Journal of Plant Sciences and Crop Protection
Volume 4 | Issue 1
ISSN: 2455-7633

Research Article Open Access

Nutrition State and Fertilization of Fusarium Wilt Resistant Banana (Zhongjiao No. 9)

Zhang X[1], Zhang L[*1], Dong T[2], Li Z[1], He W[2], Jiang J[1], Sun S[1] and Fan X[*1]

[1]College of Resources and Environment, South China Agricultural University, Guangdong Environmental Engineering Fertilizer Research Center, Guangzhou 510642, China
[2]Institute of Fruit Trees, Guangdong Academy of Agricultural Sciences, Guangzhou 510640, China
[*]These authors contributed equally

[*]**Corresponding author:** Fan X and Zhang L, College of Resources and Environment, South China Agricultural University, Guangdong Environmental Engineering Fertilizer Research Center, Guangzhou 510642, China, Tel: +86-2085288325, E-mail: xlfan@scau.edu.cn

Citation: Zhang X, Zhang L, Dong T, Li Z, He W, et al. (2021) Nutrition State and Fertilization of Fusarium Wilt Resistant Banana (Zhongjiao No. 9). J Plant Sci Crop Protec 4(1): 101

Received Date: March 11, 2021 **Accepted Date:** March 24, 2021 **Published Date:** March 26, 2021

Abstract

To apply fertilizer rationally during promotion of Zhongjiao No.9 being a fusarium wilt resistant new variety, dry matter (DM) and NPK in four organs of the banana were tested. Average fresh and dry weight (FW and DW) of No.9 were 145.35±6.42 and 18.18± 0.70 kg plant^{-1}. Ash content in DM was only 7.6%. FW of organs following the order of stem > fruit > leaves > roots. The DM of stem was mainly distributed in pseudostem (75.6%) and corm (24.4%). DM allocation in leaves and petioles was 55.4% and 44.6% respectively. DM allocation to hands was up to 93.6%, and stalk only 6.4%. For whole plant, about 2/3 DM are allocated to or 2/3 photosynthetic products are used for root, stem and leaf growth, while only about 1/3 used for fruit growth. N, P and K absorbed was 115.56 g, 23.67 g and 500.32 g per plant, and N: P: K ratio was 1:0.20:4.33. While the ratio was different among the four organs. DM accumulation and allocation is in order of stem > fruit ear > leaves > root. The NPK uptake and allocation in order of stem > fruit ear > leaf > root. Based on the biomass and NPK absorption, accumulation and allocation patterns, suggestions of the nutrient management for Zhongjiao No. 9 cultivation have been proposed. Why such high amount of DM and K in rhizome and leaves and how to promote the DM transfer to fruit are noteworthy feature of the nutrient management of the Zhongjiao No.9. The more balanced the banana nutrition, the healthier the banana, and the stronger its resistance to banana wilt.

Keywords: Zhongjiao No. 9 Banana; NPK Absorption; NPK Allocation; NPK Nutrition

Introduction

As one of the four major fruits, banana has the second largest yield in the world, and as a food crop, it ranks the fourth in the world, playing a very important role in agricultural production and regional economy (FAO, 2020) [1]. Due to its unique nutritional value and economic value, banana has become the most influential part in the production of tropical and subtropical fruits (FAO, 2020) [1]. At present, China is the third largest banana production country in the world. The banana industry is one of the main sources of income for farmers in tropical and subtropical regions of China. The banana industry in China has developed rapidly and become the pillar industry of high-efficiency agriculture in tropical regions (Xie, 2019) [2]. However, the banana industry has not only faced with natural disasters such as cold damage and typhoon, but also with the rampant fusarium wilt disease since the 1990's (Ploetz, 1992; Ploetz and Pegg, 2000; Butler, 2013; Ploetz, 2015; Pegg *et al.*, 2019) [3-5], which poses a serious threat to China's banana industry (Dong *et al.*, 2013; Li *et al.*, 2019; Wang *et al.*, 2016; Xie, 2019; Xu *et al.*, 2011; Zhang *et al.*, 2014) [2,6-10]. Up to now, the key techniques to prevent and control the banana fusarium wilt are generally rotation of cultivated land or rational fertilization to improve the resistance of banana to the disease (Alves Da Silva&Simao, 2015; Freitas *et al.*, 2015; Mburu *et al.*, 2016) [11-13]. In recent years, the research center of fruit tree institute of Guangdong Academy of Agricultural Sciences has cultivated a new disease-resistant variety of Zhongjiao No. 9 (Lin *et al.*, 2019) [14]. It is more productive and disease-free than the conventionally planted Brazil banana (*Musa nana Lour*), and it is a highly resistant variety of Panama disease (Lei *et al.*, 2018; Xie, 2019) [2,15].

Zhongjiao no.9 has excellent disease resistance performance. However, due to lack of research results on nutritional characteristics, which is closely related to the dry matter accumulation and allocation, banana farmers mostly refer to nutrient management and fertilization methods of their experience based on Brazil banana cultivation during the Zhongjiao No. 9 growth. Therefore, there are both of successful experience and failure lessons when the Zhongjiao No.9 has been grown during its promotion. Comparatively, both of height and biomass of Zhongjiao No.9 are greater than those of Brazil banana which implies that nutrient uptake and consumption are quite different from that of Brazil banana. However, no research results have been reported on the rational amount of fertilizer needed for Zhongjiao No.9. Although there have been a lot of research results on the nutritional characteristics and fertilization of Brazil Banana in China (Deng *et al.*, 2012; Fan *et al.*, 2007; Niu *et al.*, 2002; Yang *et al.*, 2007; Yao *et al.*, 2005; Zhang *et al.*, 2015) [16-21] and in the world (Hazarika *et al.*, 2015; Moreira&Fageria, 2009; Nyombi *et al.*, 2010; Turner&Lahav, 1985; Twyford &Walmsley, 1974b; Yamaguch&Araki, 2004) [22-27], those experience or fertilization technology cannot be directly applied to nutrient management of Zhongjiao No. 9 otherwise it may the problem of unreasonable fertilization. Therefore, to promote Zhongjiao 9 disease-resistant variety, which is urgent to achieve high yield and high efficiency of banana cultivation, it is necessary to systematically study the nutritional characteristics of this variety and reveal the patterns of accumulation and distribution of dry matter and demand of N, P and K of Zhongjiao 9. Therefore, the absorption and distribution of dry matter, nitrogen, phosphorus and potassium of Zhongjiao 9 were systematically determined by comparing with Brazilian banana, so as to provide theoretical basis for rational fertilization of Zhongjiao 9.

