Pertanika J. Trop. Agric. Sci. 24(2): 123 - 129 (2001)
ISSN: 1511-3701

Pineapple Residue Management Practices and Fertilizer Regimes: Effects on P and K Uptake, Yield and Some Economic Implications

O.H. AHMED, M.H.A. HUSNI, A.R. ANUAR, M.M. HANAFI & S.R. SYED OMAR
Department of Land Management,
Faculty of Agriculture
Universiti Putra Malaysia
43400 Serdang, Selangor, Malaysia
E-mail: osman60@hotmail.com

Keywords: pineapple residues management, fertilizer regime, potassium uptake, phosphorus uptake, yield, cost effectiveness, tropical peat

ABSTRAK

Kajian ini telah dijalankan untuk menentukan kesan yang paling efektif, efisien serta menguntungkan bagi kombinasi baja serta pengurusan sisa nanas untuk penanaman nenas di gambut tropika. Tiga jenis pengurusan sisa digunakan iaitu (i) pereputan sisa nanas secara in situ tanpa sebarang gangguan (R1), (ii) penimbunan sisa nanas yang dipotong dan dikaruk dari baris 0.6 m x 10 m kepada 0.9 m x 10 m (R2), dan pembakaran sisa nenas secara in situ digunakan dengan tiga rejim baja iaitu; (i) pembajaan P dan K pada hari yang ke 65, 135, 191 dan 233 selepas penanaman (F1), pembajaan P dan K pada hari yang ke 65, 135, 191 selepas penanaman (F2), dan pembajaan P dan K pada hari yang ke 65, 135, dan 191 selepas penanaman dengan baja hari yang ke 233 dibahagi dan dibaja pada hari ke 135 dan 191 (F3). Kesan pengurusan sisa bagi ketiga-tiga cara pada kandungan P dan K serta hasil didapati tidak memberikan sebarang perbezaan yang bererti. Dari segi kos pula, R1 merupakan pengurusan sisa yang paling murah manakala R3 merupakan yang paling mahal. F2 merupakan rejim pembajaan paling murah manakala F1 rejim yang paling mahal. Kombinasi rawatan yang paling kos efektif adalah R1F2. Pembakaran, penimbunan sisa nanas secara berbaris atau membiarkan sisa nanas mereput secara in situ tidak meningkatkan pengambilan P dan K serta hasil. Pembajaan K (188 gk/ha) dan P (7 kg/ha) pada hari yang ke 233 selepas penanaman adalah tidak perlu. Ini dapat menjimatkan kos baja sebanyak RM 187.98/ha. Pembajaan 'muriate of potash' dan batuan fosfat China pada hari ke 65, 135, and 191 (F2) dengan pereputan sisa nanas secara in situ (R1) menampakan sedikit kebaikan dari segi kos efektif.

ABSTRACT

The study was carried out to determine the most effective, efficient, and profitable combination of fertilizer regime and pineapple residue management practice for pineapple grown on tropical peat. Three residue management practices, namely; (i) In situ decomposition of pineapple residue without any disturbance (R1), (ii) Stacking of pineapple residue slashed and raked from 0.6 m x 10 m beds into 0.9 x 10 m beds (R2), and (iii) In situ burning of pineapple residue (R3) were used in combination with three fertilizer regimes; (i) application of P and K at the 65th, 135th, 191st, and 233rd days after planting (F1), (ii) application of P and K at the 65th, 135th, and 191st days after planting (F2), and (iii) application of P and K at the 65th, 135th, and 191st days after planting but sharing fertilizer amount of the 233rd day between the 135th and 191st days (F3). The effect of the three residue management practices on P and K uptake as well as fruit yield was not significant. Similar observation was made for the three fertilizer regimes. In terms of cost, R1 was the cheapest residue management practice with R3 being the most expensive practice. F2 emerged the cheapest fertilizer regime while F1 was the most expensive regime. The most cost effective treatment combination was R1F2. Burning, stacking of pineapple residue in rows or leaving pineapple residue to decompose in situ did not improve K and P uptake as well as fruit yield. The application of K (188 kg/ha) and P (7 kg/ha) fertilizers at 233rd day after planting is not necessary and by omitting it the practice could save as much as RM 187.98/ha. The application of muriate of potash and China phosphate rock at the 65th, 135th, and 191st days (F2) under in situ decomposition of pineapple residue (R1) looks promising in terms of the cost effectiveness.

