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Selection of sweetpotato clones for flour production

(Pemilihan klon ubi keledek untuk pengeluaran tepung)

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Key words: *Ipomoea batatas,* sweetpotato clones, multi-location testing, agro-ecologies, flour, starch

Abstract

In order to expand the current demand for sweetpotato in Malaysia, further processing into bakery and pasta products using the flour should be considered. This will also be a means of reducing the large annual wheat flour import bill. A high conversion rate from fresh roots to flour calls for a root dry matter content in excess of 35%. Ten introductions of sweetpotato clones from Peru and Japan were evaluated against local check varieties, Gendut, Telong and Jalomas, in four contrasting agro-ecologies (upland mineral soils, *bris,* sand-tailings and acid sulphate soils), the latter three of which are considered marginal, over one to two seasons. While none of the test clones had outstanding fresh root yields compared with Telong, four Japanese clones (KNAES99T-1, KNAES99T-2, KNAES99T-3 and Kyukei 63) had the highest root dry matter contents, ranging from 36.6% to 37.4%, sufficiently high for making flour. Taking both fresh root yield and root dry matter content into consideration, the best clone would be KNAES99T-1. The *bris* agro-ecology generally supported the highest fresh root yields.

Introduction

Sweetpotato *[Ipomoea batatas* (L.) Lam.] is a minor root crop in Malaysia, and one of the popular cash crops grown by small farmers for the fresh market. The demand for sweetpotato used for table consumption is somewhat limited, and is one of the reasons why the cultivated area for this crop has remained around 2,000 ha a year in Peninsular Malaysia (Anon. 1990–2000).

Demand is likely to increase if sweetpotato were used not only for direct fresh consumption, but as a raw ingredient in food processing. For example, wheat flour imports into Malaysia amount to around RM800 million a year (Anon. 2002). Sweetpotato flour can be used as a partial substitute of wheat flour in bakery (Salma and Zaidah 2006) and pasta products (Komaki and Yamakawa 2006; Salma, O., MARDI, pers. comm. 2006). Hitherto, most of the varieties planted by farmers are low in root dry matter or starch content (Tan et al. 2000b). In order to use sweetpotato as flour, the conversion rate from fresh roots must be improved; a dry matter content of at least 35% has been suggested for processing flour (Komaki and Yamakawa 2006).

Materials and methods

Ten clones with high starch content were introduced from the International Potato

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Center (CIP), Peru, and from the National Agricultural Research Center for Kyushu and Okinawa (KONARC), Japan *(Table 1)* in 1999. After bulking up of planting materials and preliminary yield evaluation, they were tested against three local checks – Gendut, a MARDI table variety, Telong and Jalomas, MARDI's processing varieties – in a series of trials sited in contrasting agro-ecologies. The agro-ecologies were upland mineral soils (MARDI Headquarters Serdang, Selangor and MARDI Seberang Perai), *bris* or sandy beach deposits (farmer's field in Kandis, Kelantan), the sand fraction of tin-tailings (farmer's field in Kuala Bikam, Perak) and acid sulphate soils (MARDI Kuala Linggi, Negeri Sembilan). The last three environments are considered marginal areas for cultivation because of inherent low soil fertility, high soil temperature and/or low soil pH, but sweetpotato will grow favourably in these areas if appropriate agronomic practices are adopted (Tan et al. 2000a).

The 13 clones were evaluated in trials set out in randomized complete block design, each having four replications. The trials were conducted over two seasons in each agro-ecology, except on *bris* where the evaluation was carried out only for one season. The recommended plant spacing of 25 cm x 1 m, apical cuttings of 30 cm length as planting materials, standard fertilizer rates and soil amelioration practices for the respective agro-ecologies (Tan 2002) were adopted. Irrigation was applied by sprinklers in the first two weeks in all the trials to ensure good plant establishment, and as and when required in the sandy soil environments (i.e. *bris* and sand-tailings).

