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SUSTAINABLE AGRICULTURE

THE DEPARTMENT OF PRIMARY INDUSTRY AND FISHERIES IS COMMITTED TO THE PRINCIPLES AND PRACTICES OF SUSTAINABLE AGRICULTURE

Definition:

Sustainable agriculture is the use of practices and systems which maintain or enhance:

- the economic viability of agricultural production;
- the natural resource base; and
- other ecosystems which are influenced by agricultural activities.

Principles:

1. Agricultural productivity is sustained or enhanced over the long term.
2. Adverse impacts on the natural resource base of agricultural and associated ecosystems are ameliorated, minimised or avoided.
3. Harmful residues resulting from the use of chemicals for agriculture are minimised.
4. The nett social benefit (in both dollar and non-dollar terms) derived from agriculture is maximised.
5. Agricultural systems are sufficiently flexible to manage risks associated with the vagaries of climate and markets.

SOYBEAN RESEARCH IN THE NORTHERN TERRITORY 1980 - 1985

A.L. GARSIDE and D.A. BUCHANAN

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SUMMARY

The results of research conducted on soybeans on Tippera clay loam soil at Douglas Daly Research Farm between 1980-1985 are discussed. Also included is a review of soybean research between 1970 and 1980.

The research program can be placed in three broad sections: cultivar evaluation; plant population, row spacing and weed control; and plant nutrition.

Results show that Buchanan is a suitable cultivar at plant populations in excess of 400,000 ha^{-1} in 15 cm rows. High plant populations provide a degree of weed control. The herbicides, treflan and basagran provide good control of grass and broadleaf weeds, respectively if used in accordance with the manufacturers recommendations.

Responses were recorded to phosphorus and sulphur and it is shown that once adequate levels of available phosphorus are carried in the soil, phosphorus fertilizer may not be necessary as loss through fixation and/or leaching appears minimal. However sulphur is readily moved to depth in the profile and applications are likely to be required every year.

Inoculation with *Rhizobium japonicum* strain CB1809 is essential in the initial year on virgin ground. Yield response to supplementary and starter nitrogen are unlikely under rainfed conditions.

On Blain sandy loam soil responses to phosphorus, sulphur, potassium and zinc are likely.

It is concluded that the major problem threatening the establishment of a stable soybean industry is poor quality planting seed and suggestions to overcome this are made.

Introduction

In this volume the results of research conducted on soybeans by the Northern Territory Department of Primary Production is reported. The report concentrates on the period 1980 - 1985 but also include a review of research conducted between 1970 - 1980. Many of the studies conducted between 1980 - 1985 were based on conclusions from the review.

The research program between 1980 - 1985 was conducted concurrently with the development of the ADMA scheme. Hence, it was necessary to design research programs that would provide results of immediate relevance to the farming community. This necessitated a pragmatic approach with short term goals. However, where possible, we have attempted to conduct the research to provide long term answers and feel that some success has been achieved in this respect.

The volume is a collection of reports that have been prepared at various times during the last five years. Hence, some inconsistencies in the reporting of results between different experiments is evident. Further, there may be more appropriate analyses for some of the data and more critical interpretation of the results may be warranted in some sections. Time does not permit a more thorough assessment at this stage, as we feel it is most important the results be documented in an accessible form prior to the senior authors departure from the Northern Territory. It is our intention to publish at least some of the work at a later stage.

The soybean research program between 1980 - 1985 was conducted at Douglas Daly Research Farm and has concentrated on three broad aspects - cultivar evaluation; plant population, row spacing and weed control; and plant nutrition. These three aspects form three sections of the report. Another section covers a review of previous work, while in the final section we attempt to draw conclusions, and suggest areas for future research.

ACKNOWLEDGEMENTS

Numerous officers of the Department of Primary Production had some input into the program. In particular, we would like to acknowledge the Chemistry Section for carrying out all soil and plant chemical analysis and the staff of Douglas-Daly Research Farm for their assistance with the field program. Input by Entomology and Plant Pathology Sections is also acknowledged. The manuscript was typed by Gai Fitzsimmons and we thank her for her perseverance.

SECTION 1

LOCATION, CLIMATE AND SOILS

Douglas Daly Research Station is located some 250 km south of Darwin on latitude 13°51'S and longitude 131°17'E. The area has a typical dry monsoonal climate with well defined wet (Oct-April) and dry (May - September) seasons. Average seasonal rainfall (Oct - April) is 1193 mm. Monthly rainfall data for each season between 1980-81 and 1984-85 along with the long term mean is shown in Table 1. As the data shows, large variations in seasonal and monthly rainfall can be expected. Further, periods of up to three weeks without rain have been recorded during the wet season. Hence, the rainfall pattern cannot be regarded as reliable.

The main agricultural soils of the Douglas-Daly Area are sandy and loamy red earths (Day and van Cuylenburg 1977). Almost all the soybean research was carried out on a loamy red earth of the Tippera family.

Reference:

Day, K.J. and van Cuylenburg, H.R.M. (1977) "Characteristics of some red earth soils in the monsoonal region of the Northern Territory, Australia" Proc. Clamatrops 1977 P 120-126

TABLE 1: Mean Monthly Rainfall (Oct - April) for seasons 1980/81, 1981/82, 1982/83, 1983/84, 1984/85 and the long term mean at Douglas Daly Research Station

	Season					
	1980/81	1981/82	1982/83	1983/84	1984/85	Longterm Mean
Oct	34	50	-	39	-	44
Nov	155	139	16	242	75	93
Dec	214	186	139	59	205	154
Jan	440	326	137	324	237	276
Feb	372	177	172	246	306	324
March	70	192	326	446	121	265
April	-	-	146	-	-	30
Total	1285	1070	936	1352	944	1186

SECTION 2

REVIEW OF SOYBEAN RESEARCH 1970 - 1980

Soybeans have long been considered a potentially suitable crop for the area of the Northern Territory between Katherine and Darwin (lats 12-15°S). For many reasons, the potential has never been realised and successful commercial soybean production has never occurred.

Renewed interest in soybeans has been stimulated by the formation of the Agricultural Development and Marketing Authority (ADMA) and subsequent development of project farms in the Douglas Daly area. Soybeans are seen as one of the main crops for this area.

Prior to 1970, cultivars suitable for production in low latitude tropical regions of Australia were unavailable. However, a breeding programme conducted by Dr D. Byth of Queensland University, rectified this situation and suitable cultivars have been available for the last decade. Successful production of Byth's cultivars has been undertaken in the Ord River Irrigation Area (ORIA) (lat 15°S) of Western Australia (Beech et al 1985 a, b). Given the known dominance of daylength in determining soybean adaptation (Garner and Allard 1930) one could expect that the same cultivars would be suitable for the Top End of the Northern Territory (12°S - 15°S). Preliminary studies (Section 3-1, this report) have shown this to be the case.

In this paper we attempt to summarise the results of research during the last decade and to establish the reasons for generally inconsistent and disappointing yields. In addition, we hope that this review will provide a foundation upon which future research can be based.

An Overview of Previous Research

Studies with soybean in the Northern Territory are in their third phase in the last decade. Cultivar evaluation experiments and bulk cropping studies dominated the early phase between 1970 - 1973. Most of this work was carried out in the area north of Katherine.

The second phase centred on Katherine in 1977 - 78 and concentrated on cultivar evaluation, plant population and establishment studies.

The third phase commenced in the 1979 - 80 season at Douglas Daly Research Farm with studies on cultivars, plant population, and bulk areas sowings. Current research is being concentrated in this area.

A striking feature throughout has been the high turnover of personnel and during the last decade at least six different agronomists have been involved in the research program.

Phase I (1970 - 1973)

Experimental results were variable with the majority of experiments producing poor yields for one reason or another. The studies between 1970 - 1973 involved both wet and dry season sowings of a range of Byth's lines bred for low latitude tropical areas.

An initial study was conducted by Ian Miller at Tipperary Station in the 1969 - 70 wet season. In this study a range of Byth's K lines were compared with several established USA cultivars. Although yields were poor the experiment demonstrated the greater suitability of the K lines for this environment. From a December 20 sowing the main flowering times were 30 days after sowing (DAS) for the USA cultivars and 41 DAS for the K lines. Resultant mean yields were 250 kg ha^{-1} for the USA cultivars and 620 kg ha^{-1} for the K lines. Miller noted that seed quality was very poor and concluded that this was due to damage caused by the green vegetable bug. Relevant data is presented in Table 1.

In 1970 - 71 cultivar evaluation studies were conducted at Coomarlie Creek, Thorak's Reserve, and Tipperary by Doug Airey (File J 71/7). The results for this season were very encouraging, particularly for the study at Coomarlie Creek. In each experiment seven K lines were tested along with Avoyelles and Improved pelican at Thorak's Reserve and a number of introduction from Angola at Coomarlie Creek. Relevant results are presented in Table 2 (Coomarlie Creek), 3 (Thorak's Reserve) and 4 (Tipperary).

Mean yield for the K lines at Coomarlie Creek was 3,300 kg ha^{-1} and they easily outyielded the other cultivars (Tables 2). While mean K line yields were lower at Thorak's (1,750 kg ha^{-1}) and Tipperary (1,227 kg ha^{-1}) they were sufficient to indicate the crops potential.

Plant population is thought to have played a major part in the yields achieved. Experience in the ORIA suggests that plant populations of the order of 400,000 - 500,000 ha^{-1} are necessary for maximum yield (Beech et al. 1985 a). Mean plant populations for the K lines were 590,000, 440,000 and 216,000 ha^{-1} for Coomarlie Creek, Thorak's and Tipperary respectively. In a separate study at Tipperary Station this season Brockway and Kilpatrick (File J 71/1) showed that yield increased with increasing plant population (Table 5) up to 860,000 plants ha^{-1} for the K lines.

Given the population at Thorak's higher yields could have been expected however a relatively wide (53 cm) row spacing was used and closed canopies were not formed. In his report on this experiment Airey noted that vigour was less than expected and that this could be blamed on the poor physical status of the soil. By contrast, at Coomarlie Creek - "The growth of the crop was very vigorous, far more so than in the Thorak's Reserve experiment. The vigour of growth and the narrowness of the row spacing produced a closed canopy early in the growth of the plots, a fact which assisted in weed control".

No data on rainfall for any of these sites was presented but it was noted that - "rainfall was particularly favourable for rain-grown crops". It was thought that neither Coomarlie Creek nor Thorak's Reserve would have suffered any moisture stress whereas Tipperary may have suffered some moisture stress at the end of the season as it was planted later.

Wet season cultivar evaluation studies were carried out by Rick Madin at Berrimah Research Farm in the 1971/72 wet season and at Tipperary Station in the 1972/73 wet season (File No. J72/1013). A total 20 cultivars sown at Tipperary in 1972-73 were the best selections from 146 lines sown at Berrimah in 1971-72.

In his summary of the Tipperary trial, Madin suggested that the relatively poor yields obtained were due to poor plant stands, bacterial pustule disease and green vegetable bug damage. The majority of the cultivars included in these experiments were Byth's K lines, 49 series, and 71 series. Most had a growing season in the range of 120 - 130 days and could be classed as mid - late season genotypes. The best yields obtained were around 1,100 kg ha^{-1} from some of the 71 series lines which were the earlier maturing lines, e.g. 71 - 18 matured in 115 days and yielded 1,120 kg ha^{-1}.

In the 1971 - 72 evaluation these 71 series lines had produced the highest yields of up to 1,800 g $plot^{-1}$. No details of plot size are given.

Apart from these experiments, there were bulk sowings of soybean in the 1971 and 1972 dry seasons at Lake Deane and Adelaide River, respectively (Files J71/201 and J72/310) and the 1972 - 73 wet season at Adelaide River (File J72/983).

In the 1972 - 73 wet season cultivars Ross and Gilbert (both K lines) were sown at Adelaide River on January 6 and harvested on May 8 (122 days growing season). Machine harvested yields were 340 and 450 kg ha^{-1} for Ross and Gilbert, respectively. A report on this crop by Airey highlighted the problems as low plant population, severe weed competition, waterlogging, nutrient deficiency, and lack of nodulation. Captan fungicide was applied to the seed and it is thought that this killed the Rhizobia. The major reason suggested for low plant population was the deep sowing of 7.5 - 10 cm. Airey noted that where seeding was shallow, good stands occurred and quadrat yields from these areas were up to 1,600 kg ha^{-1}.

Even if reduced establishment due to deep seeding had not occurred, it is felt that the initial seeding rate was inadequate to provide an acceptable plant population for January sown soybean in this environment (viz. Coomarlie Creek cultivar study; Tipperary plant population study; experience in ORIA). Cultivars Ross and Gilbert have a seed size in the order of 9-11 g per 100 seeds. At the seeding rate of 34 kg ha^{-1} maximum plant populations (100% establishment) could only have been of the order of 300 - 380 thousand ha^{-1}. The area harvested by quadrat sample had a population of 300,000 plants ha^{-1}. Airey noted that this population was "half the density of a stand at Coomarlie Creek in 1970 - 71 which produced yields of 3,000 kg ha^{-1}".

The dry season irrigated crops at Lake Deane in 1971 and Adelaide River in 1972 were both failures. At Lake Deane in 1971 sowing was carried out in late July - early August and harvesting from late October onwards. No yields are available but a general comment from Airey was that "growth was extremely poor".

The Adelaide River crop in 1972 was more successful. In this instance sowing was carried out in mid-June. Cultivar Ross flowered at the end of July (46 days) and harvesting commenced in early October. At harvest, plants were still green but pods were mature and, in fact, some had shattered. This characteristic has also been recorded with July sown Ross in the Ord River area and is probably associated with a photoperiodic response to increasing day length.

Yield from the area was 730 kg ha^{-1}, which was poor, however a comment suggests that seed quality was good. Apart from the fact that the cultivars used, Ross and Gilbert, are unsuitable for dry season sowing, particularly so late a sowing, there are indications that plant populations were again far from adequate.

Certainly the use of relatively wide 50 cm rows would have been unsuitable and the fact that grass weeds emerged as a problem in late August suggested inadequate ground cover.

Research into soybean was curtailed after 1973. Experiments were planned for 1973 - 74 but wet weather did not permit sowing. Further, loss of staff after Cyclone Tracy in 1974 stopped all crop research for several seasons.

Phase II

The second stage of soybean research was centred on Katherine and included studies on cultivars (File 79/56), plant population (File 79/1431), and establishment (File 79/1430). This work was conducted by Stan putland in 1977 and 1978.

Cultivar evaluation studies were conducted in the 1977 - 78 wet season and 1978 dry season. The wet season experiment was abandoned due to extremely poor establishment even after planting twice, on December 17 and January 16. With the initial sowing, emergence seems to have been acceptable but there was a high mortality immediately after emergence. Putland described this as 'wilting and dying'. Hot, dry conditions are thought to have been responsible. With the January 16 sowing emergence was very poor because of surface crusting. The experiment was then abandoned.

All the cultivars planted in the above experiment were sown in the 1978 dry season. In this instance establishment was acceptable although very variable between cultivars. Sowing was carried out on April 19 and 20 at Katherine Experiment Farm. Furrow irrigation was supplied as necessary. In this experiment most of the lines were again from Byth's breeding program and the majority of these were representatives of new early maturing crosses called P lines (Buchanan was P27, Fitzroy was P25).

Plant establishment was variable and population was well below optimum. The highest populations were around 200,000 plants ha^{-1} and hand harvested yields from populations of this order were 2,490 kg ha^{-1} for P25, 2,328 kg ha^{-1} for P32, and 2,014 kg ha^{-1} for P48.

In this experiment Putland collected information on characteristics such as pod height (lowest and highest), seed colour, shattering, determinancy, 100 seed weight, as well as grain yield. It is obvious from the 100 seed weight data that large seeds were produced, e.g. 17.8 gm for P27, 13.9 g for P25, 16.3 g for P2.

The results from this experiment are quite valuable and give a good indication of varietal response in the dry season. The major limitation is that all of these lines are better adapted to wet season production and it is a pity that they were not thoroughly evaluated in the wet season.

Putland planted two other experiments in the 1977/78 wet season, a plant population experiment and a method of establishment experiment. The plant population experiment encountered the same establishment problems as the wet season cultivar experiments. Like the cultivar experiments, it was planted twice. The early sowing (December 19) suffered from wilting and plant death associated with very hot, dry soil conditions, and the later sowing suffered from poor emergence due to surface crusting. This experiment was abandoned.

The establishment trial was sown on January 21, 1978, under what Putland called "ideal conditions". In this experiment three planting machines were used and planting was at three different depths (2, 5 and 10 cm). Here the results showed that there was no difference between planting machines or planting depth. Putland concluded that providing conditions were suitable, planting method had little effect on establishment.

Suitable conditions were described as moist soil at sowing, and conditions that do not encourage surface crusting nor high surface temperature.

Experimental work on soybeans at Katherine was discontinued after the 1977-78 wet season in favour of mungbeans.

Phase III

The third phase commenced at Douglas Daly Research Farm in the 1979-80 wet season with cultivar (File 79/1838), plant population (File 79/1836), and bulk sowings (File 79/1721) conducted by Irene Kernot.

In the cultivar evaluation study a range of Byth's lines were sown on both Tippera and Blain soils. Sowing dates are not known. Results from each experiment are very sketchy and no yield data is available. The Tippera site was overgrown by weeds and the Blain site suffered from severe nutrient deficiency. One important response noted by Irene Kernot was an apparent different response to nutrient status between cultivars. She noted that Canapolis, V15 and Gilbert grow more vigorously than the other lines on the Blain soil.

Information collected on phenological development suggests that most of the P lines flowered in 29-30 days and matured in 90 days, Ross flowered in 35 days and matured in 95 days, and the V lines flowered in 45-50 days and matured in 120-130 days.

Plant population studies were conducted on each soil type (Tippera and Blain). Cultivar Ross was sown at seven (7) plant populations between 50,000 and 1,000,000 plants ha^{-1} at equidistant spacings to eliminate row effects. The results showed that the highest yields were obtained with 50,000 plants ha^{-1} on the Blain soil and 600,000 plants ha^{-1} on the Tippera soil.

The soybeans on the Blain were observed to be nutrient deficient and this is suggested as the reason for lack of response to population. Yield component analysis suggest there was something drastically wrong with the plants. Only 10-11 nodes were produced regardless of population and this is considerably less than can normally be expected from a January sowing. In the ORIA normally 15 nodes are produced by January sown Ross. In addition, there was no height difference between different treatments, a known response to plant population.

On the Tippera site height differences were recorded between treatments and general nutrient status was regarded as adequate. Apparently node numbers were not recorded. Weeds were a major problem with the lower populations, leading to the conclusion that higher populations could be utilized to control weeds. Again, this lack of weed competition could in part have helped produce the better yields from the higher population treatments.

In the bulk plantings six cultivars - Ross, Canapolis, Gilbert, V15, Fitzroy and V10 - were sown on Tippera soil. Estimated yields ranged from nothing to about 1,600 kg ha^{-1}. Actual yields were considerably less due to late harvesting and severe shattering. No valid comparisons could be drawn between cultivars due to variations in plant population which ranged from 10,000 - 350,000 plants ha^{-1}. The very poor yielding cultivars, Fitzroy and V10, had the lowest plant populations.

Conclusions

The most successful studies conducted were in the 1970/71 wet season, particularly the study at Coomarlie Creek. The results from that season showed that good wet season crops of soybeans could be produced in the Top End using K line cultivars (e.g. Ross). However, given these results little was done to properly utilise the findings. Follow up work has concentrated on further cultivar evaluation while the general agronomy has been neglected except for the establishment (Putland) and Plant population studies (Brockway and Kilpatrick; Kernot). This, we believe has been a major shortcoming of the entire soybean evaluation program in the Northern Territory. Certainly, there are now more suitable cultivars available for this area than the K lines and exhaustive cultivar testing would have eventually shown this. However cultivar testing in below optimum agronomic conditions can produce very unreliable results. Intensive cultivar evaluation for the low latitude tropics has been underway in the ORIA since 1974 (Beech et al 1985a and b) and, given the overriding influence of day length on cultivar performance, the results from that area should be applicable to the low latitude areas (12-15°S) of the Northern Territory. This in fact has been shown to be the case, for the Douglas Daly area at least (Section 3-1, this report). Hence, we concluded that further exhaustive cultivar testing was not warranted at the commencement of the latest research program on soybeans.

Throughout the reports two factors were clearly highlighted. In very few instances were optimum plant populations achieved and in many cases this resulted in severe weed competition. The most successful experiment, Coomarlie Creek, had a plant population of 590,000 ha^{-1} in narrow rows and this resulted in good weed control. Low plant populations were blamed on a number of factors and certainly the establishment problems that plagued Putland have played a major part. However below optimum seeding rates and the use of relatively wide rows in many studies meant that problems of inadequate plant population were always likely from the outset.

Other problems were mentioned throughout the reports. Some of these were nutrition, poor nodulation, disease and insects. Surprisingly, there was very little mention of moisture stress as a major problem, suggesting that either researchers considered moisture supply adequate or other problems were so dominant that the effect of moisture stress was minor.

The research results do show that good yields of wet season soybeans can be obtained in the Top End of the Northern Territory. However, they also show that extremely poor yields are likely if proper agronomic practices are not employed. Most importantly, they show the major deficiencies in our knowledge of soybean production in the area and indicate where future research should be directed. It is abundantly clear that our first major problem to overcome is poor establishment. We expect that major yield increases are likely to accrue with well established plant stands at optimum populations. Once this is determined the weed situation can be placed in its true perspective and we should be able to determine what weed species are real problems and what species are problems caused by other agronomic deficiencies. Economic methods of control can then be devised.

Other possible avenues for immediate attention would appear to be plant nutrition and insect, particularly pod sucking bugs, research. In addition, we believe that moisture availability is likely to become a more important problem as other agronomic deficiencies are overcome. We see moisture conservation techniques and drought tolerant cultivars are being research priorities for the future.

Finally, in many of the reports comments were made about poor quality seed. This was blamed on a number of factors, particularly pod sucking bugs. The production of good quality planting seed is likely to assume a very important place in the development of soybean technology for the tropics. The environment is such that seed production, harvesting and storage is always likely to be a problem. Again, considerable information is available from the ORIA and the key to good seed production, apart from careful harvesting, handling and storage, is adequate soil moisture supply until maturity. This will mean that we will be dependant on irrigated production, for seed supplies of adequate quality.

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TABLE 1: Grain Yield (kg ha^{-1}) for a Range of Cultivars Grown at Tipperary Station in 1969 - 70 Wet Season

Variety	Yield (kg/ha grain)
K44	605
K53	475
K54	809
K69	707
K74	878
K152	772
K157	320
K169	399
Hernon	112
Semstar	338
Wills	327
Hill	220

TABLE 2: Results of Soybean Cultivar Evaluation at Coomarlie Creek 1970-71 Wet Season

Cultivar	Yield kg ha^{-1} at 12y Moist	Plant Population Plants m^{-2}	100 Seed wt (gm dry wt)	Nodes/ Mainstem	Plant Ht. (cm)
K54	3,600	60.5	9.2	7.9	63
Daintree	3,569	63.4	8.8	7.5	64
Gilbert	3,420	56.5	8.8	6.9	58
K53	3,339	62.8	9.3	7.5	67
K152	3,326	54.2	8.8	7.7	61
Ross	3,179	61.1	8.1	7.6	74
K162	2,827	57.4	8.5	7.4	64
46412	2,558	53.1	13.0	6.5	64
46410	2,550	42.6	12.1	7.2	60
46411	2,414	40.9	12.5	7.9	75
46413	2,330	34.9	12.6	7.4	59
46416	2,252	58.8	12.1	7.6	70
46408	2,111	40.4	12.2	7.9	64
46415	1,745	21.3	15.2	6.9	54
46414	1,491	33.5	11.6	8.9	88
30725	1,278	56.5	7.0	11.4	106

TABLE 3: Results of Soybean Cultivar Evaluation at Thorak's Reserve 1970-71 Wet Season

Cultivar	Yield kg ha^{-1} at 12y Moist	Plant Population Plants m^{-2}	100 Seed wt (gm dry wt)	Nodes/ Mainstem	Plant Ht. (cm)
Daintree	1,981	52.3	8.7	7.8	42
K53	1,962	46.1	8.9	6.8	43
Gilbert	1,881	42.3	9.0	7.9	38
K152	1,725	38.8	9.0	6.8	39
K154	1,637	38.4	8.0	6.9	39
Ross	1,618	57.7	7.7	7.0	41
K162	1,490	46.1	8.3	7.5	30
Avoyelles	1,446	33.0	8.7	12.6	67
Improved Pelican	907	28.4	10.7	9.8	51
CPI46415	625	22.3	14.1	7.1	30

TABLE 4: Yield Date, Soybean Variety Trial - Tipperary Station 1970-71 Wet Season

Variety Yield	Plant Density (Plants/sq m)	Plant Heights 1.4.71 (cms)	Grain Kg/ha
Daintree	19.5	56	1,646
K53	18.5	61	1,459
K162	38.2	53	565
Ross	28.4	65	1,705
K54	14.9	57	1,395
Gilbert	17.0	55	1,115
K152	14.5	56	704

TABLE 5: Results of Soybean Plant Population Study at Tipperary Station in 1970-71 Wet Season

Inter Row Spacing (cm)	Intra Row Spacing (cm)	Sown Population (seeds ha^{-1})	Estale Pop. (Plants ha^{-1})	Yield (kg ha^{-1})
8.8	5.0	2,273,000	864,000	3,897
17.6	5.0	1,136,000	431,000	1,976
35.2	5.0	569,000	131,000	1,258
70.4	5.0	284,000	59,000	865

SECTION 3

CULTIVAR EVALUATION

As was shown in the previous section numerous studies evaluating cultivars have been carried out over the past 10 years. Further, detailed evaluation of over 300 genotypes was carried out in the ORIA between 1974 and 1980 (Beech 1985a, b). Given the overriding effect of day length on soybean adaptation we believed, when this program commenced, that further exhaustive cultivar testing was not required in the Northern Territory to make soybeans a commercially viable crop. Our view was that improved agronomy was the major requirement and so cultivar evaluation has been a relatively minor part of the research program.

