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The response of bananas to plant spacing in double rows in north Queensland

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Summary

Bananas cv. Williams were grown at a range of plant spacings in double rows in north Queensland using a continuously variable design. Increasing the plant density from 930 to 3980 plants/ha increased the yield (t/ha/yr) of the plant crop by 200% and the first ratoon by 50%. These increases resulted from the greater number of bunches per unit area despite a 16% reduction in average bunch weight in the plant crop and a 43% reduction in the first ratoon. The duration of each of the two crop cycles increased with increasing density; from the lowest to the highest density there was an increase of 60 days in the plant crop and 125 days in the first ratoon. Plant spacings, giving acceptable yield and fruit quality, best suited to double rows were those with a distance between the two rows of the double row of 1 to 1.5 m and an intra-row distance of 1.2 to 1.8 Density in this range was 1710 to 2780 plants/ha.

INTRODUCTION

The north Queensland banana industry underwent major changes in crop management practices in the early 1970s. With the widespread adoption of new and effective pest and disease control measures, the use of irrigation and increased fertilisation became economical. This provided the opportunity to increase production by increasing plant density as indicated by Kebby and Greenhalgh (1959), Berrill (1963) and Simmonds (1966).

Plant densities at this time in north Queensland were 1300 to 1600 plants/ha in single rows. The studies already mentioned and more recently those of Robinson and Singh (1974), Kohli *et al.* (1976) and Chattopadhyay *et al.* (1980) have shown increasing yield up to densities of about 2500 plants/ha. However, in north Queensland there were limitations to increasing plant density in single rows with a set inter-row distance necessary for the passage of farm machinery. At plant densities above 1600 plants/ha in single rows there were severe management problems. These were the inability to select a following sucker of consistent size in the desired position, and considerable damage to fruit caused by contact with neighbouring plants.

Planting in double rows was proposed to allow higher densities which were more manageable. Plants develop towards the inter-rows thus reducing potential bunch damage from contact with other plants. Double rows also appeared ideally suited to forms of under-tree irrigation with irrigation laterals situated between the two rows of the double row where they were less likely to be damaged. Further, the plants could be supported with synthetic twine which was less expensive and more effective than hardwood props, but did not obstruct machinery.

The experiment reported examines the effect of plant spacing on yield and plant characteristics of bananas in north Queensland and the spacings best suited to double rows.

MATERIALS AND METHODS

Bananas, *Musa* (AAA Group, Cavendish Sub-group) cv. Williams, were grown at a range of plant spacings on a deep alluvial clay loam at South Johnstone, north Queensland (17° 38′S) during the period 1976–78. The plants were grown for two crop cycles, referred to as Plant and Ratoon 1.

The design of the experiment was a systematic, otherwise known as a continuously variable design (Bleasdale 1967). This design was chosen so that a large range of spacings could be evaluated with the limited resources available. Double rows with a constant 5 m interspace were chosen (Figure 1). This inter-row distance is about the minimum that will allow easy access by farm machinery. The distance between plants in the row ranged from 0.6 to 3 m and the distance between the two rows of the double row from 0 to 2.5 m (Figure 1). This achieved plant densities ranging from 930 to 3980 plants/ha after dispensing with guard plants (Figure 1). Each pattern was replicated four times.