INTRODUCTION

Pineapple (Ananas comosus); a tropical crop (Sampson 1980) is commonly grown on mineral soils (Py *et al.* 1987) but in Malaysia, the crop is largely and uniquely cultivated on peat (AGRIQUEST 1999/2000). This practice has been in existence for nearly a century (Selamat and Ramlah 1993). The present large scale cultivation started on a small scale basis without fertilization but after the extensive and comprehensive survey of pineapple cultivation on peat in Malaysia (Dunsmore 1957), the need to apply balanced fertilizers for a better growth and production of pineapple was found necessary. Afterwards, various fertilizer recommendations (Tay 1972; Tay 1973) were put forward. When it became obvious that the existing recommendations were unsustainable, new fertilizer recommendations were released (Selamat and Ramlah 1993; Razzaque 1999). Despite the fact that pineapple residue management practices such as burning, incorporation, mulching, and zero burn; each of which in one way or the other forms an integral part of pineapple cultivation, none of the preceding studies took due cognizance of the interactive effects of fertilizer regimes under any of the aforementioned residue management practices.

A recent study on the P, K, Ca and Mg budget in pineapple cultivation has revealed that the existing fertilizer regime is inadequate (Ahmed *et al.* 2000) as there is lack of efficient synchrony between the time frame at which nutrients are released from applied fertilizers and the optimum period of nutrient uptake. It was estimated that 46.79 % (leaching plus accumulation) of P and 73.52 % (leaching plus accumulation) of K are unutilized. In fact, this estimation is consistent with the findings of Ahmed *et al.* (1999) on P and K fertilizers use efficiencies which were found to be 53.21% and 29.91%, respectively.

In spite of the growing concern about the polluting effects of excess fertilizer application on the environment, it is on record that Malaysia is one of the heaviest users of fertilizers in the world (per unit land area basis) even though most of the fertilizers used in the country are imported. For 1995/96, Malaysia used 223.4 kilogram per hectare fertilizer nutrients, compared with a worldwide use of only 83.4 kilogram per hectare (AGRIQUEST 1999/2000). It is even thought that Malaysia is the only country in the world with a potash requirement higher than nitrogen requirement. In 1998 (January to September), the fertilizer import bills for nitrogeneous, phosphatic, and potassic fertilizers stood at RM 406.020, RM 150.870, and RM 442.662 million, respectively. In order that the Malaysian pineapple industry contributes its quota to the reduction of these alarming bills, there is the need to judiciously modify the present fertilizer regime. The modification however needs to be in tandem with a superior mode of handling pineapple residues like the modified version of zero burn technique where with the exception of leaves that needs to be removed for value addition instead of burning, roots, stems, crowns and peduncles can be left to decompose *in situ.* This approach will not only ensure that fertilizer recommendations are based on the interactive effect of fertilizers and crop residues management practices but it is also expected to be environmental friendly.

The objective of the study was to determine the most effective, efficient, and profitable combination of fertilizer regime and pineapple residue management practice for pineapple grown tropical peat.

MATERIALS AND METHODS

The study was carried out on a Hemist peat at the Simpang Rengam Pineapple Estate, Simpang Rengam, Johore, with the following residue management practices; (I) In situ decomposition of pineapple residue without any disturbance (R1); (II) Stacking of pineapple residue (leaves, crowns, and peduncles) slashed and raked from 0.6 m x 10 m beds into 0.9 m x 10 m beds (R2); and (III) *In situ* burning of pineapple leaves, crowns, and peduncles (the usual practice) (R3). In order to estimate the amount of ash added through in situ burning of pineapple leaves, crowns, and peduncles (R3), these parts that were slashed from old pineapple stumps, raked, and collected from four representative plots of R3 before the start of the experiment. The residues were air-dried and after obtaining constant weight, they were burnt and the weight of the ash recorded. A direct proportional relationship was assumed for estimating the amount of ash added through *in situ* burning on a per hectare basis. The same procedure was used to estimate the amount residue (leaves, crowns, and peduncles) added under R1 and R2 except that the residues were not burnt.