However, we thought it was necessary to check responses recorded in the ORIA, in the Douglas Daly region so an initial experiment was conducted in the 1980-81 wet season (Section 3-1). No further cultivar evaluation was carried out until 1983-84 when three Brazilian lines were evaluated in comparison with Buchanan (Section 3-2). These were again tested in 1984/85 (Section 3-3). These lines had the characteristic of reduced duration of the flowering to maturity period and it was thought they may have some advantages for insect control.

To permit a critical assessment of the cultivar evaluation program we have included copies of the Beech et al. 1985 a and b papers at the rear of this report.

It should be noted that the evaluation of introductions and the breeding of new lines for tropical Australia is being continued by CSIRO, in the Burdekin Irrigation Area, Queensland. It is anticipated that lines suitable for the Northern Territory will be generated from this program and that evaluation of these lines should be an important part of any future soybean program. However, at this stage we see very little benefit in evaluating large quantities of introductions in the Northern Territory.

3-1. SOYBEAN CULTIVAR EVALUATION IN THE 1980-81 WET SEASON

ABSTRACT

A range Soybean cultivars and a bulk area of the cultivar Buchanan were evaluated at Douglas Daly Research Farm (DDRF) in 1980-81 wet season.

The bulk area of Buchanan yielded 1.7 t ha^{-1}, a very encouraging yield considering the well below average rainfall at the end of the growing season.

Cultivars Buchanan (P27) and Fitzroy (P25) gave the highest yields of 2.3 and 2.1 t ha^{-1}, respectively, in the cultivar evaluation experiment. Yields closely followed phenology with the earliest maturing cultivars producing the highest yields.

Comparisons of cultivar phenology at DDRF and the Ord River Irrigation Area (ORIA) show that responses are similar for each area and indicate that extrapolation of results from the ORIA to DDRF is acceptable. Given the detailed cultivar evaluation studies in the ORIA in the last decade we believe it is unnecessary to duplicate these studies at DDRF. Therefore cultivar evaluation should only be a minor part of the research programme at DDRF in the immediate future.

INTRODUCTION

The formation of the Agricultural Development and Marketing Authority (ADMA) and the development of project farms in the Douglas Daly region has provided the impetus for renewed research activities into field crops. The main field crops being investigated are maize, sorghum, peanuts and soybeans.

Soybeans have been considered a potential crop for the Top End of the Northern Territory for many years but this potential has never been fully realised. Previous research has concentrated mainly on cultivar evaluation with limited success. A whole range of problems including poor establishment, weed competition, nutrition and insect pests have been named as reasons for poor yields (Section 2).

Cultivar evaluation has been a major part of soybean research in the Ord River Irrigation area (ORIA) since 1974 and a good understanding of cultivar response in that area is now available (Beech et al. 1985 a and b). Given the known dominance of daylength in determining cultivar suitability for a particular area (Garner and Allard 1938) it is reasonable to assume that cultivars well adapted to the ORIA (lat 15°S) will also be well adapted to the Top End of the Northern Territory (lat. 12-15°S). That we are considering irrigated (Ord) and dryland (NT) production is unlikely to be of major importance in cultivar selection at this stage as early maturity is likely to be the key to production in both locations - in the Ord to allow the sowing of a follow up dry season crop and in the Douglas Daly area to ensure adequate moisture availability up to maturity.

Consequently, in the 1980-81 wet season an initial experiment was designed to evaluate a range of cultivars, which had been thoroughly evaluated under irrigation in the ORIA, under dryland conditions at Douglas Daly Research Farm (DDRF). Comparisons of growth, development and yield at the two locations were an important part of this experiment.

Secondly, the cultivar Buchanan (P27), released for commercial production in the Ord River Area (Beech et al. 1985 b) was grown as a bulk planting to evaluate its performance under dryland conditions at DDRF. Buchanan is an early maturing, large seeded cultivar bred by Dr D. Byth at Queensland University.

SEASONAL CONDITIONS

The 1980/81 season was characterised by above average December, January and February rainfall but well below average March rainfall. In fact, the 70 mm recorded for March was the lowest since records have been kept (1965), although seasonal rainfall was 1,285 mm, 100 mm above the mean. Details are supplied in Table 1, Section 1.

EXPERIMENT 1: Bulk Area of Buchanan (P27)

Materials and Methods

Paddocks 72 and 73 of the Tippera experimental block were used for this sowing. A total of 3.17 ha of Buchanan was sown on December 18, 1980 with a Shearer Disc Seeder.

The area was ploughed in October and received several cultivations before sowing. At sowing the area was fertilized with Superphosphate at 200 kg ha^{-1} (19.2 kg ha^{-1} P) and Fertica at 100 kg ha^{-1}. Fertica is a proprietary fertilizer mix containing:-

N - 11.4%	S - 7.5%	B - 0.1%	Zn - 0.02%
P - 4.8%	Ca - 4.3%	Mn - 0.1%	Co - 0.006%
K - 14.6%	Mg - 1.3%	Cu - 0.02%	

All seed was inoculated with commercial peat inoculant strain CB 1809 prior to sowing and seeding rate was set to obtain a plant population of 500,000 plants ha^{-1}.

Prior to sowing the area was sprayed with Stomp 330 E(R) (Pendimethalin) at 3 l ha^{-1} of the product to control grass weeds. The herbicide was incorporated with a tyne cultivator. Four weeks after sowing the area was sprayed with basagran(R) (bentazone) at 2 l ha^{-1} to control *Sida* sp. and *Hyptis sauveolens*.

Two insecticide sprays were required during the season, one to control pod sucking bugs and another to control *Spodoptera litura*. Lannate(R) at 1.5 l ha^{-1} was used to control spodoptera while Thiodan(R) (Endosulphan) at 2 l ha^{-1} was used to control the pod sucking bugs (*Peizodorus rubrofasciatus*, *Riptortus serripes*).

At maturity the entire area was direct headed with a 585 Massey-Ferguson open front header.

RESULTS AND DISCUSSION

For the December 18 sowing flowering commenced on January 20 (33 days after sowing). Harvesting was commenced on April 4 making a growing period of 107 days. This is probably shorter than can normally be expected because of the very dry end to the season (Table 1, Section 1).

Establishment was variable with a mean plant population of 150,000 ha^{-1}. However population ranged from virtually nothing up to 600,000 ha^{-1}. In areas where establishment was poor buffalo clover (*Alysicarpus vaginalis*) was a major weed problem. However with good soybean establishment buffalo clover could not compete. *Cassia* sp. occurred throughout the area. Neither it nor buffalo clover were controlled by the herbicides. Grass weeds, *Digitaria* sp. and *Brachiaria* sp. were recorded throughout the area but were generally not a major problem.

A total of 5,523 kg was harvested from the 3.17 ha giving a yield of 1,740 kg ha^{-1} clean seed. it had been intended to keep this seed for planting the next season however germination was extremely poor at 23%. It is thought that this was due to two reasons, firstly the very dry finish to the season having an adverse effect on seed viability and secondly the limitations of the harvesting equipment causing severe mechanical damage to the seed. Minimum drum speed attainable was 500 rpm when we required 200-300 rpm.

Given the very dry finish to the season and the relatively low plant population (populations of the order of 4-5 hundred thousand ha^{-1} are thought to be necessary for this region) the yield obtained was extremely good. A price of $250/tonne is currently being paid for soybean produced in the Ord River Area for the Perth market. This represents a return of $425 ha^{-1} for this crop. Total variable costs are likely to be of the order of $300 ha^{-1} (Robertson 1980). Hence the current crop would have resulted in a gross margin of $125 ha^{-1}.

Oil and protein contents were acceptable at 20.5% and 42.3% respectively.

EXPERIMENT 2:

In this experiment a range of cultivars were evaluated as to their suitability for commercial production in the Douglas Daly Region. All the cultivars had been thoroughly tested in the ORIA over a number of years and an important part of this experiment was to compare their growth at the two localities. Hence, selection of cultivars for this experiment was such as to cover the range of types used in the ORIA although it was known that some of these were unlikely to be suitable for the Douglas-Daly area. The cultivars selected and their phenology in the ORIA are listed in Table 1.

Materials and Methods

This experiment was sown on Block 73 of the Tippera Research Area on January 7, 1981.

Experimental design was a randomised block with 12 cultivars and four replications. Plot size was 16 rows, each 18 cm apart, x 11 m. Sowing was with a one row hand planter at a depth of 2-3 cm. Cultivar germination was variable and seeding rate was adjusted in order to obtain a plant population of 500,000 ha^{-1}.

Prior to sowing the area was fertilized with Superphosphate at 200 kg ha^{-1} (19.2 kg ha^{-1} P) and fertica at 100 kg ha^{-1}. The analysis of fertica is described in experiment 1. In addition, the herbicide Stomp 330 E(R) (Pendimenthalin) was applied at 3 l ha^{-1} and incorporated with a rotary hoe for grass control.

Several sprays were required during the season to control various insect pests. An outbreak of *Spodoptera litura* occurred in late February. This was unsuccessfully sprayed with Lannate L at 1.5 l ha^{-1} on February 26. The area was then resprayed on March 5 with Lorsban 50-E(R) (Chlorpyriphos) at 1.5 l ha^{-1} with excellent results. Pod sucking bugs, particularly *Riptortus serripes*, were found in large numbers in early April and this necessitated a spray with Thiodan(R) (endosulfan) at 2 l ha^{-1} of the product on April 8.

Recordings and Data Collection

During the season we recorded the dates of various phenological occurrences. In particular, we noted emergence date, date of first flower, date of 50% of plants flowering, date of physiological maturity (95% of pods dry and brown).

After emergence established plant population was recorded on 5 x 1 m^2 quadrats per plot. At maturity yield was recorded by harvesting the centre eight rows x 10 m from each plot. Samples were threshed and cleaned and yields recorded. Sub-samples were set aside for seed size, oil and protein content/determinations.

Results and Discussion

All relevant data is presented in Table 2.

Heavy rain two days after sowing caused erosion across some of the plots resulting in seed loss. Erosion was so bad that only 31 of the 48 plots were deemed suitable for harvesting. The herbicide incorporation by rotary hoe left a very fine tilth and it is thought that this was largely responsible for the erosion. Because of the excessive number of missing plots statistical analysis has not been attempted and results are presented as the means of 1, 2 or 3 replications. For this reason the results should be viewed with caution as valid comparisons for grain yield between cultivars are not possible. However, some interesting points emerge and are worthy of discussion.

Establishment was variable and for plots not affected by erosion ranged from 314,000 for P3 to 802,000 for V15. V16 failed to establish and was discarded.

On the basis of phenology the cultivars could be placed into four maturity groups - early (P2, P3, P25, P27, P45); mid-season (P1, P44 and Ross); mid-late (V15); and late (V10). Both P2 and P45 were very uneven with a considerable number of off types. This probably explains the poor synchronisation of flowering and maturity relative to other cultivars. Experience in the ord River Area would put both these cultivars in the early maturity group (Table 1).

Considering days to flowering for each cultivar at each locality a very similar pattern is evident. For all cultivars this parameter is within 1-2 days. A somewhat different situation exists for days to maturity in that the growing season was generally shorter for DDRF. This is almost certainly due to the very dry conditions prevailing at DDRF in the latter half of this season as opposed to the irrigated conditions in the ORIA.

Yields closely followed maturity with the highest yields being obtained from the early group (1,961 kg ha^{-1}); followed by the mid-season group (1,452 kg ha^{-1}); the mid-late cultivar V15 (881 kg ha^{-1}) and the late cultivar V10 (221 kg ha^{-1}). Given the previously mentioned limitations of this experiment along with variations in plant population it would be unwise to make comparisons between cultivars within maturity groups. However, it is intersting to note that the two released P lines, P 25 (Fitzroy) and P27 (Buchanan) have produced acceptable yields (Table 2).

As mentioned previously, the season was abnormal in that rainfall in March was well below average. It is then interesting to speculate as to which cultivar group would have given the highest yields under a longer season i.e. adequate rainfall until late March. Certainly one could expect the mid-season group to yield as well as the early group in that situation and the question arises as to whether the early group may suffer losses by maturing prior to the end of the wet season.

Fortunately, there is a certain degree of phenological adjustment, within the early P lines, to different environmental conditions and under adequate moisture status the growing season is extended.

Early sowing will also extend the growing season due to photoperiodic responses in the pre-flowering and flowering periods. Our experience suggests that, under adequate soil moisture, Buchanan sown between mid-December and mid-January will mature in mid-late April, when wet weather is unlikely to cause harvest difficulties. It is then reasonable to expect that early maturing cultivars, such as Buchanan, will be suitable in most seasons. The exception is likely to be a season when dry conditions in March induce maturation and this is followed by prolonged wet weather in April.

Data for seed size, oil and protein content also reflect the dry finish to the season. Compared with the irrigated situation (ORIA) seed size and oil content was reduced and protein content increased at DDRF. This is consistent with other moisture stress studies (Laing 1966).

CONCLUSIONS

The results of this study confirm that cultivar response is similar in the ORIA and DDRF and, although it may be for different reasons, the same cultivar type is required in each area. In particular early maturity is an important character for both areas.

The cultivar Buchanan (P27), recently released for commercial production in the ORIA appears suitable for dryland production in the Douglas-Daly region.

Given the results obtained this season we believe that suitable cultivars are available for commercial production in the Douglas-Daly region. Therefore we see little benefit in further large scale cultivar testing for this area. The research effort should be towards improved agronomy (e.g. plant population) and only after acceptable management practices are developed should we look to further cultivar evaluation.

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TABLE 1: Soybean Variety Trial 1979 - Ord Project Research Station (sown 17.1.79)

Variety	Plant Population x 10^3	Date Flowering Commenced (days)	Date Flowering Finished (days)	Duration of Flowering (days)	Date of Maturity (days)	*Yield kg ha	100 Seed weight (gm)	% Oil (Dry Basis)	% Protein
P1	4.06	41	59	18	110	2,718	11.68	20.6	38.7
P2	2.14	34	59	25	105	3,010	14.42	23.7	38.7
P3	2.83	36	54	18	107	3,238	15.74	24.3	39.2
P25	1.83	34	54	20	100	1,440	10.79	26.0	30.6
P27	2.84	34	54	20	105	3,080	13.23	23.7	38.0
P39	5.64	38	54	16	107	3,722	12.38	20.7	40.5
P44	4.57	38	59	21	112	3,387	10.61	20.2	39.8
P45	2.40	34	54	20	105	2,824	12.39	23.5	35.8
Ross	3.35	41	59	18	114	2,933	7.97	20.9	38.6
V15	3.06	49	68	19	132	3,841	9.74	19.4	40.5
V16	3.06	38	59	21	120	2,304	11.67	19.9	39.8
V10	5.12	56	80	24	139	3,937	11.06	21.4	38.7

TABLE 2-2: Soybean Variety Experiment - 1980/81 Wet Season at Douglas Daly Research Farm (DDRF) Sown 7.1.81

Variety	Plant Population (plant/ha)	First Flower	Days to Harvest	Yield (kg/ha)	100 Seed Weight (g)	Oil (%)	Protein (%)	Oils (kg/ha)	Protein (kg/ha)
P27	612,000	32	92	2,327	9.3	18.3	40.5	425.8	942.4
P25	568,000	32	92	2,055	9.0	18.4	40.6	378.1	834.3
P3	314,000	34	96	1,915	11.0	19.5	42.2	373.1	808.1
P45	388,000	34	100	1,976	9.5	17.1	43.8	337.9	865.5
P2	370,000	37	92	1,533	8.8	17.4	42.3	266.7	648.5
P44	474,000	37	106	1,373	8.7	16.5	42.7	266.5	586.3
P39	326,000	37	102	1,504	8.2	16.2	42.9	243.6	645.2
P1	424,000	40	106	1,534	9.7	16.6	41.7	254.6	539.7
Ross	578,000	43	102	1,396	6.9	16.0	43.1	223.4	601.7
V15	802,000	49	121	881	7.4	13.5	44.4	118.9	391.2
V10	680,000	57	143	224	6.6	16.1	42.8	36.1	96.0

3-2 SOYBEAN CULTIVAR OBSERVATION 1983/84

Three soybean lines of Brazilian origin were obtained from the CSIRO genotype evaluation program in the ORIA. An important characteristic of these lines was that they flowered later than Buchanan but matured at a similar time (J.D. Mayers, personal communication). Hence, they effectively had a shorter reproductive period. We believed this may provide two important advantages. Firstly, with later flowering, greater vegetative biomass should accumulate prior to flowering and secondly the critical period for insect control (reproductive period) would be shortened.

These lines were sown in unreplicated observation plots with Buchanan on Jan. 6, 1984 and hand harvested on April, 16 1984 (101 days after sowing).

Results and Discussion

Variety	Days to First Flower	Days to Finish Flower	Yield kg/ha
CPAC-487-76	47	58	5,284
CPAC-639-76	44	61	5,108
CPAC-160-76	44	61	4,759
Buchanan	30	55	5,304

All three Brazilian varieties were very similar in plant type and all had pods of a rusty brown colour easily distinguishable from Buchanan. Hundred seed weight was approximately the same as Buchanan, between 12 and 13 grams. Seeds of all three types had a very dark Hilum. Yields were similar to yields obtained with Buchanan.

The Brazilian cultivars flowered much later than Buchanan and had a much shorter flowering period but matured at approximately the same time. However, they also showed a strongly determinate trait which would greatly limit their yield potential if adverse conditions occurred at flowering. The semi-determinant characteristic of Buchanan is important in providing a degree of flexibility to cope with adverse conditions during flowering. If adverse conditions occur during early flowering this can be compensated for by the extended flowering period. This particular season (1983/84 - Table 1) was very favourable.

All three Brazilian cultivars lodged to a much greater degree than did Buchanan but were not necessarily unharvestable and quality did not appear to have been affected. Not enough attention was paid to shattering characteristics to fault them on that aspect.

From this preliminary study we do not believe these lines are likely to be superior to Buchanan but certainly warrant further testing.

3-3 SOYBEAN VARIETY EVALUATION 1984/85

The three Brazilian lines discussed in the previous study were planted in a replicated experiment with Buchanan on December 28, 1984. Very poor plant stands results due to adverse seasonal conditions and poor seed quality. The experiment was abandoned.

In order to obtain adequate seed supplies for the following season the Brazilian lines were re-sown in unreplicated plots at extremely high seeding rates in 42 cm rows on Jan 23, 1985. Buchanan was not re-sown.

Results and Discussion

Variety	Establish Plant Pop x 10^3ha^{-1}	Days to Flowering	Days to Complete of Flowering	Days to Maturing	Yield kg/ha	100 Seed wt (g)
CPAC 639-76	471	46	55	96	1.67	10.7
CPAC 160-76	386	47	61	98	2.21	13.1
CPAC 487-76	244	47	65	93	1.67	13.2

Days to commencement and completion of flowering were similar to that recorded the previous season and further showed the short duration of flowering. Yields were much lower and maturity was earlier reflecting more adverse seasonal conditions than in 1983/84. All the genotypes lodged and shattering was observed at maturity. Shattering was particularly bad in CPAC 487-76. Further testing of these lines is warranted.

* Peter Hatfield was responsible for the field operations in this experiment.

SECTION 4

PLANT POPULATION, ROW SPACING, AND WEED CONTROL

4-1 PLANT POPULATION AND WEED CONTROL STUDIES WITH SOYBEANS IN THE 1981/82 WET SEASON

ABSTRACT

An experiment was conducted in the 1981/82 wet season to study the effect of plant population, primary and secondary weed control on the growth and yield of soybean.

Soybean cultivar Buchanan was established at plant populations of 30, 130, 180, 260, 320, and 420 x 10^3 ha^{-1} with primary weed control treatments of no control, treflan @ 2 l ha^{-1}, treflan @ 4 l ha^{-1} and hand weeding; and secondary weed control treatments of no basagran or basagran at 2 l ha^{-1}.

There was a quadratic response in grain yield to increasing plant populations up to 320,000 plants ha^{-1}. Increasing plant population improved weed control.

Application of treflan resulted in a 60% increase in grain yield. Application of basagran improved grain yield by only 8% but greatly facilitated harvesting.

The yield response to plant population is discussed in relation to weed species and seasonal conditions.

INTRODUCTION

Soybeans are a relatively new crop to the Northern Territory with commercial production commencing in the 1982-83 wet season. Research, mainly genotype evaluation, has been carried out sporadically since the late 1960's. These studies have produced inconsistent results but poor yields have often been attributed to low plant populations and/or severe weed competition (Section 2).

Little information is available on the effect of plant population on the growth and yield of soybeans in this environment. In studies elsewhere it has been clearly shown that the response to plant population is closely related to genotype and sowing time (Lawn *et al.* 1977). Essentially higher plant populations are required with later sowings and earlier maturing genotypes. Beech *et al.* (1985a) have confirmed this general response pattern under irrigated conditions in the Ord Irrigation Area.

Soybeans are a rainfed wet season crop in the Northern Territory, being sown in December-January and harvested in April. The short duration of the wet season imposes restrictions on sowing date and dictates suitable genotypes for the region. Essentially, the crop must be sown between mid-December and mid-January and have a growing period of 100-110 days to produce reliable yields. Hence, the genotype and sowing time effects on plant population are relatively unimportant in this region.

Studies in other areas have shown that the effects of weed competition can be reduced by increasing soybean plant population (Felton 1976, Piggot and Farrell 1982). A number of weed species have been identified as potential competitors with soybeans in the Northern Territory. Essentially, these can be placed in three broad groups - grasses (*Digitaria* spp., *Brachiara* sp.), broadleafs (*Sida* sp., *Hyptis suaveolens*) and native or introduced legumes (*Vigna* sp., *Alysicarpus vaginalis* - buffalo clover). Effective chemical control of grass weeds can be obtained with Trifluralin (Treflan(R)) and broadleafs with Bentazone (Basagran(R)), but there is no effective chemical control for native or introduced legumes in soybean crops.

In this paper the effect of different soybean plant populations and the strategic use of trifluralin and bentazone on the growth and yield of soybeans is reported.

MATERIALS AND METHODS

a) Seasonal Conditions

Total rainfall for the 1981-82 season was slightly below the long term mean at 1070 mm (Table 1, Section 1). However, distribution varied considerably from the long term mean with well below average February and March rainfall and an abrupt end to the wet season at the end of March.

Soil type was a Tippera clay loam which had been cropped for a number of years. Soybeans were grown in the previous season without any herbicide. The area had well established populations of grass, *Sida* sp., *Hyptis sauveolens* and *Alysicarpus vaginalis* (Buffalo clover).

b) Design and Management

Experimental design was a split/split plot with six soybean plant populations as main plots - 30, 130, 180, 260, 320 and 420 x 10^3 plants ha^{-1} - four primary weed control treatments - no control (NC), treflan @ 2 l ha^{-1} (T2), treflan @ 4 l ha^{-1} (T4), and hand weeding (HW) as sub plots - and two secondary weed control treatments - no basagran (NB) or basagran @ 2 l ha^{-1} (B) - as sub-sub plots. There were three replications. Intended plant populations were 50, 200, 350, 500, 650 and 800 x 10^3 plants ha^{-1} but relatively poor establishment due to poor seed quality resulted in the above populations.

All plots consisted of three beds, each 1.5 m wide with a 0.5 m gap between beds. Hence overall plot width was six metres. Main plots, sub-plots, and sub-sub plots were 60 m, 15 m and 7.5 m long, respectively. Ten rows of soybeans, each 15 cm apart, were sown on each bed.

