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SURVEY OF SORGHUM AND SUNFLOWER ESTABLISHMENT IN THE CENTRAL HIGHLANDS

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A SURVEY OF THE ESTABLISHMENT OF COMMERCIAL SORGHUM AND SUNFLOWER CROPS IN THE CENTRAL HIGHLANDS OF QUEENSLAND AND ANALYSIS OF THE EFFECTS OF LEVEL AND EVENNESS OF ESTABLISHMENT ON GRAIN YIELD

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FOREWORD

Poor establishment leading to below optimal plant stands is a common cause of lowered productivity in tropical and sub-tropical cropping in Queensland. In 1986 the Queensland Department of Primary Industries and the CSIRO Division of Tropical Crops and Pastures established a multi-organisational working group to promote and co-ordinate research, development and extension activities on crop establishment in Queensland. This working group is the Crop Establishment Working Group, or CREST. It includes representatives of the Queensland Department of Primary Industries, Queensland Graingrowers Association, University of Queensland, and CSIRO Division of Tropical Crops and Pastures.

This Survey was conceived by CREST in its initial strategic plan and carried through as a major CREST project in 1987-88. The work of the survey itself and its elaborate statistical analysis was performed by a team drawn from a wide range of disciplines. This is reflected in the authorship of the project report. The diverse skills and knowledge of team members were well used throughout the planning, execution, analysis and reporting stages and contributed markedly to the relevance and value of the report.

A unique and highly desirable aspect of the survey was the spontaneous co-operation displayed by those who took part in the survey. These included CREST members, technical staff of CSIRO and QDPI (particularly the QDPI at the Emerald Office) and the grain growers who willingly made available their crops.

Results of this survey confirmed the belief that suboptimal crop establishment is a significant factor in the failure of Central Queensland crops to reach their potential yield. The project has enabled these losses to be quantified in economic terms. Potential losses are exceedingly great and point to the need for research, development and extension programmes in this area.

I would like to congratulate the authors of this report, to thank all those who took part in the field work and to thank all co-operators, especially the farmers who provided the crops. This has been a project which has been excellent in its design and execution. The survey results, if applied commercially, have the potential to improve the profitability of grain production in Central Queensland.

RLHarty

(R.L. Harty)
CHAIRMAN
CROP ESTABLISHMENT
WORKING GROUP

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SUMMARY

During the 1987-88 summer a survey was conducted on 24 commercial grain sorghum and sunflower crops in the Central Highlands of Queensland. Spacings of 1000 plants in each crop were measured in two representative sites three to five weeks after sowing, and details were obtained of the cultural practices used prior to and at sowing. At maturity the grain yield of each plant in the measured areas was determined.

Analysis of the data confirmed the correctness of the QDPI recommendations for plant populations of 50,000 to 90,000 plants/ha for sorghum and 40,000 to 60,000 plants/ha for sunflower. A majority of the surveyed crops was found to have plant stands below these levels. Only eight of the 20 sorghum crops and none of the four sunflower crops were within the recommended population ranges. One of the main reasons was a general underestimation by growers of the percentage of sown seed which could be expected to emerge and establish. Despite generally favourable conditions for establishment, only 55% of sorghum seed and 68% of sunflower seed developed into established plants. Causes of poor establishment were inadequate planter calibration, soil compaction in the wheel tracks, the use of wide sowing points and cultivating tines on the planter, non-use of press wheels, poor depth control, inaccurate seed metering, excessive sowing speed and failure to control soil insect pests.

It was estimated that grain yields of the surveyed sorghum crops were on average 31% lower than would have been achieved if plant stands had been satisfactory. Of this, 29% was due to low plant density and 2% was due to uneven plant spacing. If the mean yield reduction on the surveyed farms is extrapolated to the whole of the Central Highlands, the total value of the 1988 sorghum yield loss was $11.3m.

Unsatisfactory plant stands reduced the yield of the surveyed sunflower crops by an average of 43%; low plant density caused a 42% reduction and uneven plant spacing a 1% reduction.

In the light of the survey results, recommendations are made for a research, development and extension programme on crop establishment in the Central Highlands, and suggestions are offered on further surveys to assess the extent and cost of suboptimal establishment in other field crops and other environments in Queensland.

* ie problem is heterogeneity of plant stand ie variability.

* Sections of low density = gaps, inadequate plant number, density less than required locally. = major contribution to yield loss.

* sections of poor uniformity = clumping where plant number is adequate ie poor distribution

1. INTRODUCTION

Poor establishment leading to suboptimal plant stands is believed to be one of the most serious problems of crop production in the tropics and subtropics.

The causes of poor establishment are complex, involving interactions of seed, soil, climate, machinery, management, and soil flora and fauna. The levels of establishment achieved in commercial crops depend on the genotype and quality of the seed and the environment of the germinating seed and emerging seedling, an environment which can be modified by fallow management and sowing techniques (Radford 1987). Fallow management involves the frequency and timing of tillage operations, the type of machinery used and its method of use, stubble management practices and the application of soil amendments. Sowing techniques include seed treatments and the design and operation of machinery to open, close and firm the soil.

Poor establishment is common on the Central Highlands of Queensland, particularly for sorghum and sunflower. Spackman (1980) found that sorghum establishment in this region in the 1979-80 season averaged 51% and sunflower 40% of the seeds sown. Growers can compensate for low establishment by sowing extra seed but it is difficult to predict the level of establishment accurately prior to sowing, and the extra seed is an additional production cost.

Plant stands may be suboptimal on two scores: the absolute density and the evenness of stand, both of which are important factors determining grain yield (Thomas *et al.* 1981, Robinson *et al.* 1982, Wade and Foreman 1988). While suboptimal stands clearly reduce yield and profitability, their adverse effects and economic significance are difficult to quantify. Consequently data on the yield losses and economic consequences of poor establishment are few. A technique developed by Wade *et al.* (1988) offered promise for quantifying the effects of both population density and spatial uniformity of plants on grain yield and profitability in a single crop. Such data enable the cost of poor establishment to be estimated and provide a rational basis for decisions on future research, development and extension programmes on establishment.

A pilot survey was therefore conducted in the Central Highlands of Queensland (22 to 24°S, 147 to 149°E; altitude 150 to 300 m) to determine levels and evenness of establishment in commercial crops of sorghum and sunflower, to relate these factors to yield and profitability and to develop procedures for more extensive future surveys. We used the technique of Wade *et al.* (1988), which analyses the relationship between grain yield of individual plants and their spacing in relation to their neighbours. We also questioned growers about management factors which may have affected establishment percentage, plant density and uniformity of plant spacing. The survey involved 19 farms and 23 crops grown during the 1987-88 summer season.

2. SURVEY PROCEDURES

2.1 Selection of farmers

Because resources were limited it was decided to restrict the survey to about 20 farms in the Central Highlands region. The farmers were selected from the membership rolls of the eight branches of the Queensland Graingrowers Association (QGGA) in the Central Highlands using a stratified random sampling technique. The number of farmers selected from a particular branch was proportional to the membership of that branch. In addition to the random selection, one farmer (farm 21) with advanced seeding equipment was included to provide a measure of the uniformity of spacing obtainable with the best broadacre planters in use.

The distribution of the selected farms is shown in Figure 1. They range in location from the Orion area near Rolleston in the south to the Clermont/Mt McClaren area in the north. All selected farmers were contacted prior to sowing to obtain their agreement to the conduct of the survey on their properties.

2.2 Data collection

Two farms (6 and 20) had to be omitted from the survey due to lack of resources. The remaining 19 farmers were interviewed and details obtained for 24 crops (20 sorghum and 4 sunflower crops). Plant spacings were measured soon after emergence on two blocks (a and b) of about 500 plants in each crop. Corresponding yield data for individual heads were obtained before commercial harvesting. Details are given below.

On one farm (14), we subsequently found that the two surveyed blocks of sorghum had been sown with different machines, so each block was treated as a separate crop (14A and 14B). On another (21), sorghum crops had been sown with two different machines, so the opportunity was taken to survey two adjacent crops sown with different machines (21A and 21B). In all, 20 sorghum crops were surveyed involving 18 sorghum growers. Three of the sorghum growers had also sown sunflower crops with the same planter; these three sunflower crops were included in the survey.

2.2.1 Interview questionnaire

The questionnaire used in the survey (Appendix I) was designed to obtain information on aspects of the seed, soil, equipment and management practices. Details of the viability and amount of seed sown and the plant population and percentage field establishment aimed for and thought to have been achieved were used for comparison with the values calculated from our survey.

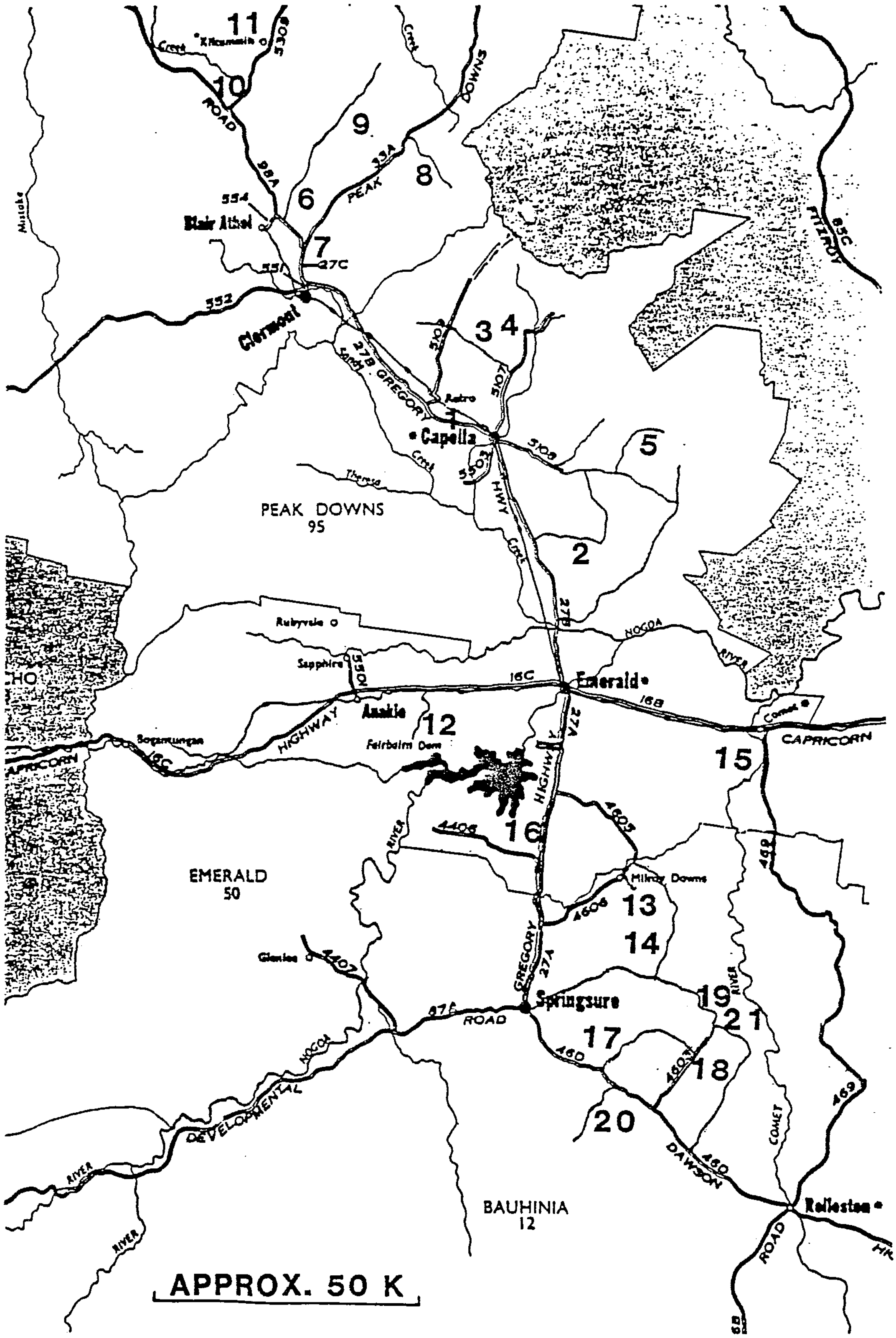

Figure 1. Location of survey farms

2.2.2 Post-emergence data collection

A detailed survey of the plant stand and plant spacing was made at two randomly selected sites (blocks a and b) within each crop three to five weeks after sowing. At each site, 10 neighbouring lengths of row, each containing about 50 plants, were pegged, and plant and row spacings were measured.

