PRODUCTIVITY OF LESSER YAM (*DIOSCOREA ESCULENTA*) IN PAPUA NEW GUINEA AS INFLUENCED BY SETT WEIGHT AND STAKING

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ABSTRACT

*Field experiments were conducted to determine the effects of sett weight and staking on the productivity of the lesser yam, (*Dioscorea esculenta. *(Lour.) Burk). Setts weighing 100 g, 200 g, 300 g, or 400 g were grown with or without staking. Increasing sett weight resulted in significant increases in total tuber yield (from 38 to 75 tonnes ha^{-1}), net tuber yield (harvest yield less the weight of planting material) (from 36 to 67 tonnes ha^{-1}), yield of marketable tubers (>100 g) (from 35 to 71 tonnes ha^{-1}), number of marketable tubers (from 5.0 to 6.5 plant^{-1}), and mean weight per marketable tuber (from 340 to 539 g tuber^{-1}). Staking also significantly increased each of these yield variables, as well as total tuber number per plant. The total tuber yield increased from 44 to 70 tonnes ha^{-1}, net tuber yield increased from 39 to 66 tonnes ha^{-1}, yield of marketable tubers (>100 g) increased from 41 to 66 tonnes ha^{-1}, total number of tubers increased from 10 to 12 plant^{-1}, number of marketable tubers increased from 5.1 to 6.1 plant^{-1}, and mean weight per marketable tuber increased from 468 to 611 g tuber^{-1} with staking. The multiplication ratio (tuber weight produced/tuber weight that was planted) declined as sett weight increased show that without staking small planting setts (100 g) produced a mean yield of marketable tubers of 27 tonnes ha^{-1} Although this was significantly less than the 91 tonnes ha^{-1} marketable yield from the staked plants grown from larger setts (400 g). it is suggested that a producer after considering the economic and environmental savings due to not staking and the higher multiplication ratio from the smaller setts may be willing to tolerate a reduced yield.*

***Key words**: Yam, staple food, sett weight, staking.*

INTRODUCTION

Yams (*Dioscorea* spp.) are an important staple crop for millions of people living in the tropics. About 30 million tonnes are produced each year on approximately 3 million hectares of land around the world with an estimated production in Papua New Guinea (PNG) of 220,000 tonnes (FAO 1998).

About 250,000 rural people in PNG villages partly depend on yams as an important staple food, according to results from the Mapping Agricultural Systems Project. Yam (*Dioscorea esculenta*) is a particularly important food in the Prince Alexander foothills of East Sepik Province, the Bogia area of Madang Province, most islands and mainland locations of Milne Bay Province, parts of coastal Central Province, and the trans-Fly region between Balimo and Daru. In all locations, yams are eaten with other staple foods, such as taro, sweet potato and cassava. They are never the sole staple food (R.M. Bourke, pers. Comm.).

One of the central problems in yam production is the relatively large amount of planting material required, usually more than one tonne for each hectare. The problem is exacerbated by the high cost of the planting material, and the fact that the planted material is otherwise edible. The need to reduce the weight of the planted sett is therefore critical.

The search for a solution has led to numerious experments of the effect of sett weight on yam productivity. The findings have shown clearly that reduction in the weight of the planted sett invariably results in a reduction in yield (Enyi 1972; Onwueme 1972; Lyonga *et al.* 1973; Nwoke *et*

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al. 1973; Onwueme 1973; Onwueme & Fadayomi 1980). Most of the experiments were conducted in West Africa or the Caribean, with emphasis placed on *Dioscorea rotundata* Pori. or *D. alata* L. which are the dominant yam species in those regions. In parts of the Pacific were *D. esculenta* is the major yam for consumption, there is equal interest in the effect of sett weight on the performance of this species. There is a lack of reliable information on this. Dingal *et al.* (1987) worked in the Philippines on the effect of sett type (as opposed to sett weight) on *D. esculenta*, and found that whole tubers and heads (the part of the tuber closer to the primary nodal complex from which the tubers are formed) were the best sett types. One of the first reports on the influence of sett size on yam yield in PNG was by Green (1941). Based on the description of the yams given it is most likely that Green (1941) was referring to *D. esculenta*. Quinn (1985) also reported that sett weight has a significant influence on field yield and yield components of *D. esculenta*.

