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Cereal, pasture legume and water supply prospects at Forrestania : results of experimental work east of Hyden, Western Australia

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by J. W. Gartrell, M. G. Mason, W. J. Toms, T. E. McDowell and I. A. F. Laing

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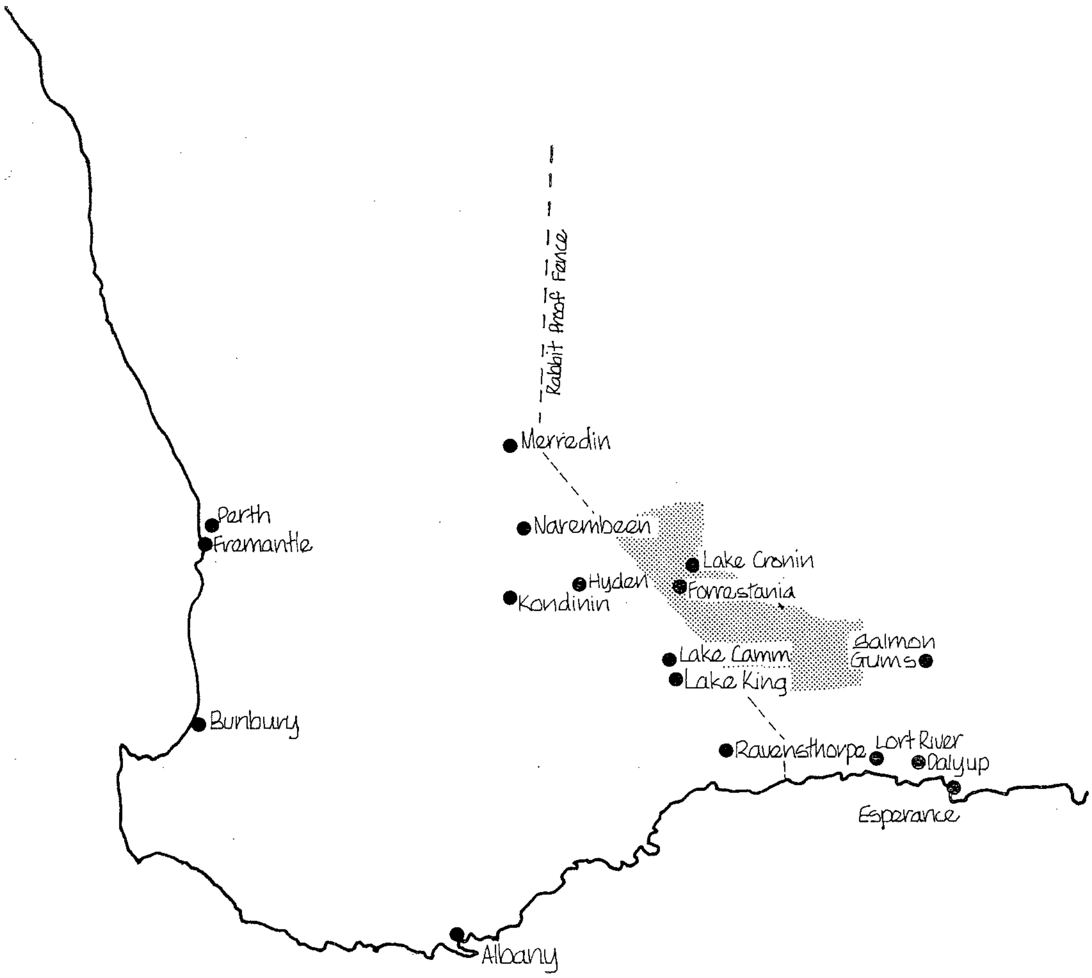

Figure 1—Map of the South West of Western Australia showing the location of the '3500 Farms Scheme' of 1926.

INTRODUCTION

In the late 1920's the 2.8 million hectares of virgin land between Hyden and Salmon Gums were considered for settlement under the "3,500 farms scheme" (Figure 1) because it constituted "practically the only large area of wheat lands in a suitable climatic zone not then settled in Australia" (Teakle, 1939). At that time the sandy scrub-plain was more a liability than an asset because methods of profitably farming the light soils had not been evolved. The scrubplain soils merely increased the distances between patches of more fertile soils. A scheme for settlement was based mainly on the potential of heavy woodland soils, with limited use made of clay based mallee soils on which yields quickly dropped off after a small number of cereal crops (which more recent experience suggests was caused by nitrogen deficiency).

Woodland soils constituted only about 30 per cent. of the total area, with a further 30 per cent. of the woodland soil area deemed unsuitable for normal cropping because of excess soil salt. Despite the fact that only about 25 per cent. of the total area was considered sound for intensive cereal cropping and an additional 20 per cent. for extensive grazing, Teakle concluded there seemed no reason from the standpoint of soils why settlement should not spread across the area should there be an economic urge for increased wheat and wool production after consolidation in previously settled areas.

In the 1950's and 1960's, until the introduction of wheat quotas in 1969, there was a strong demand for all types of virgin agricultural land and strains of pasture legumes had been found which could flourish on many of the sandy soils in dry areas. Some farmers found they could successfully grow these pasture legumes and sowings of pasture legumes increased. The price of fertiliser nitrogen also dropped to a level at which its use on light land cereal crops was clearly economic.

These two factors, together with earlier discoveries of the need to apply copper and zinc, and high rates of phosphate fertilisers, allowed scrubplain soils to be farmed at a profit by some but not all farmers.

Vacant land east and west of the No. 1 Rabbit Proof Fence in the Hyden-Forrestania area (Figure 2) is characterised by large unbroken tracts of yellow sandy soils. Although having similar rainfall and soils to nearby settled areas the land is still unalienated.

Because farmers in nearby settled areas were interested in the possible development of the Forrestania area for cereal and sheep farming the area was inspected in 1958. Major findings (Burvill, 1958) were that:—

- Vacant scrubplain land within 50 km of Hyden amounted to about 40 000 ha (mostly since released by the Crown) with at least 200 000 ha of similar land in a strip between Lake Cronin and Lake Camm.

- Between Hyden and Merredin, farmers with similar soils usually obtained 540 to 1 000 kg grain/ha on newly cleared land but often only 470 to 800 kg/ha after intensive cropping. Pasture legumes were not being grown successfully and stocking rates were low at about 0.8 sheep per ha. Also, scrubplain was being farmed successfully only in conjunction with more fertile heavy textured forest soils.

  As heavy textured soils were almost non-existent east of Hyden, there were therefore potential farm problems because means of economically maintaining fertility of scrubplain soils in the eastern wheatbelt had not been proven. The early maturing Geraldton subterranean clover was not available until 1960 and the fact that molybdenum deficiency reduced the chances of establishing clovers on most of this type of light land was not recognised until 1964/65. Fertiliser nitrogen, the alternative means of maintaining soil fertility, cost twice as much per unit in 1958 as in 1970.

- Prospects for providing adequate stock and domestic water were thought poor because potential dam sites appeared to be separated by considerable distances.

- The climate could not be closely compared with settled districts because of the lack of rainfall records from the area. It seemed likely however that annual rainfall on the western edge would be little less than Hyden's 330 mm while the eastern section would receive 12 to 25 mm less.

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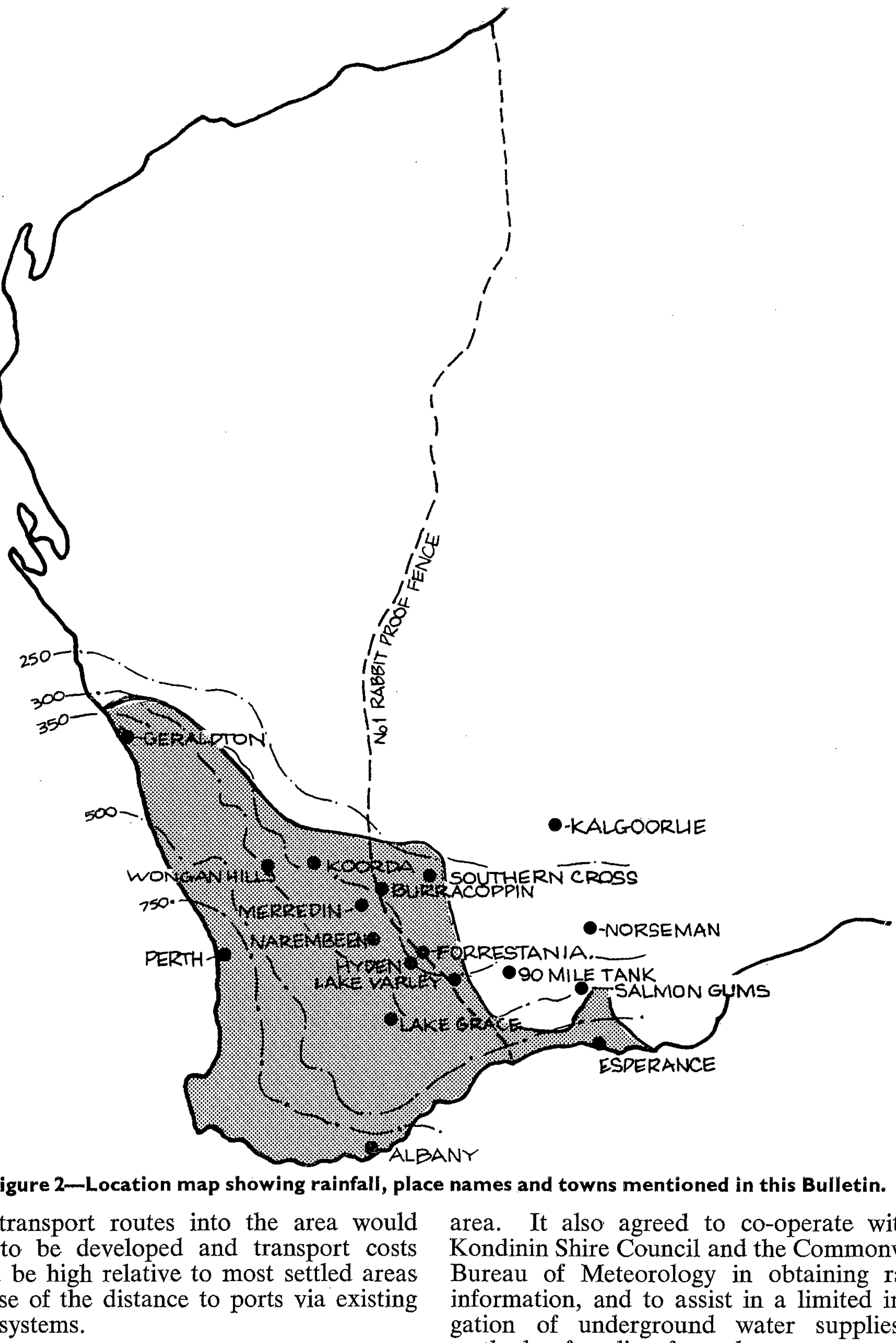

Figure 2—Location map showing rainfall, place names and towns mentioned in this Bulletin.