Inoculated seed of soybean cultivar Buchanan was sown on December 22, 1981 using a small plot combine. Prior to sowing the entire experimental area was fertilized with single superphosphate @ 300 kg ha^{-1} (29 kg ha^{-1} of both phosphorus and sulphur).

Treflan was applied by boomspray and immediately incorporated five days before sowing (Dec. 17). Conditions were hot and dry at application. All plots not treated with treflan were given an incorporation treatment for uniformity.

Basagran was applied by boomspray 14 days after sowing (January 5).

Hand weeding was carried out as required to maintain hand weeded plots in a weed free condition.

Insects were controlled as required throughout the season with Thiodan @ 2 l ha^{-1}. The experiment was sprayed three times.

c) Recordings and data collection

Dates of the commencement and completion of flowering and physiological maturity were recorded.

Established plant populations were recorded on January 4 by counting the number of plants in the centre six rows x 1 m at six locations in each plot (2 locations in each bed).

Dry matter production was measured on two dates during the growing season (February 3, March 23). On each occasion a sample comprising the centre four rows x 0.5 m was taken from each outside bed of each plot. All above ground plant parts were collected and later divided into soybeans, grass, Sida sp., Hyptis sauveolens, and Alysicarpus vaginalis. These components were dried separately and dry weights were recorded.

At physiological maturity, 10 plants were selected from the centre of the outside beds (5 from each) of each plot for yield component analysis. On these plants we measured plant height, node number, branch number, pods per plant, seeds per plant, and seed weight per plant. Seeds per pod and seed size (100 seed weight) were calculated from these data.

Grain yield was measured by direct heading the centre bed of each plot with a KEW experimental header. All seed was cleaned and weights were recorded. Sub-samples were dried at 50°C for 96 hrs and dry weights were recorded. These data were subsequently used to convert yield to a dry weight basis. Further sub-samples were set aside to determine oil and protein content.

Prior to harvest two plants were randomly selected from each hand weeded plot and divided into two segments. These segments were 0-15 cm above ground level, and above 15 cm from ground level. Seed from each segment was threshed separately and weighed.

From this the percentage of plant yield below 15 cm was determined. It was deemed that seed set below 15 cm would be difficult to collect with a header.

RESULTS AND DISCUSSION

1. Species Composition

Both treflan and basagran provided very good weed control of selected species. Treflan provided good grass control, basagran good sida and hyptis control, while buffalo clover was not controlled by either herbicide. Hence species composition varied with treatment. Combinations are shown in Table 1.

Some other weed species were present in very low numbers and these have been ignored in this experiment.

2. Phenology

There was no effect of any treatment on the commencement (Jan 23, 31 days after sowing) or completion (Feb 21, 60 days after sowing) of flowering. However maturity was delayed by four days with the lowest plant population. All other treatments were mature on April 6 (105 days after sowing).

3. Plant Establishment

Overall establishment was poor with populations in all treatments of the order of 50-60% of sown seed. This was due to a combination of poor seed quality and hot dry conditions immediately after sowing.

Establishment was adversely effected by treflan (P 0.05), particularly at 4 l ha^{-1} which had 80% of the establishment of no control and hand weeded. There was no interaction between treflan and plant population (Table 2).

4. Dry Matter Production

Significant treatment effects on the dry matter production of soybeans, grass, sida, hyptis and buffalo clover are shown in Tables 3, 4, 5, 6 and 7, respectively.

a) Soybean Plant Population Effects

Increasing soybean plant population increased soybean dry matter (Table 3a) but reduced both grass (Table 4a) and buffalo clover (Table 7a) dry matter. There was no effect on sida or hyptis dry matter. This suggests that some degree of control of grass and buffalo clover can be obtained with plant population. The effect was most dramatic on buffalo clover (Table 7a) there being a ten fold decrease from the lowest to the highest plant population. For grass the decrease was only two fold (Table 4a).

Plant population effects varied with sampling date for soybean, grass and buffalo clover dry weight. For soybeans, the difference in dry weight between the highest and lowest plant populations was almost six fold with the initial sampling date but just over two fold with the second sampling date (Table 3e). This reflects a compensatory effect from larger soybean plants with lower plant populations later in the growing period. For both grass and buffalo clover dry weights there was no significant difference between soybean plant populations for the initial sampling date however large differences developed by the second sampling date with much higher dry weights at low soybean plant populations (Tables 4e, 7d). At high plant populations clover dry weights were similar at both sampling dates (Table 7d) while there was only a two fold increase in grass dry weight (Table 4e).

b) Primary Weed Control Effects

There were effects of primary weed control on soybean (Table 3b), grass (Table 4b), sida (Table 5b) and clover (Table 7b) dry weights. There was no effect on hyptis dry weights.

The application of treflan produced large increases in soybean dry weight (Table 3b) mainly due to large reductions in grass dry weight (Table 4b). However soybean dry weights were significantly lower with treflan than with hand weeding because other species sida, hyptis and clover were all still present. In fact the removal of grass with treflan promoted the growth of both sida and buffalo clover compared with no control (Tables 5a, 7b). Hyptis was unaffected.

The response to primary weed control in soybean (Table 3e), grass (Table 4f), sida (Table 5e) and clover (Table 7e) was also affected by sampling date. Increasing the intensity of primary weed control (NC - T2 - T4) had larger effects on all species except grass at the later sampling date i.e. the increase in soybean, sida and clover dry weights in response to primary weed control was greater at the later sampling date whereas for all except no control there was no difference between sampling dates for grass dry weight.

c) Secondary Weed Control

There were effects of secondary weed control on soybean (Table 3c), sida (Table 5b) and hyptis (Table 6a). Essentially, the application of basagran improved soybean dry weights through the removal of both sida and hyptis. Grass and buffalo clover were unaffected by basagran.

There was a secondary weed control x sampling date effect on buffalo clover (Table 7f). On the second sampling date clover dry weight was higher where basagran was applied, presumably due to a reduction in competition from sida and hyptis.

d) Interactions between plant population, primary and secondary weed control

There were no interactions between plant population, primary and secondary weed control for soybean dry weight. Effects were simply additive. Mean soybean dry weights for the lowest population with no control was 99 gm m^{-2} while for the highest population with no control it was 313 gm m^{-2}. Applying treflan with the highest plant population increased yields to 563 gm m^{-2} while the combination of highest plant population plus treflan plus basagran did not improve soybean dry matter (566 gm m^{-2}). There was a further small yield increase (588 gm m^{-2}) for the hand weeded situation without basagran. These results clearly show that soybean dry weights are mainly influenced by plant population and grass weed control.

For grass there was a significant plant population by primary weed control effect (Table 4d). This reflected the elimination of grasses, with hand weeding, with T4 at greater than 130,000 plants ha^{-1}, and with T2 at greater than 260 plants ha^{-1}.

A primary by secondary weed control interaction was recorded for sida. Essentially this showed that basagran eliminated sida regardless of primary weed control treatment. However, with the exception of hand weeding, increasing intensity of primary weed control (NC - T2 - T4) without secondary weed control promoted sida growth. Presumably this is due to a lack of grass competition.

5. <u>Yield and Yield Components</u>

Treatment effects on soybean grain yield, plant height, node number, branch number, pods per plant, seeds per pod, and seed weight are shown in tables 8-14, respectively. There was no effect of any treatment on oil (21.2%) or protein (39.6%) content.

a) Plant Population Effects

There was a significant quadratic response in grain to increasing plant population up to 320,000 ha^{-1}. In absolute terms there was no significant yield difference between 260,000 and 420,000 plants ha^{-1} (Table 8a).

Increasing plant population increased plant height (Table 9a) but reduced node number (Table 10a) branch number (Table 11a) and pods per plant (Table 12a). There was no effect on seeds per pod or seed size.

b) Primary Weed Control

Yield increased with the intensity of primary weed control (Table 8b). The application of treflan @ 2 l ha^{-1} improved yield by 60%. There was a further 24% increase with hand weeding.

The application of treflan increased plant height compared with no control and hand weeding (Table 9b) increased node number (Table 10b), branch number (Table 11b) and pods per plant (Table 12b) but appears to have had a slightly adverse effect on seeds per pod (Table 13a) and seed size (Table 14a).

c) Secondary Weed Control

The application of basagran produced an 8% increase in grain yield (Table 8c). There was no effect on plant height but significant increases in node number (Table 10c) branch number (Table 11c), pods per plant (Table 12c) and seed size (Table 14c). There was no effect on seeds per pod.

d) Interactions Between Plant Population, Primary and Secondary Weed Control

There were significant interactions between plant population and primary weed control for grain yield (Table 8d), branch number (Table 11d), pods per plant (Table 12d), and seed size (Table 14d). Essentially all these variates responded more to increasing intensity of primary weed control at low plant populations. At high plant populations only pods per plant and yield were improved by imposing primary weed control compared with no control. However at high populations there was no difference for any variate when primary weed control was applied.

There were no interactions between plant population and secondary weed control for any variate measured. However there were primary x secondary weed control interactions for grain yield (Table 8e) plant height (Table 9c), pods per plant (Table 12e), seeds per pod (Table 13b) and seed size (Table 14d).

Essentially where treflan was not applied yield was not increased with the use of basagran. Further, in the hand weeded situations there is a trend (although not significant) for basagran to have an adverse affect on grain yield (Table 8e). This latter effect is supported by trends in pods per plant (Table 12e) and seeds per pod (13b).

6. Yield Distribution

Data for yield distribution on individual plants for each plant population in the hand weeded treatment is shown in Table 15. Essentially the percentage of yield in the segment 0-15 cm above ground decreased as plant population increased. For the lowest plant population almost 10% of the yield was below 15 cm.

GENERAL DISCUSSION

The results of this study clearly show that maximum soybean yields will only be achieved with plant populations in excess of 250,000 ha^{-1} and the control of grass and broadleaf weeds. Control of grass weeds is extremely important and, as these results show can produce a 60% increase in grain yield.

In terms of grain yield the control of broadleaf weeds was less important only producing an 8% yield increase. Further, when grass weeds were not controlled there was no grain yield increase from controlling broadleafs. However, the control of sida and hyptis facilitated harvesting. Plots with sida and hyptis were extremely difficult to harvest and the resultant grain sample was heavily contaminated with seeds of these species. Sida and hyptis populations were not excessive in this experiment with the worst infested plots having of the order of 250 gm m^{-2} on March 23. Situations where considerably more sida and hyptis are present can be envisaged and in such cases a more significant reduction in grain yield is likely to occur.

Buffalo clover only appears of minor importance except in low soybean plant population areas where grass, sida and hyptis are well controlled. It appears a very poor competitor. However, where present, it did contaminate grain samples.

In considering the response to plant population it is worth closely examining seasonal conditions. This season varied from the long term mean, not so much in total rainfall, but in distribution. Essentially well below average rainfall was recorded for the latter part of the growing season (Table 1, Section 1) when yield and yield components were being determined and it is reasonable to suggest that moisture stress was having an important impact on plant growth late in the season. This probably explains the relatively small seed harvested from this experiment (trial mean = 11.8 gm/100 seeds). Studies in seasons with more favourable conditions at the end of the growing period suggest a seed size of the order of 13-14 gm per 100 seeds is more normal (Table 6, Section 4-2). Although soybean plant population did not have an overall effect on seed size the results are probably confounded by weeds replacing soybeans in many situations. However, for the hand weeded situation there was a general decrease in seed size with increasing soybean plant population (Table 14c).

We believe that moisture stress at the end of the growing period was responsible for this and that under more favourable conditions seed size would have remained stable increasing grain yield in the higher plant population treatments.

There was some indication that both herbicides may have had some adverse effect on soybeans. Certainly, treflan reduced initial establishment and there was a trend for slightly reduced yields when basagran was applied in a weed free situation. Regardless, these effects are minor and are far outweighed by their beneficial effects. Both herbicides were extremely effective under the conditions of this experiment.

CONCLUSIONS

The following conclusions can be drawn from this experiment:

1. Yield increased with increasing soybean plant population up to 320,000 plants ha^{-1}.

2. Increasing soybean plant population provided a degree of control of grass and buffalo clover.

3. Control of grass weeds increased soybean yield by 60%.

4. Control of broadleaf weeds (sida, hyptis) only increased soybean yield by 8% but made harvesting easier and resulted in a cleaner grain sample.

5. Control of broadleaf weeds did not improve soybean yields when grass weeds were not controlled.

6. Treflan reduced soybean establishment and there were some indications of an adverse effect of basagran on soybean yields in a weed free situation. However, the benefits of both herbicides far outweighed any detrimental effects.

7. Both treflan and basagran were very effective herbicides in this particular season.

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TABLE 1: Species composition with various weed control treatments

Treatment	Code	Species Present
No control	NC	Soybean, grass, broadleaf, clover
No control plus basagran	NCB	Soybean, grass, clover
Treflan @ 2 l ha^{-1}	T2	Soybean, broadleaf, clover
Treflan @ 2 l ha^{-1} + basagran	T2B	Soybean, clover
Treflan @ 4 l ha^{-1}	T4	Soybean, broadleaf, clover
Treflan @ 4 l ha^{-1} + basagran	T4B	Soybean, clover
Hand weeding	HW	Soybean
Hand weeding + basagran	HWB*	Soybean

* This treatment provides a measure of any adverse effect of basagran on soybeans.

TABLE 2: Effect of Primary Weed Control on Soybean Establishment

Treatment	Plant Population (Plants ha^{-1})
NC	239,000
T2	214,000
T4	195,000
HW	235,000

Level of Significance *, L.S.D. = 34,000

TABLE 3: Effects of various treatments on soybean dry weight (gm m^{-2})

a) Plant Population Effect

Plant Population (x 10^3 ha^{-1})	30	130	180	260	320	420
Soybean dry wt. (gm m^{-2})	193	362	446	506	482	496

Level of Signif: *, LSD 5% = 137

b) Primary Weed Control Effect

Treatment	NC	T2	T4	HW
Soybean dry wt (gm m^{-2})	265	460	403	530

Level of Signif: **, LSD 5% = 68

c) Secondary Weed Control Effect

Treatment	NB	B
Soybean dry wt (gm m^{-2})	388	441

Level of Signif: **, LSD 5% = 51

d) Sample Date Effect

Sample date	Feb 4	March 23
Soybean dry wt (gm m^{-2})	110	718

Level of Signif: **, LSD 5% = 54

e) Plant Population x Sample Date Effect

	Plant Population (x 10^3 ha^{-1})					
Sample date	30	130	180	260	320	420
Feb 4	28	71	102	150	167	143
March 23	357	654	790	863	796	849

Level of Signif: **, LSD 5% = 154

f) Primary Weed Control x Sample Date Effect

	Primary Weed Control			
Sample Date	NC	T2	T4	HW
Feb 4	86	126	108	121
March 23	443	795	697	938

Level of Signif: **, LSD5% = 102

TABLE 4: Effects of various treatments on grass dry weight (gm m^{-2})

a) Soybean Plant Population Effect

Plant Population (x 10^3 ha^{-1})	30	130	180	260	320	420
Grass dry wt. (gm m^{-2})	96	57	53	58	44	45

Level of Signif: **, LSD 5% = 18

b) Primary Weed Control Effect

Treatment	NC	T2	T4	HW
Grass dry wt (gm m^{-2})	227	9	1	0

Level of Signif: **, LSD 5% = 18

c) Sample Date Effect

Sample date	Feb 4	March 23
Grass dry wt (gm m^{-2})	35	83

Level of Signif: **, LSD 5% = 12

d) Plant Population x Primary Weed Control Effect

	Plant Population (x10^3 ha^{-1})					
Primary Weed Control	30	130	180	260	320	420
NC	356	214	204	233	178	179
T2	25	15	6	0	0	0
T4	3	0	0	0	0	0
HW	0	0	0	0	0	0

Level of Signif: **, LSD 5% = 42

e) Plant Population x Sample Date Effect

	Plant Population (x 10^3 ha^{-1})					
Sample date	30	130	180	260	320	420
Feb 4	46	36	29	41	30	30
March 23	146	79	76	76	59	62

Level of Signif: **, LSD 5% = 27

f) Primary Weed Control x Sample Date Effect

	Primary Weed Control			
Sample Date	NC	T2	T4	HW
Feb 4	139	2	0	0
March 23	316	15	0	0

Level of Signif: **, LSD 5% = 25

TABLE 5: Effects of various treatments on sida dry weight ($gm\ m^{-2}$)

a) Primary Weed Control Effect

Treatment	NC	T2	T4	HW
Sida dry wt ($gm\ m^{-2}$)	25	53	59	0

Level of Signif: **, LSD 5% = 26

b) Secondary Weed Control Effects

Treatment	NB	B
Sida dry wt ($gm\ m^{-2}$)	68	0

c) Sample Date Effect

Sample date	Feb 4	March 23
Sida dry wt ($gm\ m^{-2}$)	5	63

Level of Signif: **, LSD 5% = 16

d) Primary x Secondary Weed Control Effects

	NC	T2	T4	HW
NB	51	106	118	0
B	0	0	0	0

Level of Signif: **, LSD 5% = 36

e) Primary Weed Control x Sample Date Effect

	Primary Weed Control			
Sample Date	NC	T2	T4	HW
Feb 4	6	9	6	0
March 23	45	96	111	0

Level of Signif: **, LSD 5% = 34

f) Secondary Weed Control x Sample Date Effects

	NB	B
Feb 4	11	0
March 23	126	0

Level of Signif: **, LSD 5% =

TABLE 6: Effect of various treatments on hyptis dry weight ($gm\ m^{-2}$)

a) Secondary Weed Control Effect

Treatment	NB	B
Hyptis dry wt ($gm\ m^{-2}$)	31	0

Level of Signif: **, LSD 5% = 20

b) Sample Date Effect

	Feb 4	March 23
Hyptis dry wt ($gm\ m^{-2}$)	2	30

Level of Signif: **, LSD 5% = 19

c) Secondary Weed Control x Sample Date Effect

	NB	B
Feb 4	3	0
March 23	59	0

Level of Signif: **, LSD 5% = 28

TABLE 7: Effects of various treatments on buffalo clover dry weight ($gm\ m^{-2}$)

a) Plant Population Effect

Plant Population ($x\ 10^3\ ha^{-1}$)	30	130	180	260	320	420
Clover dry wt. ($gm\ m^{-2}$)	79	49	33	11	8	7

Level of Signif: *, LSD 5% = 24

b) Primary Weed Control Effect

Treatment	NC	T2	T4	HW
Clover dry wt ($gm\ m^{-2}$)	26	44	55	0

Level of Signif: **, LSD 5% = 24

c) Sample Date Effect

Sample date	Feb 4	March 23
Clover dry wt ($gm\ m^{-2}$)	14	48

Level of Signif: **, LSD 5% = 15

d) Soybean Plant Population x Sample Date Effect

Sample date	Plant Population ($x\ 10^3\ ha^{-1}$) 30	130	180	260	320	420
Feb 4	34	17	10	10	6	9
March 23	124	81	55	13	9	5

Level of Signif: **, LSD 5% = 34

e) Primary Weed Control x Sample Date Effect

Sample Date	Primary Weed Control NC	T2	T4	HW
Feb 4	13	24	20	0
March 23	38	63	89	0

Level of Signif: **, LSD 5% = 31

f) Secondary Weed Control x Sample Date Effect

	NB	B
Feb 4	16	12
March 23	34	61

Level of Signif: **, LSD 5% = 21

TABLE 8: Effects of various treatments on soybean grain yield (kg ha^{-1})

a) Plant Population Effect

Plant Population (x 10^3 ha^{-1})	30	130	180	260	320	420
	725	1687	1826	2461	2665	2627

Level of Signif: **, LSD 5% = 308

b) Primary Weed Control Effect

Treatment	NC	T2	T4	HW
	1312	2111	2155	2415

Level of Signif: *, LSD 5% = 179

c) Plant Population x Primary Weed Control Effect

	Plant Population (x10^3 ha^{-1})					
Primary Weed Control	30	130	180	260	320	420
NC	265	1010	1382	1815	1839	1562
T2	641	1523	1761	2541	3042	3160
T4	857	1925	1995	2710	2788	2656
HW	1136	2290	2166	2777	2992	3130

Level of Signif: *, LSD 5% = 472

d) Primary x Secondary Weed Control Effect

	Primary Weed Control			
Secondary Weed Control	NC	T2	T4	HW
NB	1271	1947	1982	2491
B	1353	2275	2328	2339

Level of Signif: *, LSD 5% = 252

TABLE 9: Effect of various treatments on soybean plant height (cm)

a) Plant Population Effect

Plant Population ($x 10^3 ha^{-1}$)	30	130	180	260	320	420
	82	89	87	94	95	95

Level of Signif: **, LSD 5% = 5

b) Primary Weed Control Effect

Treatment	NC	T2	T4	HW
	88	94	92	87

Level of Signif: **, LSD 5% = 3

c) Primary x Secondary Weed Control Effect

	Primary Weed Control			
Secondary Weed Control	NC	T2	T4	HW
NB	90	94	92	86
B	85	95	92	88

Level of Signif: *, LSD 5% = 4

TABLE 10: Effect of various treatments on main stem node number

a) Plant Population Effect

Plant Population (x 10^3 ha^{-1})	30	130	180	260	320	420
	24.4	23.3	22.8	23.3	21.9	21.6

Level of Signif: *, LSD 5% = 1.5

b) Primary Weed Control Effect

Treatment	NC	T2	T4	HW
	21.4	23.4	23.6	23.2

Level of Signif: *, LSD 5% = 1.0

c) Secondary Weed Control Effect

Treatment	NB	B
	22.6	23.2

Level of Signif: *, LSD 5% = 0.5

TABLE 11: Effects of various treatments on branch number

a) Plant Population Effect

Plant Population ($x\ 10^3\ ha^{-1}$)	30	130	180	260	320	420
	6.0	5.2	4.9	4.2	3.6	3.5

Level of Signif: **, LSD 5% = 0.7

b) Primary Weed Control Effect

Treatment	NC	T2	T4	HW
	3.3	4.7	5.2	5.0

Level of Signif: **, LSD 5% = 0.5

c) Secondary Weed Control Effect

Treatment	NB	B
	4.4	4.7

Level of Signif: **, LSD 5% = 0.3

d) Plant Population x Primary Weed Control Effect

	Plant Population ($x10^3\ ha^{-1}$)					
Primary Weed Control	30	130	180	260	320	420
NC	3.6	4.0	3.6	2.9	3.1	2.8
T2	6.2	5.2	5.6	3.9	3.8	3.7
T4	6.8	6.3	5.4	5.2	3.7	3.9
HW	7.5	5.3	4.9	4.7	3.8	3.8

Level of Signif: **, LSD 5% = 1.2

TABLE 12: Effects of various treatments on pods per plant

a) Plant Population Effect

Plant Population (x 10^3 ha^{-1})	30	130	180	260	320	420
	223	152	136	119	89	88

Level of Signif: **, LSD 5% = 21

b) Primary Weed Control Effect

Treatment	NC	T2	T4	HW
	89	137	155	157

Level of Signif: **, LSD 5% = 19

c) Secondary Weed Control Effect

Treatment	NB	B
	126	144

Level of Signif: **, LSD 5% = 7

d) Plant Population x Primary Weed Control Effect

	Plant Population (x10^3 ha^{-1})					
Primary Weed Control	30	130	180	260	320	420
NC	102	115	95	86	68	70
T2	222	156	150	107	98	90
T4	260	174	143	154	97	100
HW	308	162	156	129	93	93

Level of Signif: **, LSD 5% = 44

e) Primary x Secondary Weed Control Effects

	Primary Weed Control			
Secondary Weed Control	NC	T2	T4	HW
NB	80	122	139	161
B	99	152	170	153

Level of Signif: **, LSD 5% = 21

TABLE 13: Effect of various treatments on seeds per pod

a) Primary Weed Control Effect

Treatment	NC	T2	T4	HW
	1.95	1.91	1.87	2.00

Level of Signif: **, LSD 5% = 0.08

b) Primary x Secondary Weed Control Effect

	Primary Weed Control			
Secondary Weed Control	NC	T2	T4	HW
NB	1.94	1.90	1.82	2.06
B	1.96	1.92	1.92	1.93

Level of Signif: **, LSD 5% = 0.1

TABLE 14: Effects of various treatments on seed size (100 seed wt gm)

a) Primary Weed Control Effect

Treatment	NC	T2	T4	HW
	11.78	11.46	11.71	12.25

Level of Signif: **, LSD 5% = 0.28

b) Secondary Weed Control Effect

Treatment	NB	B
	11.57	12.02

Level of Signif: **, LSD 5% = 0.16

c) Plant Population x Primary Weed Control Effect

	Plant Population (x10^3 ha^{-1})					
Primary Weed Control	30	130	180	260	320	420
NC	11.69	11.81	12.46	11.91	11.28	11.55
T2	10.95	11.52	11.56	11.51	11.46	11.73
T4	12.17	11.89	11.55	11.74	11.68	11.19
HW	13.89	12.16	12.13	11.60	11.83.	11.86

Level of Signif: **, LSD 5% = 0.72

d) Primary x Secondary Weed Control

	Primary Weed Control			
Secondary Weed Control	NC	T2	T4	HW
NB	11.58	11.13	11.31	12.27
B	11.99	11.78	12.10	12.22

Level of Signif: **, LSD 5% = 0.36

TABLE 15: Effect of plant population on yield lost due to pods being within 15 cm of the ground

Plant Population ($x10^3$ ha^{-1})	% Yield (0-15 cm)
30	10
130	9
180	5
260	3
320	2
420	2

4-2 EFFECT OF PLANT POPULATIONS X ROW SPACING ON THE YIELD OF SOYBEANS IN THE 1982/83 WET SEASON

ABSTRACT

Soybean cultivar Buchanan was sown at three row spacings - 15, 45 and 75 cm - and three palnt populations - 150, 280 and 430 x 10^3 ha^{-1} in an experiment on Tippera clay loam soil at Douglas Daly Research Farm in the 1982/83 wet season.

