennel' fresh fruit quality, and also its stored quality and maximum storage period are unknown. This knowledge is important to guarantee fruit quality to supply the national market, with distances by road exceeding 1000 km, and also to export it. The goal of this research was to evaluate the effects of potassium and nitrogen fertilization on the plum fresh fruit quality and after cold storage.

MATERIALS AND METHODS

This experiment was carried out in a five years old plum orchard 'Reubennel', grafted onto 'Okinawa' rootstock. The orchard was located at Araucaria County, Parana State, Southern Brazil, in a Haplumbrept Soil (fertility shown in the Table 1). Potassium fertilizer was applied as potassium chloride at K_1= 55, and K_2=110 kg/ha/year of K_2O, split in two periods: full bloom (60%), and after thinning (40%). Nitrogen fertilizer was applied as urea at N_1=40, N_2=80, N_3=120, N_4=160 and N_5=200 kg/ha/year. Each rate was split in three periods: full bloom (30%), after thinning (30%), and after harvest (40%). Nitrogen and potassium fertilization were carried out manually under the canopy without incorporation. Phosphorus was manually applied once a year during the winter, broadcasting 22 kg/ha/year of P_2O_5 in the whole area. Experimental area comprehended 750 plants (approximately one-hectare), in a split-plot design in three randomized complete block in a factorial scheme (2x5). Main plot treatments were potassium rates, and subplot treatments were the nitrogen rates.

One hundred plum fruits were harvested from nine selected plants for each treatment, in the same day. The selected fruits presented between 25 to 50% of the peel with yellow-reddish color. These fruits were grouped in four sub-samples and packed into paper bags with five fruits in each. One of those sub-samples was maintained at environmental temperature during three days, simulating in such way the 0 days storage period, and then submitted to physical-chemical fresh fruit quality evaluation. The other three sub-samples were stored at 0 ± 0.5 ºC during respectively 17, 27 and 37 days, with physical-chemical evaluation performed three days after each storage period.

Flesh firmness (FF) was measured on both sides of each fruit, after peeling, by using a manual penetrometer FT 327 with an 8mm tip. Two slices of flesh were taken from each fruit and juiced to determine the total soluble solids (SSC) (ºBrix) with an auto temperature compensated refractometer (Atago). Titratable acidity (TA) was measured by titrating 10 mL of juice diluted to 10% with NaOH 0.1 N to pH 8.2, results obtained represent the % of malic acid.

RESULTS AND DISCUSSION

This orchard produced an average of 32.9 ton/ha over 3 years, without any differences between N and K rates, explained by the orchard´s good soil properties and plant management (DOLINSKI et al., 2007), however fertilizer rates applied affected brown rot, caused by *Monilinia fructicola* (MAY-DEMIO et al., 2008), and shot hole, caused by *Wilsonomyces carpophilus* (TUTIDA et al., 2007), important plum's diseases.

Fresh fruit quality

There was no influence of potassium rates over fruits quality parameters, neither as single nor as interactive effect with nitrogen rates. Similar to this study, Gazolla-Neto et al. (2007) did not found difference of potassium fertilization on peach fruit quality parameters. However, usually potassium has been associated with fruit quality in general (SAMS et al., 1999). Perhaps this result might be explained by the high level of soil available K (see Table 1).

In opposition to potassium, nitrogen application affected all fruits quality parameters (Figure 1). This is significant since Chatzitheodorou et al. (2004) reported that on fertile soils nitrogen is often the only nutrient that needs to be supplied to peach, another stone fruit, on a regular basis. Nitrogen rates showed quadratics effects with different minimum value for each parameter (Figure 1).

At harvest fruit must be firm enough to be transported and packed or processed without damage (RETTKE et al., 2006). The N has been linked with stone fruit flesh softening (RETTKE et al., 2006; JIA et al., 2006), such as was observed in this research until the rate of 123 kg/ha/year (Figure 1). It might have due to the N feature diminishing the cell wall thickness, which in consequence decreases the flesh texture (MURAMATSU, 1996; JIA et al., 2006). This undesirable decrease in firmness due to excess nitrogen fertilization is well documented in several crops (PRASAD et al., 1988; SAMS, 1999). Like nitrogen, potassium fertilization can also result in a decrease in firmness (SAMS, 1999). Over 123 kg/ha/year of N the FF increased (Figure 1) as result of maturation delay. It corroborates with Crisosto et al. (1995, 1997) who reported that stone fruits submitted over nitrogen fertilization have more vegetative growth, which carried out to excessive shading, smaller fruits, and delayed fruit maturation.