- New transport routes into the area would have to be developed and transport costs would be high relative to most settled areas because of the distance to ports via existing road systems.

In spite of the disadvantages, the agricultural potential and size of the region caused the Department of Agriculture to establish an experimental area to study the performance of cereals and pastures over a number of seasons under conditions representative of much of the area. It also agreed to co-operate with the Kondinin Shire Council and the Commonwealth Bureau of Meteorology in obtaining rainfall information, and to assist in a limited investigation of underground water supplies and methods of sealing farm dams.

This Bulletin draws together technical information relating to the agricultural potential of the Forrestania region. Broad economic and social aspects of possible agricultural developments are not considered.

FORRESTANIA SITE

To achieve these aims a four hectare experimental area of yellow sandy scrubplain was cleared and fenced in 1959, 11 km east of the Rabbit Proof Fence on the Hyden-Norseman road. The Forests Department also planted a range of shrubs and trees on a 5 hectare site adjoining the experimental area. This was enlarged by a further four hectares in 1965. Soil at the site was considered as typical of the dominant soil type in the area and is discussed in Appendix 1 (which includes Table 1—Soil analysis.)

NINETY MILE TANK SITE

To obtain factual information on plant performance in that part of the area most distant from settled districts two new experimental sites were established in 1968 near the Ninety Mile Tank, half way between Salmon Gums and Hyden (Figure 2). Rainfall figures collected here since 1963 suggested the long term average to be just over 305 mm with a flatter winter peak than Hyden but sharper than Salmon Gums.

Near the Ninety Mile Tank many of the major soils appeared identical with those on the Salmon Gums Research Station or the plots east of Hyden. However, there were large areas of two soil types which did not occur at these places. These were sands and gravelly sands containing less fine material than the loamy sand at the east Hyden plots, and heavy brown soils which appeared more similar to the heavy soils of the eastern wheatbelt than those at Salmon Gums. Experimental sites were located on each of these two types of soil. Rainfall for the site area is summarised in Appendix 2 Table 4.

Development procedures at the Ninety Mile Tank site indicate necessary agricultural preparations in the region.

The sites were logged in October 1967 and burnt on February 27, 1968. The 1968 experimental sites were ploughed April 18 and 19 rootraked April 24 and sown by drill on May 7 to 9. Experiments were harvested November 19 and 20 using a 1.8 m autoheader. For land preparation for the 1969 sowings, the fallowed areas were ploughed in November, 1968 and the non-fallowed areas scarified on April 28, 1969. First year cereal crops were sown between May 6 and 8. Areas sown to second successive cereal crops were burnt late March, scarified May 8 and seeded on May 20.

Where pasture legumes were sown on stubbles, the areas were burnt in March, scarified late March and sown May 6 to 8.

RESULTS AND DISCUSSION

FORRESTANIA SITE

Wheat yield levels

All trial results are tabled in Appendix 3. The highest yielding wheats—Bencubbin, Gabo, Gamenya, Insignia and Heron—when grown on fallowed new land with 202 kg/ha superphosphate, adequate copper and zinc but no nitrogen fertiliser, produced 1 210 to 1 480 kg/ha in five seasons, 874 kg/ha in 1963 and 1 748 kg/ha in 1962.

Wheat yields of 940 to 1 480 kg/ha were obtained in 1964 from the fifth (Table 2) and fourth (Table 3) successive crops with no nitrogen fertiliser.

The usual expectation for fourth and fifth successive crops grown without nitrogen fertiliser on eastern wheatbelt scrubplain is 470 to 806 kg/ha and high yields obtained in the trials indicate higher than average reserves of soil nitrogen in the initial trial area.

Tables 2 to 6 show variety comparisons in different trials. Gamenya is currently the best variety for most conditions in the Hyden area because it combines high yield with superior quality and some resistance to prevalent stem rust strains. However, the taller Bencubbin has an advantage on new land where leaves from mallee regrowth must be kept out of harvested grain.

Fertilisers

Superphosphate

Tables 8 and 9 show results of trials in the initial trial area where 180 kg/ha superphosphate appeared to give maximum yields.

On the more gravelly second experimental site, 270 to 314 kg/ha superphosphate was required (Table 7).

First crops on newly cleared scrubplain soils throughout the eastern wheatbelt usually give most profitable results with 224 to 280

kg/ha superphosphate. The rate can then be reduced by 11 to 22 kg/ha with each successive crop because of the residual effectiveness of earlier applications.

Copper and zinc

Copper deficiency was most obvious in wheat compared with oats or subterranean clover, but zinc deficiency was more apparent in oats and clover than wheat.

Experiments in the Hyden district have shown that bluestone 5.6 kg/ha and zinc oxide 0.84 kg/ha are sufficient to correct deficiencies on virtually all scrubplain soils but at the Forrestania site 2.8 kg/ha bluestone provided adequate copper (Tables 10 to 16).

Nitrogen

Response of cereal yields to fertiliser nitrogen was extremely inconsistant, as shown in Tables 2 to 7, similar to the variability encountered in other trials on scrubplain soils throughout the eastern wheatbelt. On average, and at 1970 prices, the use of 16 to 20 kg/ha nitrogen (equivalent to 34 to 45 kg/ha urea) has been profitable for first crops on fallowed land. On non-fallowed land, or consecutive wheat crops on new light land, 20 to 25 kg/ha nitrogen (45 to 56 kg/ha urea) has been profitable. The benefits of a fallow period are highlighted in Table 6.

Molybdenum

Molybdenum clearly resulted in improved clover growth and nitrogen content, e.g. Tables 20a and b. Wheat yields were not immediately increased by molybdenum application (Table 6) although vegetative growth improved slightly in some instances and grain molybdenum levels were below 0.10 ppm Mo, the level at which responses are usually recorded in the Western Australian wheatbelt. The improvement in nitrogen fixation by clovers following molybdenum application would however increase the yield of subsequent wheat crops in an intensive cropping system.

Pasture legumes

Varieties tested in trials planted between 1960 and 1966 were:—

Subterranean clovers: Carnamah, Geraldton, Dwalganup and Northam A.

Rose clovers: Sirint, Troodos, Kondinin, and an imported commercial mixture.

Cupped clovers: Beenong, Yamina.

Annual medics: Harbinger, Cyprus barrel, Commercial barrel.

Lupins: Crossbred 10/54-1-10 x Box's (W.A. Univ.), Crossbred 10/54-1-10 (W.A. Univ.), Box's, W.A. Blue, N.Z. Blue, Borre, Weiko.

Serradella: W.A. (yellow flowered or Pittman's).

Lucerne: Hunter River.

Kondinin rose clover and W.A. serradella were consistently superior to other varieties tested. First year stands of W.A. serradella were sparse because of low percentage germinations, but second year and subsequent stands were dense. The four best pasture legumes maintained dense swards which yielded about 3.7 tonnes/ha dry matter ungrazed (Tables 18 and 19) indicating a carrying capacity of at least 3.7 sheep per hectare in 1965 and 1966.

Lupins grew vigorously for the first two seasons but a fungal disease appeared in the third season and killed most seedlings within six weeks of germination.

Lucerne established well but was planted only in one year when unusually heavy rains were recorded the following summer. Its ability to establish in years with dry summers needs further testing. Once established, the lucerne grew well through several winters with little plant mortality in summer stress periods.

Other legume varieties tested set seed each year but were not impressive.

Fertilisers for legume pastures

Provided copper, zinc and molybdenum were applied with a preceding crop, the only fertiliser required by legume pastures was superphosphate. After two successive crops which received a total of 336 kg/ha superphosphate Geraldton subterranean-clover required 134 kg/ha superphosphate drilled with the seed for near maximum growth of a first year stand. Subsequently, 224 to 270 kg/ha topdressed superphosphate was required annually for maximum yields.

Less productive but reasonably dense clover stands were maintained with 134 to 170 kg/ha superphosphate each year but lower rates resulted in unsatisfactory pastures.

Inoculation and lime pelleting

Inoculation and lime pelletting were essential when planting pasture legumes to allow development of the root nodules needed to provide the nitrogen necessary for pasture growth and fertility build-up.

Planting time

Good pasture establishment was achieved, even in years of low rainfall and short growing season, by planting in early May without a cereal cover crop.

Weeds

Cotton fireweed (*Senecio quadradentata*) occurred as an insignificant native plant in virgin scrub but quickly invaded pasture trials. Effective control measures are outlined in the Department of Agriculture's Bulletin No. 3081.

Annual (Wimmera) rye grass became a serious weed in cereal experiments following its introduction as a pasture plant and its subsequent spread over the whole area. In areas where cereals are to be grown it appears inadvisable to introduce this rye grass because of the expense and difficulty of controlling it.

CLIMATIC NOTES

Appendix 2 contains climatic data including rainfall recorded at gauges in the Forrestania area and Hyden since 1960, the frequency with which various quantities of rain were recorded at Hyden since 1929, and length of growing season, evaporation and rainfall of Hyden compared with other selected stations in settled parts of the Western Australian wheat growing region.