The necessity for staking in yam production constitutes a major input of cost and labour in the production process. Most of the experiments evaluating the effect of staking have found that failure to stake results in decreased yields (Waitt 1960; Chapman 1965; Igwilo 1989; King 1989; King & Risimeri, 1992). However, Lyonga and Ayuk-takem (1982) found that the yield of *D. dumetorum* Kunth was not affected by staking which constrasted with *D. cayenensis* Lam. and *D. rotundata* where staking significantly increased tuber yield.

Quinn (1985) described two main groups of *D. esculenta* cultivars grown in the Maprik District in East Sepik Province of PNG. The cultivars within one group are never staked while the cultivars within other group are usually staked. Quinn (1985) found that one cultivar of non staking yam (Takura) had superior or equal yielding ability to the staked cultivars examined. Quinn (1985) also conducted one trial and found there was no significant difference in the yield and yield components of 4 different cultivars of normally staked *D. esculenta* as a result of staking. However, King (1989) and King and Risimeri (1992) tested the effect of staking on *D. esculenta* in PNG and found that staked plants produced greater yields then those not staked. The possible effects of staking on different sett weights were not determined in these experiments.

The objective of this experiment was, to determine the influence of sett weight and staking, separately or jointly, on the productivity of *D. esculenta* under PNG conditions. Such information might lead to the development of more efficient production packages that will reduce the present high cost of using large setts and of utilizing stakes.

MATERIALS AND METHODS

Dioscorea esculenta (Unitech cultivar number 2) were grown at the University Farm in Lae, Morobe Province, Papua New Guinea. The farm is located 6°41' S, 146°98' E and is on an alluvial plain at an altitude of about 65 m a.s.l. Hartemink *et al.* (1997) described the soil at the farm as a sandy, mixed, isohyperthermic Typic Topofluvents (USDA Soil Taxonomy). Average daily temperatures are 26.3°C with a mean daily minimum of 22.9°C and maximum of 29.7°C (McAlpine *et al.*, 1975) The mean annual rainfall is 4420 mm which is fairly evenly distributed throughout the year. The annual evaporation is 2140 mm (USDA Class A pan), and the rainfall exceeds evaporation each month (McAlpine *et al.*, 1975). The mean total annual sunshine for Lae is 2012 hr with a maximum mean monthly sunshine of 6.9 hr per day in October and a minimum mean monthly sunshine of 3.5 hr per day in July (McAlpine *et al.* 1975). Lae receives between 180 and 170 W-h cm^{-2} $year^{1}$ total annual solar radiation (McAlpine *et al.* 1983). The plants were grown from intact tubers weighing 100 g (50-150 g weight range), 200 g (150-250 g weight range), 300 g (250-350 g weight range) or 400 g (350-450 g weight range). Each sett weight group was grown both staked or not staked. Setts were planted on level soil (i.e. not mounded or ridged) in 18 m^2 plots at a spacing of 1x0.5 m, giving 16 experimental plants and a guard row per plot. Staked plots were staked with bamboo stakes at planting, with one stake for two plants. The length of the stakes above the ground was 2.5-3.5 m. Treatments were arranged factorially in a randomised complete block design with four replicates.

The land was prepared by ploughing and rotary hoeing. Fertilizer was incorporated into the soil at a rate of 200 kg/ha NPK (16:12:16) prior to planting. Weeds were controlled by hand weeding when required. The plots relied solely on natural rainfall which ranged from 250 to 520 mm/month during the experimental period. Harvesting was done 39 weeks after planting. At harvest the weight of each tuber and the vine fresh weight for each plot were recorded. Data were analysed using Minitab Release 11 statistical software.