The SSC was from 13.7 to 11.3 ^{0}Brix (Figure 1) with the N increasing. This result agrees with Crisosto et al. (1997) who observed that although stone trees over N fertilized may look healthy and lush, excess of N do not increases the SSC. The lowest 'Reubennel' plum fruits SSC (11.3 ^{0}Brix) found here is lower to those found in 'Amarelinha' plum cultivar (KLUGE et al., 1999). Comparing with the consumers' acceptance trial of 'Blackamber' plum fruits performed by Crisosto et al. (2003) 'Reubennel' plum fruits SSC with 11.3 ^{0}Brix probably would not to be well accepted.

The plant growth was boosted by N application, resulting on increment of light interception from canopy (DOLINSKI et al., 2007). This might be the major reason for the continuous diminishing of SSC as result of N increment (Figure 1). It is well known that there is a direct link between light exposition and SSC in stone fruits (PATTEN; PROEBSTING, 1986; SOUTHWICK et al., 1990; MARINI et al., 1991; MULEO et al., 1994). They attributed it to an improvement in the photosynthetic activity of adjacent leaves, which are not shaded, enhancing in this way the carbohydrates availability for the fruit development (SEELEY et al., 1980; BARRITT et al., 1987). This is a great treat to the fruit quality since the SSC represents the fruit sweetest and is one of the most important fruit property considered by consumers (PARKER at al., 1991; ROBERTSON et al., 1988; CRISOSTO et al., 1997; CRISOSTO et al., 2003).

The TA decreased to the limit of 148 kg/ha/year of N (Figure 1). Since low TA is a desirable feature for fruit, N until this rate provided better fruit quality. Higher TA levels indicate less mature stone fruits (CRISOSTO et al., 1997). Like the others two parameters discussed above, higher than 148 kg/ha/year of N (Figure 1) rates increased the vegetative growth (DOLINSKI et al., 2007), what increases the fruit shading, and in consequence delayed the fruit ripening. The results obtained here are different from Brunetto et al. (2007) whom did not find influence of N on peach fruits over TA, using less N doses (88 kg/ha/year of N).

The ratio SSC: TA is a standard for fruits quality (CRISOSTO et al., 1997; CRISOSTO et al., 2003), and it minimum was observed to 120 kg/ha/year of N (Figure 1). This N rate is close to that is applied by the local growers, and is the rate suggested by Peach Integrated Fruit Production (IFP) management system (FACHINELLO et al., 2003).

The N application showed influence over fruit quality, contrasting with fruit yield, which was not affected by N application for the same period (DOLINSKI et al., 2007). So it seems that fruit quality showed higher sensibility to N application than yield. Crisosto et al. (1997) also found that excessive N induces poor visual red color development, and inhibits ground color change from green to yellow. It is clear that the lowest N rate (40 kg/ha/year of N) was the best and that N rates above 120 kg/ha/year are not recommended since did not increase fruit quality (Figure 1). In addition it increase costs (HUETT; DIROU, 2000) and can be a threat to the environmental (McNULTY et al., 2005).

The responses of FF, SSC, and TA for N rates application rates (Figure 1), observed in this research, might be due to low soil organic matter level (Table 1). Opposite results were observed by Brunetto et al. (2007), with high organic matter level on the soil, where was not necessary to supply N for the plant growing and fruit production.

Stored fruit quality

All plum fruits stored quality after 37 days of cold storage showed strong visual signs of deterioration, represented by shriveled and internal breakdown. Internal breakdown is one of the most important reasons for consumers' compliments of apricots, peaches, nectarines, and prunes (CRISOSTO et al., 1995; MITCHELL; KADER, 1989). This result agrees with Kluge et al. (1995, 1999), who recommended that the cold storage of 'Reubennel' plum fruits should last the maximum of 30 days. Additionally, Crisosto (1997) also indicated that prolonged cold storage cause internal breakdown as consequence of chilling injury.

It was observed an interaction between nitrogen and potassium over FF, SSC, and TA during 37 days of cold storage (Figures 2 to 4). The lowest nitrogen rate (40 kg N/ha/year) produced and maintained during the storage the sweetest fruits (SSC). Generally with the low potassium rate (55 kg/ha/year of K_2O) SSC content decreased during the storage faster that with the high potassium rate (110 kg/ha/year of K_2O) (Figure 2).