Since 1960, April-October rainfall recorded at the plots and the crossroads has on average exceeded that at Hyden by approximately 25 mm, while a gauge in sandplain 34.6 km ENE of the crossroads has averaged about the same as Hyden since recording commenced in late 1963. This recent experience suggests that climate of the Forrestania area would in all respects be similar to Hyden. Based on available Hyden records, the Figure in Appendix 2 shows that the area can expect 23 droughts, (years with April-October rainfall 152 mm or less) in every 1 000 years and an additional 45 seasons with 178 mm or less in the April to October period.

The frequency of various types of opening and finishing rainfall sequences can be calculated from the data in Appendix 2. September rainfall exceeds 25 mm and October rainfall exceeds 19 mm more frequently at Hyden than at Merredin, and more frequently at Merredin than at Burracoppin.

Appendix 2 also shows that the average calculated length of the growing season at Hyden is similar to that of Wongan Hills which is considered a sound wheat producing district. With rainfall and evaporation at Forrestania likely to be similar to that at Hyden, the climate of the Forrestania area must therefore be considered more favourable for wheat production than many settled parts of the eastern wheatbelt.

Soils

The soil of the first four hectare area was a yellow sandy earth with a sandy surface grading into a loamy subsoil. A profile from this area was:

0-127 mm —	yellow brown loamy sand;
128-610 mm —	yellow loamy sand grading into sandy loam;
611-838 mm —	mottled yellow sandy loam with soft ferruginous aggregates.

Significant features of this soil which make it a good medium for plant roots in the Forrestania environment are:

- A highly permeable coarse textured surface with a low water holding capacity which permits rapid penetration of rainfall to the root zone and reduces evaporative loss from the root zone. Run-off losses from even moderately heavy falls of rain are negligible.
- Because the subsoil contains up to 24 per cent. by weight of particles of clay size, it could hold important quantities of moisture in the root zone which could tide plants over dry periods. The water holding capacity was probably about 4.16 per cent. H_2O (by weight).
- The soil profile contained no barrier to root or water penetration to at least 2.1 m. Consequently there was no waterlogging in wet winter periods and there was a large volume of soil from which plants, depending on their root habit, could extract soil moisture.
- Leaching losses of nutrients are reduced by clay particles capable of absorbing nutrients onto their surfaces.

While soils with the above characteristics predominate in the Forrestania area, sandier variants (called yellow earthy sands) with less favourable properties for plant growth, also occur.

Soil at the second four hectare experimental sandy surface had a hard coarse ferruginous gravel in a yellow loamy sand matrix below 150 mm. By reducing the water holding capacity and the ability of plant roots to penetrate to depths, the presence of large quantities of gravel in the subsoil suggests that soil at the second area would provide less moisture and

nutrients to plants than soil of the first area. Similar soils commonly occur on ridges and other erosional surfaces throughout the district.

Vegetation

Vegetation where gravel occurs near the surface is mainly heath with small acacias, casuarinas, banksias and scattered mallee, all usually less than 2.5 m tall. Where gravel is absent from the surface 0.3 to 1 m, mallee is less abundant and flame grevilleas (*Grevillea excelsior*) up to about 4.5 m tall are a feature.

Appendix 1, Table 1, contains data relating to the physical and chemical composition of the soil of the first area. The Figure in Appendix 1 shows the distribution of dominant soils throughout the region.

District yield potential

In the seven seasons 1960 to 1966, wheat on new fallowed land at the Forrestania plots averaged more than 1 200 kg/ha grown with 224 kg/ha superphosphate, adequate copper and zinc, but without nitrogen fertiliser.

The district could expect to average about 1 075 kg/ha wheat from the scrubplain, including that from smaller areas of soils poorer than those of the plots, provided farmers adopted the same techniques used in the experiments. Fertility of the scrubplain soils could be raised further by growing dense subterranean clover pastures, or maintained by fertiliser nitrogen. Crops grown on scrubplain in a clover ley rotation have a higher potential for yield than new land provided weeds and crop diseases are controlled and planting is completed by mid-June.

Dense subterranean clover pastures capable of carrying 1.8 and 3.7 sheep per hectare depending on seasonal conditions can be established by proven methods.

Because most farmers in the Lake Camm-Narembeen area averaged less than 940 kg/ha wheat from their scrubplain crops between 1960 and 1966 it may be thought that 1 075 kg/ha is too much to expect from the Forrestania scrubplain. While precise information on farmer practice in the region is not available, general experience suggested that:—

- A number of farmers used no more than 144 kg/ha superphosphate compared with the 224 kg/ha which has been found more profitable. Also, some may not have used any copper-zinc fertiliser on their new land.
- Not all farmers allowed a September to May fallow when preparing their new land, although a fallow period would 'pay' provided the farmers' resources could be profitably employed elsewhere in the first season.
- Animals, and often the farmers' own sheep, are sometimes allowed to graze crops in winter, so markedly reducing grain yields.
- The common practice of undersowing 1 or 2 kg of clover seed in the hope of establishing pastures cheaply in the cropping year reduces grain yields by 130 to 250 kg/ha. The clover stands produced are also often poorer than those from pure sowings because the cereal crop greatly reduces the amount of seed set by the undersown clover.
- Shedding of farm cereal crops could be higher than from experimental plots because of smaller losses from better adjusted harvesters.
- Not all farmers used the high yielding cereal varieties Gabo, Gamenya and Bencubbin.
- Some farm crops were sown too deep (more than 50 mm), particularly where new land was roughly prepared. The resulting delayed or reduced emergence produced lower yields.

Highest cereal yields usually result from early plantings provided there is no false break to the season but obviously the area any farmer can plant early is limited by the amount of machinery and labour at his disposal. Although some farmers are better managers than others there will always be some crop planted later than desirable and this will reduce the average yield figure for the district by an unpredictable amount. In the Hyden area, crops planted before the third week of May have a higher yield potential than later sown crops provided weeds are controlled.

A few farmers topdressed superphosphate fertilisers before seeding without doubling the rate used as recommended, resulting in low yielding, phosphate deficient crops. (Note: 448 kg/ha phosphate topdressed is approximately equally effective for crops as 224 kg/ha drilled.)

Seasonal variation and yields

The Hyden and Forrestania areas appear to have similar climates, and Hyden records since 1929 suggest that the Forrestania area could expect less than 208 mm of rain between April and October in about 50 per cent. of years.

However, between 1960 and 1966 only two seasons registered less than 208 mm at the plots. In each of these years, 1961 and 1962, April-October rainfall amounted to about 178 mm.

Table 1. Yields of wheat and oats according to growing season rainfall and cultural history.
(Based on experimental results with 220 kg/ha super phosphate, adequate copper and zinc, no nitrogen feriliser)

Season	Rainfall mm	Gabo and/or Gamenya Wheat kg/ha		Kent oats kg/ha	
		1st crop on fallow	2nd successive crop	1st crop on fallow	2nd successive crop
1962	177	1 749	1 681	1 524	897
1961	182	1 211	1 143	807	807
1960	279	1 211	....	1 659	....
1966	294	1 211	1 211	....	....
1964[1]	330	1 412	....	1 524	....
1963[2]	366	874	740	717	717
1965[3]	374	1 480	....	....	....

1. Estimate based on 3rd, 4th and 5th successive crops planted 1964.
2. Estimate based on 2nd, 3rd and 4th successive crops planted 1963.
3. Estimate based on 1st crop on non-fallow planted 1965.

Hyden records show the expectation for less than 165 mm is about 4 per cent. of years and that for about 180 mm is about 93 per cent. of all years. Thus 1961 and 1962 were dry seasons, but about four even drier seasons occur every 100 years (Figure, Appendix 2).

Wheat yields obtained in 1961 and 1962 (Table 1) are noteworthy on two counts, the first being that the 1 747 kg/ha obtained in 1962 was higher than yields in any of the other six years. The second count is that although April-October rainfalls in 1961 and 1962 were almost the same in total, 1961 wheat yields were about 540 kg/ha less than those in 1962. This difference was attributed to the better distribution of rainfall throughout the 1962 season compared with 1961, as techniques and the soil type involved in both years were almost identical. The wheat germinated in mid-May 1962 while dry May conditions prevented wheat from germinating until June in 1961. Finishing conditions too were better in 1962 than in 1961.

Total April-October rainfall in 1960 and 1966 was 280 to 292 mm. In both years first wheat crops after clearing yielded 1 210 kg/ha, the same as in 1961. In the high rainfall years, 1964 and 1965, wheat yielded 1 411 to 1 478 kg/ha, while in 1963, also a high rainfall year, wheat yield was only 874 kg/ha as a result of an epidemic of wheat stem rust.

It is concluded that the consistently good wheat yields obtained were not merely the result of an unusual sequence of wet seasons as evidenced by the 1961 and 1962 results.

Transport routes

Straight-line distances between the experimental site and ports are: Esperance, 257 km; Albany, 322 km; Fremantle, 370 km; Bunbury, 386 km. Esperance is the nearest port but the distance via a connecting link to existing roads through Lake King is 370 km.

The agricultural potential of the large vacant area south of the Johnston Lakes appears to at least equal that of the Forrestania area. If the Forrestania area is to be developed for agriculture, it seems logical to develop all the area between Forrestania and Esperance, although an entirely new road system would be necessary. A highway from Forrestania to Native Dog Camp on the Lort River, and then connecting with the Ravensthorpe-Esperance road at Dalyup, would bring Esperance considerably closer and serve as an artery for the development of the area south of the Johnston Lakes (Figure 1). Esperance to Perth via Hyden would then be about 50 km less than the present shortest practical route.

Water supplies

Underground supplies

Surveys in the eastern wheatbelt have shown that only one bore in seven or eight is successful. In 1963, the Geological Survey of Western Australia sank five exploratory bores within a 3 km radius of the plots. No bore produced a satisfactory stock water supply (Berliat, 1963) and this limited experience suggests prospects for underground water in the Forrestania area are no better than in other parts of the wheatbelt. At least 30 additional holes would be required before a firm conclusion was possible.