At the end of four months, the crops were harvested, and data were collected on total fresh root yield and harvest index (total fresh root weight divided by total fresh plant weight). A chopped up sample of 100 g of roots was oven-dried at 70 °C until constant weight to determine root dry matter content (a character which correlates with starch content). Dry root yield was then calculated by multiplying fresh root yield by dry matter content. Using the SAS statistical package, combined analyses of variance (ANOVA) were carried out on data collected in the first season from all five sites, and on two seasons' data from four sites, viz. two on upland mineral soils, and one each on tin-tailings and acid sulphate soils.

Starch contents of all the clones, including the three checks, from the first season's trial on acid sulphate soils were also determined.

Table 1. Ten sweetpotato clones with high root dry matter content and three checks and their origin

Name of clone/variety	Origin	Institution
Koganesengan	Japan	CIP
Minamiyutaka	Japan	KONARC*
Shiroyutaka	Japan	KONARC
KNAES99T-1	Japan	KONARC
KNAES99T-2	Japan	KONARC
KNAES99T-3	Japan	KONARC
101291	Thailand	CIP
Kyukei No. 63	Japan	CIP
TIS 2498	Burundi	CIP
Unknown	Peru	CIP
Gendut – Check 1 (table variety)	Malaysia	MARDI
Telong – Check 2 (processing variety)	Malaysia	MARDI
Jalomas – Check 3 (processing variety)	Malaysia	MARDI

*Formerly known as Kyushu National Agricultural Experiment Station (KNAES)

Results and discussion

Performance of clones

Single-season data In the first combined ANOVA using first season's data from all five sites on four agro-ecologies, the results show that none of the 10 test clones outperformed the check variety Telong which attained a mean fresh root yield, significantly higher (at 18.7 t/ha) than all the rest *(Figure 1)*.

Following after Telong were check variety Gendut, KNAES99T-1, Minamiyutaka, KNAES99T-3 and the third check Jalomas (ranging from 14.6 to 15.9 t/ha). By contrast, the Japanese clones, KNAES99T-3, KNAES99T-2, KNAES99T-1, Shiroyutaka and Kyukei No. 63, had highest values for root dry matter content, ranging 36.6–39.0% *(Figure 1)*. These values are generally higher than what has so far been recorded in sweetpotato grown in Malaysia (Zaharah et al. 2004), and in excess of the 35% level set by Komaki and Yamakawa (2006). As a result of their higher dry matter contents, KNAES99T-1 and KNAES99T-3 produced dry root yields which were not significantly different from Telong (5.88–6.17 t/ha) *(Table 2)*.

Using the correlation coefficient of 0.689 between dry matter and starch contents (Mok et al. 1996), the starch contents of KNAES99T-1, KNAES99T-2, KNAES99T-3, Shiroyutaka and Kyukei No. 63 will range from 25.2–26.9%. These calculated values are in quite close agreement with the data from actual starch analysis on samples from a single site *(Figure 2)*, where they range from 24.8–29.1% for the five clones mentioned. Such values are just as high as the starch contents of local cassava varieties. For example, recent cassava varieties, Sri Kanji 1 and Sri Kanji 2, released by MARDI boast of starch contents of 27% or more (Mohsin et al. 2005).

For harvest index, KNAES99T-1 and Minamiyutaka had significantly higher values (0.55 and 0.54, respectively) than the others, followed by Telong, Shiroyutaka, Gendut and Jalomas (0.47–0.49) *(Table 2)*. A high harvest index is desirable as it reflects the accumulation of dry matter in favour of the economic plant part, in this case the storage roots.

Two-season data When the two seasons' data over four sites on three agro-ecologies were analysed, the mean fresh root yield of the check Telong (13.3 t/ha) was significantly higher than all the test clones. Nevertheless, KNAES99T-1 had a mean fresh root yield level (10.3 t/ha), equivalent