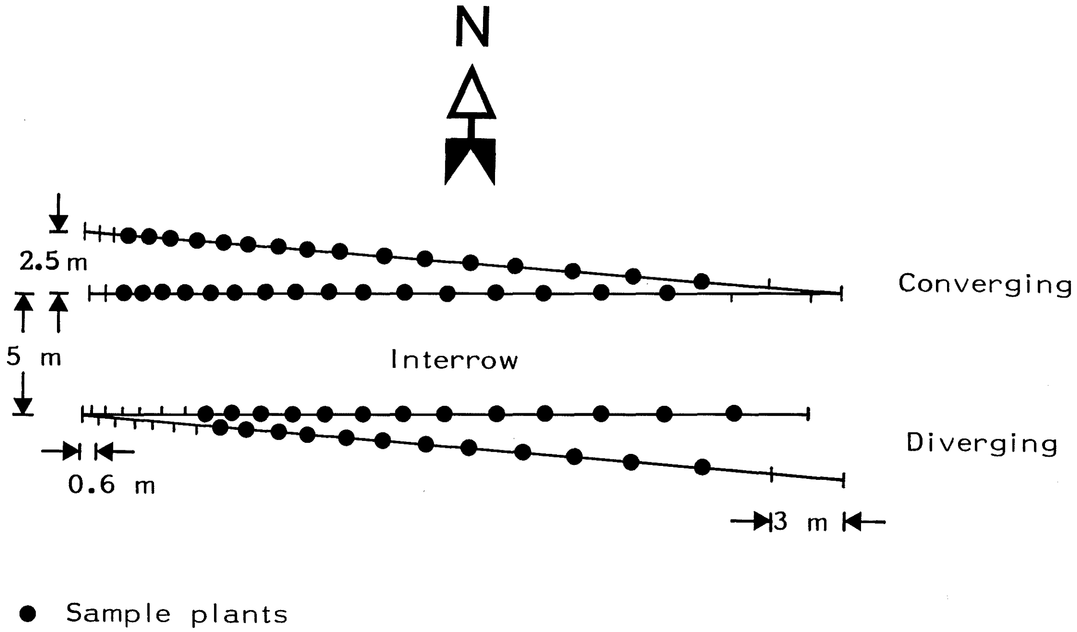

Figure 1. Systematic spacing design.

The trial area received a preplanting fertiliser of dolomitic limestone at 2 t/ha, 67 kg P/ha as superphosphate, 140 kg N/ha as ammonium nitrate and 225 kg K/ha as potassium chloride which was broadcast in the drill just before planting. Side dressings of the same quantities were broadcast on the rows with a Vicon® mechanical fertiliser spreader at intervals of 12 months, for dolomite, 6 months for P, and 2 months for N and K. This rate of fertilisation was considered to place all treatments in the range of luxury supply.

Planting material in the form of bits was hand planted in drills in August 1976. To minimise edge effects there were guard rows on each side of each replication.

Weeds were controlled by hand chipping for the first three months. After this, paraquat was sprayed as required. Trickle irrigation ensured that water was freely available to plants throughout their growth. Leaf Spot caused by *Mycosphaerella musicola* Leach. was controlled by the application of mancozeb and miscible oil at fortnightly intervals.

The total number of leaves unfurled from plant emergence till bunch emergence was recorded. The number of suckers present at bunch emergence, which was the time of follower selection, was recorded in both crops. In Ratoon 1 the individual heights of these suckers were recorded. 'Sucker' refers to all visible suckers from peepers (Simmonds 1966) upward.

As is common with bananas, there was a spread of harvest time of several months in the experiment. This was caused by plant to plant variability (not measured here) and the effect of treatments. Bunches were harvested when the average finger girth of the middle three fingers of the outer whorl of the third hand from the proximal end reached 11.5 cm (Plant) and 13 cm (Ratoon) or, at 150 days from bunch emergence if this came sooner, to ensure an adequate greenlife (pre-climacteric phase) for the fruit.

The following measurements were made on each plant at harvest: bunch fresh weight; number of hands per bunch; number of fingers per bunch; average finger length on third hand; maturity bronzing rated from 0 to 7 on the top three hands (Campbell and Williams 1976); bunch orientation to the row; pseudostem height; pseudostem girth at 15 cm above the ground; and pseudostem height of the following sucker. Yield was estimated by multiplying the number of plants/ha by the average bunch weight with a correction factor of 0.9±0.01 for the bunch stem. This correction factor was determined by dehanding a sample of bunches from both plant and ratoon crops.

Because of the systematic experimental design a statistical analysis, while possible, was unsound because the randomisation of treatments assumption is not met. Therefore results for each treatment were averaged over the four replications and interpreted from the best fitting linear or quadratic regressions of measured characters on plant density.

RESULTS AND DISCUSSION

Plant crop yield

Yield increased linearly with increasing density in the Plant crop (Figure 2). Because there was only a small decrease in bunch size from 18.4 to 15.5 kg with increasing density from 930 to 3980 plants/ha, the improvement in yield at higher densities was quite spectacular with yield increasing by 200% with a four-fold increase in density (Table 1; Figure 2).

