Original article

Pineapple response to nitrogen application on tropical peat: II. Effect on fruit yield and quality

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Abstract — Introduction. Field experiments were conducted to determine the optimum nitrogen rates for obtaining the best fruit yield and quality with cv. 'Gandul' (Spanish group of *A. comosus*) pineapple grown on peat soil. **Materials and methods**. Urea at the rates of 0, 200, 400, 600, 800 and 1 000 kg·ha^{-1} N was applied to experiments located at two sites in Malaysia. Data on fruit yield components – fruit length, fruit diameter, core diameter and fruit weight – were achieved. Fruit quality components – soluble solids concentrations and titratable acidity – were determined at harvest. **Results and discussion**. Application of N significantly influenced the fruit length and fruit core diameter at both sites, but fruit diameter and mean fruit weight were affected at only one of the sites. In the two locations, the highest fruit yield (57 et 63 t·ha^{-1}) was produced with 1 000 kg·ha^{-1} N. Nevertheless, no significant changes in fruit quality were highlighted. **Conclusion**. Application of about 800 kg·ha^{-1} N is required to realize the maximum economic returns with the cv. Gandul pineapple grown on peat soil in Malaysia. © Éditions scientifiques et médicales Elsevier SAS

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Réponse de l'ananas à l'apport d'azote sur tourbe tropicale : II. Effet de N sur le rendement et la qualité des fruits.

Résumé — Introduction. Des expérimentations en champ ont permis d'étudier les doses optimales d'azote (N) à appliquer pour obtenir conjointement les plus forts rendements et la meilleure qualité de fruit chez des ananas de la variété Gandul (groupe Spanish de l'espèce *A. comosus*) cultivés sur de la tourbe. **Matériel et méthodes**. Six doses d'azote ont été appliquées sous forme d'urée aux taux de 0, 200, 400, 600, 800 et 1 000 kg·ha^{-1} N sur les parcelles de deux sites d'expérimentation, en Malaisie. Les observations ont porté sur des composantes du rendement – longueur, diamètre du fruit, diamètre du cœur et poids du fruit –, et des caractéristiques de la qualité du fruit – teneur en solides solubles et acidité titrable – évaluées à la récolte. **Résultats et discussion**. Dans les deux sites expérimentaux, l'application d'azote a influencé de manière significative le diamètre du cœur et la longueur du fruit, mais le diamètre du fruit et son poids moyen n'ont été affectés que sur un seul de ces emplacements. Dans les deux endroits, le rendement le plus élevé (57 et 63 t·ha^{-1}) a été obtenu avec des applications de 1 000 kg·ha^{-1} N. Cependant, aucun changement important touchant la qualité du fruit n'a été mis en évidence. **Conclusion**. L'application d'environ 800 kg·ha^{-1} N est nécessaire à l'obtention des meilleures retombées économiques escomptables à partir de la culture de la variété Gandul sur tourbe en Malaisie. © Éditions scientifiques et médicales Elsevier SAS

Malaisie / *Ananas comosus* / réponse de la plante / rendement des cultures / fruits / qualité / tourbe / sol tropical / fertilisation / azote / dose d'application

1. introduction

Pineapple (*Ananas comosus* [L.] Merr.) is one of the major fruit crops in Malaysia where it is largely cultivated on peat soil. Approximately 7,054 ha of land is under pineapple cultivation with a total production of 121,915 t as fresh fruits [1]. But the production is declining each year in spite of the utmost effort by the growers to sustain it. At present, Gandul, a Spanish group variety well adapted to peat soil, is the principal cultivar grown for canning industry [2]. However, precise studies on its nutritional requirements are limited. As a result, the full yield potential of the cultivar is not realized.

Although peat contains high total nitrogen (N), pineapple responds with additional N application [3] which has the greatest effect on yield [4]. Fruit quality, such as fruit sugar and titratable acidity are important parameters for pineapple eating and canning quality. Nitrogen applications have been shown to influence these quality attributes to a large extent [3, 5, 6]. Therefore, the present studies were designed to find the optimum nitrogen rate(s) for optimum yield and fruit quality attributes in pineapple cv. Gandul cultivated on peat soil.