Grain yield increased with increasing plant population up to 430 x 10^3 ha^{-1}, was higher in 15 and 75 cm rows than 45 cm rows, was highest with 75 cm rows at low plant population and with 15 cm rows at high plant population. The highest treatment yield of 4626 kg ha^{-1} was obtained with a plant population x row spacing combination of 430 x 10^3 ha^{-1} sown in 15 cm rows.

Results are discussed in relation to specific aspects of this experiment and seasonal conditions.

In considering the results of this and the previous experiment it is concluded that the most appropriate soybean plant population for Tippera clay loam is of the order of 400,000 - 450,000 plants ha^{-1} sown in 15 cm rows.

INTRODUCTION

Studies at Douglas Daly Research Farm in the 1981/82 wet season showed that there was no yield difference between soybean plant population of 250-450 x 10^3 ha^{-1} sown in late December in narrow (15 cm) rows (Section 4-1). However, the results also clearly showed that higher plant populations can facilitate weed control.

The response to plant population in soybeans varies for different localities and is very dependent of genotype and sowing time (Lawn et al 1977). In higher latitude areas, with a relatively long growing period (120-140 days) plant populations of the order of 250,000 ha^{-1} or less are often adequate. Further, wide row spacings (90 cm) are often used. Although these reduce the rate of canopy closure; with a relatively long growing season they do not necessarily have a detrimental effect on yield (Hicks et al 1969, Felton 1976).

The growing period for wet season soybeans in the Douglas-Daly area is relatively short at 100-110 days, so any factors likely to limit growth rate are also likely to limit ultimate grain yield. Although the use of wide rows (75-90 cm) will reduce the rate of canopy closure and therefore light interception, wide rows are likely to facilitate inter-row cultivation and therefore give better weed control.

A study was initiated in the 1982/83 season to evaluate the effects of different soybean plant populations and row spacings on the yield of soybeans in the Douglas-Daly region, NT. This paper reports the results of that study.

MATERIALS AND METHODS

1. Seasonal Conditions

The 1982/83 season had well below average rainfall at only 919 mm (Table 1, Section 1). More importantly, the season was characterised by major variations in distribution from the long term means with very dry December, January and February but above average March and April rainfall. This season contrasted greatly with the previous (1981/82) season when plant population studies were also conducted (Table 1, Section 1).

Soil type was a Tippera clay loam which grew sorghum the previous season. Prior to that the area was virgin ground.

2. Design, Treatments and Management

Design was a complete factorial with three row spacings - 15, 45 and 75 cm - and three plant populations - 150, 280 and 430 x 10^3 plants ha^{-1}. Intended populations were 200, 350 and 500 x 10^3 ha^{-1} but establishment was poorer than expected due to very dry conditions after sowing. There were four replications.

Plot size varied with row spacing. All plots were 20 m long but the 75 and 45 cm row spacing were four rows wide and the 15 cm row spacing 10 rows wide. A gap of 0.5 m was left between plots

Inoculated seed of soybean cultivar Buchanan was sown with a small plot combine on Dec 21, 1982. Wider rows were achieved by blocking off individual outlets.

Prior to sowing the area was fertilized with single superphosphate at 300 kg ha^{-1} (29 kg ha^{-1} P and S), zinc sulphate monohydrate at 15 kg ha^{-1} (5 kg ha^{-1} Zn) and Muriate of Potash at 100 kg ha^{-1}, (50 kg ha^{-1} K). Trifluralin herbicide (Treflan(R)) was applied at 2 l ha^{-1} and incorporated one week prior to sowing.

Plots with 75 cm row spacing were inter-row cultivated on January 18. Sida sp. and Hyptis suaveolens were removed by hand weeding as necessary from all plots. No other weed control was imposed.

Very few insect problems occurred and only one spray with endosulfan (Thiodan(R)) was required to control pod sucking bugs on February 22.

3. Recordings and Data Collection

Established plant populations were estimated by counting the number of plants at four locations in each plot three weeks after sowing. For the 75 and 45 cm rows sample size was the centre 2 rows x 1 m while for the 15 cm rows it was the centre 4 rows x 1 m.

No dry matter sampling was carried out during the season.

At maturity 10 plants were randomly selected from internal rows of each plot to measure yield components. On these plants we recorded plant height, node number, branch number, pods per plant, seeds per plant and seed weight per plant. These data were used to calculate seeds per pod and seed size (100 seed weight).

Grain yield was measured by sampling the centre two rows x 5 m in the 75 and 45 cm rows and the centre 6 rows x 5 m in the 15 cm rows. Plots were hand harvested, threshed and seed weights were recorded. Samples were dried at 50°C for 96 hrs to determine moisture content and yields were converted to a dry weight basis.

Grain samples were also set aside for subsequent determination of oil and protein content.

RESULTS

Established plant populations were 150, 280, 430 x 10^3 ha^{-1}. There was no effect of row spacing on plant population.

a) Plant Population Effects

Increasing plant population increased grain yield (P 0.01) (Table 1), plant height (P 0.05) (Table 2), branch number (P 0.01) (Table 4) but decreased pods per plant (P 0.01) (Table 4). There was no effect on seeds per pod (Table 5), seed size (Table 6), protein content (Table 7) or oil content (20.3%, data not presented).

The yield increase with 430 x 10^3 ha^{-1} over 150 x 10^3 ha^{-1} was 90%.

b) Row Spacing Effects

There were significant row spacing effects on grain yield (P 0.01) (Table 1), plant height (P 0.05) (Table 2), branch number (P 0.05) (Table 3), seed size (P 0.01) (Table 6) and protein content (P 0.01) (Table 8). There was no effect on pods per plant (Table 7), seeds per pod (Table 5) and oil content.

Similar yields were recorded with 15 and 75 cm rows but both outyielded 45 cm rows by 27 and 38%, respectively (Table 1). Both seed size (Table 6) and protein content (Table 7) were increased with 75 cm rows.

c) Plant Population x Row Spacing Effects

There was a significant (P 0.01) interaction between row spacing and plant population for grain yield (Table 1). This reflected higher yields with 75 cm rows at the lowest plant population but higher yields with 15 cm rows at the highest plant population. The highest individual treatment yield was for 430 x 10^3 ha^{-1} sown in 15 cm rows.

DISCUSSION

The results from this experiment differ considerably from those obtained the previous season (Section 4-1). From these results it is clear that increasing plant population above 250 x 10^3 ha^{-1} will result in improved yields (comparison of yield for 15 cm rows in each season). We believe the conflicting responses are largely due to seasonal conditions (Table 1, Section 1). The 1981/82 season was characterised by a very dry finish to the growing period whereas the current season was the reverse. This is clearly reflected in much larger seed size this season (trial mean 14.3 compared with 11.8 in 1981/82). Further, there was no trend towards a reduction in seed size with increasing plant population in the current season (Table 6).

There was no consistent trend in row spacing effects (15 and 75 cm giving similar yields with both outyielding 45 cm rows). We believe this was due to a number of confounding factors in this experiment. These factors are likely to have important implications in determining the most appropriate row spacing.

Treflan did not provide good grass control this season and grass and buffalo clover were prevalent throughout the experiment. As the 75 cm rows were inter-row cultivated good weed control was achieved and this, in part, explains the higher yield with 75 cm rows at low plant populations. However as plant populations were increased weed competition became less important so yield differences between row spacings were considerably reduced. At high plant populations (430 x 10^3 ha^{-1}) more equidistant plant arrangement appears to have had a major influence on yield. In the wide rows, intra-row competition has probably been responsible for reduced pods per plant (Table 4) and subsequently lower yield (Table 1) than with narrow rows.

Two other factors are likely to have also benefited the 75 cm rows. Firstly, the site was growing soybeans for the first time so there was no established soybean rhizobia in the soil. Poor nodulation and nitrogen deficiency were obvious in all treatments early in the growing period, but the effect appeared worse in the 15 and 45 cm rows. The hot dry conditions immediately after sowing have probably been instrumental in causing rhizobium mortality. With the 75 cm rows a higher concentration of inoculant would have been applied to a smaller area given the higher density of seed placement in a row. This may well have produced better early nodulation in the 75 cm rows. Further, the Tippera clay loam used in this experiment is very hard setting. The effect of cultivation may have had two additional benefits. Soil disturbance is likely to have improved water infiltration and released more soil nitrogen. Resultant grain protein content (Table 7) clearly shows better nitrogen status with the 75 cm rows.

The 45 cm rows suffered in all ways. They did not have the benefit of high inoculant density or cultivation that the 75 cm rows had, nor did they have the benefit of more equidistant spatial arrangement that applied with the 15 cm rows. Hence their yield was lower than the other row spacings at all plant populations.

FIELD IMPLICATIONS

The results here suggest that the highest yields will be achieved with 430 x 10^3 ha^{-1} sown in 15 cm rows. However, they also show that the use of wide rows may be beneficial in some circumstances. Unfortunately, those circumstances cannot be predicted prior to sowing. Firstly, the hot dry conditions during the early part of this season were abnormai. In more normal seasons the suspected beneficial effects of wide rows on nodulation, water infiltration, and soil nitrogen release are unlikely to assume the same importance. Secondly, once established in the soil soybean rhizobia will survive indefinitely, so the problems associated with poor nodulation on new land are likely to disappear. Thirdly, and most importantly, wet conditions in many seasons are likely to prevent inter-row cultivation on tippera clay loam. In such situations major weed problems can be expected with 75 cm rows. We then conclude that the use of 15 cm rows is preferred on Tippera clay loam.

However, we also suggest that the evaluation of wide rows on the sandy soils is worth considering. Poor survival of soybeans is often recorded on these soils due to high surface temperatures causing "ring barking" of plants at the soil surface (Price and Garside, 1983). High within row densities are likely to provide some protection from these high soil temperatures. Further, inter-row cultivation will be possible in most seasons.

CONCLUSIONS

The results of two seasons experiments suggest that in seasons with a good finish to the wet season (current experiment) yields will be improved by increased plant population up to 430,000 x 10^3 ha^{-1} whereas with a dry finish (previous experiment) to the wet season yields will not be improved above plant populations of 250,000 x 10^3 ha^{-1}. However, in seasons with a dry finish there is no disadvantage from populations as high as 420 x 10^3 ha^{-1}, except for some seed wastage.

It is concluded then that the best overall option for the tippera clay loam soil is a plant population in excess of 400,000 ha^{-1} sown in 15 cm rows.

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TABLE 1: Effect of Plant Population and Row Spacing on Grain Yield (kg ha^{-1})

Row Spacing (cm)	Plant Population x 10^3 ha^{-1}			
	150	280	430	Mean
15	1641	3471	4626	3246
45	1317	2552	3150	2340
75	3299	3260	4064	3541
Mean	2086	3094	3947	3042

Level of Signif: Row Spac = **, LSD 5% = 462
Pl. Pop = **, LSD 5% = 462
Row Spac x Pl. Pop = **, LSD 5% = 800

TABLE 2: Effect of Plant Population and Row Spacing on Plant Height (cm)

Row Spacing (cm)	Plant Population x 10^3 ha^{-1}			
	150	280	430	Mean
15	72	72	78	74
45	64	73	74	70
75	78	81	83	81
Mean	71	75	78	75

Level of Signif: Row Spac = **, LSD 5% = 5
Pl. Pop = *, LSD 5% = 5
Row Spac x Pl. Pop = NSD

TABLE 3: Effect of Plant Population and Row Spacing on branch number per plant.

	Plant Population x 10^3 ha^{-1}			
Row Spacing (cm)	150	280	430	Mean
15	6.5	6.6	5.5	6.2
45	7.3	6.6	5.5	6.5
75	6.3	5.6	4.2	5.4
Mean	6.7	6.3	5.1	6.0

Level of Signif: Row Spac = *, LSD 5% = 0.8
Pl. Pop = **, LSD 5% = 0.8
Row Spac x Pl. Pop = NSD

TABLE 4: Effect of Plant Population and Row Spacing on pods per plant.

	Plant Population x 10^3 ha^{-1}			
Row Spacing (cm)	150	280	430	Mean
15	97	91	76	88
45	94	81	74	83
75	108	85	64	86
Mean	100	86	71	86

Level of Signif: Row Spac = NSD
Pl. Pop = **, LSD 5% = 12
Row Spac x Pl. Pop = NSD

TABLE 5: Effect of Plant Population and Row Spacing on seeds per pod

Row Spacing (cm)	Plant Population x 10^3 ha^{-1} 150	280	430	Mean
15	1.96	2.00	1.91	1.96
45	1.90	1.87	1.87	1.88
75	1.94	1.95	1.84	1.91
Mean	1.93	1.94	1.87	1.92

Level of Signif: NSD

TABLE 6: Effect of Plant Population and Row Spacing on seed size (100 seed wt) gm.

Row Spacing (cm)	Plant Population x 10^3 ha^{-1} 150	280	430	Mean
15	13.9	14.2	14.0	14.0
45	13.7	14.2	14.0	14.0
75	14.6	14.8	15.0	14.8
Mean	14.1	14.4	14.3	14.3

Level of Signif: Row Spac = **, LSD 5% = 0.7
Pl. Pop = NSD
Row Spac x Pl Pop = NSD

TABLE 7: Effect of Plant Population and Row Spacing on grain protein content

	Plant Population x 10^3 ha^{-1}			
Row Spacing (cm)	150	280	430	Mean
15	36.3	35.9	35.8	36.0
45	36.1	35.3	37.0	36.2
75	39.1	39.2	38.9	39.1
Mean	37.1	36.8	37.2	37.1

Level of Signif: Row Spac = **, LSD 5% = 1.4
Pl. Pop = NSD
Row Spac x Pl Pop = NSD

SECTION 5

PLANT NUTRITION

5-1 EFFECT OF INOCULATION ON THE YIELD OF SOYBEANS ON VIRGIN TIPPERA CLAY LOAM

It is well established that effective nodulation is necessary to obtain maximum soybean yields. Unfortunately the strain of Rhizobium japonicum (CB 1809) is not native to the soils of Northern Australia so inoculation is essential for, at least, the first soybean crop in an area.

By way of demonstration two blocks of soybeans, each 0.1 ha, were established on virgin Tippera clay loam at Douglas Daly Research Farm in the 1981/82 wet season. One block was inoculated with commercial peat inoculant (Strain CB 1809) while the other was not inoculated. All other cultural practices were standard.

From the outset the non-inoculated area had fewer nodules, was generally paler in colour and showed poorer growth. Although there was a tendency for this to dissipate late in the season the effect was serious enough to result in a yield difference of 1 t ha^{-1}. Yields were:-

Inoculated	3,450 kg ha^{-1}
Non-Inoculated	2,414 kg ha^{-1}

As the blocks were adjacent and some nodules were apparent on non-inoculated plants by the end of the season it is suspected that some movement of rhizobia from the inoculated block may have occurred. Consequently, the relative difference between the two areas may be less here than in a more isolated situation.

5-2 RESPONSE OF SOYBEANS TO STARTER AND SUPPLEMENTARY NITROGEN UNDER RAINFED CONDITIONS AT DOUGLAS-DALY RESEARCH FARM, NT

ABSTRACT

The effect of starter and supplementary nitrogen on the growth and yield of soybeans was evaluated in the 1983/84 wet season. Starter nitrogen was applied at 0, 15, or 30 kg ha^{-1} at sowing and supplementary nitrogen at 100 kg ha^{-1} just prior to flowering.

Although both starter and supplementary nitrogen increased pods per plant there was no consequent increase in grain yield due to a reduction in seed size.

The results are discussed in terms of seasonal conditions and it is suggested that yield increases are unlikely to occur with nitrogen fertilization except in seasons where high levels of soil moisture are available until physiological maturity.

Introduction

Soybeans are legumes and as such are capable of symbiotically fixing atmospheric nitrogen. Hence, the use of nitrogen fertilizer is generally not an adopted practice. Nevertheless, reports exist of responses to both starter and supplementary nitrogen (de Mooy et al. 1973).

Inconsistent responses to nitrogen fertilization of soybeans have been recorded in numerous experiments but positive responses have normally occurred in greenhouse studies or field studies when available moisture is high throughout the growing period (Mederski et al. 1958).

Recent studies have shown that nitrogen supply, even in a well nodulated crop, often limits grain yield because the symbiotic nitrogen fixing system breaks down during pod fill due to competition for carbohydrate from the developing seed (Lawn and Brun 1974). Sinclair and de Witt (1976) theorised that soybean yields were seriously limited by inadequate supplies of nitrogen during grain filling. This theory is supported by recent studies with soybeans grown in wet soil culture. With this technique yields have been increased through the maintenance of symbiotic nitrogen fixation well into pod filling (Troedson et al., unpub. data, Garside et al., unpub. data).

In tropical Australia, soybeans are a wet season crop, being sown in December - January and harvested in April. The growing period is relatively short (100-110 days), so reductions in growth rate at any stage are likely to have important implications for grain yield. Slow, insiped early growth is often observed in soybeans in tropical Australia and it is thought this is due to nitrogen deficiency caused by slow early nodulation and nitrogen fixation. Hatfield et al. 1974 showed that the application of small quantities (15-30 kg ha^{-1}) of starter nitrogen at sowing can improve early growth without inhibitory effects on the development of the symbiotic system.

In other studies numerous workers have reported that the greatest response to nitrogen fertilizer in soybeans has been with applications at flowering (Mederski et al. 1958, Enken 1959, Rios and dos Santos 1973). Brevedan et al. (1978) showed that yield increases of up to 30% could occur with the application of 168 kg N ha^{-1} at bloom, due mainly to increases in the number of seeds per plant.

This paper reports the results of a study on the effect of starter nitrogen applied at sowing and supplementary nitrogen applied at the commencement of flowering on the growth and yield of rainfed soybeans at Douglas Daly Research Farm in the Northern Territory during the 1983/84 wet season.

MATERIALS AND METHODS

Seasonal Conditions

Total rainfall for the 1983-84 season (Table 1, Section 1) was slightly above the long term mean at 1370 mm. However, distribution varied considerably from the long term mean. In particular, well above average rainfall occurred in March and no rain fell in April.

Soil type was Tippera clay loam. Soybeans were grown on the area the previous season and levels of available soil nitrogen were high (100 ppm) prior to sowing.

Experiment details

Design was a split plot with three rates of starter nitrogen as main plots - 0, 15 and 30 kg N ha^{-1} - applied just prior to sowing (Jan 2, 1984) and two rates of supplementary nitrogen as sub-plots - 0 and 100 kg N ha^{-1} applied just prior to the commencement of flowering (Jan 31). There were four replications.

Main plots consisted of 10 rows of soybeans, each 15 cm apart, by 30 m long. Sub-plots were the same width by 15 m long.

Inoculated seed of soybean cultivar Buchanan was sown at 500,000 seeds ha^{-1} with a small plot seeder on Jan. 2, 1984. Prior to sowing the area was fertilized with 312 kg ha^{-1} of single superphosphate (30 kg P ha^{-1}, 30 kg S ha^{-1}) and the pre-emergent herbicide treflan was applied at 2 l ha^{-1} and incorporated. Soil analysis showed that, potentially deficient nutrients potassium and zinc were adequate.

All nitrogen was applied as ammonium nitrate, starter nitrogen was drilled to a depth of 8 cm whereas supplementary nitrogen was applied to the soil surface using a small plot combine with the under carriage raised to avoid crop damage. Extended outlet tubes permitted nitrogen application to the soil surface without fertilizer contact with plant foliage.

Insect pests were controlled as required with Thiodan @ 2 l ha^{-1}.

Measurements and Data Collection

Dates of commencement and completion of flowering and physiological maturity were recorded.

Established plant populations were estimated by counting the plants in four areas, each 6 rows x 1 m in each plot.

Shoot dry matter accumulation was measured twice during the growing period. On each occasion two areas, each 6 rows x 1 m, were sampled from each plot. The samples were dried at 50°C for 96 hrs and dry weights were recorded. Sample dates were Jan. 31 (29 days after sowing and just prior to the application of supplementary nitrogen) and February 21 (three weeks after the application of supplementary nitrogen and just prior to the completion of flowering).

At physiological maturity, 10 plants were randomly selected from each plot to measure yield components. On each plant we measured height, node number, pod number, seed number, seed weight, stem weight and pod case weight. Seeds per pod, 100 seed weight and harvest index (seed weight/(seed weight + pod case weight + stem weight)) were calculated from these data.

Grain yield was measured by direct heading each plot with a KEW experimental header on April 17. Moisture content was determined with a Motomco moisture meter and yields were converted to a dry weight basis. Samples were set aside for protein and oil analysis.

RESULTS

Established plant population was of the order of 300,000 plants ha^{-1} and did not vary between treatments.

There was no effect of starter nitrogen on the commencement of flowering (Feb 3, 32 days after sowing) and no effect of starter or supplementary nitrogen on the completion of flowering (Feb 28, 57 days after sowing) or the time to physiological maturity (April 13, 102 days after sowing).

There was no effect of starter nitrogen on shoot dry matter production (Table 1A) at either sampling date however there was a significant increase in shoot dry matter with supplementary nitrogen (Table 1B).

Grain yield did not respond to either starter or supplementary nitrogen (Table 2) but there were significant effects on yield components. Most importantly both starter and supplementary nitrogen produced more pods per plant (Table 3) but reduced seed size (Table 4). Seeds per pod (1.9) and node number (23) were unaffected but plant height (Table 5) was increased with supplementary nitrogen. Harvest index was unaffected and of the order of 0.52. Similarly oil content (21.1%) and protein content (41.3%) were unaffected.

DISCUSSION

Although there was no grain yield response recorded in this experiment the results indicate that potential exists for improved grain yields with nitrogen fertilization of soybeans. The primary yield component, pods per plant and thereby seeds per plant, was increased substantially by both starter and supplementary nitrogen. That this was not transferred to grain yield is because smaller seed was produced with increased nitrogen nutrition. We do not believe this is an inherent effect of high rates of nitrogen but more an effect of moisture stress during seed filling. Physiological maturity occurred on April 13 while the last rain (10 mm) was recorded some two weeks earlier on March 31. Further, the last substantial rain (50 mm) was recorded on March 17, almost a month prior to physiological maturity. Conversely, good falls of rain were recorded during flowering and for some three weeks post flowering when pod and seed numbers were being determined. We believe that these conditions provided an environment capable of utilising applied nitrogen fertilizer and resulted in improved dry matter and pod numbers but that seed size could not be maintained with the imposition of water stress later in the growing period.

How much the results have been effected by the previous soybean crop and resultant high levels of available soil nitrogen at sowing is not known but it could be substantial. That starter nitrogen had no effect on early growth may well be due to the high levels of available soil nitrogen.

However, this may have all been utilised by the plants and/or leached from the profile by flowering resulting in the differential effect of starter nitrogen rates on pod numbers. The additive effect of supplementary nitrogen is consistent with this hypothesis. Further, it is well established that high levels of available soil nitrogen can inhibit nodulation (de Mooy et al 1973). Nodule attributes were not measured in this experiment but the possibility remains that nodulation and symbiotic nitrogen fixation was relatively ineffective during early growth resulting in nitrogen deficiency when soil supplies were exhausted. If this did occur the magnitude of the response to supplementary nitrogen in this study may be considerably greater than that from a well nodulated soybean crop.

CONCLUSIONS

The results of this experiment suggest that soybean yields will not be improved by either starter nitrogen or supplementary nitrogen at flowering in rainfed cropping areas of the Northern Territory. Possibly, starter and supplementary nitrogen may have beneficial effects in seasons when rainfall continues well into April and may produce increased yields under full irrigation. However, further work is required to test the effect of supplementary nitrogen in well nodulated symbiotically active soybean crops before definite conclusion can be drawn.

