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ROW SPACING AND POPULATION DENSITY EFFECTS ON YIELD OF GRAIN SORGHUM IN CENTRAL QUEENSLAND

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SUMMARY

Seven trials were carried out in the main grain growing areas of central Queensland from 1968 to 1971 to determine the most suitable combinations of row spacing and population density for producing raingrown grain sorghum in this area. Two cultivars, Alpha and E57 were grown at three row spacings 0·36 m, 0·71 m and 1·07 m and four densities 3·7, 8·6, 13·6 and 18·5 m^{-2}. Grain yield, stubble dry matter yield, weight of 1 000 grains, number of days from planting to anthesis and number of panicles per plant were measured.

Mean grain yields ranged from 1541 to 3068 kg ha^{-1}. Results did not show a consistent effect of row spacing or population density on grain yield at particular yield levels or seasonal conditions, but densities of 8·6 and 13·6 m^{-2} were equally optimum over the range of yield levels and row spacings involved. Stubble yields generally increased as population density increased and decreased as row spacing became wider. In some trials, flowering was more even and of shorter duration in wide rows at densities of 8·6 m^{-2} or greater. This is a desirable effect with regard to insect control and evenness of ripening of the crop.

I. INTRODUCTION

In central Queensland, grain sorghum is grown mainly in areas with average annual rainfall between 650 mm and 750 mm. Most rain falls in summer, but its variability produces large fluctuations in soil water and hence in crop and pasture yields (Fitzpatrick 1965).

From work at Biloela Research Station, Bygott (1956) concluded that a row spacing of 0·36 m had a greater yield potential than either 0·71-m or 1·07-m row spacings under favourable conditions. However, this spacing was more susceptible to crop failure under water stress. Use of wider row spacings was strongly recommended to provide a margin of safety for the plants during stress periods. However, in Bygott's trials, row spacing and population density effects were confounded, as plant spacing within rows was kept constant while inter-row spacing was varied.

This paper reports on the results of further trials carried out in central Queensland between 1968 and 1971 to determine the most suitable combinations of row spacing and population density for producing raingrown grain sorghum in this area.

II. METHODS

Sites

Seven trials were conducted in central Queensland over a four year period from 1968 to 1971. Three trials were carried out in the Springsure district (latitude 24°09′S, longitude 148°04′E) in 1968, 1970 and 1971 on open downs uniform cracking clay soils (Ug 5·13 and Ug 5·15, Northcote 1971). Three trials were carried out at the Queensland Department of Primary Industries' Biloela Research Station (latitude 24°22′S, longitude 150°31′E) in 1969, 1970 and 1971, on an alluvial clay loam soil (Gn 3·43, Northcote 1971). One trial was conducted in 1970 at the Queensland Department of Primary Industries' Brigalow Research Station (latitude 24°42′S, longitude 149°50′E) Theodore, on a brigalow–wilga uniform cracking clay soil (Ug 5·23, Northcote 1971). No fertilizer was applied to soils in any of the trials.

Treatments

Treatments were the same at all sites, although design and layout varied slightly. Two cultivars, Alpha an open-pollinated type and the hybrid E57* were grown at three row spacings 0·36 m, 0·71 m, and 1·07 m, at each of four population densities 3·7, 8·6, 13·6 and 18·5 m^{-2}. Design in the Springsure trials was a 12 x 4 randomized block with split plots (cultivars) while design of the Biloela and Theodore trials was a 24 x 4 randomized block.

Planting

In all cases, the trials were planted at a heavier rate than required (30 to 40 kg ha^{-1}) in 0·36-m rows and subsequently hand thinned and cultivated, to obtain the required densities and row spacings respectively. These operations were carried out within two weeks of seedling emergence. Plot dimension ranged from 3 to 4 m by 8 to 12 m.

Preplant irrigation of 50 mm was required for establishment of the Biloela trials in 1969 and 1970 due to lack of adequate planting rains. Planting dates are shown in table 1.