Materials and Methods

Experimental site and the test banana

Banana field is located in the variety demonstration base of China Agriculture Research System in Longmen County, Huizhou city (114.25 E; 23.73 N). The soil of the banana garden were lateritic and clay soil. Soil pH, organic matter content, total nitrogen, available phosphorus (P) and available potassium (K) were 5.09, 21.89 g kg^{-1}, 105 mg kg^{-1}, 4.95 mg kg^{-1} and 229.71 mg kg^{-1} respectively. The banana tested was the first seedling and second generation seedling (suck) of Zhongjiao No.9 being fsarium wilt resistant cultivar of banana, which is a new banana variety bred from hybrid goldfinger (AAAB) and SH-3142 (AA) by the institute of fruit tree research, Guangdong Academy of Agricultural Sciences. The genetic relationship between Zhongjiao No.9 and Brazil banana is close. Both are AAA genotypes and have similar fruit shape and ripening process. However, there are significant differences in plant size or biomass and nutrients consumption between them, which make them excellent materials for studying nitrogen, phosphorus and potassium nutrition characteristics to establish nutrient management technology of the Zhongjiao No.9.

Experiment design and field management

The experiment adopted the dismembered method to decompose the banana into four organs: root, stem, leaf and fruit (ear). The stem is divided into pseudostem and corm. The leaf is separated into leaf blade (being mesophyll and branch vein) and leaf vein (major vein).The fruit ear was dismembered into hands (or comb) and fruit axis. In the test, the Zhongjiao No.9 banana plant was grown up with a space of 2m between plant and 2.5m between two rows. The density was 2000 plants /hm^2. The first harvest was in June 2018 and the second was harvested in June 2019. Before the first generation transplanting, each plant was applied with 10 kg chicken manure. The amount of fertilizer applied to banana in the second generation was as followings. Five times of top dressing with 100g of 15-15-15 compounds for each were applied to per plant for small banana plantlet before its bud extraction. Ten times of top dressing with 150g of 15-15-15 compounds for each time were applied to every plant for large plantlet before bud extraction. Another 5 times of top dressing with 150g of 9-15-21compounds each time were applied per plant after bud extraction. The total NPK fertilizer applied were equivalent to 374 g pure N, 413 g P_2O_5 and 458 g K_2O per banana tree. Irrigation and pest control measures were consistent with banana field management.

Sample collection and preparations methods

Samples were collected at harvest time. Before sampling, 5 healthy banana plants with no disease or insect damage, uniform growth and normal fruit were selected from the field, namely 5 replications. For the first generation, whole banana tree was collected and its biomass was measured. The fruit ear yield was recorded at harvest time. For the second generation of the Zhongjiao No.9, whole plant was excavated, and then, according to the experiment design, the root, stem, leaf, fruit ear were dissected and samples collected quantitatively. Before sampling, the organs were weighed and the biomass of each organ was recorded, and then subsamples were collected quantitatively by quartering method. Before taking the subsamples, the dust of each organ was washed clean with tap water, and the bright water was sucked dry with absorbent cloth. Before collecting leaf samples, the leaf blade and major vein were separated from both sides of the main vein. After the leaf blade was cut into pieces, the subsamples were divided evenly, the veins of the leaves were cut into several sections and half of them were cut from the middle lengthwise and mixed thoroughly. Before collecting the pseudostem samples, cut the pseudostem into sections of 30 cm long from the ground up, divide each section of the pseudostem into 4 longitudinal sections, take 2 diagonal sections, cut each half into thin strips, cut off and mix evenly, and sample by quarting. After the whole ear is harvested, comb and axis are harvested and fresh weight is measured. The comb and axis were separated. Three fingers were selected from the upper and lower sides and the middle of each comb respectively. After being brought back to the laboratory, they were chopped and mixed and sampled by quartering method, which were subsamples of the comb. The fruit axis was cut into 10cm segments, divided lengthwise into 8 segments, randomly selected 2 diagonal segments, cut into 1cm segments, mixed and divided into sub-samples. When collecting root samples, dig all roots in the soil from top to 40 cm in depth from 2 diagonal sections inside the crown projection line of the banana tree. All of the roots was rinsed and brought back to the laboratory for washing, chopping and blending, and sampling by quarting method.

Sample treatment method: the samples of each organ were dehydrated at 80 °C for 30min and then dried to constant weight at 60 °C. The dry weight and water content of each organ were calculated. Then the plant samples smashed and prepared for analysis of N, P and K content and their uptake.

Analyze items and methods

The crushed dry samples were pretreated by use of H_2SO_4-H_2O_2 discoloration method to make system digestion solution. N content was determined by flow analyzer, P was determined by automatic intermittent chemical analyzer, and K was determined by flame photometry (Bao, 2000) [28].

Data analysis and statistical methods

The experimental data were sorted and graphed by use of Excel. The data analysis of variance was performed by SPSS software. The absorption accumulation of nitrogen, phosphorus and potassium and their allocation in each organ are calculated as follows:

Element absorption and accumulation = organ dry matter mass × the element content (%)

Allocation rate of the element (%) = (accumulation amount of the element absorbed in an organ / the accumulation amount of the element absorbed in the whole plant) ×100%

Results

Pattern of dry matter accumulation and allocation of Zhongjiao No. 9 and its nutrient management

Dry matter accumulation of Zhongjiao No. 9

The results showed that the plant biomass at maturity stage of the Zhongjiao No. 9 banana was large. The average fresh weight per plant was from 138.18 ± 6.18 to 145.35 ± 6.42 kg plant^{-1}, but the dry matter was 17.27 ± 0.59 to 18.18 ± 0.70 kg/plant. There was no significantly difference of both fresh and dry weight between the two harvests (Figure 1). In dry materials organic matter accounted for about 92.4%% and ash only for 7.6% (Figure 1a and b). In other words, the dry matter of Zhongjiao No. 9 banana is less than 1/5 of the whole plant, and the mineral element is less than 10 percent in average. In case the fresh weight, organic matter and ash content are no statistic difference, the paper will take the second banana to do the further study because the second banana receives the normal fertilization management in practice.

