J. Trop. Agric. and Fd. Sc. 26(1)(1998): 25–33

Agronomic modifications for mechanized planting of sweet potato

(Pengubahsuaian agronomi untuk penanaman ubi keledek secara berjentera)

S. L. Tan*

Key words: sweet potato, storage of cuttings, spacings

Abstrak

Ubi keledek berpotensi menjadi tanaman industri, dan potensi ini boleh menjadi kenyataan dengan penanamannya secara berjentera. Oleh yang demikian, beberapa pengubahsuaian agronomi diperlukan. Dua aspek dikaji dalam artikel ini: kesan penyimpanan keratan batang bagi jangka pendek dan kesan jarak tanaman yang sesuai untuk penanaman berjentera terhadap prestasi hasil ubi keledek. Keratan boleh disimpan selama 72 jam sebelum ditanam. Cara yang terbaik untuk menyimpan keratan adalah dengan pendinginan menyejat iaitu melapiskan keratan di antara guni yang basah dan diletak di atas rak kayu. Cara yang kedua terbaik dan mungkin yang paling murah dan praktis adalah membiarkan keratan layu di tempat teduh. Jarak tanaman yang sesuai untuk penanaman berjentera (baris tunggal pada 0.7 m x 35 cm dan 1.0 m x 25 cm; baris berkembar yang berjarak 60 cm pada 1.4 m x 35 cm) didapati memberi hasil yang kurang memuaskan. Keadaan ini mungkin disebabkan oleh penanaman dibuat pada tanah rata dan batas dibuat kemudian. Amalan manual sekarang adalah menanam ubi keledek di batas yang berjarak 1.0 m dengan jarak tanaman 25 cm.

Abstract

With the potential of sweet potato becoming an industrial crop, and the need for its mechanized planting to fulfil this role in the future, it is anticipated that certain agronomic modifications are necessary. Two aspects are studied in this paper: the effects of short-term storage of vine cuttings, and of spacings to suit machine-planting on the yield performance of sweet potato. Cuttings may be stored for as long as 72 h before planting. The best storage method was by evaporative cooling, involving sandwiching a layer of cuttings between wet gunny sacks laid on wooden racks. Leaving cuttings to wilt in a shady area was next best, and probably the cheapest and most practical. Spacings to suit mechanized planting (single rows at 0.7 m x 35 cm and 1.0 m x 25 cm; double rows spaced at 60 cm apart at 1.4 m x 35 cm) generally resulted in poorer performance, probably because these treatments involved planting on the flat with subsequent ridging. The current manual practice is to plant on ridges at 1.0 m ridge spacing and 25 cm plant spacing.

---

*Food and Industrial Crops Research Centre, MARDI Headquarters, P.O. Box 12301, 50774 Kuala Lumpur, Malaysia
Author's full name: Tan Swee Lian

Introduction

MARDI is set to transform sweet potato [*Ipomoea batatas* (L.) Lam.] from a traditional minor food crop grown by small farmers to a crop with agro-industrial applications, through medium to large-scale production. Two major end-uses spring to mind: starch with its myriad down-stream industries and livestock feedstuff (mainly as a partial substitute for grain). A breeding and selection programme is currently identifying clones with high yield, desired quality characteristics (such as high starch content) for various end-uses and adaptability to various agro-ecologies. Concurrent to developing superior new cultivars is the need to modify agronomic practices to complement the use of machinery in the various field operations in sweet potato production. Mechanized production is inevitable in view of the increasing shortages in farm labour as well as the economically inefficient manual production systems suited only to small farms.

Two major field operations have been perceived to be particularly labour-intensive: these are planting and harvesting. In this paper, I shall endeavour to address the former. With the medium to large production scales envisaged, mechanized planting raises two important questions: First, the preparation of planting materials, i.e. vine cuttings. In the case of the small farmer, he can cut his planting materials on the day he intends to plant, or one day earlier. With mechanized planting on the scale proposed, it will be necessary to prepare cuttings days in advance. Furthermore, initial testing of a tractor-drawn mechanical planter revealed a problem of long petioles on fresh cuttings having a tendency to get entangled in the drive mechanism, thereby jamming up the planting operation. The question then is: will stored cuttings or cuttings with petioles removed affect germination and subsequent yield performance?