The results of TA showed in Figure 4 and 5 indicated that the low K rate result in higher variation among the N rates. It is well known that K plays an important control of N plant metabolism, and this variation may associated to the N imbalance (MARSCHNER, 1995). The lowest nitrogen rate (40 kg N/ha/year) also produced and maintained during the storage fruits with the highest TA content (Figure 3).

Like the other parameters, the lowest nitrogen rate (40 kg N/ha/year) provided the highest FF (Figures 4). It was also observed that the FF decreased during the storage with all N rates applied. Several previous researches reported flesh softening as an usual process observed in stone fruits during cold storage (ABDI et al., 1997; AKBUDAK; ERIS, 2004; RATO et al., 2008). Corroborating, Prasad et al. (1988) who reported kiwi fruit growth under excessive N application showing premature fruit softening during the storage. Different from the others parameter FF showed a slight increment at 27 days storage (Figures 4). This might be due to the fruit wooliness; however this physiological process was not measured in this research.

TABLE 1 – Soil analysis from a 'Reubennel' plum orchard (*Prunus salicina*), samples collected under the trees canopy (Araucaria, PR, Brazil).

Sampling deep (cm)	pH $CaCl_2$	pH SMP	Al^{+3}	H^{+}+Al^{+3}	Ca^{+2}	Mg^{+2}	K^{+}	ECC (1)	Organic Matter	P (2)	V
			cmol$_c$/dm^3						(%)	mg/dm^3	% (3)
0-20	5,60	6,60	0	3,30	4,03	1,96	0,59	9,85	2,68	27,8	67
20-40	5,40	6,50	0	3,40	3,74	2,01	0,30	9,41	2,27	20,4	64

(1)ECC: Cation exchange capacity at pH 7,0, (2)Mehlich I extractor, (3)V: Base saturation

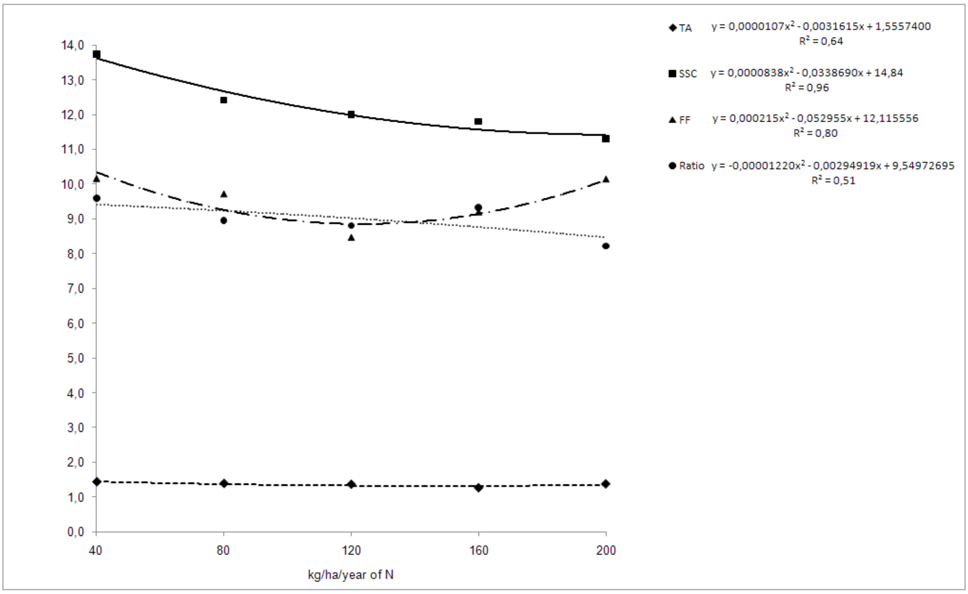


FIGURE 1 - Effect of nitrogen levels over the soluble solids (SSC) (^{0}Brix), flesh firmness (pound/inc^2), and titratable acidity (TA) (% of malic acid), and ratio (SSC:TA) of plum fruits (*Prunus salicina*) 'Reubennel'. Evaluation performed three days after harvest.

