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# Phosphorus Rates Applied by Soil on Yield of Japanese Hybrid Pumpkin

João Victor Gonçalves Carline[1,*], Aline Torquato Tavares[1], Luziano Lopes da Silva[2], Tiago Alves Ferreira[1], Danilo Alves Porto da Silva Lopes[1], Rodrigo Robson Cavalcante[1], Flavio Coelho Mendes[1], Renato Sales Coelho[1], Irais Dolores Pascual Reyes[1], Francielly Quitéria Guimarães Alves[1], Camilo Gomes Antunes[1], Lucas Vinício Rodrigues Ventura1[1], Thales Aquino de Queiroz Ramalho[1], Ildon Rodrigues do Nascimento[1]

[1]Plant Production, Federal University of Tocantins, Small farm 69 - 72 Street.Badejos, Lot 7 s / n - Sevilha Garden,, Gurupi, 77404-970, Tocantins, Brazil
[2]Federal Institute of Education Science and Technology. Alameda Madrid, 545 - Sevilha Garden, Gurupi, 77 410 - 470. Tocantins, Brazil
[*]Corresponding Author

***Abstract*—*Growing Japanese hybrid squash has been a cost-effective alternative to growers; however, several factors directly influence plant growth and development, nutrition being one of the main ones. Data regarding the nutrition of these vegetables are scarce. The objective of this study was to verify the effect of phosphorus doses applied via soil, on fruit yield of Japanese hybrid squash. Two experiments were conducted in 2017, May 1 through July and September 2 through November, in the experimental area of the Olericulture Sector of the Federal University of Tocantins. For the development of both experiments, it was used the Divina® cultivar owned by the company "Horticeres seeds". The experimental design was randomized blocks with five treatments and four replications, as follows: 0; 75; 150; 225 and 300 kg $ha^{-1}$ of $P_2O_5$. The characteristics evaluated were: productivity (ton $ha^{-1}$), average fruit mass (kg), number of flowers per parcel (unit), transverse diameter (cm) and phosphorus content in Japanese squash (g $kg^{-1}$). The mean values related to the study variables were submitted to analysis of variance, and subsequently, regression analysis. The 300 kg $ha^{-1}$ dose of $P_2O_5$ provided higher yield and average fruit mass. In both growing seasons. Cultivation of the Japanese hybrid squash between September and November showed higher productivity.*

***Keywords*—Curcubita spp., Cucurbita moschata Duch, Cucurbita maxima Duch, phosphate fertilizer, productivity.**

## I. INTRODUCTION

In Brazil, pumpkin cultivation has great social and economic importance, being consumed by all social classes, as it is a source of sugars, fiber, and carbohydrates, in Brazil, pumpkin cultivation has great social and economic importance, being consumed by all social classes, as it is a source of sugars, fiber and carbohydrates, besides being rich in carotenoids such as α-carotene, β-carotene, and lutein (Veronezi and Jorge, 2011). The Japanese squash is an interspecific hybrid resulting from the crossbreeding of selected strains of squash (*Cucurbita maxima* Duch) with strains of the species (*Cucurbita moschata* Duch), the first being used as a female parent (Bisognin, 2002).

It has several advantages over open-pollinated cultivars, such as precocity, resistance to borer, yield stability, uniformity in size and color of the fruit, resistance to handling, transport and post-harvest conservation (Vilela et al., 2007). Thus, for the fruiting of the plant, it is necessary to synchronize other pumpkins or strawberries that will serve as pollen suppliers for entomophilic cross-pollination or even the use of Parthenocarpy induction techniques through the application of growth regulators (Cheng and Gavilanes, 1980; Pereira, 1999).

Data on the national production of these vegetables are scarce. But according to IBGE (2006), pumpkin consumption has been increasing over the years, from 1.6 kg per person-year to 4.2 kg per person $year^{-1}$. Hybrid squash cultivation is booming, dominating the market in some Brazilian regions. Brazil produces 426 thousand tons of hybrid squash, in an area of approximately 44, 9 thousand hectares, where the average productivity varies from 8-15 t $ha^{-1}$ (Filgueira, 2008). Several

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factors influence plant growth and development, being fertilization one of the main ones, Vidigal et al., (2007) found that phosphorus was the third element most exported by the Japanese pumpkin fruit, just behind potassium and nitrogen. In fertilization, phosphorus is particularly involved in many functions within the plant, such as energy transfer, ATP required for photosynthesis, translocation, among others. In inorganic form, inorganic phosphorus (Pi) is a substrate or end product in many important enzyme reactions, including photosynthesis and carbohydrate metabolism (Fernandes, 2006). According to Mendes et al. (2016), it is the element that most influences fruit size and its deficiency begins with lower development of plants. Phosphorus is generally a limiting nutrient for agricultural production in tropical and subtropical soils due to its low soil content, which implies the constant practice of phosphate fertilization. Given the above, the objective was to verify the effect of phosphorus doses applied via soil on the yield of fruits of the Japanese hybrid pumpkin.