Excavated dams

Suitable dam sites are uncommon in the scrubplain but may occur where gravel is underlain by good clay. In other parts of the state such clays sometimes fail to hold water because although the yellow sands usually increase in clay content with depth they remain permeable. Dams in the yellow sands are thus likely to fail unless suitably sealed.

A dam at the experimental site constructed and lined with "Rivaseal"* in early 1968 successfully held water in the 1968-69 summer. Such linings should last at least 15 years although costing three times as much as a normal dam of the same capacity.

Roaded catchments constructed on yellow loamy sands would be sufficiently effective to ensure replenishment of lined dams in most years.

* "Rivaseal" is a waterproof membrane composed of a polyester and glass fibre mat in bitumen.

SUMMARY OF EXPERIMENTAL RESULTS AT 90 MILE TANK SITES

Details and comments relating to experimental areas and trials at the 90 Mile Tank site are contained in Appendix 4. The summary below highlights major findings.

Cereal yields were measured from plots on heavy and light land sites at the 90 Mile Tank in two seasons, 1968 and 1969. In the absence of serious weed, insect, vermin or disease problems, and with early planting of selected varieties by sound techniques, it is thought that the physical environment will be the major influence restricting yield levels.

Given adequate nutrition the estimated yield potentials were as shown in Table 2.

Based on urea costing $79 per tonne at gate and wheat priced at $41 per tonne at gate, the most profitable rates of urea and superphosphate found during the two seasons is suggested in Tables 3 and 4 (1971 prices).

Table 2.—Yields of Gamenya wheat (kg/ha) where adequate nitrogen and phosphorus fertilisers were applied 90 Mile Tank Site.

Soil	Non fallow		Fallow 1969	2nd successive crop 1969
	1968	1969		
Light land	1 930	1 009	1 076–1 549 *	841†
Heavy land	1 480	1 009	1 547	1 009

* Variation depended on location of different trials within the light land area.
† Self sown in this trial increased the effective plant density to the equivalent of more than 134 kg/ha seed which aggravated the degree of moisture stress in this dry season.

Table 3.—Rates of urea (kg/ha) found most profitable under various conditions.

Soil	Non fallow		Fallow 1969	2nd successive crop 1969
	1968	1969		
Light land	90	33·6	33·6	135*
Heavy land	45	0	34	90

* Overall yield level so low that the whole cropping operation would probably have been commercially unprofitable.

Table 4.—Profitable of superphosphate rates (kg/ha) in 1968 and 1969.

Soil	1968	1969
Light land	202 or 235	235 better than 202
Heavy land	67	101 not obviously worse than 135

The trace element requirement of crops and pastures has been relatively low. On light land, zinc oxide at 0.84 kg/ha increased wheat yields by 101 kg/ha compared with wheat planted without zinc oxide. Molybdenum application slightly increased the growth and greenness of subterranean clover on the light land.

A low rate of copper (2.8 kg/ha bluestone) would probably be needed as insurance against copper deficiency in crops and animals on the light land but this was not shown in the single wheat experiment planted in 1968. Nor were clear benefits shown from the use of copper, zinc, molybdenum or manganese on the heavy land site. Using inoculated and lime pelleted seed, the growth and nodulation of various pasture legumes was satisfactory, although the growth of these legumes on the light land site in the second year was slightly better where either lime or muriate of potash was used. Because this effect of lime and muriate of potash was not additive it seems likely that the different materials were acting on the same unidentified growth factor.

CONCLUSIONS

The agricultural potential of the Forrestania area appears at least equal to that of much of the settled eastern wheatbelt. The scrubplain soils of the Forrestania area have an average yield potential of at least 1 000 kg/ha wheat and carrying capacity of 1.8 to 3.7 sheep per hectare on improved pastures. The use of clover ley rotations would maintain these levels of potential yield.

As the climate is similar to that of Hyden, partial crop failures caused by adverse seasonal conditions could be expected 10 years in every 100.

Underground stock water is likely to be confined to small, poorly distributed localised basins which are hard to find. In the scrubplain, lined dams, although expensive, offer the best means of ensuring a well distributed supply of stock water. Heavy soils of the lower valleys may provide excellent dam sites provided rising saline water tables can be avoided, but heavy soils are not found in much of the area. Roaded catchments to all dams would be advisable unless adequate run-off is assured by other features such as roads or granite bosses.

Development of the country south of Lake Tay would increase the feasibility of a direct road route to Esperance. This would reduce the distance to 280 km from the 370 km by the shortest existing route.

The climate of the area around the 90 Mile Tank site is more like that of Salmon Gums than of Forrestania. Thus while light land at the 90 Mile Tank area may have a similar agricultural potential to that at Forrestania and Hyden, heavy soils without a salt problem will have the potential of similar soils in the Salmon Gums district.

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Chemical analyses were carried out by officers of the Government Chemical Laboratories.

The conduct of the Ninety Mile Tank trials would not have been possible without the full support of many individuals. These included the managers of Salmon Gums and Newdegate Research Stations and officers of the Division of Regional Services stationed at Esperance and Lake Grace who supervised field operations.

The Division of Plant Research was responsible for programme design, interpretation and general administration.

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REFERENCES

Berlait, K. (1963).—Report on Exploratory Drilling for Ground water in the Sandplain Country 40 miles East of Hyden. Records of the Geological Survey of W.A. No. 1963/17.

Bettenay, E., and Hingston, F. J., (1961).—The Soils and Land Use of the Merredin Area, Western Australia. CSIRO. Soils and Land Use Series No. 41.

Burvill, G. H. (1958).—Inspection of the Hyden-Forrestania Area—October 1958. W.A. Department of Agriculture, Plant Research Division, Unpublished Report.

Northcote, K. H., Bettenay, E., Churchward, H. M., and McArthur, W. M. (1967).—CSIRO. Atlas of Australian Soils, Sheet 5 and Explanatory Data.

Teakle, L. J. H. (1939).—The soils of the 3 500 Farms Scheme Area, Western Australia. J.Ag.W.Aust. (2nd Series) **16:** 202-30.

APPENDIX I—SOILS

On the next page is an enlargement from the Atlas of Australian Soils, Sheet 5. The mapping units are called "soil associations" which usually include several distinctly different individual soil types which are dominant in extent and overall influence in that association.

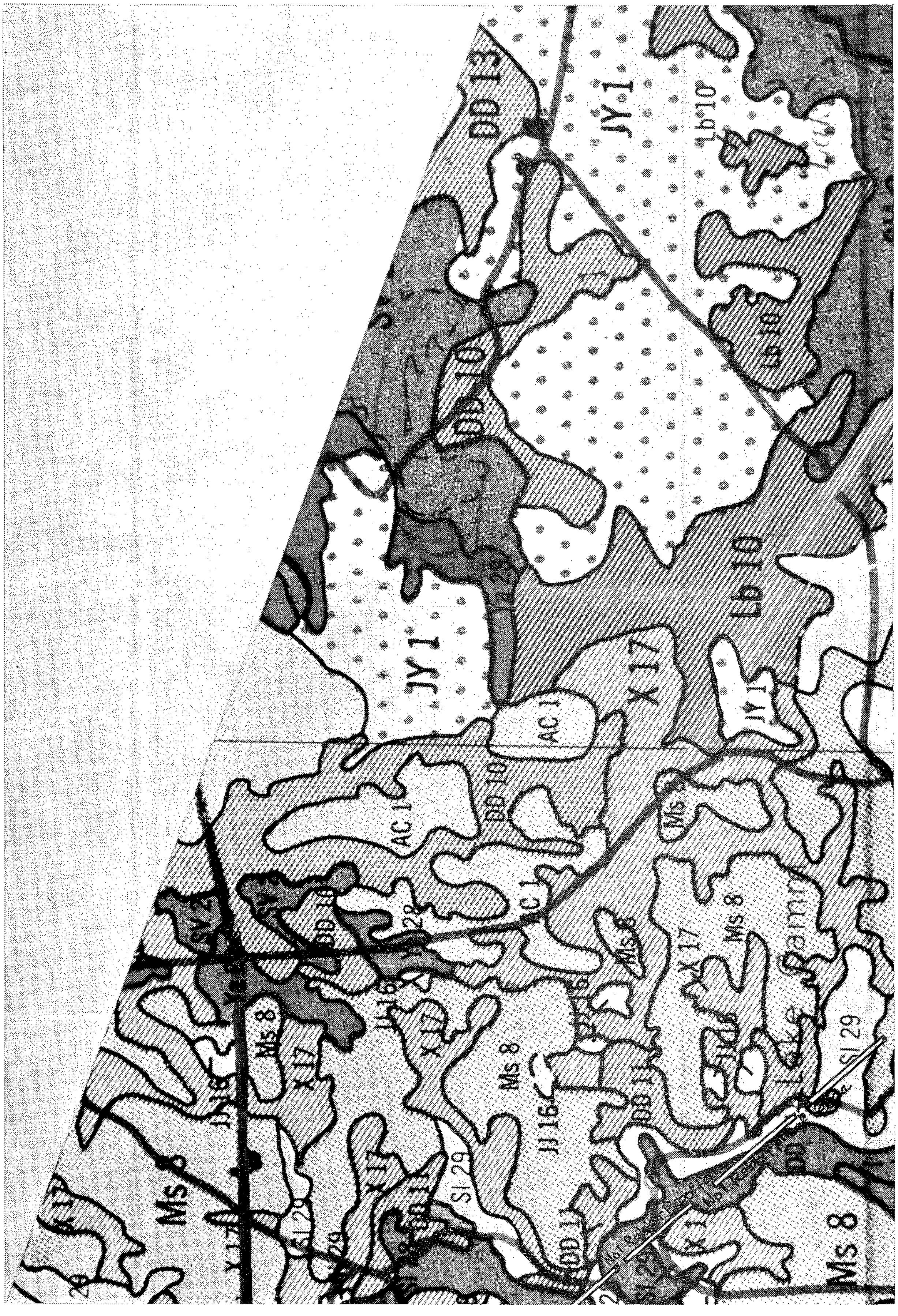
Thus the map of soil associations gives an *overall picture of the distribution of the dominant soils of the region* but it must be borne in mind that many dissimilar soil types may occur within areas mapped as a single entity.

