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NITROGENOUS FERTILISERS FOR CEREAL PRODUCTION

By M. G. MASON, B.Sc (Agric.), Research Officer, Plant Research Division

THE greatest responses to nitrogenous fertilisers can be expected in areas with a relatively long growing season. In such areas light soils with a low nitrogen status provide the best prospects for addition of nitrogen—provided adequate moisture is available.

Response also depends on the recommended variety being sown at the best time, a weed and disease free crop, and the correct timing of the fertiliser application.

Weather and climate

Rainfall causes great variations in the response to nitrogenous fertilisers. In general, the chance of obtaining a profitable response to nitrogen diminishes as the average annual rainfall decreases.

Sufficient soil moisture is essential for the crop to make full use of nitrogen fertilisers. Therefore, in the cereal growing areas the chances of nitrogen being profitable become less with increasing distance from the coast. On the other hand, high rates of nitrogen may be profitable for cropping in wetter areas.

Rainfall distribution is even more important than total rainfall. Rainfall during the growing season is all-important and, as a rule, summer rains do not affect the response to nitrogen. For example, Wongan Hills has less than 1 inch more annual rainfall than Salmon Gums, but with 3 inches more rain during the growing season it would be more likely to have a profitable nitrogen response.

Finishing rains are particularly important as they keep up the level of soil moisture at the time of grain formation. If the level of soil moisture becomes very low at this stage, nitrogen fertiliser applied earlier in the season may not give profitable yield increases and in severe cases it may actually cause a yield reduction.

Perhaps the most important recent development in cereal growing in Western Australia has been the increase in the use of nitrogenous fertilisers and the rapid expansion in the range of these fertilisers available to farmers.

Many things influence crop response to the application of nitrogen, the most important being the season, soil type, time of application, source of nitrogen and paddock history. Before deciding whether to use nitrogen on a cereal crop, which fertiliser to use and at what rate, the farmer should have some understanding of how these things work.

This article, based on the results of Department of Agriculture trials over many seasons, in many districts and on a wide range of soil types, provides the background on which farmers can base these decisions.

A comprehensive research programme such as this is necessary to allow firm recommendations to be made for the use of nitrogenous fertilisers. Local considerations are also important, so the man best equipped to make recommendations for an individual property is the Department of Agriculture's district agricultural adviser.

Under most conditions nitrogen application results in a greater leaf area per acre. In turn this creates an increased demand
for soil moisture and if the supply of soil moisture is low it will be used up much more quickly than with a thinner crop. Lack of moisture then causes "burning-off" of the crop and reduces yield. Only where finishing rains are sufficient to maintain soil moisture can the full potential of the crop be realised.

Temperature may also affect the response to nitrogen. High temperatures during the growing season may increase the crop's growth rate and bring about the uptake of more of the applied nitrogen. However, higher temperatures also cause an increased loss of moisture which could partly offset the effect of the better growth rate.

The relative prices of fertiliser and cereal grains

Prices for fertiliser and cereal grains greatly affect the cash return from increased cereal yields.

The yield increase should cover both cost of fertiliser and the cost of application and still leave a margin for profit. As the cost of fertiliser decreases, or the price received for grain increases, the chance of making a profit from the application will increase.

Soil type

Soil type greatly affects the profitability of nitrogenous fertilisers. Heavier soils are usually more fertile and less prone to leaching than lighter soils. Consequently, heavy soils do not often give profitable responses to nitrogen fertilisers unless they are continuously cropped.

Successive crops, even on heavy land, gradually reduce the nitrogen supply until a profitable response to nitrogen may be obtained.

In drier years heavier soils have less favourable moisture relations than lighter soils and this would limit any response to nitrogen.

Generally then, lighter soils provide a better prospect for the use of nitrogen fertilisers. Such soils have usually been subject to a great deal of leaching and have a low nitrogen content. Furthermore, soil moisture is more available to the plant in light than in heavier soils.

Some light soils, such as the coarse, deep, white and grey sands, cannot grow a profitable crop even with the addition of nitrogen.

Recent history of the paddock

Past treatment of the land has a large effect on the response obtained to additional nitrogen—even on two otherwise similar paddocks.

If the area to be cropped is new land, the response to nitrogen will generally be different on fallowed land from that obtained on similar but non-fallowed land. On land fallowed the previous year, "ploughed in" organic matter is partly broken down by soil micro-organisms. This breakdown releases nitrogen from the organic matter, allowing it to be used by the crop.

If an area is ploughed for the first time in the cropping year nitrogen in the organic matter will not be available to the plant. At the same time, the soil microorganisms use some of the soil's available nitrogen during the early stage of the breakdown process. This leaves little available nitrogen for the crop, so a higher rate of applied nitrogen is needed.