## II. MATERIALS AND METHODS

Two experiments were installed in 2017, the first from May to July and the second from September to November, in the experimental area of the Olericulture Sector of the Federal University of Tocantins (UFT), in the municipality of Gurupi, located in the south. From the state of Tocantins at latitude 11º44'42 "south and longitude 49º03'05" west at 287 meters elevation. The climate of the region is characterized as being AW-Tropical climate domain of humid summer and drought period in winter, according to the Köppen classification (1928). Temperatures and rainfall rates in the southern region of the state of Tocantins, from May to November, are shown in Figure 1.

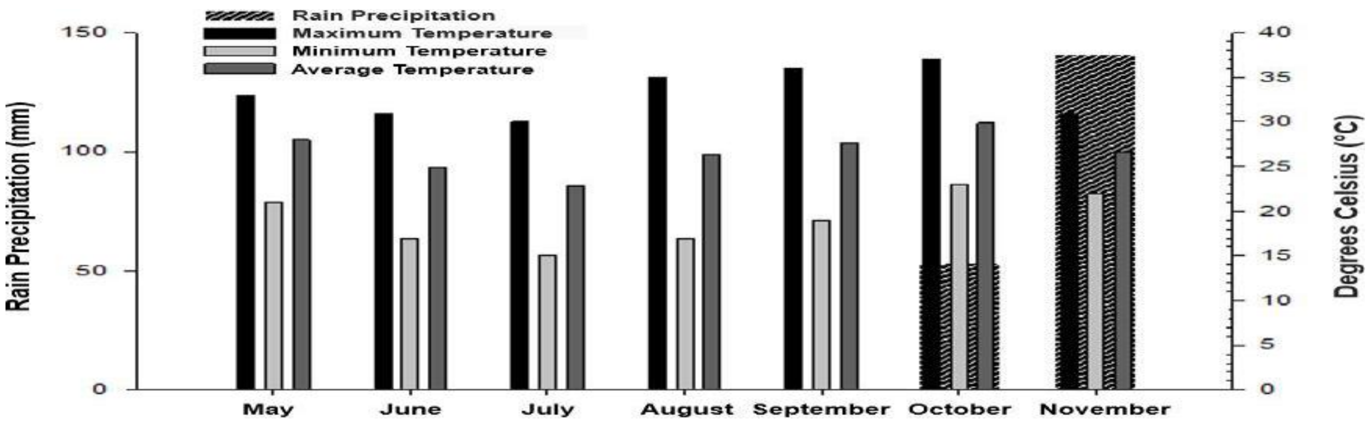


*Fig. 1: Maximum (° C), minimum (° C), average (° C) and rainfall (mm) temperatures during the experiment period. Gurupi-TO.2018. Source: INMET, 2017.*

The soil of the region in which the experiments were conducted is classified as Dystrophic Red Yellow Latosol, whose chemical characterization is presented below (Table 1).

The chemical attributes table presents the soil analysis of two distinct areas, being area 1 used for experimenting from May to July and area 2 for experimental conduction between September and November. The chemical attributes table presents the soil analysis of two distinct areas, being area 1 used for experimenting from May to July and area 2 for experimental conduction between September and November.

*Table 1. Chemical and physical attributes of the soils of the experimental area where the experiments were conducted.*

| Area | pH | P meh | K | Ca | Mg | Al | H+Al | M.O. | Clay | Silt | Sand |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | $CaCl_2$ | --mg.dm$^{-3}$-- | ------------cmolc.dm$^{-3}$----------------- | | | | | --dag.kg$^{-1}$-- | --------------%-------------- | | |
| 1 | 4.9 | 5 | 0.07 | 0.9 | 0.3 | 0.0 | 3.40 | 1.0 | 26 | 5 | 69 |
| 2 | 5.3 | 4.6 | 0.24 | 3.8 | 1.4 | 0.0 | 2.5 | 2.3 | 35 | 5 | 60 |

O.M - organic matter; O.C - organic carbon. The soil in the cultivated areas is classified as sandy loam.