A

B

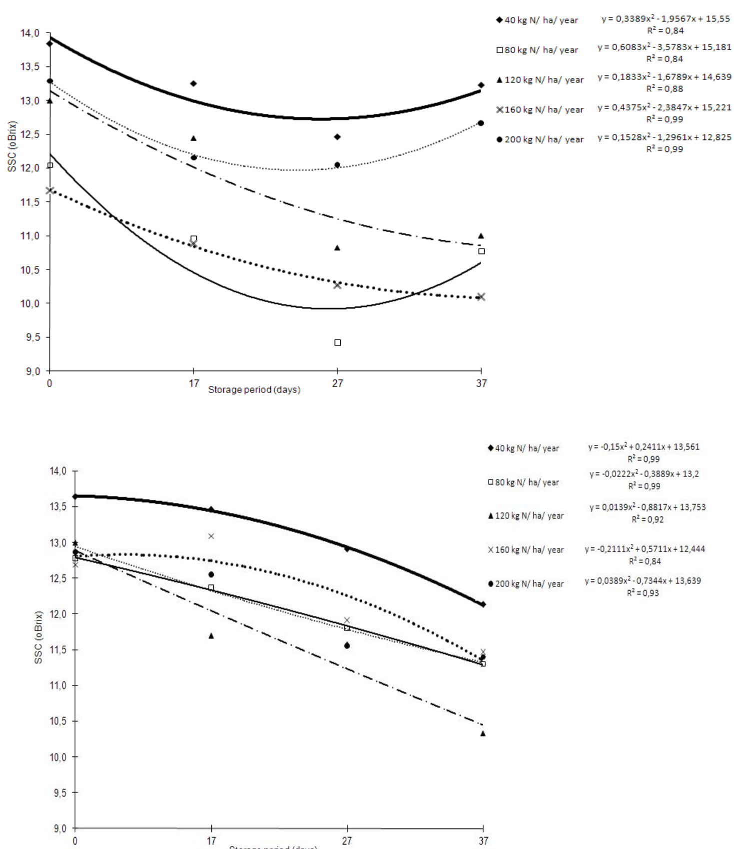
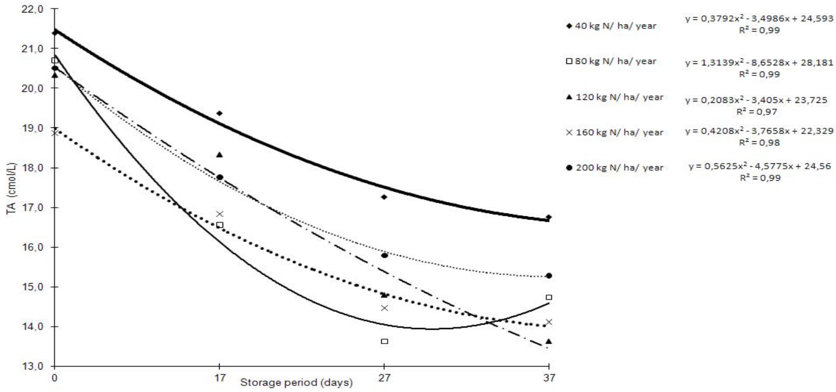


FIGURE 2 - Effect of nitrogen levels over the solid soluble content (SSC) (^{0}Brix) of plum fruits (*Prunus salicina*) 'Reubennel' fertilized 55 kg/ha/year of potassium (A), 110 kg/ha/year of potassium (B), and stored during till 37 days at 0 ± 0.5 ºC. Evaluation performed three days after storage.