A measuring tape was placed along each row and the location of each plant was recorded. The spacing between the rows was also measured, as considerable variation was found. These measurements of intrarow and interrow plant spacings permit the construction of plant distribution maps.

The 10 rows comprising a block were chosen so that they were reasonably representative of the crop. For example, where there were pronounced wheel track effects, the sampled rows included no more than one wheel track. Also, the 'guess rows' that occur between successive runs of the planter were excluded because their varying width complicated the subsequent analysis of the data. At each site, tall white corner pegs were installed to facilitate relocation of the site at maturity.

Depth of soil cover was measured at seven sites by excavating 20 emerged seedlings per site. This method failed to measure seeds placed too deep or too shallow to emerge.

In 13 of the crops surveyed, the species of soil insect pests present at the time of the survey and their density in the soil were determined. In each crop 30 samples, covering 1 sq. m in total, were randomly selected from rows in the vicinity of the survey areas and examined for insect pests. However, as crops were sampled 22 to 32 days after sowing, there could be no certainty that the insect populations at the time of inspection were comparable with those at germination and emergence.

2.2.3 Harvest data collection

Sixteen sorghum and three sunflower crops were harvested. At farms 2 and 15, only one of the two blocks was harvested because the primary sorghum heads had been damaged by thrips in the former and the crop was severely lodged in the latter. The surveyed areas at farms 3, 9, 12 and 14 were not harvested because of insufficient resources.

The plants at each site were individually harvested at physiological maturity. A computer printout of the spacing data was used to identify the individual plants and was corrected where necessary for errors in the earlier measurements, missing plants and plants which had emerged since the initial measurements were taken.

The primary and secondary sorghum heads (secondary heads are those developed on tillers) were cut at the lowest inflorescence node and weighed individually at the site to determine head fresh weight. The sunflower heads were cut where the head joins the stem. In addition, grain dry weight was determined on the individual heads of 50 plants from one or both blocks at each site. Heads from these plants were threshed by hand or in a single head thresher and the grain was oven-dried at 85°C for 24 hours before weighing.

The cooperating farmer also provided details of the harvested grain yield from each paddock from which samples were taken.

3. CROPPING DETAILS

Information on the crops surveyed is given in Table 1. All sites received a sowing rain $\geq$ 23 mm between 28 and 31 December 1987 and all crops were sown during the first 11 days of January 1988. The sowing rain would have been sufficient to link surface and subsoil moisture.

Information on native vegetation, soil type, the previous crop sown and tillage is presented in Appendix II.

4. ANALYSIS OF THE SURVEY DATA

4.1 Plant and row spacing data

The plant spacing measurements, which were recorded manually in the field, were later transferred into a computer data set using the program SUPERCALC 4. Each plant was numbered for later reference and its position in each block was defined by the X, Y coordinates from one corner of the block.

4.2 Calculation of single plant grain yields

The data for head fresh weight and grain dry weight of the primary and secondary heads of 50 plants per block were recorded manually and later transferred to a data set using the program QUATTRO. These data sets were used to obtain regressions between grain dry weight and head fresh weight for both primary and secondary heads. A linear regression of grain dry weight per head (D) against head fresh weight (F) of the form

$$D = a + b.F \quad \text{(where a and b are regression coefficients)} \qquad [1]$$

was fitted satisfactorily to each data set. Inclusion of a quadratic term ($c.F^2$) did not significantly improve the regressions. Details of the regressions obtained for each block are given in Table 2. Dry grain yields for the remaining plants in each block were then estimated from the regressions. Calculated block yields were adjusted to a moisture content of 12% for comparison with the actual crop yields recorded by the grower.

Table 1. Details of crops surveyed

Farm	Crop species	Cultivar	Soil type	No. of tillage operations	Rainfall, 0-21 days	Cropped area	Farmer's figure for grain yield of total cropped area	Sample estimate of grain yield of block
					mm	ha	t/ha	t/ha
1	Sorghum	E57+	Scrub	5	7	217	3.34	3.04
2	Sorghum	Goldrush II	Open downs	3-4	0	243	2.40	1.38
3	Sunflower	Ag-seed 40R	Open downs	3	13	-[1]	-[1]	-
4	Sorghum	Bullet 2	Open downs	4	7	45	1.88	3.98
5	Sorghum	Goldrush II	Scrub	4	0	81	3.63	4.34
7	Sorghum	Goldmine	Open downs	4	0	20	2.96	2.74
	Sunflower	Hysun 33	Open downs	4	0	20	1.26	1.24
8	Sorghum	Goldmine	Open downs	3	22	53	2.83	2.66
	Sunflower	Cannon	Open downs	3	22	36	1.26	1.36
9	Sorghum	E57	Open downs	4	0	-[1]	-[1]	-
10	Sorghum	Goldmine	Open downs	5	10	24	1.82	2.48
	Sunflower	Hysun 33	Open downs	5	10	57	0.73	1.22
11	Sorghum	DK37	Scrub	6	15	-[1]	-[2]	1.88
12	Sorghum	Goldmine	Semi-open downs	2-3	26	-[1]	-[1]	-
13	Sorghum	White Charger	Semi-open downs	2	23	160	2.66	2.33
14	Sorghum	Leader	Scrub	3	10	-[1]	-[1]	-
15	Sorghum	Duke	Open downs	3	10	243	2.51[3]	2.13
16	Sorghum	Goldmine	Open downs	3	6	162	1.82	1.99
17	Sorghum	Goldmine	Scrub	3	15	126	2.83	3.01
18	Sorghum	Goldmine	Open downs	4	3	28	2.68	2.97
19	Sorghum	White Charger	Scrub	3	0	903	3.77	3.80
21A	Sorghum	MR50	Open downs	3	0	729	3.03	2.73
21B	Sorghum	Goldmine	Open downs	3	0	729	3.03	2.48

1 Information not sought because irrelevant to data interpretation.
2 Farmer's yield not relevant because he waited and harvested the heads which developed following rain.
3 Grain yield from unlodged areas; average for whole paddock 2.12 t/ha.

Table 2. Regressions of grain dry weight against head fresh weight for sorghum (primary and secondary heads) and sunflower.

Block	Primary head						Secondary head(s)					
	a	se	b	se	r^2	n	a	se	b	se	r^2	n
Sorghum												
1a	-2.25	1.43	0.560	0.010	0.98	50	-2.28	2.64	0.532	0.023	0.97	20
2a	-2.77	0.67	0.664	0.019	0.96	50	-2.13	0.43	0.521	0.025	0.94	31
4a	2.89		0.548		0.94		-1.63		0.575		0.99	
5a	-1.70	1.44	0.629	0.016	0.97	52	-1.51	1.51	0.595	0.022	0.91	79
7a	-1.69	0.56	0.517	0.008	0.99	50						1
8b	-1.07	0.71	0.615	0.009	0.99	52	-4.51	0.58	0.617	0.018	0.98	23
10a	-3.98	0.91	0.635	0.012	0.98	50	-3.68	1.62	0.575	0.045	0.98	6
11a	-2.76	1.67	0.618	0.020	0.95	50	-8.97	3.73	0.702	0.063	0.87	21
13a	-1.61	0.83	0.615	0.014	0.98	51	-3.64	1.62	0.548	0.029	0.98	10
15a	-2.66	0.81	0.728	0.017	0.98	50	-2.31	0.68	0.729	0.026	0.99	12
17a	-11.21	1.72	0.725	0.015	0.98	50	-11.84	1.53	0.746	0.017	0.99	30
17b	-2.20	1.52	0.755	0.010	0.99	51	-2.93	2.78	0.765	0.021	0.96	56
18a	-3.86	3.04	0.738	0.013	0.99	51	-5.20	5.81	0.582	0.131	0.60	15*
18b	-1.24	2.70	0.748	0.009	0.99	53	-7.79	2.96	0.801	0.019	0.98	31
19a	-1.30	1.68	0.747	0.011	0.99	51	1.52	1.70	0.684	0.042	0.98	8
19b	-1.73	2.53	0.723	0.015	0.98	50	-1.19	1.77	0.702	0.023	0.98	21
21Aa	-1.50	2.32	0.710	0.013	0.99	50	-2.93	0.31	0.740	0.004	1.00	3
21Ab	-5.08	4.66	0.735	0.012	0.99	51	-2.26	1.57	0.675	0.182	1.00	5
21Ba	-4.80	2.32	0.752	0.014	0.99	50	-6.28	2.75	0.755	0.024	0.98	26
21Bb	-3.24	2.04	0.701	0.016	0.98	49	-2.63	3.74	0.558	0.044	0.90	20*
Mean	-2.98	2.03	0.680	0.014	0.98	51	-3.92	2.50	0.657	0.060	0.94	22
Sunflower												
7a	-2.74	7.10	0.605	0.027	0.92	45						
7b	-3.30	4.36	0.597	0.013	0.98	52						
8a	9.02	7.77	0.480	0.034	0.80	50						
8b	-2.68	4.63	0.699	0.029	0.93	50						
10a	17.13	11.20	0.213	0.014	0.83	46						
10b	22.84	17.52	0.196	0.023	0.61	48						
Mean	6.71	8.76	0.465	0.023	0.85	49						

* 30-50% of these heads had no grain

A regression of the form D = a + bF was fitted to the data for each block, where D = grain dry weight, F = head fresh weight, a and b are constants (± se), r^2 is the correlation coefficient, n = number of plants used.

4.3 Plant distribution maps

The individual plant coordinates and calculated dry grain yields for each plant were used to construct plant distribution maps (Appendix III) to display the variation in interplant spacing and individual plant yield in a block. Each plant was represented on a scaled (1:100) map of the block by a circle which was proportional in size to the dry grain yield. These maps display the spatial distribution of plants within a block and the effect of spacing on individual plant yield. The maps were generated on a NEC LC890 laser printer using a custom written POSTSCRIPT program.