For the development of both experiments, it was used the cultivar Divina® owned by the company "Horticeres Sementes".

In both experiments, the experimental design was randomized blocks with five treatments that were doses of $P_2O_5$ applied as MAP (Mono Ammonium Phosphate — 11% nitrogen and 51% $P_2O_5$) with four replications. In both experiments, the experimental design was randomized blocks with five treatments that were doses of $P_2O_5$ applied as MAP (Mono Ammonium Phosphate — 11% nitrogen and 51% $P_2O_5$) with four replications. The doses were established as recommended for the crop and soil analysis results. In each plot, after the draw was established, 0 were applied; 75; 150; 225 and 300 kg ha $^{-1}$ of $P_2O_5$.

The acidity was corrected by applying 2 and 3 tons per hectare of lime filler (PRNT- 99.99%) with $MgCO_3$ content above 25%, for areas 1 and 2, respectively, increasing the saturation by the base at 60%. For plant fertilization 150 kg ha$^{-1}$ FTE, 100 kg ha$^{-1}$ potassium chloride (60% $K_2O$) and as $P_2O_5$ doses. Coverage fertilization was performed at 15 and 45 days after planting, using 80 kg ha$^{-1}$ of urea (45% nitrogen) and 50 kg ha $^{-1}$ of potassium chloride (60% $K_2O$) per application.

The planting was carried out in pits (0.40 m × 0.40 m × 0.40 m), spaced 2.0 m × 2.0 m. Each pit was sown with two seeds and subsequently, germination was thinned, ensuring one plant per pit. The experimental plot, as well as the useful plot, consisted of 6 consecutive plants within the same row. At 30 days after planting, the daily monitoring of all plots of the experimental field began in the afternoon shift, aiming to identify flower buds capable of inducing asexual fruiting (parthenocarpy) the following morning. After opening the flower bud the next morning, between 6 and 7 am, with the aid of a mini hand sprayer, about 2 ml of 2, 4-D solution (2, 4-dichlorophenoxyacetic acid) was applied. At 200 ppm, inside the newly opened flowers of each plot. For the manufacture of the solution, 1 ml of the commercial product DMA 806 BR® Dow Elanco (pure source of 2, 4-dichlorophenoxyacetic acid), diluted in 5 liters of distilled water, was used and this solution was renewed every 7 days and stored in room temperature.

Weed control was carried out from chemical control and weeding. The water supply of the crop was performed with drip irrigation, where at 6 am and 6 pm, hoses with drippers spaced 25 cm and a pot of 2.5 liters per hour was triggered for 1 hour.

The harvest was performed 85 days after sowing from the observation that 90% of the fruits presented dry stalk and peel resistant to nail penetration.

The characteristics evaluated were:

— Average fruit productivity (ton ha$^{-1}$): obtained by summing the average mass of fruits harvested from the useful area of each plot and the result was converted to ton ha$^{-1}$;

— Average fruit mass (kg fruit$^{-1}$): obtained by the total weight in a kilo of fruits harvested in each useful plot, divided by the number of fruits of each useful plot; — Average fruit mass (kg fruit$^{-1}$): obtained by the total weight in a kilo of fruits harvested in each useful plot, divided by the number of fruits of each useful plot;

— Number of flowers per plot (unit): obtained from counting the number of flowers of the 6 plants that make up the useful plot of each treatment; — Fruit cross diameter (cm): expressed in centimeter and obtained by measuring the fruit cross diameter;

— Phosphorus content (g kg-1): determined from equitable samples collected from all plants of the parcel at the vegetative stage, and on the fruits of each parcel.

The mean values for the measured variables were submitted to variance analysis and then regression analysis using SISVAR version 5.0 software (Ferreira, 2008).

## III. RESULTS AND DISCUSSION

In the analysis of joint variance, there was no significant effect of the interaction between the doses and growing seasons at the 5% probability level compared to the "F" test for all characteristics evaluated (Table 2), but in the unfolding of dose-effect levels within each season, there was a response to these characteristics with the variation of the applied dose. Only for the average fruit yield characteristic, a significant effect was observed at 5% probability by the "F" test concerning the applied $P_2O_5$ doses (Table 2).