In drier areas fallowing may also lead to conservation of some moisture from summer rains. This would tend to increase the chance of a profitable response to nitrogen.

An area of old land which has not grown a good legume pasture could be expected to give a greater response to nitrogen application than an area which has grown such a pasture. A good stand of legumes causes a large build up in soil nitrogen and fertility so that the first cereal crop obtains much of its nitrogen requirement from the soil. However this nitrogen supply is gradually used up by successive crops and nitrogen fertilisers become more profitable. The rate of application can also be increased with successive crops.

Treatment of stubble from previous crops

If stubble is ploughed into the soil it is broken down by soil micro-organisms. Much of the available soil nitrogen is tied up during this process, and higher rates of nitrogen fertiliser are necessary than if the stubble is burnt.

Time of seeding

Time of seeding has a great effect on the response to nitrogenous fertilisers in areas with a short growing season. In
such areas the crop should be sown as early as possible because, if seeding is delayed, the season may “cut out” before the grain has properly developed. This reduces the possible response to nitrogen fertiliser.

Other nutrients

To obtain maximum benefit from nitrogenous fertilisers a shortage of other essential nutrients must not be allowed to limit crop growth.

For instance, if the phosphate level is too low the response to nitrogen can be severely reduced. In some trials, even when as much as 200 lb. per acre of urea was applied, no wheat was obtained until super was added. The same can apply if nutrients such as copper and zinc are severely deficient.

Nitrogen is not a substitute for other deficient nutrients. They must also be added.

Which crop?

The type of cereal also affects the profitability of nitrogenous fertilisers. Because of their lower return per bushel, oats and barley must give greater yield increases than wheat to get the same profit. Whereas a 1½ bushel increase in wheat yield may be profitable when 50 lb. per acre of urea is applied, an extra 2½ bushels of barley or 3 bushels of oats will be needed to show the same profit. There is also some evidence that oats and par-
particularly barley do not respond so readily to nitrogen in the drier areas.

To obtain the best result the recommended variety should be sown at the correct time. In areas with a short growing season an early maturing variety should be sown as early as possible. Where the growing season is longer, later maturing varieties can be used if sown early; if seeding is delayed in these areas, an early maturing variety should be used.

If the wrong variety is used in an area the response to nitrogen may be limited. Also, in areas with a longer growing season, if an early-maturing wheat variety is sown early it may come into ear while conditions are warm but still moist. Such conditions could result in the occurrence of septoria which further reduces yields and response to nitrogen.

Weeds, diseases and pests

The response to nitrogen will be reduced if weeds are not properly controlled. Yield is further reduced if diseases such as rust, septoria and root rots occur to a serious degree. Insect pests and vermin will also lower yields and limit response.

What rates should be used?

In Fig. 1 the agricultural areas of Western Australia have been divided into three zones, in which nitrogen fertilisers give different responses.

Lines separating the zones are based on a combination of annual rainfall and growing season. Zone A includes the drier areas from approximately the 13 in. rainfall isohyet to the outer limit of the cereal growing areas. Zone C includes cereal growing areas of over 18 to 20 in. annual rainfall. Zone B receives about 13 to 18 in. annual rainfall.

General recommendations for Zones A, B and C are set out in Table 1. Due to the lower rainfall in zone A, the chance of obtaining a profitable response to nitrogen fertilisers is lower than in the other two zones.

The rates set out in Table 1 will not be the best in every season; in a good season higher rates might be used profitably and in a poor season lower rates might be better. The rates recommended are considered to offer the greatest profit in an average season and some profit in most seasons.

Which nitrogenous fertiliser?

Table 2 compares the nitrogen content and price characteristics of the currently available nitrogenous fertilisers.

In general, high analysis fertilisers such as anhydrous ammonia, urea and ammonium nitrate have the advantage that lower amounts are needed to supply the required nitrogen. However, all sources have advantages and disadvantages, as set out below.

