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Effect of bed size and spacing on sweetpotato yield

(Kesan saiz batas dan jarak tanaman terhadap hasil keledek)

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Key words: sweetpotato, bed size, spacing, yield, size grades

Abstrak

Penanaman ubi keledek (kultivar Gendut) di batas rata dengan lebar 1.3 m dan 2.0 m dibandingkan dengan penanaman di batas biasa dengan lebar 2.0 m yang diamalkan oleh petani. Saiz dan jenis batas ini diuji bersama jarak tanaman 20, 25 dan 30 cm antara pokok serta menanam satu atau dua baris setiap batas. Jarak di antara dua baris pokok ialah 50 cm untuk batas rata dan 25 cm untuk batas biasa, manakala batas rata 30 cm tinggi dan batas biasa 50 cm tinggi. Selepas dua musim ujian, hasil ubi yang paling tinggi (sehingga 29.0 t/ha) diperoleh apabila menanam di batas rata yang lebarnya 1.3 m pada jarak tanaman 20 atau 25 cm dengan menggunakan dua baris sebatas. Tindak balas hasil merupakan fungsi bilangan pokok sehektar: gabungan amalan yang tersebut memberi populasi sebanyak 61 500–76 900 pokok/ha. Namun begitu, lebih tinggi peratusan ubi besar (>20 cm panjang) dihasilkan jika menggunakan batas biasa 2.0 m lebar pada jarak tanaman 30 cm serta satu baris pokok sebatas, seperti yang diamalkan oleh petani masa kini. Oleh yang demikian, pada masa depan jika harga ubi bergantung pada gred, amalan penanaman ini patut dipertimbangkan.

Abstract

Planting sweetpotato (cv. Gendut) on raised flat beds of 1.3 and 2.0-meter widths were tested against the farmers' preferred practice of using 2.0-meter ridges. Superimposed on bed size were plant spacings of 20, 25 and 30 cm, as well as single or double planted rows per bed. The distance between double rows was 50 cm for the flat beds, and 25 cm for the ridges, while the height of beds was 30 cm and 50 cm for ridges. Over two seasons of testing, the highest total root yield (up to 29.0 t/ha) was recorded when planting on 1.3 m wide flat beds, at 20 or 25 cm plant spacing using double rows per bed. Yield responses appear to be a function of plant population and the above-mentioned combination of practices give a population of 61 500–76 900 plants/ha. Nevertheless, a higher percentage of large roots (>20 cm length) resulted from the use of 2.0 m ridges at 30 cm plant spacing with single-row planting, as is currently practised by some farmers. Thus, if in the future root price is based on grades, this combination of practices should be considered.

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Introduction

Considerable interest has been shown in techniques to increase the yield of sweetpotato (*Ipomoea batatas* (L.) Lam.) with the view of improving food production. The need is never more urgent than now, following the economic recession which hit Malaysia in 1997, and which has resulted in a huge food import bill of almost RM12 billion per year (Raziah 2001).

The earliest record of research on cultural techniques to improve sweetpotato yield was by Chan (1969) who showed that yield was enhanced by closer plant spacing, but not by row spacing, nor size of beds. The cultivar used in his investigations was Centennial. Since then, there has been no record of local work in this area, and as such the usual spacing and bed size practised by researchers has been maintained at 1 m row spacing, 25 cm plant spacing, and a bed size of 60 cm wide at the base with a height of 30 cm. These spacings and bed size have not found favour with many sweetpotato growers who opt for much larger bed size – anywhere from 1.5 to 2.0 m.

Chew (1970) found that while several sweetpotato cultivars responded in a variable fashion to fertilizer rate and growing period, the cultivar Centennial and two other popular table cultivars responded poorly. This may explain why Centennial did not respond significantly to the high and wide beds tested by Chan (1969). By contrast, Kimber (1976) in Papua New Guinea showed that spacing, size and type of bed influenced the yield of several sweetpotato cultivars. The introduction, in recent years, of exotic sweetpotato germplasm which have higher yield potential plus shorter maturity periods also opens the way to re-examining the effect of spatial arrangement on yield. Furthermore, with the advent of machine planting and harvesting to reduce labour requirement (and overcome farm labour shortages), there is a critical need for new planting techniques to suit tractor wheel spacing.

An experiment was conducted at MARDI Station Seberang Perai over two seasons to study the effect of planting techniques on yield in sweetpotato.

Materials and methods

The experiment was sited at the station in a field of deep gravelly sandy clay loam over light brown gravelly sandy clay.