2. materials and methods

The same two field experiments as those described in the previous part of this work (related to the effect of N on plant growth, N uptake and recovery [7]) were used: they were conducted, with cv. Gandul pineapples, at two locations (designated as site 1 and site 2) at the Peninsula (Pineapple) Plantation Estate, Simpang Rengam, Johore, Malaysia. The main difference between the two sites is that site 1 has been under continuous pineapple cultivation for the last 24 years and that of site 2 for about 42 years. Cultivation, fertilizers and experiment design were already described [7]; six levels of N were studied: 0, 200, 400, 600, 800 and 1 000 kg·ha^{-1}.

Data on fruit yield components – fruit length, diameter, core diameter and fruit weight – were achieved. Fruit quality components – soluble solids concentrations and titratable acidity – were determined at harvest.

Fruit length, diameter and fruit core diameter were measured from 10 randomly selected fruits out of the 40 fruits harvested for measuring the individual fruit weight in each treatment; yield per ha was calculated multiplying the fruit weight with the total harvestable fruit number [3]. Soluble solids concentrations were estimated as Brix % using hand held refractometer with temperature adjustment (ATAGO N-1E, Japan) and acidity (% citric acid equivalent) as described by Tay [8].

The maximum and economic optimum levels of nitrogen (kg·ha^{-1}) were calculated from the response function equation [9]: $y = a + bN + cN^2$ [10]:

– the N maximum level (N_{max}) was equivalent to – b / 2c,

– the N economic optimum level (N_{opt}) was equivalent to 1/2 c ([Pf / Py] – b), where Pf = price of 1 kg nitrogen and Py = price of 1 kg fresh pineapple.

The analyses of variances (Anova) were calculated using the statistical package of Mstat (Mstat-C, Michigan State Univ.) and the mean values were compared by Duncan's New Multiple Range Test (DMRT) at 5 % level when significant F value existed.

3. results and discussion

3.1. fruit yield component

The fruit lengths of pineapple cv. Gandul were influenced significantly with all nitrogen application levels at both sites (*tables I* and *II*) if compared with the untreated control plants.

The fruit diameter was influenced significantly by N application only at site 1. The largest fruit diameter resulted from the application of 800 kg·ha^{-1} N and this was statistically similar to all other N treated

Table I.
Effect of different nitrogen levels on fruit yield and quality of cv. Gandul pineapple grown on peat soil at a first location, called site 1, which is a plot under continuous pineapple cultivation for the last 24 years, in Malaysia.

Nitrogen ($kg \cdot ha^{-1}$)	Fruit length (cm)	Fruit diameter (cm)	Fruit core diameter (cm)	Fruit weight (kg)	Fruit sugar (Brix %)	Fruit acidity[1]
0	15.0 b	12.1 b	1.78 b	0.99 c	10.01	0.67
200	16.4 a	12.4 ab	1.85 ab	1.06 bc	9.95	0.64
400	16.4 a	12.5 ab	1.97 a	1.12 b	9.68	0.63
600	16.6 a	12.5 ab	1.93 ab	1.16 b	9.66	0.63
800	16.9 a	12.9 a	2.01 a	1.17 a	9.66	0.62
1 000	16.4 a	12.4 ab	1.97 a	1.18 a	9.58	0.62
F test significance	**	**	**	**	ns	ns

Means within a column followed by the same letters are not significantly different at 5 % level by Duncan's New Multiple Range Test.
**: Significant means at 1 % level.
ns: not significant means at 1 % level.
[1] % equivalent of citric acid.

Table II.
Effect of different nitrogen levels on fruit yield and quality of cv. Gandul pineapple grown on peat soil at a second location, called site 2, which is a plot under continuous pineapple cultivation for about 42 years, in Malaysia.

Nitrogen ($kg \cdot ha^{-1}$)	Fruit length (cm)	Fruit diameter (cm)	Fruit core diameter (cm)	Fruit weight (kg)	Fruit sugar (Brix %)	Fruit acidity[1]
0	14.6 b	11.6	1.67 c	0.93	9.40	0.62
200	15.6 ab	11.8	1.71 bc	1.00	9.33	0.62
400	16.3 a	11.9	1.79 ab	1.05	9.33	0.68
600	16.2 a	12.0	1.81 a	1.06	9.53	0.67
800	16.7 a	12.0	1.76 abc	1.06	9.27	0.65
1 000	15.3 ab	11.9	1.80 ab	1.07	9.20	0.66
F test significance	**	ns	**	ns	ns	ns

Means within a column followed by the same letters are not significantly different at 5 % level by Duncan's New Multiple Range Test.
**: Significant means at 1 % level.
ns: not significant means.
[1] % equivalent of citric acid.

plants. The untreated control plants produced significantly the lowest fruit diameter at this site.