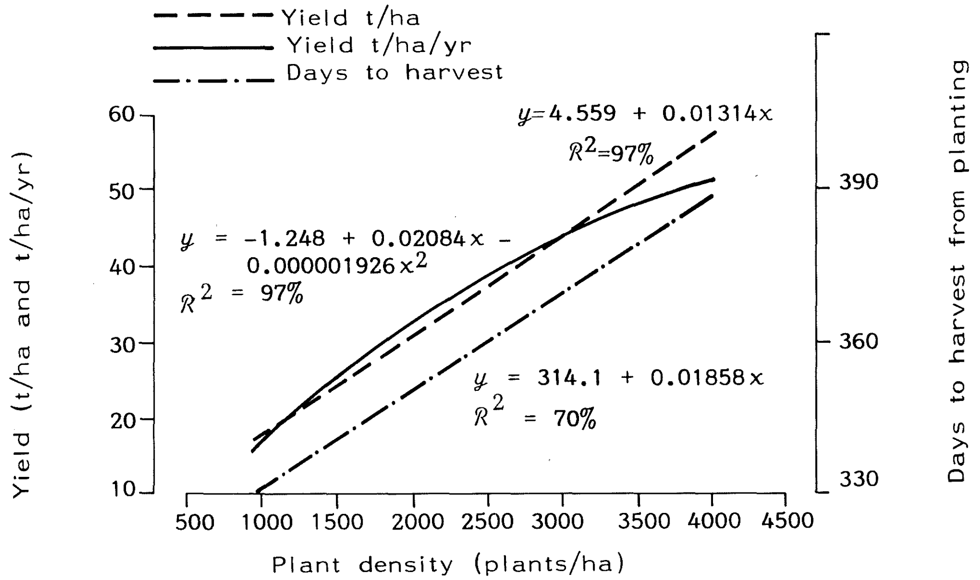

Figure 2. Effect of plant density on yield and days to harvest (from planting) in the plant crop.

The number of days from planting to bunch harvest increased with increasing density (Figure 2). It took about 60 days (17%) longer for the highest density to be harvested compared with the lowest density.

Because of this trend in time to harvest, it needs to be considered when comparing yields of treatments. While other researchers (Osborne 1953; Kebby and Greenhalgh 1959; Oppenheimer and Gottreich 1960; Ahmad and Mannan 1970; Irizarry *et al.* 1975) have noted an increase in the duration of the crop cycle with increasing density, there has been little attempt to quantify it and make valid comparisons between treatments. Yield is probably better expressed as t/ha/yr rather than t/ha/crop . While the problems of comparing treatments of different duration are far from solved by employing this technique (Turner 1979) the interpretation of results is greatly improved. In our experiment yield in t/ha/yr shows a curvilinear response to increasing density in contrast to yield in t/ha which increased linearly with increasing density (Figure 2).

Table 1. Regression equations of best fit for plant characters (*y*) as affected by plant density (*x)**

	Plant character	Regression equation	R_2
Plant crop			
	Bunch weight (kg)	y=19.26−0.0009503x	45%
	Finger number per bunch	y=121.3−0.004809x	27%
	Pseudostem height (cm)	y=193.4+0.005821x	40%
	Follower height (cm)	y=207.3−0.01953x	54%
	Sucker number per plant	y=6.63−0.000605x	71%
Ratoon 1			
	Bunch weight (kg)	y=60.69−0.007476x	73%
	Average finger weight (g)	y=212.3−0.01832x	68%
	Finger number per bunch	y=233+0.01373x − 0.000005997x^2	62%
	Finger length of third hand (cm)	y=25.16−0.0003897x	24%
	Finger girth of third hand (cm)	y=13.94−0.0005647x	76%
	Pseudostem height (cm)	y=255.8+0.05115x − 0.000008157x^2	60%
	Pseudostem girth (cm)	y=99.55−0.003011x	38%
	Sucker number per plant	y=9.05−0.000926x	64%
	Total sucker height (cm)	y=515.8−0.0988x	86%

* plants per hectare.