The map shows the belt of sandplain which extends about 32 km north of the experimental area and about 64 km south of the plots to east of Lake Camm. The belt is approximately 32 km wide. In the valleys and lower slopes between sandplain areas the main soils are grey to brown sands overlying clay at various depths and supporting a mallee vegetation. Within the sandplain areas but not mapped separately are scattered granite rock outcrops surrounded by shallow gritty and brown loamy soils of limited extent.

The main soil of the sandplain in the vicinity of the plots is a yellow loamy sand in which the clay content gradually increases with depth (this soil type is also called a yellow sandy earth). Ironstone gravel usually occurs within 0.6 m of the surface. Yellow soils with less clay in the profile (yellow earthy sands) also occur. Greyish brown gravelly sandy earths and gravelly earthy sands are occasionally found, mainly towards the tops of rises. Closely similar soils occur in the Merredin district and have been described in detail as the Norpa series (the yellow earths) and Ulva series (the gravels) by Bettenay and Hingston (1961).

Table I.—Analytical data of a sample profile from the first four hectare experimental area.

	Depth (cm)		
	0–13	14–61	62–84
Mechanical analysis (%)			
Gravel	0·5	0·0	0·2
Coarse sand	54·0	52·0	50·3
Fine sand	26·5	25·0	22·3
Silt	2·7	6·0	2·7
Clay	16·3	17·0	24·5
pH	5·6	5·5	5·2
Exchangeable cations (m.e./100g)			
Calcium	1·6	1·0	0·5
Magnesium	0·8	0·4	1·0
Potassium	0·3	0·3	0·1
Sodium	below 0·1	below 0·1	below 0·1
C.E.C. at pH7	3·3	2·8	2·8
Per cent total bases			
Calcium	59	59	31
Magnesium	30	23	63
Potassium	11	18	6
Sodium	below 1	below 1	below 1
Organic carbon (%)	0·79	....	....
Total nitrogen (%)	0·032	....	....
C : N ratio	24·7	....	....
HCl soluble			
K_2O (%)	0·058	....	0·073
P_2O_5 (%)	0·004	....	0·005



DD 13
JY 1
Lb 10
JY 1
X 17
AC 1
DD 10
AC 1
Ms 8
X 17
SI 29
JJ 16
Ms 8
Ms
Ms 8

Key and explanatory notes to figure

Soil Association Map Unit/Dominant Soil	Description
Ms 8 Yellow sandy earth .... (Gn 2.21) Forrestania plots situated on this soil type	Gently sloping to gently undulating plateau areas or uplands with long and very gentle slopes and, in places, abrupt erosional scarps: chief soils are (i) on depositional slopes, sandy yellow earths (Gn 2.21 and Gn 2.22) containing some ironstone gravels, and yellow earthy sands (Uc 5.22) often with ironstone gravels at depths below 6–7 ft; and (ii) on erosional ridges and slopes, ironstone gravels (KS-Uc 4.11) together with (Uc 4.11) and (Uc 2.12) (both containing ironstone gravels), all underlain by hardened mottled-zone material by depths of 12–24 in. Soil dominance tends to vary locally between (i) and (ii) but overall the soils of (i) seem to have a slight dominance over the soils of (ii). Associated are smaller areas of other soils, such as (Dy 3.82) containing ironstone gravels in its surface horizons. As mapped, small areas of units JJ16, X17, and possibly S128 are included.
JY 1 Yellow sand .... (Uc 4.11) Johnston Lakes light land site on this soil type	Undulating land with small valleys and flats: chief soils are ironstone gravels (KS-Uc 4.11) together with sand soils (Uc 4.11) and/or (Uc 2.12) both containing ironstone gravels on low flat-topped rises. These soils are underlain by hardened mottled-zone material by depths of 12–24 in. Associated are valleys and flats of various (Dy) and (Dr) soils such as (Dy 5.43), (Dy 4.83), (Dy 2.83) and (Dr 3.43) deposits of earthy sands (Uc 5.22) and siliceous sand (Uc 1.22); and flat to gently undulating areas of calcareous earths (Gc 1.12) and (Gc 1.22).
DD 10 Brown calcareous earth .... (Gc 1.12 and Gc 1.22) Johnston Lakes heavy land site on these soil types.	Plains with some clay pans and small salt lakes, dunes, and lunettes: chief soils are brown and grey-brown calcareous earths (Gc 1.12) and (Gc 1.22). All the soils of unit Ya28 are associated, the proportions of each vary greatly within short distances. There are similarities with units Lb10 and DD11. As mapped, areas of adjacent units are included.
X 17 Sands/mottled yellow clay .... (Dy 5.42 and Dy 5.43)	Slopes and valleys: chief soils are sandy neutral and alkaline yellow mottled soils (Dy 5.42 and Dy 5.43). Associated are various related (Dy) soils such as (Dr 5.43); leached sands such as (Uc 2.31); and areas of undescribed soils. There are similarities with unit Va66. As mapped, small areas of units JJ16, Ms8, S128, S129 and DD11 are included.
S1 29 Hard setting loams/yellow clay .... (Dy 2.43)	Plains flanking saline valleys; some local occurrences of small clay pans and lakes with dunes and lunettes: chief soils are hard alkaline yellow soils (Dy 2.43) with low rises of sandy alkaline yellow mottled soils (Dy 5.43). Associated are related (Dy) soils such as (Dy 4.43) and similar (Dg) soils; some (Gc 1.22) soils; and silty (Um) and clayey (Uf) soils on dunes and lunettes. This unit has similarities with unit S128 (the (Dy 2.43) soils) and units Ya30 and Ya28 (the (Dy 5.43) soils). As mapped small areas of unit DD11 are included.
DD11 Brown calcareous earth .... (Gc 1.12 and Gc 1.22)	Very gently undulating plains sloping upwards from the eastern sides of saline valleys: chief soils are brown and grey-brown calcareous earths (Gc 1.12), (Gc 1.22) and (Gc 2.12). Associated are various (Dy) soils, such as (Dy 5.43), which may be very prominent locally and may form complexes with the (Gc) soils; and lesser areas of (Dr 2.33) soils. There are similarities with units DD9, Lb10 and DD12. As mapped, small areas of units JJ16, X17 and S129 are included.

Key and explanatory notes to map 1—*continued*

Soil association Map unit/Dominant soil	Description
Ya 28 Sands/mottled yellow clay .... (Dy 5.43 and Dy 5.83)	Sandy plains with some clay pans and small salt lakes, dunes and lunettes: chief soils are sandy alkaline yellow mottled soils (Dy 5.43 and Dy 5.83). Associated are various (Dr) soils such as (Dr 5.43); more saline (Dy) and (Dr) soils including (Dy 1.43), (Dr 1.43) and (Dr 1.83); some calcareous earths (Gc 1.12) and (Gc 1.22); and various (Uc), (Um) and/or (Uf) soils on small dunes and lunettes. As mapped, areas of adjacent units are included.
Ac 1 Yellow sands .... (Uc 5.22)	Gently sloping to gently undulating plateau areas, or uplands on granites, gneisses, and allied rocks, with long gentle slopes and in places abrupt erosional scarps; some granitic bosses and tors; irregularly traversed by narrow shallow valleys and flats: chief soils are yellow earthy sands (Uc 5.22) and sandy yellow earths (Gn 2.21 and Gn 2.22) on depositional sites, and ironstone gravels (KS-Uc 4.11) together with (Uc 4.11) and (Uc 2.12) both containing ironstone gravels on erosional sites where they are underlain by hardened mottled-zone material. Soil dominance varies locally. Associated are shallow valleys and flats of the various (Dy) soils of unit Ya28; small areas of other soils are likely: This unit has similarities with unit Ms8. As mapped, areas of adjacent units are included.
Lb10 Grey-brown highly calcareous earths (Gc 1.12)	Gently undulating plains with some granitic bosses and tors; acid clays common below depths of 6 ft: chief soils are grey-brown highly calcareous earths (Gc 1.12) commonly in intimate and complex association with hard alkaline yellow and yellow mottled and red mottled soils (Dy 2.83, Dy 3.83, Dy 3.73) and (Dr 3.83, Dr 3.43, Dr 2.33). Associated are smaller areas of sandy yellow and yellow mottled soils (Dy 4.43, Dy 4.83, Dy 5.43 and Dy 5.83). As mapped, areas of units DD12, Ya29 and JY1 are included, as are small areas of many other soils such as those in the vicinity of granitic tors.
DD13 Brown calcareous .... (Gc 1.12 and Gc 1.22)	Gently undulating plains with some gilgai areas, occasionally broken by stony ridges and hills: chief soils seem to be brown and grey-brown calcareous earths (Gc 1.12) and (Gc 1.22) on the local rises and crusty loamy soils (Dr 1.43), (Dr 1.33) and (Dr 1.83) in the intervening flats. Associated are soils of unit BB5 on the stony ridges and hills; areas of other soils, such as (Gn 2.12) with ironstone gravels, and (Dy) soils similar to those of unit Ya28, are likely. Weathering greenstones are common below the (Gc) soils at depths of 3–5 ft.
JJ16 Shallow sand .... (Uc 4.1)	Broken terrain characterized by rock outcrops (granitic bosses and tors) which may cover large areas within the unit: shallow and often stony or gritty sandy soils (Uc 4.11), (Uc 4.33) and (Uc 4.22) form a soil scree around the areas of bree rock. Associated are small areas of many other soils, such as (Dr 2.62) and (Gc 2.22); their occurrence reflects the chemistry of the individual rock outcrop. As mapped, small areas of units Va66 and Ms8 are included.
SV2 Gypseous and saline .... (Um 1.1 and Um 1.2)	Saline valleys with some dunes including barchan forms—salt lake channels, mostly devoid of true soils, and their fringing areas: common soils are gypseous and saline loams (Um 1.1 and Um 1.2) together with grey-brown highly calcareous earths (Gc 1.12). Associated on fringe areas are various (Dy) soils as for unit Ya28; siliceous sand (Uc 1.2) on dunes and lunettes; and other undescribed soils. Deposits of common salt, gypsum, lime and alunite may occur.

