**Original Research Article**

# Effect of fertilization on yield and NPK contents in Red Ginger


.ABSTRACT

**Aims:** The aim of the researcu was to evaluate the effect of NPK fertilization on Red Ginger yield and nutrient content of mature plants.

**Study design:** 16 treatments were defined from combinations of N (0,108, 216, 322 kg ha$^{-1}$), P (0, 4, 10, 14 kg ha$^{-1}$) and K (0, 90, 178, 268 kg ha$^{-1}$). The treatments with three replications were set up in complete random blocks. The experimental unit was one cluster with stems.

**Place and Duration of Study:** The study was conducted from February 2012 to January 2013 on a 10-years-old commercial plantation. The plantation is located at 18°17'43.49'' N and 93°12'28.68'' W in Comalcalco, Tabasco, Mexico.

**Methodology:** Each 15 days along a year were recorded variables for the cluster, and for commercial stems and flowers. Then one plant per experimental unit was separated into flower, leaf, stem and rhizome to analyze NPK. With the data, an analysis of variance, means comparison (Tukey, $P \leq 0.05$), and Pearson correlation were performed.

**Results:** With the dosage 216-00-99, the plants developed the largest stem (2.17 cm) and flower (6.33 cm) diameters and the highest dry commercial (28.89 g) and total (199.3 g) biomass. The highest fresh weight of the non-commercial biomass (383.2 g) was found in plants fertilized with 322-04-90, but this value was statistically equal to that obtained with the dosage 216-00-00 (335.81 g). The NPK content found in Red Ginger leaf, stem, flower and rhizome satisfied the requirements established for P, but not for N and K. The N content was the unique nutrient correlated to the yield of Red Ginger.

**Conclusion:** The fertilization dosage 216-00-00 kg ha$^{-1}$ NPK was the best to favor Red Ginger yield. The NPK fertilization effects were observed on the content of K in stem and of P in flower, rhizome and leaf.


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*Keywords: Alpinia purpurata*; tropical flowers; plant nutrient content; Red Ginger production.


## 1. INTRODUCTION

Red Ginger (*Alpinia purpurata* Vieill) is one of the most cultivated and demanded tropical ornamental species worlwide. When temperatures, humidity and fertilization are the required by the plant, Red Ginger flowering is constant year round [1]. Constant production of cut flowers suggests constant nutrients extraction and yield decrease in the future [2]. Therefore, fertilization is essential for successful cultivation of Red Ginger and can promote large benefits when used appropriately [3]. There are no specific rules for fertilizing tropical ornamentals since

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**Comment [U4]:** Rephrase the sentence for clarity edaphoclimatic conditions are different in each region. Soil and leaf analyses are highly recommended to determine the quantity of nutrients that should be applied [4, 5].

Among nutrients N, P and K are key for plant growth and flowering [6]. Therefore, at least these elements should be analyzed both in the soil and in plant foliage. Levels of 2%, 16% and 18% NPK in the foliage of *A. purpurata* indicate that the crop's nutritional state is good [1]. These authors cited that in Red Ginger the more the N, the higher the number of floral stems.

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Of the total N absorbed from the soil by the plant, if there is a low proportion of $NO_3^-$ in the soil, a high proportion is reduced in the root, while if there is enough available $NO_3^-$, most is transported to the shoot where it can accumulate in both stem and leaves [7] of plants. In most plants, once absorbed, P is distributed from one organ to another; it accumulates in young leaves, in flowers and developing seeds and is lost in old leaves [8]. Application of simple superphosphate and organic fertilizers in *Alpinia zerumbet* crop resulted in a larger number of stems and leaves per stem and higher levels of P in the plants to which chemical fertilizer was applied than in those fertilized with organic fertilizers [9].

The K deficiency in crops results in weaker stems that make plants sensitive to the action of wind and rain, particularly monocotyledons [7] such as ginger. Haque et al. [10] report that growth and yield of *Zingiber officinale* increase significantly in accord with increments in levels of K applied, up to 100 kg $ha^{-1}$.