Potassium, P, and N were applied in the forms of muriate of potash (MOP, 49.80 % K), China phosphate rock (CPR, 14.00% P), and urea (46.00% N) at the total rates of 554 K, 36 P, and 704 kg/ha N, respectively. The fertilizer regimes adopted were: (I) application of N (176, 176, 176, and 176 kg/ha), P (11, 11, 7, and 7 kg/ha), and K (89, 89, 188, and 188 kg/ha) fertilizers at the 65th, 135th, 191st, and 233rd days after planting (F1), respectively (the usual practice); (II) application of N (176, 176, and 176 kg/ha) P (11, 11, and 7 kg/ha) and K (89, 89, and 188 kg/ha) fertilizers at the 65th, 135th, and 191st days after planting (F2), respectively, and (III) application of N (176, 264, and 264 kg/ha) P (11, 14, and 11 kg/ha) and K (89, 183, and 285 kg/ha) fertilizers at the 65th, 135th, and 191st days after planting (F3), respectively. Combinations of the residue management practices and fertilizer regimes gave the following treatments; RIF1, RIF2, RIF3, R2FI, R2F2, R2F3, R3F1, R3F2, and R3F3. It must be pointed out that a treatment without residue was excluded in this study because of the following reasons: (I) To the pineapple estates, removal of pineapple residues in pineapple cultivation on peat is not practical because the issue of how to handle or what to do with the pineapple residue after removal is still open to discussion in Malaysia. Not until value is added to or products are developed from pineapple residues that are of commercial value, the estates are unwilling to adopt this kind of residue management practice. (II) In their study to ascertain the effects of pineapple residue management practices on P and K uptake and fruit yield using the treatments, leaf residue removed and fertilization, and leaf residue burnt and fertilization, the Ahmed *et al.* (1999) found no significant difference between the effect of the practices on P and K uptake as well as fruit yield.

The study entailed 3 x 3 factorial experiment in a randomized complete block design with 4 replications. The experimental plot was 8 m x 10 m, and 480 cultivar Gandul suckers (most popularly grown cultivar) were planted in each of the plots. Planting distance of 0.3 m between plants and 0.6 m between rows was used. A day before the start of the experiment, soil samples were taken at a depth of 0-25 cm using peat auger in the already designated experimental plots. A second batch of soil samples was taken 466 days after planting (harvest time). At maturity, two plant samples were uprooted within 1m square area but prior to that, D-leaf (longest and easily identifiable leaf that provides a reliable and sensitive indication of pineapple nutritional status (Py *et al.* 1987) was taken from the two samples to be uprooted. The plants (tops without roots) were then oven dried at 60°C and their dry weights determined after ensuring that constant weights have been attained. Fruits were harvested from the various plots (excluding guard rows) and weighed. The roots of the uprooted plants were removed.

Soil extractable K and P were determined using the double acid method (0.05 M HCL:0.025 M H_2SO_4) with soil to solution ratio of 1:10 for 1 hour (Modified version (1:3) of Van Lierop *et al.* 1980). The reasons behind the modification of the extraction method were: (I) A dilute soil extractant helps in eliminating the possibility of the neutralization of the extracting solution through reaction with the soil and possibly reaction of Ca and Mg coming from the burnt crop residue plus artifacts in the soil, and (II) Prolonged extraction time plus wider extraction ratio helps in minimizing the effects of rewetting time variability of dry peat (Van Lierop *et al.* 1980). Single dry ashing method was used to determine total K and P in D-leaf, ash, and residue (leaves, crowns, and peduncles). Phosphorus was determined using the molybdate blue method (Murphy and Riley 1962) at a wavelength of 882 nm. Potassium was determined using atomic absorption spectrophotometer. Potassium and P concentrations in D-leaf multiplied by the plant weight gave the uptake of these nutrients. The respective amounts of ash and residue per hectare multiplied by the P and K concentrations represented the amounts P and K recycled through burning of leaves, crowns, and peduncles and that recycled through in situ decomposing of these parts.

The cost effectiveness of the nine treatments were estimated based on the cost involved in the amounts of fertilizers used under each fertilizer regime, residue management practices (burning, slashing and stacking), fertilizer application, weeding, and air pollution (for burning pineapple residue). These estimations were based on those used by the pineapple estate. Other costs like planting, preparation of suckers, pesticides and pesticide application, hormone and hormone application, land (rent), and maintenance have been reported to be the same (Husni *et al.* 1999), and as such were not included.

Interest rate of 12% on capital was used. Interest factor was calculated using the formula (Davis and Johnson 1987); $(1 + i)^{w-1}$ where; i represents interest rate; w is the number of years for attainment of crop maturity (harvest period).