*Table 2. Summary of analysis of joint variance (two evaluation times) on average fruit yield (PROD), average fruit mass (AFM), number of flowers per plot (NFP) and cross-sectional diameter (CSD) of Japanese squash produced as a function of $P_2O_5$ doses. Gurupi –TO. 2017.*

| F. V. | D. F. | Q. S. | | | |
|---|---|---|---|---|---|
| | | PROD (ton ha$^{-1}$) | AFM (Kg) | NFP (und.) | C.S. (cm) |
| Blocks / Season | 6 | 11,855 $^{ns}$ | 0,0706 $^{ns}$ | 39,700 $^{ns}$ | 0,244 $^{ns}$ |
| Doses | 4 | 29,128* | 0,1392 $^{ns}$ | 16,025 $^{ns}$ | 1,339 $^{ns}$ |
| Season | 1 | 37,597* | 0,1587 $^{ns}$ | 1060,9* | 10,09* |
| Doses *vs* Season | 4 | 3,4806 $^{ns}$ | 0,0082 $^{ns}$ | 16,525 $^{ns}$ | 0,2543 $^{ns}$ |
| Average waste | 24 | 7,6387 | 0,0441 | 17,408 | 0,7068 |
| **Overall Average** | | **13,05** | **1,69** | **18,850** | **11,55** |
| **CV (%)** | | **21,17** | **12,41** | **22,13** | **7,28** |

* Significant at the 5% probability level; $^{ns}$ Not significant.

The second growing season presented superior results concerning the first growing season for all the evaluated characteristics. This fact must be related to the climatic conditions observed in the second growing season, mainly concerning precipitation that was higher than that observed for the first growing season Marouelli et al. (2017), evaluating the response of the Tetsukabuto hybrid squash to water depths (irrigation + effective precipitation) and nitrogen doses, found that the average soil water stress at irrigation associated with water depths precipitation, maximized fruit yield, corroborating the results observed in this work.

The average yield, regardless of the growing season, increased linearly as $P_2O_5$ doses were increased (Figure 2).

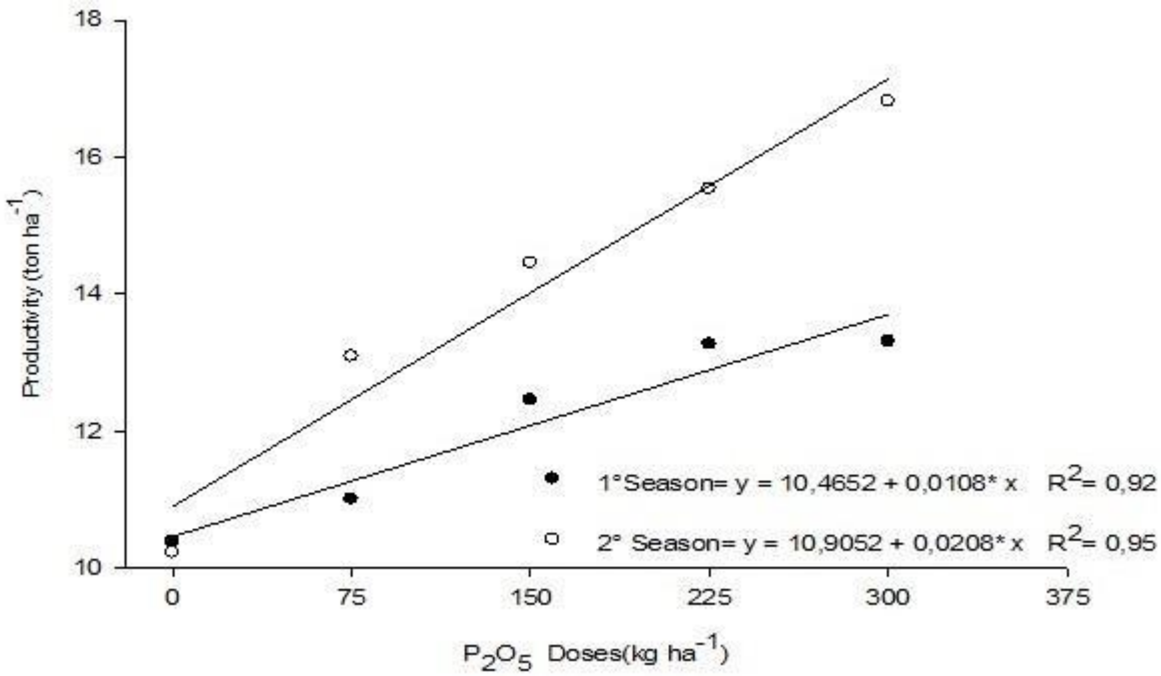


*Fig. 2: Average productivity (ton ha$^{-1}$) of Japanese pumpkin fruits produced as a function of $P_2O_5$ doses. Gurupi –TO. 2017.*

The 300 kg ha$^{-1}$ dose of $P_2O_5$ was higher in both growing seasons, which means that the maximum point was not reached under the studied experimental conditions.