A



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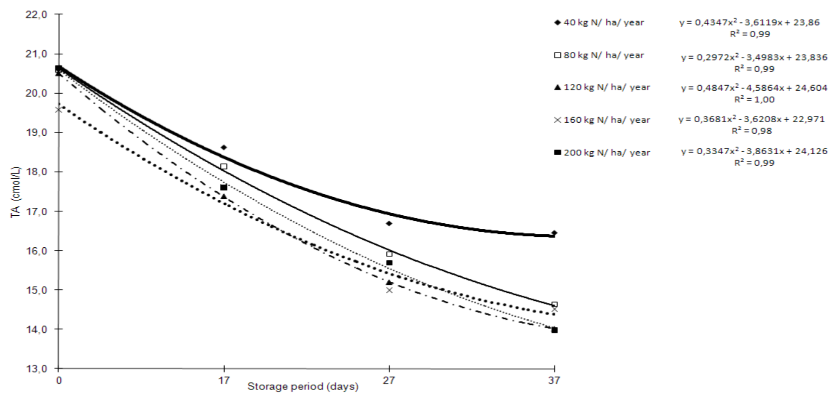
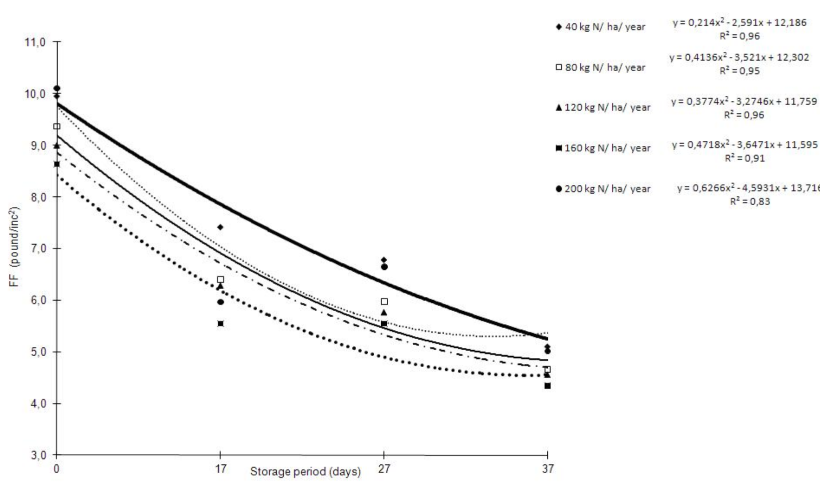


FIGURE 3 - Effect of nitrogen levels over the titratable acidity (TA) (% of malic acid) of plum fruits (*Prunus salicina*) 'Reubennel' fertilized 55 kg/ha/year of potassium (A), 110 kg/ha/year of potassium (B), and stored during till 37 days at 0 ± 0.5 ºC. Evaluation performed three days after storage.

A



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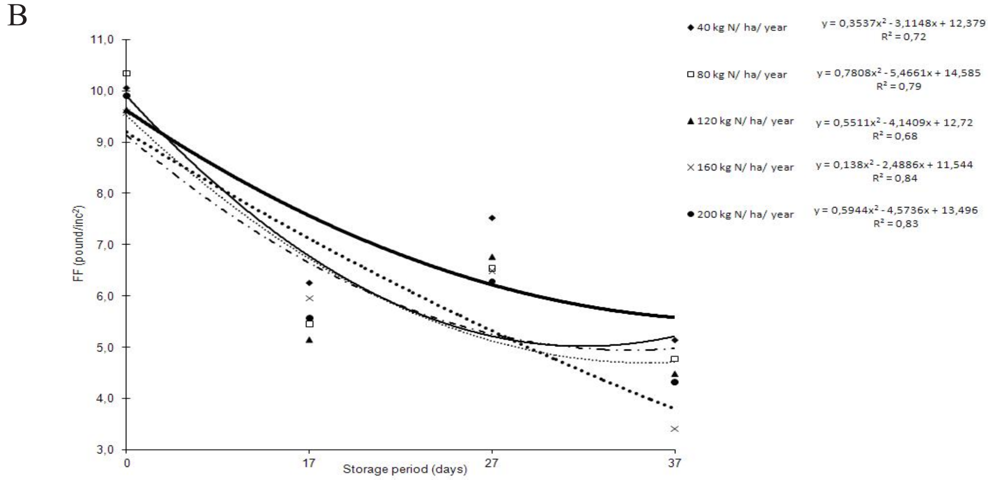

FIGURE 4 - Effect of nitrogen levels over flesh firmness (FF) (pound/inc^2) of plum fruits (*Prunus salicina*) 'Reubennel' fertilized 55 kg/ha/year of potassium (A), 110 kg/ha/year of potassium (B), and stored during till 37 days at 0 ± 0.5 ºC. Evaluation performed three days after storage.

CONCLUSIONS

1. The best 'Reubennel' fresh fruit quality was provided by applying 40 kg/ha/year N and K showed no influence over the fruit parameters.
2. The application of 40 and 110 kg/ha/year N and K_2O, respectively, maintained the 'Reubennel' plum fruit quality during the storage.

The maximum storage period of 'Reubennel' plum fruits is less than 27 days.

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