APPENDIX 2—CLIMATIC DATA

Table 1.—Rainfall mm recorded at **(a) Hyden**
(b) plots 64km east of Hyden
(c) crossroads 88km east of Hyden
(d) in sandplain 122km east of Hyden from 1960 to 1968.

	April	May	June	July	August	Sept.	Oct.	Apr–Oct	Year
1960–									
Hyden	25	48	30	78	23	29	1	234	341
Plots	46	22	63	30	74	41	2	279	398
Crossroads	58	31	72	41	56	49	1	308	422
1961–									
Hyden	35	7	54	41	33	18	2	190	258
Plots	79	7	41	16	27	10	2	182	262
Crossroads	58	6	44	14	34	10	2	215	264
1962—									
Hyden	0	80	33	22	22	29	13	198	283
Plots	0·5	69	28	24	17	21	18	177	287
Crossroads	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	342
1963–									
Hyden	27	70	80	76	72	17	12	354	485
Plots	21	86	79	76	74	11	19	366	576
Crossroads	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	575
1964–									
Hyden	42	4	62	92	57	35	21	311	371
Plots	22	6	59	122	62	38	22	330	405
Crossroads	25	6	64	124	71	40	22	352	440
East of Crossroads 4km	19	3	56	86	48	42	23	277	399
1965–									
Hyden	8	53	68	52	40	10	46	278	331
Plots	11	—	246	—	50	18	47	372	431
Crossroads	15	—	233	—	52	18	45	364	431
East	13	—	211	—	45	13	41	322	402
1966–									
Hyden	54	3	96	50	22	17	45	287	447
Plots	49	3	64	8	—	57	40	294	412
Crossroads	50	3	72	76	20	13	52	284	399
East	34	3	71	74	20	9	36	246	403
1967–									
Hyden	12	65	35	42	23	6	32	214	249
Plots	16	83	41	51	24	17	40	271	305
Crossroads	13	88	45	45	27	10	37	265	303
East	11	68	34	38	24	8	34	217	280
1968–									
Hyden	29	28	100	25	33	29	12	256	391
Plots	25	36	108	27	43	33	10	281	384
Crossroads	35	36	110	28	50	40	11	307	415
East	30	29	119	22	44	34	11	290	388

* N/A—Not Available.

APPENDIX 3—TRIAL RESULTS FORRESTANIA SITE

Table 1.—Wheat variety trial in first 4 ha area.

Wheat Variety	1964	1965*	Mean
	kg/ha	kg/ha	kg/ha
Mengavi	1 150	847	999
Bencubbin	1 634	1 130	1 382
Wagin	1 298	942	1 120
Falcon	1 506	1 009	1 258
Stockade	995	Not planted	....
Heron	Not planted	1 009	....

Stubble burnt   * Wimmera ryegrass a problem in 1965

Table 2.—Nitrogen on cereal varieties, continuously cropped in first area.

	Ammonium sulphate	1960	1961	1962	1963	1964
WHEAT	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha
Gabo	0 125·5	1 123 1 399	1 197 1 473	1 399 1 466	1 016 1 137	1 345 1 298
Mean		1 261	1 335	1 433	1 076	1 322
Insignia	0 125·5	1 130 1 365	841 1 237	1 170 1 318	504 787	955 1 271
Mean		1 248	1 039	1 244	646	1 113
Wongoondy	0 125·5	1 083 942	847 894	1 042 881	760 800	Not Planted
Mean		1 012	871	962	780	
Gamenya	0 125·5		Not	Planted		1 103 1 466
Mean						1 285
Bencubbin	0 125·5		Not	Planted		1 258 1 116
Mean						1 187
Claymore	0 125·5		Not	Planted		800 726
Mean						763
OATS—						
Ballidu	0 125·5	1 695 1 663	623 812	838 861	816 955	Not Planted
Mean		1 679	717	850	886	
Kent	0 125·5	1 524 1 578	847 1 027	1 004 1 045	915 1 094	933 1 143
Mean		1 551	937	1 025	1 004	1 038
BARLEY—						
Beecher	0 125·5	930 886	622 499	964 673	633 432	Not Planted
Mean		908	560	818	532	

Site fallowed August, 1959.   Stubbles burnt each year.

Table 3.—Nitrogen on cereal varieties, continuously cropped in the first area.

Cereal	Ammonium sulphate	1961	1962	1963	1964
	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha
WHEAT—					
Bencubbin	0 62·8 125·5	1 359 1 204 1 493	1 601 1 695 1 614	545 673 794	1 500 1 466 1 574
Mean		1 352	1 637	670	1 513
Gabo	0 62·8 125·5	955 1 170 1 412		Not Planted	
Mean		1 179			
Wongoondy	0 62·8 125·5	908 1 096 1 063		Not Planted	
Mean		1 022			
OATS—					
Kent	0 62·8 125·5	Not Planted	834 803 753	516 820 1 072	767 1 018 1 013
Mean			797	803	933
Ballidu	0 62·8 125·5	695 628 471		Not Planted	
Mean		598			
BARLEY—					
Beecher	0 62·8 125·5	560 667 622		Not Planted	
Mean		616			

Site fallowed August, 1959 and left until scarified in 1961 before planting. Stubbles burnt each year.

Table 4.—Nitrogen on cereal varieties, continuously cropped in first area.

Cereal	Ammonium sulphate	1962	1963	1964	Mean
	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha
WHEAT—					
Bencubbin	0	2 065	511	1 237	1 271
	62·8	1 971	652	1 473	1 365
Mean		2 018	582	1 355	1 318
Gabo	0	1 153	679	1 338	1 177
	62·8	1 681	894	1 278	1 285
Mean		1 597	787	1 308	1 231
OATS—					
Kent	0	1 547	574	812	991
	62·8	1 529	1 157	964	1 215
Mean		1 538	865	888	1 103
BARLEY—					
Beecher	0	1 474	813	1 048	1 110
	62·8	1 407	958	1 267	1 211
Mean		1 440	886	1 157	1 160

Site fallowed August 1959 and left until scarified in 1962 before planting. Stubbles burnt each year.

Table 5.—Nitrogen on wheat varieties on non-fallow second area.

Variety of wheat	Urea kg/ha			Mean
	0	28	56	
		kg/ha		
Gamenya	915	1 493	1 554	1 320
Falcon	1 002	1 278	1 372	1 217
Gabo	1 157	1 311	1 433	1 300
Wagin	915	1 278	1 309	1 197
Bencubbin	1 130	1 157	1 554	1 280
Heron	1 096	1 493	1 433	1 341
Insignia	1 190	1 459	1 580	1 410
Mean	1 058	1 353	1 475	

Site burnt 1965 and ploughed 1966 before seeding.

Table 6.—Following nitrogen and molybdenum on Gamenya wheat in second area.

Urea kg/ha	Fallowed			Not fallowed		
	0	gm/ha	Mean	0	gm/ha	Mean
0	1 366	1 205	1 286	827	981	904
28	1 520	1 457	1 489	1 331	1 331	1 331
56	1 681	1 842	1 762	1 618	1 583	1 601
84	1 807	1 969	1 888	1 583	1 681	1 632
112	1 906	1 969	1 937	1 807	1 779	1 793
168	2 060	1 969	2 014	1 807	1 871	1 839
Mean	1 723	1 735	1 729	1 496	1 538	1 517

Table 7.—Superphosphate and nitrogen on Gamenya wheat in second area.

Superphosphate kg/ha	Urea kg/ha 0		Urea kg/ha 25		Mean	
	1965	1966	1965	1966	1965	1966
kg/ha	0	0	0	0	0	0
0	0·0	0·0	0·0	0·0	0·0	0·0
45	612	484	686	551	649	518
90	1 029	551	1 137	854	1 083	703
135	1 083	915	1 130	975	1 106	945
179	1 365	1 157	1 412	1 217	1 389	1 187
224	1 399	1 278	1 789	1 217	1 594	1 248
269	1 143	1 036	1 997	1 648	1 570	1 342
314	1 533	1 217	1 937	1 890	1 735	1 554
Mean	1 021	830	1 261	1 044		

Stubble burnt.

Table 8.—Superphosphate on Gabo wheat in first area.

Superphosphate	1960	1961	Mean
kg/ha	kg/ha	kg/ha	kg/ha
0	0	0	0
45	478	444	461
90	874	773	824
135	1 103	1 211	1 157
179	1 365	1 190	1 278
224	1 217	1 110	1 163
269	1 110	1 110	1 110

Stubble burnt.

Table 9.—Superphosphate on Gabo wheat in first area.

Superphosphate	1961	1962	1963	1964	Mean
kg/ha	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha
0	0	0	0	0	0
45	370	780	222	303	419
90	921	1 285	410	847	866
135	1 137	1 466	464	720	947
157	1 352	1 513	767	1 332	1 241
179	1 426	1 648	807	1 271	1 288
202	1 271	1 601	794	1 271	1 234
235	1 654	1 923	942	2 058	1 644

Stubble burnt.

Table 10.—Copper and zinc fertiliser on Wongoondy wheat in first area.

Copper ore	Zinc oxide (kg/ha)		Mean
	0	3	
kg/ha			
0	1 103	504	804
22	1 533	1 157	1 345
Mean	1 318	831	

22 kg copper ore contained some copper as 5·5 kg bluestone.

Table 11.—Copper fertiliser on Gabo wheat in first area.

Copper ore	Yield
kg/ha	kg/ha
0	1 190
11	1 453
22	1 493
34	1 325
45	1 392
56	1 103
67	1 419
+ zinc oxide kg/ha	1 446

11 kg copper ore contained some copper as 2·8 kg bluestone.

Table 12.—Copper and zinc fertiliser on Gabo wheat in first area. Results for year of application (1962).

Copper ore	Zinc oxide (kg/ha)			Mean
	0	1	3	
kg/ha				
0	1 762	1 406	1 372	1 513
34	2 045	1 937	1 802	1 928
67	1 802	1 863	1 755	1 807
Mean	1 870	1 735	1 643	

33 kg copper ore contained some amount of copper as 8·3 kg bluestone.