Weed Control

The Biloela trials were sprayed with a pre-emergence application of atrazine at a rate of 1·1 kg a.c. ha^{-1} for control of black pigweed (*Trianthema portulacastrum L.*) and some lesser weeds. Weed control measures were not necessary at the other sites.

Harvesting

Harvesting was generally carried out between mid-June and mid-July. Most trials were hand harvested and grain yields obtained using a stationary thresher. The 1969 trial at Biloela was harvested with a small plot autoheader. Stubble yields were obtained by hand cutting of samples after removal of panicles and drying the samples at 90°C before weighing.

Data obtained

Data include: depth of moist soil at planting; rainfall over the growing period for each trial; grain and stubble dry matter yield; weight of 1 000 grains; number of days from planting to anthesis; and number of panicles per plant. Anthesis date was recorded as the day when approximately half the panicles in a plot were showing some anthers. The data for grain yield, stubble yield and weight of 1 000 grains were subjected to analysis of variance.

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* 'DeKalb Shand Seed Company Pty. Ltd. registered cultivar'.

TABLE 1

RAINFALL, IRRIGATION (IN PARENTHESES) (mm), DEPTH OF MOIST SOIL AT PLANTING (m) AND PLANTING DATE FOR EACH SITE

—	Springsure 1968	Biloela 1969	Springsure 1970	Biloela 1970	Theodore 1970	Springsure 1971	Biloela 1971	Average Long Term Rainfall	
								Springsure 1926–1960	Biloela 1924–1973
Jan	94	3	86	73 (70)	155	127	179	107	106
Feb	110	24 (50)	71	19	37	225	290	113	115
Mar	86	14 (50)	12	25	21	30	23	71	66
Apr	113	2	4	12	12	31	6	42	39
May	59	49	0	0	0	27	8	29	37
Total rainfall	462	92 (100)	173	129 (70)	225	440	506	362	363
Average depth moist soil at planting (m)	1·2	1·0	1·1	0·7	1·0	1·0	1·0	..	..
Planting date	22 Jan	10 Feb	13 Feb	9 Feb	9 Feb	15 Feb	14 Feb	..	..

TABLE 2

MEAN CULTIVAR, ROW SPACING AND POPULATION DENSITY GRAIN YIELDS (kg ha^{-1})

Treatments		Springsure 1968	Biloela 1969	Springsure 1970	Biloela 1970	Theodore 1970	Springsure 1971	Biloela 1971	Combined 1968–1971
CULTIVAR	E57	3 432	3 256	3 408	2 254	3 121	1 718	2 047	2 734
	Alpha	2 490	2 652	2 728	2 066	2 133	1 364	1 406	2 119
Necessary differences for significance	5% ..	521	169	571	n.s.	169	n.s.	148	113
	1% ..	956	225	1 047	n.s.	226	n.s.	196	149
ROW SPACING (m)	0·36	3 159	2 906	3 224	2 061	2 452	1 734	1 696	2 462
	0·71	2 917	3 141	3 052	2 169	2 656	1 407	1 776	2 437
	1·07	2 928	2 816	2 928	2 249	2 772	1 480	1 708	2 380
Necessary differences for significance	5% ..	n.s.	207	n.s.	n.s.	207	164	n.s.	n.s.
	1% ..	n.s.	275	n.s.	n.s.	276	218	n.s.	n.s.
POPULATION DENSITY (m^{-2})	3·7	2 692	2 356	3 273	2 206	2 460	1 355	1 593	2 269
	8·6	3 146	3 058	3 236	2 216	2 633	1 631	1 849	2 535
	13·6	3 058	3 129	3 123	2 322	2 862	1 646	1 719	2 539
	18·5	2 952	3 273	2 641	1 895	2 550	1 531	1 746	2 363
Necessary differences for significance	5% ..	n.s.	239	332	n.s.	239	189	n.s.	159
	1% ..	n.s.	318	440	n.s.	319	252	n.s.	211
Mean		2 961	2 954	3 068	2 160	2 627	1 541	1 727	..

n.s. — F test not significant at $P < 0{\cdot}05$.