4.4 Density/Uniformity/Yield Analysis

The data for each block were analysed separately for yield losses due to suboptimal density and uniformity using the method developed by Wade *et al.* (1988) and Wade and Foreman (1988). In essence, the method uses a multiple regression technique to determine the quantitative relationship between grain weight per plant, plant density and the uniformity of the stand. For each plant, spacing accuracy can be measured in terms of the proximity of its two neighbouring plants within the row, which would be expected to dominate interplant competition in wide-row summer crops. Wade *et al.* (1988) concluded that spacing uniformity was best expressed in terms of coefficient of variation. If the distances to the nearest neighbours are X1 and X2, the equation for coefficient of variation simplifies to the following for X1 > X2:

$$C = 100 \times 2^{0.5} \times (X1 - X2)/(X1+X2) \qquad [2]$$

Wade *et al.* (1988) found that a parabolic relationship of the form shown in Equation 3 best accounted for the variation in grain yield per plant for raingrown sunflower on the Darling Downs of Queensland:

$$W = a + b.A + c.A^2 + d.C \qquad [3]$$

where W = grain weight/plant (g), A = area/plant (sq m), C = coefficient of variation (%), and a, b, c and d are regression coefficients. A direct relationship with grain yield is obtained by multiplying through by plant density:

$$Y = a.P + b + c.A + d.C.P \qquad [4]$$

where Y = grain yield (g/sq m), P = plant density (per sq m), A = area/plant (sq m), C = coefficient of variation (%) and a, b, c and d are regression coefficients. Grain yield in kg/ha may be obtained by multiplying by 10.

Wade *et al.* (1988) and Wade and Foreman (1988) attributed biological significance to the constants a, b, c and d in Equation 4, for situations in which b is positive and a, c and d are zero or negative. The crop yield potential at a site is represented by the constant b, which is reduced at low density by the proportion of space available per plant which is not utilised (c). When the intercept 'a' is negative, grain yield increases to a maximum before declining again with further increase in density. Thus 'a' represents the proportional change in dry matter distribution, with less being allocated to reproductive components at high density. For uneven plant spacings, the crop yield potential is reduced by the proportion (d) of the most scarce resource denied to the individual plant, relative to an equivalent plant at even spacing.

Values for W, A and C were obtained for each plant, and Equation 3 was fitted by stepwise multiple regression for each block of 500 plants. Grain yield relationships (Equation 4) then provided a basis for quantifying yield losses due to suboptimal density and uniformity at each site.

4.5 Estimation of yield losses for each block

Substitution of actual values of mean plant density and mean uniformity into Equation 4 allows the estimation of overall yield reduction at a site relative to the theoretical yield potential (b). The overall yield reduction may be partitioned into its density and uniformity components, and appropriate percentage yield reductions may be calculated, relative to either a theoretical site yield potential (Y_{max}) or to a commercially achievable site yield potential (Y_{opt}). Y_{max} represents the yield prediction from Equation 4 for high plant densities ($P > 10$/sq m for sorghum and $P > 6$/sq m for sunflower) at high uniformity ($C = 0$ to 50%). This yield is not currently achievable on a paddock scale and our estimate may be artificially high due to the possibility of clumped plants exploiting areas ascribed to their neighbours. In poorer seasons Y_{max} would be quite low due to an excessive plant population for the environmental conditions. Y_{opt} was of more interest here, representing the yield prediction from Equation 4 for recommended plant densities ($P = 5$ to 10/sq m for sorghum and $P = 4$ to 6/sq m for sunflower) at levels of uniformity attainable by leading farmers ($C = 0$ to 50%).

For each block of 500 plants, reductions in grain yield due to suboptimal plant density and non-uniformity of plant spacing relative to the commercially achievable yield potential were obtained as follows.

Each plant was allocated to a group according to its density ($P<5$, $5<P<10$ and $P>10$/sq m for sorghum and $P<4$, $4<P<6$ and $P>6$/sq m for sunflower) and uniformity ($C<50$, $50<C<100$ and $C>100$%). Plant number (N) and mean values of A and C were obtained for each of the nine groups. Mean grain yield for each group was obtained by substituting the appropriate A and C values into Equation 4. Commercially achievable site yield potential (Y_{opt}) was taken as the value for the group with $5<P<10$/sq m and $C<50$% for sorghum and with $4<P<6$/sq m and $C<50$% for sunflower. Yield reductions for other groups relative to Y_{opt} were calculated as follows:

$$Lg = \frac{100\ (Y_{opt} - Y_g) \cdot p_g}{Y_{opt}}$$

where L_g = yield loss in group g (%), Y_{opt} = commercially achievable site yield potential, Y_g = yield for group g and p_g = proportion of block occupied by group g.

Contributions to yield reduction at each site can be considered by examining values for each of the nine groups, or alternatively, density and uniformity contributions may be estimated. The contribution of suboptimal density was taken as the sum of yield loss percentages for the three groups with densities less than five sorghum or four sunflower plants/sq m. The contribution of non-uniformity in plant stand was taken as the sum of yield loss percentages for the four groups with densities greater than five sorghum or four sunflower plants/sq m and coefficients of variation greater than 50%. Using this methodology, a commercially achievable site yield potential (Y_{opt}), a yield loss in relation to density (L_P) and a yield loss in relation to uniformity (L_C) can be obtained for each block.

These values can then be used to estimate the economic consequences of poor crop establishment.

4.6 Economic analysis

The total sorghum yield loss associated with suboptimal plant spacing was estimated for the Central Highlands for the 1987-88 season using the mean percentage loss for the 16 sorghum crops analysed for yield loss and the total tonnage produced in the region. The value of this yield loss was estimated assuming a price of $105/t at the farm gate.

The value of recoverable yield losses expected from a research/development/extension programme to improve plant spacing was determined as a gross present value, with no allowance for extra costs incurred to prevent those losses. This value was calculated by summing the discounted values of recoverable yield losses over a 12 year period. The discounting procedure used was contained in a computer spreadsheet developed to measure the Net Present Value (NPV) of crop research projects. NPV is defined as the present value of future profits less the present value of the expenditures giving rise to the profits. The spreadsheet incorporates a mathematical technique (Metwally, *et al.*) to determine the yield and value of a research project from estimates of the worst, most likely and best possible outcomes. An interactive discussion group of involved scientists used the results of the survey to estimate these three outcomes, the proportion of the region that would benefit and the rate of change of costs, returns and treated area. No attempt has yet been made to apportion losses to the research projects that would be required to achieve the predicted yield gains nor was the cost of the required research, extension or on-farm investment estimated.

Table 3. Target and measured populations for sorghum and sunflower crops

Crop	Farm	Target population (10^3 plants/ha)	Population at sampling sites (10^3 plants/ha)	Population as a % of target population
Sorghum	1	62	40	65
	2	61	90	148
	4	-	35	-
	5	-	47	-
	7	-	98	-
	8	-	72	-
	9	50	41	82
	10	-	53	-
	11	87	35	40
	12	87	46	53
	13	74	49	66
	14A	75	34	45
	14B	75	65	87
	15	-	88	-
	16	57	31	54
	17	70	59	54
	18	-	37	-
	19	64	67	105
	21A	69	41	59
	21B	69	50	72
Sunflower	3	37	27	76
	7	30	34	110
	8	-	35	-
	10	-	23	-

5. RESULTS

5.1 Plant population densities

5.1.1 Target populations

Only 11 of the 18 sorghum growers actually had a target plant population density at the time of sowing, and these ranged from 50,000 to 86,000 plants/ha (Table 3). If the recommendation of Thomas *et al.* (1981) of 60,000 to 80,000 plants/ha for dryland sorghum is accepted, then three growers aimed too low and three too high. However, if the broader extension recommendation of 50,000 to 90,000 plants/ha is accepted, then all growers with a specific target population were within an appropriate range. It appears that growers who recognised the need for a target population accepted the broad QDPI recommendation.

Only two of the four sunflower growers had a target population at sowing and both (Table 3) were lower than the recommendation of Wade and Foreman (1988) of 40,000 to 60,000 plants/ha. This is not uncommon among sunflower growers, who erroneously think that the large seedheads on widely-spaced plants will maximise yield per unit area (Radford 1981). Extension personnel from agribusiness often reinforce such misconceptions (Bailey 1981).

5.1.2 Observed populations

Only eight of the 20 sorghum crops had populations within the QDPI-recommended range of 50,000 to 90,000 plants/ha; one exceeded this range and 11 were below it (Table 3). Of 13 sorghum crops for which the farmer nominated a target population within the recommended range, only five achieved populations within that range.

All four sunflower crops had populations below the QDPI-recommended range of 40,000 to 60,000 plants/ha (Table 3).

5.2 Establishment

5.2.1 Germination percentage of seed

The germination percentage shown on the bag label (Table 4) varied from 70 to 95% for sorghum and from 75 to 90+% for sunflower. Mean germination percentage for sorghum averaged 88%; the corresponding mean for sunflower was 84%.

5.2.2 Expected establishment percentages

Twelve of the 19 growers used an estimate of establishment percentage in calculating their sowing rate. It is significant that all farmers who had a target population did use a specific establishment percentage in their calculation of sowing rate.

Table 4. Seed germination percentages, farmers' anticipated establishment, actual levels of establishment at survey sites, and farmers' estimates of actual establishment

Crop	Farm	Seed germination percentage on bag	Establishment allowed for (questionnaire replies)	Observed establishment at survey sites		Farmer's estimate of establishment (questionnaire replies)
		%	%	% of seed sown	% of viable seed	%
Sorghum	1	85 (min.)	83	53	62	83
	2	95	55	79	83	75
	4	86	-	37	43	50
	5	90	-	53	59	-
	7	85	75	71	83	-
	8	90+	-	73	81	-
	9	?	80	73	-	75
	10	?	-	52	-	-
	11	85 (min.)	95	37	44	<95
	12	95	70	60	63	70
	13	80	80	54	68	-
	14A	90	80	26	29	60
	14B	90	80	60	66	60
	15	70	-	71	102	-
	16	91	85	38	42	77
	17	95	80	67	71	-
	18	91	70	34	37	80
	19	80	70	59	73	-
	21A	88	80	38	44	-
	21B	95	80	57	60	-
Sunflower	3	86 (min.)	90	65	76	75
	7	75	75	75	100	62
	8	90+	-	93	103	-
	10	?	-	38	-	-

The establishment figure allowed for (Table 4) averaged 78%, but some farmers made their calculations on the basis of viable seed sown while others calculated on the basis of total seed sown.

5.2.3 Observed establishment percentages

The establishment levels measured at each site are presented in Table 4.

All sorghum growers except two had lower levels of establishment than they expected. The grower from Farm 2 had the lowest expectation of sorghum establishment (55%) but actually obtained the highest (79%). (This farmer recognised that he had an insect problem likely to affect establishment and was also concerned about post-emergence mortality due to *Fusarium* in the soil.) Average expectation was 78% while average achievement was only 55% of the seed sown, which is similar to the 51% obtained by Spackman (1980) in 1979-80. This represents 62% of the viable seed sown (for farms where establishment could be determined on the basis of viable seed). The germination percentage shown on the seed label was assumed to be correct at the time of sowing (an assumption which needs to be checked in future surveys).

Mean sunflower establishment was 68% of the seed sown. Most farmers clearly have an unrealistic expectation of the level of establishment they achieve with present technology, at least in some seasons.

The method of estimating planter seeding rate affects the accuracy of determination of establishment percentage. Of the farmers interviewed, 15% simply used the chart on the planter, 55% calculated the output by stationary or mobile calibration and 30% used the ratio of total seed used/total area sown.

5.2.4 Estimated establishment after emergence (by farmers)

In the questionnaire, growers were asked what establishment percentage they thought they had achieved (Table 4). The limited number of replies indicates that only about half checked their stands following emergence to make an estimate of establishment.

Some estimates were far in excess of the observed value. For example, the farmer expecting 95% establishment only obtained 37% establishment of seed sown.