Average results for subsequent two seasons (1963 and 1964)

Copper ore	Zinc oxide (kg/ha) in 1962			Mean
	0	1	3	
kg/ha in 1962		kg/ha		
0	1 211	1 278	1 298	1 262
34	1 426	1 332	1 150	1 302
67	1 325	1 372	1 453	1 383
Mean	1 320	1 327	1 300	

Stubbles burnt.

Table 13.—Copper and zinc fertiliser on Gamenya wheat in second area.

Copper sulphate	Zinc oxide (kg/ha)				Mean
	0	0·5	1·5	3	
kg/ha	kg/ha	kg/ha	kg/ha	kg/ha	
0	1 547	1 607	1 466	1 412	1 508
1	1 641	1 621	1 567	1 520	1 587
2	1 453	1 607	1 533	1 567	1 540
4	1 533	1 641	1 675	1 735	1 646
8	1 614	1 681	1 661	1 654	1 653
Mean	1 558	1 632	1 580	1 578	

Table 14.—Copper and zinc fertiliser on Ballidu oats in first area.

Copper Ore	Zinc oxide (kg/ha)		Mean
	0	3	
kg/ha	kg/ha	kg/ha	
0	1 686	1 426	1 556
22	1 901	1 619	1 760
Mean	1 793	1 522	1 658

Table 15.—Copper and zinc fertiliser on Ballidu oats in first area.

Copper Ore	Yield
kg/ha	kg/ha
0	695
11	933
22	762
34	865
45	771
56	964
67	834
+ zinc oxide kg/ha	1 273

Table 16.—Copper and zinc fertiliser on Kent oats in first area. Results for year of application (1962).

Copper Ore kg/ha	Zinc oxide kg/ha 0	Zinc oxide kg/ha 1	Zinc oxide kg/ha 3	Mean
0	1 551	1 462	1 547	1 520
34	1 533	1 533	1 560	1 542
67	1 421	1 547	1 529	1 499
Mean	1 502	1 514	1 545	

Result for subsequent two seasons (1963 and 1964).

Copper ore kg/ha 1962	Zinc oxide kg/ha 0	Zinc oxide kg/ha 1	Zinc oxide kg/ha 3	Mean
0	861	955	865	894
34	995	1 063	874	977
67	955	1 040	888	961
Mean	937	1 019	876	

Stubble burnt.

Table 17.—Rate of seeding Gabo wheat in first area.

Seed kg/ha	Yield kg/ha
11	868
22	1 083
34	1 009
45	1 009
56	1 063
67	1 083
78	1 063
90	1 110
101	908
112	1 130

Table 18.—Superphosphate on Geraldton sub-clover in first area. Planted 1961 onto fallowed ground. Super rates applied each year. Sampled 11/10/66.

Superphosphate	Herbage dry matter
kg/ha/annum	kg/ha
0	75
45	703
90	1 105
123	2 247
157	2 586
191	2 963
235	3 390

Table 19.—Superphosphate on W.A. serradella in first area. Planted 1964 after three oat crops which received a total of 500 kg/ha superphosphate. Super rates were applied in 1964, 1965 and 1966.

Superphosphate	Herbage dry matter
kg/ha/annum	kg/ha
0	716
56	1 506
112	1 544
168	1 682
224	2 184
280	2 674
336	2 862
448	3 277

Table 20.—Superphosphate and molybdenum on Geraldton subclover in second area. Planted 1965 onto oats non-fallowed virgin ground. Sampled 1/10/65.

Herbage Yield.

Superphosphate kg/ha	Molybdenum trioxide (55% Mo) g/ha			
	0 kg/ha	210 gm/ha	420	841
		Dry matter	kg/ha	
67	690			929
135	1 105	1 230	1 281	1 193
168	1 356			1 481
202	1 356	1 607	1 481	1 720
269	1 745	1 720	1 607	1 532
404	1 381			1 519
Mean of super 135, 202, 269	1 402	1 519	1 456	1 481
Mean of all super rates	1 272			

Chemical Composition 1/10/65

Treatment

MoO g/ha	Super kg/ha	Nitrogen level %N	Nitrogen in herbage kg/ha	Phosphorus level %P	Molybdenum level ppm Mo
0....	67	1·17	8	0·075	0·57
	135	1·21	13	0·090	0·34
	168	1·17	16	0·090	0·29
	202	1·23	17	0·095	0·25
	269	1·33	23	0·130	0·25
	404	1·38	19	0·135	0·29
210....	135	1·22	15	0·090	7·50
	202	1·36	22	0·105	6·65
	269	1·40	24	0·125	5·35
420....	135	1·30	17	0·090	13·0
	202	1·33	20	0·105	8·7
	269	1·35	22	0·110	7·9
841....	67	1·24	12	0·075	27·5
	135	1·32	16	0·085	26·5
	168	1·39	21	0·095	19·0
	202	1·36	23	0·110	14·5
	269	1·35	21	0·105	12·5
	404	1·43	22	0·125	10·9

APPENDIX 4—RESULTS AT 90 MILE TANK SITES

Notes on 1968 and 1969 seasons

1968 May-June

Light late-May rains allowed good germination of sown cereals and pastures, but June was excessively wet causing waterlogging on heavy land and loss of nitrogen. Nitrogen deficiency occurred in cereals grown at low rates of nitrogen fertiliser but pasture growth was satisfactory.

1968 July-October

By the end of August crops grown with high nitrogen rates were stressed for moisture because of the dry July and August. However crops and pastures continued to grow quite well in the intermittent cool moist periods which occurred until the end of September. Pastures stopped growing and cereal grain matured in very dry October conditions. Overall, conditions were judged as having been slightly better than the anticipated norm.

1969 May-June

Germination of cereals and pastures was erratic with only light May rains following a dry April. A high proportion of pasture seedlings died from lack of moisture. Rainfall was adequate in June but low temperatures retarded growth and pastures were particularly slow and backward.

July-August

Moisture stress was severe during most of this period and crops, which began to head at the end of August were short. Pasture plants were stunted with new sowings more affected than second year stands, largely because of competition from dense self-sown cereals and later germination.

September-October

Relatively good finishing rains provided favourable grain filling conditions for the short crops but there were many signs of drought and frost damage on cereal ears in late September, particularly on heavy land. Crops grown on fallowed new land were clearly less affected by drought than those on non-fallowed new land. Most pasture varieties set some seed but production appeared low and all annuals had dried off by the end of October. For cereals the season appeared to be average or slightly less favourable than the anticipated average while for pastures it is thought 1969 was substantially worse than usual.

SOILS

Site 1—Lateritic sandplain

Yellow sand containing large amounts of ironstone gravel occurring from 5 to 20 cm beneath the surface overlying, in most places, hard siliceous stone at 15 to 51 cm.

Site 2—Heavy land site

Brown earth with smaller areas of grey-brown highly calcareous earth. Typically the profile consisted of 5 to 15 cm brown slightly calcareous loamy sand or sandy loam over highly calcareous sandy clay containing variable quantities of lime nodules. Weak doming of the subsoil was evident in places and shallower and deeper variants of the soil type occurred. The subsoil is likely to be saline. Salt may be a problem particularly in dry seasons but has not yet appeared.

Table I.—Continuous cropping with urea on Gamenya wheat (a) Light land.

Urea kg/ha	Yield kg/ha			
	1968 Potash, muriate kg/ha			1969
	0	105	Mean	
0	565	726	645	302
45	1 304	1 304	1 310	544
90	1 720	1 619	1 673	732
135	1 781	1 761	1 774	833
224	1 935	1 855	1 895	840
Mean	1 458	1 452		
LSD's ∠ 0·05	Between treatments = 207 Urea means = 146			Urea means = 134

Replications: 1968, 2 and 1969, 4 for urea rates only.

Other conditions:

1968 Superphosphate 246 kg/ha, Bluestone 5·6 kg/ha, zinc oxide 1·7 kg/ha, roasted molybdenite 140 kg/ha. Potash was topdressed immediately after seeding and urea two days later. New land was not fallowed.

1969 Superphosphate 224 kg/ha with urea topdressed immediately after seeding on May 20. An attempt was made to burn the stubbles during summer but the nil urea plots would not carry fire and the burn on the urea 45 kg/ha plots was patchy. On other treatments the burn was reasonable but not complete.

(b) Heavy land

Urea kg/ha	Yield kg/ha	
	1968	1969
0	1 021	444
45	1 458	853
90	1 519	995
135	1 465	1 082
224	1 404	995
LSD ∠ 0·05	91	134

Replications: 4.

Other conditions:

Superphosphate 202 kg/ha each year and urea topdressed by drill within a day of seeding in each year. The trial was sown on non fallowed new land in 1968. 1968 stubbles were burnt in summer 1969 but the fire carried unevenly, particularly on nil urea plots

The unusually large response to nitrogen in 1968 was attributable to the area not being fallowed so available natural soil nitrogen was low, to a June rainfall of nearly 112 mm causing some leaching of any mineralised nitrate nitrogen, and to loss of grain from the autoheader on low yielding treatments making the actual response to urea larger than the harvester results indicate.

Maximum yield potential was about 1 950 kg/ha with potash having no effect on yields.

In 1969 there was again a large increase caused by urea. Soil at this site appears to have had low reserves of nitrogen and if it had been possible to burn stubble on urea plots, the increase because of nitrogen would have been smaller. At 840 kg/ha the maximum yield was very poor because of a combination of low rainfall, high seeding rate following incomplete control of self sown wheat, and a later seeding date compared with other light land trials.

Comments for the corresponding light land trial generally apply to this trial although waterlogging rather than leaching would have resulted from the heavy June 1968 rains. The maximum yield in 1968 was about 1 512 kg/ha compared with 1 075 kg/ha in 1969.

Table 2.—Superphosphate rates on Gamenya wheat Light land site.