For the first season, there was an increase of 2.9 tons, equivalent to an increase of 28% when compared to the control, while for the second growing season there was an increase of 64%

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compared to the control, equivalent to a 6.5 tons, showing that the crop is very responsive to phosphate fertilization (Figure 2).

The average yield obtained with the 300 kg $ha^{-1}$ dose of $P_2O_5$ in the second growing season is higher than the average yield observed for the state of Minas Gerais of 15 ton $ha^{-1}$ (Sediyama et al., 2009), however. Lower than the average productivity observed by Ferreira et al. (2017), for the state of Tocantins. Studying the phosphate fertilization in the irrigated watermelon crop in Cassilândia, Freitas júnior et al. (2008), observed that the application of increasing doses of phosphorus in the planting did not provide the significant difference for the average fruit yield.

Cortez et al. (2011) studying the effect of phosphate fertilization on melon production observed that there was a significant result for average yield, with 320 and 311 kg $ha^{-1}$ doses of $P_2O_5$, respectively.

The same was observed by Souza et al. (2017), who study the agronomic performance of zucchini as a function of phosphate fertilization, found that increasing phosphorus doses increased the accumulation and concentration of phosphorus in the plant and, consequently, the productivity of zucchini fruits. Similar results were found in this work.

Studies have shown that the effect of phosphate fertilization on crops is especially pronounced in low fertility soils, in which case phosphorus stimulates root development, it is fundamental to the production of early reproductive parts and generally increases crop production (Raij, 1991).

For the average fruit mass characteristic, a behavior similar to that observed for average yield was observed, since the increase of the phosphorus dose in the soil increased the average fruit mass (Figure 3).

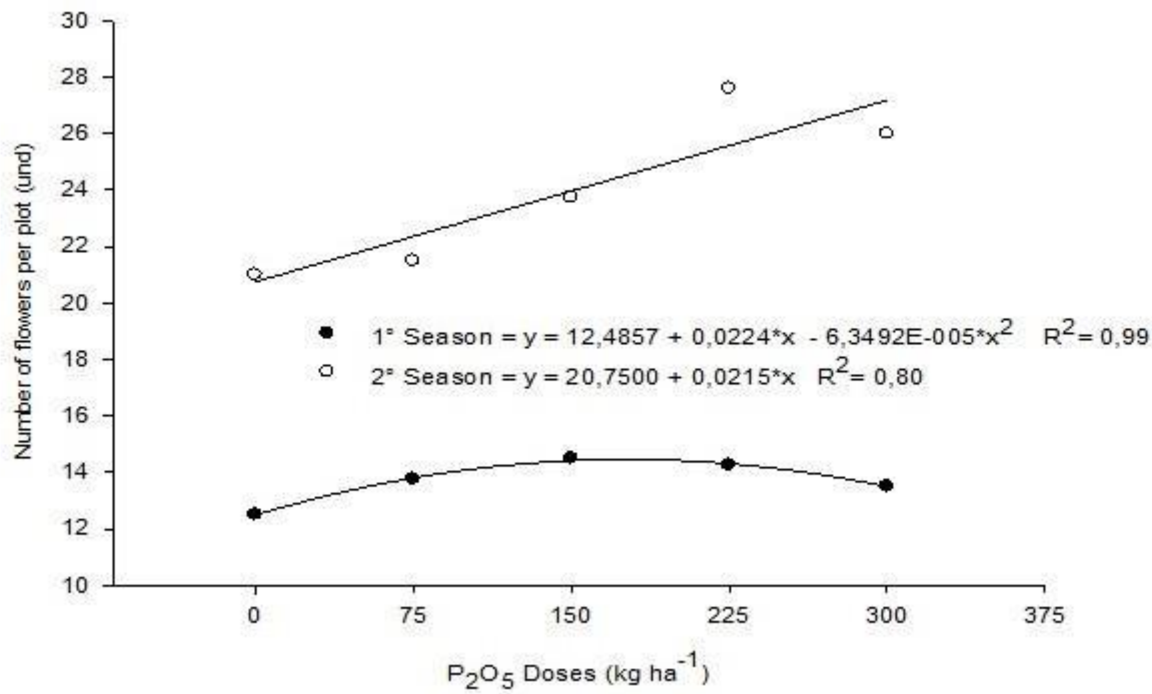


*Fig. 3: Average fruit mass (kg) of Japanese squash produced as a function of $P_2O_5$ doses and growing seasons. Gurupi –TO. 2017.*

The 300 kg $ha^{-1}$ dose of $P_2O_5$ was higher than the others, presenting an increase of 18%, or 0.27 kg when compared to the control of the first season while for the second growing season, the increase was 24% concerning the control, which represents an increase of 0.38 kg (Figure 3), indicating that the maximum point was not reached in the studied interval.