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Kobayashi et al. [1] recommend fertilizing ginger once or twice a year with formulas of 1:1:1 to 3:1:5 NPK. Lamas [5] recommends a dosage of 350-400, 200-250, 300-350 kg $ha^{-1}$ NPK for a plantation older than 13 months. In contrast, [4] indicates that fertilization is different for the conditions of each region. Therefore, it is necessary to determine the nutritional requirements of Red Ginger where it is actually produced. Based on the above, the objective of this study was to evaluate the effect of application of different dosages of NPK on yield and nutrient content of Red Ginger plants.

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## 2. MATERIAL AND METHODS

### 2.1. Experimental site

The study was conducted from February 2012 to January 2013 on a 10-years-old commercial plantation. The plantation is located 2 km north of the city of Comalcalco, Tabasco, Mexico, at 18°17'43.49'' N and 93°12'28.68'' W. The climate is Am (f) hot humid tropics with abundant summer rains; annual precipitation 2000 mm, with a dry season in March and April, and mean annual temperature of 26.5 ºC [11].

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The soil type in the plantation was Eutric fluvisol, which is considered first class farm soil [12]. Its physical-chemical characteristics are pH 6.84, EC 0.01 ds $m^{-1}$, organic matter 3.49%, total N 0.17%, P Olsen 12.67 mg $kg^{-1}$, K 0.27 Cmol $kg^{-1}$, Ca 15.70 Cmol.$kg^{-1}$, Mg 3.34 Cmol.$kg^{-1}$, CIC 12.64 Cmol.$kg^{-1}$, Fe 45.37, Zn 2.13, clay 38%, silt 44 % and sand 18%, texture class crumb silty clay. The Red Ginger plantation was in the open and plants were interspersed among cedar trees (*Cedrela odorata* L.). Plant density is 2000 plants per ha, 5 m between rows and 1 m between plants. Cultural practices included manual weeding and drip irrigation during the dry season.

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### 2.2. Plant material and experimental design

The plant material used was 48 Red Ginger clusters. Table 1 shows the nutrient content of the commercial and non-commercial biomass of the plants before the experiment. The commercial part included 60 cm of stem, two upper leaves and the flower. The non-commercial part included the rest of the foliage and of the stem. With the leaf and soil analyses, together with plant density, the dosage 108-04-90 kg $ha^{-1}$ NPK was estimated for the study plantation and used as a relative control for the experiment. The experiment was set up under a design of complete random blocks with three replications. The treatments were defined based on the San Cristobal design [13] with combinations of N (0, 108, 216 and 322 kg $ha^{-1}$), P (0, 4, 10 and 14 kg $ha^{-1}$) and K (0, 90, 178 and 268 kg $ha^{-1}$). The 16 NPK treatments were the absolute control (T1) 00-00-00 Kg $ha^{-1}$, 00-00-178, 00-10-00, 00-10-178, 108-04-90, 108-04-268, 108-14-90, 108-

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14-268, 216-00-00, 216-00-178, 216-10-00, 216-10-178, 322-04-90, 322-04-268, 322-14-90, and (T16)322-14-268 Kg $ha^{-1}$. The experimental unit was one cluster of plants.

**Table 1. Nutrient content of the commercial and non-commercial biomass from Red Ginger (*Alpinia purpurata*) plants before fertilization.**

| *Red* | N | P | K | Ca | Mg | Na | Fe | Cu | Zn | Mn | S |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Ginger* | % | | | | | | mg $kg^{-1}$ | | | | |
| CB | 0.68 | 0.27 | 1.39 | 0.61 | 0.20 | 0.09 | 70.46 | 4.76 | 76.00 | 20.32 | 0.24 |
| NCB | 1.36 | 0.24 | 1.57 | 0.83 | 0.31 | 0.05 | 99.0 | 4.88 | 40.72 | 26.50 | 0.74 |

CB, Commercial biomass. NCB, Non-commercial biomass. Methods: N semi-micro Kjeldahl, P, K, Ca, Mg, Na, Fe, Cu, Zn and Mn by digestion with $HNO_3$-$HClO_4$.

The fertilizers used as the sources of NPK were urea (46% N), triple calcium superphosphate (46% $P_2O_5$) and potassium chloride (60 % $K_2O$). The fertilizer was placed around the cluster at a distance of 10 cm and ca. 5 cm of depth.