There were significant effects of N on the fruit core diameter of pineapple at the two sites. At site 1, the largest core diameter was stastistically recorded with the 400, 800 and 1 000 $kg \cdot ha^{-1}$ N. Furthermore, the core diameter produced in the control treatment was identical to those of 200 and 600 $kg \cdot ha^{-1}$ N (*table I*). At site 2, the largest fruit core diameter resulted from the application of 600 $kg \cdot ha^{-1}$ N. Core diameters produced in the fruits of untreated plants were similar to those of 200 and 800 $kg \cdot ha^{-1}$ N (*table II*).

The effect of N on pineapple fruit components is not consistent. Mustaffa [6] found no significant effect of N on fruit length and

fruit diameter in Kew pineapple, however, the maximum fruit length and diameter were recorded with 500 and 700 kg·ha^{-1} N. While significant increase in fruit length and diameter with the application of 400 kg·ha^{-1} N were reported by Dodson [11]. Significant increase in fruit length, fruit diameter and fruit core diameter with increased N levels also occurred in the cv. Gandul on peat soil [3].

3.2. pineapple fruit yield

The mean pineapple fruit weight was significantly affected only at site 1. The statistically greatest fruit weight was produced with the higher N levels: 800 and 1 000 kg·ha^{-1} N. Fruit weights produced with other N treatments were similar to each other, however, the application of 200 kg·ha^{-1} N also gave results not significantly different to those of the control treatment. The pineapples of the untreated control were the least heavy (*table I*).

Effect of N on the pineapple fruit weight has been obvious from many works on both mineral and peat soils. But the levels of N application vary widely, depending largely on the initial N status of the soil, cultivar, location of cultivation and growing environments [11, 12]. In most cases, the effect of lower doses of N is sharp and, at higher doses, fruit weights reach to plateau or has a depressing effect. Similar variability was also evident on peat soil [13–15]. A significant increase in mean fruit weight with the applied nitrogen was observed in another field trial with the cv. Gandul [3]. Tay [16] observed a quadratic response in the mean fruit weight by increasing N rates up to 672 kg·ha^{-1}. Asoegwu [10] observed a significant increase in individual fruit weight with increased N in Smooth Cayenne pineapple.

Fruit yield of cv. Gandul pineapple increased quadratically with increased N rates both at site 1 (R^2 = 0.99**) and site 2 (R^2 = 0.97*). The increase in yield continued until the application of 800 kg·ha^{-1} N and thereafter tended to decline with further increase in N at both sites (*figure 1*). Selamat and Ramlah [3] reported the yield of 44.5 t·ha^{-1} without nitrogen and 55.2 t·ha^{-1} with the application of 353 kg·ha^{-1} N. However, a linear increase in fruit weight until the application of 896 kg·ha^{-1} had also been reported in other cultivars grown on peat soil [13, 14]. Mustaffa [6] reported a significant increase in fruit yield up to the application of 500 kg·ha^{-1} and declined beyond that rate in Kew pineapple.

To realize the full yield potential of a cultivar, a judicious application of N along with other nutrients are essential. The levels of N that would produce the maximum and economic optimum yields of pineapple cv. Gandul were determined from the response function equations at both sites. The maximum and economic levels of N were 919 and 857 kg·ha^{-1} N for site 1 and 782 and 720 kg·ha^{-1} N for site 2.

3.3. fruit quality attributes

At either site, nitrogen levels had no significant effect on pineapple soluble solids concentrations (SSC) and titratable acidity (TA). However, fruit SSC tended to decline with the application of N, the highest content being recorded in the unfertilized fruits. At site 1, TA tended to decline with increased N rates, but there was no consistency at site 2.