Although starter nitrogen did not improve early growth in this study, its effect requires evaluation on sites with relatively low levels of available soil nitrogen at sowing.

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TABLE 1A: Effect of starter nitrogen and shoot dry matter production 29 days after sowing.

	Starter N rate (kg ha^{-1})			
	0	15	30	Mean
Dry Matter (gm m^{-2})	37	35	39	37

Level of Signif. = NSD

CV = 13%

TABLE 1B: Effect of starter nitrogen and supplementary nitrogen on shoot dry matter (gm m^{-2}) 50 days after sowing and 21 days after application of supplementary nitrogen.

	Starter N rate (kg ha^{-1})			
	0	15	30	Mean
Supplementary N rate (kg ha^{-1})				
0	226	228	249	234
100	292	280	264	279
Mean	259	254	257	

Level of Significance - Starter = NSD
- Supp = **, LSD 5% = 24.4
Starter x Supp = NSD

CV = 8%

TABLE 2: Effect of starter nitrogen at 0, 15, and 30 kg N ha^{-1} and supplementary nitrogen at 0 and 100 kg N ha^{-1} applied at the commencement of flowering on the grain yield (kg ha^{-1}) of soybean Buchanan.

Supplementary N (kg ha^{-1})	Starter Nitrogen (kg ha^{-1}) 0	15	30	Mean
0	3396	3550	3575	3507
100	3482	3285	3439	3402
Mean	3439	3418	3507	3455

Level of significance = N.S.D.

C.V. = 13%

TABLE 3: Effect of starter and supplementary nitrogen on pods per plant at maturity

Supplementary N (kg ha^{-1})	Starter N (kg ha^{-1}) 0	15	30	Mean
0	87.3	101.8	107.4	98.9
100	99.5	110.6	122.6	110.9
Mean	93.4	106.2	115.0	104.9

Level of Signif: Start = *, LSD 5% = 11.96
Supp = *, LSD 5% = 9.79
Start x Supp = NSD

CV = 10.1%

TABLE 4: Effect of starter and supplementary nitrogen on seed size (100 seed weight) at maturity

Supplementary N (kg ha^{-1})	Starter N (kg ha^{-1}) 0	15	30	Mean
0	13.57	13.46	12.87	13.30
100	13.45	12.56	12.18	12.73
Mean	13.51	13.01	12.53	13.03

Level of significance: Starter = **, LSD 5% = 0.43
Supp = NSD (Signif. at 10%)
Start x Supp = NSD

CV = 13%

TABLE 5: Effect of starter and supplementary nitrogen on plant height at maturity

Supplementary N (kg ha^{-1})	Starter N (kg ha^{-1}) 0	15	30	Mean
0	101	96	96	98
100	103	100	101	101
Mean	102	98	99	99

Level of Signif: Starter = NSD
Supp = *, LSD = 3.53
Start x Supp = NSD

CV = 7%

5-3 RESPONSE OF SOYBEANS TO PHOSPHORUS AND SULPHUR ON VIRGIN TIPPERA CLAY LOAM IN THE 1981/82 SEASON

ABSTRACT

The effect of different rates of phosphorus and sulphur on the growth and yield of soybeans was studied in an experiment on virgin Tippera Clay loam in the 1981-82 wet season.

Soybean cv. Buchanan was sown with 0, 10, 20, 40 and 80 kg ha^{-1} phosphorus in all combinations with 0, 20 and 40 kg ha^{-1} sulphur. There were significant grain yield responses to phosphorus (p 0.01) and sulphur (p 0.05). The highest yield, 4,148 kg ha^{-1}, was obtained with the combination of 80 kg ha^{-1} phosphorus and 20 kg ha^{-1} sulphur.

Although non significant, there was a trend for yield to increase up to 40 kg ha^{-1} sulphur in the absence of phosphorus but not when phosphorus was applied.

Plots from this experiment have been permanently marked and additional rates will be superimposed in following seasons.

INTRODUCTION

The majority of soils in the Top-End of the Northern Territory are inherently low in phosphorus and sulphur (Jones et al 1983). However, very little research has been conducted into the response of crops to various rates of these elements.

Studies by Day (1977) showed there was no response to sulphur with grain sorghum on three different red earth soils (2 clay loams and 1 sandy loam) but a response to phosphorus which was closely related to seasonal conditions. Under good rainfall conditions optimum phosphorus rate was 45 kg ha^{-1} on the Tippera clay loam soil. In earlier studies Arndt and Phillips (1961) had shown responses up to 35 kg ha^{-1} phosphorus with peanuts, sorghum and cotton on newly cleared Tippera clay loam at Katherine and more recently Myers (1978) measured responses with up to 50 kg ha^{-1} on sorghum. Like Day (1977), Myers recorded a greater response in a wetter year.

Although no responses have been recorded to sulphur with field crops, responses with pasture legumes and *Pinus caribea* have been recorded on a number of soil types in the Top End (Jones et al 1983; B.J. Ross and A.G. Cameron, pers. comm.).

Soybeans are an important crop in the ADMA crop development scheme in the Douglas-Daly region and although research with this crop started more than 15 years ago very little work except cultivar evaluation has been conducted (Section 2). As part of the current soybean research program a long term experiment was established on virgin Tippera clay loam soil at D.D.R.F. in the 1981/82 wet season to evaluate the effect of various rates of phosphorus and sulphur on soybean yield.

There is a general lack of published information on the effect of phosphorus and sulphur on soybean yields. In recent years soybean yield responses up to 40 kg ha^{-1} phosphorus have been measured on the red friable earth soils of the South Burnett area, Queensland (Dickson et al 1983) and up to 60 kg ha^{-1} phosphorus on Cununurra clay in the Ord Irrigation Area (Garside and Fulton, in prep.). Dickson et al (1983) did not obtain a response to sulphur.

MATERIALS AND METHODS

Experimental design was a factorial with five rates of phosphorus - 0, 10, 20, 40 and 80 kg ha^{-1} and three rates of sulphur - 0, 20 and 40 kg ha^{-1}, replicated three times. Plot size was 6 m x 30 m, with three sets of 10 (15 cm) rows planted across the 6 m. A 0.5 m gap was left between each 10 row set.

Phosphorus rates of 0, 10, 20, 40 and 80 kg ha^{-1} were drilled as Super King fertilizer (19.2% P and 1.5%S) with a Connor Shea disc seeder, while sulphur rates of 0, 20 and 40 kg ha^{-1} were hand applied as gypsum (14.5% S, 18%Ca). Basal dressings of 50 kg ha^{-1} potassium as Muriate of Potash (50% K) and 10 kg ha^{-1} zinc as zinc oxide (81 % Zn) were applied to all plots.

Land was ploughed and cultivated several times to provide a weed free seedbed. Trifluralin (Treflan$^{(R)}$) was applied and incorporated at 2 l ha^{-1} (product) one week before sowing. The experiment was sown with inoculated seed of cultivar Buchanan at 500,000 plants ha^{-1} on 22 December 1981.

Broadleaf weed species (Hyptus sauveolens and Sida sp) were controlled with bentazone (Basagran$^{(R)}$) at 2 l ha^{-1} (product) at the third tri-foliate leaf stage and insects were controlled by three sprayings during the season, twice using endosulphan (Thiodan$^{(R)}$) at 2 l ha^{-1} (product) and once with methomyl (Lannate$^{(R)}$) at 1.5 l ha^{-1} (product).

Eighteen soil samples (0-10 cm) were taken across the area prior to sowing for the determination of initial available soil phosphorus and sulphur levels.

After emergence plant population was estimated by taking four quadrats, each 0.3 m^2, from the centre 10 row section of each plot.

Dry matter production was determined on day 63 (Feb. 23) by cutting 4 rows x 1 m, from the centre of the centre 10 row section of each plot. At this stage flowering was almost complete. Samples were oven dried, weighed, and later milled for tissue analyses (phosphorus and sulphur content).

At maturity, the centre 10 row area of each plot was direct headed with a K.E.W. experimental header and plot yields were recorded. Grain samples were taken from each plot for the analysis of seed size, N, P, S and oil content. Protein content was calculated by multiply grain N by 6.25.

SEASONAL CONDITIONS

Total season rainfall (October - March) is shown in Table 1, Section 1. Although the total was slightly below the long term mean, distribution was good with the only significant dry period being in late December - early January.

RESULTS AND DISCUSSION

There was no effect of treatment on plant population with the experiment mean being 330 x 10^3 ha^{-1}.

Neither phosphorus nor sulphur had any effect on crop phenology.

There were significant grain yield (Table 1) responses to both phosphorus (P 0.01) and sulphur (P 0.05). For phosphorus the response was linear while it was quadratic for sulphur with no yield increase above 20 kg ha^{-1} S. There was no significant interaction.

Although non significant, a trend existed for yield to increase up to 40 kg ha^{-1} S in the absence of phosphorus but only up to 20 kg ha^{-1} S, and then decrease, when phosphorus was applied. A similar dry matter yield depression has been recorded with high rates of sulphur (80 kg ha^{-1}) applied as sodium sulphate with the pasture legume verano stylo (B.J. Ross and A.G. Cameron, pers. comm.). No specific reason can be given for this response but it may be due to a depressing effect of calcium applied in the gypsum, making some applied phosphorus unavailable. However, if this was the case it would be expected that phosphorus concentration in the grain would be lower with increasing rates of sulphur. This did not occur. Alternatively, calcium may have made phosphorus temporarily unavailable, and this has reduced pod set, which occurred in February, in the higher sulphur treatments. A known major response to phosphorus deficiency in soybeans in reduced pod set (Garside and Fulton, in prep.). Phosphorus has then become available later in the season and has accumulated in the higher sulphur treatments which had a shortage of sinks. Regardless, more work is required on sources and rates of sulphur to clearly elucidate this effect.

There was a significant (P 0.01) dry matter response to phosphorus at day 63 but no response to sulphur (Table 2). The magnitude of the dry matter response between 0-80 kg ha^{-1} P was greater (41%) than that for the grain yield (22%) suggesting that the overall effect was becoming less with increasing crop duration or that vegetative growth was excessive and harvest index reduced with the higher phosphorus rates.

Some of the yield response to increasing phosphorus can be explained by increased seed size (Table 3) but seed size was not affected by sulphur. Other yield components e.g. pods per plant, seeds per pod were not measured here. However, studies in the Ord Irrigation Area showed a major response in pods per plant to varying phosphorus rates (Garside and Fulton, in prep.) and it is suspected a similar response may have occurred here. We have no data on which yield components were affected by sulphur.

Phosphorus and sulphur contents of the grain and dry matter varied in accordance with applied rates but even for zero rates of each, levels can be regarded as sufficient (Tables 4, 5, 6, 7). Further, there was no effect of the rates of one, on plant levels of the other.

Grain protein content (Table 8) was not affected overall by either phosphorus or sulphur but there was a small significant (P 0.05) interaction with an increase in response to applied phosphorus for 0 and 20 kg ha^{-1} S but a decrease with 40 kg ha^{-1} S. Oil content decreased slightly (P 0.05) in response to applied phosphorus.

Nutrient Removal and Loss

Estimates of N, P and S removal in the grain for each treatment are given in Tables 10, 11 and 12. Essentially, nitrogen removal was increased by increasing phosphorus rates but there was no effect of sulphur. Total amounts of nitrogen removed were high, ranging from 224 kg ha^{-1} for zero P up to 300 kg ha^{-1} for 80 P. A number of workers have estimated nitrogen fixation by soybeans at somewhere between 80 - 160 kg ha^{-1} N (Hardy et al 1968, 1971 b, Weber et al 1971) with this being 40 - 60% of the total nitrogen requirement. Hence it would appear that with the removal measured here there is unlikely to have been any net nitrogen input to the soil and probably a net nitrogen loss.

Initial soil available phosphorus and sulphur levels were of the order of 7 and 8 ppm, respectively. On the basis of 1 ha x 10cm of soil weighing 1,400,000 kg (using bulk density of 1.4- Day 1977) initial available soil phosphorus and sulphur levels could be estimated at 10 and 11 kg ha^{-1}, respectively. Our data suggest that plots receiving no fertilizer removed 13 and 9 kg ha^{-1} of phosphorus and sulphur, respectively (Tables 11, 12) while the highest yielding plots (80P x 20S) removed 30 and 16 kg ha^{-1} phosphorus and sulphur, respectively. Applications of 80 kg ha^{-1} P and 20 kg ha^{-1} S should give initial soil reserves of 90 kg ha^{-1} P and 31 kg ha^{-1} S. Hence, available soil reserves at the commencement of the second season (1982-83) for 80 P x 20 S plots should be 43 ppm P and 11 ppm S, respectively. Subsequent soil analysis at the commencement of the 1982-83 season indicate that available soil phosphorus and sulphur levels for 80 P and 20 S plots are 9 and 14, respectively. Although small amounts will be contained in the stubble, these figures suggest that considerable amounts of phosphorus are being fixed while sulphur is remaining available. Of course the possibility remains that this fixed phosphorus will be released at a later stage and not necessarily lost.

ECONOMIC ANALYSIS:-

The results from this experiment show that both phosphorus and sulphur fertilizers are needed to maximise the yield of soybeans on Tippera clay loam soils. The economics of applying these elements will be dependent or the relative costs of each element from various sources.

In this experiment triple superphosphate and gypsum were used as phosphorus and sulphur sources, respectively. Single superphosphate could be used to supply both elements at a cost of $155/t here (freight subsidy deducted). The cost of applying various rates of superphosphate and increased return in $/ha at $250/t for soybeans are shown in Table 13. From the data here the most economical rate of single supherphosphate would be 200 kg ha^{-1}.

However if we accept that only 20kg ha^{-1} sulphur is applied as elemental sulphur at $420/t i.e. $8.40/ha and apply phosphorus as triple superphosphate at $286/t (freight subsidy deducted) the relative costs and returns are shown in Table 14. On this basis the most economical rate of phosphorus is 40 kg ha^{-1}.

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TABLE 1: Grain yield (kg ha^{-1}) for soybeans grown with varying rates of Phosphorus and Sulphur

Phosphorus (kg ha^{-1})	Sulphur (kg ha^{-1}) 0	20	40	Mean
0	2818	3063	3348	3077
10	3298	3589	3370	3419
20	3467	3818	3604	3630
40	3644	4004	3752	3800
80	3797	4148	3963	3969
Mean	3405	3724	3607	

Level of Significance - P= 0.01, S= 0.05, PxS =NSD

L.S.D. 5% Phos. 278
Sulp. 215
Phos x Sulp. 480
C.V. 8.1%

TABLE 2: Dry Matter (gmm^{-2}) for soybean grown with varying rates of phosphorus and sulphur

Phosphorus (kg ha^{-1})	Sulphur (kg ha^{-1}) 0	20	40	Mean
0	275	296	410	327
10	262	421	374	352
20	319	420	388	376
40	546	427	492	488
80	624	448	585	552
Mean	405	402	450	

Level of Significance - P = 0.01, S = NSD, P x S = NSD

L.S.D. 5% Phos. 127
Sulp. 99
Phos x Sulp. 221
C.V. 31.6%

TABLE 3: Seed size (100 seed wt.) for soybean grown with varying rates of phosphorus and sulphur

Phosphorus (kg ha^{-1})	Sulphur (kg ha^{-1}) 0	20	40	Mean
0	11.4	11.4	11.7	11.5
10	12.2	11.9	11.7	11.9
20	11.9	12.3	12.2	12.1
40	12.3	12.3	12.4	12.3
80	13.0	12.9	13.5	13.1
Mean	12.2	12.2	12.3	

Level of significance - P= 0.01, S= NSD, PxS = NSD

L.S.D. 5% Phos. 0.37
Sulp. 0.29
Phos x Sulp. 0.64
C.V. = 3.1%

TABLE 4: Phosphorus percentage of grain in response to various phosphorus and sulphur rates

Phosphorus (kg ha^{-1})	Sulphur (kg ha^{-1}) 0	20	40	Mean
0	0.47	0.47	0.53	0.49
10	0.55	0.50	0.62	0.56
20	0.56	0.54	0.56	0.55
40	0.64	0.62	0.58	0.61
80	0.71	0.71	0.73	0.71
Mean	0.58	0.57	0.60	

Level of Significance - P= 0.01, S= NSD, PxS=NSD

L.S.D. 5% Phos. 0.05
Sulp. 0.04
Phos x Sulp. 0.08
C.V. = 8.5%

TABLE 5: Sulphur percentage of grain in response to various phosphorus and sulphur rates

Phosphorus (kg ha^{-1})	Sulphur (kg ha^{-1}) 0	20	40	Mean
0	0.33	0.38	0.40	0.37
10	0.32	0.35	0.41	0.36
20	0.29	0.39	0.37	0.35
40	0.32	0.40	0.36	0.36
80	0.36	0.37	0.38	0.37
Mean	0.32	0.38	0.38	

Level of Significance - P=NSD, S = 0.01, PxS = NSD.

L.S.D. 5% Phos. 0.03
Sulp. 0.02
Phos x Sulp. 0.05
C.V. 8.8%

TABLE 6: Percentage of phosphorus in dry matter sample for different rates of phosphorus and sulphur

Phosphorus (kg ha^{-1})	Sulphur (kg ha^{-1}) 0	20	40	Mean
0	0.23	0.19	0.22	0.21
10	0.20	0.19	0.21	0.20
20	0.24	0.23	0.24	0.24
40	0.21	0.26	0.22	0.23
80	0.26	0.25	0.24	0.25
Mean	0.23	0.22	0.23	

Level of Significance - P,S, PxS = NSD
N.S.D.

LSD 5% Phos. 0.05
Sulp. 0.03
Phos. x Sulp. 0.08
C.V. 20.6%

TABLE 7: Percentage of sulphur in dry matter sample for different rates of phosphorus and sulphur

	Sulphur (kg ha^{-1})			
Phosphorus (kg ha^{-1})	0	20	40	Mean
0	0.19	0.18	0.17	0.18
10	0.17	0.16	0.18	0.17
20	0.19	0.19	0.17	0.18
40	0.18	0.19	0.18	0.18
80	0.15	0.16	0.17	0.16
Mean	0.18	0.18	0.18	

Level of Significance - P,S, PxS = NSD.

LSD 5% Phos. 0.02
Sulp. 0.02
Phos x Sulp. 0.04
C.V. 14.2%

TABLE 8: Grain protein content (% dry wt) in response to varying rates of phosphorus and sulphur

	Sulphur (kg ha^{-1})			
Phosphorus (kg ha^{-1})	0	20	40	Mean
0	43.1	45.8	47.5	45.5
10	47.1	41.3	49.8	46.0
20	48.8	44.0	43.8	45.5
40	47.9	47.9	46.0	47.3
80	47.7	47.9	44.8	46.8
Mean	46.9	45.4	46.4	

Level of Significance - P= NSD, PxS = 0.05

L.S.D. 5% Phos. 3.2
Sulp. 2.5
Phos x Sulp. 5.5
C.V. 7.1%

TABLE 9: Grain oil (% dry wt) in response to varying rates of phosphorus and sulphur

Phosphorus (kg ha^{-1})	Sulphur (kg ha^{-1}) 0	20	40	Mean
0	21.7	22.0	22.1	21.9
10	21.7	21.6	21.9	21.7
20	21.9	22.1	21.7	21.9
40	21.6	21.6	21.7	21.6
80	21.1	21.0	20.9	21.0
Mean	21.6	21.6	21.7	

Level of Significance - P= 0.01, S=NSD, PxS= NSD

L.S.D. 5% Phos. 0.5
Sulp. 0.4
Phos x Sulp. 0.8
C.V. 2.3%

TABLE 10: Nitrogen (kg ha^{-1}) removed in grain for different rates of phosphorus and sulphur

Phosphorus (kg ha^{-1})	Sulphur (kg ha^{-1}) 0	20	40	Mean
0	193	225	255	224
10	261	237	268	255
20	272	268	253	264
40	280	306	276	287
80	301	317	284	301
Mean	261	270	267	

Level of Significance - P= 0.05, S= NSD, PxS = NSD

L.S.D. 5% Phos. 27
Sulp. 20
Phos x Sulp. 46
C.V. 10.3%

TABLE 11: Phosphorus (kg ha^{-1}) removed in grain for different rates of phosphorus and sulphur

Phosphorus (kg ha^{-1})	Sulphur (kg ha^{-1}) 0	20	40	Mean
0	13	15	18	15
10	19	18	21	19
20	20	21	20	20
40	23	25	22	23
80	28	29	29	29
Mean	21	21	22	

Level of Significance - P= 0.01, S= NSD, PxS=NSD

L.S.D. 5% Phos. 3
Sulp. 2
Phos x Sulp. 5
C.V. 13.5%

TABLE 12: Sulphur (kg ha^{-1}) removed in grain for different rates of phosphorus and sulphur

Phosphorus (kg ha^{-1})	Sulphur (kg ha^{-1}) 0	20	40	Mean
0	9	12	14	12
10	11	13	14	12
20	10	15	13	13
40	12	16	14	14
80	15	16	15	15
Mean	11	14	14	

Level of Significance - P= 0.01, S= 0.01, PxS= NSD

L.S.D. 5% Phos. 1.5
Sulp. 1.0
Phos x Sulp. 2.6
C.V. 12%

TABLE 13:- Cost and returns of applying various rates of Phosphorus and Sulphur as single Superphosphate

P rate (kg ha^{-1})	S rate (kg ha^{-1})	Superphosphate (kg ha^{-1})	Super cost @$155/t	Yield	Return @$250/t soybeans of Super	Net Return ie return less cost
0	0	0	0	2818	705	705
10	10	100	16	3444	861	861
20	20	200	31	3818	955	955
40	40	400	62	3752	938	938
80	*80	800	124	3963	991	991

*Yield assumed similar to 80 P and 40 S

TABLE 14: Cost and returns for applying 20kg ha^{-1} as Elemental Sulphur and Phosphorus at various rates as triple Superphosphate

P rate (kg ha^{-1})	S rate (kg ha^{-1})	TSP rate @19.1%P	Cost of* P + S	Yield (kg ha^{-1})	Return @ $250/t	Return less Fert. cost
0	20	0	8.40	3063	766	758
10	20	52	14.80+8.40	3589	897	873
20	20	104	29.60+8.40	3818	955	917
40	20	208	59.20+8.40	4004	1001	933
80	20	416	118.40+8.40	4148	1037	910

*Elemental Sulphur @ $420/t
Triple Superphosphate @ $286/t (freight subsidy deducted)

5-4 RESPONSE OF SOYBEANS AND MAIZE TO PHOSPHORUS AND SULPHUR IN 1982/83

ABSTRACT

Very adverse seasonal conditions reduced the amount of useful information that could be collected. Only one replication of soybean was harvested for grain yield. Trends suggested that there were responses to both phosphorus and sulphur. No grain was harvested from maize.

Introduction

An experiment was commenced on virgin Tippera Clay Loam at Douglas - Daly Research Farm in the 1981/82 season to study the effect of phosphorus and sulphur on the growth and yield of soybean. Results showed that maximum yields would be obtained with 80 kg ha^{-1} phosphorus and 20 kg ha^{-1} sulphur while the most economic combination was 40 Pand 20 S. There was a trend for yield to be depressed when 40 kg ha^{-1} sulphur was applied with all phosphorus rates apart from zero.

In the 1982-83 season all plots from the previous season were split to 0, 20 or 40 kg ha^{-1} phosphorus as triple Superphosphate and to either maize or soybeans.

Materials and Methods:-

Design was a split plot with Soybean and Maize as main plots, the 1981/82 treatment i.e. all combinations of 0, 10, 20, 40 and 80 kg^{-1} P and 0, 20, 40 kg^{-1} P as sub-sub plots, and 1982/83 rates as sub-sub plots. There were three replications.

Prior to sowing all plots were soil sampled (0-10cm) to determine levels of available phosphorus and sulphur.

Land was ploughed and cultivated several times to provide a weed free seedbed after which trifluralin (treflan [R]) was applied at 2lha^{-1} (product) and incorporated.

Inoculated seed of soybean cultivar Buchanan and Apron treated seed of maize cultivar Hycorn 9 was sown on December 22, in 15 and 45cm rows, respectively. Nitrogen as Urea was applied at 100 kg ha^{-1} to the maize at sowing.

Maize establishment was good and the stand was thinned to 50,000 plants ha^{-1} on January 4 - 5. Soybean establishment was fair but extremely variable between plots so it was decided to replant. Hence, all soybean plots were sprayed with Reglone at 4l ha^{-1} on January 5 and were replanted on January 6. The stand from this second sowing was very good.