Ratoon 1 yield

Plants were much larger and had higher yields (about double) in Ratoon 1 compared with the Plant crop (Table 1; Figures 2 and 3). This has been noted before by Wills (1957) and Missingham (1963) in Queensland but is generally not mentioned in the literature. This difference between plant and ratoon crops will vary according to variety, pest and disease load and other environmental factors such as soil fertility and seasonal effects. In some situations no difference results (Azouz *et al.* 1971; Kohli *et al.* 1976; Bredell *et al.* 1978). Where plantation life is much longer than the six or so years in north Queensland the less profitable plant crop is of less consequence. In north Queensland any increase in plantation life would be of great benefit.

Why ratoons grow larger and yield more than plant crops seems to be related to the extra nourishment given by the parent plant to the following sucker. In the same way Ratoon 2 crops are usually higher yielding than Ratoon 1 because of the greater size of Ratoon 1 compared to the Plant crop. The contribution by the parent to the following sucker is very evident from observations I have made of bunches cut off at bunch emergence with the leaves retained. The following plant produced in this situation grows to impressive proportions. Because of the greater size of ratoon plants and thus greater inter-plant competition which occurred compared to the Plant crop the response to plant density is somewhat different from the Plant crop. Yield again increased with increasing density (Figure 3), but there was only an 100% increase in yield (t/ha) for the four-fold increase in density. This occurred because of a large decrease in bunch weight from 53.7 to 30.9 kg (43%) with increasing density (Table 1).

It took about 125 days (60%) longer for the highest density to be harvested compared with the lowest, so that yield in t/ha/yr gives a more valid comparison of treatments. Yield at the highest density was only about 50% greater than at the lowest density, with yield plateauing near 2500 plants/ha (Figure 5). Residuals from the regressions indicated there was slightly greater variability of yield (t/ha and t/ha/yr) and days to bunch harvest at higher densities in both the plant and ratoon crops. Glenn and Daynard (1974) working with maize have also reported greater plant-to-plant variability with increasing density.

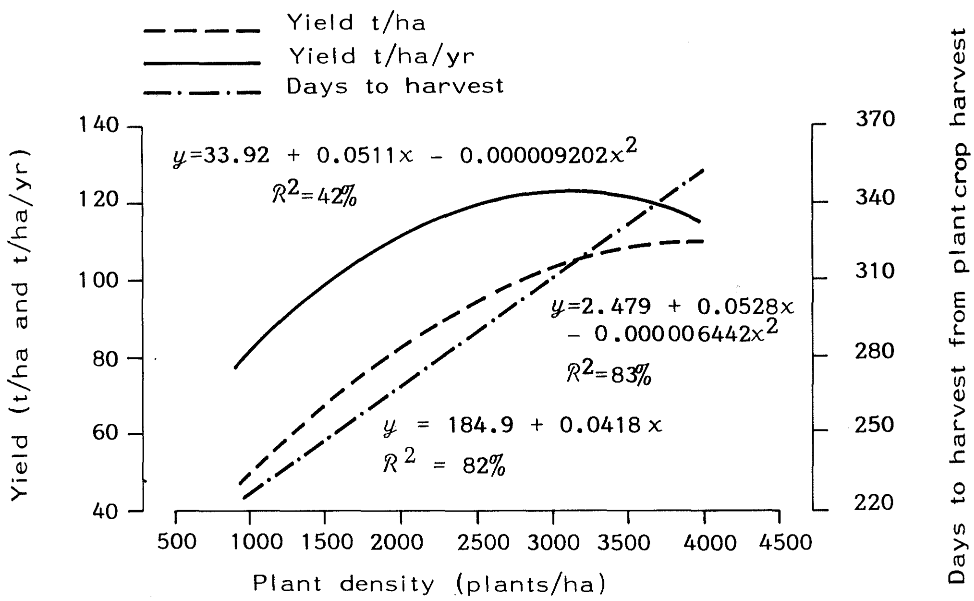

Figure 3. Effect of plant density on yield and days to harvest (from plant crop harvest) in Ratoon 1.