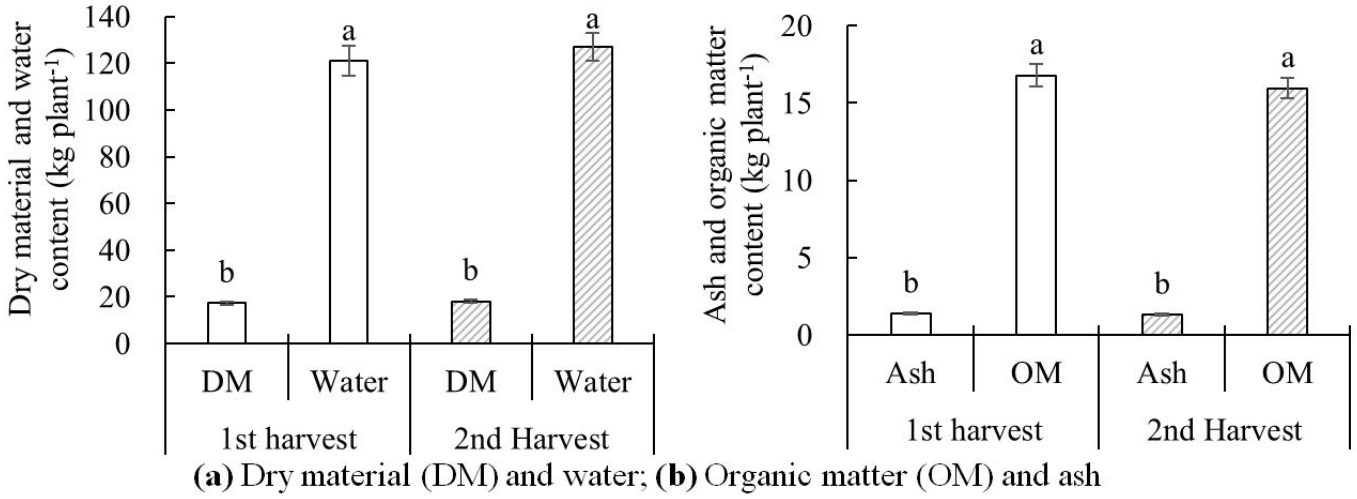

Figure 1: DM, water, organic material and ash composition of the Zhongjiao No.9 banana
Note: Different lowercase letters indicate significant difference at 0.05 level (DMRT, P<0.05, n=5)

Dry matter accumulation and allocation among root, stem, leaf and fruit of Zhongjiao No.9 banana

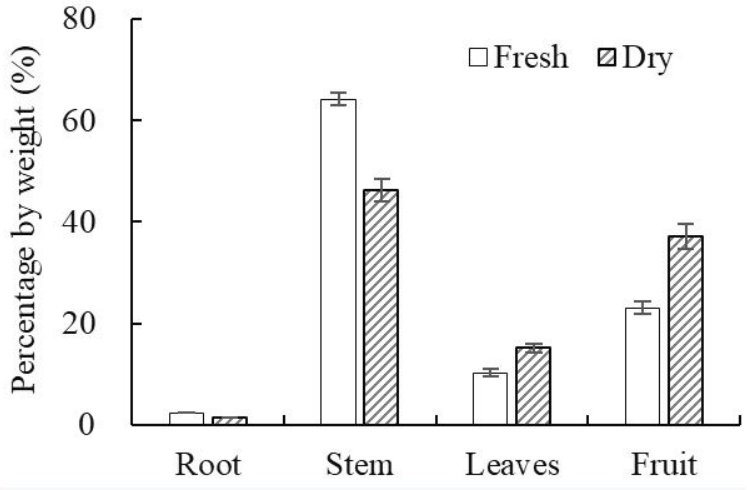

Figure 2: Distribution of root, stem, leaf and fruit in Zhongjiao No. 9 by fresh and dry weight (n=5)

The results showed that the fresh weight of the four nutritive organs of root, stem, leaf and fruit (ear) was in order of the stems (93.5 kg plant^{-1}) > ear (33.4 kg plant^{-1}) > leaves (14.9 kg plant^{-1}) > roots (3.51kg plant^{-1}). The dry weight was in the same order as fresh weight (Figure 2). However, the proportion of dry matter in the whole plant was changed. The proportion of root and stem was significantly reduced, while the proportion of leaf and fruit was significantly increased (Figure 2). The dry weight of the root system decreased from 3% to 1.5%. The dry weight of the stem decreased by 39%, while the dry weight of the leaf and fruit increased by 50% and 61%, respectively. The average dry weight of root, stem and leaf was 11.48±0.94 kg, and the average fruit weight was 6.71±0.32 kg. Stem dry weight accounted for nearly 74% among the nutritive organs. The results showed that about 2/3 of dry matter or photosynthetic products of the Zhongjiao No. 9 banana was used for root, stem and leaf growth, while only 1/3 of the photosynthetic products of the banana were used for fruit growth.

Pattern of dry matter accumulation and allocation in Stem of the Zhongjiao No. 9 banana

The stem is composed of pseudostem and corm. The fresh weight of pseudostem and corm are 82.37 kg plant^{-1} and 11.16 kg plant^{-1} respectively, while the dry weight is 6.39 kg plant^{-1} and 2.06 kg plant^{-1} respectively. It can be seen that the dry matter accumulation of pseudostem is about 3 times of that of corm. It can also be seen from the results that the proportion of fresh weight (Figure 3a) and dry weight (Figure 3b) of pseudostem were bigger than those of corm. However, the proportion of dry weight of corm was two times of that of the fresh weight which indicates that the dry matter content of corm was greater than that of pseudostem per unit fresh tissue.

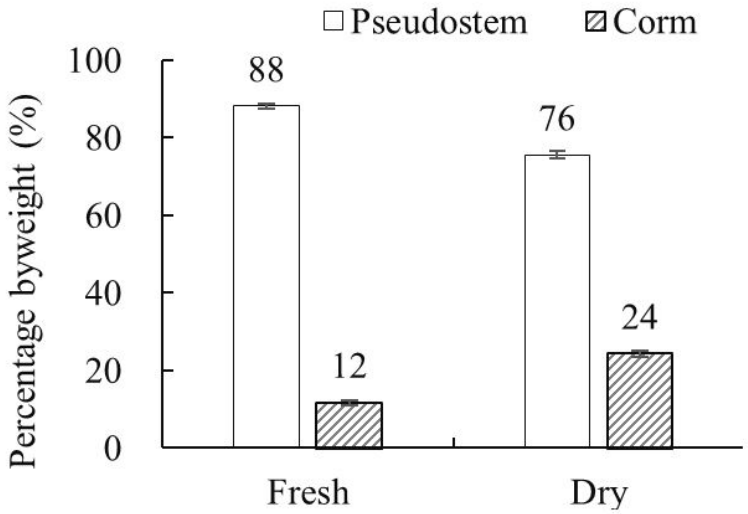

Figure 3: Composition of stem and tis mass ratio of the Zhongjiao No. 9 banana (n=5)