Effect of Seasonal Conditions

This experiment was essentially a failure due to very adverse seasonal conditions (Table 1, Section 1). Grain yields were only obtained from one replication of soybeans. Samples were taken for plant nutrient status by sampling 10 flag leaves per plot at tasseling in the maize and 10 topmost fully expanded leaves at flowering in the soybeans.

Soybeans - Although establishment was good with the second sowing prolonged dry weather (3 weeks without rain) in January resulted in severe plant mortality from charcoal rot (*Macrophomina phaseoli*). Mortality was so severe that only one replication had enough plants to warrant harvesting.

Maize - Maize also suffered severely from the dry conditions at silking and tasselling and virtually no grain was produced. The most noticeable feature with maize was the lack of synchrony between tasseling and silking. Tasseling commenced on February 8 yet very few silks were observed until March 2. Consequently there was a total lack of pollination and no grain was formed.

Results and Discussion:-

(1) Soybean Grain Yield:-

Soybean grain yield is shown in Table 1. Given the lack of replication very little can be gleaned from the results. However, there appears to have been a response to both residual and applied phosphorus and a residual response to sulphur.

(2) Soybean Grain Oil, Protein & Phosphorus Levels:-

Data for oil, protein, and phosphorus content of the grain is shown in Table 2, 3 and 4. No obvious effects can be seen.

(3) Plant levels of N, P & S in Soybean & Maize:-

Nitrogen, phosphorus and Sulphur levels in the topmost fully expanded leaf of soybean at flowering are shown in Tables 5, 6 and 7, respectively and in the flag leaf of maize at tasselling in Tables 8, 9 and 10, respectively.

There was no effect of any treatment on soybean leaf nitrogen and sulphur levels but phosphorus levels responded to both residual and applied phosphorus. For maize, nitrogen levels decreased with increasing applied P up to 20 kg ha^{-1}, phosphorus levels increased in response to both residual and applied P, and sulphur increased with increasing sulphur but decreased with increasing applied P.

Conclusions:-

The vagueries of the season make it impossible to draw any valid conclusions. It is intended to sow the entire area to soybeans in the 1983/84 season without additional fertilizer application.

Table 1: Grain Yields for Soybeans receiving various rates of phosphorus and sulphur. (one replication only)

P rate 1981-82 Season	S rate 1981-82 Season	P rate 1982-83 season 0	20	40
0	0	1194	1652	2089
	20	1322	1535	2399
	40	1407	2228	2025
10	0	725	1151	2292
	20	1386	1770	2345
	40	1226	1780	1674
20	0	1354	981	2239
	20	1333	1450	1972
	40	1748	2345	2420
40	0	1055	2089	1802
	20	2420	3070	2665
	40	1801	2665	1919
80	0	2836	2665	2633
	20	1439	2089	1844
	40	2633	1844	2590

<u>Means</u>						
	1981-82 Phos. Rates	<u>0</u> 1761	<u>10</u> 1594	<u>20</u> 1760	<u>40</u> 2111	<u>80</u> 2348
	1981-82 Sulph. Rates	<u>0</u> 1784	<u>20</u> 1936	<u>40</u> 2025		
	1982-83 Phos. Rates	1562	1988	2194		

Table 2: Soybean Grain Oil Content (% dry wt)
(one replication only)

P Rate 1981-82	S Rate 1981-82	P rate 1982-83: 0	20	40
0	0	22.1	22.1	22.0
	20	22.2	22.2	21.7
	40	22.2	21.8	22.3
10	0	22.0	21.7	21.9
	20	22.5	22.1	22.3
	40	22.0	21.7	21.7
20	0	21.8	21.5	21.8
	20	21.9	22.1	22.3
	40	21.9	21.9	21.8
40	0	22.5	22.3	22.1
	20	22.0	21.0	22.1
	40	22.2	21.9	21.7
80	0	22.0	21.7	21.8
	20	21.8	22.0	22.1
	40	21.9	21.7	21.8

Means

1981-82	0	10	20	40	80
P Rates	22.1	22.0	21.9	22.0	21.9
1981-82	0	20	40		
S Rates	21.9	22.0	21.9		
1982-83	0	20	40		
P Rates	22.1	21.8	22.0		

Table 3: Soybean Grain Protein Content (% dry wt - one replication only)

P Rate 1981/82	S Rate 1981/82	P Rate (1982/83) 0	20	40
0	0	39.5	39.7	39.8
	20	39.5	39.9	40.1
	40	39.9	40.0	39.2
10	0	39.8	40.1	40.1
	20	39.1	39.9	39.8
	40	39.7	40.2	40.8
20	0	40.7	40.9	40.5
	20	39.9	40.0	39.4
	40	40.1	40.1	40.3
40	0	39.4	39.3	39.6
	20	40.0	39.9	39.7
	40	39.8	39.9	40.1
80	0	40.3	40.4	40.0
	20	40.5	39.9	39.3
	40	39.9	40.1	40.4

Means						
	1981/82 P Rates	0: 39.7	10: 39.9	20: 40.2	40: 39.7	80: 40.1
	1981/82 S. Rates	0: 40.0	20: 39.8	40: 40.0		
	1982/83 P Rates	0: 39.9	20: 40.0	40: 39.9		

Table 4: Soybean Grain Phosphorus Content (% dry wt - one replication only)

P Rate 1981/82	S Rate 1981/82	P Rate (1982/83) 0	20	40
0	0	0.48	0.53	0.52
	20	0.48	0.46	0.56
	40	0.58	0.59	0.62
10	0	0.47	0.57	0.62
	20	0.44	0.50	0.58
	40	0.50	0.51	0.48
20	0	0.49	0.48	0.53
	20	0.57	0.51	0.54
	40	0.51	0.53	0.54
40	0	0.53	0.51	0.53
	20	0.52	0.58	0.55
80	40	0.49	0.52	0.54
	0	0.64	0.61	0.59
	20	0.53	0.53	0.58
	40	0.55	0.61	0.61

Means						
	1981/82 P Rates	0	10	20	40	80
		0.54	0.52	0.52	0.53	0.58
	1981/82 S. Rates	0	20	40		
		0.54	0.53	0.55		
	1982/83 P Rates	0	20	40		
		0.52	0.54	0.56		

Table 5: Soybean Leaf Nitrogen Content (% dry wt.)

P Rate 1981/82	S Rate 1981/82	P rate (1982/83) 0	20	40
0	0	4.3	4.4	4.4
	20	4.4	4.3	4.4
	40	4.3	4.0	4.3
10	0	4.5	4.4	4.4
	20	4.3	4.3	4.4
	40	4.1	4.4	4.3
20	0	4.1	4.3	4.2
	20	4.2	4.3	4.3
	40	4.5	4.5	4.6
40	0	4.3	4.2	4.2
	20	4.4	4.2	4.4
	40	4.4	4.4	4.2
80	0	4.4	4.2	4.2
	20	4.4	4.2	4.3
	40	4.0	4.5	4.4

Means						
	1981/82 P Rates	0: 4.3	10: 4.3	20: 4.3	40: 4.3	80: 4.3
	1981/82 S. Rates	0: 4.3	20: 4.3	40: 4.3		
	1982/83 P. Rates	0: 4.3	20: 4.3	40: 4.3		

No significant effects.

Table 6: Soybean Leaf Phosphorus Content (% dry wt.)

P Rate 1981/82	S Rate 1981/82	P Rate (1982/83) 0	20	40
0	0	0.23	0.32	0.35
	20	0.23	0.29	0.31
	40	0.28	0.32	0.30
10	0	0.26	0.34	0.33
	20	0.23	0.28	0.33
	40	0.24	0.32	0.33
20	0	0.29	0.31	0.32
	20	0.26	0.32	0.32
	40	0.28	0.32	0.32
40	0	0.25	0.30	0.31
	20	0.31	0.33	0.37
	40	0.27	0.31	0.32
80	0	0.36	0.36	0.37
	20	0.33	0.34	0.36
	40	0.30	0.35	0.37

Means						
	1981/82 P Rates	0	10	20	40	80
		0.29	0.30	0.30	0.31	0.35
	1981/82 S. Rates	0	20	40		
		0.31	0.31	0.31		
	1982/83 P Rates	0	20	40		
		0.28	0.32	0.33		

Significant effects - P rates 81/82 = p 0.01
P rates 82/83 = p 0.01

LSD 5% P rates 81/82 = 0.03
P rates 82/83 = 0.01

Table 7: Soybean Leaf Sulphur Content (% dry wt.)

P Rate 1981/82	S Rate 1981/82	P Rate (1982/83) 0	20	40
0	0	0.20	0.22	0.23
	20	0.22	0.23	0.23
	40	0.20	0.23	0.22
10	0	0.22	0.21	0.22
	20	0.20	0.22	0.22
	40	0.21	0.22	0.21
20	0	0.21	0.22	0.21
	20	0.21	0.23	0.21
	40	0.23	0.23	0.23
40	0	0.20	0.20	0.21
	20	0.19	0.21	0.21
	40	0.21	0.21	0.22
80	0	0.22	0.20	0.23
	20	0.23	0.23	0.23
	40	0.22	0.23	0.23

Means						
	1981/82 P Rates	0: 0.22	10: 0.21	20: 0.22	40: 0.21	80: 0.22
	1981/82 S. Rates	0: 0.21	20: 0.22	40: 0.22		
	1982/83 P Rates	0: 0.21	20: 0.22	40: 0.22		

No significant effects

Table 8: Maize Leaf Nitrogen Content (% dry wt.)

		P Rate (1982/83)		
P Rate 1981/82	S Rate 1981/82	0	20	40
0	0	2.5	2.5	2.6
	20	2.8	2.6	2.6
	40	2.7	2.8	2.6
10	0	2.8	2.7	2.8
	20	2.5	2.5	2.7
	40	2.8	2.5	2.6
20	0	2.6	2.5	2.5
	20	2.7	2.4	2.8
	40	2.7	2.5	2.5
40	0	2.5	2.6	2.6
	20	2.6	2.6	2.6
	40	2.5	2.6	2.5
80	0	2.7	2.8	2.5
	20	2.8	2.7	2.7
	40	2.9	2.7	2.7

Means						
	1981/82 P Rates	0 2.63	10 2.65	20 2.58	40 2.58	80 2.72
	1981/82 S. Rates	0 2.61	20 2.64	40 2.64		
	1982/83 P Rates	0 2.67	20 2.60	40 2.62		

Significant Effects - P rates 1982/83 = p 0.05

LSD 5% - P rates 1982/83 = 0.06

Table 9: Maize Leaf Phosphorus Content (% dry wt.)

P Rate 1981/82	S Rate 1981/82	P Rate (1982/83) 0	20	40
0	0	0.21	0.24	0.26
	20	0.22	0.23	0.24
	40	0.24	0.26	0.24
10	0	0.22	0.25	0.25
	20	0.21	0.24	0.24
	40	0.26	0.25	0.28
20	0	0.22	0.24	0.24
	20	0.24	0.24	0.26
	40	0.23	0.24	0.23
40	0	0.24	0.26	0.26
	20	0.16	0.28	0.28
	40	0.22	0.26	0.26
80	0	0.27	0.28	0.29
	20	0.28	0.26	0.25
	40	0.29	0.27	0.28

Means						
	1981/82 P Rates	0: 0.24	10: 0.25	20: 0.24	40: 0.26	80: 0.27
	1981/82 S. Rates	0: 0.25	20: 0.25	40: 0.25		
	1982/83 P Rates	0: 0.24	20: 0.25	40: 0.26		

Significant Effects - P rates 1981/82 = p 0.01
P rates 1982/83 = p 0.01

LSD 5% P rates 1981/82 = 0.02
P rates 1982/83 = 0.01

Table 10: Maize Leaf Sulphur Content (% dry wt.)

P Rate 1981/82	S Rate 1981/82	P Rate (1982/83) 0	20	40
0	0	0.15	0.15	0.16
	20	0.15	0.15	0.15
	40	0.15	0.15	0.16
10	0	0.17	0.14	0.16
	20	0.16	0.16	0.16
	40	0.18	0.16	0.15
20	0	0.16	0.15	0.14
	20	0.16	0.16	0.16
	40	0.16	0.16	0.16
40	0	0.15	0.15	0.15
	20	0.15	0.15	0.16
	40	0.17	0.16	0.15
80	0	0.15	0.15	0.16
	20	0.17	0.16	0.15
	40	0.16	0.16	0.16

Means						
	1981/82 P Rates	0 0.15	10 0.16	20 0.15	40 0.15	80 0.16
	1981/82 S. Rates	0 0.15	20 0.16	40 0.16		
	1982/83 P Rates	0 0.16	20 0.15	40 0.15		

Significant Effects - Sulphur rates 1981/82 = p 0.01
P rates (1982/83) = p 0.01

LSD 5% Sulphur rates = 0.005
P rates (1982/83) = 0.004

5-5 RESPONSE OF SOYBEANS TO PHOSPHORUS AND SULPHUR IN THE 1983/84 WET SEASON

ABSTRACT

Studies on the effect of phosphorus and sulphur on the yield of soybeans on Tippera clay loam were continued in the 1983/84 wet season when plots established in 1981/82 and 1982/83 were sown to soybeans without additional phosphorus and sulphur fertilization.

Yield increased with increasing rates of phosphorus applied in 1981/82 and 1982/83. There was no yield increase from phosphorus applied in 1982/83 when 80 kg P ha^{-1} was applied in 1981/82.

A relationship was developed between grain yield and available soil phosphorus:

$$\text{Grain Yield} = 1183 + 299.5\,P - 10.5\,P^2 \quad (R^2 = 0.54,\ P\ \ 0.01)$$

The results show that high rates of fertilizer phosphorus applied in the initial season are likely to remain available in the surface soil in subsequent seasons and it is argued that the application of fertilizer phosphorus may not be necessary if available soil phosphorus exceed 14 ppm.

There was no response to sulphur in this season. However, it is argued that this was not due to adequate supplies of sulphur but to an overall deficiency of sulphur throughout the whole experiment due to its movement to depth in the profile. We conclude that sulphur application will be required every season.

Introduction

An experiment to assess the response of soybean to phosphorus and sulphur on Tippera clay loam was commenced in the 1981/82 wet season and continued in 1982/83. It was further continued in 1983/84.

Results for 1981/82 and 1982/83 are discussed in the previous two reports (Sections 5-3, 5-4). Briefly, in the initial experiment (1981/82) all combinations of 0, 10, 20, 40 and 80 kg ha^{-1} P and 0, 20, and 40 kg ha^{-1} S were evaluated on virgin Tippera clay loam. Results showed that yield increased with increasing phosphorus rate up to 80 kg ha^{-1} and with increasing sulphur up to 20 kg ha^{-1}.

Plots from the first season were permanently marked. In the second season (1982/83) each replication was split to maize or soybeans and each plot was split to 0, 20 or 40 kg ha^{-1} P. No additional sulphur was added. Very adverse seasonal conditions resulted in extremely poor soybean establishment; and severe drought stress in maize at silking and tasseling. Only one replication of soybeans was harvested. Yield trends for soybeans suggested responses to both applied (1982/83 rates) and residual phosphorus (1981/82 rates) and residual sulphur.

In the current experiment, no additional phosphorus or sulphur was applied and all plots were sown to soybeans.

MATERIALS AND METHODS

Design, treatments and plot size are detailed in the previous two reports. Briefly, design was a split-split plot with 1982/83 crop (soybean, maize) as main plots, 1981/82 phosphorus and sulphur rates as sub plots (5 P rates x 3 S rates) and 1982/83 phosphorus rates (3 P rates) as sub-sub plots. There were three replications. Hence treatment combination were:-

Main Plots (1982/83 Crop)	Sub-Plots (1981/82 rates)	Sub-Sub Plots (1982/83 rates)	Reps
Soybean	0P x 0S	0P	3
	20S		
	40S		
	10P x 0S		
	20S		
	40S		
	20P x 0S	20P	
	20S		
Maize	40S		
	40P x 0S		
	20S		
	40S		
	80P x 0S	40P	
	20S		
	40S		

Overall then there were 90 treatments by three replications or 270 plots.

In addition, border areas on each side of the experiment, which had not previously received any fertilizer phosphorus, were sown to soybeans with 40 kg ha^{-1} P applied as triple superphosphate. No sulphur was applied.

Inoculated seed of soybean cultivar Buchanan was sown on January 2, 1984. Plot size was the same as for 1982/83. Establishment was good with a resultant plant population of 430 x 10^3 ha^{-1}. Prior to sowing the area was treated with treflan herbicide at 2 l ha^{-1}. The herbicide was immediately incorporated after application.

All plots were soil sampled to a depth of 10 cm prior to sowing. These samples were used to determine available phosphorus (bi-carbonate extractable) and sulphur levels. In addition, we sampled plots that received 80 P and 40S in season 1 and 40 P in season 2 (a total of six plots in all) at 10 cm increments from 0 - 100 cm. These samples were analysed for available phosphorus and sulphur to determine the distribution of each in the soil profile.

At maturity all plots were harvested with a KEW experimental header to determine grain yield. Sub-samples were dried at 50°C for 96 hr and these data were used to convert yield to a dry weight basis. Further samples were taken to determine oil, protein, phosphorus and sulphur content of the grain.

Seasonal Conditions

Seasonal rainfall (Oct - April) is shown in Table 1, Section 1. Essentially rainfall was slightly above average with very good falls for January, February and March. This was the best season since the commencement of the ADMA development.

RESULTS

a) Grain Yield

Significant effects are shown in Table 1. There were significant effects of initial phosphorus (1981/82 rates) (P 0.01), supplementary phosphorus (1982/83 rates) (P 0.01) and initial by supplementary phosphorus (P 0.01). There was no effect of sulphur and no effect of the previous crop (maize or soybeans).

Essentially, yield increased with increasing initial phosphorus rate (1981/82 rates) up to 80 kg ha^{-1} P but only up to 20 kg ha^{-1} P for supplementary phosphorus (1982/83 rates). The interaction reflected yield increases with supplementary phosphorus for all initial phosphorus rates except 80 kg ha^{-1} P i.e. where 80 kg ha^{-1} P was applied in season 1 there was no response in season 3 to additional phosphorus applied in season 2. Further, where 10, 20 or 40 kg ha^{-1} P were applied in season 1 yield increases were recorded in season 3 for 20 kg ha^{-1} P applied in season 2.

It was only where nothing had been applied in season 1 that 40 kg ha^{-1} P applied in season 2 produced a yield increase in season 3.

As no phosphorus fertilizer was applied to the experiment this season it is not possible to assess the effect of additional fertilizer phosphorus. However, a guide can be obtained from the border plots fertilized with 40 kg ha^{-1} P this season. These yielded 3,545 kg ha^{-1} which was less than 200 kg ha^{-1} more than the combination of 80 kg ha^{-1} P in the initial year and 0 kg ha^{-1} P in season 2 and season 3.

b) Relationship between Yield and Available Soil Phosphorus

Regression analysis were conducted to relate available soil phosphorus and grain yield. The regression equation was a highly significant quadratic function best represented by the equation:-

$$Yield = 1183 + 299.5 P - 10.5 P^2 \quad (R^2 = 0.54, P \ 0.01)$$

The plot of this data is shown in Fig. 1 and shows that yield will not be increased with available soil phosphorus levels above 14 ppm. Data used to develop this relationship is shown in appendix 1.

c) Distribution of Phosphorus and Sulphur in the Profile

This data is shown in Fig. 2. Essentially applied phosphorus remained in the 0 - 10 cm zone and there was no change in levels below 20 cm. However, the majority of available sulphur was between 50-80 cm from the surface.

d) Grain Chemical Composition

Significant treatments effects on oil, protein, phosphorus, and sulphur content of the grain are shown in tables 2, 3, 4 and 5, respectively.

Grain oil content (Table 2) was only affected by the previous crop being slightly higher where maize was previously grown. The reverse was true for grain protein content (Table 3a) and presumably reflects higher levels of available nitrogen where soybeans were grown in 1982/83. An inverse relationship between oil and protein content has been reported in numerous studies.

For protein content there were also effects of supplementary phosphorus (Table 3b), initial by supplementary phosphorus (Table 3c) and crop x sulphur (Table 3d). Protein content increased with increasing rates of supplementary phosphorus when initial phosphorus rates were 0 or 10 kg ha^{-1}.

Grain phosphorus content increased with increasing rates of initial (Table 4a) and supplementary phosphorus (Table 4b). There was also a crop by sulphur effect (Table 4c). Essentially grain phosphorus increased with increasing rates of sulphur where maize was grown in 1982/83 but decreased with increasing rate of sulphur where soybeans were grown in 1982/83.

Grain sulphur content increased with increasing rates of sulphur (Table 5a).

DISCUSSION

The results from this study clearly show the importance of adequate levels of available phosphorus in producing maximum soybean yields. However, they also suggest that very little phosphorus is lost through fixation and/or leaching. This is reflected in the relatively high yields obtained in 1983/84 from 80 kg ha^{-1} P applied in 1981/82 with no further application in subsequent seasons. This effect may not have been as large had a crop been harvested in 1982/83. However growth of volunteer species was profuse in failed plots in 1982/83. These were all mown and removed at the end of the season and would have accounted for some phosphorus removal from the profile. This is supported by the fact that we could not detect a difference in available phosphorus at the commencement of this season between plots harvested for grain and harvested for volunteer species in 1982/83.

Although there was no response to sulphur in this season, it does not necessarily mean that sulphur was not required. We believe its distribution in the profile (Fig 2) has made it largely unavailable to the plants for a majority of the growing period and that, in fact, all plots may have been deficient in sulphur. Extraction of nutrients from depth is dependent on root exploration. In an season such as this, where rainfall is high and well distributed, deep exploration of roots is less likely to occur. Soil samples taken prior to sowing for the 0-10 cm increment in all plots showed an available sulphur level of 5 ppm (similar to that measured on virgin soil) with no difference between sulphur treatments. That there was a slight difference in grain sulphur content between different sulphur treatments suggests that sulphur was being exploited late in the growing season. However by this stage the main component of grain yield, pods per plant, would have been determined.

Some circumstantial evidence supporting sulphur deficiency this season can be gained from comparing yields in the first season of this experiment (1981/82) and the current season. Although rainfall was lower in the initial season we do not believe this has had a major detrimental effect on yield. In 1981/82 the 40 P x 0 S treatment yielded 3644 kg ha^{-1} (Table 1, Section 5-3) while the border plots in this experiment which received the same treatment (40 P x 0 S) yielded 3545 kg ha^{-1}. The addition of 20 kg ha^{-1} S in 1981/82 (40 P x 20 S tratement) increased yield to 4,004 kg ha^{-1}.

We have developed a relationship which suggests that soybean yields are unlikely to be increased with available soil phosphorus levels in excess of 14 ppm. However, we do not know the effect of a small amount of phosphorus fertilizer added to the crop when available soil levels are of this order. Available soil phosphorus levels were of the order of 5 ppm for the border plots in this experiment prior to sowing. On the basis of bulk density of tippera clay loam being 1.4 (Day 1977), 1 ha of soil x 10 cm will weigh, 1,400,000 kg. By applying 40 kg ha^{-1} P, available soil phosphorus level in the top 10 cm will be approx. 33 ppm (28 ppm added to the soil plus 5 ppm available at sowing) assuming no long term fixation. Yield for this treatment was 3,545 kg ha^{-1} and this suggests that these higher levels of available phosphorus are only having a small effect on grain yield. However, this suspected minor effect of phosphorus fertilizer added to soils with relatively high levels of available soil phosphorus requires validation.

Field Implications

These results suggest that large quantities of phosphorus fertilizer applied in one season will not be lost and will provide adequate phosphorus for a number of seasons. We see this as an important logistical advantage for farmers in that it would not be necessary to carry out phosphorus application in all seasons. Further, the results also suggest that phosphorus application can be carried out well before sowing (late dry season) without the concern that considerable quantities will be lost. This should greatly improve the efficiency of the planting operation.

However, we believe this is unlikely to apply with sulphur. Our results suggest that sulphur application will be required each season, preferably at or immediately before planting. As suggested previously (1981/82 report) the selection of a sulphur source warrants investigation. We used gypsum in these studies and showed that 40 kg ha^{-1} S as gypsum gave a slight reduction in yield when phosphorus was applied (1981/82 report). We do not believe this was due to sulphur toxicity but was possibly due to some short term phosphorus fixation from calcium applied in the gypsum. Both elemental sulphur and ammonium sulphate (particularly for maize and sorghum) warrant evaluation.

TABLE 1: Soybean yield (kg ha^{-1}) in 1983/84 as affected by (a) initial phosphorus rate (1981/82), (b) supplementary phosphorus rate (1982/83) and (c) the interaction between initial and supplementary phosphorus rate.