RESULTS AND DISCUSSION

The initial status of the soil extractable K and P before the start of the experiment ranged between 24.71 to 40.01 mg/kg and 402.00 to 575.00 mg/kg, respectively (Table 1). These concentrations were relatively high (Ahmed *et al.* 2000). This was attributed to the period of cultivation as the land has been under pineapple cultivation for the past 32 years, hence the tendency of residual accumulation. The differences in K and P contents in all the experimental plots before the start of the study were statistically insignificant.

TABLE 1
Initial status of soil extractable P and K

Treatment	P	K
	mg/kg soil	
R1F1	30.78	402
R1F2	26.17	477
R1F3	27.71	575
R2F1	24.71	445
R2F2	33.34	450.50
R2F3	28.95	575.50
R3F1	40.01	564
R3F2	28.95	590
R3F3	34.44	534

Note: No significant difference between treatments using Duncan's Multiple Range Test $P \leq 0.05$ was observed for all the treatments

In situ burning of leaves, crowns, and peduncles recycled 1.31 Mg/ha of ash which contained 18.69 and 240.43 kg/ha P and K. In the case of *in situ* decomposition of leaves, crowns, and peduncles as much as 5.5 Mg/ha containing 6.10 and 13.81 kg/ha P and K were recycled. At the end of the study, the three different residue management practices (R1, R2, and R3) had significant effect on the soil extractable K and P contents; of which the P and K values of R1 (116.20, 729.67 mg/kg) were the highest followed by R3 (97.61, 658.67 mg/kg), and finally R2 (50.26, 533.83 mg/kg) (Table 2). Even though burning (R3) contributed relatively high amounts of P and K the lower concentrations of these macronutrients compared to R1 may be partly due to losses through surface runoff and leaching. Unlike crop residues which release nutrients relatively slowly, the opposite is the case of ash, and since ash was added at the early growth period, a period when P and K uptake in pineapple is generally slow (Py *et al.* 1987) and coupled with annual rainfall of 1917 mm (Ahmed 1999), P and K loss through surface runoff and leaching was possible. The lower P and K concentrations under R2 may be due the method of residue application. In R2, pineapple leaves, crowns, and peduncles were slashed and raked from 0.9 m x 10 m beds, and stacked in 0.6 m x 10 m beds. This might have affected the rate of the decomposition of the residues. The differences in soil extractable P and K however did not reflect in K and P uptake or fruit yield as shown in Table 4.

TABLE 2
Influence of different pineapple residue management practices on the status of soil extractable P and K at harvest

Residue Management	P	K
	mg/kg soil	
R1	116.20[a]	729.67[a]
R2	50.26[c]	533.83[c]
R3	97.61[b]	658.67[b]

Note: Different letters within columns indicate significant difference between treatment means using single degree of freedom contrast $P \leq 0.05$.

For no apparent reason, the effect of the different fertilizer regimes F1, F2, and F3 on K and P concentrations under the different residue management practices, differed significantly for only R1 (Table 3). Those under R2 and R3 were not significant. The fertilizer regimes also did not have significant influence on both K and P uptake, and fruit yield (Table 5). Studies have shown that cultivar Gandul P requirement on peat is generally low (Tay 1972, 1973; Selamat and Ramlah 1993; Razzaque *et al.* 1999) and hence, rarely responds to P application, but the presence of P enhances or increases the absorption of K in peat (Dunsmore 1957). In the case of K, at lower rates (0, 102, 203, 305 K kg/ ha), Selamat and Ramlah (1993) observed a significant linear response for fruit weight but at higher rates (0, 221, 442, 662, 883, and 1104 K kg/ha), such relationship was not obtained but rather, K uptake and fruit yield depressed at higher doses particularly at 883 and 1104 K kg/ha (Razzaque 1999).