The linear behavior of $P_2O_5$ doses concerning the average fruit mass, corroborate the results found by Porto (2015), in a study on watermelon yield under phosphorus and potassium doses in the Cerrado of Roraima, however, Chaves (2014), in a study on watermelon yield under phosphorus and potassium doses in the Cerrado of Roraima, however, Chaves (2014), studying the residual effect of phosphate fertilization on production and accumulation of pumpkin nutrients did not observe significant results for this variable.

The $P_2O_5$ doses directly influenced the number of flowers per plot of Japanese squash (Figure 4).

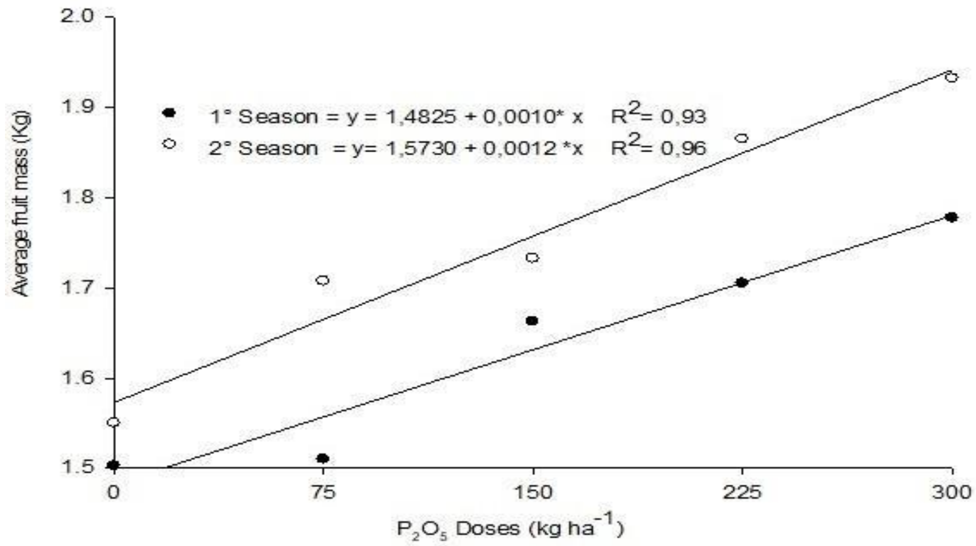


*Fig. 4: The number of flowers per plot (unit) of Japanese squash produced as a function of $P_2O_5$ doses. Gurupi-TO. 2017.*

It is observed that in the first growing season the variable number of flowers per plot adjusted to a quadratic regression model wherefrom the derivation of the regression equation, the maximum point was found at the dose of 176 kg ha$^{-1}$ of $P_2O_5$, presenting an increase of 16% when compared to the control, for the second growing season there was a linear adjustment of the regression equation, where the 300 kg ha$^{-1}$ $P_2O_5$ dose was higher than the other doses evaluated, presenting an increase of 31% concerning the control, clearly demonstrating that the observed doses were sufficient to supply the energy demand of the culture, because, according to Sardans et al. (2005), the formation and maintenance of flowers and fruits are processes of high energy expenditure and require the synthesis of substances (proteins and hormones) that demand nutrients such as phosphorus, which is required to form the main energy molecule of plants.

The results observed in the study corroborate the results found by Pereira et al., (2011), in a study on the flowering and fruiting of Manso pine genotypes under phosphorus doses in the cerrado of southern Tocantins.

For the variable cross-sectional diameter of Japanese squash fruits produced as a function of $P_2O_5$ doses, a distinct behavior was observed between growing seasons, where the averages observed for the first growing season were adjusted to a linear equation model, while the averages observed for the second growing season were adjusted to a quadratic equation model (Figure 5).