RESULTS

Tuber yield

The planting sett weight had a significant effect on the total tuber yield (Table 1). The total tuber yield increased steadily with increase in sett weight, with the 100 g setts yielding significantly lower than all the others, and the 400 g setts yielding significantly higher than all the others. The tuber yield from the 400 g setts was approximately twice that of the 100 g setts. The tuber yield from the 200 g and 300 g setts did not differ significantly from each other.

Staking resulted in a significantly higher total tuber yield than the unstaked (Table 1). However, there was no interaction of staking and sett weiight on the total tuber yield, suggesting that for each sett weight, staking increased total tuber yield in a similar way.

The results for net tuber yield (Table 1) followed the same pattern as for total tuber yield, although, as expected, the yield difference between the largest and smallest setts was smaller. The net yield results for staking and for the sett weight x staking interaction were identical for those already stated for total tuber yield.

The pattern of results for marketable tuber yield (i.e. tubers > 100 g) were identical to those for total tuber yield (Table 1). However, the non-marketable tuber yield was not significantly affected by either sett weight or staking or their interaction.

Tuber number

Staking (Table 2) significantly increased the total and marketable number of tubers. Sett weight effects were not significant for total tuber number. However, the smallest setts (100 g) gave significantly lower number of marketable tubers than the two largest sett weights. In all cases, the interaction of sett weight x staking was not significant.

Numbers of non-marketable tubers were not significantly affected by staking, sett weight or staking x sett weight interaction (Table 2).

Tuber weight at harvest

The size of the yam tuber is a very important yield criterion, given the preference of consumers for large tubers. The yield of large tubers in the harvest was improved by staking and increased sett weight (Fig. 1). A similar pattern emerges when the mean weight per marketable tuber is considered (Table 2). The mean weight per marketable tuber was significantly increased by staking. It was also significantly influenced by sett weight, with the largest sett (400 g) giving a significantly higher mean weight than each of the others, and the smallest sett (100 g) giving a significantly lower mean weight than each of the others. The 200 g and 300 g setts did not differ significantly from each other.

Multiplication Ratio

The multiplication ratio is the weight of tuber yield divided by the weight of tuber planted. The multiplication ratio decreased steadily as sett weight increased (Table 1). The two largest setts had significantly lower multiplication ratios than the smallest two, while the smallest sett (100 g) was significantly higher than all the others.

Staking (Table 1) also significantly increased multiplication ratio. However, the interaction of staking x sett weight was not significant.

Shoot weight at harvest

Shoot weight at harvest was significantly higher for the staked plants (Table 1 & 2). It was also significatly influenced by sett weight, with the 400 g sett resulting in a higher shoot weight at harvest than each of the others except the 200 g sett. The interaction of sett weight x staking was also significant, with an $LSD_{0.05}$ of 163 g $plant^{-1}$ or 1.3 tonne ha^{-1}.

Table 1. *Effect of sett weight and staking on yield and tuber multiplication ratio.*