5.2.5 Row spacings

Row spacing on the surveyed farms varied from 23 to 100 cm and there was also marked variation in spacings within individual crops. This was largely due to variation in spacing of the planting points across the machine, but the action of cultivating tines behind the sowing tines in moving rows laterally may also have played some part. At Farm 11, for example, row spacing averaged 83 cm but ranged from 64 to 108 cm. Furthermore, because there was often extremely poor establishment in the rows sown into wheel tracks, these wheel track rows effectively became missing rows. One farmer did not plant in his wheel tracks to save wasting seed. This concept could be extended to the placement of rows on either side of the tractor wheel tracks to minimise wastage of space as well as seed. This may not be practicable with dual wheel tractors.

In addition to the variation in row spacing across the width of the planter, variation in the spacing of 'guess rows' between successive planter runs also contributes to the variation in plant arrangement in a farmer's field.

5.3 Planters

A total of 21 planters were used to sow the surveyed crops. Information on sowing techniques and the machinery used is presented in Appendices IV and V.

5.3.1 Planting points

Ground engaging components or planting points are used to place seed in contact with moist soil. Wide points are used for weed control at sowing, but increase in the width of the planting point generally increases soil disturbance, which reduces seed-soil contact, causes mixing of wet and dry soil and increases evaporation of seedbed water after sowing. Information on the planting points used is given in Table 5. Most were quite wide, indicating that weed control at sowing is seen as a higher priority than optimising the environment for establishment.

Table 5. Details of planting points on the 21 planters used to sow the surveyed crops

Type of point*	Width of point	No. of machines
	mm	
Spear-point	25	4
Reversible chisel (Gyral)	25	1
Reversible chisel (Janke)	50	1
Duckfoot	125	5
Duckfoot	150	3
Duckfoot	175	4
Duckfoot	225	2
Duckfoot sweep	300	1

* Points are ranked in order of width down the column

5.3.2 Cultivating tines

The high priority on weed control at sowing is further indicated by the fact that 19 of the 21 machines surveyed combined cultivation with sowing. The use of cultivating tines behind sowing tines increases seedbed disturbance and also the depth of soil cover over some rows, especially at high sowing speeds.

5.3.3 Press wheels

Fourteen of the 21 machines surveyed had press wheels. Details of pressures and types are given in Table 6. Nielsen *et al.* (1986) recommended press wheel pressures of 2 to 6 kg/cm width of wheel for sorghum.

Table 6. Details of press wheel pressures and designs on the 21 planters used to sow the surveyed crops

Press wheel pressure	No. of machines
(kg/cm)	
0 (no press wheel)	7
2-2.5	4
3	2
4	2
7	2
Variable (row to row)	2
Not measured	2

Press wheel type	No. of machines
Zero centre pressure	11
Single rib	1
Double rib	1
Car tyres	1

One farmer (farm 15) used 'Terrasorb'in lieu of press wheels.

5.3.4 Sowing depth

In response to the question on sowing depth, farmers indicated sowing depths varying from 38 to 102 mm. Several farmers said they were giving the depth of soil cover above the seed after sowing rather than the depth of seed placement below the original level of the soil surface. This is probably what others were also referring to.

At all seven sites where we measured depth of soil cover, the range of depths was $\geq$ 40 mm, indicating poor depth control.

One farmer who said he sowed at 38 mm had an average depth of soil cover of 61 mm (range 35 to 75 mm). Two farmers who sowed at "64 to 76 mm" had depths of soil cover of 25 to 80 mm and 45 to 100 mm.

Types of depth control are shown in Table 7. Good depth control systems are particularly important on the wide planting machines used in the Central Highlands. Seed placed too deep or too shallow is less likely to emerge.

Table 7. Depth control systems on the 21 planters used to sow the surveyed crops

Type of depth control*	No. of machines
Parallelogram unit planters with press wheel depth control	3
Unit planters with single pivot press wheel depth control	2
Main frame depth control (wheels within frame)	13
Main frame depth control (wheels outside frame)	3

* Depth control systems are ranked from best to worst down the column.

5.3.5 Fertiliser placement with seed

No farmer placed fertiliser with the seed.

5.3.6 Sowing speed

Sowing speed varied from 6.4 to 12 km/hr.

It is generally accepted that speeds in excess of 10 km/hr are excessive, causing too much seed bounce. Of the farmers interviewed, 20% indicated they sowed at speeds in excess of 10 km/hr.

5.3.7 Seed metering

Acceptable spacing index (ASI) is a measure of the accuracy of a seed meter and seed delivery tube and is defined as the percentage of spacings within 50 to 150% of the target spacing (Agness and Luth 1975). ASI for the 21 machines in the survey are shown in Table 8.

Table 8. Acceptable spacing index (ASI) for the 21 metering mechanisms at normal sorghum metering speeds (10 to 30 seeds/sec)

Seed metering mechanism	ASI (%)		No. of machines
	Meter	Meter + seed tube	
Cycloplanter (I.H.)	80-95	50-55	1
Feed cup (J.D.)	55-65	50-55	1
Inclined plate (Janke)	45-60	40-50	2
Air seeder (various)	30-45	30-45	16
Fluted roller (C.S. combine)	35-40	35-40	1

While the cycloplanter is very accurate at all normal metering rates, the forward rake of the seed tube and the high velocity of the seed cause severe seed bounce problems. Seed bounce reduces spacing accuracy and reduces establishment because seed is placed too shallow in dry soil.

5.4 Biotic factors

5.4.1 Soil insect pests

Details of the soil insects found during the survey and the insecticide treatments applied by farmers are presented in Table 9. The insects in order of importance as seed/seedling pests are wingless cockroaches, false wireworm, field cricket and scarabs. Species were identified and stage of growth recorded. Minor and non-pest species are not listed.

Five farms had insect pest densities high enough to cause crop damage. Two of the growers applied no insecticide at all, two applied chlorpyrifos seed dressing but also needed chlorpyrifos beetle bait, and one applied chlorpyrifos beetle bait but also needed chlorpyrifos seed dressing. It is not easy, however, for growers to identify soil insect pests, assess their populations and select the most appropriate control measure.

Farm 16 represented a case where no insecticide was applied to a crop heavily infested with insect pests. This site had the lowest sorghum population (31,100 plants/ha), one of the lowest establishment percentages (38%) and one of the lowest grain yields.

Table 9. Soil insect pest densities at 13 farms, insecticides applied by the farmers and the probability of crop damage during establishment

Farm	Insect pests/sq m: Wingless cock-roaches	False wire-worms* (4 spp)	Field crickets (2 spp)	Scarabs (2 spp)	Probability of crop damage+	Insecticide treatment: recommended by entomologist+	applied by farmer
1				1	Negligible	Nil	Nil
2	2	6 (4)	1	6	Likely	Lorsban# (or in-furrow spray)	Beetle bait
3	1				Negligible	Nil	Nil
4		1 (1)		1	Negligible	Nil	Nil
12	3	2	1	2	Possible/ likely	Beetle bait	Lorsban#
13	1			4	Negligible	Nil	Nil
14		2		1	Possible	Beetle bait	Lorsban#
15	1	1	1		Negligible	Nil	Lorsban#
16	14	13	2		Certain	Beetle bait	Nil
17					Negligible	Nil	Nil
18	2	1 (1)			Negligible	Nil	Nil
19		1		1	Negligible	Nil	Nil
21	1	1	1		Possible	Beetle bait	Nil

* No. of larvae in parenthesis

+ Based on counts made 3 to 5 weeks after sowing

Lorsban seed treatment at 160 g/100 kg seed

5.5 Grain yields

5.5.1 Paddock and block grain yields

Figures for mean paddock grain yield provided by the farmers and yield from the sampling blocks are given in Table 1. In the Central Highlands of Queensland, commercial dryland grain sorghum crops generally yield 1.5 t/ha on average, with a standard deviation of 0.5 t/ha, but yields as high as 5.0 t/ha have been recorded (Milne *et al.* 1988). The range of whole-paddock sorghum yields attained (1.8 to 3.8 t/ha) supports the validity of the survey data as representative of much of the seasonal diversity to which sorghum crops are exposed in this environment.

5.5.2 Single plant grain yields

Regressions between grain dry weight and head fresh weight for sorghum (both primary and secondary heads) are shown in Table 2. The linear regressions commonly accounted for more than 95% of the variation. The gradient of the regression indicates the proportion of fresh head weight which is dry grain, a combination of threshing percentage and grain moisture percentage. For main stems, the gradient ranged from 0.52 to 0.76, with tiller values generally slightly lower. With fewer heads available to fit the regressions, precision for the tillers was generally lower. Intercepts were generally negative, indicating a minimum head size was necessary before grain was present. A consistent regression form was apparent, but the coefficients varied with cultivar and location (seasonal favourability).

Regressions between grain dry weight and head fresh weight were not as precise or consistent in form for sunflower as for sorghum (Table 2) but were adequate for estimating the grain yield from individual heads.

Because of the significant differences between blocks, the specific grain dry weight regressions for each block were used to estimate individual plant grain yields.

5.5.3 Grain yields, plant densities and coefficients of variation

Mean grain yield, mean plant density and coefficient of variation for each block are shown in Table 10. Block mean yields for sorghum ranged from 1.4 to 4.4 t/ha with a mean of 2.8 t/ha. On average, a sorghum plant density within the recommended range at the time of the survey (5 to 9 plants/sq m) was obtained on the surveyed farms. However, the mean density of 5.35 plants/sq m was associated with a standard deviation of 2.06 and a range of 2.3 to 9.8 plants/sq m. Mean yield for sunflower was 1.3 t/ha but plant density was always below the recommended range (4 to 6 plants/sq m). Mean uniformity was consistent and intermediate in value (55 to 75% on average) but such values disguise considerable within-site variability as subsequent analysis shows.

5.5.4 Density/uniformity analyses

Regression coefficients from Equation 3 for each block are presented in Table 11. The 'b' coefficient was in all cases large, positive and statistically highly significant. With the exception of site 7 (sorghum), the 'c' coefficient was always negative, and generally large and statistically highly significant. The 'd' coefficient was also negative and generally statistically significant. The positive 'b' and negative 'c' and 'd' coefficients are in accord with the expected form of the model (Wade *et al.* 1988). The intercept 'a' was generally positive and non-significant however, which is not in accord with the model. As discussed in Section 5.5.5, the positive intercept and disappointingly low R^2 values (ranging from 0.09 to 0.40) are attributable to either imprecision in the estimation of W, the grain dry weight per plant, or to the inadequacy of A, the area per plant, as a measure of resource availability.