Pattern of dry matter accumulation and allocation in leaves of Zhongjiao No. 9 banana

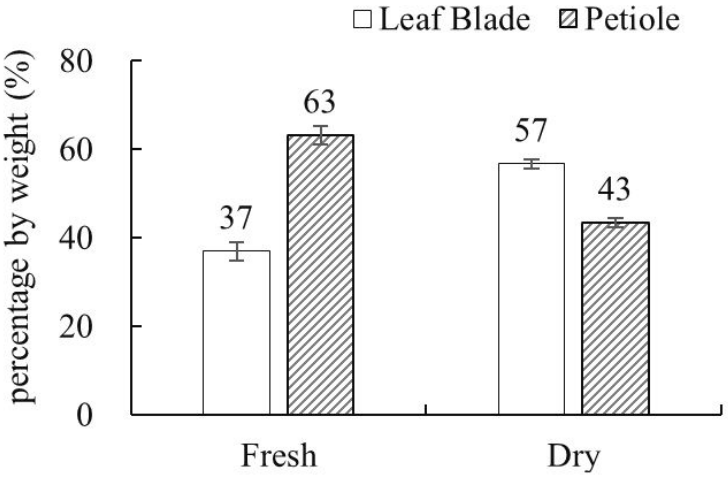

Figure 4: Composition of leaf and its mass ratio of the Zhongjiao No. 9 banana (n=5)

The leaves are composed of leaf blade (mesophyll and lateral veins) and petiole (major vein). In 14.93 kg of fresh leaves, the weight of leaf blade and petiole was 5.52 kg and 9.41 kg respectively. In 2.33 kg of dry leaves, the weight of leaf blade and petiole was 1.29kg and 1.03kg separately. As can be seen from Figure 4, the proportion of petiole in fresh leaves is greater than that of leaf blade, while the petiole ratio of dry leaves is opposite. This indicates that although the petiole is heavy, there is more dry matter accumulated in the leaf blade. The leaf blade is the tissue where photosynthesis products formed and petiole is the tissue where the photosynthesis products delivered to other organs. That is why the dry matter of the leaves is greater than that of petiole.

Pattern of dry matter accumulation and allocation in fruit of Zhongjiao No. 9 banana

The economic output of banana at harvest to farmers is fruit ear which consists of a stalk or axi and hands or combs. The hands are the commercial products which are the fruit sold in the market, while stalk is no commercial value being invalid yield. The results showed that the average weight of fresh fruit ear per plant was 33.38±0.39 kg. 83% of which is hands (Figure 5), and the invalid yield was as high as 17%. In terms of fresh mass ratio, fruit hands > fruit stalk. However, the dry weight ratio of the two parts changed greatly (Figure 5). Although the order was still the hands > fruit stalk, the dry weight ratio of the hands (94%) increased significantly and the proportion of the fruit stalk decreased significantly. It can be concluded that distribution of fertilizer or fertilization in the fruit growing and fruit size developing stage could promote the fruit growth and then is able to enhance more than 90% of carbohydrates to be allocated and accumulated in the fruits so as to increase the nutritional efficiency of fertilizer significantly.

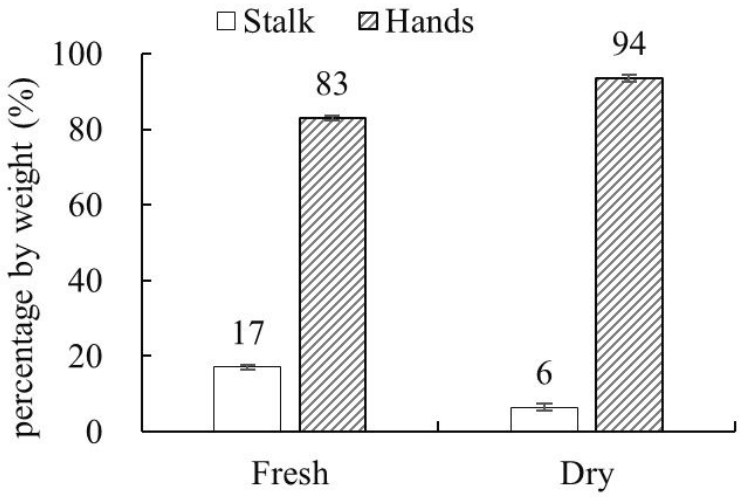

Figure 5: Composition of fruit and its mass ratio of the Zhongjiao No. 9 banana (n=5)

In summary, the dry matter of Zhongjiao No. 9 banana only accounts for less than 1/5 of the whole plant, and the mineral element accounts for less than 1/10. The pattern of dry matter allocation and accumulation among root, stem, leaves and fruit is as following order, stem > fruit > leaves > root. Within fruit ear, the dry matter accumulation with commercial value accounted for about 94%, and the stalk being non-commercial value only accumulated about 6%. However, the fruit stalk or axi accounted for 17% in fresh fruit which significantly reduced the proportion of commercial yield. The dry matter accumulated in the pseudostem is occupied 76% of the stem. Dry matter accumulation in leaf blade is greater than that in petiole (major vein). In view of nutrition management of Zhongjiao No. 9, the biomass accumulation of stems and leaves of the banana should be limited and the growth of roots and fruit ear should be promoted. In other words, in fertilization of the banana, water and fertilizer supply should be properly controlled during the vegetative growth stage of the Zhongjiao No. 9, so as to avoid excessive growth of stems and leaves and their consumption of nutrients. In fruit growth stage, water and nutrient supply should be strengthened to ensure fruit expansion and dry matter accumulation.

Pattern of N, P and K absorption, accumulation and allocation in the Zhongjiao No. 9 banana

NPK uptake and accumulation of the Zhongjiao No. 9 banana

As can be seen from Figure 6, the cumulative absorption of nitrogen, phosphorus and potassium per plant of the Zhongjiao No. 9 was 116.89 g N, 23.67g P and 510.29 g K. Each plant of the Zhongjiao No. 9 consumed about 651 g of NPK during one growth cycle and N, P and K absorption ratio was 1:0.20:4.37. The potassium absorption ratio was much higher than that of Brazil banana (Fan *et al.*, 2007) [17]. In terms of nutrient absorption ratio only, it seems that more potassium fertilizer should be supplied to Zhongjia No.9 banana in its NPK nutrients management. However, compared with the N, P and K absorption ratio of commonly cultivated Brazil banana being 1:0.11:3.02, such a high potassium absorption ratio does not necessarily mean that so much potassium should be applied during the Zhongjiao No. 9 growth. Therefore, how the absorption and distribution of N, P and K in the banana plant should be investigated deeply.