In formulating the treatments, the requirements of mechanized production were taken into consideration. Raised flat beds of 1.3-m and 2.0-m widths were tested against the farmers' preferred practice of 2.0-m ridges. Incorporated into these three treatments was plant spacing of 20, 25 and 30 cm (making up the main plots of a split-plot experiment). The number of planted rows, single or double, made up the sub-plots. The distance between double rows was 50 cm for the flat beds, and 25 cm for the ridges, while the height of beds was 30 cm and 50 cm for ridges *(Figure 1)*. The main plot measured 20 m while the sub-plot was 10 m. All plots were replicated thrice.

Apical cuttings of 30 cm length were taken from cultivar Gendut, and soaked in malathion solution before planting (as a control measure against the sweetpotato weevil). Fertilizers at the rate of 35 kg N, 35 kg P_2O_5 and 70 kg K_2O per ha using the straight fertilizer sources urea, triple superphosphate and muriate of potash, respectively, were applied at planting. Carbofuran granules (at 1 g per plant) were applied at 3-weekly intervals, starting at 2 weeks, until the 14th week after planting. Overhead sprinkler irrigation was used when necessary.

In both seasons, the crops were harvested after 4 months. Data were collected on plant weight (i.e. vines and leaves) and weight of storage roots. The storage roots were also separated into damaged and undamaged roots, and graded by size:

Large : >20 cm length
Medium : 10–20 cm length
Small : <10 cm length

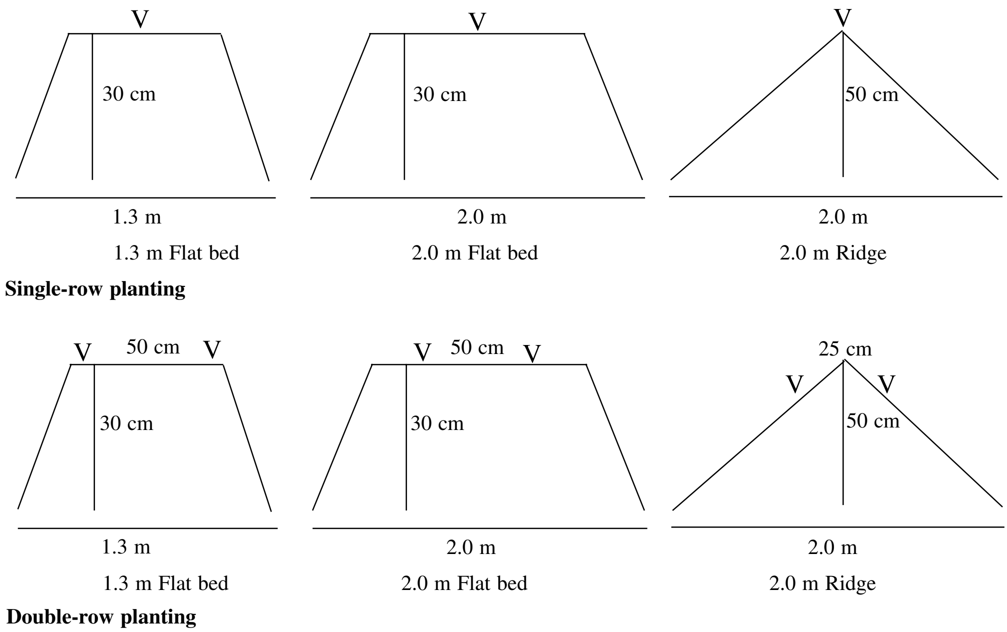

*Figure 1. Dimensions of the flat beds and ridges as well as row spacings used in the study (**V** = sweetpotato plant)*

Results and discussion

Analyses of variance combined over two seasons revealed significant single-factor effects *(Table 1)*. Interaction effects were less noticeable except for some planting practices with season *(Table 2)*. Total yield (both in terms of root number and weight per hectare) as well as plant weight were highest when 1.3-m beds were used. Root yield reached almost 30 t/ha, while plant weight peaked at 31 t/ha. In this treatment, the plant spacings of 20 cm and 25 cm resulted in significantly higher root yields compared to 30 cm spacing, while double rows further increased the yield by 20%. The effect of these plant spacings confirm the results of Chan (1969), although with the low-yielding cultivar Centennial, he was unable to evoke any positive reaction from the use of wider and higher beds. The current results with cultivar Gendut also showed that larger beds do not ensure higher yields of sweetpotato. A bed size of 1.3 m using double-row planting not only results in higher root yields but can also accommodate the requirements of mechanization.