## 2.3. Measurements and statistical analysis

The yield variables assessed, every 15 days, were those of the cluster, the commercial floral stem and the flower. The cluster variables recorded were cluster area ($cm^2$), total number of floral stems (stems with at least two leaves), stems with closed flowers (bracts completely closed), stems with open flowers (1 to 50% open bracts), stems with commercial flowers (50 to 100% open bracts). Each commercial stem was measured for length (cm) and diameter (cm, 2 cm from the stem base), length of the apical leaf (cm, from the base of the leaf lamina to its apex), fresh and dry weight (g) of the commercial and non-commercial biomass, and total biomass (g). Commercial and non-commercial biomass was assessed as indicated for Table 1. Total biomass was the sum of dry commercial and non-commercial biomass. On the commercial flower, diameter (cm, from mid-length of the inflorescence) and longitude (cm, from the base of the inflorescence to the apex) were measured.

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At the end of the experiment NPK content was analyzed in one plant per experimental unit. Before analysis, the plant was divided into flower, leaf, stem and rhizome. Each organ was sectioned and placed in a drying oven at 50 ºC until constant weight. The dry samples were ground and sent to the Plant, Soil and Water Analysis Laboratory at the Graduate College - Campus Tabasco. Determination of NPK content in the plant samples was done following NOM-021-SEMARNAT-2000 by the micro-Kjeldahl, Olsen and gas chromatography methods, respectively. Data were subject to analysis of variance (ANOVA), means comparison (Tukey, ($P \leq 0.05$) and a Pearson correlation. The statistical software used was SAS V.9.4 for Windows.

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## 3. RESULTS AND DISCUSSION

### 3.1 Effect of NPK fertilization on yield

The ANOVA indicated an effect of NPK fertilization on diameter of floral stem ($F_{15,30}$= 1.94, *P* = .05), flower diameter ($F_{15, 30}$ = 2.34, *P* = .02), non-commercial biomass fresh weight ($F_{15, 30}$ = 2.89, *P* = .006), commercial biomass dry weight ($F_{15, 30}$ = 2.38, *P* = .02) and total biomass ($F_{15, 30}$ = 8.49, *P* = .0001). There was no effect of fertilization on the other variables. The largest stem diameter (SD) was obtained with treatment 216-00-00. This SD was statistically different only from that obtained with treatment 216-00-178 (Table 2).

Although many plant characteristics are determined genetically [7], in general, the SD recorded in our study are larger than those reported by [2]. These authors applied 150-50-250 kg $ha^{-1}$ NPK and achieved SD of 1.73 and 1.62 cm in ginger at two different sites. [14], with a fertilization of 50 kg $ha^{-1}$ N, reported a stem diameter of 2.02 cm in Red Ginger plants. [5] and [15] stated SD could be homogenized by pruning very thin stems during crop development. This practice help to obtain more uniform commercial stems. For commercialization, [14] classify Red Ginger stems by its diameter into type A (> 1 cm) and type B (< 1 cm). The stems obtained in our study were classified as type A.

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The flower diameter (FD) obtained with treatment 215-00-00 (6.33 cm) was statistically superior to that obtained with treatments 5, 10 and 15 (Table 2). [14] reported a FD of 8.63 cm for totally expanded Red Ginger inflorescences. [2] reported a FD of 7.9 and 8.4 cm when 150-50-250 kg ha$^{-1}$ NPK were applied to Red Ginger at two different sites.

The highest NCBFW value was recorded for plants fertilized with 322-04-90 kg ha$^{-1}$ NPK, but it was statistically equal to that obtained with the treatment 216-00-00. Both values were statistically superior to that obtained with the absolute control but equal to that obtained with the other treatments. This can be attributed to the absence of NPK macroelements in the control since these elements are essential in the synthesis of molecules for growth [16]. [17] quoted that N is the most important nutrient in growth and flowering of *Zingiberaceae* plants, and the N content in plants is 67% lower in plants without a complete NPK fertilization. In *Tagetes* spp., higher N and P applications increase plant growth, flower yield and leaf nutrient content [6].