III. RESULTS

Grain yield

Grain yield results for individual trials and for a combined analysis over all sites are given in table 2.

In five of the seven trials and in the combined analysis over all sites, E57 gave significantly ($P < 0{\cdot}05$) higher grain yields than Alpha. Their yields did not differ significantly ($P < 0{\cdot}05$) in the other two trials (Springsure 1971 and Biloela 1970).

No significant ($P < 0{\cdot}05$) differences in grain yield due to row spacing occurred in the combined analysis over all sites or in four individual trials (Springsure 1968 and 1970, Biloela 1970 and 1971). The 0·36-m row spacing gave significantly ($P < 0{\cdot}01$) higher grain yields than both 0·71 and 1·07-m spacings in the Springsure 1971 trial, the 0·71-m spacing significantly outyielded the 0·36-m ($P < 0{\cdot}05$) and 1·07-m ($P < 0{\cdot}01$) spacings in the Biloela 1969 trial, while the 1·07-m row spacing gave significantly ($P < 0{\cdot}05$) higher yields than the 0·36-m spacing in the Theodore 1970 trial.

Population density had no significant effect ($P < 0{\cdot}05$) on grain yield at three sites (Springsure 1968, Biloela 1970 and Biloela 1971). The density of 3·7 m^{-2} was significantly ($P < 0{\cdot}01$) outyielded by all higher densities in the Biloela 1969 trial and by all except the 18·5-m^{-2} treatment in the Springsure 1971 trial. The lower densities were superior ($P < 0{\cdot}01$) to 18·5 m^{-2} in the Springsure 1970 trial, while in the Theodore 1970 trial, that of 13·6 m^{-2} significantly outyielded the 3·7-m^{-2} ($P < 0{\cdot}01$) and 18·5-m^{-2} ($P < 0{\cdot}05$) treatments. In the combined analysis over all sites, densities of 8·6 and 13·6 m^{-2} gave significantly higher yields than 3·7 ($P < 0{\cdot}01$) and 18·5 ($P < 0{\cdot}05$) m^{-2}.

In two trials, Springsure 1970 and Theodore 1970 and in the combined analysis over all sites, significant ($P < 0{\cdot}05$) row spacing x population density interactions occurred. The interaction was most pronounced in E57 in the Theodore 1970 trial. The general trend of these interactions, as shown for the combined analysis (table 3) was for lower densities to outyield higher at the 0·36-m spacing while the reverse situation occurred at the 1·07-m spacing. As row spacing became wider, yields tended to decrease at a density of 3·7 m^{-2} but to increase at 18·5 m^{-2}.

TABLE 3

MEAN ROW SPACING x POPULATION DENSITY INTERACTION IN GRAIN YIELD (kg ha^{-1}) OVER ALL SITES

Row Spacing (m)	Population Density (m^{-2})			
	3·7	8·6	13·6	18·5
0·36	2 228	2 325	2 187	2 048
0·71	1 982	2 316	2 351	2 052
1·07	1 867	2 145	2 260	2 226

Necessary differences for significance: 5%, 246; 1%, 325.

Stubble dry matter yield

Stubble yields for individual trials and for the combined analysis over all sites are given in table 4.

TABLE 4

MEAN CULTIVAR, ROW SPACING AND POPULATION DENSITY STUBBLE YIELDS (kg ha^{-1})