(a) Initial Phosphorus rate effects

P rate (kg ha^{-1})	0	10	20	40	80
Yield (kg ha^{-1})	2753	2755	2916	3079	3305

Level of signif = **, LSD 5% = 240

b) Supplementary Phosphorus rate effects

0	20	40
2799	3013	3072

Level of signif = **, LSD 5% = 84

c) Initial x supplementary phosphorus rate effects

Supp. P rate (kg ha^{-1})	Initial P rate (kg ha^{-1}) 0	10	20	40	80
0	2561	2815	2780	2852	3367
20	2616	2972	2988	3146	3214
40	3083	2977	2979	3240	3334

Level of signif = **, LSD 5% = 285 (whole table)
= 187 (supp. P with same rate of initial P)

TABLE 2: Effects on oil content (% dry weight)

a) Crop Effect

1982/83 Crop	Maize	Soybean
Oil Content	21.8	21.6

Level of significance = *, LSD 5% = 0.19

TABLE 3: Effects on Protein Content (% dry weight)

a) Crop Effect

1982/83 Crop	Maize	Soybean
Protein content	39.1	40.0

Level of significance: *, LSD 5% = 0.9

b) Supplementary Phosphorus Effect

1982/83 Phosphorus rate ($kg\ ha^{-1}$)	0	20	40
Protein Content	39.4	39.6	39.7

Level of significance: **, LSD 5% = 0.19

c) Initial x Supplementary Phosphorus Effect

1981/82 Phosphorus rate ($kg\ ha^{-1}$)	1982/83 Phosphorus rate ($kg\ ha^{-1}$) 0	20	40
0	39.3	39.5	39.6
10	39.1	39.8	39.6
20	39.6	39.4	39.5
40	39.6	39.7	39.9
80	39.8	39.6	39.8

Level of signif: **, LSD 5% = 0.54 (whole table)
= 0.42 (Supp. P with same level of initial P)

d) Crop x Sulphur Effect

1982/83 Crop	1981/82 Sulphur rate (kg ha^{-1}) 0	20	40
Maize	38.8	39.2	29.2
Soybean	39.9	40.3	40.0

Level of Signif: *, LSD 5% = 0.6 (whole table)
= 0.5 (sulphur rate for same crop)

TABLE 4: Effects on Grain phosphorus Content (% dry wt)

a) Initial Phosphorus Effect (1981/82 rates)

1981/82 Phosphorus rate (kg ha^{-1})	0	10	20	40	80
Grain phosphorus (% dry wt)	0.46	0.47	0.48	0.51	0.56

Level of Signif: **, LSD 5% = 0.03

b) Supplementary Phosphorus Effect (1982/83 rates)

1982/83 Phosphorus rate (kg ha^{-1})	0	20	40
Grain Phosphorus (% dry wt)	0.48	0.49	0.52

Level of Signif: **, LSD 5% = 0.01

c) Crop by Sulphur Effect:

1982/83 Crop	Sulphur rate (1981/82) 0	20	40
Maize	0.48	0.46	0.50
Soybean	0.53	0.52	0.50

Level of Signif: *, LSD 5% = 0.09 (whole table)
= 0.04 (sulphur rate with same crop)

d) Initial Phosphorus by Sulphur by Supplementary Phosphorus Effect

Initial Phosphorus Rate (kg ha^{-1})	Sulphur Rate (kg ha^{-1})	Supplementary Phosphorus Rate (kg ha^{-1})		
		0	20	40
0	0	0.45	0.49	0.48
	20	0.44	0.43	0.48
	40	0.46	0.46	0.48
10	0	0.46	0.46	0.49
	20	0.45	0.49	0.51
	40	0.44	0.47	0.49
20	0	0.46	0.46	0.50
	20	0.47	0.45	0.47
	40	0.51	0.53	0.52
40	0	0.52	0.48	0.56
	20	0.49	0.52	0.51
	40	0.46	0.48	0.54
80	0	0.57	0.57	0.58
	20	0.52	0.55	0.55
	40	0.58	0.53	0.60

Level of signif: *, LSD 5% = 0.07 (whole table)
= 0.04 (suppl. P with same levels of initial P and sulphur)

TABLE 5: Effects on Grain Sulphur Content (% dry wt)

a) Effect of Sulphur Rates

1981/82 sulphur rates (kg ha^{-1})	0	20	40
Grain sulphur (% dry wt)	0.24	0.25	0.26

Level of Signif: **, LSD 5% = 0.007

APPENDIX 1

Data for grain yield and available soil phosphorus (0 - 10 cm) used to develop regression equation yield = 1183 + 299.5 P - 10.5 P^2

Grain Yield (kg/ha)	Avail Soil P (ppm)	Grain Yield (kg/ha)	Avail Soil P (ppm)
2303	5.3	2831	8.2
2665	7.2	3226	8.8
2596	5.3	3251	8.7
2685	8.2	3205	10.2
3438	11.0	3218	13.8
2689	8.2	2978	7.0
2915	6.2	2180	6.3
2796	8.7	2884	6.8
2905	8.2	3120	6.3
3345	13.2	3242	14.2
2692	8.5	2541	6.5
2865	8.3	2931	7.8
2949	9.3	3381	8.7
2967	12.7	3441	13.7
3318	14.5	3194	8.2
2454	5.7	2809	8.5
2573	7.7	3121	9.3
2764	7.0	3219	11.0
2963	7.7	3319	16.8
3143	10.7		
2562	7.2		
3118	7.5		
2947	8.5		
3271	9.0		
3282	11.8		

5-6 RESPONSE OF SOYBEANS TO ZINC IN 1981/82

ABSTRACT

Soybean cultivar Buchanan was sown with five rates of zinc on a Virgin Tippera Clay Loam in the 1981-82 Wet Season. Initial soil tests indicated a very marginal available zinc level of 0.35 ppm.

Plant analysis tests performed during the growing season showed significant differences in plant tissue zinc levels. However, no response in soybean plant growth or yield occurred in this initial year.

Post harvest soil tests showed a decline in soil zinc to 0.27 ppm in plots where no zinc was applied and an excellent range between other rates.

The experiment area was sown to soybeans again in 1982/83 but very poor establishment resulted in its being abandoned.

Introduction

In the initial stages of research and crop production in the Douglas Daly area, zinc deficiency on several crops of maize was identified.

Tests on Tippera clay loam soils on new development farms indicated soil zinc levels ranging from 0.2 ppm to 1.2 ppm.

From these results it was expected that zinc may be a limiting factor to crop production, either immediately or after several seasons.

As soybeans are expected to be one of the major crops grown on these soils, it was decided to set up a long term zinc experiment to determine if zinc fertilizer was required and if so how frequently.

Seasonal Conditions

The season was characterized by below average rainfall with a long dry spell during the establishment phase and an abrupt end in late March (Table 1, Section 1).

Materials and Methods

The site was virgin tippera, cleared and raked during the 1980-81 wet season. Initial soil samples to determine nutrient levels were taken from numerous locations on the trial site.

Experimental design was a randomized block with four replications of five rates of zinc, 0, 5, 10, 15, and 20 kg ha^{-1}. Each plot consisted of 3 beds, 1.5 m wide by 30 m long. Ten rows, 15 cm apart, were sown on each bed.

Land was prepared by conventional cultivation to provide a weed free seedbed prior to Treflan application and incorporation at 2 l/ha^{-1} on December 13, 1981.

Soybean cultivar Buchanan was inoculated with rhizolium strain CB 1809 and sown with a 10 row Conor Shea disc seeder on December 22, 1981 to obtain a plant population of 500,000 plants ha^{-1}.

Phosphorus at 40 kg ha^{-1} was applied as Super King (19.2% P) and Sulphur as Gypsum at 14 kg/ha^{-1} S. Single Super was not used in this experiment because of its usual high zinc contamination. Muriate of Potash at 100 kg ha^{-1} (50 kg ha^{-1}) K) was also applied.

The five rates of zinc were hand applied in the form of zinc oxide. Zinc sulphate was avoided because of the possible confounding effect of its sulphur component.

Basagran herbicide was sprayed at the 3 trifoliate stage on all plots to control broadleaf weed species.

Insecticide was applied 3 times during the growing season by back-pack mister. Thiodan at 2 l/ha^{-1} was used twice, to control leaf eating insects early in the season and pod sucking bugs near : Lannate at 1.5 l/ha^{-1} was applied once in an effort to control <u>Spo</u> <u>litura</u>

Recordings and Data Collection

Established plant populations were determined one week after emergence.

All plots were sampled on February 23, 1982 for dry matter production. Samples were retained and subsequently ground and analysed for plant zinc levels.

At maturity the centre bed of each plot was machine harvested using a K.E.W. experimental header and plot yields recorded.

Grain samples were analysed for percentage P, Zn, Oil and Protein.

Results and Discussion

All results and recordings are listed in Table 1.

Plant populations were very uniform throughout with an established mean population of 400,000 plants ha^{-1}.

During the growing season no visual response was noted to the varying rates of zinc applied. This observation was verified by plant dry weight yields and ultimately by grain yields with no significant differences recorded between rates. Average grain yield over all plots was 3,567 kg ha^{-1}.

Grain analysis of protein, phosphorus, zinc and oil content as well, indicated no response to zinc.

Whole plant analysis however did show a significant response (p 0.05) up to 10 kg/ha^{-1} of applied zinc. However, zinc levels for all treatments were above that regarded as marginal.

Post harvest soil sampling (see Table 1) of all plots indicated that in plots where no zinc was applied available zinc levels had dropped to 0.27 ppm from an initial 0.35. Other rates of zinc applied produced available soil levels of 1.32 ppm for 5 kg ha^{-1} up to of 4.00 ppm for 20 kg ha^{-1}.

Conclusion

These results show that a soybean crop grown on Virgin Tippera soil would not directly benefit from an application of zinc. However, soil zinc levels in these soils are often thought to be marginal and certainly available levels below 0.35 ppm are quite common. It is then suggested that the current practice of applying small quantities (5 kg ha^{-1}) in the initial year of cropping be continued at this stage.

Given the establishment of a range of soil zinc levels, and particularly the mining of the no zinc plots it is intended that this experiment be continued for a number of years to define at what available soil levels zinc will be a limiting factor. In this way it is hoped that a strategy for zinc application can be developed.

TABLE 1: Effect of Different Zinc Rates on Various Soybean Attributes

Rates of Zinc (hg/ha)	Grain Yield (kg/ha)	Grain Protein %	Grain Phosphorous %	Grain Zn ppm	Oil %	Plant Nitrogen %	Plant Phosphorous %	Plant Zn ppm	Plant Dry Weight Yields kg/ha 64 days	Soil Zn Levels Post Harvest ppm
0	3374	37.66	0.55	36.25	20.48	2.55	0.24	23.2	5,333	0.27
5	3404	39.06	0.54	38.00	20.83	2.53	0.24	24.1	5,347	1.32
10	3630	37.81	0.56	39.75	20.33	2.60	0.26	27.7	5,586	2.55
15	3593	34.69	0.53	39.25	20.88	2.70	0.26	32.1	5,489	3.50
20	3796	37.81	0.54	40.00	20.60	2.63	0.27	27.5	5,456	4.00
L.S.P. 5%	NSD	NSD	NSD	NSD	NSD	NSD	NSD	5.41	NSD	1.36

5-7 ASSESSMENT OF NUTRIENT DEFICIENCIES ON BLAIN SANDY LOAM - RESULTS OF POT STUDIES

ABSTRACT

The effect of withholding a number of nutrients in turn on the growth of maize, soybean, and sword bean (Canavalia sp.) was assessed on Blain Sandy loam soil from DDRF.

Results were seriously confounded by chloride toxicity and suspected overall nitrogen and sulphur deficiency in all treatments. However, the results provided indications that phosphorus, sulphur, potassium and zinc are all likely to be deficient. Of course, nitrogen will be essential for maize production. There was some indication that maize yields may be depressed by the addition of copper.

* Mr C.J. Flint, Peanut Agronomist, was a joint worker on this study.

Introduction

The Blain sandy loam soil is a major soil type in the Douglas-Daly area of the Northern Territory. Indifferent growth of crop and pasture species has often been recorded on this soil type. In many instances symptoms of nutrient deficiency have been obvious.

In the 1980-81 season poor growth was recorded with a number of crop species, including maize, soybean, sword bean (Canavalia sp.) and cowpea grown on previously cropped Blain sandy loam at Douglas-Daly Research Station. Plant analysis suggested that at least zinc was deficient.

In pot studies with the pasture legume verano stylo, Day et al. (1983) recorded responses to phosphorus, sulphur and zinc and suggested that potassium and copper were likely to be deficient when phosphorus and sulphur were corrected. In field studies with the same species responses to phosphorus, sulphur, zinc and molybdenum have been recorded (B.J. Ross and A.G. Cameron, pers. comm.).

This paper reports the results of two pot studies with Blain sandy loam from DDRF where one element was withheld in turn. In the first study, maize and soybean were grown in pots containing virgin Blain sandy loam collected from the area now known as the Blain Irrigation Area. In the second study maize and sword bean were grown on previously cropped Blain soil from the stockyard paddock.

Materials and Methods

Experiment 1:

Virgin Blain sandy loam was collected from the area now known as the Blain Irrigation Area at DDRF. All soil was from the surface 15 cm.

Experimental design was a randomised block with 15 nutrient treatments and three replications on each of two crops, maize and soybeans i.e. 45 pots for each crop.

The 15 treatments were:

T1 - complete basal based on chloride
T2 - complete basal based on sulphate
T3 - complete basal based on sulphate with chloride added as magnesium sulphate
T5 - Nil
T6 - Basal minus nitrogen
T7 - Basal minus phosphorus
T8 - Basal minus potassium
T9 - Basal minus calcium
T10 - Basal minus magnesium
T11 - Basal minus zinc
T12 - Basal minus manganese
T13 - Basal minus copper
T14 - Basal minus boron
T15 - Basal minus molybdenum

Basal fertilizer for treatments T6 - 15 were based on sulphate (T2) except that calcium chloride was applied as the calcium source instead of calcium sulphate. Hence all treatments except T2 (Basal based on sulphate) and T9 (Basal minus calcium) have some chloride added. For T1, T3 and T4 this was the equivalent of 308 kg ha^{-1} while for T6 - 15 (excluding T9) it was the equivalent of 215 kg ha^{-1}.

Details of actual chemicals used and rates in kg ha^{-1} for each treatment are shown in appendix 1 while the actual amounts applied to each pot are shown in appendix 2. Pot size was 250 mm diameter at the surface and 250 mm depth. All chemical were mixed into the top 2 cm of soil prior to sowing.

The experiment was sown on Jan. 12, 1982 in the screenhouse at DDRF. Four seeds were sown in each pot. After establishment plants were thinned to one per pot. All soybean seed was inoculated with Rhizobium japonicum strain CB1809 prior to sowing. Maize seed was not treated. Cultivars used were Buchanan soybean and QK694 maize. Pots were watered each day with de-ionised water to avoid any visible signs of water stress.

Harvesting was carried out on March 3, 1982 (55 days after sowing) when all above ground plant parts were removed, washed with de-ionised water, and dried at 50°C for 96 hrs. Dry weights were recorded and samples were then milled for plant nutrient analyses.

Experiment 2:

This experiment was conducted with previously cropped Blain sandy loam collected from the stockyard paddock at DDRF. Soil was collected from the top 15 cm. There were seven treatments and three replications for each of maize and sword bean i.e. 21 plots for each crop. Each plot consisted of two pots (same size as experiment 1) with one plant per pot.

Treatments were:-

T1 - Nil
T2 - Complete basal based on sulphate (except calcium chloride) + iron chelate
T3 - T2 - Zn
T4 - T2 - Cu
T5 - T2 - Iron chelate
T6 - Complete basal based on chloride + iron chelate
T7 - Complete basal based on chloride + sulphate + iron chelate

In this experiment all treatments except nil had some chloride. Rates were the same as for experiment 1 and the same chemicals were used. Iron chelate was applied at a rate which gave 8 kg ha^{-1} Fe.

The experiment was sown on June 30 and harvested on Sept. 15 (77 days after sowing. Pots were regularly watered with de-ironised water. Plant tops were removed, washed with de-ironised water and dried at 50°C for 96 hrs. Dry weights were recorded and samples were then milled for nutrient analyses.

Results

1. Soil Analyses

	Experiment 1 (Virgin)	Experiment 2 (Previously cropped)
pH	7.2	7.2
Conductivity (ms/cm)	0.04	0.02
P (ppm)	5	7
Ca (ppm)	485	453
Mg (ppm)	67	44
K (ppm)	78	63
S (ppm)	2	9
Cu (ppm)	0.27	0.5
Mn (ppm)	32	48
Fe (ppm)	6.8	10
Zn (ppm)	0.47	0.1

Extractants:

ph, conduct - 1:5 soil: water extraction
P - 0.5 M $NaHCO_3$ extract at pH 8.5
S - 0.01 M KH_2PO_4 extract at pH 4.0
Ca, Mg, K - 1M CH_3 $CONH_4$ extract at pH 7.0
Zn, Cu, Mn, Fe - 0.005 M DTPA extract at pH 7.3

Dry Matter Production

Experiment 1

For both crops the highest dry matter yield was for the basal treatment based on sulphate (Table 1). With soybeans similar yield were recorded for Basal sulphate + chloride and Basal chloride + sulphate and both were superior to Basal chloride. This suggests a sulphate response in soybeans. However, such was not the case for maize, where basal sulphate far outyielded the other three basal treatments between which there was no difference. This suggests that maize is either not responding to sulphur or any effect is being masked by a large depressive effect of chlorine. Given the recorded response to sulphur in other studies with other species on this soil the latter is suspected. If this is the case it makes comparison between the effects of other nutrients difficult.

All treatments except basal sulphate and basal - Ca received some chlorine and further the three basal treatments with chlorine received more chlorine (308 kg ha^{-1}) than any of the minus nutrient treatments (215 kg ha^{-1}). It is then reasonable to suggest that the basal treatments on chlorine probably have relatively low yields while the minus nutrient treatments have relatively high yields. Hence some nutrients which are not having a significant effect on growth in this experiment may in fact be deficient.

For soybeans we believe it is acceptable to compare basal based on sulphate with the minus nutrient treatments whereas for maize we have used the basal treatments based on chlorine.

For soybeans yield were depressed when no nutrients were added and when phosphorus was removed. There was no other significant effect.

For maize the basal based on chlorine produced significantly higher yields than nil, -P and -K. There were no other significant effects. However, basal based on sulphur had singificantly higher yields than all other treatments.

Hence the results from this experiment suggest that phosphorus, sulphur and potassium are likely to be deficient.

Experiment 2

Yield data is presented in Table 11. The highest maize yield was obtained with basal based on sulphur without copper. This was significantly superior to nil, basal based on chlorine and basal - Zn. Essentially the depressive effect of chlorine recorded previously was still occurring but was alleviated when sulphur was added. There is a trend for yield to be increased when copper is removed and a trend for it to be decreased when zinc is removed.

The same occurred with Canavalia but there was no evidence of a depression when zinc was removed and no evidence of an increase when copper was removed. Iron appears to have had no effect.

Plant Chemical Analyses

Results of Plant chemical status are shown in Tables 2-10 (Experiment 1) and Tables 12-17 (Experiment 2). In general lower levels of specific nutrients were measured when specific elements were not added. However for both experiments levels of nitrogen and sulphur were very low in maize and sulphur in soybean and sword bean. This may have also confounded the results.

One important aspect of both experiments was the accumulation of high levels of zinc in basal treatments based on chloride (Tables 8 and 16). No specific reason can be given for this. Similarly there appears to have been an accumulation of manganese with basal chloride treatment (Table 10).

Plant levels of zinc suggest that it is generally in low supply and that deficiencies are likely in all crops. Although we didn't measure a yield depression in Sword bean to minus Zn obvious deficiency symptoms were apparent early in the growth of the crop. These dissipated and weren't obvious on later leaves.

CONCLUSION

Results from these experiments are seriously confounded so firm conclusions cannot be drawn. However it is reasonable to suggest that phosphorus, sulphur, potassium and zinc are all likely to be required. There is some indication that for maize, yields may be depressed by the addition of copper.

References:

Day, K.J., Fogarty, P.J., Jones, R.K., Dalgleish, N.P. and Kermot, J.C. (1983) "Fertility Studies on Some Soils of the Adelaide and Daly Basins, Northern Territory" Conservation Comm. of NT, Technical Report No. 5.

TABLE 1: Dry Matter Production (gm pot^{-1}) for each treatment in experiment 1.

	Maize	Soybean
Basal chloride	41.9	8.8
Basal Sulphur	56.1	13.5
Basal Sulphur + Chloride	40.3	10.9
Basal Chloride + Sulphur	40.2	10.1
Nil	25.5	6.9
Basal -N	35.1	12.5
Basal -P	29.2	9.5
Basal -K	29.5	12.2
Basal -Ca	35.9	12.5
Basal -Mg	44.8	13.5
Basal -Zn	40.9	12.0
Basal -Mn	35.5	11.4
Basal -Cu	45.8	13.5
Basal -B	37.1	11.9
Basal -Mo	38.0	12.3
LSD 5%	11.1	2.1

TABLE 2: % Nitrogen in whole tops for each treatment in experiment 1

	Maize	Soybean
Basal chloride	0.80	2.9
Basal Sulphur	0.73	2.5
Basal Sulphur + Chloride	0.70	2.5
Basal Chloride + Sulphur	0.90	2.8
Nil	0.88	2.2
Basal -N	0.68	2.6
Basal -P	1.43	2.9
Basal -K	0.98	2.6
Basal -Ca	0.87	2.5
Basal -Mg	0.63	2.4
Basal -Zn	0.77	2.5
Basal -Mn	0.77	2.6
Basal -Cu	0.70	2.4
Basal -B	0.67	2.5
Basal -Mo	0.70	2.4
LSD 5%	0.35	0.47

TABLE 3: % Phosphorus in whole tops for each treatment in experiment 1

	Maize	Soybean
Basal chloride	0.15	0.26
Basal Sulphur	0.15	0.28
Basal Sulphur + Chloride	0.14	0.27
Basal Chloride + Sulphur	0.13	0.31
Nil	0.08	0.28
Basal -N	0.13	0.29
Basal -P	0.09	0.18
Basal -K	0.18	0.28
Basal -Ca	0.13	0.28
Basal -Mg	0.14	0.27
Basal -Zn	0.14	0.29
Basal -Mn	0.16	0.31
Basal -Cu	0.16	0.26
Basal -B	0.15	0.29
Basal -Mo	0.15	0.27
LSD 5%	0.04	0.05

TABLE 4: % Calcium in whole tops for each treatment in experiment 1

	Maize	Soybean
Basal chloride	0.45	1.24
Basal Sulphur	0.36	0.96
Basal Sulphur + Chloride	0.35	1.08
Basal Chloride + Sulphur	0.45	1.10
Nil	0.28	1.10
Basal -N	0.37	1.08
Basal -P	0.37	1.02
Basal -K	0.41	1.21
Basal -Ca	0.32	0.88
Basal -Mg	0.39	1.10
Basal -Zn	0.27	1.09
Basal -Mn	0.37	1.17
Basal -Cu	0.37	1.02
Basal -B	0.33	1.11
Basal -Mo	0.37	1.10
LSD 5%	0.10	0.15

TABLE 5: % Magnesium in whole tops for each treatment in experiment 1

	Maize	Soybean
Basal chloride	0.16	0.52
Basal Sulphur	0.14	0.48
Basal Sulphur + Chloride	0.20	0.56
Basal Chloride + Sulphur	0.24	0.58
Nil	0.17	0.42
Basal -N	0.15	0.40
Basal -P	0.21	0.46
Basal -K	0.23	0.45
Basal -Ca	0.14	0.43
Basal -Mg	0.15	0.37
Basal -Zn	0.13	0.42
Basal -Mn	0.16	0.45
Basal -Cu	0.16	0.37
Basal -B	0.15	0.48
Basal -Mo	0.17	0.40
LSD 5%	0.04	0.09

TABLE 6: % Potassium in whole tops for each treatment in experiment 1

	Maize	Soybean
Basal chloride	1.84	2.15
Basal Sulphur	1.69	1.97
Basal Sulphur + Chloride	1.68	2.02
Basal Chloride + Sulphur	1.83	2.21
Nil	1.68	1.97
Basal -N	1.76	2.10
Basal -P	2.09	2.13
Basal -K	1.43	1.83
Basal -Ca	1.62	2.10
Basal -Mg	1.52	2.09
Basal -Zn	1.47	2.04
Basal -Mn	1.72	2.10
Basal -Cu	1.51	1.94
Basal -B	1.64	2.10
Basal -Mo	1.78	1.97
LSD 5%	0.26	0.23

