Nutrient supply and dry-matter partitioning of pineapple cv. Josapine on sandy tin tailings

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Abstract — **Introduction**. Their physical and chemical properties make sandy tin tailings unsuitable for agricultural purposes without proper fertilizer and crop management practices. An attempt was made to use these tailings for sustainable production of pineapple using fertilization and irrigation techniques. Therefore, the objective of the study was to determine the effect of ground sucker size and levels of fertilizer used on yield and nutrient accumulation in plant components of pineapple cv. Josapine grown on sandy tin tailings. **Materials and methods**. Three fertilizer levels (plot 1, plot 2 and plot 3) containing N, P, K, Ca, Mg and Cu in solution and three classes of ground suckers (> 70 cm, 70–40 cm and < 70 cm) were used. They were arranged in a randomized complete block design with three replicates. There were 32 plants in each experimental plot. Each plot received a similar quantity of Fe, B, Mn, Zn and Mo. At harvest, each plant's parts were divided into fruit, leaves, stem and roots. The dry matter yield and nutrient contents of each pineapple part were analyzed and recorded. **Results and discussion**. The highest and the lowest amounts of dry matter were 397 $g \cdot plant^{-1}$ (size > 70 cm) and 96 $g \cdot plant^{-1}$ (size < 70 cm), respectively. Total dry matter accumulation was greater (26%) for plot 1 than for plots 2 and 3. Substantial amounts of the dry matter accumulation occurred in leaves (45.0%) and fruit (34.0%) and less in stems (16.0%) and roots (5%). A similar pattern was also observed for the total (major and micro-) nutrient accumulation in the plant components. Besides the fruit parameters, the length of the pineapple stem is an important factor affecting the yield of pineapple, either expressed on a fresh ($R^2 = 0.904^{***}$) or dry ($R^2 = 0.855^{***}$) weight basis. **Conclusion**. Ground sucker size is a very important factor for successful production of a high fruit yield and quality of pineapple planted on sandy tin tailings.

Malaysia / *Ananas comosus* / lithological soil types / fertigation / ratoons / yields

Nutrition et répartition de la matière sèche chez l'ananas cv. Josapine cultivé sur sols à résidus d'étains.

Résumé — **Introduction**. Les propriétés physiques et chimiques rendent les sols à résidus d'étains peu favorables à l'agriculture s'il n'y a pas une gestion appropriée de la culture et de la fertilisation. Un essai a tenté d'utiliser ces sols pour une production durable de l'ananas en appliquant certaines techniques de fertilisation et d'irrigation. L'objectif de l'étude a donc été de déterminer l'effet de la dimension du rejet souterrain planté et de la fertilisation utilisée sur le rendement et sur l'accumulation d'éléments nutritifs dans diverses parties de plants d'ananas cv. Josapine développés sur sols à résidus d'étain. **Matériel et méthodes**. Trois niveaux de fertilisation (parcelles 1, 2 et 3) contenant différentes solutions de N, P, K, Ca, Mg et Cu et trois classes de rejets souterrains (> 70 cm, 70–40 cm et < 70 cm) ont été utilisés. Les traitements ont été disposés en blocs complets randomisés à trois répétitions, à raison de 32 plants par parcelle testée. Chacune de ces parcelles a reçu une quantité semblable de Fe, B, Mn, Zn et Mo. À la récolte, chaque plant a été divisé en fruit, feuilles, tige et racines. Le rendement de matière sèche et la teneur minérale de chaque partie des plants d'ananas ont été analysés et enregistrés. **Résultats et discussion**. Les poids de matière sèche le plus élevé et le plus bas ont été de 397 $g \cdot plant^{-1}$ pour les rejets > 70 cm et de 96 $g \cdot plant^{-1}$ pour les rejets < 70 cm. L'accumulation de matière sèche totale a été plus importante (26 %) pour la parcelle 1 que pour les parcelles 2 et 3. Une accumulation significative de matière sèche a eu lieu dans des feuilles (45,0 %) et le fruit (34,0 %) ; elle a été moindre dans la tige (16,0 %) et les racines (5 %). Une répartition semblable des éléments nutritifs a été aussi observée pour l'accumulation totale des macro et micro éléments minéraux dans les différentes parties du plant. Outre certains paramètres du fruit, la longueur de la tige d'ananas a été un facteur important qui a affecté le rendement de l'ananas exprimé en poids frais ($R^2 = 0{,}904^{***}$) ou en poids sec ($R^2 = 0{,}855^{***}$). **Conclusion**. La dimension du rejet souterrain planté est un facteur très important pour une production de fruits à haut rendement et de bonne qualité pour des ananas plantés sur sols à résidus d'étains.