Table 10. Mean grain yield, plant density (P) and coefficient of variation (C) for each block

Sorghum

Block	Yield	P	C
	t/ha	plants m^{-2}	%
1a	2.86	4.14	66.9
1b	3.09	3.89	69.4
2a	1.35	8.95	69.9
4a	4.04	3.49	66.9
4b	3.74	3.52	71.6
5a	4.16	3.74	70.7
5b	4.34	5.71	75.0
7a	2.64	9.84	68.7
7b	2.73	9.79	69.8
8a	2.14	6.12	65.8
8b	3.06	8.26	67.5
10a	2.37	5.48	72.4
10b	2.48	5.11	72.5
11a	2.07	3.74	55.1
11b	1.61	3.27	60.8
13a	2.27	4.31	67.9
13b	2.30	5.43	71.8
15a	2.08	8.84	67.0
16a	2.17	3.95	71.3
16b	1.73	2.27	61.7
17a	3.07	6.52	69.0
17b	2.83	5.25	68.9
18a	2.72	3.85	68.9
18b	3.09	3.47	70.8
19a	4.03	6.81	70.1
19b	3.42	6.46	66.7
21Aa	2.41	4.14	65.4
21Ab	2.93	4.08	69.1
21Ba	2.42	3.97	68.8
21Bb	2.44	6.04	65.7
Mean	2.75	5.35	68.2
Range	1.35-4.43	2.27-9.84	55.1-75.0

Sunflower

Block	Yield	P	C
	t/ha	plants m^{-2}	%
7a	1.26	3.15	68.3
7b	1.49	3.64	69.1
8a	1.38	2.93	64.8
8b	1.65	4.03	71.7
10a	1.16	1.79	74.8
10b	1.55	2.80	68.0
Mean	1.42	3.06	69.5
Range	1.16-1.65	1.79-4.03	64.8-74.8

Table 11. Regression coefficients from Equation 3 for each block

Block	a	b	c	d	R^2	N
			Sorghum			
1a	49.7ns	148.0**	-78.3**	-0.134**	0.21	490
1b	49.9ns	191.5**	-88.6**	-0.138**	0.31	493
2a	8.9ns	73.5**	-24.5ns	-0.023*	0.20	482
4a	85.2ns	252.2**	-100.9	-0.386**	0.33	476
4b	83.1ns	138.5**	-38.0**	-0.136*	0.16	449
5a	66.9ns	276.1**	-111.4**	-0.204**	0.40	490
5b	47.3ns	264.9**	-135.0**	-0.140**	0.34	483
7a	22.4ns	68.2**	-16.2ns	-0.033*	0.15	487
7b	22.0ns	80.0**	10.8ns	-0.036*	0.21	426
8a	26.6ns	73.6**	-37.9**	-0.025ns	0.10	517
8b	21.5ns	185.7**	-167.1**	-0.041ns	0.21	498
10a	30.2ns	110.5**	-39.8ns	-0.067*	0.19	481
10b	25.0ns	164.1**	-97.0**	-0.024ns	0.24	482
11a	28.6ns	121.8**	-29.6ns	-0.051ns	0.20	489
11b	28.0ns	121.2**	-43.3**	-0.052*	0.10	384
13a	37.5ns	110.8**	-53.6**	-0.086*	0.17	486
13b	31.3ns	127.1**	-121.1**	-0.087**	0.17	499
15a	17.6ns	102.2**	-95.8*	-0.052**	0.16	488
16a	31.6ns	92.9**	-37.0**	0.070ns	0.12	502
16b	39.9ns	133.2**	-34.9**	-0.093ns	0.25	482
17a	29.4ns	238.9**	-227.8**	-0.153**	0.35	446
17b	34.2ns	219.0**	-136.3**	-0.182**	0.37	484
18a	50.4ns	155.6**	-107.2**	-0.095**	0.19	513
18b	67.0ns	193.6**	-88.3**	-0.273**	0.24	494
19a	37.7ns	214.0**	-149.7*	-0.071*	0.29	502
19b	30.8ns	233.8**	-194.7**	-0.106**	0.29	496
21Aa	30.9ns	137.0**	-55.9*	-0.016ns	0.26	493
21Ab	52.9ns	159.8**	-71.8**	-0.195**	0.21	495
21Ba	41.7ns	164.0**	-88.1**	-0.170**	0.26	485
21Bb	19.9ns	173.1**	-121.2**	-0.049**	0.39	490
Mean	38.3	157.5	-86.0	-0.102	0.24	483
Range	8.9- 85.2	68.2- 264.9	-227.8- 10.8	-0.386- 0.070	0.10- 0.40	384- 517
			Sunflower			
7a	28.6ns	64.5**	-39.2**	-0.041ns	0.09	470
7b	27.3ns	98.1**	-54.3**	-0.097**	0.22	471
8a	41.2*	32.1**	-9.8**	-0.035ns	0.11	472
8b	34.3ns	52.4**	-23.0*	-0.057*	0.10	472
10a	51.5*	46.3**	-13.2**	-0.074**	0.19	418
10b	44.5*	47.4**	-17.1**	-0.025ns	0.11	463
Mean	37.9	56.8	-26.1	-0.055	0.14	461
Range	27.3- 51.5	32.1- 98.1	-54.3- -9.8	-0.097- -0.025	0.09- 0.22	418- 472

(ns, not significant; * $P < 0.05$; ** $P < 0.01$)

While the form of the model is consistent with Wade *et al.* (1988), the precision of the regression was low (low R^2), with consequently large standard errors on the intercept and on the yield estimate at each point on the curve. Percentage yield loss estimates, calculated as per section 4.5, should nevertheless provide a valid basis for considering losses attributable to suboptimal plant density and non-uniformity in plant spacing. Such yield loss percentages are discussed further in section 5.5.6.

5.5.5 Departures from the regression model

As the area per plant (A) increases from zero, the grain weight per plant (W) would be expected to increase from zero to the maximum value. Consequently, zero or negative intercepts are preferred for Equation 3, implying that a minimum value of A is necessary before W exists (Wade *et al.* 1988). Positive intercepts resulting from these data may be attributable either to imprecision in the estimation of W, or to inadequacy of A as a measure of resource availability.

Grain dry weight per plant (W) was generally estimated from head fresh weight (Equation 1). While the R^2 values were generally large (Table 2), this method could introduce some additional variability into estimates of W, since both threshing percentage and moisture content were being corrected. We do not consider this source of variability to account for much of the variation overall.

Misclassification of tillers as plants could also influence Equation 3. A tiller with a small area available would presumably have a significant advantage over a plant with a similarly small area available, because of the contribution the parent plant presumably could make to the tiller early in its growth. Misclassified tillers would therefore provide larger values of W for small values of A than would otherwise be possible. We tested this by deleting cases for which the inter-plant spacing (X1-X2) was less than 5 cm. Values of the regression coefficients were not significantly affected.

The third possibility is that A is inadequate as a measure of resource availability, which dominates the value of W attained by the individual plant. As Wade *et al.* (1988) noted, considerable variation can be attributed to factors not considered in the regression. These include seed vigour, seed size, depth of seed placement, time of emergence, the quality of the microenvironment for seedling establishment and subsequent growth, weed competition, and the proximity of neighbouring plants in adjacent rows and at distances greater than X1 and X2 within the row. Variation in these factors could result in a larger W than the available A would be expected to support. Such a plant would behave as if it had access to larger A (which it has, via enhanced competitive ability). Large values of W at low A would have a big effect on the magnitude of the intercept 'a' of Equation 3. Departures from the expected form of the regression model are thus principally attributable to plant-to-plant variation in these factors affecting vigour.

We conclude that while the form of the model is consistent, imprecision in the data associated with differential plant-to-plant vigour reduced the precision of Equation 3. Percent yield loss estimates, calculated as in section 4.5, should nevertheless provide a valid basis for considering losses attributable to suboptimal plant density and non-uniformity in plant spacing.

5.5.6 Percent yield loss estimates for each block

Potential yield (Y_{max}), percent yield reductions due to suboptimal density and uniformity relative to that potential (L_P and L_C), and the resulting Y_{est} values for each block, are presented in Table 12. The comparable values for achievable yield (Y_{opt}, L_P, L_C, Y_{est}) are presented alongside, together with the block mean yield. Correlations among these values for the sorghum data are shown in Table 13.

For sorghum sites 1, 4, 5 and 18, large positive intercept values in Equation 3 resulted in excessively high estimates of potential yield (Y_{max}). After deducting density and uniformity losses however, mean yield estimates relative to that potential (Y_{est}) are nevertheless realistic and well correlated with block yield. Because of the excessively high estimates of Y_{max} however, estimates of L_P and L_C relative to Y_{max} would also be unrealistically large. Consequently, we have more confidence in values of Y_{opt}, L_P, L_C and Y_{est} associated with achievable yield.

The estimates of achievable yield (Y_{opt}) provide meaningful values with lower standard deviations. These yield estimates, and the percent yield losses L_P and L_C associated with them, are therefore considered valid estimates for the blocks sampled.

The results suggest that on average, yield losses of 29.1% for sorghum and 42.4% for sunflower occurred due to lack of plants in each square metre of crop stand, with a further loss of 1.7% for sorghum and 0.6% for sunflower due to poor distribution of those plants within each square metre. Obtaining the target plant number in each square meter of crop is thus more important than obtaining uniform distribution. From block to block there was considerable variation in density contribution to yield loss (7.3 to 52.1%), with a much smaller contribution for uniformity (0 to 3.8%). The significant negative correlation between L_P and L_C indicates that uniformity effects are larger when target density is attained but nevertheless are of little consequence relative to plant density.

The low yield losses due to poor plant distribution are not necessarily an argument against precision seed meters. In general, precision metering reduces the number of large gaps (which result in areas with insufficient plants per square metre) as well as improving uniformity.

Table 12. Values of Lp and Lc relative to potential and achievable yield for each block.

Block	Yield	Potential yield				Achievable yield			
		Ymax	Lp	Lc	Yest	Yopt	Lp	Lc	Yest
	t/ha	t/ha	%	%	t/ha	t/ha	%	%	t/ha
					Sorghum				
1a	2.86	8.38	58.2	7.0	2.62	4.00	36.9	1.3	2.47
1b	3.09	9.50	59.7	6.8	2.85	4.35	37.4	1.3	2.67
2a	1.35	2.08	15.9	19.3	1.22	1.16	7.3	2.9	1.04
4a	4.04	12.80	63.0	5.8	3.77	6.77	45.6	2.0	3.55
4b	3.74	15.84	68.5	6.0	3.43	6.07	46.9	0.6	3.19
5a	4.16	11.78	58.4	6.5	3.87	6.00	38.2	1.5	3.61
5b	4.34	10.22	43.6	13.5	3.95	4.80	24.2	2.1	3.53
7a	2.64	4.52	24.2	18.4	2.35	2.07	13.8	2.8	1.73
7b	2.73	4.68	17.3	21.2	2.46	2.07	7.8	2.0	1.87
8a	2.14	4.37	41.2	7.8	1.95	2.22	25.9	0.3	1.64
8b	3.06	4.78	22.9	13.8	2.78	2.66	12.6	1.0	2.30
10a	2.37	5.53	47.3	10.0	2.15	2.70	28.4	1.6	1.89
10b	2.48	5.55	48.2	7.7	2.29	2.91	28.4	0.6	2.06
11a	2.07	4.67	50.9	3.7	1.87	2.65	30.0	0.6	1.84
11b	1.61	4.43	60.8	3.2	1.49	2.70	44.8	0.8	1.47
13a	2.27	6.99	58.0	8.9	2.07	3.10	36.9	1.7	1.90
13b	2.30	5.91	47.0	12.4	2.09	2.70	28.2	2.3	1.88
15a	2.08	3.69	28.9	14.3	1.88	1.82	15.9	2.7	1.48
16a	2.17	5.81	57.3	5.2	2.00	2.80	17.4	0.0	2.31
16b	1.73	6.31	69.2	2.3	1.71	3.49	52.1	0.5	1.66
17a	3.07	6.29	35.4	14.1	2.82	3.39	20.1	3.1	2.71
17b	2.83	6.75	43.7	13.0	2.65	3.55	26.5	3.8	2.48
18a	2.72	8.38	61.1	6.2	2.57	4.15	42.4	1.2	2.34
18b	3.08	9.97	63.0	5.2	2.91	5.29	46.4	1.8	2.74
19a	4.03	7.83	36.4	13.4	3.65	4.17	21.2	2.9	3.17
19b	3.42	6.05	31.9	11.3	3.11	3.68	19.3	2.8	2.86
21Aa	2.41	5.56	49.5	7.6	2.19	3.09	30.5	1.4	2.10
21Ab	2.93	7.93	56.3	6.8	2.68	4.30	38.1	2.1	2.57
21Ba	2.42	7.31	47.3	11.6	2.61	3.70	31.9	3.3	2.40
21Bb	2.44	4.59	35.2	10.3	2.22	2.51	17.6	1.0	2.04
Mean	2.75	6.95	46.7	9.8	2.54	3.50	29.1	1.7	2.32
Range	1.35- 4.34	2.08- 15.85	15.9- 68.5	2.3- 21.2	1.22- 3.95	1.16- 6.77	7.3- 52.1	0.0- 3.8	1.04- 3.61
					Sunflower				
7a	1.26	2.95	55.5	3.5	1.16	1.73	38.9	0.5	1.05
7b	1.49	3.44	50.6	6.8	1.37	1.90	32.4	1.3	1.26
8a	1.38	3.71	61.3	3.2	1.27	1.99	45.9	0.2	1.08
8b	1.65	3.80	49.0	8.5	1.49	1.85	31.4	1.0	1.25
10a	1.16	5.23	76.9	1.7	1.07	2.57	60.3	0.3	1.10
10b	1.55	4.29	62.2	2.7	1.43	2.30	45.3	0.1	1.26
Mean	1.42	3.90	59.3	4.4	1.30	2.06	42.4	0.6	1.15
Range	1.16- 1.65	2.95- 5.23	50.6- 76.9	1.7- 6.8	1.16- 1.49	1.73- 2.57	31.4- 60.3	0.1- 1.3	1.01- 1.25

Table 13. Correlations (R) among yield values and yield loss percentages (* P < 0.05, N = 30) for sorghum.