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**Table 2. Effect of NPK fertilization on yield variables of Red Ginger.**

| Treatment NPK (Kg ha$^{-1}$) | SD (cm) | FD (cm) | NCBFW (g) | CBDW (g) | TB (g) |
|---|---|---|---|---|---|
| T1 00-00-00 | 1.77 ab | 5.63 ab | 235.56 b | 23.90 ab | 120.00 c |
| T2 00-00-178 | 1.87 ab | 5.63 ab | 359.75 ab | 22.16 ab | 94.05 c |
| T3 00-10-00 | 1.87 ab | 5.50 ab | 293.23 ab | 21.32 ab | 95.07 c |
| T4 00-10-178 | 1.80 ab | 5.80 ab | 268.49 ab | 20.64 b | 128.00 c |
| T5 108-04-90 | 1.87 ab | 5.27 b | 330.27 ab | 27.51 ab | 102.30 c |
| T6 108-04-268 | 2.07 ab | 5.77 ab | 318.01 ab | 25.83 ab | 122.40 c |
| T7 108-14-90 | 1.83 ab | 5.47 ab | 354.19 ab | 27.20 ab | 107.10 c |
| T8 108-14-268 | 1.83 ab | 5.50 ab | 380.13 a | 24.75 ab | 103.60 c |
| T9 216-00-00 | 2.17 a | 6.33 a | 335.81 ab | 28.89 a | 199.30 ab |
| T10 216-00-178 | 1.67 b | 5.07 b | 277.13 ab | 22.45 ab | 161.10 abc |
| T11 216-10-00 | 1.80 ab | 5.57 ab | 328.11 ab | 25.26 ab | 122.40 c |
| T12 216-10-178 | 1.83 ab | 5.57 ab | 348.50 ab | 27.60 ab | 228.80 a |
| T13 322-04-90 | 1.90 ab | 6.03 ab | 383.29 a | 24.75 ab | 109.10 c |

| | | | | | | |
|---|---|---|---|---|---|---|
| T14 | 322-04-268 | 1.93 ab | 5.73 ab | 285.32 ab | 24.15 ab | 163.30 abc |
| T15 | 322-14-90 | 1.77 ab | 5.30 b | 343.79 ab | 23.74 ab | 136.90 bc |
| T16 | 322-14-268 | 1.87 ab | 5.70 ab | 330.30 ab | 24.90 ab | 96.37 c |

ST, Stem diameter. FD, Commercial flower diameter, NCBFW. Non-commercial biomass fresh weight. CBDW, Commercial biomass dry weight. TB, Total biomass.

n = 72. Means with same letter in a column are not significantly different (Tukey, $P \leq .05$).

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The commercial biomass dry weight (CBDW) from plants fertilized with treatment 216-00-00 was statistically superior to that obtained from plants fertilized with treatment 00-10-178, but equal to that obtained in the rest of the treatments (Table 2). These results, however, are lower than the 49.8 g reported by [4] for commercial Red Ginger dry matter. The highest total biomass weight (TB) was obtained in plants fertilized with treatment 216-10-178. This weight was statistically equal to that recorded for treatments 9, 10 and 14, but different from weights recorded for the other treatments (Table 2). These results agree to [4], who reported TB values of 206 g per ginger stem. [16], for *Etlingera eliator* Jack (*Zingiberaceae*), reported a TB value of 311.57 g, which is higher than our results since this species is larger than *A. purpurata* (Red Ginger).

### 3.2 Effect of NPK fertilization on nutrient content and its relationship with yield

The ANOVA indicated only the effect of the treatments on K content in the stem ($F_{15, 30} = 2.82$, $P = .008$) and P content in the flower ($F_{15, 30} = 2.02$, $P = .05$), leaf ($F_{15, 30} = 4.08$, $P = .0005$) and rhizome ($F_{15, 30} = 2.16$, $P = .035$). This effect was confirmed by the comparison of means (Table 3). Regarding K in the stem, treatment 00-10-178 was statistically superior to treatments 1, 3, 6, 8, 9 and 13, but equal to the relative control and to the other treatments. The K content in stem obtained with these treatments was similar to 1.85% reported by [4] as the level required by the plant. In terms of stem N content, none of the treatments satisfied the N requirements of 0.78% reported by [4], but all the treatments surpassed the P content of 0.23% cited by the same author as the level required by the plant.