Treatments		Springsure 1968	Biloela 1969	Springsure 1970	Biloela 1970	Theodore 1970	Springsure 1971	Biloela 1971	Combined 1968–1971
CULTIVAR	E57	2 205	1 517	2 434	1 258	2 133	1 150	2 173	1 828
	Alpha	2 128	1 728	2 254	1 411	1 717	1 112	1 932	1 756
Necessary differences for significance	5%	n.s.	121	n.s.	99	163	n.s.	126	n.s.
	1%	n.s.	161	n.s.	132	218	n.s.	167	n.s.
ROW SPACING (m)	0·36	2 223	1 687	2 775	1 418	1 922	1 375	2 250	1 951
	0·71	2 194	1 647	2 250	1 372	2 026	1 054	2 055	1 792
	1·07	2 083	1 534	2 007	1 215	1 825	965	1 853	1 634
Necessary differences for significance	5%	n.s.	n.s.	226	122	n.s.	103	154	86
	1%	n.s.	n.s.	300	162	n.s.	137	205	114
POPULATION DENSITY (m^{-2})	3·7	1 905	1 396	2 028	1 040	1 507	776	1 840	1 498
	8·6	2 103	1 591	2 280	1 233	1 799	1 115	1 897	1 713
	13·6	2 379	1 694	2 435	1 503	2 262	1 272	2 162	1 946
	18·5	2 279	1 810	2 632	1 563	2 129	1 361	2 312	2 008
Necessary differences for significance	5%	274	171	195	141	231	119	178	100
	1%	364	227	259	187	309	158	236	132
Mean		2 167	1 623	2 344	1 335	1 925	1 131	2 053	..

n.s. — F test not significant at $P < 0{\cdot}05$.

TABLE 5

WEIGHT OF 1 000 GRAINS (g O.D.) FOR FOUR SITES

Row Spacing (m)	Population Density (m^{-2})	Biloela 1969		Biloela 1970		Theodore 1970		Biloela 1971	
		E57	Alpha	E57	Alpha	E57	Alpha	E57	Alpha
0·36	3·7	26·6	21·1	21·8	16·1	22·6	16·4	14·4	11·6
	8·6	24·4	20·4	15·0	13·5	21·4	16·1	13·0	9·7
	13·6	22·8	17·6	14·4	12·9	21·3	14·7	11·5	9·0
	18·5	21·9	18·6	14·3	13·4	18·2	13·7	11·9	10·1
0·71	3·7	27·5	20·0	19·5	15·6	23·0	16·0	13·2	11·1
	8·6	24·9	18·6	18·9	14·6	21·8	15·7	12·9	9·8
	13·6	23·8	17·9	17·5	12·1	20·4	14·5	12·9	9·6
	18·5	23·1	18·3	16·3	12·1	19·6	14·6	11·9	9·3
1·07	3·7	27·0	20·4	22·8	16·5	22·7	16·7	13·3	10·8
	8·6	27·9	19·9	17·4	13·3	21·9	16·7	15·0	10·9
	13·6	26·8	19·3	18·6	14·1	22·0	14·6	15·3	9·4
	18·5	25·6	19·5	16·5	13·5	21·2	15·0	12·3	8·9
Necessary differences for significance	5%	2·3		3·2		1·3		1·9	
	1%	3·1		4·2		1·7		2·5	

In the combined analysis, mean stubble yields of E57 and Alpha did not differ significantly ($P < 0 \cdot 05$). However, E57 gave significantly ($P < 0 \cdot 01$) higher stubble yield than Alpha in two trials (Theodore 1970 and Biloela 1971), the opposite effect occurred in two other trials (Biloela 1969 and 1970) and there was no difference ($P < 0 \cdot 05$) in the three Springsure trials.

In general, stubble yields increased as population density increased and decreased as row spacing became wider. Significant differences ($P < 0 \cdot 05$) to this effect occurred in most trials and in the combined analysis.

Weight of 1 000 grains

Results for four sites are shown in table 5.

Weight of 1 000 grains was higher for E57 than for Alpha. Both cultivars showed a decrease in grain weight as population density increased and an increase in grain weight as row spacing became wider. This increase was particularly marked in E57 at densities greater than $8 \cdot 6 \text{ m}^{-2}$

Number of panicles per plant

Panicles per plant at six of the seven sites are given in table 6.