Malaisie / *Ananas comosus* / type de sol lithologique / irrigation fertilisante / rejet de souche / rendement

1. Introduction

The physical and chemical properties of sandy (> 75% sand) tin tailings make them unsuitable for agricultural purposes without proper fertilizer and crop management practices. Malaysia has a vast area (200 000 ha) of abandoned barren sandy tailings. Sandy tailings are classified as marginal land (low in organic matter and nutrient status and with a high infiltration rate). Added nutrients are easily leached, even during a short period of rainfall. The landscape of tailing areas is generally undulating to mostly flat.

Smallholders and/or large-scale estate plantations of the pineapple [*Ananas comosus* (L.) Merr.] generally grow plants on mineral and/or peat soils. At present, Gandul, a Spanish group variety, is the main cultivar grown for the canning industry and well adapted to peat soils [1]. Approximately 7 054 ha of land are under pineapple cultivation with a total production of 121 915 t as fresh fruits [2]. However, the production of pineapple on this soil is declining each year in spite of several efforts by growers to sustain it. Furthermore, the inherent physical characteristics of peat soil limit its capability to adapt to new technology-driven techniques, such as for planting and harvesting.

Alternatively, the sandy tailings have a great potential to be developed for pineapple plantation using mechanized technology. Heavy leaching of nutrients in these soils may be overcome by controlling the amounts of water and nutrients added at specific times during pineapple growth. The technique of delivering nutrients in solution form (fertigation) is beneficial and cost-effective for large-scale plantation. The process can be automated and use less labor. Furthermore, the pineapple parts (leaves, stems and roots) can be incorporated back into the soil during land preparation, thus, in the long run increasing the organic matter content of the sandy tailings. Therefore, the objectives of our study were: (i) to determine the effect of fertilizer rates and sizes of ground sucker on dry matter accumulation and partitioning into pineapple leaf, stem, fruit and root at harvest; (ii) to determine the nutrient contents of each plant part, and (iii) to identify the most important parameter affecting yield and yield quality of pineapple cv. Josapine grown on sandy tin tailings using the fertigation technique.

2. Materials and methods

The field experiment was conducted on three plots of the sandy tin tailing research area of the Department of Land Management, Faculty of Agriculture, University Putra, Malaysia (UPM). Prior to the field trial, the soil was sampled for each plot and physico-chemical characteristics such as total N [3], extractable P [4], extractable Cu [5], organic-C content [6], pH of water at a soil / solution ratio of 1:5, cation exchange capacity (CEC), and exchangeable K, Ca and Mg [7] were determined (*table I*).

Ground suckers of pineapple cv. Josapine of about 20–70 cm length with about 9–25 leaves were planted randomly on beds with a double-row planting system (76.2 cm × 55.9 cm × 24.4 cm) at a planting density of 62 117 plants·ha^{-1}. Before planting, the bed was sprayed with pre-emergence herbicide, and perforated polyethylene tubing (ϕ = 3 mm) for the fertilizer delivery system was laid down on the bed and covered with a black plastic sheet.

Table I.
Some physico-chemical characteristics of the sandy tin tailing soils used to investigate pineapple growth in Malaysia. Only the means of some general properties are given because the nutrient content of soils of the three plots used showed a variation of less than 10%.

pH_w	C	N	P	K	Ca	Mg	Cu	Fe	B	Zn	Mn	CEC (cmol (+)·kg^{-1})	Textural classes (%)		
	(%)		(mg·kg^{-1} soil)										> 50 µm (sand)	2–50 µm (silt)	< 2 µm (clay)
5.2	0.6	0.1	6.3	41.6	0.1	65.0	5.2	60.4	51.9	18.5	7.7	4.8	78.9	8.0	12.9

The fertilizer solution used was prepared from mixtures of urea, triple superphosphate, muriate of potash, gypsum, kieserite and copper sulfate (*table II*). A similar quantity of micronutrients was added to each plot at the rates of 0.1 kg Fe·ha^{-1}, 0.23 kg B·ha^{-1}, 0.0015 kg Zn·ha^{-1}, 0.0001 kg Mo·ha^{-1} and 0.0045 kg Mn·ha^{-1}. The fertilizer application rates for plot 1 and plot 2 were determined by Hanafi and Razzaque [8] using a nutrient optimization procedure for optimum yield of the Gandul variety on peat soils with continuous cultivation for the last 24 years (site 1) and for about 40 years (site 2), respectively, at the Peninsula (Pineapple) Plantation Estate, Simpang Rengam, Johor, Malaysia.