The P content in flowers of plants fertilized with treatment 00-10-178 was statistically superior to relative control but equal to the absolute control. The P content in all of the treatments was equal to or superior to the flower P level recommended by [4], but the N and K contents were lower than the recommendations of the same author for the species and variety used in our study.

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**Table 3. Effect of fertilization dosages in the NPK content (%) of Red Ginger flower, leaf, stem and rhizome, 12 months after application.**

| NPK (Kg $ha^{-1}$) | Flower | | | Leaf | | | Stem | | | Rhizome | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Treatment | N | P | K | N | P | K | N | P | K | N | P | K |
| T1 00-00-00 | 0.93 a | 0.24 ab | 1.45 a | 1.91 ab | 0.21 abc | 1.52 b | 0.35 a | 0.30 a | 1.58 b | 0.32 a | 0.32 a | 1.32 a |
| T2 00-00-178 | 0.96 a | 0.21 ab | 1.77 a | 1.97 ab | 0.19 c | 1.85 ab | 0.38 a | 0.26 a | 1.86 ab | 0.35 a | 0.25 a | 1.69 a |
| T3 00-10-00 | 0.93 a | 0.21 ab | 1.61 a | 1.88 ab | 0.20 c | 1.55 ab | 0.38 a | 0.25 a | 1.61 b | 0.35 a | 0.26 a | 1.26 a |
| T4 00-10-178 | 0.93 a | 0.29 a | 2.22 a | 2.00 ab | 0.25 ab | 2.05 a | 0.38 a | 0.34 a | 2.45 a | 0.33 a | 0.38 a | 1.55 a |
| T5 108-04-90 | 0.92 a | 0.18 b | 1.85 a | 2.00 ab | 0.19 c | 1.61 ab | 0.40 a | 0.25 a | 1.85 ab | 0.49 a | 0.26 a | 1.65 a |
| T6 108-04-268 | 0.90 a | 0.23 ab | 1.67 a | 1.87 ab | 0.19 c | 1.63 ab | 0.46 a | 0.29 a | 1.66 ab | 0.43 a | 0.36 a | 1.57 a |
| T7 108-14-90 | 0.99 a | 0.22 ab | 1.63 a | 2.00 ab | 0.19 c | 1.58 ab | 0.41 a | 0.32 a | 1.64 b | 0.43 a | 0.41 a | 1.50 a |
| T8 108-14-268 | 0.95 a | 0.27 ab | 1.77 a | 1.93 ab | 0.21 abc | 1.79 ab | 0.43 a | 0.30 a | 1.52 b | 0.40 a | 0.31 a | 1.58 a |
| T9 216-00-00 | 0.96 a | 0.24 ab | 2.11 a | 1.94 ab | 0.20 c | 1.67 ab | 0.46 a | 0.23 a | 1.57 b | 0.35 a | 0.23 a | 1.46 a |
| T10 216-00-178 | 1.04 a | 0.23 ab | 1.88 a | 2.23 a | 0.25 a | 1.65 ab | 0.47 a | 0.31 a | 1.82 ab | 0.35 a | 0.39 a | 1.78 a |
| T11 216-10-00 | 1.07 a | 0.23 ab | 1.77 a | 2.00 ab | 0.22 abc | 1.66 ab | 0.61 a | 0.30 a | 1.71 b | 0.58 a | 0.31 a | 1.67 a |
| T12 216-10-178 | 0.99 a | 0.23 ab | 1.96 a | 1.94 ab | 0.20 bc | 1.69 ab | 0.40 a | 0.27 a | 1.97 ab | 0.46 a | 0.25 a | 1.73 a |
| T13 322-04-90 | 1.02 a | 0.22 ab | 1.79 a | 1.88 ab | 0.21 abc | 1.74 ab | 0.49 a | 0.30 a | 1.62 b | 0.35 a | 0.27 a | 1.67 a |
| T14 322-04-268 | 0.98 a | 0.24 ab | 1.81 a | 1.70 b | 0.21 abc | 1.65 ab | 0.37 a | 0.33 a | 1.76 ab | 0.33 a | 0.32 a | 1.54 a |
| T15 322-14-90 | 1.03 a | 0.24 ab | 1.92 a | 1.94 ab | 0.21 abc | 1.81 ab | 0.46 a | 0.29 a | 1.95 ab | 0.34 a | 0.34 a | 1.66 a |
| T16 322-14-268 | 0.99 a | 0.25 ab | 1.75 a | 1.88 ab | 0.21 abc | 1.75 ab | 0.46 a | 0.28 a | 1.76 ab | 0.41 a | 0.34 a | 1.49 a |