The yields in the first ratoon of 100 t/ha/yr were high compared with those generally obtained elsewhere in the world. This is because of different environments, varieties and cultural practices. These factors also make it difficult to compare the optimum densities with those found elsewhere. Furthermore, the range of densities considered here has seldom been evaluated.

Fruit quality

Fruit quality is a very broad term of which two aspects will be dealt with, fruit size and incidence of the maturity bronzing disorder.

In the Plant crop there was no effect of density on average finger weight. The small decrease in bunch weight with increasing density was due solely to a decrease in finger number per bunch from 117 to 102 Table 1.

In Ratoon 1 there was a decrease in average finger weight from 195 to 139 g with increasing density which accompanied the decrease in finger number per bunch from 241 to 193 with increasing density(Table 1). This reduction in average finger weight was a function of reduced girth of fingers as measured on the third hand from 13.4 to 11.7 cm and to a lesser extent reduced length from 24.8 to 23.6 cm with increasing density (Table 1). At higher densities most bunches were harvested after 150 days, hence the reduction in finger girth. Greenlife of fruit was not measured in this experiment but the longer period of fruit filling at higher densities may have decreased the greenlife (Daniells and

Watson 1984). Harvesting of fruit at high densities may require greater attention to bunch age, rather than fruit size as used at present, to ensure adequate greenlife. The measurements that were made of finger length indicated only a small decrease (about 1.5 cm) in length of fingers on the third hand across the range of increasing densities.

There was no effect of density on maturity bronzing in the Plant crop. There was a decrease from slight–moderate (rating 3) to very slight (rating 1) in the visual rating of bronzing with increasing density in Ratoon 1. However, Campbell and Williams (1976) have shown that different environmental conditions near harvest have great effects on the incidence of maturity bronzing. Thus, the result is confounded with the different times of fruit filling and harvest of the treatments.

Plant characteristics

There was a small increase in pseudostem height with increasing density in both the Plant crop (199 to 217 cm) and first ratoon (296 to 330 cm) (Table 1). In the Plant crop this was presumably due to an increase in internode length as there was no effect of plant density on the leaf number per plant (30 leaves). However, in Ratoon 1 the number of leaves increased by 1 to 2 when plant densities exceeded 3000 plants/ha. Robinson and Nel (1985) also found an increase in the number of leaves in ratoons with increasing density.

The increase in the number of days to harvest with increasing density in the two crop cycles (Figures 2 and 3) resulted from an increase in the number of days from bunch emergence to harvest. The increase in length of the crop cycle in Ratoon 1 with increasing density also resulted from an increase in the number of days to bunch emergence from harvest of the Plant crop. This was caused by delayed sucker emergence at higher densities such that the follower height at harvest of the Plant crop decreased from 189 to 130 cm with increasing density (Table 1). There also may have been a slower rate of appearance of new leaves at higher densities as was found by Robinson and Nel (1985).

There was no effect of plant density on pseudostem girth in the Plant crop. However, in the first ratoon the girth decreased from 97 to 88 cm (9%) with increasing density (Table 1). This is actually a cross-sectional area decrease of some 18%. The smaller bunches at higher densities are associated with this reduction in pseudostem girth.

Sucker growth in general was very poor at the higher densities because of greater competition for resources between plants and less light available to the suckers. There was a decline in the number of suckers present per plant with increasing density in both the Plant crop (6.1 to 4.2) and first ratoon (8.2 to 5.4). The latter was a 35% decrease in sucker number but what is more significant was the 70% decrease (from 424 to 123 cm) in the sum total of their heights (Table 1). With so much less sucker material present this made selection of the following sucker particularly difficult at high densities.

Bunch orientation

There was uniform orientation of bunches towards the inter-rows when the distance between the two rows of the double row was 1 to 1.5 m and when the intra-row distance was 1.2 to 1.8 m. Density in this range was 1710 to 2780 plants/ha. When the distance between plants was less than these limits plants grew as in a single row arrangement with bunch orientation following no particular pattern. When the interplant distances were greater than the above limits there was insufficient competition between plants so that bunches were orientated randomly.

The spacings outlined above produce the desired orientation of bunches in the double row arrangement. More detailed information is required from plots with plants at different densities within this range. A comparison of double rows with other planting arrays in commercial practice is also required.

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