The key to high root yield is plant density. While larger bed size (e.g. 2.0 m vs 1.3 m) appears to yield more on a per bed basis, in reality the narrower 1.3 m bed will result in a higher plant population per hectare. This is further increased with a closer plant spacing of 20 or 25 cm and the practice of double-row planting. The current recommended practice of using 1.0 m sized ridges and a plant spacing of 25 cm results in a population of 40 000 plants per hectare. A double row planting system using 1.3 m beds at 20 cm plant spacing produces a population of over 76 900 plants per hectare. If a plant spacing of 25 cm were used instead, the population will be more than 61 500 plants per hectare.

Yields of the various grades of storage roots due to the different treatments are shown in *Table 3*. Both undamaged and damaged roots were taken into account in the calculations of percentages of the different grades. It appears that a higher plant population led to a decline in the number and corresponding weight of large roots, e.g. 49% of total root weight for 20

Table 1. Response of sweetpotato cv. Gendut to planting practices (per hectare basis)

Planting practice	Total root		Plant weight (t)	Large roots (>20 cm length)				Medium roots (10–20 cm length)				Small roots (<10 cm length)			
	No.	Wt. (t)		Undamaged		Damaged		Undamaged		Damaged		Undamaged		Damaged	
				No.	Wt. (t)	No.	Wt. (t)	No.	Wt. (t)	No.	Wt. (t)	No.	Wt. (t)	No.	Wt. (t)
Bed size and type*															
1.3 m, F	155 737a	28.99a	31.27a	3 5170a	13.67a	3 333ab	1.32b	4 7022a	8.31a	4 935a	0.91a	6 0705a	4.41a	4 572a	0.37ab
2.0 m, F	110 065b	21.02b	22.97b	2 6152b	10.37b	2 388b	1.02b	31 069b	5.66b	3 777a	0.73a	43 888b	3.03a	2791a	0.21b
2.0 m, R	94 859c	21.19b	21.67b	21 750c	10.20b	4 597a	2.35a	24 444c	4.62b	5 527a	1.11a	33 041c	2.46b	5 500a	0.45c
Plant spacing															
20 cm	132 870a	24.25a	25.86a	26 473a	10.46b	3 371a	1.49a	37 072a	6.80a	5 633a	1.08a	55 114a	3.99a	5 207a	0.44a
25 cm	120 616b	24.71a	25.01a	28 849a	12.17a	3 980a	1.83a	34 378a	6.35a	4 221a	0.81a	45 679b	3.24ab	3 509a	0.30a
30 cm	107 234c	22.25b	25.03a	27 759a	11.60ab	2 966a	1.36a	31 135a	5.44a	4 386a	0.88a	36 841c	2.66b	4 147a	0.30a
Number of rows															
Single	95 204b	21.19b	24.47a	26 039b	11.26a	3 307a	1.57a	26 205b	4.97b	3 380b	0.67b	33 922b	2.52b	2 351b	0.20b
Double	145 270a	26.27a	26.13a	29 342a	11.56a	3 571a	1.55a	42 185a	7.42a	6 113a	1.18a	57 834a	4.08a	6 225a	0.48a
Season															
First	126 624a	25.11a	16.30b	27 549a	11.60a	4 788a	2.25a	36 131a	6.46a	7 098a	1.38a	43 136a	2.83b	7 922a	0.59a
Second	113 852b	22.26b	34.30a	27 832a	11.23a	2 091b	0.88b	32 259a	5.94a	2 396b	0.46b	48 621a	3.76a	653b	0.09b

*F = flat bed
R = ridge
Values within the same column in the same treatment subset bearing the same letter are not significantly different at $p = 0.05$

Table 2. Significant interaction effects in the study

Roots >20 cm long		Roots 10–20 cm long		Roots <10 cm long	
Number	Weight	Number	Weight	Number	Weight
None	Spacing x Season*	None	None	Bed size x No. row*	Bed size x Season**
None	Spacing x No. row x Season*	None	None	None	Bed size x No. row x Season*

*Significant at $p = 0.05$ **Significant at $p = 0.01$
Undamaged and damaged roots had been added together in each grade for statistical analyses

Table 3. Percentages by number and by weight of three grades of storage roots in relation to total root yield as influenced by planting practice