Urea

Urea's main advantage is that, at present, it is by far the cheapest source

| Table 1.—Recommended rates of urea* for cereal growing areas of Western Australia (lb. urea per acre) |
|---|---|---|---|---|---|---|---|---|---|
| Situation | ZONE A | ZONE B | ZONE C |
| | Wheat | Oats | Barley | Wheat | Oats | Barley | Wheat | Oats | Barley |
| Heavy Land | 0 | 0 | 0 | 30 | 0 | 0 | 30 | 0 | 0 |
| New Light Land—1st Crop—Fallow | 45 | 30 | 0 | 50-60 | 30 | 30 | 80 | 80 | 80 |
| New Light Land—1st Crop—Non Fallow | 40-45 | 30 | 30 | 80 | 50 | 50 | 100 | 85 | 85 |
| New Light Land—Subsequent Crops | 40-45 | 30 | 30 | 90 | 60 | 60 | 100 | 100 | 100 |
| Old Light Land—1st Crop After Legume | 30 | 0 | 0 | 45 | 45 | 45 | 50 | 50 | 50 |
| Old Light Land—2nd Crop After Legume | 45 | 30 | 30 | 80 | 60 | 60 | 70-75 | 70 | 70 |
| Old Light Land—3rd and later Crops after Legume | 45 | 30 | 30 | 80 | 60 | 60 | 80 | 70 | 70 |
| Old Light Land—1st Crop—Non Legume | 40 | 30 | 30 | 60-65 | 60 | 60 | 80 | 80 | 80 |
| Old Light Land—2nd and later Crops—Non Legume | 70 | 45 | 45 | 60-65 | 60 | 60 | 80 | 80 | 80 |

* The recommendations are made for Urea because this is the most widely used nitrogenous fertiliser.

136
Table 2.—Nitrogen contents and prices of nitrogenous fertilisers

<table>
<thead>
<tr>
<th>Fertiliser</th>
<th>Nitrogen</th>
<th>Price per ton (Perth)</th>
<th>* Price per unit of nitrogen</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%</td>
<td>$</td>
<td>$</td>
</tr>
<tr>
<td>Urea</td>
<td>46.0</td>
<td>53.20</td>
<td>1.16</td>
</tr>
<tr>
<td>Sulphate of Ammonia</td>
<td>20.5</td>
<td>51.20</td>
<td>2.50</td>
</tr>
<tr>
<td>Sodium nitrate</td>
<td>16.0</td>
<td>79.50</td>
<td>4.97</td>
</tr>
<tr>
<td>Calcium ammonium nitrate</td>
<td>23.0</td>
<td>65.60</td>
<td>2.89</td>
</tr>
<tr>
<td>Anhydrous ammonia</td>
<td>82.0</td>
<td>**234.00</td>
<td>***2.85(c)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(custom)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>**202.00</td>
<td>***2.46(f)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(farmer)</td>
<td></td>
</tr>
<tr>
<td>Ammonia nitrate</td>
<td>33.5</td>
<td>$</td>
<td>$</td>
</tr>
<tr>
<td>N-P compound fertiliser 24 : 24</td>
<td>24.0</td>
<td>98.50</td>
<td>$</td>
</tr>
<tr>
<td>N-P compound fertiliser 28 : 14</td>
<td>28.0</td>
<td>98.50</td>
<td>$</td>
</tr>
</tbody>
</table>

* 1 unit of nitrogen=22.4 lb. nitrogen (1 per cent. of a ton).
** Add $11.00 per ton if more than 125 road miles from Perth. This price includes application costs and handling costs.
† The price per unit of nitrogen cannot be accurately determined for compound fertilisers because they also contain phosphate.
§ Price of ammonium nitrate not known at this stage.
*** Add 14 cents if more than 125 road miles from Perth.
**** Price as at March 31, 1968.

per unit of nitrogen. However, urea cannot be mixed with super because the product becomes very sticky. There have also been cases where urea sown close to the seed has adversely affected germination. Urea must be applied separately from the super and this may involve an extra operation.

Urea is a very soluble nitrogen source and much can be lost by leaching. It also has an acidifying effect on the soil but this is not a serious problem with this source. Gaseous losses of nitrogen from urea broadcast on sandy soils have also been reported from overseas.

**Sulphate of ammonia**

Trials carried out by the Department of Agriculture indicate that sulphate of ammonia is about as effective as urea. However it is currently much more costly per unit of nitrogen and is not recommended in preference to urea.

One advantage of sulphate of ammonia is that it can be mixed with super and drilled in the one operation. There may be a slight reduction in germination but this is unlikely to be important at rates of 112 lb. per acre or less.

Sulphate of ammonia is quite strongly acid forming in the soil but this effect may sometimes be an advantage. In soils deficient in manganese the local acidifying effect around the seed may make any manganese present more readily available. However, the acidifying effect may become quite harmful if high rates of this fertiliser are used repeatedly on any one area.

**Sodium nitrate**

This source is very expensive per unit of nitrogen but it does have the advantage that its nitrogen is in the nitrate form, which is easily taken up by the plant. It is therefore a quick-acting fertiliser. However it is very soluble and prone to rapid leaching.

Sodium nitrate has no acidifying effect on the soil.