		Sett weight (g)				
		100	200	300	400	Staking means
Total tuber yield (tonnes ha^{-1})	Staked	45.2	70.8	70.5	95.6	70.5
	Unstaked	30.8	40.1	52.0	54.3	44.3
	Sett weight mean	38.0	55.4	61.3	74.9	
	LSD sett weight	11.6				
	LSD staking	8.2				
Net tuber yield (tonnes ha^{-1})	Staked	43.2	66.8	64.5	87.6	65.5
	Unstaked	28.8	36.1	46.0	46.3	39.3
	Sett weight mean	36.0	51.4	55.3	66.9	
	LSD sett weight	11.6				
	LSD staking	8.2				
Marketable tuber yield (tonnes ha^{-1})	Staked	41.9	62.6	67.0	91.5	65.7
	Unstaked	27.3	37.2	48.5	51.3	41.1
	Sett weight mean	34.6	49.9	57.7	71.4	
	LSD sett weight	12.0				
	LSD staking	8.5				
Non-marketable tuber yield (tonnes ha^{-1})	Staked	3.4	8.2	3.6	4.1	4.8
	Unstaked	3.5	2.9	3.5	3.0	3.2
	Sett weight mean	3.4	5.5	3.6	3.5	
	LSD sett weight	NS				
	LSD staking	NS				
Multiplication ratio	Staked	22.6	17.7	11.8	12.0	16.0
	Unstaked	15.4	10.0	8.7	6.7	10.2
	Sett weight mean	19.0	13.9	10.2	9.4	
	LSD sett weight	2.5				
	LSD staking	1.8				
Shoot yield (tonnes ha^{-1})	Staked	6.8	7.8	5.3	12.4	8.1
	Unstaked	5.3	5.1	5.4	4.8	5.2
	Sett weight mean	6.1	6.5	5.4	8.6	
	LSD set weight	2.3				
	LSD staking	1.6				
Total plant yield (tonnes ha^{-1})	Staked	52.0	78.5	75.9	108.0	78.6
	Unstaked	36.1	45.3	57.4	59.1	49.5
	Sett weight mean	44.1	61.9	66.6	83.6	
	LSD sett weight	11.4				
	LSD staking	8.1				

Note: For shoot yield and total plant yield the L/SD for staking x sett weight interaction was 1.3 and 6.6 tonnes ha^{-1} respectively.

Table 2. *Effect of sett weight and staking on tuber number, mean weight per marketable tuber, and shoot weight at harvest.*

		Sett weight (g)				
		100	200	300	400	Staking means
Total tubers (number plant-1)	Staked	10.8	11.9	12.5	13.3	12.1
	Unstaked	9.8	9.7	11.1	10.0	10.4
	Sett weight mean	10.3	10.8	11.8	11.6	
	LSD sett weight	NS				
	LSD staking	1.7				
Marketable tuber (number plant-1)	Staked	5.5	6.5	6.5	7.5	6.5
	Unstaked	4.6	4.9	5.3	5.5	5.1
	Sett weight mean	5.0	5.7	5.9	6.5	
	LSD sett weight	0.9				
	LSD staking	0.6				
Non-marketable tuber (number plant-1)	Staked	5.2	5.5	6.0	5.8	5.6
	Unstaked	5.2	4.8	5.8	4.5	5.1
	Sett weight mean	5.2	5.1	5.9	5.2	
	LSD sett weight	NS				
	LSD staking	NS				
Mean weight per marketable tuber (g)	Staked	380	521	513	611	506
	Unstaked	300	380	442	568	397
	Sett weight mean	340	451	477	539	
	LSD sett weight	54				
	LSD staking	38				
Shoot weight at harvest (g plant^{-1})	Staked	339	389	267	622	404
	Unstaked	267	258	271	243	260
	Sett weight mean	303	323	269	532	
	LSD sett weight	115				
	LSD staking	82				

Note: For shoot weight at harvest the LSD for staking x sett weight interaction was 163 g/plant.