Planting practice	Large[1]		Medium[2]		Small[3]	
	No.	Wt.	No.	Wt.	No.	Wt.
1.3 m, F*	24.7	51.7	33.4	31.8	41.9	16.5
2.0 m, F*	25.9	54.2	31.7	30.4	42.4	15.4
2.0 m, R**	27.8	59.2	31.6	27.0	40.6	13.7
20 cm spacing	19.9	49.3	32.1	32.5	45.4	18.3
25 cm spacing	27.2	56.6	32.0	29.0	40.8	14.3
30 cm spacing	28.6	58.2	33.1	28.4	38.2	13.3
Single row	30.8	60.6	31.1	26.6	38.1	12.8
Double row	22.7	49.9	33.2	32.7	44.1	17.4

*flat bed [1]Large : >20 cm length
**ridge [2]Medium : 10–20 cm length
[3]Small : <10 cm length

cm plant spacing compared with 58% for 30 cm spacing which produces a lower plant density. Similarly, the higher density double-row planting produces fewer large roots (50%) compared with single-row planting (60%). The reverse was true for medium-sized and small roots although the differences were not as large. Regardless of the planting practice, the percentage of large roots from a sweetpotato crop ranges from 49–61% weight-wise, 27–33% for medium-sized roots, and from 13–18% for small.

Use of a 2.0-m ridge increased the yield of large roots (total of undamaged and damaged) by 10% over that obtained from a 2.0-m flat bed. It has, however, to be pointed out that *Table 1* shows a higher incidence of damaged roots in all grades (significant for the large roots) when using ridges, due almost entirely to the sweet-potato weevil (*Cylas formicarius*). It may well be that the less stable conditions of the soil on the sides of a ridge (as compared to a bed) exposes the sweetpotato roots to the weevil.

Current farm practice does not include grading of sweetpotato roots by size. Everything is packed into rattan baskets or sacks and sold. FAMA has only a single grade coded as FAQ (for “fair and acceptable quality”). This means that total root yield is more important for the farmer, as he will be paid according to weight. However, if the sweetpotato industry is to become far more sophisticated, especially with regard to table varieties, it will be important to include grading in postharvest handling before marketing as is practised in advanced countries.

In Taiwan, roots of 80 mm x 120 mm size and more than 300 g qualify as Grade 1 for table use. Roots smaller than 50 g end up as animal feed (Chen, Y.S., Taiwan Agricultural Research Institute pers. comm. 2000). In Japan, roots are graded not only by size but also by uniformity of shape. The best grade consists of uniformly shaped roots of 350–500 g each. The worst grade (<60 g) are used for starch extraction. In the U.S.A., US No. 1 grade comprises well-shaped roots, free of defects, with dimensions of 76–229 mm in length and 50–89 mm in diameter. The lowest grade roots are used in canning (Peet 2001).

This would mean that the large roots in this study *(Table 4)* fall roughly into the best grade in Japan and US No. 1 grade; in which case, the highest percentages of large roots came from the use of 2.0 m ridges at 30 cm plant spacing and adopting single-row planting *(Table 3)*, i.e. at a lower plant density as is advocated by farmers currently.

Conclusion

The use of 1.3 m raised flat beds is advantageous to root yield. This effect was further enhanced by increasing plant population per hectare through the practice of a plant spacing of 25 cm as well as double-row planting. Raised flat beds facilitate mechanization, and may reduce surface evaporation compared to ridges which expose a larger surface area to the sun. This may eliminate the need for more frequent irrigation and would thus benefit farmers growing sweetpotato on sandy soils, such as sand-tailings and bris. Nevertheless, this hypothesis remains to be investigated further.

While the present study did not include a control using 1.0 m ridges, it is expected that the current findings of better yield with 1.3 m beds at 25 cm plant spacing and double-row planting will persist from plant density effects.

Table 4. Mean root weight (g) by grade as influenced by planting practice

Planting practice	Large (>200 mm length)			Medium (100–200 mm length)			Small (<100 mm length)		
	Undamaged	Damaged	Mean	Undamaged	Damaged	Mean	Undamaged	Damaged	Mean
1.3 m, F*	389	396	392	177	184	180	73	81	77
2.0 m, F*	396	427	412	182	193	188	69	75	72
2.0 m, R**	469	511	490	189	201	195	74	82	78
20 cm	395	442	418	183	192	188	72	84	78
25 cm	422	460	441	185	192	188	71	86	78
30 cm	418	458	438	175	201	188	72	72	72
Single row	432	475	454	190	198	194	74	57	66
Double row	394	434	414	176	193	184	71	47	59

*flat bed
**ridge

However, keeping in mind the establishment of market grades for the future, there is a need to consider a higher total large root yield. In such an instance, 1.3 m flat beds and 25 cm plant spacing appeared to be equally important, while single or double-row planting did not seem to make a difference *(Table 1)*.

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