After about 2 months, the pineapple plants were tagged and divided into three classes (A: > 70 cm, B: 40–70 cm and C: < 40 cm) based on plant height. There were 32 plants in each sub-unit in each treatment. The fertilizer solution in the plastic container was delivered to each bed for about 1 month to avoid salt injury to the plants. Subsequently, only water was supplied once per week to each bed until harvest.

Flower induction was carried out using 50 mL of 200 mg etephon·L^{-1} for each plant at 10 months after planting. The fruits were harvested when one-third of them were ripe, which was achieved 155 d after flower induction.

At harvest, each plant was divided into fruit, leaf, stem and roots and dried in an air-ventilated oven at 70 °C until it reached a constant weight. The total dry matter weight of each plant part was recorded.

The plants were uprooted and cleaned with water. The outlet of the sink was fitted with a wire screen to prevent any loss of roots. The roots left in the soil were collected by hand and washed by spraying water onto a 1-mm sieve. All roots were collected and spread on a plastic tray for some time to lose excess water. The roots were then transferred to paper bags and dried in an oven at 70 °C until they reached a constant weight. Dry weights were measured with electronic scales. Dry roots were ground with a Wiley hammer mill to pass through a < 2 mm size sieve and stored in plastic bags for further analysis.

Table II.
Fertilizer rates used for planting of pineapple cv. Josapine on sandy tin tailings.

Number of the plot (fertilizer level)	N	P_2O_5	K_2O	CaO	MgO	CuO
	(kg·ha^{-1})					
Plot 1	872	24	400	108	24	2.0
Plot 2	750	48	266	84	36	3.0
Plot 3	600	72	798	108	24	3.2

The fruit, stem, leaf, and root samples were digested with a mixture of H_2SO_4 and H_2O_2 according to the procedure described by Thomas *et al.* [9]. The N and P contents in solution were determined using an auto-analyzer; K, Ca, Mg, Cu, Fe, Mn and Zn in solution were determined using an atomic absorption spectrophotometer; Mo and B in solution were determined using an optical emission inductively coupled plasma spectrophotometer.

The analysis of variance (ANOVA) and comparison between means (Least Significant Difference) of the treatments were carried out using the SAS statistical procedure [10].

3. Results and discussion

3.1. Dry matter partitioning of pineapple

The total dry matter accumulation is one of the factors that determine yield. Synthesis, translocation, partitioning and accumulation of the photosynthates within the plant are controlled genetically and influenced by the environmental conditions [11]. Post-flowering dry matter accumulation greatly influences fruit yield, since most of the photosynthates produced at this stage are transferred for fruit development. Plants with a [fruit weight / plant weight] ratio < 1 have disproportionate amounts of leaves and little, if any, dry matter accumulated in the stem, presumably in the form of starch. Thus, plants that grow rapidly just before forcing produce leaves at the expense of storage in the stems [12].

Table III.
Effect of ground sucker size and fertilizer levels on the dry matter partitioning of pineapple cv. Josapine grown on sandy tin tailings. Interaction [plant size × fertilizer level] is not significant at the 5% level according to the F-test of ANOVA.

Ground sucker size (cm)	Roots		Stem		Leaves		Fruit	
	$g \cdot plant^{-1}$	Total dry matter (%)	$g \cdot plant^{-1}$	Total dry matter (%)	$g \cdot plant^{-1}$	Total dry matter (%)	$g \cdot plant^{-1}$	Total dry matter (%)
> 70	14.04 a	3.5	63.50 a	16.0	177.73 a	44.8	141.44 a	35.7
70–40	11.52 a	4.7	40.05 b	16.4	111.24 b	45.6	81.34 b	33.3
< 40	6.51 b	6.8	14.96 c	15.5	43.31 c	45.0	31.47 c	32.7

Number of the plot (fertilizer level)	Roots		Stem		Leaves		Fruit	
	$g \cdot plant^{-1}$	Total dry matter (%)	$g \cdot plant^{-1}$	Total dry matter (%)	$g \cdot plant^{-1}$	Total dry matter (%)	$g \cdot plant^{-1}$	Total dry matter (%)
Plot 1	10.40 a	3.7	50.92 a	18.0	119.37 a	42.3	101.57 a	36.0
Plot 2	10.47 a	4.5	31.76 b	13.8	103.69 a	45.0	84.37 ab	36.6
Plot 3	11.20 a	5.0	35.83 b	16.0	109.22 a	48.6	68.32 b	30.4

Means within a column followed by the same letters are not significant at the 5% level by LSD.