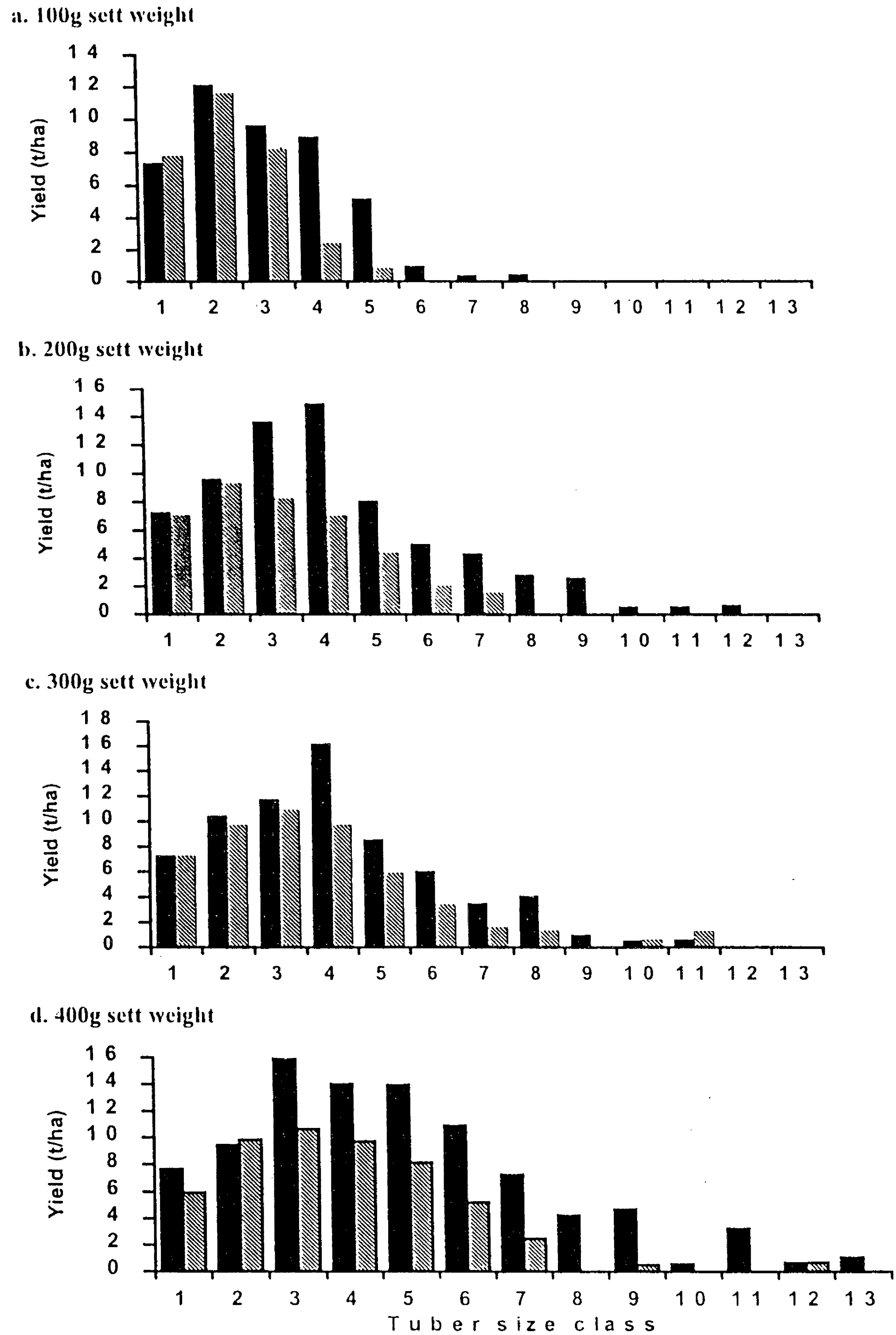
Total Plant Yield

The total plant yield showed a similar trend as the tuber yield, with larger planting setts and staking significantly increasing the total plant yield (Table 1). This would be expected as the tuber yield makes up about 90% of the total plant fresh weight yield at harvest. As reflected with the shoot weight there was also a significant interaction between sett weight and staking for total plant yield.