Pineapples grown on peat soils did not show either any significant response to N application on sugar content in Singapore Spanish variety [15]. But, in many trials, sugar contents were found to decrease with increased nitrogen in peat soils [13, 14, 16].

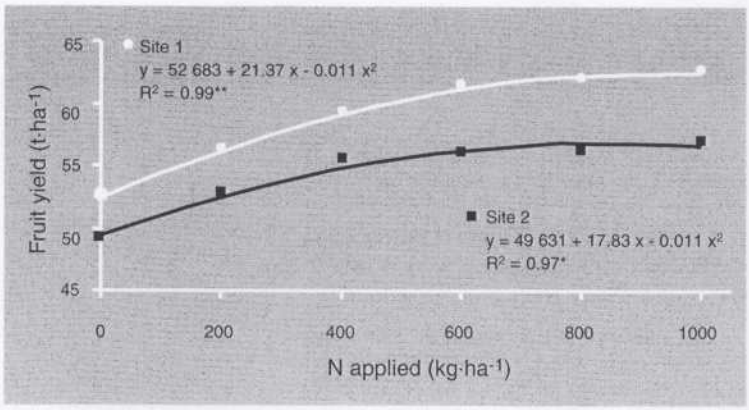

Figure 1.
Effect of different levels of nitrogen on the yield of cv. Gandul pineapple grown in two Malaysian locations.

Contrary to the present study results, nitrogen showed a significant effect on fruit sugar contents in the cv. Gandul in another trial on deep peat soil. Considerably low content of sugar was found in fruits raised with high levels of N [3]. Results of previous works with other pineapple varieties indicated similar response regarding fruit acidity as in the present study. Mustaffa [6] found a significant decrease in acid contents with increased N applications in Kew pineapple. This was in agreement with the results of Dodson [11] and Velez-Ramos and Borges [5]. Others however reported insignificant effect of N on fruit acidity [5, 15, 17]. Reduction in acid content in pineapple cv. Gandul resulted with the application of N on peat soil [3].

4. conclusion

Despite a high content of total N in peat soil, pineapple responded in respect of fruit yield with higher N level application at both experiment sites of the study. Since the requirement of N is high, pineapple depletes the natural reserves of peat, unless N is applied judiciously. N application as high as 857 $kg \cdot ha^{-1}$ (site 1) and 720 $kg \cdot ha^{-1}$ (site 2) are required to realize the high yield potential of the cv. Gandul with maximum economic returns on peat soils in Malaysia.

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Respuesta de la piña al aporte de nitrógeno en turba tropical: II. Efecto del N en el rendimiento y calidad de los frutos.

Resumen — Introducción. Una serie de experimentos de campo permitió estudiar las dosis óptimas de nitrógeno (N) que había que aplicar para obtener a la vez los rendimientos más altos y la mejor calidad de fruta en piñas de la variedad 'Gandul' (grupo Spanish de la especie *A. comosus*) cultivadas en turba. **Material y métodos**. Se aplicaron seis dosis de nitrógeno en forma de urea con una tasa de 0, 200, 400, 600, 800 y 1 000 kg·ha^{-1} N en las parcelas de los dos sitios de experimentación, en Malasia. Se observaron los componentes del rendimiento: longitud, diámetro del fruto, diámetro del corazón y peso del fruto; así como las características de calidad del fruto: contenido de sólidos solubles y acidez titulable, evaluadas durante la cosecha. **Resultados y discusión**. En ambos sitios experimentales, la aplicación de nitrógeno influyó considerablemente en el diámetro del corazón y la longitud del fruto, pero el diámetro del fruto y su peso medio sólo se vieron afectados en uno de los emplazamientos. En ambos lugares, el rendimiento más alto (57 y 63 t·ha^{-1}) se obtuvo con aplicaciones de 1 000 kg·ha^{-1} N. No obstante, no se puso de manifiesto ningún cambio significativo en cuanto a la calidad del fruto. **Conclusión**. Se necesita la aplicación de unos 800 kg·ha^{-1} N para obtener el mejor impacto económico a partir del cultivo en turba de la variedad Gandul en Malasia.

Malasia / *Ananas comosus* / respuesta de la planta / rendimiento de cultivos / frutas / calidad / turba / suelo tropical / aplicación de abonos / nitrógeno / dosis de aplicación