The dry matter accumulation and partitioning of pineapple cv. Josapine into roots, stem, leaf and fruit depended on the size of the ground suckers and levels of fertilizer used (*table III*). The plant size > 70 cm gave the highest amount of dry matter for each plant part compared with other sizes (< 40 cm and 40–70 cm). Similarly, the total dry matter yield of the pineapples followed the same trend as in the plant parts, with the highest being 396.7 g total dry matter·plant^{-1} (size > 70 cm) and the lowest being 96.3 g total dry matter·plant^{-1} (size < 40 cm). With the exception of the roots and leaves, there were significant differences in the dry matter yield of the pineapples between the levels of fertilizer used. The total dry matter yield was greater for the levels of fertilizer used on plot 1 (282.3 g total dry matter·plant^{-1}) than that on both plot 2 (230.3 g total dry matter·plant^{-1}) and plot 3 (224.6 g total dry matter·plant^{-1}) (*table III*).

Based on the average of plant parts across the size of ground suckers or levels of fertilizer used, a substantial amount of the dry matter accumulation occurred in leaves (45.0%) and fruit (33.8%), while a smaller portion was observed in the stem (16.1%) and roots (5.1%). However, the partitioning of total dry matter into the components (roots, stem and leaf parts) of pineapple cv. Gandul at maximum growth (10 months after planting) showed that more than 80% of the total dry matter accumulation occurred in leaves [8]. The results also showed that the distribution of the dry matters in leaves, stem and roots were similar for control and N-treated plots at 1000 kg N·ha^{-1}. However, application of 500 kg N·ha^{-1}reduced the root dry weight and, consequently, increased the leaf dry weight without affecting stem dry weight. This shows that optimum application of N as in the present experiment promoted more photoassimilate accumulation in the leaves and less in the roots. In the same study, Hanafi and Razzaque [8] showed that application of K fertilizer (0–1250 kg K_2O·ha^{-1}) had no significant effect on the distribution of dry matter in different pineapple plant components. Generally, partitioning of leaf dry matter increased with increasing levels of K. In unfertilized plants, more photoassimilates were stored in the stem and roots at the expense of the leaves of plants,

Table IV.
Effect of ground sucker size and fertilizer levels on nutrient content of pineapple leaves cv. Josapine grown on sandy tin tailings. Interaction [plant size × fertilizer level] is not significant at the 5% level according to the F-test of ANOVA.

Ground sucker size (cm)	N	P	K	Ca	Mg	Zn	Fe	Mn	Cu	B
	(mg·plant^{-1})									
> 70	4181.6 a	1201.2 a	3006.8 a	1653.6 a	1025.5 a	2.69 a	13.35 a	2.57 a	0.27 a	8.95 a
70–40	1445.8 b	428.0 b	1854.9 a	518.0 b	179.4 b	0.98 b	2.69 b	0.81 b	0.11 b	0.86 b
< 40	213.5 c	60.3 b	229.8 b	116.4 b	21.9 b	0.15 b	0.67 b	0.14 b	0.02 c	0.02 b

Number of the plot (fertilizer level)	N	P	K	Ca	Mg	Zn	Fe	Mn	Cu	B
	(mg·plant^{-1})									
Plot 1	2374.1 a	545.1 a	2036.1 a	883.1 a	312.3 a	1.40 a	4.46 a	1.29 a	0.15 a	4.59 a
Plot 2	1571.6 a	410.2 a	1560.1 a	671.5	436.0 a	0.95 a	5.40 a	0.89 a	0.11 a	3.30 a
Plot 3	1895.2 a	734.2 a	1495.4 a	733.4 a	478.5 a	1.46 a	6.85 a	1.34 a	0.14 a	1.93 a

Means within a column followed by the same letters are not significant at the 5% level by LSD.

which are the main source of carbohydrate synthesis and transfer it to the point of active growth. The imbalance of the proportion of the dry matter accumulation in the leaves and stem may have direct bearing on the fruit weight of pineapple [12].