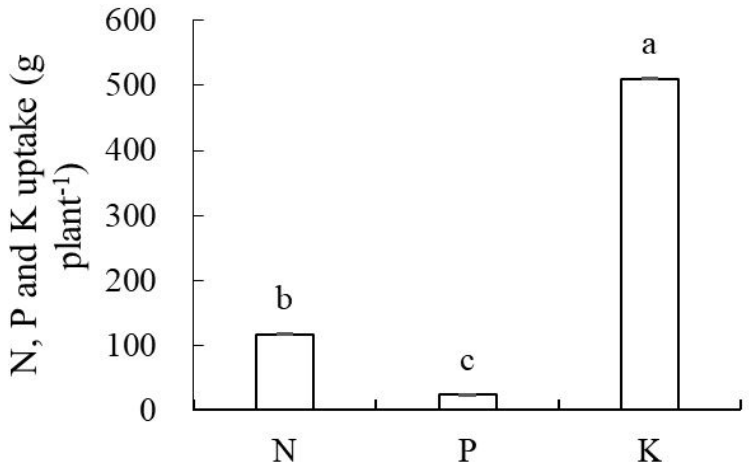

Figure 6: The total nitrogen, phosphorus and potassium uptake of the whole plant of Zhongjiao No.9.
Note: Different lowercase letters above the bars indicate significant differences at the 0.05 level (n=5)

The accumulation and allocation of N, P and K in each organ of the Zhongjiao No. 9

In order to understand why the potassium accumulation was so high, the accumulation of nitrogen, phosphorus and potassium in roots, stem, leaves and ear and the allocation of total nitrogen, phosphorus and potassium in various organs were further analyzed. The results in Table 1 and Figure 7 showed the allocation pattern of total nitrogen, phosphorus and potassium absorbed among the four organs was in the order of stem > ear > leaves > root. The results showed that not only the total distribution ratio of N, P and K in the stem was the largest (Figure 7), but also the distribution ratio of P and K in the stem was the largest (Table 1). In terms of the proportion of nitrogen, phosphorus and potassium absorbed in the stem, nearly 9 parts of potassium are absorbed for each part of nitrogen consumption, which is obviously unreasonable. There may be a possibility of luxury absorption of potassium. The results imply that potassium accumulation ability in stem cells of the Zhongjia No.9 banana was relatively strong. The ratio of NPK uptake and accumulation in the roots is similar to that in the stems, which suggested that the roots may also have the luxury of potassium absorption. According to the analysis of the nitrogen, phosphorus and potassium absorption ratio of leaf and ear in Table 1, the phosphorus and potassium absorption ratio of these two organs are significantly lower than that of stem. However, compared with the commonly grown cultivar of brazil banana, the cumulative uptake and allocation of phosphorus and potassium is still larger (Fan *et al.*, 2007) [17]. Therefore, if the nutrient management of the Zhongjiao No. 9 banana is to be carried out according to the above absorption ratio of N, P and K, and rational fertilization to be achieved. It is necessary to do further study on the role and function of K in the stem of the Zhongjiao No. 9 banana and to understand how the K is transported and distributed to the fruit.

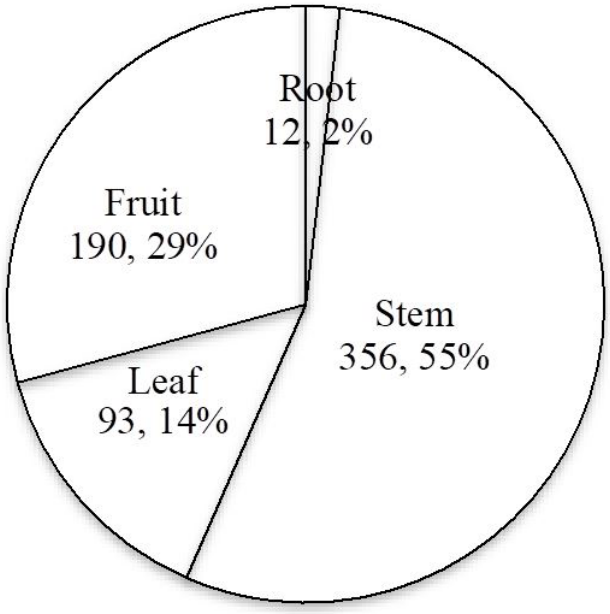

Figure 7: The proportion of NPK absorbed by the Zhongjiao No. 9 banana in each organ

Organs	Nutrients uptake (g plant^{-1})						NPK ratio
	N	SE	P_2O_5	SE	K_2O	SE	N: P_2O_5: K_2O
Root	1.50	0.09	0.16	0.00	10.23	0.09	1: 0.24: 8.23
Stem	41.25	0.86	10.49	0.28	304.37	0.55	1: 0.58: 8.89
Leaf	30.01	0.76	3.90	0.12	58.70	2.38	1: 0.30: 2.36
Fruit ear	44.14	0.13	9.12	0.13	136.99	0.85	1: 0.47: 3.74
Average							1: 0.20: 4.37

Note: The NPK absorption in the table is the average of 5 replications and SE is the standard error.
Table 1: Nitrogen, phosphorus, potassium cumulative uptake and their ratio in root, stem, leaf and fruit of the Zhongjiao No.9 banana

The accumulation and allocation of N, P and K in the stem of the Zhongjiao No. 9 banana

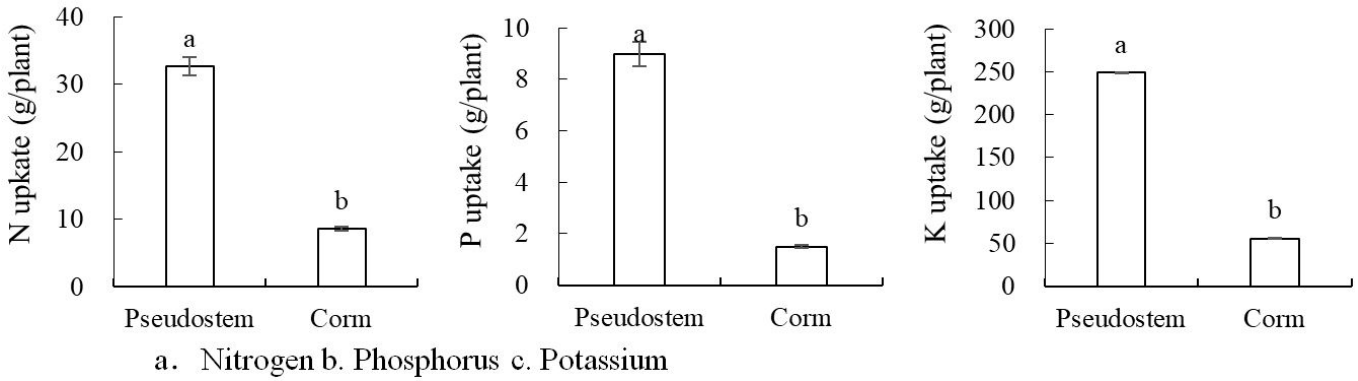

Figure 8: Allocation of N, P and K uptake in the stem
Note: Different lowercase letters above the bars indicate significant differences at the 0.05 level (n=5)