	Block	Potential				Achievable			
	Yb	Ymax	Lp	Lc	Yest	Yopt	Lp	Lc	Yest
Yb	1.000	-	-	-	-	-	-	-	-
Ymax	0.760*	1.000	-	-	-	-	-	-	-
Lp	0.128	0.638*	1.000	-	-	-	-	-	-
Lc	0.027	-0.399*	-0.899*	1.000	-	-	-	-	-
Yest	0.993*	0.786*	0.169	-0.001	1.000	-	-	-	-
Yopt	0.786*	0.956*	0.650*	-0.468*	0.819*	1.000	-	-	-
Lp	0.139	0.637*	0.935*	-0.825*	0.186	0.672*	1.000	-	-
Lc	0.205	-0.079	-0.473*	0.622*	0.224	-0.029	-0.344	1.000	-
Yest	0.950*	0.838*	0.342	-0.189	0.965*	0.888*	0.306	0.129	1.000

5.5.7 Economic analysis

The total yield of sorghum grain on the Central Highlands in 1987-88 was 242,628 t (from an area of 134,403 ha). If our sorghum data are extrapolated to the entire Central Highlands, an extra 107,990 t could have been achieved in 1988 with a value of $11338950, assuming a value of $105/t at the farm gate.

The discussion among scientists generated the following assumptions: the current average sorghum yield for the central Queensland (Capricornia) region of 1.5 t/ha could be increased by an average of 15% or 0.23 t/ha and the area likely to benefit would be about 60% or 142,000 ha. The area was based on the average sorghum area for the eight year period 1979-80 to 1986-87. The predicted rate of achievement for these outcomes is shown in the spreadsheet in Appendix VI. No change in crop price or the area planted to sorghum was expected as a result of improved plant spacing.

A 15% yield recovery over 60% of the current area was found to have a present value of $11m. The discount analysis and details of the assumptions used are shown in Appendix VI. A recoverable loss having a present value of $11m means that the community of scientists, extension staff, agribusiness and sorghum producers could afford to spend $11m in present value terms to recover the loss and be just as well off. The costs of research, extension and on-farm improvements in equipment and management in order to achieve the predicted yield increase have not been estimated but would comprise a significant proportion of the $11m.

The value of recoverable losses determined in this study should be apportioned among project areas and then related to the research, extension and on-farm costs of potential projects in order to calculate their NPV and IRR values. This will help to identify key projects which give the best returns on investment.

6. DISCUSSION

It could be argued that the generally low establishment levels obtained in this survey were a result of the particular season in which it was carried out. However, this is unlikely since seedbed conditions were generally satisfactory for the crop species investigated, although no measurements were taken. Furthermore, the wide range of geographical locations of the farms surveyed resulted in a range of weather conditions after sowing. Seven sorghum crops which received no rain in the first 21 days after sowing averaged 61% establishment while five which received 15 mm or more averaged 53% (percentages of the seed sown). Rain after sowing is clearly no panacea and may in fact reduce establishment due to soil crusting, poor aeration or increased incidence of seedling disease.

Because so many factors affect crop establishment, it is difficult in such a limited survey to pinpoint the main reasons for each low establishment percentage. It appears that all farmers failed to use the full range of information now available on sowing techniques. It is important to find out why. Is it lack of knowledge, lack of incentive, lack of time, or lack of finance? Whatever the reason, a suitable extension programme is recommended.

The serious damage to crop seedlings by soil insect pests on some farms warrants attention. In view of the special skills required to assess populations of pests in the soil accurately, the employment of scouts by farmers may be advantageous. Suitable personnel may be available from the ranks of agribusiness. Such people are also needed to decide the most efficacious insecticide treatment. However, returns from dryland farming in the Central Highlands may not warrant such specialist input.

The average reduction in yield due to suboptimal plant spacing, which was determined in comparison with the commercially achievable yield at each site, was a surprisingly high 31% for sorghum and 43% for sunflower. Yield reductions among the blocks sampled varied from 9.8 to 60.6%. The achievable yield levels on which these calculations are based could be achieved by any farmer adopting all available technology. If the average loss we measured occurred throughout the Central Highlands, then every hectare of sorghum lost 0.80 t, a total loss for the region of 107,990 t in 1987-88 with a value of $11.3m.

These results well justify a research, development and extension programme on sorghum and sunflower establishment in the Central Highlands. One component of such a programme should be a demonstration for growers of the effects of plant density and uniformity on grain yield. Such a demonstration would be more credible to farmers than our mathematical analysis of individual plant yields in relation to spacing.

Further such surveys are needed to evaluate the extent and cost of establishment problems in other regions and other field crops where problems are suspected. A technique for future surveys, based on our experience, is outlined in Section 7.

Further, data analysis not reported here has shown positive linear regressions between yield loss percentage and measures of spacing uniformity such as acceptable spacing index (ASI). If these relationships can be validated for a wide range of yield levels, they may greatly simplify the requirements for future assessments of yield losses due to suboptimal spacing. The major advantage would be that individual grain weights per plant would no longer need to be recorded, although plant spacings would still be needed. Mean grain yield would be required at the site where spacings were measured. This could easily be obtained by mechanically harvesting a strip of crop and using a grainbridge to weigh the grain. In order to use such a technique with confidence, simultaneous validation would be required at selected sites.

7. IMPLICATIONS FOR FUTURE SURVEYS

The primary objectives of this survey were to check on the adequacy of the techniques used to conduct the survey, to measure plant spacings, to sample the crop and to analyse the data. The survey also provided information necessary for planning and costing more extensive surveys if these should be considered necessary. In this section we consider these aspects and offer a number of suggestions for future surveys.

7.1 Conduct of the survey

The technique used to select farmers in this survey is considered to have provided a reasonable sample of graingrowers in the region. The sample was selected from the rolls of the eight branches of the Queensland Grain Growers Association (QGGA) in the Central Highlands, and 80 to 90% of graingrowers in the area are members of the QGGA. While this meant that some 10 to 20% of farmers were automatically excluded from selection it is considered unlikely that this would have seriously biased the sample. The selection of a representative sample of farmers is essential for an efficient survey and any future surveys should ensure that as far as possible the sample selected is free of bias.

In this survey the first visits to properties were made three to five weeks after sowing. This made it impossible to obtain a reliable seed sample to check on the germination percentage of the seed at the time of sowing. It was also too late to ascertain the causes of poor plant stands, the incidence of insect pests and the extent of insect damage.

From the experience of this survey the following suggestions are offered regarding the conduct of future surveys.

A member of the survey team should contact each selected farmer some four weeks prior to the expected sowing date to ensure that he is prepared to cooperate. Cooperating farmers should be asked to advise when their sowing operations commence.

Three visits to each farm are proposed: at sowing, one week after emergence and just prior to harvest. A summary of the proposed visits with estimates of time and labour requirements is given in Table 14.

Table 14. Summary of visits proposed for an establishment survey, with estimates of the labour required per farm and the tasks required to be undertaken.

Visit	Timing	Time	Tasks
Sowing	At sowing	1-2 h (2)#	Collect seed sample. Record sowing and seedbed details. Assess incidence of insect pests.
Emergence	10 to 15 days after sowing	0.5 day (2)#*	Complete questionnaire. Check on insect pests. Peg and map survey blocks.
Maturity	2 to 3 days prior to harvest	1 day (4)	Record plant spacings. Harvest heads. Weigh heads. ++

# indicates number of individuals recommended for operation.
* an entomologist should be included in the survey team for the sowing and emergence visits
++ post-harvest drying, threshing and weighing of heads could be expected to take 1 man-day

The objectives of the first visit are to obtain a representative seed sample for assessment of viability and seed weight, to record details of the sowing operations and to assess the physical condition of the seedbed and the incidence of insect pests. The soil type should be identified and soil samples taken for appropriate chemical and physical analyses. Because the farmers will be very busy at this time, it is important to minimise disruption to sowing. Survey team members should make no comment at this time on sowing or cultural practices which could influence the way the farmer subsequently conducts his operations. If the farmer seeks advice on any aspect, he could be asked to consult the local extension officer.

The second visit should be made about a week after emergence to ascertain the likely causes of seed and seedling mortality. A technique for doing this has been described by Radford (1987). An entomologist should be included in the survey team during this visit to assess pest damage and identify the species involved. This is also an appropriate time to interview the farmer and complete the questionnaire. The sites of the survey blocks should be selected, pegged and mapped so that they can be readily located at maturity.

A third visit should be made as close as possible to the time when the farmer plans to harvest the particular paddock. Plant spacings should then be recorded and harvesting carried out as described for this survey. The harvesting operation necessitates the setting up of a balance at the site operated by a battery or portable generator. It will be found necessary to utilise some form of screen to shield the balance from wind during weighing.

Following the final harvest it is necessary to oven dry and thresh the 100 heads to be used for the regression analysis of dry weight of grain against fresh weight of head. The heads should be dried at 85^{o}C in a forced draught oven to constant weight. Threshing can be done either on a small single head thresher or by hand. We found that hand threshing of sorghum could be done very rapidly using a small calico bag, with the final cleaning being done on a small seed cleaner.

7.2 Plant measurements

Results generally indicated the adequacy of the 1000 plant sample size per farm (2 blocks) and the 50 plant sample per block (i.e. 100 plants/farm) used to establish the regression of dry weight of grain/head against fresh weight of head. The often poor correlation between yield from the sampled area and yield obtained from the whole paddock is indicative of the heterogeneity of crop growth throughout the very large paddocks. Clearly the heterogeneity is such that two small blocks of about 500 plants are generally inadequate to provide an accurate estimate of paddock yield. Because of the labour involved it would not be practical to increase the sample size. However, estimation of paddock yield is not a critical factor in the survey and the heterogeneity does not invalidate the general results on the levels and evenness of establishment and their effects on yield.