TABLE 6

MEAN AND RANGE IN NUMBER OF PANICLES PER PLANT FOR SIX SITES

Row Spacing (m)	Population Density (m^{-2})	Mean (Six Sites)		Range (Six Sites)	
		E57	Alpha	E57	Alpha
0·36	3·7	2·0	2·3	1·2—2·9	1·5—3·7
	8·6	1·1	1·2	1·0—1·4	1·0—1·7
	13·6	1·0	1·1	1·0—1·1	1·0—1·2
	18·5	1·0	1·0	1·0—1·1	1·0—1·1
0·71	3·7	1·8	2·0	1·0—2·5	1·2—3·1
	8·6	1·1	1·2	1·0—1·3	1·0—1·6
	13·6	1·0	1·1	1·0—1·1	1·0—1·1
	18·5	1·0	1·0	1·0—1·1	1·0—1·1
1·07	3·7	1·6	2·0	1·0—2·1	1·2—2·9
	8·6	1·1	1·2	1·0—1·2	1·0—1·4
	13·6	1·0	1·0	1·0—1·1	1·0—1·1
	18·5	1·0	1·0	1·0	1·0—1·1

These data indicate that most fertile tillers were produced at a population density of $3 \cdot 7 \text{ m}^{-2}$ at each row spacing and the number declined as density increased, being of only minor occurrence in the $13 \cdot 6$ and $18 \cdot 5\text{-m}^{-2}$ treatments. As shown by the range data, tillering in the $3 \cdot 7\text{-m}^{-2}$ treatment varied considerably, depending on seasonal conditions and was slightly greater at the 0·36-m row spacing than at wider spacings. Differences in panicles per plant between row spacing treatments were negligible at higher densities. The mean value of panicles per plant was slightly greater for Alpha than E57 at densities of 3·7 and $8 \cdot 6 \text{ m}^{-2}$ at all row spacings.

Number of days from planting to anthesis

Days to anthesis did not differ markedly between row spacing or density treatments in most trials. Slight differences were recorded in the Biloela 1970 and 1971 trials for which mean data are shown in table 7. Anthesis was delayed slightly (1 to 2 days) at the lowest density ($3 \cdot 7\ m^{-2}$) and hastened slightly at the highest ($18 \cdot 5\ m^{-2}$) when compared with the two intermediate levels. These density effects on anthesis were more pronounced at the 0·36-m spacing.

TABLE 7

NUMBER OF DAYS FROM PLANTING TO ANTHESIS (MEAN 2 SITES)

Row Spacing (m)	Population Density (m^{-2})	E57	Alpha
0·36	3·7	58	62
	8·6	58	60
	13·6	57	60
	18·5	56	59
0·71	3·7	58	61
	8·6	57	60
	13·6	57	60
	18·5	57	60
1·07	3·7	58	61
	8·6	57	60
	13·6	57	60
	18·5	57	60

In the Theodore 1970 trial, plants in wide rows at a density of $8 \cdot 6\ m^{-2}$ or greater were observed to flower over a shorter period than in treatments where plants were more widely spaced. This was probably associated with the low occurrence of fertile tillers in the former treatments.

IV. DISCUSSION

Grain yield of the hybrid cultivar E57 was on average, 29% higher than that of the open-pollinated type Alpha over the seven sites (table 2). A similar yield advantage for E57 over Alpha has also been recorded in grain sorghum variety trials conducted in central Queensland (Fletcher *et al.* 1978). Average stubble yields over the seven sites (table 4) indicate that, over a number of years, the amount of stubble available for grazing after harvest would be similar for both cultivars.

Row spacing and population density effects on grain yield were not consistent at particular yield levels (table 2) and did not always follow the trend of results of other workers. These have indicated that in general, maximum grain sorghum yields occurred at narrow row spacings (0·18 m) and high densities ($25\ m^{-2}$) when soil water was not limiting (Grimes and Musick 1960), while under water stress conditions that greatly reduced yield, maximum yields were obtained at wide inter-row spacings (1·02 m) and lower densities ($3 \cdot 7$ to $7 \cdot 4\ m^{-2}$) (Brown and Shrader 1959; Bond, Army and Lehman 1964).