As mentioned above, the stem consists of a pseudostem and corm. Figure 8 showed that the consistent pattern was that the N, P, K accumulation and allocation to pseudostem were significantly higher than that to corm. The accumulation and distribution of N, P and K in pseudostem were 3.81, 6.00 and 4.47 times of that in corm, respectively. This indicated that N, P and K were

mainly accumulated in the pseudostem of the Zhongjiao No. 9 banana. From nitrogen, phosphorus and potassium content in both pseudostem and corm, the average nitrogen content is 0.48% and 0.56% respectively. The average phosphorus content is 0.12% and 0.083% and the average potassium content was 4.21% and 3.18%, separately. It clearly that the phosphorus and potassium content of the pseudostem were higher than those of corm except for nitrogen content. The reason for more nitrogen uptake and accumulation in pseudostem was the large biomass of pseudostem (Figure 8). One of the reasons for the high uptake and accumulation of P and K in pseudostem is their large biomass (Figure 8). The other reason is the high content of P and K in pseudostem.

Accumulation and allocation of N, P and K in leaf of the Zhongjiao No. 9 banana

The accumulation and allocation of N, P and K in leaf blade of the Zhongjiao No.9 banana were significantly higher than those in petioles. The amount of N, P and K accumulated in leaf blade was 4.89, 2.67 and 1.56 times of those in petiole respectively. The results showed that the difference of nitrogen accumulation between leaf blade and petiole was the largest, potassium was the smallest and phosphorus was the middle. The main reason is that the nitrogen content of leaf blade (1.81%) is significantly greater than that of petioles (0.56%) (Figure 9), and the dry matter accumulation of leaf blade is also greater than that of petioles (Figure 4). Similarly, the phosphorus content of leaf blade (0.21%) was significantly greater than that of the petiole (0.098%). However, the difference of potassium content of leaf blade (2.60%) and petioles (1.61%) was not greater than that of N or P. Therefore, the difference in cumulative potassium allocation between leaf blade and petioles was smaller. It can be seen that the allocation of NPK in the transport tissue (petiole) of the Zhongjiao No. 9 banana is much smaller than that in leaf blade. In summary, how to exert the effect of nitrogen, phosphorus and potassium in the leaf blade of the Zhongjiao No. 9 banana may be a subject worth to study for nutrient management and rational fertilization of the variety.

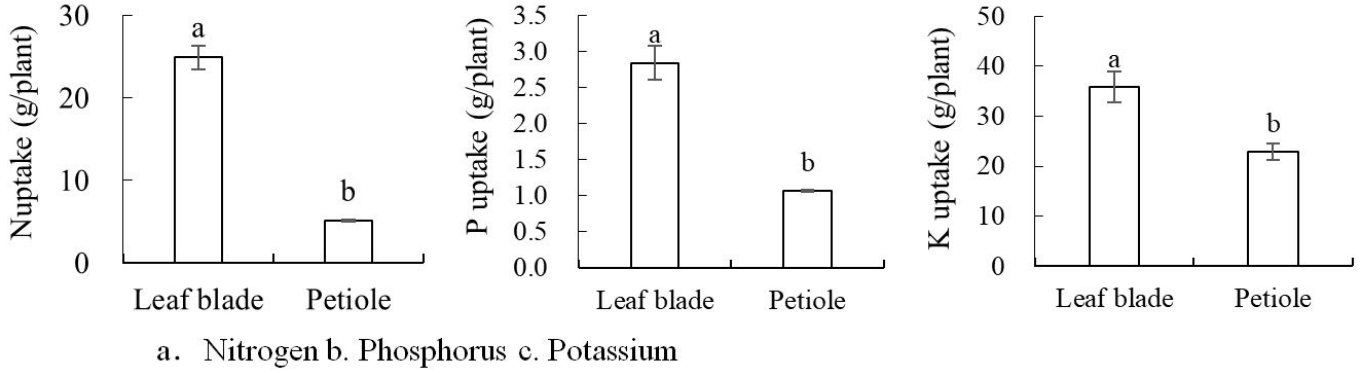

Figure 9: Distribution of nitrogen, phosphorus and potassium absorption in leaf
Note: Different lowercase letters above the bars indicate significant differences at the 0.05 level (n=5)

Discussion

Difference in dry matter accumulation pattern between the Zhongjiao No.9 and Brazil banana

As a highly resistant variety of Panama disease, the Zhongjiao No.9 banana is characterized by its size and biomass accumulation. Compared with the main cultivar of Brazil banana (Fan *et al.*, 2007; Liu *et al.*, 2011; Zhang *et al.*, 2015) [17,29], the biomass of single plant of the Zhongjiao No.9 (145.35± 6.42 kg/plant) was 1.6 times that of Brazil banana (84.7~ 92.9, with an average of 89.9± 1.2 kg/plant). The average dry matter of the Zhongjiao No. 9 was 18.18 ± 0.70 kg/plant, which was 2.20 times of the dry weight of Brazil banana (8.27± 0.20kg/plant). Does such a difference of more than one time in dry matter accumulation between the two cultivars mean that the nutrient management of the Zhongjiao No. 9 banana requires twice as much fertilizer as that of Brazil banana? If the fruit comb yield were analyzed furtherly, it is found that the average fruit ear (fresh weight) of the Zhongjiao No. 9 banana is 33.38 ± 0.54 kg/plant, and that of the Brazil banana is 29.50 ± 1.69kg/ plant. The fruit yield of the Zhongjiao No. 9 banana is only 1.13 times that of the Brazil banana. The difference of fruit yield is not as great as that of biomass (Fan *et al.*, 2007) [17]. That is to say, the economic performance of biomass accumulation and distribution of the Zhongjiao No. 9 banana requires water

and fertilizer management and regulation to promote the transportation of carbohydrates to ear, rather than accumulating a large amount of carbohydrates in stem and leaves and forming dry matter in them (Figure 2). The research on this aspect will be one of the directions for further research on the nutrient management of the Zhongjiao No. 9 banana.