The field data in this survey were recorded by hand onto field sheets and subsequently entered as a computer file using a data base program. It has been suggested that field entry of the data into a small hand-held computer might reduce the overall labour requirement. The experience from this survey indicates that field entry of data would be much slower than manual recording onto prepared sheets and would prolong the period spent in the field, often under adverse conditions and at a time when it is important to survey and harvest as many crops as possible over a short period.

7.3 Training of survey team

Where surveys are being conducted by a number of teams it is important to standardise procedures. If future surveys are planned with a number of teams, it is strongly recommended that a set of notes on procedures be prepared and used as a basis for a short training course for all those involved. The training course should include a field exercise to demonstrate procedures for selecting sampling sites, taking and recording measurements, harvesting heads from individual plants and threshing them.

8. CONCLUSIONS

A rapid but reliable technique is available for determining grain yield per plant for large numbers of sorghum plants. Heads are cut and weighed in the field and a subsample of heads from 100 plants is used to regress grain dry weight per head against head fresh weight. The linear regressions obtained commonly account for more than 95% of the variation.

Summer crop establishment in the Central Highlands was low in our 1987-88 survey; only 55% of the sorghum seed sown and 68% of the sunflower seed became established. Establishment was extremely low in the tractor wheel tracks. As it is difficult to achieve satisfactory establishment in wheel tracks, it is recommended that row spacings be adjusted to avoid sowing into them.

Growers generally expected higher establishment than they obtained, so the plant densities they achieved were generally low. Low establishment along with poor seed metering also resulted in unevenly-spaced plant stands.

The poor stands reduced the commercially achievable grain yield by an average of 31% for sorghum and 43% for sunflower. On this basis, a research, development and extension programme on sorghum and sunflower establishment in the Central Highlands is recommended. Further surveys are also recommended to evaluate the extent and cost of establishment problems in other field crops and regions.

Poor establishment was caused by a large number of factors including failure to predict establishment percentage, inadequate planter calibration, wheel track effects, wide sowing points, the use of cultivating tines at sowing, failure to use press wheels, poor depth control, excessive sowing speed, imprecise seed meters, long and poorly designed seed tubes and failure to apply necessary insecticides. Seedbed conditions seemed generally satisfactory for sorghum and sunflower establishment, but potential seedbed factors that could limit establishment were not measured in this survey.

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APPENDIX I. Questionnaire for Farmer Cooperators

Cooperator/location: ....

Crop species: ....

What cultivar was sown in the test paddock? ....

When was the test crop sown? (Date) ....

How much sowing rain fell, and when? ....

How much rain has fallen since sowing, and when? ....

What seeding rate was used? (Plants/ha? kg/ha?) ....

How was this seeding rate measured? ....

(Planter calibration, total seed sown/total area?) ....

What is the soil type for the test crop? ....

(Open downs, scrub, other?) ....

What is the native vegetation? ....

(Bluegrass, brigalow/yellow-wood, other?) ....

What was the previous crop sown? ....

Was the stubble burnt? (Y/N) ....

How many tillage operations were carried out during the fallow? ....

What tillage implements were used? ....

Was a herbicide used during the previous crop or fallow? (Y/N) ....

If so, what herbicide and at what rate? ....

When was the herbicide applied? ....

What is the make and model of your planter? ....

Is it an air seeder? (Y/N) ....

If yes, what make and model is the cultivator? ....

What type of soil openers does the planter have? ....

(Runners, discs, duckfeet, narrow points, spearpoints, other?) ....

Does the planter have cultivating tines? (Y/N) ....

Were harrows used behind the planter? (Y/N) ....

If so, what type? (Stubble, spike-tooth, other?) ....

Were rollers or press wheels used? (Y/N) ....

If so, what type and what loading? ....

What is the height above ground of the seed meter/divide head? ....

What are the lengths of the seed tubes? Longest .... Shortest ....

What is the internal shape of the seed tubes? ....

(Round, square, fluted?) ....

What is the diameter of the seed tubes? ....

Do the seed tubes have internal corrugation? (Y/N) ....

What was the planting speed? ....

What is the estimated depth of sowing of the test crop? ....

How did you decide on your depth setting? ....

(Soil examination? Seed placement check?) ....

Was fertiliser applied with the seed? (Y/N) ....

If so, what fertiliser and at what rate? ....

Were any other treatments used before, at or after sowing? (Y/N) ......

If so, what? ....

(Seed soaking, insecticides (seed treatment, beetle bait), herbicides?)

Did you aim for a particular plant population? (Y/N) ....

If so, what population? ....

Did you allow for a certain percentage establishment? (Y/N) ....

If so, what percentage? ....

What percentage establishment did you get? ....

What was the seed germination percentage? ....

How many seeds per kg? ....

What was the row spacing? ....

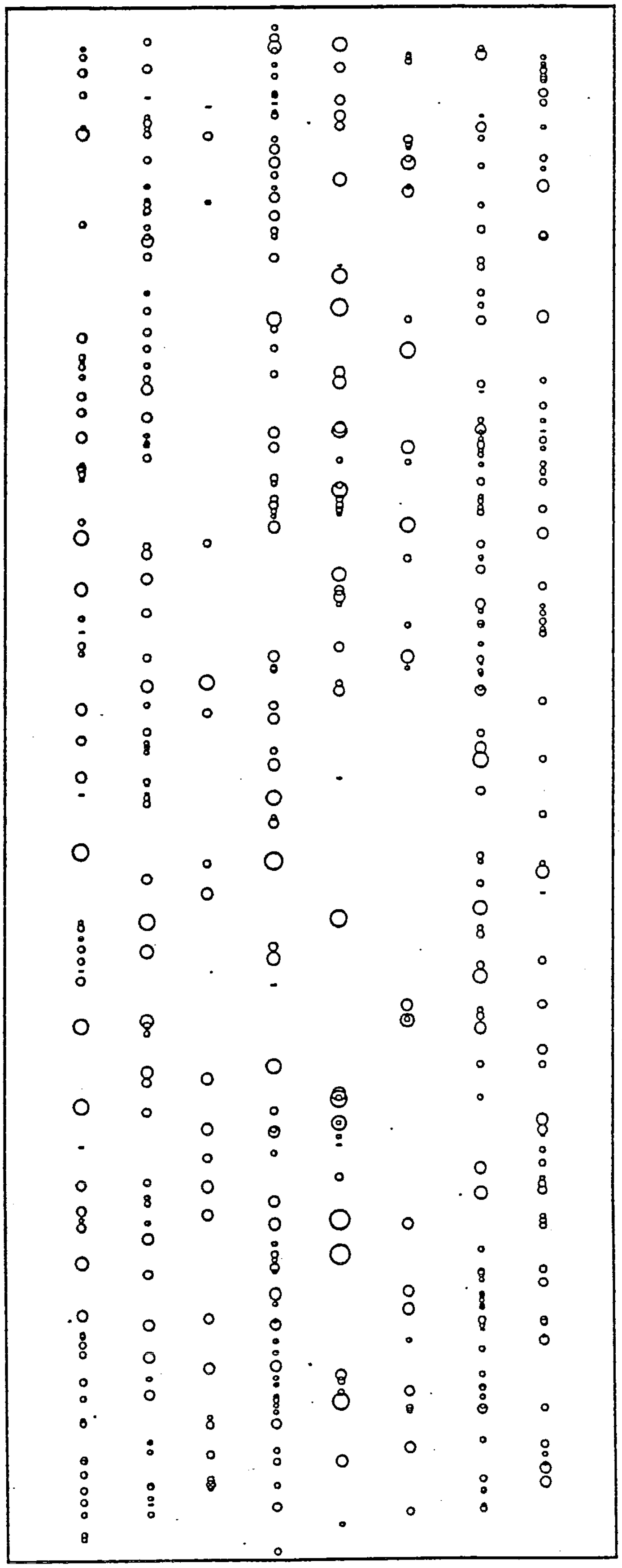
APPENDIX II. Soil and soil management details.

Farm	Native vegetation	Soil type	Previous crop	No. of tillage operations	Tillage implements
1	Coolibah	Scrub-coolibah	Sunflower	5	Trashmaster/finger harrows (5)
2	Blue grass, bloodwood/coolibah	Open downs	Sorghum	3-4	Chisel (2-3), scarifier (1)
3	Blue grass/white speargrass	Open downs	Sunflower	3	Chisel (3)
4	Blue grass	Open downs	Sunflower	4	Scarifier (2), AFM cultivator (2)
5	Yellowood/bottle trees	Scrub	Sorghum	4	Deep ripper (1), trashworker with sweeps (3)
7	Blue grass (some coolibah)	Open downs	Sunflower	4	Chisel (2), scarifier (1), cultivator (1)
8	Coolibah/tea tree/ blue grass	Open downs	Sunflower	3	Blade (1), chisel (1), Gyral cultivator (1)
9	Blue grass	Open downs	Sorghum	4	Chisel (4)
10	Blue grass/coolibah	Open downs	Sorghum (grazed)	5	Disc (1) or blade (1)⁺, scarifier (4)
11	Blue grass	Open downs	Sunflower*	6	Trashworker, blade plough
12	Coolibah/bloodwood/bunary	Semi-open downs	Sorghum	3 (A), 2 (B)	Trashworker
13	Blue grass	Semi-open downs	Sunflower	2	Blade (1), chisel + "Conservation King" (1)
14	Ironbark	Scrub	Sorghum	3	Trashworker (3)
15	?	Open downs	Sorghum	3	Disc (1), sweep (1), wideline (1)
16	Blue grass	Open downs	Sorghum	3	Trashworker (3)
17	Brigalow/softwood	Scrub	Sorghum (grazed)	3	Lely ripper (1), scarifier (2)
18	Black speargrass	Open downs	Sorghum*	4	Blade (4)
19	Brigalow	Scrub	Sorghum	3	Blade/trashworker
21	Blue grass	Open downs	Sunflower	3	Trashworker (1), blade (2)

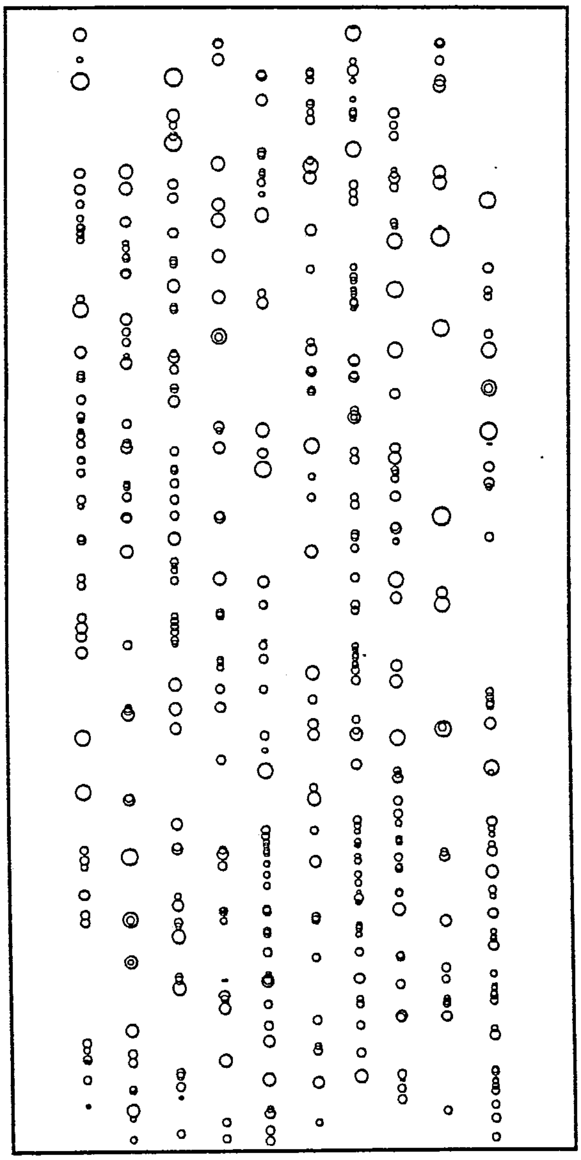
* Grown two summers ago

⁺ Disc at sunflower site, blade at sorghum site

APPENDIX III. Plant Distribution Map for Sorghum,
Block 16b
Scale: 1 cm = 1 m
Yield loss = 52.6%