Second, in manual sweet potato planting, it has been found that a plant population of 40 000 plants/ha is optimal for yield (Tan and Saad 1994). The planting distance adopted to achieve this density is a row (ridge) spacing of 1.0 m apart (centre to centre) and a plant spacing (within row) of 25 cm. The use of machines for planting does not permit a strict adherence to these spacings by virtue of the tractor wheel width and fixed tread spacing. The question, therefore, is: will readjustment of row and plant spacing, while trying to keep to the optimal plant population, affect yield performance?

Materials and methods

Two trials were carried out to provide answers to the two questions posed earlier. In both trials, the test cultivar was Gendut, released by MARDI in 1994. Cuttings used in the planting were 30 cm long and taken from nursery-raised plants aged 2–2.5 months. Both trials were repeated for a second season.

Trial 1 investigated the effect of cutting treatment and method of storage on germination and subsequent yield performance. It was carried out on mineral soils at the MARDI Headquarters Station located in Serdang, Selangor. A total of 10 treatments were tested against a control *(Table 1).*

The experiment design adopted was a randomized complete block with four replications. Apical cuttings were used in two replications (1 and 2), while the remaining two replicates (3 and 4) used non-apical cuttings. Plant spacing was 1.0 m between rows (ridges) and 0.25 m between plants. A plot size of 2 m x 5 m was used, yielding 40 plants/plot. The usual rate of fertilizers, i.e. 35 kg N, 35 kg P_2O_5 and 70 kg K_2O per ha (formulated from the straight fertilizers urea, triple superphosphate and muriate of potash), was applied at planting. Weed control was by a pre-emergence spray of 4 L alachlor/ha. The sweet potato weevil was managed by dipping the cuttings in 0.01–0.05% a.i. malathion for 1 h prior to planting, and applying endosulfan granules

Table 1. Cutting treatments and description

No.	Treatment code	Description
1	L	Cuttings with leaves including petioles excised
2	W24	Cuttings wilted over 24 h (kept in a covered, shady area)
3	W48	Cuttings wilted over 48 h (kept in a covered, shady area)
4	W72	Cuttings wilted over 72 h (kept in a covered, shady area)
5	LS24	Cuttings with leaves including petioles excised and soaked in water over 24 h
6	LS48	Cuttings with leaves including petioles excised and soaked in water over 48 h
7	LS72	Cuttings with leaves including petioles excised and soaked in water over 72 h
8	EC24	Cuttings stored on racks with evaporative cooling* over 24 h
9	EC48	Cuttings stored on racks with evaporative cooling over 48 h
10	EC72	Cuttings stored on racks with evaporative cooling over 72 h
11	C	Cuttings without any of the above treatments (Control)

*Evaporative cooling was provided by arranging the cuttings between two layers of wet gunny sacks

Table 2. Spacing for mechanized planting of sweet potato vines

Treatment	Row spacing (m)	Plant spacing (m)	Remarks	Population (per ha)
12HP	0.7	0.35	Single rows	40 816
25HP	1.0	0.25	Single rows	40 000
60HP	1.4	0.35	Double rows, spaced 0.6 m apart	40 816
C (control)	1.0	0.25	Single rows, with ridges	40 000

(16 kg *Acmaron* 5G/ha) near the planting hole at planting. All *Ipomoea* weed species which are alternate hosts of the weevil, were cleared from around the field.

Trial 2 examined the effect of spacing and configuration to suit mechanized planting on yield performance of sweet potato. The trial was carried out on sand tailings at the MARDI station in Kundang, Selangor. The spacing recommended for manual planting (1.0 m x 0.25 m) was used as the control to compare with the three treatments *(Table 2).*

The spacings were chosen (in consultation with the agricultural engineer) to be compatible with different sized tractors: 12HP for a 12 hp power tiller, 25HP for a 25 hp tractor, and 60HP for a 60 hp tractor. All three treatments were planted manually on the flat and hilled up 2–4 weeks later, whereas in the Control, manual planting was on ridges. Hilling up with a hoe was along the planted row, effectively forming ridges similar in size to those in the control, i.e. 60 cm high. A randomized complete block design with five replications was adopted. Plot size was 3.5 m x 7 m.