Difference in NPK accumulation between the Zhongjiao No. 9 and the Brazil banana

From the above results and discussion it can be found that the biggest difference between Zhongjiao No.9 and Brazil banana in nutrient metabolism is that nitrogen, phosphorus and potassium absorbed and accumulated by the whole plant of the Zhongjiao No.9 banana was much more greater (Fan *et al.*, 2007; Liu *et al.*, 2011; Zhang *et al.*, 2015) [17,29,30]. The nitrogen, phosphorus and potassium element accumulated are 116.9, 23.7 and 510.3 g/plant respectively by Zhongjiao No.9 banana and 116.9, 54.2, and 615.0 g/plant respectively by converting into N, P_2O_5 and K_2O. While for whole plant of Brazil banana the nitrogen, phosphorus and potassium accumulation are 103.4, 11.1, 311.9 g respectively and 103.4, 25.3, 375.8 g/plant by converting into N, P_2O_5 and K_2O, respectively (Fan *et al.*, 2007) [17]. The ratio of absorption and accumulation of NPK by Zhongjiao No.9 banana plant is 1:0.20:4.37 or 1:0.46:5.2 by converting into N:P_2O_5:K_2O, while that of Brazil banana is 1:0.11:3.02 (N:P:K) or 1:0.24:3.64 (N:P_2O_5:K_2O being). In other words, the biggest difference lies in the absolute amount of N, P and K absorbed and accumulated by Zhongjia No. 9 banana, especially the amount of P and K is much higher than that of Brazil banana. The amount of P and K absorbed is 1.8 and 1.4 times of that of Brazil banana. Combining with the above discussion, because the fruit yield increase of the Zhongjiao No.9 banana is not such a large proportion of biomass and the most part of K allocated into the stems and leaves (Table 1 and Figure 7), the authors believe that the Zhongjiao No.9 banana possesses large ability of phosphorus and potassium luxury absorption. It also accord with the characteristics that bananas prefer potassium (Fan *et al.*, 2007; Turner & Barkus, 1980; Twyford &Walmsley, 1974a) [17,31,32]. Luxury absorption of potassium has no positive effect on the yield of the Zhongjiao No.9 banana, which has also been proved in previous studies (Jiang *et al.*, 2018; Shi *et al.*, 2019; Soratto *et al.*, 2020) [33-35]. If the potassium allocated and accumulated could be returned through the stems and leaves, then nutrients, including nitrogen and phosphorus, might be returned without losses (Zhang *et al.*, 2015) [30]. However, in banana cultivation, banana farmers often discard banana stem and leaves, resulting in a large loss of nitrogen, phosphorus and potassium nutrients (Raphael *et al.*, 2012) [36]. This is also the reason why banana is fertilized in a large amount of chemical fertilizers during its cultivation. Thus, from the perspective of nutrient management of the Zhongjiao No.9 banana, the nutrition research of the banana should be further studied in terms of the operation and allocation of potassium and reduction of its luxury absorption.

Suggestions on nutrient management and fertilization of the Zhongjiao No. 9 banana

Based on the above research results and discussions, it is suggested that the following measures should be taken for nutrient management of the Zhongjiao No.9. Before the extraction of buds, under the premise of no influence on the extraction speed and expanding growth rate of leaves, proper control of nutrients and water supply should be adopted to limit stem and leaf growth. The ratio of nitrogen, phosphorus and potassium before pregnancy buds, the ratio of fertilizer N: P_2O_5: K_2O was 2:0.5~1:1. The ratio of fertilizer N: P_2O_5: K_2O was 1:0.5:2 during the pregnancy buds to bud extraction stage. The ratio of fertilizer N: P_2O_5: K_2O was 1:0.5:2.5~3 from bud extraction to harvest stage.

Possible effect of nutritional status of banana on its defense or susceptibility to Fusarium Wilt

It is well known that the health of bananas is positively correlated with their resistance to blight. In general, the healthier a banana is, the more resistant it is to disease. This is the reason why China agriculture research system has advocated health and disease resistance in recent decades. However, banana health depends on its nutrition status. As shown above, not only N, P and K content of the banana, but also the ratio of N, P, K in plant and their allocation in different organs determine the banana health. Furthermore, nutrients management or rational fertilization technology is the key to adjust the banana growth and to promote the banana to resistant Fusarium wilt disease.

Conclusion

To sum up, the main results and conclusions are as followings.

- The dry matter of the Zhongjiao No. 9 banana is less than 1/5 of the whole plant, and the mineral element is less than 1/10 of the dry matter.
- About 2/3 of the dry matter of the Zhongjiao No.9 banana is used for root, stem and leaf growth or 2/3 photosynthetic products are allocated to those organs. Only 1/3 of the photosynthetic products are used for fruit growth. The pattern of dry matter allocation of the four organs is in order of stem > fruit ear > leaves > root.
- The cumulative uptake and allocation of total nitrogen, phosphorus and potassium of the four organs were in turn stem > fruit ear > leaves > roots. The absorption ratio of phosphorus, potassium by the Zhongjiao No.9 banana was much higher than that of the Brazil banana.
- According to the biomass, the absorption, accumulation and distribution of N, P and K of Zhongjiao No.9 banana and the research results of the Brazil banana, the nutrient management suggestions of the Zhongjiao No.9 banana were put forward.

Acknowledgement

This research was supported by the National Key R&D Program of China 2017YFD0200701 and 2018YFD0201100, China Agriculture Research System (CARS) (CARS-31-06), the Major Scientific Research Projects of Guangdong Province in China (2016KZDXM029), Science and technology plan project of Guangzhou, No. (201903010010).

References

1. Food and Agriculture Organisation FAO (2020) Crops, USA.

2. Xie JH (2019) Fruit scientific research in New China in the past 70 years: Banana. J Fruit Sci (in Chinese) 36: 1429-40.

3. Ploetz RC (2015) Fusarium Wilt of Banana. Phytopathology 105: 1512-21.

4. Pegg KG, Coates LM, O'Neill WT, Turner DW (2019) The epidemiology of Fusarium wilt of banana. Front Plant Sci 10: DOI: 10.3389/fpls.2019.01395.

5. Butler D (2013) Fungus threatens top banana. Nature 504: 195.

6. Dong T, Chen XJ, Fan C, Jin Y, Yi GJ (2013) Analysis on the development of the banana industry in China. Guangdong Agri Sci (in Chinese) 40: 220-3.