Means with same letter in a column are not significantly different (Tukey, $P \leq .05$).

In general, the nutrient contents in Red Ginger leaf, stem and flower satisfied the level established for P but not for N or K. This could indicate that the soil is rich in P but not in N or K. In soils of humid tropic available N and K are low [18]. Another explanation is that the analyses were done one year after fertilization and total N content and K diminishs a year after soil fertilization due leaching by high precipitation in wet tropical regions [18].

Likewise, N is shifted toward new leaves as the consequence of its high mobility in the phloem [19]. In many species, P and N interact closely as the plant matures. In most plants, P is easily take off from one organ to another and is lost in old leaves, while accumulating in young leaves, flowers and developing seeds. K is an element that activates many essential enzymes in photosynthesis, respiration, and formation of proteins and starch; it also contributes in an important way to cell osmosis [8]. This can be observed in the positive correlation between N and P in the flower ($r^2$ = 88, $P$ = .04) and in the stem ($r^2$ = 99, $P$ = .005) and in the correlation of N in the leaf with P in the stem ($r^2$ = 98, $P$ = .01) and N in the stem with K in the leaf ($r^2$ = 99, $P$ = .005).

With the exception of flower P content, which correlated with SD, the N contents in the different yield components was the only element correlated with the yield variables. The TB correlated positively with N content in leaf ($r^2$ = 0.87, $P$ = .04), rhizome ($r^2$ = 0.91, $P$ = .03) and stem ($r^2$ = 0.97, $P$ = .01). The SD correlated with N content in rhizome ($r^2$ = 91, $P$ = -.03). The FD correlated with N in the stem ($r^2$ = 0.82, $P$ = .006), NCBFW with N in the leaf ($r^2$ = 0.84, $P$ = -.06), and CBDW correlated with N in the flower ($r^2$ = 93, $P$ =.03). This can be due to the fact that N is essential to plant growth required by plants and is an important component of amino acids, proteins, nucleic acids, growth regulators and chlorophyll formation [3]. Another possible explanation is its presence in the rhizomes. The rhizomes contain a large quantity of nutrients and water, which are transferred in large proportions to the stem and leaves [20], thus permitting constant development and blooming of ginger, which requires constant mobility of N. This is important because the rhizomes, besides vegetative propagation [21], make the plants more resistant to adverse conditions [22] and can provide more dry matter to the flower stem and thus greater postharvest durability [5, 23].

An adequate level of N in tissues results in good sized, vigorous plants with good green coloring and well-developed flowers [24]. According to the soil and plant analyses before treatment application (Table 1) and the plant analyses after treatment application (Table 3), and according to [4], the N concentration in flower and stem is lower than what is required by the plant, but in the foliage, it is similar.

## 4. CONCLUSION

As conclusion, the fertilization dosage 216-00-00 kg $ha^{-1}$ NPK was the best to favor Red Ginger yield. With this dosage, the largest SD and FD, as well as the highest CBDW and TB per plant, were obtained. With the exception of treatment 00-10-178 for which NPK content in leaf was higher than the recommended level, the fertilization dosages evaluated did not have an effect on the level of N or K in rhizome or flower, nor on N or P in the stem. The NPK fertilization effects were observed on the content of K in stem and of P in flower, rhizome and leaf.

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**Comment [U26]:** Formatt the references, use punctuation where necessary