3.2. Nutrient content in plant components

The amounts of macro- and micronutrients in the roots, stem, leaves and fruit of pineapple cv. Josapine differed widely between the size of ground suckers and levels of fertilizer used. For instance, in leaves (*table IV*), a significantly ($P \leq 0.05$) higher amount of nutrient content was obtained in plant size > 70 cm as compared with the results obtained with the other plant size classes. In particular, the N and K contents were the highest among the other nutrient contents measured for this plant size, > 70 cm, as compared with the other classes. This is in agreement with a higher accumulation of the total dry matter for this plant size, > 70 cm, compared with plant size < 70 cm (*table III*). A similar pattern but lower amount of nutrients was observed in the roots, stem, and fruit (data not shown).

Because several nutrients were used in the fertilizer solution, it is expected that the compound effect of nutrients may significantly affect plant growth. Therefore, a comparison between treatments can be simplified using a summation of the individual nutrients to give the total nutrients accumulated in the plant component (*table V*). For each plant component, plants from size > 70 cm gave significantly ($P \leq 0.05$) higher values of total nutrient content compared with plants of sizes ≤ 70 cm. The total amount of nutrients accumulated in the leaves was the highest (11 097 mg·plant^{-1}) for plant size > 70 cm and the lowest (77 mg·plant^{-1}) in the stem of plant size < 70 cm. However, a significant effect of the fertilizer levels used was observed only for the stem and fruit (*table V*). The total nutrient content for these plant parts for plot 1 differed significantly ($P \leq 0.05$) from plots 2 and 3. The highest (6 163 mg·plant^{-1}) and the lowest (423 mg·plant^{-1}) amounts of total nutrients accumulated were in the leaves for plot 1 and in the stem for plot 3, respectively. These results are in agreement with the amount of total dry matter accumulation and partitioning mentioned earlier. A better growth and higher fruit weight of pineapple cv. Josapine in plot 1 coincided with accumulation of slightly higher amounts of N and

Table V.
Total nutrients accumulated in the pineapple components of cv. Josapine grown on sandy tin tailings. Interaction [plant size × fertilizer level] is significant at the 1% level for the stem data, according to the F-test of ANOVA.

Ground sucker size (cm)	Roots	Stem	Leaves	Fruit
	(mg of total nutrient content·plant^{-1})			
> 70	1329.4 a	1423.0 a	11097.0 a	5353.1 a
40–70	1028.6 ab	491.9 b	4431.0 b	2237.7 b
< 40	306.8 b	76.7 c	643.0 b	295.9 c
Number of the plot (fertilizer level)	Roots	Stem	Leaves	Fruit
	(mg of total nutrient content·plant^{-1})			
Plot 1	917.6 a	1145.2 a	6163.0 a	3463.9 a
Plot 2	799.1 a	423.5 b	4660.0 a	2642.2 ab
Plot 3	948.0 a	422.9 b	5348.0 a	1780.7 b

Means within a column followed by the same letters are not significant at the 5% level by LSD.

K contents in the leaves (*table IV*) and fruit (data not shown) components.

Based on the total average amount of nutrients accumulated in the pineapple components (*table V*) across the size of ground suckers or levels of fertilizer used, a substantial amount of the dry matter accumulation occurred in leaves (57.0%) and fruit (27.0%), while a smaller portion was observed in the stem (7.0%) and roots (9.0%). However, these results showed a slight variation to the values obtained by partitioning of total dry matter into the components (roots, stem, leaf and fruit parts) of pineapple cv. Josapine described earlier. The total nutrients in the leaf and fruit were thus in the same order as for the total dry matter partitioning (leaf > fruit).

3.3. Effect of plant components on yield of pineapple

The plant components, such as roots (dry weight and volume), stem (dry weight and length), leaf (dry weight and leaf number), fruit yield (fresh and dry weight) and fruit quality (length, diameter, sugar content and acidity) were identified and measured at harvest. With the exception of fruit acidity, there were positive significant ($P \le 0.05$) relationships between the parameters measured as indicated by Pearson's correlation coefficient ($n = 27$) (data not shown). In order to determine a meaningful relationship, the data were subjected to multiple regression analysis using the stepwise procedure [10]. In this procedure, the fruit fresh and dry weight were used separately as dependent variables and the other plant components and fruit parameters as independent variables. The relationship obtained is as follows:

– Fruit fresh weight (g) = 87.28 fruit diameter (cm) + 9.95 stem length (cm) – 797.82 ($R^2 = 0.904^{***}$). (1)