Organic manure in the form of 30 t of POME[1]/ha was applied along the plant rows before planting. A compound fertilizer of 12: 6: 22: 3 (N: P_2O_5: K_2O: MgO) formulation was supplied at the rate of 550 kg/ha, split into three applications at 1, 4 and 8 weeks after planting. Weed control and sweet potato weevil management practices were similar to those of Trial 1. The field was irrigated by a sprinkler system in the first 2 weeks after planting.

In both trials, data were collected on the following characters: fresh weight and number of marketable roots (>150 g each) and of non-marketable roots, fresh weight of

[1] palm oil mill effluent, 0.5% N, 0.4% P, 0.5% K, 0.8% Ca, 0.3% Mg, 225 ppm Mn, 9 900 ppm Fe, 90 ppm Cu and 110 ppm Zn (Ahmad et al. 1994).

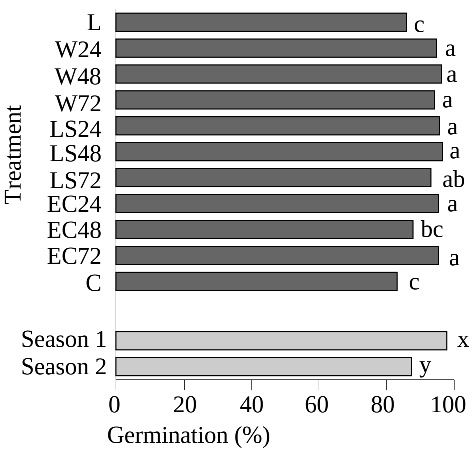
vines, and dry matter content of roots (determined by oven-drying of root samples at 70 °C). Secondary data on fresh root yield, harvest index and dry root yield were computed subsequently. In addition, for Trial 1, germination was recorded, while for Trial 2, the spread and depth of storage roots were determined by careful manual excavation of three sample plants per plot. Except for the spread and depth of storage roots (data collected only in the first season), the data were analyzed in a combined ANOVA over two seasons.

Results and discussion

Trial 1. Effects of cutting treatment and storage

Germination High germination, exceeding 90%, was generally observed in all treatments except in C and L, the ones where fresh cuttings were used for planting (control and cuttings with leaves excised respectively) as well as in EC48 where the cuttings were stored for 48 h with evaporative cooling *(Figure 1)*.

Yield performance Marketable root weight and number as well as fresh root yield were generally higher in those



Note: Bars with the same letter are not significantly different from one another at p = 0.05 according to the LSD test

Figure 1. Germination of sweet potato vine cuttings receiving different treatments

treatments where the cuttings were stored with evaporative cooling, regardless of length of storage (24, 48 or 72 h). The values of these characters in the three treatments were significantly higher than those of the control, especially when the cuttings had been stored for 48 h or 72 h *(Table 3)*. Excision of the leaves seemed to be detrimental to yield performance as evidenced by treatments L, LS24, LS48 and LS72, which together with the control gave the lowest values for marketable root weight and number, and fresh root yield. This is perhaps due to a lag phase when active photosynthetic area had to be regenerated through the production of new leaves.

Cuttings which had been wilted showed intermediate performance, although generally wilting for 72 h seemed to give better results. This finding is important as cuttings which have been wilted will have less of a tendency for the leaves and petioles to be entangled in the mechanical planter.

Other agronomic traits Harvest index (the ratio of storage root weight to total plant weight) was highest in those treatments which were stored with evaporative cooling (EC24, EC48 and EC72) as well as where the cuttings were wilted for 72 h (W72) *(Table 3)*. Root dry matter content, however, seemed to be improved in EC72 (cuttings stored for 72 h with evaporative cooling) and in those treatments with leaves excised and soaked (especially LS24 and LS72).

The product of fresh root yield and dry matter content generates data on dry root yield. Best values came with storage with evaporative cooling (regardless of length of time) as well as with wilting over 48 h and 72 h.

In general, agronomic performance was better in the first than in the second season (*Figure 1* and *Table 3*). The effects of allelopathy might be in play (Walker and Jenkins 1986), depressing both germination and subsequent plant growth, and development in the second crop.