**Calcium ammonium nitrate**

Nitrogen in this source is present half as ammonium nitrogen and half as nitrate nitrogen. The nitrate form is readily taken up by plants and is therefore quick acting. The ammonium form is also freely available but is less readily leached.

Because of its content of calcium, calcium ammonium nitrate does not increase soil acidity. It can also be mixed with super but should be used shortly after mixing.

Calcium ammonium nitrate is more costly per unit of nitrogen than either
urea or sulphate of ammonia. It does not differ greatly in effectiveness from these sources and is not recommended in preference to them.

**Anhydrous ammonia**

Although anhydrous ammonia is more costly per unit of nitrogen than is urea, it is competitive (because it produces better returns) in some cases. Its superiority over urea in these cases depends on its application as close to seeding as possible and sufficiently deep to avoid large losses to the atmosphere. Anhydrous ammonia gave much higher yields than urea in some trials but in others urea gave the best results.

Anhydrous ammonia is liquid ammonia and is applied as a liquid under pressure. When the pressure is released in the soil the liquid evaporates and forms gaseous ammonia. This is very soluble and readily dissolves in soil moisture but, if the soil is very dry, or if application is not made deep enough, some of the gas escapes into the atmosphere.

Because of its nature anhydrous ammonia has to be handled with special equipment which adds considerably to its cost. Thus its main disadvantage at present is its high price per unit of nitrogen. However it appears likely that the present price will be reduced and this source could then be highly competitive with urea.

Anhydrous ammonia is not as easily leached as urea. The ammonia attaches itself to clay particles and soil organic matter and resists downward leaching. However it gradually changes to the nitrate form, which is readily leached. The fertiliser is more acid forming than urea but less so than sulphate of ammonia.

**Ammonium nitrate**

Ammonium nitrate will be available in the 1969 season but has not yet been tested by the Department of Agriculture. Like calcium ammonium nitrate it has nitrogen in both the ammonium and nitrate forms.

**N-P compound fertiliser**

Two compound fertilisers tested in 1967 compared favourably with urea and super on a yield and monetary return basis. They have the advantage of applying nitrogen and phosphorus together as they are drilled with the seed.

The two fertilisers available in 1967 were much more costly than equivalent mixtures of urea and super. They also have the disadvantage of having an inflexible content of nitrogen and phosphorus. If the level of one of these nutrients in the soil needs to be raised the level of the other must necessarily be raised in the same proportion unless additional nitrogen or phosphorus is added separately.

**Time of application**

The response to nitrogenous fertiliser varies considerably according to the time of application. Application should be made at a time when the crop can make best use of it. The response may be affected by the following:

**Length of growing season**

Where the growing season is very short (zone A in the map) nitrogen should be applied very early in the season. This allows the crop to make maximum use of the nitrogen in the short time available.

**The incidence of heavy rainfall**

If the application of an easily leached fertiliser is followed by heavy rainfall the fertiliser may be lost from the root zone before the plant can make much use of it. Conversely, if there is a very dry period following application the fertiliser may remain on top of the ground for some time before it is washed down to the root zone and taken up by the plants.

These are circumstances which cannot be foreseen but which cause results to vary from one season to the next.

**The source of nitrogen**

Anhydrous ammonia should always be applied before seeding. Experiments carried out to test application of this fertiliser after seeding indicated that plants were damaged, resulting in much lower yields than where application was made before seeding. Best results were obtained with anhydrous ammonia when it was applied before seeding but as close to seeding as possible.

N-P compound fertilisers will always be drilled with the seed but other solid fertilisers may be applied at some other time. Application at seeding requires only one
operation but applications at other times involves the cost of an extra operation.

Early application stimulates growth and tillering before the cold winter period. These effects are lost if the application is made too late. Results of trials using urea (which behaves much the same as other solid nitrogenous fertilisers) have led to the following conclusions:

- An application made more than one week before seeding gives poor results. This is due to high losses of nitrogen caused by leaching by heavy rains soon after application and before the crop has developed a root system, or because of losses to the atmosphere when rain starts the breakdown of urea to ammonia but is not heavy enough to wash the urea into the soil.
- In areas with a short growing season the urea should be applied as close to germination as possible.
- In heavier rainfall areas (Zone C) the urea application should be delayed for three to four weeks after seeding in order to minimise leaching.
- In intermediate rainfall regions (Zone B), application is generally recommended at seeding, but in many cases better yields are obtained if the application is delayed for up to three weeks. Results have varied in this zone from year to year, favouring first the application at seeding and then the delayed application. However, application at seeding can save the cost of a second operation and is therefore recommended unless leaching is likely to be severe in the particular situation.
- Application should not be made later than six weeks after seeding. Very late applications do not increase yield but can raise the level of protein in the grain. Urea applied after the period of heavy winter rains may take some time to be washed down to the root zone. This in effect makes it a very late application.