All trials in this series commenced with quite good subsoil moisture reserves so that, even though rainfall over the growing period was below average for most trials (table 1), moisture was possibly between the extremes at which the results of these other workers were obtained. There was no apparent, consistent relationship between trial moisture conditions and grain yield responses to row spacing and population density. The timing of rainfall in relation to stage of growth in different trials may have caused the variable responses observed.

The row spacing x population density interaction in the trials reported here (table 3) was opposite to that observed by Stickler and Laude (1960) and Phillips and Norman (1962). The reason for this difference is not evident, although the result of Stickler and Laude (1960) was obtained at considerably higher yield levels and the water supply characteristics of the soil used by Phillips and Norman (1962) at Katherine undoubtedly differed from ours.

No definite conclusions can be drawn on optimum row spacings for central Queensland conditions on the basis of grain yield results. However, wider row spacings at densities of $8 \cdot 6\ m^{-2}$ or higher were observed to have the practical advantage of flowering more evenly and over a shorter period in some trials due to reduced tillering (table 6). This feature would enable more efficient control of insect pests, in particular sorghum midge, and result in more uniform ripening of the crop. Use of row spacings of $0 \cdot 71$ m or wider also enables inter-row cultivation to be carried out for weed control. Stubble yields tended to decline as row spacing became wider (table 4), so that in situations where maximum amounts of stubble may be required e.g. where the grazing of stubble or use of stubble as an erosion control measure is an important consideration, use of narrower row spacings may be preferable.

Population densities of $8 \cdot 6$ and $13 \cdot 6\ m^{-2}$ gave relatively good grain yields over a range of yield levels (table 2) and row spacings (table 3). A density of approximately $8 \cdot 6\ m^{-2}$ is therefore considered to be optimum, on the basis of these results, where depth of moist soil at planting is approximately 1 m or greater. Use of higher densities, up to $13 \cdot 6\ m^{-2}$ would optimize stubble production is necessary, the only additional cost being the extra seed required.

The trend for grain weight to increase as row spacing became wider and to decrease as density increased (table 5) was not generally reflected in grain yields (table 2). These effects were evidently compensated for by the decrease in panicles per plant as row spacing became wider (table 6) and the increase in panicles per unit area as density increased.

Grain yields were not related consistently to differences observed in number of days from planting to anthesis in some trials (table 7).

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REFERENCES

BOND, J. J., ARMY, T. J. and LEHMAN, O. R. (1964).—Row spacing, plant populations and moisture supply as factors in dryland grain sorghum production. *Agronomy Journal* 56:3-6.

BROWN, P. L. and SHRADER, W. D. (1959).—Grain yields, evapotranspiration and water use efficiency of grain sorghum under different cultural practices. *Agronomy Journal* 51:339-343.

BYGOTT, R. B. (1956).—Effect of row spacing on grain sorghum yield. *Queensland Agricultural Journal* 82:581-584.

FITZPATRICK, E. A. (1965).—Climate in relation to pasture and crop growth. *In* 'Climate', Fitzroy Region, Queensland, Resource Series. (Department of National Development: Canberra).

FLETCHER, D. S., HENZELL, R. G., VAN SLOBBE, L., VINCENT, M. S. and KEYS, P. J. (1978).—Queensland grain sorghum variety trial results. Progress Report No. 7, Queensland Department of Primary Industries.

GRIMES, D. W. and MUSICK, J. T. (1960).—Effect of plant spacing, fertility and irrigation management on grain sorghum production. *Agronomy Journal* 52:647-650.

NORTHCOTE, K. H. (1971).—'A factual key for the recognition of Australian soils'. (Rellim Technical Publications: Glenside, South Australia).

PHILLIPS, L. J. and NORMAN, M. J. T. (1962).—The influence of inter-row and intra-row spacing and inter-row cultivation on the yield of grain sorghum at Katherine, N.T. *Australian Journal of Experimental Agriculture and Animal Husbandry* 2:204-208.

STICKLER, F. C. and LAUDE, H. H. (1960).—Effect of row spacing and plant population on performance of corn, grain sorghum and forage sorghum. *Agronomy Journal* 52:275-277.

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