Table 3. Agronomic traits at harvest of sweet potato plants arising from cuttings undergoing different treatments and storage durations

Treatment	Fresh root yield (t/ha)	Marketable roots		Harvest index	Root dry matter content (%)	Dry root yield (t/ha)
		Weight (kg/plot)	Number (per plot)			
L	7.5d	4.7c	20d	0.46b	31.9cde	2.4d
W24	9.2cd	5.1bc	27bcd	0.47b	30.5de	2.8cd
W48	12.5ab	7.5ab	39a	0.49b	30.4de	3.8ab
W72	12.1abc	7.6ab	35ab	0.54a	32.1a–d	3.7abc
LS24	8.2d	4.7c	23cd	0.36c	33.8ab	2.8cd
LS48	7.5d	4.2c	24bcd	0.36c	32.0bcd	2.4d
LS72	9.6bcd	6.3abc	34abc	0.48b	33.2abc	3.1bcd
EC24	12.3ab	6.8abc	39a	0.50ab	30.1e	3.7abc
EC48	13.3a	8.3a	40a	0.54a	31.9cde	4.2a
EC72	13.8a	8.7a	45a	0.50ab	33.9a	4.6a
C	7.7d	5.0bc	25bcd	0.48b	31.8cde	2.4d
Season 1	10.8a	6.4a	37a	0.52a	34.2a	3.6a
Season 2	9.9a	6.1a	27b	0.43b	29.7b	2.9b

Mean values in each column in the same group with the same letter are not significantly different from one another at $p \leq 0.05$ according to the LSD test

Table 4. Agronomic traits at harvest of sweet potato plants arising from apical and non-apical cuttings

Type of cutting	Germi-nation (%)	Fresh root yield (t/ha)	Marketable roots		Harvest index	Root dry matter content (%)	Dry root yield (t/ha)
			Weight (kg/plot)	Number (per plot)			
Apical	92.8a	14.5a	9.6a	44a	0.47a	31.2b	4.6a
Non-apical	92.2a	6.2b	3.0b	19b	0.47a	32.7a	2.0b

Mean values in each column with the same letter are not significantly different from one another at $p \leq 0.05$ according to the LSD test

Use of apical cuttings vs non-apical cuttings Apical cuttings, as has been reported elsewhere (de Kraker and Bolhuis 1969; Nzima and del Rosario 1982), were superior to non-apical ones, as they produced plants having significantly higher marketable root weight and number, as well as fresh and dry root yields *(Table 4)*. The effects on germination and harvest index are less clear-cut. Dry root matter, on the other hand, seemed to be better in plants from non-apical cuttings.

Statistical analyses of the data ran separately for apical cuttings and non-apical cuttings gave the following results. When apical cuttings were used, germination was unaffected by any of the imposed treatments *(Table 5)*. This suggests that with a terminal growing shoot, the cuttings were better able to establish as rooted plants. With non-apical cuttings, the effects were somewhat similar to when the data were not analyzed separately (see *Figure 1*). More interesting, treatments had no effects on fresh and dry root yields, marketable root weight and number, as well as harvest index when non-apical cuttings were used, while the results using apical cuttings closely paralleled those when the data set was analyzed *in toto*. Nevertheless, a look at the absolute values show that even with non-apical cuttings, higher values for the various traits were recorded with the treatments EC48, EC72 as well as W48 and W72. For example, fresh

Table 5. Differences in effects of cutting treatment and storage duration when using apical and non-apical cuttings