**Soil type**

If the soil is very light it is more prone to leaching than heavier soils. Therefore, in areas of intermediate rainfall (Zone B), application on very light soils should be delayed for about three weeks after seeding. In heavy rainfall areas (Zone C) application should be three to four weeks after seeding.

If the area is prone to waterlogging it may become difficult to drive a vehicle on it for some time after seeding. In this case application will have to be at seeding unless applied by air, which would add to costs.

Early sowing of a crop will allow more roots to develop before the very heavy winter rains. This means that applications at seeding may be safer than they would be with later sowing in intermediate or heavy rainfall areas.

**Recommendations—time of application**

- **Zone A**—apply at seeding if the crop is sown after the break of the season, or at germination if the crop is sown dry.
- **Zone B**—apply at seeding in most situations. Application can be delayed up to three weeks after seeding on very light soils more prone to leaching.
- **Zone C**—apply 3 to 4 weeks after seeding unless the land is generally too wet to make an application at this time. In this case application should be made at seeding.

**Method of application**

**Mixed with other fertiliser at seeding**

This method cannot be used with urea and super as the result is a sticky mess. Low rates of urea mixed with high rates of super will flow through a drill but the mixture will still cause trouble in damp weather. Sulphate of ammonia can be mixed with super and drilled with the seed but if the mixture is kept for a long period it tends to cake. However the lumps are soft and readily broken up.

**Mixed with the seed at seeding**

This method is used by some people but trials with urea have indicated that the practice has an injurious effect on germination. At low rates it delays germination and gives lower yields than urea topdressed.
—at high rates plant numbers are severely reduced. Sulphate of ammonia also has a harmful effect on germination if drilled with the grain. These effects are greatest if the fertilisers are drilled with the grain under moist conditions and a dry period follows seeding.

**Topdressed at seeding but separated from the seed**

If an extra fertiliser box is fitted to the seeding machine, the nitrogen fertiliser can be dropped just in front of the seeding tynes or discs and turned in during seeding. Alternatively the fertiliser can be dropped just behind the seeding tynes and left on the surface. Nitrogen fertiliser can also be dropped from an extra combine or drill towed either just in front or just behind the seeding machine. If the extra machine is towed in front the fertiliser is turned in by the seeding machine. The thin covering of soil reduces loss of nitrogen to the atmosphere.

**Topdressed in an operation separate from seeding**

Separate application can be made by dropper type applicators such as combines or drills, broadcasters or spinner machines, or by aircraft. Dropper types are generally preferred because they give a more even distribution than a spinner type machine. Aerial application is expensive but may be used when the land is too wet for ground vehicles.

**Spraying**

Nitrogenous fertilisers are very soluble in water but highly concentrated sprays may cause some crop damage. Spraying from an aircraft requires the use of low volumes and concentrated solutions which allow large losses of nitrogen into the atmosphere. However, Toms & Burvill (1961) state “Experience has shown that large amounts of urea per acre can be applied to wheat by spraying, without damage.”

Urea is better than other nitrogenous fertilisers for spraying and quite large amounts of urea per acre can be applied to wheat. For example, an application of 176 lb. of urea dissolved in 100 gallons of water, per acre, left white deposits of urea on the leaves but caused no important damage. Generally, however, spray application has no advantage over other methods of application.

Anhydrous ammonia is applied using special applicator rigs which inject it into the soil before seeding. N-P compound fertilisers are designed to be drilled with the seed.

The best method of applying urea would be by way of an extra fertiliser box or an extra combine. However, urea often cannot be applied at night or in other damp conditions during which seeding may be carried on. Areas sown in such conditions could be marked and urea applied to them separately at a later date.

**Residual effect**

Nitrogen is a very mobile nutrient and under Western Australian conditions there is little chance of any residual effect. Very high rates of nitrogen may have a residual benefit and a possible residual effect due to anhydrous amonia application is now being investigated.

**District agricultural advisers may be consulted**

Advisers stationed at Geraldton, Three Springs, Moora, Northam, Merredin, Narrogin, Lake Grace, Katanning, Esperance, Albany and Bridgetown should be consulted for advice about the use of nitrogenous fertilisers for cereal crops in their districts.

**Acknowledgment**

The conclusions made in this article are based on the results of many trials, some of which were carried out by other members of the Department of Agriculture either alone or in co-operation with the author.

**References**