TABLE 3
Effect of fertilizer regimes under different pineapple residue management practices on the status soil extractable P and K at harvest

Treatment	P	K
	mg/kg soil	
R1F1	161.10a	957.50a
R1F2	90.64b	565.00b
R1F3	96.85b	666.50b
R2F1	42.84ns	566.50ns
R2F2	47.70ns	444.50ns
R2F3	60.24ns	590.50ns
R3F1	86.23ns	659.50ns
R3F2	88.72ns	664.00ns
R3F3	117.87ns	652.50ns

Note: Same letter within columns indicates insignificant difference between treatment means using single degree of freedom contrast $P \leq 0.05$.
ns: indicates no significance between treatments

TABLE 4
Influence of different pineapple residue management practices on P and K uptake and yield

Residue Management	P	K	Yield
	g/plant		kg/m^2
R1	0.33	8.16	5.18
R2	0.36	8.93	5.09
R3	0.32	9.10	5.25

Note: No significant difference between residue management practices using single degree of freedom contrast $P \leq 0.05$ was observed for all the practices

TABLE 5
Effect of fertilizer regimes under different pineapple residue management practices on the uptake of P and K, and yield

Treatment Management	P	K	Yield
	g/plant		kg/m^2
R1F1	0.30	7.00	5.30
R1F2	0.41	10.48	5.16
R1F3	0.27	7.00	5.09
R2F1	0.31	7.22	5.21
R2F2	0.43	10.74	5.03
R2F3	0.33	8.84	5.03
R3F1	0.32	8.29	5.18
R3F2	0.30	8.42	5.24
R3F3	0.46	10.58	5.34

Note: No significant difference between treatments using single degree of freedom contrast $P \leq 0.05$ was observed for all the treatments

Without regard to air pollution that burning of pineapple residues (normal practice) may cause to the environment, the most expensive residue management practice was R2 and second to it was R3 (Table 6). The least expensive residue management practice was R1. However, the reverse was the case when the cost of pollution (Husni *et al.* 1999) was taken into account (Table 6).

Comparing the costs associated with fertilizer regimes F2 (RM 390.99/ha) and F3 (RM 547.77/ha) to the usual fertilization schedule F1 (RM 578.97/ha), it was realized F2 is the most

TABLE 6
Present value (12 % interest) of costs associated with different pineapple residue management practices

Management Practice	Type of Cost: Slashing of Leaves	Raking and Packing	Burning	Weeding	Total (a)	Air Pollution	Total (b)
	RM/ha						
R1	0	0	0	28.45	28.45	0	28.45
R2	85.34	42.67	0	14.22	142.23	0	142.23
R3	0	0	14.22	28.45	42.67	2,382.47	2,425.14

TABLE 7
Present value (12 % interest) of costs associated with different pineapple fertilizer regimes

Fertilizer Regime	MoP	CPR	Fertilizer Application	Total
	RM/ha			
F1	389.28	65.69	124.00	578.97
F2	256.57	41.42	93.00	390.99
F3	389.28	65.69	93.00	547.77

TABLE 8
Present value (12 % interest) of the overall costs associated with different pineapple fertilizer regimes under different pineapple residue management practices

Treatment	Residue Management (R)	Fertilizer Regime (F)	Total (R + F)
	RM/ha		
R1F1	28.45	578.97	607.42
R1F2	28.45	390.99	419.44
R1F3	28.45	547.77	576.22
R2F1	142.23	578.97	721.12
R2F2	142.23	390.99	533.22
R2F3	142.23	547.77	690.10
R3F1	2425.14	578.97	3004.11
R3F2	2425.14	390.99	2816.13
R3F3	2425.14	547.77	2972.91

cost effective practice in which as much as RM 187.98/ha (RM 578 – RM 390.99/ha) could be saved compared to RM 31.20/ha (RM 578.97 – RM 547.77/ha) for F3 (Table 7). Table 8 shows the overall costs for each treatment combination. The costs for the treatment combinations; R3F1, R3F2, and R3F3 (different fertilization regimes under burning pineapple residue) were generally higher than those under the respective unburnt (R1 and R2) practices. Under any of these three residue management practices, costs associated with the combination with F2 (R1F2, R2F2, and R3F2) were consistently lower than the other combinations. Among all the treatment combinations, R1F2 emerged the most cost effective (RM 419.44/ha) practice. It must however be pointed out that all is not well with this practice. Under this practice, pineapple residues are left untouched to decompose in situ and the fear is that a prolonged adoption without proper handling of the residues might not only lead to possible fire, pests and diseases outbreak but there is also the problem of adding more organic matter to the already existing one. In the course of the study, it was observed that it takes not less than 10 months for the pineapple residues to decompose. Regardless of burning pineapple residues on tropical peat or removing them from the field, observation shows that there is no significant difference between P, and K uptake (Ahmed *et al.* 1999), yield, and cost of production except the cost of land preparation of RM 218.95/ha for the unburnt practice (Husni *et al.* 1999). A residue management practice of this kind may not only take care of the limitation associated with the residue management practice R1F2 but the possibility of adding value or developing products from the removed pineapple residues that may off set the cost of removing the residues and other on-farm activities is there.