Superphosphate kg/ha	Yields kg/ha	
	1968	1969
0	0	....
67	1 183	....
135	1 284	....
168	1 297	....
202	1 357	1 513
235	1 411	1 650
269	1 364	1 650
302	1 357	....
370	1 378	....
LSD ∠ 0·05	107	By t-test, difference significant at P ∠0·05

Replications: 1968, 4 and 1969, 16.

Other conditions:

1968 Urea 56 kg/ha, bluestone 6 kg/ha, zinc oxide 2 kg/ha, roasted molybdenite ·14 kg/ha. New land not fallowed.
1969 Urea 56 kg/ha, bluestone 6 kg/ha, zinc oxide ·84 kg/ha, roasted molybdenite ·14 kg/ha. New land not fallowed.

Heavy land site.

Superphosphate kg/ha	Yields kg/ha	
	1968	1969
0	269	....
67	1 015	....
101	968	1 121
135	907	1 165
168	1 001	....
202	988	....
235	988	....
302	921	....
LSD ∠ 0·05	169	By t-test, no significant difference

Replications: 1968, 4 and 1969, 12.

Other conditions:

1968 No other fertiliser, New land not fallowed. Some harvesting loss from the superphosphate nil treatment
1969 Urea 34 kg/ha. Fallowed new land.

On the light land, in 1968, the unusual pattern of a very large response to the first increment of superphosphate and relatively small increases to additional increments was thought to be associated with the wet June conditions which may have increased the availability of applied superphosphate. This is consistent with results obtained in the dry conditions of 1969 when 235 kg/ha superphosphate was clearly superior to 202 kg/ha which was not the case in 1968.

The 1 646 kg/ha obtained with 235 kg/ha superphosphate in 1969 was remarkable considering the dry seasonal conditions. Early planting (May 6) on fallowed, weed free new land produced conditions which allowed a high yield such that adequate fertiliser and a good wheat variety alone could not have given.

As for the light land it is suspected that the wet 1968 June conditions increased phosphate availability on the heavy land site. Nevertheless 134 kg/ha superphosphate was not statistically better than 101 kg/ha in the dry conditions.

In 1968 yields were limited by nitrogen deficiency which was not a factor in 1969.

Table 3.—Cereal varieties, with or without 56 kg/ha urea Light land

Variety	Yields kg/ha						
	1968			1969			2 yr Mean
	nil urea	urea	Mean	nil urea	urea	mean	
WHEAT—							
Falcon	695	1 537	1 116	1 004	1 115	1 060	1 088
Gamenya	684	1 301	993	1 014	1 041	1 028	1 010
Bencubbin	651	1 505	1 078	1 215	1 110	1 162	1 120
Mean	677	1 448	1 062	1 078	1 089	1 083	1 073
BARLEY—							
Bussell	642	1 689	1 166	888	1 036	962	1 064
Beecher	843	1 926	1 334	1 115	1 184	1 150	1 242
LSD ∠ 0·05		127	90			154	

Replications: 1968, 2.

Other conditions:

Superphosphate 247 kg/ha, bluestone 5·6 kg/ha, zinc oxide 1·7 kg/ha, roasted molybdenite ·14 kg/ha. Urea topdressed by drill within two days after seeding. New land not fallowed in 1968. New land fallowed in 1969.

Heavy land

Variety	Yields kg/ha						
	1968			1969			2 yr Mean
	nil urea	urea	Mean	nil urea	urea	Mean	
WHEAT—							
Falcon	918	1 430	1 174	1 152	1 273	1 213	1 194
Gamenya	908	1 239	1 073	1 410	1 612	1 511	1 292
Bencubbin	833	1 378	1 105	962	1 094	1 028	1 067
Mean	886	1 349	1 118	1 175	1 326	1 251	1 184
BARLEY—							
Bussell	1 093	1 737	1 415	1 310	1 443	1 377	1 396
Beecher	1 227	1 990	1 609	1 369	1 548	1 458	1 533
LSD ∠ 0·05		235	169		215	154	

Replications: 1968, 2.

Other conditions:

Superphosphate 202 kg/ha. New land, not fallowed 1968. New land, fallowed 1969.

In 1968 Beecher barley produced higher yields than other cereals while Falcon wheat outyielded Gamenya wheat.

The only statistically significant difference in 1969 was the overall superiority of Beecher barley compared with Bussell barley.

On the heavy land site in 1968, Beecher barley was again the highest yielder with the wheats all yielding about the same as one another. In 1969, Beecher barley and Gamenya wheat gave similar yields, both superior to other cereal varieties. The large response to urea 56 kg/ha in 1968 contrasts with the small responses obtained in 1969.

Table 4.—Effect of seven month fallow on 1st wheat crop Light land—1969

Urea kg/ha	Yield kg/ha		Mean
	no fallow	fallow	
0	780	1 197	989
34	969	1 345	1 157
67	995	1 385	1 190
101	995	1 426	1 211
135	1 042	1 466	1 254
202	995	1 554	1 275
Mean	963	1 396	
LSD ∠ 0·05	88		61
∠ 0·01	120		87

Replications: 3.

Other conditions:

Superphosphate 247 kg/ha, bluestone 5·6 kg/ha, zinc oxide ·8 kg/ha, roasted molybdenite ·1 kg/ha. Whole area logged October 1967 and burnt February 1968. Fallowed treatments ploughed October 1968, non-fallowed scarified May 1969. Urea topdressed by drill immediately after seeding.

Heavy land—1969

Urea kg/ha	Yield kg/ha		Mean
	no fallow	fallow	
0	928	1 439	1 184
34	975	1 574	1 275
67	1 029	1 493	1 261
135	995	1 567	1 281
Mean	982	1 518	
LSD ∠ 0·05	137		
∠ 0·01	188		188

Replications: 4.

Other conditions:

Superphosphate 247 kg/ha. Whole area logged October 1967 and burnt February 1968. Fallow treatments ploughed October 1968. Urea topdressed by drill immediately after seeding.

Little of the large 1969 response to fallowing on the light land site appeared to have been caused by the release of nitrogen from soil organic matter. Fallowing appeared to increase the moisture supply to the wheat even though only about 51 mm of rain fell in the seven-months fallow period and wheat response may have been at least partly due to better root growth. Urea also increased yields more on fallowed than on non-fallowed treatments.

On the heavy land site wheat on the non-fallowed area germinated better and appeared to grow slightly faster early on than on fallowed plots, possibly because of the rough, cloddy nature of the fallow. Plants on fallowed plots appeared less stressed for moisture than on non-fallow.

Table 5.—Effect of copper, zinc and molybdenum on wheat Light land—1968.

Zinc oxide kg/ha	Yield kg/ha				
	Bluestone kg/ha				Mean
	0	2·8	5·6	8·4	
0	1 433	1 433	1 385	1 338	1 397
·8	1 500	1 507	1 513	1 507	1 506
1·7	1 480	1 473	1 486	1 594	1 508
Mean	1 471	1 471	1 462	1 480	1 471

LSD Treatments P ∠ 0·05 = 137 Copper means P ∠ 0·05 = 79 Zinc means P ∠ 0·05 = 69

Other conditions:

Superphosphate at 235 kg/ha and MoO_3 at 0·1 kg/ha applied to all treatments.

Comparison of molybdenum with non-molybdenum treatments—wheat yields in kg/ha.

Other fertiliser treatments	Nil molybdenum	Molybdenum
Superphosphate 235 kg/ha	1 365	1 433
Super + Cu 2·8 and Zn 0·8 kg/ha	1 453	1 507
Super + Cu 5·6 and Zn 1·6 kg/ha	1 527	1 486
Mean	1 448	1 475

LSD Treatments P ∠ 0·05 = 137 Mo means P ∠ 0·05 = 79

Comparison of effects of small quantities of copper and zinc in superphosphate with MCP* plus gypsum

Treatment	kg/ha	LSD
Superphosphate 202 kg/ha	982	P ∠ 0·05 — 136
MCP + gypsum equivalent to above	1 197	

Replications: 2.

Other conditions:

Superphosphate at 202 kg/ha to all treatments except the MCP + gypsum. Trace elements mixed with superphosphate and drilled with seed.

* Mono calcium phosphate.

In the absence of manganese sulphate, molybdenum appeared to increase grain yield but MCP + gypsum also gave a higher yield than superphosphate. Neither response can be readily explained by existing knowledge of plant nutrition on soils of this general type and the responses may have been due to chance.

Neither copper nor zinc increased yield and at the rates used nitrogen supply was inadequate for maximum yields.

Tornafield disc medic was sown on this site in 1969 but trace elements applied to the previous crop had no effect on medic growth.

Pasture Legumes

All pasture legumes sown in 1968 (the first year of the trials) on both soil types produced reasonable first year stands. Varieties sown were—

- Geraldton, Uniwager, Dwalganup, Daliak and Seaton Park subterranean clovers.
- Harbinger, Cyprus and Snail annual medics
- Hunter River lucerne
- Sirint, Hykon, Troodos and Kondinin Rose clovers
- Beenong and Lisare cupper clovers
- W. Australian and French serradellas
- W. Australian blue and N.Z. blue lupins

Although lupins were rather sparse, the only variety which failed to set enough seed in 1968 for regeneration as a reasonable stand in 1969 was French serradella. The survival of lucerne on both soils as a very good stand over a dry summer was remarkable. Noteworthy also was the good seed set of the latest maturing of the subterranean clovers, Seaton Park, in its first year. Tornafield medic was not available for 1968 plantings but was sown on the heavy land site in 1969.

At the end of the three year period the annual medics appeared well suited to the heavy land and it was anticipated that Geraldton and Daliak subterranean clovers would prove satisfactory on light lands. The good performance of lucerne on both soil types suggested it could be useful in even drier areas, particularly on lighter soil types, with wide row spacing and low seeding rates. Seasonal conditions in 1969 were adverse for annual pasture legumes. Seedling mortality was high because of moisture stress following erratic light May rains. Growth was slow in the cold June and July and seed set was restricted by moisture stress in spring, particularly for first year stands competing with self sown cereals. Substantial germination following cyclone Ingrid would also have reduced seed supplies.

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