DISCUSSION

Tuber formation in *D. esculenta* differs from that in the other major yams (*D. rotundata* and *D. alata*) in two important respects. Firstly, the tubers of *D. esculenta* usually do not arise directly from the primary nodal complex, but are borne at the end of stolon-like structures which may be very short in some cultivars and relatively long in others. Each tuber, as it grows and matures, is therefore attached to the rest of the plant by a rope-like stalk. Secondly, unlike the other major yam species, each plant of *D. esculenta* tends to

Figure 1. *The effect of staking and sett weight on the tuber size. Solid bars represent staked plants, hatched bars represent non-staked plant for **a.** 100 g sett weight, **b.** 200 g set weight, **c.** 300 g sett weight and **d.** 40 g sett weight grown plants. The tuber size classes are as follows; 1, 0-100 g; 2, 100-200 g; 3, 200-300 g; 4, 300-400 g; 5, 400-500 g; 6, 500-600 g; 7, 600-700 g; 8, 700-800 g; 9, 800-900 g; 10, 900-1000 g; 11, 1000-1100 g; 12, 1100-1200 g; and 13, >1200 g.*



produce several tubers, with new ones being added progresively throughout the growing season. These qualitative and quantitative differences in tuber morphogenesis of *D. esculenta* have made it difficult to predict whether or not this species will behave like other species in terms of the effects of sett weight and staking.

The foregoing results indicated that the various tuber yield factors in *D. esculenta* increase as sett weight increases. This agree with previous results for *D. esculenta* (Green 1941; Enyi 1972; Quinn 1985) and with the pattern generally observed with *D. rotundata* and *D. alata* (Onwueme 1973; Onwueme and Fadayomi 1980). Marketable tuber numbers and weight were also influenced by sett weight, larger setts producing a greater mean weight of marketable tubers than small setts. In each case, there were nearly as many unmarketable tubers per plant as marketable ones. This is a reflection of the continued initiation of new tubers throughout the season, so that at harvest, there is always a large number of small tubers in various stages of formation. Even though the total yield of these small tubers is small, some Pacific farmers actually prune newly forming tubes once the main tubers have begun to bulk.

As with *D. rotundata* (Onwueme 1978), these results indicate that multiplication ratio for *D. esculenta* decreases as sett weight increases. In practical terms, this means that farmers cannot increase their sett weight indefinitely in an effort to realise higher yields. At the higher sett weights, the inefficiency of low multiplication ratio must be considered.

These results also show that staking resulted in an increase in tuber yield of 59%, 67% and 60% for total, net, and marketable tuber yields, respectively. This agrees with the findings of King and Risimeri (1992), but Quinn (1985) found there was no significant difference in the yield and yield components of the 4 cultivars of normally staked *D. esculenta* examined as a result of staking. Further investigation of the *D. esculenta* cultivar response to staking is required.

The above results, quite remarkably, show that staking also increased the multiplication ratio, and therefore, improved the efficiency of utilization of the planting material. Thus, while the yield advantage derived from large setts is somewhat negated by a decreased multiplication ratio, the yield advantage derived from staking is made additionally attractive by the increased multiplication ratio.

The use of staking in yam production is not without economic and environmental cost. Economically, the procurement and installation of stakes may require up to 60 person-days per hectare, accounting for about one-fifth of the total labour required for yam production (Phillips 1964; Nwosu 1975). With progressive increase in labour costs in most paces, the absolute and relative cost of using stakes in yam production is likely to continue to increase and is ultimately unsustainable (Onwueme 1994).

Fortunately, these results also show that even without staking, a mean yield of marketable tubers of 41 tonnes ha^{-1} could still be produced. Considering the economics of labour savings due to not staking, the producer might be willing to tolerate such a resulting yield level.

In conclusion this study indicates that *D. esculenta* growers in PNG can choose the system for growing the yam that best suits their requirements. If the requirement is to achieve maximum yield and there is abundant planting material then large planting setts (400 g) and staking should be used. If the emphasis is on getting a high multiplication rate when planting material is limited then smaller setts (100 g) and staking should be practiced. If either labour and/or yam stakes are limited or uneconomical then a substantial yield is still obtainable by growing the yams without staking. In this situation the larger setts will still produce significantly greater yields all though the multiplication ratio will be lower than that for the smaller setts.

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