CONCLUSION

Burning, stacking of pineapple residue in rows or leaving pineapple residue to decompose in situ does not improve K and P uptake as well as yield. The application of K (188 kg/ha) and P (7 kg/ha) fertilizers at 233rd day after planting is not necessary and as this practice could save as much as RM 187.98/ha. The application of muriate of potash and China phosphate rock at the 65th, 135th, and 191st days (F2) under *in situ* decomposition of pineapple residue (R1) looks promising in terms of cost effectiveness.

ACKNOWLEDGEMENT

We are thankful to Mr. Lee Sing Kim, Mr. Koh Soo Koon and Mr Faisol Abdul Ghani, Simpang Rengam Pineapple Estate, Peninsula Pineapple Plantation, Johor, Malaysia for the partnership in the collaborative research. We also acknowledge the financial support of the National Council for Scientific Research and Development, Malaysia and the encouragement of Universiti Putra Malaysia (UPM) in research and development. We also appreciate the assistance of the staff of the Soil Fertility Laboratory, Department of Land Management, UPM.

REFERENCES

AGRIQUEST SDN. BHD. 1999/2000. *Malaysia Agricultural Directory and Index.* Kuala Lumpur: AGRIQUEST Sdn. Bhd.

AHMED, O. H., M. H. A. HUSNI, R.S. SYED OMAR and M. M. HANAFI. 2000. Nutrients distribution and cycling of pineapple planted on tropical peat. *Pertanika Journal of Tropical Agricultural Science* **23(1)** (in press).

AHMED, O. H., M. H. A. HUSNI, R.S. SYED OMAR, M. M. HANAFI and S. K. KOH. 1999. The effects of residue management practices on phosphorus and potassium uptake in pineapple. *Malaysian Journal of Soil Science* **3**: 29-37.

AHMED, O. H. 1999. Nutrients uptake and cycling of pineapple planted on tropical peat. Masters Thesis 95p. Universiti Putra Malaysia.

DAVIS, L. S. and K. N. JOHNSON. 1987. *Forest Management.* pp790. New York: McGraw-Hill, Inc.

DUNSMORE, J. R. 1957. Pineapple fertilizer in Malaysia. *Malay Agric. Journal* **40**: 159.

HUSNI, M. H. A.,O. H. AHMED, A.G. AWANG NOOR and S. K. KOH. 1999. Evaluation of burnt and unburnt pineapple residues management practices on tropical peat. In *Proc. Soil. Sc. Conf. of Malaysia 1999*, eds. J. Shamsuddin and J. Fauziah. pp. 125-132. Msss. Kuala Lumpur.

MURPHY, J. and P. J. RILEY. 1962. A modified single solution method for the determination of phosphate in natural waters. *Anal. Chem. Acta* **27**: 31-36.

PY, C., J. J. LACOEUILHE and C. TEISSEN. 1987. *The Pineapple Cultivation and Uses* (translated by Daphe and J. Goodfellow. 15 rue Victor-Cousin, Paris (ve).

RAZZAQUE, A. H. M. 1999. Improvement of pineapple production on tropical peat through fertilizer use. Ph.D. Thesis, 361 p. Universiti Putra Malaysia.

SAMPSON, J. A. 1980. *Tropical Fruits.* London: Longman.

SELAMAT, M. M. and M. RAMLAH. 1993. The response of pineapple cv. Gandul to nitrogen, phosphorus, and potassium on peat soils in Malaysia. *ACTA Horticulturae* **334**: 247-254.

TAY, T. H. 1972. Comparative study of different types of fertilizers as sources of nitrogen, phosphorous, and potassium in pineapple cultivation. *Tropical Agriculture* (Trinidad) **49**: 51-59.

TAY, T. H. 1973. Response of an improved Singapore Spanish pineapple to nitrogen, phosphorous, and potassium fertilization. *Planter* **49**: 414-420.

VAN LIEROP, W., Y. A. MARTEL and M. P. CESCAS. 1980. Optimal soil, pH, and sufficiency concentrations of N, P, and K max. alfalfa and onion yields on acid organic soils. *Can. J. Soil Sci.:* 107-117.

(Received: 29 June 2000)
(Accepted: 9 November 2001)