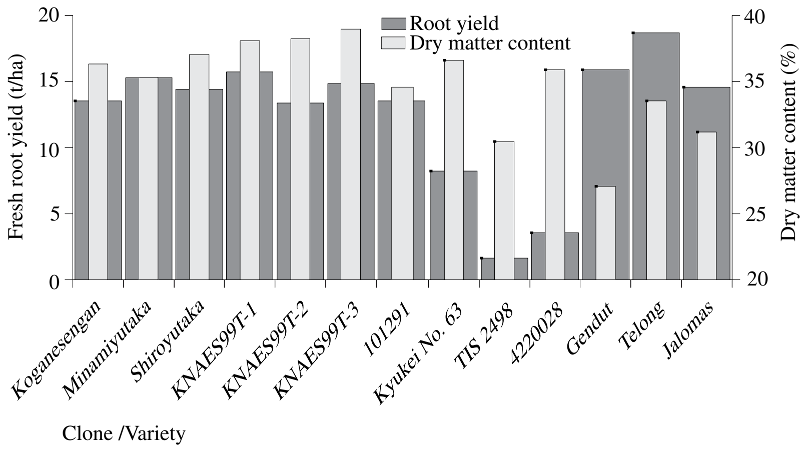

Figure 1. Mean fresh root yields and root dry matter contents of 10 test clones and three check varieties of five sites over four agro-ecologies in the first season

Table 2. Harvest indices and dry root yields of 10 sweetpotato clones with high root dry matter content against three checks at five sites on four contrasting agro-ecologies (single season's data)

Group	Harvest index	Dry root yield (t/ha)
Clone/Variety		
Koganesengan	0.41c	4.88cd
Minamiyutaka	0.54a	5.30bc
Shiroyutaka	0.48b	5.30bc
KNAES99T-1	0.55a	6.08a
KNAES99T-2	0.36d	5.19c
KNAES99T-3	0.41c	5.88ab
101291	0.37d	4.76cd
Kyukei No. 63	0.30e	3.31e
TIS 2498	0.07g	0.73f
420028	0.21f	1.26f
Gendut – Check 1	0.47b	4.45d
Telong – Check 2	0.49b	6.17a
Jalomas – Check 3	0.47b	4.64cd
Agro-ecology/Site		
Upland mineral soils	0.29d	5.75b
Serdang	0.12e	1.47e
Seberang Perai		
Bris (Kandis)	0.44c	8.99a
Tin-tailings (Kuala Bikam)	0.55b	2.48d
Acid sulphate soils (Kuala Linggi)	0.58a	3.96c

Values within a column in the same group and bearing the same letter are not significantly different from one another at $p = 0.05$ according to DMRT

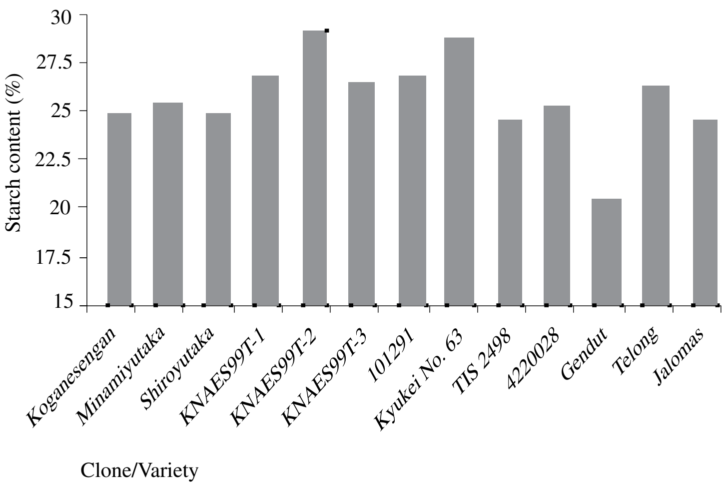

Figure 2. Starch contents of the 10 clones including the check varieties, Gendut, Telong and Jalomas, in root samples collected from the acid sulphate site

Table 3. Agronomic performance of 10 sweetpotato clones with high root dry matter content against three check varieties over two seasons at four sites on three contrasting agro-ecologies+