TABLE 7: % Sulphur in whole tops for each treatment in experiment 1

	Maize	Soybean
Basal chloride	0.04	0.13
Basal Sulphur	0.14	0.18
Basal Sulphur + Chloride	0.09	0.18
Basal Chloride + Sulphur	0.09	0.17
Nil	0.06	0.14
Basal -N	0.05	0.15
Basal -P	0.10	0.16
Basal -K	0.08	0.14
Basal -Ca	0.08	0.15
Basal -Mg	0.05	0.15
Basal -Zn	0.06	0.16
Basal -Mn	0.06	0.16
Basal -Cu	0.06	0.14
Basal -B	0.06	0.16
Basal -Mo	0.06	0.15
LSD 5%	0.02	0.02

TABLE 8: Copper (ppm) in whole tops for each treatment in experiment 1

	Maize	Soybean
Basal chloride	3	7
Basal Sulphur	3	5
Basal Sulphur + Chloride	4	6
Basal Chloride + Sulphur	5	6
Nil	5	6
Basal -N	3	5
Basal -P	5	11
Basal -K	3	4
Basal -Ca	4	5
Basal -Mg	3	5
Basal -Zn	3	5
Basal -Mn	4	5
Basal -Cu	3	5
Basal -B	3	7
Basal -Mo	4	6
LSD 5%	1	2

TABLE 9: Zinc (ppm) in whole tops for each treatment in experiment 1

	Maize	Soybean
Basal chloride	71	199
Basal Sulphur	25	54
Basal Sulphur + Chloride	20	68
Basal Chloride + Sulphur	80	210
Nil	23	61
Basal -N	17	54
Basal -P	40	68
Basal -K	23	60
Basal -Ca	35	44
Basal -Mg	21	52
Basal -Zn	8	23
Basal -Mn	18	47
Basal -Cu	20	51
Basal -B	19	45
Basal -Mo	25	54
LSD 5%	14	46

TABLE 10: Iron (ppm) in whole tops for each treatment in experiment 1

	Maize	Soybean
Basal chloride	129	292
Basal Sulphur	112	304
Basal Sulphur + Chloride	99	273
Basal Chloride + Sulphur	124	268
Nil	116	273
Basal -N	124	271
Basal -P	114	275
Basal -K	105	283
Basal -Ca	113	263
Basal -Mg	102	285
Basal -Zn	143	260
Basal -Mn	133	252
Basal -Cu	101	234
Basal -B	94	284
Basal -Mo	107	249
LSD 5%	NSD	NSD

TABLE 11: Manganese (ppm) in whole tops for each treatment in experiment 1

	Maize	Soybean
Basal Chloride	40	345
Basal Sulphur	8	145
Basal Sulphur + Chloride	8	187
Basal Chloride + Sulphur	10	240
Nil	6	211
Basal -N	8	187
Basal -P	7	172
Basal -K	8	219
Basal -Ca	8	128
Basal -Mg	8	213
Basal -Zn	8	201
Basal -Mn	8	170
Basal -Cu	8	160
Basal -B	8	229
Basal -Mo	8	193
LSD 5%	NSD	73

TABLE 12: Dry Matter Yield of Maize and Canavalia in Experiment 2

	Maize (gm/plant)	Canavalia (gm/plant)
T1 Nil	13.6	10.3
T2 Basal SO_4 (except $CaCl_2$) + Fe Chelate	24.5	13.3
T3 T2 -Zn	21.5	12.9
T4 T2 -Cu	26.9	13.5
T5 T2 -Fe	23.1	13.8
T6 Basal Cl	17.8	10.4
T7 Basal Cl + SO_4	24.8	13.1
LSD 5%	4.7	1.5

TABLE 13: % N in Tops for Pot Trial 2

	Maize (gm/plant)	Canavalia (gm/plant)
T1 Nil	0.72	1.97
T2 Basal SO_4 (except $CaCl_2$) + Fe Chelate	0.47	2.47
T3 T2 -Zn	0.58	2.67
T4 T2 -Cu	0.52	2.65
T5 T2 -Fe	0.47	2.15
T6 Basal Cl + Fe Chelate	0.58	2.13
T7 Basal Cl + SO_4 + Fe Chelate	0.55	2.20
LSD 5%	0.10	0.37

TABLE 14: % P in Tops for Pot Trial 2

	Maize (gm/plant)	Canavalia (gm/plant)
T1 Nil	0.16	0.14
T2 Basal SO_4 (except $CaCl_2$) + Fe Chelate	0.29	0.24
T3 T2 -Zn	0.33	0.26
T4 T2 -Cu	0.24	0.26
T5 T2 -Fe	0.26	0.22
T6 Basal Cl + Fe Chelate	0.31	0.21
T7 Basal Cl + SO_4 + Fe Chelate	0.24	0.21
LSD 5%	0.05	0.03

TABLE 15: % S in Tops for Pot Trial 2

	Maize (gm/plant)	Canavalia (gm/plant)
T1 Nil	0.05	0.11
T2 Basal SO_4 (except $CaCl_2$) + Fe Chelate	0.06	0.18
T3 T2 -Zn	0.06	0.17
T4 T2 -Cu	0.05	0.18
T5 T2 -Fe	0.04	0.18
T6 Basal Cl + Fe Chelate	0.04	0.09
T7 Basal Cl + SO_4 + Fe Chelate	0.05	0.22
LSD 5%	0.01	0.03

TABLE 16: Copper (ppm) in Tops for Pot Trial 2

	Maize (gm/plant)	Canavalia (gm/plant)
T1 Nil	3.7	3.8
T2 Basal SO_4 (except $CaCl_2$) + Fe Chelate	3.3	5.3
T3 T2 -Zn	5.2	5.5
T4 T2 -Cu	2.7	5.5
T5 T2 -Fe	3.8	5.0
T6 Basal Cl + Fe Chelate	4.3	4.2
T7 Basal Cl + SO_4 + Fe Chelate	2.0	5.5
LSD 5%	1.0	0.9

TABLE 17: Zinc (ppm) in Tops for Pot Trial 2

	Maize (gm/plant)	Canavalia (gm/plant)
T1 Nil	23	9
T2 Basal SO_4 (except $CaCl_2$) + Fe Chelate	32	27
T3 T2 -Zn	20	11
T4 T2 -Cu	29	30
T5 T2 -Fe	27	30
T6 Basal Cl + Fe Chelate	104	94
T7 Basal Cl + SO_4 + Fe Chelate	172	280
LSD 5%	31	48

TABLE 18: Iron (ppm) in Tops for Pot Trial 2

	Maize (gm/plant)	Canavalia (gm/plant)
T1 Nil	1197	139
T2 Basal SO_4 (except $CaCl_2$) + Fe Chelate	1404	178
T3 T2 -Zn	1117	177
T4 T2 -Cu	1506	251
T5 T2 -Fe	1802	175
T6 Basal Cl + Fe Chelate	1975	146
T7 Basal Cl + SO_4 + Fe Chelate	1464	158
LSD 5%	538	72

APPENDIX 1

Treat 1 (Complete Basal) Cl

Urea	107 kg ha^{-1}	50 kg ha^{-1} N
KH_2 PO_4	200 kg ha^{-1}	46 kg ha^{-1} P 57 kg ha^{-1} K
Ca Cl_2 $2H_2O$	446 kg ha^{-1}	200 kg ha^{-1} Ca 215 kg ha^{-1} Cl
Mg Cl_2 $6H_2O$	167 kg ha^{-1}	20 kg ha^{-1} Mg 58 kg ha^{-1} Cl
Zn Cl_2	21 kg ha^{-1}	10 kg ha^{-1} Zn 10.8 kg ha^{-1} Cl
Mn $Cl_2 4H_2O$	36 kg ha^{-1}	10 kg ha^{-1} Mn 12.9 kg ha^{-1} Cl
Cu Cl_2 $2H_2O$	27 kg ha^{-1}	10 kg ha^{-1} Cu 11.15 kg ha^{-1} Cl
Boron (H_3 BO_3)	11.4 kg ha^{-1}	2 kg ha^{-1} B
Molybdenum Mo O_3	0.54 kg ha^{-1}	0.3 kg ha^{-1} Mo

Total Cl = 308 kg ha^{-1}

Treat 2 (Complete Basal) SO_4

Urea	107 kg ha^{-1}	50 kg ha^{-1} N
KH_2 PO_4	200 kg ha^{-1}	46 kg ha^{-1} P 57 kg ha^{-1} K
Ca SO_4 $2H_2O$	859 kg ha^{-1}	200 kg ha^{-1} Ca 160 kg ha^{-1} S
Mg SO_4 $6H_2O$	203 kg ha^{-1}	20 kg ha^{-1} Mg 26 kg ha^{-1} S
Zn SO_4 $7H_2O$	44 kg ha^{-1}	10 kg ha^{-1} Zn 5 kg ha^{-1} S
Mn $SO_4 4H_2O$	40 kg ha^{-1}	10 kg ha^{-1} Cu 5 kg ha^{-1} S
Cu SO_4 $2H_2O$	40 kg ha^{-1}	10 kg ha^{-1} Cu 5 kg ha^{-1} S
Boron (H_3 BO_3)	11.4 kg ha^{-1}	2 kg ha^{-1} B
Molybdenum Mo O_3	0.54 kg ha^{-1}	0.3 kg ha^{-1} Mo

Total Sulphur = 202 kg ha^{-1}

<u>Treat 3 (Complete Basal) SO_4 - with Cl</u>

Urea	107 kg ha^{-1}	50 kg ha^{-1} N
KH_2 PO_4	200 kg ha^{-1}	46 kg ha^{-1} P 57 kg ha^{-1} K
Ca SO_4 $2H_2O$	859 kg ha^{-1}	200 kg ha^{-1} Ca 160 kg ha^{-1} S
Mg SO_4 $7H_2O$	203 kg ha^{-1}	20 kg ha^{-1} Mg 26 kg ha^{-1} S
Zn SO_4 $7H_2O$	44 kg ha^{-1}	10 kg ha^{-1} Zn 5 kg ha^{-1} S
Mn SO_4 H_2O	31 kg ha^{-1}	10 kg ha^{-1} Cu 6 kg ha^{-1} S
Cu SO_4 $5H_2O$	40 kg ha^{-1}	10 kg ha^{-1} Cu 5 kg ha^{-1} S
Boron (H_3 BO_3)	11.4 kg ha^{-1}	2 kg ha^{-1} B
Molybdenum Mo O_3	0.54 kg ha^{-1}	0.3 kg ha^{-1} Mo

Total Sulphur = 202 kg ha^{-1}

Cl @ 308 kg ha^{-1} as Mg Cl_2 $6H_2O$

<u>Treat 4 (Complete Basal) Cl with SO_4</u>

Urea	107 kg ha^{-1}	50 kg ha^{-1} N
KH_2 PO_4	200 kg ha^{-1}	46 kg ha^{-1} P 57 kg ha^{-1} K
Ca Cl_2 $2H_2O$	446 kg ha^{-1}	200 kg ha^{-1} Ca 215 kg ha^{-1} Cl
Mg Cl_2 $6H_2O$	167 kg ha^{-1}	20 kg ha^{-1} Mg 58 kg ha^{-1} Cl
Zn Cl_2	21 kg ha^{-1}	10 kg ha^{-1} Zn 10.8 kg ha^{-1} Cl
Mn $Cl_2 4H_2O$	36 kg ha^{-1}	10 kg ha^{-1} Mn 12.9 kg ha^{-1} Cl
Cu Cl_2 $2H_2O$	27 kg ha^{-1}	10 kg ha^{-1} Cu 11.15 kg ha^{-1} Cl
Boron (H_3 BO_3)	11.4 kg ha^{-1}	2 kg ha^{-1} B
Molybdenum Mo O_3	0.54 kg ha^{-1}	0.3 kg ha^{-1} Mo

Total Cl = 308 kg ha^{-1}

SO_4 - @ 202 kg ha^{-1} as Mg SO_4 $7H_2O$

Treat 5	Nil
Treat 6	TR 2 -N (urea)
Treat 7	TR 2 -P (KH_2PO_4) + K_2SO_4 @ 127.23 kg ha^{-1}
Treat 8	TR 2 -K (KH_2PO_4) + Ca $(H_2PO_4)_2$ H_2O
Treat 9	TR 2 -Ca
Treat 10	TR 2 -Mg
Treat 11	TR 2 -Zn
Treat 12	TR 2 -Mn
Treat 13	TR 2 -Cu
Treat 14	TR 2 -B
Treat 15	TR 2 -Mo

APPENDIX 2

NITROGEN

Source:	Urea - NH_2 CO NH_2
Analysis:	46.65% N
Rate:	50 kg ha^{-1}
Rate of Urea:	107.18 kg ha^{-1}
Area of Pot:	0.000005
Quantity per Pot:	539 mg

PHOSPHOROUS

Source:	Calcium Tetrahydrogen di-orthophosphate - $Ca(H_2PO_4)_2 H_2O$
Analysis:	24.58 P 15.90% Ca
Rate:	46 kg ha^{-1} P
Rate of $Ca(H_2PO_4)_2 H_2O$:	187.14 kg ha^{-1}
Area of Pot:	0.000005
Quantity per Pot:	936 mg

* Also supplies 29.76 kg ha^{-1} Ca

POTASSIUM

Source:	Potassium Sulphate - K_2SO_4 Potassium Chloride - KCl
Analysis:	K_2SO_4 - 44.8% K, 18% Sulphur KCl - 52.5% K, 47.5% Chlorine
Rate:	57 kg ha^{-1} K
Rate of K_2SO_4:	127.23 kg ha^{-1}
Rate of KCl:	109.61 kg ha^{-1}
Area of Pot:	0.000005
Quantity per Pot:	*K_2SO_4 - 636 mg KCl - 548 mg

* Also supplies 22.86 kg ha^{01} Sulphur
KCl supplies 52.06 kg ha^{-1} Chlorine

PHOSPHOROUS AND POTASSIUM

Source:	Potassium di-hydrogen orthophosphate - KH_2PO_4
Analysis:	K - 28.73% P - 22.76%
Rate:	200 kg ha^{-1} gives 57 kg ha^{-1} K 46 kg ha^{-1} P
Area of Pot:	0.00005
Quantity of Pot:	1000 mg

CALCIUM

Source: Calcium Sulphate (di-hydrate) - $CaSO_4\ 2H_2O$

Calcium Chloride - $Ca\ Cl_2\ 2H_2O$

Analysis:
23.28 Ca) Ca $So_4\ 2H_2O$
18.60 S)
44.87 Ca in $Ca\ Cl_2$
48.23 Cl in $Ca\ Cl_2$

Rate: 200 kg ha^{-1} Ca

Rate of -

(a) $Ca\ SO_4\ 2H_2O$ 859 kg ha^{-1}
(b) $Ca\ Cl_2\ 2H_2O$ 446 kg ha^{-1}

Area of Pot: 0.000005 ha

Quantity per Pot: 4295 mg $CaSO_4\ 2H_2O$

2230 mg $CaCl_2\ 2\ H_2O$

* Sulphur supplied in $Ca\ SO_4\ 2H_2O$ @ 859 kg ha^{-1} = 159.8 kg
Chlorine supplied in $Ca\ Cl_2\ 2H_2O$ @ 446 kg ha^{-1} = 215.0 kg

MAGNESIUM

Source: Magnesium Sulphate $Mg\ SO_4\ 7H_2O$
Magnesium Chloride $Mg\ Cl_2\ 6H_2O$

Analysis:
$Mg\ SO_4\ 7H_2O$ - (9.86 Mg
(13.01 S
$Mg\ Cl_2\ 6H_2O$ - (11.96 Mg
(34.90 Cl

Rate: 20 kg ha^{-1}

Rate of $Mg\ SO_4\ 7H_2$ = 202.83 kg ha^{-1}
$Mg\ Cl_2\ 6H_2O$ = 167.22 kg ha^{-1}

Area of Pot: 0.000005

Quantity per Pot: 1014 mg $Mg\ CO_4\ 7H_2O$
836 $Mg\ Cl_2\ 6H_2O$

* $Mg\ So_4\ 7H_2O$ at 202.83 kg ha^{-1} supplies 26.39 kg S ha^{-1}
$Mg\ Cl_2\ 6H_2O$ at 167.22 kg ha^{-1} supplies 58.36 kg Cl ha^{-1}

ZINC

Source:	Zinc Sulphate - $Zn\ SO_4\ 7H_2O$ Zinc Chloride - $Zn\ Cl_2$
Analysis:	$Zn\ SO_4\ 7H_2O$ = 22.74 Zn, 11.15 S $Zn\ Cl_2$ = 47.97 Zn, 52.03 Cl
Rate:	10 kg ha^{-1}
Rate of $Zn\ SO_4\ 7H_2O$ $Zn\ Cl_2$	= 43.97 kg ha^{-1} = 20.85 kg ha^{-1}
Area of Pot:	0.000005
Quantity per Pot:	220 mg $Zn\ SO_4\ 7H_2O$ 104 mg $Zn\ Cl_2$

* $Zn\ SO_4\ 7H_2O$ at 43.97 kg ha^{-1} supplies 4.9 kg ha^{-1} S
$Zn\ Cl_2$ at 20.85 kg ha^{-1} supplies 10.84 kg ha^{-1} Cl

MANGANESE

Source:	Manganous Sulphate - $Mn\ SO_4\ H_2O$ Manganous Chloride - $Mn\ Cl_2\ 4H_2O$
Analysis;	$Mn\ SO_4\ H_2O$ - Mn - 32.51% S - 18.97% $Mn\ Cl_2\ 4\ H_2O$ - Mn 27.76% Cl 35.83%
Rate:	10 kg ha^{-1}
Rate of $Mn\ SO_4\ H_2O$ $Mn\ Cl_2\ 4H_2O$	= 30.76 kg ha^{-1} = 36.02 kg ha^{-1}
Area of Pot:	0.000005
Quantity per Pot:	154 mg $Mn\ SO_4H_2O$ 180 mg $Mn\ Cl_24H_2O$

* Mn So_4 $7H_2O$ at 30.76 kg ha^{-1} supplies 5.8 kg ha^{-1}
Mn Cl_2 $4H_2O$ at 36.02 kg ha^{-1} supplies 12.91 kg ha^{-1} Cl

COPPER

Source:	Cupric Sulphate - Cu SO_4 $5H_2O$ Cupric Chloride - Cu Cl_2 $2H_2O$
Analysis:	Cupric Sulphate - 25.45 Cu, 12.84 S Cupric Chloride - 37.28 Cu, 41.59 Cl
Rate:	10 kg ha^{-1}
Rate of Cu SO_4 $5H_2O$ Cu Cl_2 $2H_2O$	= 39.29 kg ha^{-1} = 26.82 kg ha^{-1}
Area of Pot:	197 mg Cu SO_4 $5H_2O$ 134 mg Cu Cl_2 $2H_2O$

* Cu SO_4 $5H_2O$ at 39.29 kg ha^{-1} supplies 5.04 kg ha^{-1} S
Cu Cl_2 $2H_2O$ at 26.82 kg ha^{-1} supplies 11.15 kg ha^{-1} Cl

BORON

Source:	Boric Acid - H_3 BO_3
Analysis:	17.48% B
Rate:	2 kg ha^{-1}
Rate of H_3 BO_3:	11.44
Area of Pot:	0.000005
Quantity per Pot:	57 mg

MOLYBDENUM

Source:	Molybdic Acid (85%) Mo O_3
Analysis:	66.7% Mo or 56% of 85% Mo O_3
Rate:	0.3 kg ha^{-1}
Rate of Mo O_3:	0.54 kg ha^{-1} <u>or</u> 540 gm
Area of Pot:	0.000005
Quantity per Pot:	2.7 mg

CHLORINE

Source:	$Mg\ Cl_2\ 6H_2O$
Analysis:	12.0% Mg, 34.9% Cl
Rate/ha of Chlorine	308 Kg ha^{-1}
Rate of $Mg\ Cl_2$	883 kg ha^{-1}
Area of Pot:	0.000005
Quantity per Pot:	4.42 gm

This also supplies 106 kg ha^{-1} Mg

SULPHUR

Source:	$Mg\ SO_4\ 7H_2O$
Analysis:	9.9% Mg, 13.01% S
Rate/ha of S:	202 kg ha^{-1}
Rate of $Mg\ SO_4$:	1554 kg ha^{-1}
Area of Pot:	0.000005
Quantity per Pot:	7.77 gm

This also supplies 154 kg ha^{-1} Mg

SECTION 6

CONCLUSIONS, RECOMMENDATIONS, AND FUTURE RESEARCH

We believe the results of these studies provide adequate information to allow successful soybean production on the Tippera clay loam soil in most wet seasons. However, two major problems remain which have caused severe difficulties in nearly all seasons. Both result in below optimum plant populations. These two problems are those of poor seed quality and hot dry conditions immediately after emergence causing 'ringbarking' of young seedlings. Poor establishment has been mentioned numerous times throughout this report.

The latter, 'ringbarking' effect, invariably occurs on the sandy surfaced soils and we believe will be a continuing problem and will preclude reliable production with conventional cultivation. We never have and still don't recommend soybean production on the sandy Oolloo and Blain soils. This may change if zero tillage and associated surface mulching can be developed on a commercial basis. The problem is nowhere near as severe on the Tippera clay loam soils and plant losses have only occurred during abnormal extended periods of extremely hot dry weather and have never been severe enough to warrant the abandonment of any soybean crop. Whether there is any genetic diversity in soybean lines to allow development of some tolerance to high surface temperatures is not known. We had intended looking at this aspect in the coming season and strongly recommend this line of research be pursued.

The problem of poor quality seed has been the single-most important factor limiting soybean production. This should not be the case. In the initial review (Section 1) we suggested that the reliable production of good quality seed would be dependent on the availability of irrigation to ensure adequate moisture supplies until physiological maturity. Nothing has occurred to alter our views. With very little irrigation available in the Northern Territory we believe that a firm commitment should be made with growers in the Ord Irrigation Area for the supply of good quality planting seed each season for the foreseeable future. The Ord has demonstrated that good quality supplies of Buchanan seed can be produced, particularly from February - March sown crops that mature in June - July under mild conditions. Until such time as reliable production can be guaranteed in the Northern Territory we suggest that local production of soybean seed be forgotten.

The obtaining of regular supplies from the ORIA will require the lifting of quarantine regulations with regard to soybean rust. To say the least we feel that the imposition of these regulations was ill conceived. Certainly, soybean rust was found in the Ord in the 1983/84 season on a crop of Durack soybeans under cool, cloudy conditions in late May. Further, it has been recorded previously in the Northern Territory in the 1970/71 season but has not been recorded in crops since then. We believe it is probably latent in the region and will emerge on susceptible cultivars under cool, cloudy conditions.

The likelihood of such conditions occurring during the growing season in the NT are quite remote. Regardless, if they do occur soybean rust is likely to occur whether we have seed from the ORIA or not.

Although our cultivar evaluation program was limited during this period of research we do not believe we have neglected the importance of well adapted cultivars. The attached publications (Beech *et al*. 1985a,b) clearly show that comprehensive genotype studies for tropical Australia have been conducted. Further, we have maintained close contact with agencies conducting genotype evaluation and breeding programs on soybeans in the tropics. At this stage we can confidently say that there are no genotypes better suited to our cropping situation than the semi-determinant P lines, such as Buchanan. This is not to say that better genotypes will not emerge in future, they most certainly will. It is our strong recommendation that close contact be maintained with introduction and breeding programs in other tropical areas, and particularly with the CSIRO program now being carried out in the Burdekin.

There are two other aspects that we believe warrant immediate attention. Firstly, the problem of legume weeds (Vigna sp., buffalo clover, cowpeas) in soybean and other legume crops. This has been stressed in two ADMA monitoring reports (Price and Garside 1983, 1984) and is a problem that we believe will become worse. Research into this problem is now commencing and we strongly urge it be given high priority. Secondly, we feel that research into insect pests and the effect they are having on grain yield is an important requirement. The highest experiment yield recorded in these studies was 4.6 t ha^{-1} (Section 4-2, table 1). However, in a crop x environment experiment in 1983/84, Buchanan soybeans that were sprayed every week during the growing season yielded in excess of 5 t ha^{-1}. Plot yields from other adjacent experiments which were sprayed only three times during the season were 3.5 t ha^{-1}. We are not advocating spraying for insect control on a weekly basis but suggest that considerably more losses than originally thought may be occuring through insect damage. This requires evaluation.

There are obviously other research areas and certianly follow up work is required on some of the research reported in these studies. More work is required on zinc and we feel that follow up work on phosphorus with other crops and sites is warranted. Sources of sulphur also requires evaluation, as does the efficacy of herbicides.

CONCLUSIONS

We feel that the results reported here, combined with research conducted in the ORIA, provide adequate information to reliably produce soybeans on the Tippera clay loam, if, and only if, adequate supplies of good quality planting seed can regularly be acquired. Efforts to obtain such supplies should be given the highest priority. Attempts to grow soybeans on sandy surface soils should be discouraged at this stage.