Treatment	Apical cuttings							Non-apical cuttings						
	Germination (%)	Fresh root yield (t/ha)	Marketable roots		Harvest index	Root dry matter content (%)	Dry root yield (t/ha)	Germination (%)	Fresh root yield (t/ha)	Marketable roots		Harvest index	Root dry matter content (%)	Dry root yield (t/ha)
			Weight (kg)	Number						Weight (kg)	Number			
L	87.5a	11.8ab	7.6a	32b	0.48ab	31.8abc	3.86ab	85.9bc	7.5a	4.7a	20a	0.46a	31.9ab	2.43a
W24	92.5a	13.0ab	8.0a	39ab	0.48ab	27.8d	3.63ab	94.7a	9.2a	5.1a	27a	0.47a	30.5b	2.75a
W48	95.6a	17.2ab	11.4a	51ab	0.50a	29.5cd	5.05ab	96.2a	12.5a	7.5a	39a	0.49a	30.4b	3.76a
W72	92.5a	17.2ab	12.4a	50ab	0.54a	30.0bcd	5.11ab	94.1ab	12.1a	7.6a	35a	0.54a	32.1ab	3.73a
LS24	95.6a	11.7ab	7.6a	34b	0.37b	34.5a	4.07ab	95.6a	8.2a	4.7a	23a	0.36b	33.8a	2.81a
LS48	95.0a	10.2b	6.0a	30b	0.37b	32.2abc	3.35b	96.6a	7.5a	4.2a	24a	0.36b	32.0ab	2.40a
LS72	90.6a	15.2ab	10.6a	51ab	0.46ab	31.8abc	4.83ab	93.1ab	9.6a	6.3a	34a	0.48a	33.2ab	3.11a
EC24	95.6a	14.2ab	8.3a	48ab	0.47ab	30.5bcd	4.41ab	95.3a	12.3a	6.8a	39a	0.50a	30.1b	3.73a
EC48	94.4a	18.5a	12.5a	55a	0.51a	32.0abc	5.97a	87.8abc	13.3a	8.3a	40a	0.54a	31.9ab	4.24a
EC72	95.0a	18.1a	12.3a	56a	0.53a	33.2ab	5.93a	95.3a	13.8a	8.7a	45a	0.50a	33.9a	4.59a
C	86.9a	12.6ab	8.8a	41ab	0.47ab	30.2bcd	3.83ab	83.1c	7.7a	5.0a	25a	0.48a	31.8ab	2.42a
Season 1	98.8a	15.9a	10.7a	57a	0.54a	33.1a	5.25a	97.8a	10.8a	6.4a	37a	0.52a	34.2a	3.64a
Season 2	86.9b	13.2a	8.5a	32b	0.40b	29.4b	3.85b	87.3b	9.9a	6.1a	27b	0.43b	29.7b	2.91a
Treatment x season	ns	ns	ns	ns	ns	ns	ns	**	ns	ns	ns	ns	ns	ns

Mean values in each column in the same group with the same letter are not significantly different from one another according to the new DMRT
ns = not significant **significant at $p = 0.01$

Table 6. Depth and spread of storage roots of sweet potato planted at spacings compatible with mechanization

Spacing	Depth (cm)	Range of depth (cm)	Spread (cm)	Range of spread (cm)
12HP	15.1a	10.0–21.0	19.6b	12.0–30.0
25HP	16.2a	10.5–23.0	23.9ab	15.0–35.0
60HP	16.0a	11.0–24.0	24.0ab	13.0–36.0
Control	15.2a	11.0–25.0	25.6a	20.0–36.0

Mean values in each column with the same letter are not significantly different from one another at $p \leq 0.05$ according to the LSD test

Table 7. Agronomic traits at harvest of sweet potato planted at spacings compatible with mechanization

Spacing	Fresh root yield (t/ha)	Marketable roots		Harvest index	Root dry matter content (%)	Dry root yield (t/ha)
		Weight (kg/plot)	Number (per plot)			
12HP	11.9b	13.4a	59ab	0.37b	29.0a	3.4b
25HP	10.6b	11.3b	50c	0.36b	28.8a	3.1b
60HP	11.2b	13.0a	54bc	0.39b	28.0a	3.1b
Control	14.3a	14.3a	65a	0.48a	28.4a	4.0a
Season 1	10.0b	9.4b	41b	0.40a	30.1a	3.0b
Season 2	14.0a	16.6a	74a	0.30a	27.0b	3.8a

Mean values in each column in the same group with the same letter are not significantly different from one another at $p \leq 0.05$ according to the LSD test

root yields in these treatments were 57–79% higher than the control, C *(Table 5).*

Trial 2. Effects of plant spacing and configuration

Depth and spread of storage roots No significant difference in depth of the storage roots was detected among the treatments or when compared to the control, all averaging 15–16 cm deep *(Table 6).* The implication is that the harvesting of the storage roots will not be more difficult than in the control when sweet potato is planted at the tested spacings because the roots are not formed any deeper. The range of depths for all the treatments was marginally smaller than for the control.

Treatment 12HP (spacing of 0.7 m x 0.35 m) registered significantly less spread compared to the control (20 cm vs 25 cm), but was no different from the other two treatments *(Table 6).* This is to be expected with its closer spacing. The range of spread was also smallest in the Treatment 12HP, whereas the range was largest in the Treatment 60HP. It would appear that the delayed ridging discouraged greater spread during growth and development of the storage roots.