Group	Fresh root yield t/ha)	Harvest index	Dry matter content (%)	Dry root yield (t/ha)
Clone/Variety				
Koganesengan	7.8cde	0.39cde	36.3ab	2.83cd
Minamiyutaka	7.4de	0.50a	34.3de	2.60d
Shiroyutaka	8.0cde	0.44bc	35.8bc	2.97cd
KNAES99T-1	10.3b	0.53a	36.6ab	3.84b
KNAES99T-2	6.7e	0.29g	37.4a	2.68d
KNAES99T-3	8.7cd	0.36ef	36.8ab	3.26c
101291	9.0c	0.34f	33.8de	3.07cd
Kyukei No. 63	3.9f	0.20h	36.6ab	1.73e
TIS 2498	0.7h	0.05i	31.3f	0.50f
420028	2.6g	0.17h	34.8cd	0.95f
Gendut – Check 1	11.3b	0.41bcd	26.3h	3.09cd
Telong – Check 2	13.3a	0.45b	33.4e	4.59a
Jalomas – Check 3	8.1cd	0.37def	29.7g	2.61d
Agro-ecology/Site				
Upland mineral soils				
Serdang	8.8b	0.28c	38.8a	3.94a
Seberang Perai	5.0d	0.17d	34.2b	1.90d
Tin-tailings (Kuala Bikam)	6.7c	0.51a	33.0c	2.23c
Acid sulphate soils (Kuala Linggi)	9.6a	0.43b	31.0d	3.19b
Season				
Season 1	9.2a	0.38a	35.3a	3.42a
Season 2	5.9b	0.31b	32.9b	2.13b
Interaction effects				
Season x Clone	**	**	n.s.	**
Site x Clone	**	**	*	**
Season x Site x Clone	**	**	n.s.	**

+Upland mineral soils, tin-tailings and acid sulphate soils
Values within a column in the same group and bearing the same letter are not significantly different from one another at $p = 0.05$ according to DMRT
n.s. = Not significant; * = Significant at $p = 0.05$; ** = Significant at $p = 0.01$

to Gendut (11.3 t/ha), and significantly higher than the third check, Jalomas (8.1 t/ha) *(Table 3)*. The top four clones for high dry matter content were the Japanese clones, KNAES99T-2, KNAES99T-3, KNAES99T-1 and Kyukei No. 63, confirming the results from the first season. In this case, only KNAES99T-1 had a mean dry root yield higher than those of Gendut and Jalomas, but was significantly lower than that of Telong. As before, KNAES99T-1 had the highest harvest index of 0.53, which was not significantly different from that of Minamiyutaka (0.50).

Performance of agro-ecologies

Single-season data The combined ANOVA using only first season's data showed that the *bris* environment produced significantly higher fresh and dry root yields (26.2 and 8.99 t/ha, respectively), while upland mineral soils at Serdang produced the highest mean dry matter content of 40.1% *(Figure 3)*. The highest mean harvest index (0.58) was recorded in the acid sulphate environment *(Table 2)*.

Significant site x clone interactions were noted for fresh root yield, harvest index and dry root yield, but not for dry

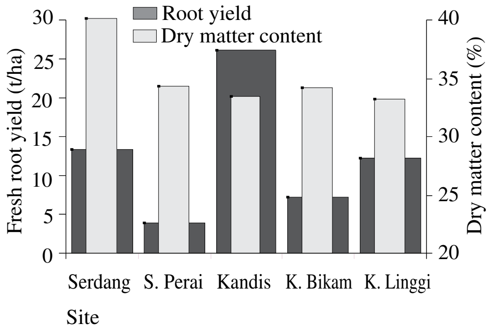

Figure 3. Mean fresh root yields and root dry matter contents at five sites in four agro-ecologies in the first season (Serdang and Seberang Perai = upland mineral soils; Kandis = bris; Kuala Bikam = tin-tailings; Kuala Linggi = acid sulphate soils)

matter content. Thus, dry matter or starch content may be considered a fairly stable character in sweetpotato over contrasting agro-ecologies.

Two-season data For the combined ANOVA using two seasons' data from three agro-ecologies, the agro-ecology with the highest mean fresh yield was the acid sulphate soils, while upland mineral soils still recorded the highest mean dry matter content *(Table 3)*. The tin-tailing agro-ecology recorded the highest mean harvest index. Generally, better agronomic performance was recorded in the first season than in the second *(Table 3)*.