– Fruit dry weight (g) = 6.23 fruit length (cm) + 7.84 fruit sugar (°Brix) + 1.05 stem length (cm) – 132.40 ($R^2 = 0.855^{***}$). (2)

For both equations, the fruit quality and length of the pineapple stem parameters strongly affect the pineapple yield. About (90 and 86)% of the data can fully be described by the relationship between plant and fruit quality parameters for the yield of pineapple as measured by fresh weight equation (1) and dry weight equation (2), respectively. As indicated in equation (1) and equation (2), the addition of the plant parameters and length of the pineapple stem suggest the importance of physiological processes in the stem. Most of the starch is accumulated in the stem before being transported to the fruit. Thus, the fruit yield and quality depend on the amount and quality of starch storage in the stem. Hepton *et al.* [12] suggested that pineapple plants that grow rapidly just before forcing produce leaves at the expense of storage in the stems. In a study to determine the disparity of the yield of pineapple cv. Gandul grown on tropical peat at sites 1 and 2, Razzaque [8] showed that when the dry matter accumulated in the stems (for site 1) was > 8% as compared with the roots, the fruit size was bigger and contributed to a higher yield.

4. Conclusion

The dry matter accumulation and partitioning of pineapple cv. Josapine into roots, stem, leaves and fruits depend on the size of ground suckers and levels of fertilizer used. The plant size > 70 cm gave the highest amount of dry matter for each plant parts as compared with the smaller sizes. Substantial amounts of the dry matter accumulation occurred in leaves (45.0%) and fruit (34.0%) and less in the stem (16.0%) and roots (5%). The total nutrients (major and micronutrients) accumulated in the plant components also follow the same pattern. Besides the fruit parameters, the stem length of the pineapple also greatly affects the pineapple yield, either expressed on a fresh ($R^2 = 0.904^{***}$) or dry ($R^2 = 0.855^{***}$) weight basis.

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Nutrición y distribución de la materia seca en la piña cv. Josapine cultivada en suelos con residuos de estaño.

Resumen — **Introducción**. Las propiedades físicas y químicas hacen que los suelos con residuos de estaño sean poco favorables para la agricultura si no existe una gestión adecuada del cultivo y la fertilización. Un ensayo intentó utilizar estos suelos para una producción sostenible de piña aplicando ciertas técnicas de fertilización y riego. El objetivo del estudio consistió, pues, en determinar el efecto de la dimensión del vástago subterráneo plantado y de la fertilización utilizada en el rendimiento y la acumulación de elementos nutritivos en distintas partes de plantas de piña cv. Josapine desarrolladas en suelos con residuos de estaño. **Material y métodos**. Se utilizaron tres niveles de fertilización (parcelas 1, 2 y 3) con diferentes soluciones de N, P, K, Ca, Mg y Cu y tres clases de vástagos subterráneos (> 70 cm, 70–40 cm y < 70 cm). Los tratamientos siguieron un diseño en bloques completos al azar con tres repeticiones y 32 plantas por parcela de experimentación. Cada una de dichas parcelas recibió una cantidad similar de Fe, B, Mn, Zn y Mo. Durante la cosecha, cada planta se dividió en fruto, hojas, tallo y raíces. Se analizó y se registró el rendimiento de materia seca y el contenido mineral de cada parte de las plantas de piña. **Resultados y discusión**. Los pesos de materia seca más altos y más bajos fueron respectivamente de 397 $g \cdot planta^{-1}$ en los vástagos > 70 cm y de 96 $g \cdot planta^{-1}$ en los vástagos < 70 cm. La acumulación de materia seca total fue más importante (26%) en la parcela 1 que las 2 y 3. Se produjo una acumulación significativa de materia seca en las hojas (45,0%) y el fruto (34,0%), siendo inferior en el tallo (16,0%) y las raíces (5%). Se observó también una distribución similar de los elementos nutritivos en la acumulación total de los macro y micro elementos minerales en las distintas partes de la planta. Además de algunos parámetros del fruto, la longitud del tallo de piña fue un factor importante que afectó al rendimiento de la piña expresado en peso fresco (R^2 = 0,904***) o en peso seco (R^2 = 0,855***). **Conclusión**. La dimensión del vástago subterráneo plantado es un factor muy importante para una producción de frutas de gran rendimiento y de buena calidad para piñas plantadas en suelos con residuos de estaño.

Malasia / *Ananas comosus* / tipos litológicos de suelo / fertirrigación / renuevo / rendimiento