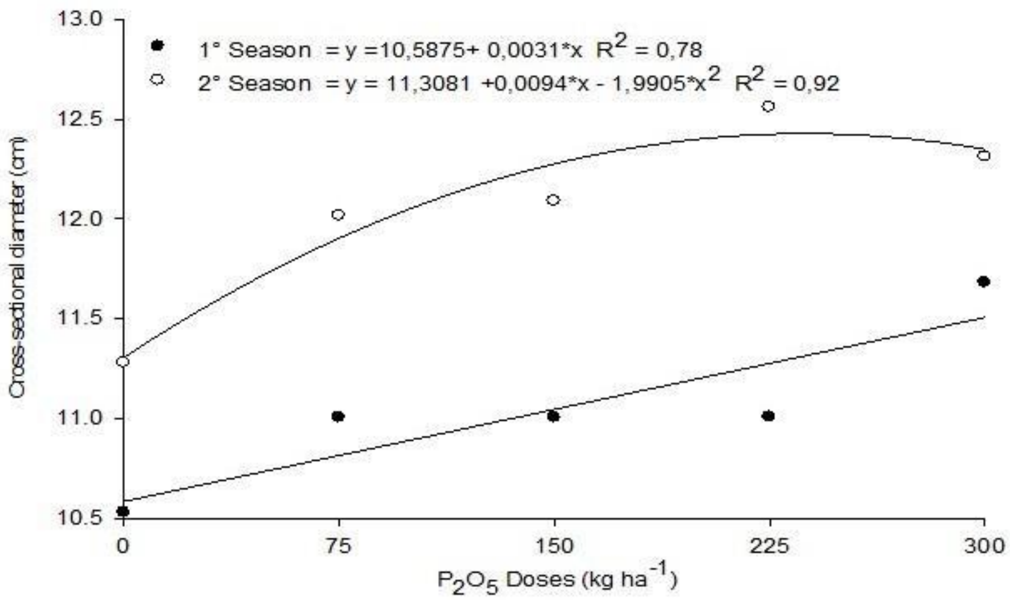


*Fig. 5: Cross-sectional diameter (cm) of Japanese pumpkin fruits produced as a function of $P_2O_5$ doses. Gurupi -TO. 2017.*

The 300 kg ha$^{-1}$ dose of $P_2O_5$ was higher in the first growing season, indicating that the maximum point was not reached in the study dose range, however, the 300 kg ha$^{-1}$ dose, presented an increase of 11% in fruit cross-sectional diameter (11.68 cm) concerning the control, representing an increase of 1.15 cm.

For the second growing season, the upper $P_2O_5$ dose was 236 kg ha$^{-1}$, with a cross-sectional diameter of 12.42 cm, representing an increase of 1.78 cm in the cross-sectional diameter and an increase of 16% concerning the control (Figure 5). The observed values of cross-sectional diameter are below the 17 cm values found by Pereira et al., (2012), working with Tetsukabuto pumpkin fruiting under application of 2,4-D doses in the dry season in Pombal-PB.

The same behavior is observed by Gonçalves (2014), in a study of the quality of 'Tetsukabuto' Hybrid Pumpkin fruits submitted to different applications of synthetic auxin and nitrogen fertilization. The observed averages corroborate the results found by Abreu et al. (2011), who verified positive effects of $P_2O_5$ doses on the diameter of melon fruits, obtaining the maximum value of 13.15 cm at the dose of 354.4 kg ha$^{-1}$. For the variable phosphorus content (g kg$^{-1}$) present in leaves and fruits of Japanese squash produced as a function of $P_2O_5$ doses, regardless of the sampling season, a quadratic adjustment of the regression equations was observed (Figure 6).