APPENDIX III (contd.). Plant Distribution Map for Sorghum, Block 5b
Scale: 1 cm = 1 m
Yield loss = 26.3%



APPENDIX IV. Sowing Details Supplied by Farmers

Farm	Planter	Cultivator	Soil openers	Harrows	Press wheels	Sowing speed (k/h)	Sowing depth (mm)
1	Napier 610 airseeder	All Farm	150 mm duckfeet	None	Janke, hole 5	10.4	64
2	Mason-Deere Contour Flex precision planter	None	25 mm spearpoints	Light	Mason-Deere	9.3	64-76
3	Connor Shea airseeder	Connor Shea Wideline	175 mm duckfeet	Light	None	9.6	102
4	Connor Shea airseeder	Connor Shea Wideline	175 mm duckfeet	None	Janke, hole 7	8-9	51
5	Ryan airseeder	4150 Shearer	225 mm duckfeet	None	Janke, hole 5	10	76
7	Napier airseeder	All Farm	175 mm duckfeet	None	Car wheels	8	51*
8	Gyral SC airseeder	Gyral	150 mm duckfeet	None	Janke, hole 3	9.6	64-76
9	Janke Nu-module boxes on home-made tool bar	None	50 mm reversible	Finger	Janke	7.2	Up to 51
10	Connor Shea seedbox	IH scarifier	300 mm sweeps	Heavy duty, hinged	None	8	51
11	Janke boxes	None	25 mm reversible chisel (Gyral)	None	Gyral, hole 3 + ticklers	6.4	38
12	Gyral SC airseeder	Gyral	150 mm duckfeet	Tine	None	11.2	76
13	Gyral TC airseeder	Gyral	125 mm duckfeet	Spike tooth	None	8.8	76
14A	Gyral TC airseeder	Gyral	125 mm duckfeet	Mounted rod	None	10.4	51-64
14B	Gason Hiniker airseeder	Gason Hiniker	125 mm duckfeet	Mounted tine	None	10.4	51-64
15	Connor Shea airseeder + Shearer Wideline	Shearer Wideline	175 mm duckfeet	Light	None	9.6	38-51
16	Simplicity airseeder feeding home-made unit planters	Shearer trashworker	24 mm spearpoints (Janke)	Chains	Janke double rib	12	76
17	Gyral TC airseeder	Gyral	125 mm duckfeet	None	Janke @ 2 kg/cm	6.4	51-102
18	Connor Shea Airseeder + Janke parallelogram planters	None	25 mm spearpoints (Janke)	Heavy fire harrows	Janke zero pressure	9.4	102
19	Gyral SC airseeder	Gyral	125 mm duckfeet	None	Janke, hole 4 (4 kg/cm)	8-8.8	76-102
21A	Cycloplanter airseeder + Orthman tool bar	None	25 mm spearpoints (John Deere)	None	Mason zero centre pressure	9.6	51*
21B	Connor Shea airseeder	Connor Shea	225 mm duckfeet (25 mm spearpoints on wheeltracks)	None	Janke zero till single rib	8	51*

* Depth of soil cover

APPENDIX V. Seed Metering Details

Farm	Height of meter or divide head above ground (m)	Lengths of seed tubes		Internal shape of seed tubes	Diameter of seed tubes (mm)	Internal corrugation?
		Longest (m)	Shortest (m)			
1	1.30	2.22	1.36	Round	32	Y
2	0.70	0.70	0.70	Geometric*	Variable	N
3	1.04	1.40	1.15	Round	25 (internal)	N
4	1.12	1.35	1.26	Round	25 (internal)	N
5	1.05	2.00	1.30	Fluted	32	Y
7	1.30	2.00	1.60	Round	32	N
8	1.83	4.57	1.98	Round	?	N
9	0.91	1.04	1.04	Square	?	N
10	1.52	1.83	?	Round	?	N
11	?	1.45	1.35	Square	51	N
12	1.45	4.00	2.00	Round	19 (internal)	N
13	1.40 (highest)	3.55	2.25	Round	25	N
14A	1.48	2.88	2.45	Round	?	N
14B	1.48 - 2.54	2.44	1.62	Round	?	Y
15	1.75	5.55	3.00	Round	32	N
16	1.63	2.50	2.00	Round	25	Y
17	1.50	3.65	2.30	Round	25	N
18	1.30 - 2.50	5.00	1.83?	Round	?	Y
19	1.35	2.34	2.20	Round	25	N
21A	1.05	4.31	2.40	Round	25	N
21B	1.20 - 1.60	2.60	1.40	Round	32	N

* Geometric seed tube (J.D.) designed to ensure similar drop times regardless of seed entry point and to reduce bounce by projecting seeds rearnard.

APPENDIX VI. Computation of Value of Recoverable Yield Loss.

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

SPREADSHEET FOR THE EVALUATION OF AGRICULTURAL RESEARCH PROPOSALS.

By J R Page, Biloela Research Station.

(File name- RESORLEN: research evaluation/ sorghum/ Len Wade.)

1. Date of evaluation: 22/2/89
2. Crop/ variety that is subject of research: Sorghum
3. A brief description of the research proposal: An evaluation of improved sorghum plant spacing on yield and returns.
4. What is the current average yield? 1.50 t/ ha
5. What is the current average price? 105.00 $/ t at farm gate
6. What is the total of current average costs? 98.00 $/ ha

THE CURRENT AVERAGE GROSS MARGIN IS $59.50 $/ ha

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7. What is your worst yield gain expectation? 0.00 t/ ha
8. What is the most likely yield gain expectation? 0.23 t/ ha
9. What is the optimistic yield gain expectation? 0.45 t/ ha

THE AVERAGE EXPECTED YIELD GAIN IS: 0.23 t/ ha

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10. Nominate the percentage of yield gain achieved each year.

Yr 0	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7	Yr 8	Yr 9	Yr 10	Yr 11	Yr 12	Yr 13
0.00%	10.00%	15.00%	30.00%	40.00%	55.00%	70.00%	85.00%	100.00%	100.00%	100.00%	100.00%	100.00%	0.00%

11. What is your worst price gain expectation? $0.00
12. What is the most likely price gain outcome? $0.00
13. What is your optimistic price gain expect'n? $0.00

THE AVERAGE EXPECTED PRICE GAIN IS: $0.00 / t

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14. Nominate the percentage of price gain achieved each year.

Yr 0	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7	Yr 8	Yr 9	Yr 10	Yr 11	Yr 12	Yr 13
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

15. By how much will seed costs change? $0.00 / ha of treated area
16. By how much will fertilizer costs change? $0.00 / ha of treated area
17. By how much will herbicide costs change? $0.00 / ha of treated area
18. By how much will insect control/ scouting costs change? $0.00 / ha of treated area
19. By how much will fungicide costs change? $0.00 / ha of treated area
20. By how much will defolient costs change? $0.00 / ha of treated area
21. By how much will irrigation costs change? $0.00 / ha of treated area
21. By how much will aerial spraying costs change? $0.00 / ha of treated area
22. By how much will harvesting costs change? $0.00 / ha of treated area
23. By how much will cartage costs change? $0.00 / ha of treated area
24. By how much will drying/cleaning/storage costs change? $0.00 / ha of treated area
25. By how much will machinery costs change? $0.00 / ha of treated area

THE AVERAGE EXPECTED VARIABLE COST CHANGE IS: $0.00 / ha of treated area

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26. Nominate the percentage of variable cost change achieved each year.

Yr 0	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7	Yr 8	Yr 9	Yr 10	Yr 11	Yr 12	Yr 13
0.00%	10.00%	30.00%	50.00%	80.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	0.00%

THE GAIN IN GROSS MARGIN/ HA ON THE TREATED ESTABLISHED AREA EACH YEAR IS:

Yr 0	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7	Yr 8	Yr 9	Yr 10	Yr 11	Yr 12	Yr 13
0.00	2.40	3.60	7.19	9.59	13.19	16.78	20.38	23.98	23.98	23.98	23.98	23.98	0.00

27. How much of the current area will benefit? 142352. ha, 60% of average area for period 1979/80 to 1986/7

APPENDIX VI (contd.).

28. What percentage of the area nominated in 27 will benefit from this proposal each year?

Yr 0	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7	Yr 8	Yr 9	Yr 10	Yr 11	Yr 12	Yr 13
0.00%	10.00%	15.00%	30.00%	40.00%	55.00%	70.00%	85.00%	100.00%	100.00%	100.00%	100.00%	100.00%	

THE GAIN IN TOTAL GROSS MARGIN ON THE ESTABLISHED AREA IS:

Yr 0	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7	Yr 8	Yr 9	Yr 10	Yr 11	Yr 12	Yr 13
0	34129	76790	307161	546064	1032402	1672320	2465819	3412899	3412899	3412899	3412899	3412899	0

29. By how much will the area planted to this crop CHANGE as a result of this research? (do not include any change in area not directly due to this research)

Yr 0	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7	Yr 8	Yr 9	Yr 10	Yr 11	Yr 12	Yr 13
0	0	0	0	0	0	0	0	0	0	0	0	0	0

30. What is the average gross margin/ ha of the crops displaced by the researched crop? $0.00 / ha

THE GAIN IN TOTAL GROSS MARGIN ON THE EXPANDED AREA IS:

Yr 0	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7	Yr 8	Yr 9	Yr 10	Yr 11	Yr 12	Yr 13
0	0	0	0	0	0	0	0	0	0	0	0	0	0

THE GAIN IN TOTAL GROSS MARGIN ON THE CURRENT & EXPANDED AREA IS:

Yr 0	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7	Yr 8	Yr 9	Yr 10	Yr 11	Yr 12	Yr 13
	34129	76790	307161	546064	1032402	1672320	2465819	3412899	3412899	3412899	3412899	3412899	0

31. How much will the research program cost? (include the cost of the scientist, his assistant and their operating and capital costs)

Yr 0	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7	Yr 8	Yr 9	Yr 10	Yr 11	Yr 12	Yr 13
0	0	0											

32. How much will it cost to train producers in the application of the research findings?

Yr 0	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7	Yr 8	Yr 9	Yr 10	Yr 11	Yr 12	Yr 13
0	0	0	0	0									

33. How much will producers have to invest to gain the predicted research benefits?

Yr 0	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7	Yr 8	Yr 9	Yr 10	Yr 11	Yr 12	Yr 13

THE NET CASH FLOW OF THE PROJECT IS PREDICTED TO BE:

Yr 0	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7	Yr 8	Yr 9	Yr 10	Yr 11	Yr 12	Yr 13
0	34129	76790	307161	546064	1032402	1672320	2465819	3412899	3412899	3412899	3412899	3412899	0

34. What interest rate should be used to calculate the NET PRESENT VALUE? 9.00%

THE NET PRESENT VALUE FOR THIS PROJECT IS: 10998874

THE INTERNAL RATE OF RETURN OF THE PROJECT IS:Error 30