Yield performance Marketable root weight and number were least affected (compared to the control) when spacing was compatible with the use of a 12 hp tractor (not statistically significant) *(Table 7).* However, root yield was significantly reduced in all three treatments compared to the control, with reductions ranging from 17% to 26%. Despite the spacing of treatment 25HP being similar to the control, the lack of ridges at planting seemed to have a detrimental effect on yield performance. It is suspected that the delayed ridging is a more significant factor than plant spacing and configuration as the latter did not change plant population from the optimum of 40 000/ha very much. Planting on the flat instead of on ridges may have caused the cuttings to encounter conditions of compacted soil at the crucial stage of plant establishment when new roots were developing. Furthermore, the operation of hilling up with a hoe after initial planting on the flat may have damaged developing roots and partially buried the vines and leaves.

Other agronomic traits Harvest index and dry root yield were both affected in all three treatments, whereas root dry matter content remained the same as in the control *(Table 7).* It would appear that root dry matter content as in the case of cassava (Tan and Mak 1995) is a more environmentally stable (and therefore a highly heritable) trait. Again, delayed ridging seemed to have an adverse effect on subsequent crop performance.

In this trial, the second season data were in general significantly higher than in the first season. In this case, the sandy texture of the soil probably allowed for the leaching of any allelopathic exudates from the first crop of sweet potato. At the same time, the second season crop might have benefited from the residual effects of POME applied to the first crop.

Conclusions

- Cuttings may be cut and stored for as long as 72 h or 3 days before planting. Indeed, with specific storage treatments, yield performance is improved with storage compared to the control where freshly cut setts are planted on the same day,
- The best method of storing cuttings is by evaporative cooling (sandwiching a layer of cuttings between two wet gunny sacks laid on wooden racks),
- The next best storage method is by leaving the cuttings to wilt in a shady area with sufficient ventilation. This is likely to be the most practical and cheapest method,
- Apical cuttings make better planting materials than non-apical cuttings, resulting in more superior agronomic performance,
- Spacings to suit mechanized planting generally resulted in poorer agronomic performance compared to the control, most probably because of delayed ridging with its suspected effects of soil compaction at plant establishment as well as root damage and partial burial of vines and leaves due to the subsequent hilling operation when forming ridges.

Acknowledgements

The author wishes to thank Mr Ayob bin Sukra, formerly the agricultural engineer working on sweet potato, for his constructive suggestions and ideas for the research conducted, and Ms P. Vimala and the field staff of MARDI Station Kundang for helping out with the trials there. Her heartfelt gratitude also goes to her ever-dependent research staff, Mr Mohsin bin Yusof and Mr Zainal Abidin bin Karim.

References

Ahmad, A. R., Arulandoo, X. and Aminuddin, Y. (1994). Fertility improvement of fluvial padi soils of Kelantan Plain by organic matter addition. In *Studies in soil science: some recent work in Malaysia* (Ghulam, M. H., ed.) p. 93–103. Kuala Lumpur: Malays. Soc. Soil Sci.

de Kraker, J. P. and Bolhuis, G. G. (1969). Propagation of sweet potato with different kinds of cuttings. *Proc. International Symp. Tropical Root Crops* 2–8 April 1967, St. Augustine, Trinidad (Tai, E. A. et al., ed.) Vol. I, Section III (Agronomy) p. 131–5. St. Augustine, Trinidad: Univ. West Indies and Intern. Soc. Trop. Root Crops

Nzima, M. D. S. and del Rosario, D. A. (1982). Physiological basis of low tuber yield from basal sweet potato [*Ipomoea batatas* (L.) Lam.] cuttings. *The Philippine Agriculturalist* ***65(2):*** 119–29

Tan, S. L. and Mak, C. (1995). Genotype x environment influence on cassava performance *Field Crops Res.* ***42:*** 111–23

Tan, S. L. and Saad, M. S. (1994). Sweet potato varieties for fresh consumption *Proc. National Seminar on Tuber Crop Production and Utilization* 5–7 Sept. 1994, Kuantan (Tan, S. L., et al., ed.) p. 120–31. Serdang: MARDI, UPM and Malays. Soc. Hort. Sci.

Walker, D. W. and Jenkins, D. D. (1986). Influence of sweet potato plant residue on growth of sweet potato vine cuttings and cowpea plants. *HortScience* ***21(3):*** 426–8

Accepted for publication on 16 April 1998