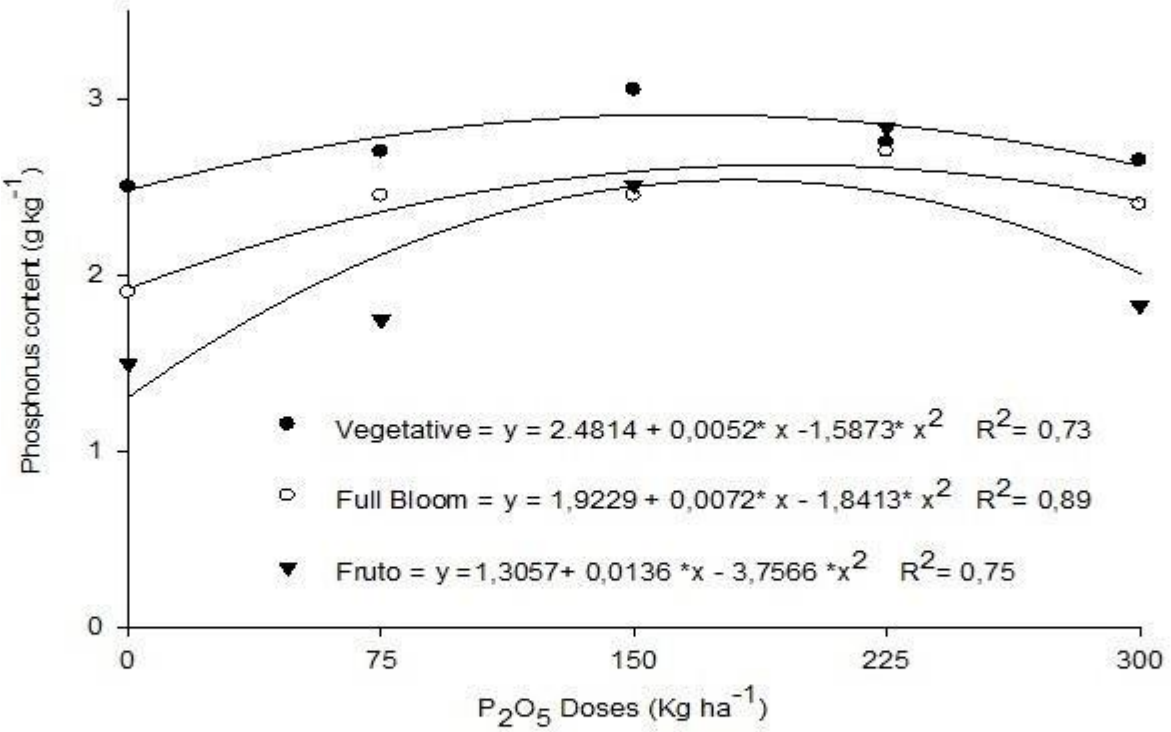


*Fig. 6: Phosphorus content (g kg$^{-1}$) present in leaves and fruits of Japanese squash produced as a function of $P_2O_5$ doses. Gurupi –TO. 2017.*

A sampling at the vegetative stage showed that the dose of 164.06 kg ha$^{-1}$ $P_2O_5$ provided higher phosphorus contents in g Kg$^{-1}$ of plant, equivalent to 2.91 g Kg$^{-1}$, representing about 17%. More than that observed in the witness. For the sampling in full bloom, the dose 195.7 kg ha$^{-1}$ of $P_2O_5$, was responsible for presenting the highest phosphorus contents, 2.5 g Kg$^{-1}$ of plant, representing an accumulation of 36% concerning the witness. The 181.64 kg ha$^{-1}$ dose of $P_2O_5$ provided the highest phosphorus accumulation in g kg$^{-1}$ of fruit, this accumulation being 2.53 g kg$^{-1}$ of fruit.

Silva et al. (1999) verified $P_2O_5$ leaf content of 4.6 g kg$^{-1}$ in hybrid squash (Tetsukabuto), as well as Carmo et al., (2011) working with leaf contents, accumulation and partition of macronutrients in the culture of pumpkin irrigated with saline water, the values observed by these authors are higher than the values observed in the present work, however, these values are very close to those obtained by Vidigal et al. (2007), in a study on mineral composition and macronutrient deficiency symptoms in hybrid squash, Tetsukabuto type, in this study the levels of $P_2O_5$ in normal leaves were around 1.8 g kg$^{-1}$, while the deficiency was only observed in leaf with contents equal to 0.8 g kg$^{-1}$.

It should be noted that nutrient accumulation is dependent on the species, cultivar/hybrid studied, planting time, among other factors that may affect yield per plant, It should be noted that nutrient accumulation is dependent on the species, cultivar/hybrid studied, planting time, among other factors that may affect yield per plant, because, as a general rule, the higher the DM production per plant, the higher the nutrient extraction per plant. For this reason, it is difficult to compare the extraction values obtained by different authors (Corrêa, 2016). Then, as a general rule, the higher the DM production per plant, the higher the nutrient extraction per plant. For this reason, it is difficult to compare the extraction values obtained by different authors (Corrêa, 2016).

## IV. CONCLUSION

- The 300 kg $ha^{-1}$ dose of $P_2O_5$ provided higher yield and average fruit mass in both growing seasons.
- Japanese hybrid pumpkin plants accumulated phosphorus up to the dose of 195.7 kg $ha^{-1}$ $P_2O_5$.
- The dose 181.64 kg $ha^{-1}$ of $P_2O_5$ provided the highest phosphorus accumulation in g $kg^{-1}$ of fruit.
- Cultivation of Japanese hybrid squash between September and November showed higher yield.

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