7. Li HP, Li YF, Nie YF (2019) Research status of occurrence and control of Fusarium wilt of banana. J South China Agri Univer (in Chinese) 40: 128-36.

8. Wang BB, Shen ZZ, Zhang FG, Waseem RZ, Yuan J, et al. (2016) Bacillus amyloliquefaciens Strain W19 can Promote Growth and Yield and Suppress Fusarium Wilt in Banana Under Greenhouse and Field Conditions. Pedosphere 26: 733-44.

9. Xu LB, Huang BZ, Wu YL, Huang YH, Dong T (2011) The cost-benefit analysis for bananas diversity production in China Foc zones. Am J Plant Sci 2: 561-8.

10. Zhang N, He X, Zhang J, Raza W, Yang XM, et al. (2014) Suppression of Fusarium Wilt of Banana with Application of Bio-Organic Fertilizers. Pedosphere 24: 613-24.

11. Alves Da Silva JT, Simao FR (2015) Yield, nutrition and incidence of Panama disease in 'Prata Ana' banana fertilized with potassium. Pesquisa agropecuaria brasileira 50: 807-13.

12. Freitas AS, Pozza EA, Pozza AAA, Oliveira MGF, Silva HR, et al. (2015) Impact of nutritional deficiency on Yellow Sigatoka of banana. Australasian Plant Pathology. 44: 583-590

13. Mburu K, Oduor R, Mgutu A, Tripathi L (2016) Silicon application enhances resistance to xanthomonas wilt disease in banana. Plant Pathol 65: 807-18.

14. Lin XQ, Peng M, Wu SP, Yi GJ, Dong T, et al. (2019) Comparative analysis of the differences in starch degradation and soluble sugar accumulation between 'Zhongjiao No. 9' and 'Baxijiao' during fruit ripening. J Fruit Sci (in Chinese) 36: 1524-39.

15. Lei CX, Wang WW, Dong HH, Li HP (2018) Difference analysis of different banana varieties infected by banana fusarium Foc4. Proceedings of the 2018 Annual Conference of the Chinese Society of PlantPathology, China.

16. Deng LS, Tu PF, Gong L, Chen K, Ye QQ, et al. (2012) Effect of boron drip fertigation on growth and nutrients absorption of bananas. J Anhui Agri Sci (in Chinese) 40: 691-3.

17. Fan XL, Liang YL, Wang XQ, Dai JJ, Du ZY (2007) Banana nutrient and fertilization. China Agricultural Press, Beijing, China.

18. Niu ZY, He P (2002) Mineral nutrition characteristics and fertilization of banana. Chinese J Tropical Agri (in Chinese) 22: 62-9.

19. Yang BM, Lin D, Li JJ, Liu F, Zhu ZQ, et al. (2007) Studies on the nutrition characteristics of banana. J Yunan Gricultural Univer (in Chinese) 22: 117-21.

20. Yao LX, Zhou CX, Peng ZP, Chen WZ (2005) Nutritional characteristics and K and Mg fertilizer combination in Baxi banana. Plant Nutr Fertilizer Sci (in Chinese) 11: 116-21.

21. Zhang AH, Ruan YZ, Dong MC, Zhao Y, Tang H, et al. (2015) Effect of fertilizer on biomass and nutrient accumulation of banana. Chinese Agri Sci Bullet (in Chinese) 31: 141-5.

22. Hazarika TK, Nautiyal BP, Bhattacharyya RK (2015) Sustainable banana (Musa spp) production through integrated plant nutrition system - A review. Ind J Agricult Sci 85: 987-95.

23. Moreira A, Fageria NK (2009) Yield, uptake, and retranslocation of nutrients in banana plants cultivated in upland soil of central Amazonian. J Plant Nutr 32: 443-57.

24. Nyombi K, van Asten PJA, Corbeels M, Taulya G, Leffelaar PA, et al. (2010) Mineral fertilizer response and nutrient use efficiencies of East African highland banana (Musa spp., AAA-EAHB, cv. Kisansa). Field Crops Res 117: 38-50.

25. Turner DW, Lahav E (1985) The temperature influences nutrient absorption and uptake rates of bananas‟ grown in controlled environments. Banana Newsletter 8: 25.

26. Twyford IT, Walmsley D (1974b) The mineral composition of the robusta banana plant IV. The application of fertilizers for high yieldsobusta banana plant. Plant Soil 41: 493-508.

27. Yamaguchi J, Araki S (2004) Biomass production of banana plants in the indigenous farming system of the east African highland. Agriculture, Ecosystems & Environment 102: 93-111.

28. Bao SD (2000) Soil agrochemical analysis. China Agricultural Press, Beijing, China.

29. Liu F, Yu JG, Fan XL, Wang XQ (2011) Research on Nitrogen, Phosphorus and Potassium contents and concentration law in banana. J Fruit Sci (in Chinese) 28: 340-3.

30. Zhang XJ, Wang C, Li BS, Zhang JZ (2015) Utilization status and outlook of banana stalk and leaves residues in China. Chinese J Tropic Agricult 35: 69-74.

31. Turner DW, Barkus B (1980) Plant growth and dry-matter production of the Williams banana in relation to supply of potassium magnesium and manganese in sand culture. Scientia Horticulturae 12: 27-45.

32. Twyford IT, Walmsley D (1974a) The mineral composition of the Robusta banana plant III. uptake and distribution of mineral constituents. Plant Soil 41: 471-91.

33. Jiang WT, Liu XH, Wang Y, Zhang Y, Qi W (2011) Responses to potassium application and economic optimum k rate of maize under different soil indigenous K supply. Sustainability 10: DOI 10.3390/su10072267

34. Shi XH, Zhang X, Kang WQ, Chen Y, Fan MS (2019) Possibility of recommending potassium application rates based on a rapid detection of the potato petiole K Status with a portable K ion meter. Am J Potato Res 96: 48-54.

35. Soratto RP, Job ALG, Fernandes AM, Assuncao NS, Fernandes FM (2020) Biomass Accumulation and Nutritional Requirements of Potato as Affected by Potassium Supply. J Soil Sci Plant Nutr 10.1007/s42729 020-00192-3.

36. Raphael L, Sierra J, Recous S, Ozier-Lafontaine H, Desfontaines L (2012) Soil turnover of crop residues from the banana (Musa AAA cv. Petite-Naine) mother plant and simultaneous uptake by the daughter plant of released nitrogen. Eur J Agronomy 38: 117-23.