Significant season x clone, site x clone and season x site x clone effects were noted for fresh and dry root yields and for harvest index. Dry matter content had no significant interaction effects for season x clone and season x site x clone, once again confirming its relatively more stable nature.

Yield performance was generally poor at all the sites in both seasons, as all the agro-ecologies had been reported to support yields from Telong and Gendut in access of 20 t/ha (Tan et al. 2000b; Tan 2002).

Conclusion

Telong and Jalomas were released in the year 2000 as varieties suitable for processing into flour at that time. Although check varieties Telong and Gendut produced the highest mean fresh yields in this series of trials, KNAES99T-1, KNAES99T-2 and KNAES99T-3 with their higher dry matter contents will give better conversion rates to flour.

The use of these clones as a starch source, however, may not be practical from the standpoint of economics. Cassava starch varieties sell at RM0.18/kg and they have a high root starch content, whereas low sweetpotato prices are in the region of RM0.30/kg. It is therefore unlikely that farmers will be willing to plant sweetpotato for sale to starch processing factories at the price of RM0.18/kg. By contrast, table varieties of sweetpotato can fetch as much as RM0.70/kg.

Planting the high dry matter clones in marginal areas such as *bris* and tin-tailings can produce even higher yields than on upland mineral soils. This is important as sweetpotato needs a niche production area which faces less competition from other more lucrative crops, such as oil palm and fruits, to be able to take off as a source of raw material for industry.

As in the case of cassava (Tan and Mak 1993), root dry matter content is a more stable character compared to fresh

Plate 1. Leaf, shoot and flower characteristics of clone KNAES99T-1

Plate 2. Storage roots of KNAES99T-1

root yield, with season x clone and season x site x clone effects being insignificant in this study. This being the case, it would make sense for the selection of clones for flour or starch production to be based more on a combination of dry matter content and fresh root yield, rather than on fresh root yield alone. Taking this into account, KNAES99T-1 would be the best selection. Some morphological characteristics of KNAES99T-1 are given in the *Plates 1* and *2* as well as in *Appendix* 1.

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Abstrak
Untuk meningkatkan permintaan ubi keledek di Malaysia, pemprosesan selanjutnya menjadi produk reroti dan pasta daripada tepung ubi keledek patut dipertimbangkan. Ini bertujuan untuk mengurangkan jumlah import gandum yang begitu banyak setiap tahun. Kadar pertukaran menjadi tepung memerlukan kandungan bahan kering di dalam ubi yang melebihi 35%. Sepuluh klon ubi keledek yang berasal dari Peru dan Jepun diuji bersama varieti bandingan tempatan, Gendut, Telong and Jalomas, di empat agro-ekologi yang berbeza (tanah mineral biasa, *bris,* tanah bekas lombong dan tanah asid sulfat) selama satu atau dua musim. Selain tanah mineral biasa, yang lain dianggap sebagai tanah marginal. Walaupun tiada klon ujian melebihi varieti bandingan Telong dari segi hasil ubi basah, empat klon dari Jepun (KNAES99T-1, KNAES99T-2, KNAES99T-3 dan Kyukei 63) memberi kandungan bahan kering yang tertinggi, iaitu dalam lingkungan 36.6% hingga 37.4%. Nilai ini sudah mencukupi untuk dipertimbangkan bagi pemprosesan kepada tepung. Jika hasil ubi basah dan kandungan bahan kering diambil kira bersama, klon yang terbaik ialah KNAES99T-1. Agro-ekologi *bris* pada amnya memberi hasil ubi basah yang terbaik.

Appendix 1. Morphological characteristics of KNAES99T–1

Plant organ	Character	Description
Leaf	Shoot colour	Light green with slight brownish tinge
	Mature colour	Green
	Leaf shape	Cordate
	Abaxial vein colour	Green
Vine	Vine colour	Yellowish-green
Storage root	Shape	Oblong to spindle-shaped
	Skin colour	Light brown
	Flesh colour	White
Flower	Colour	Pale lilac with purple throat

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